NOTICE

**CERTAIN DATA
CONTAINED IN THIS
DOCUMENT MAY BE
DIFFICULT TO READ
IN MICROFICHE
PRODUCTS.**

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.

BNWL-CC--505

DE92 003730

RESULTS OF RESEARCH CONCERNING PHOSPHORUS-32 IN REACTOR EFFLUENT

DEC 0 4 1965

W. B. Silker

DATE	TIME	LOCATION	PHOSPHORUS-32

November, 1965

BATTELLE-NORTHWEST

RICHLAND, WASHINGTON

PACIFIC NORTHWEST LABORATORY operated by BATTELLE MEMORIAL INSTITUTE

DISTRIBUTION RESTRICTED TO U.S. ONLY

RESULTS OF RESEARCH CONCERNING
PHOSPHORUS-32 IN REACTOR EFFLUENT

By

W. B. Silker
Chemistry Department

November 1965

PRELIMINARY REPORT

This report contains information of a preliminary nature prepared in the course of work under Atomic Energy Commission Contract AT(45-1)1830. This information is subject to correction or modification upon the collection and evaluation of additional data.

PATENT STATUS

This document copy, since it is transmitted in advance of patent clearance, is made available in confidence solely for use in performance of work under contracts with the U. S. Atomic Energy Commission. This document is not to be published nor its contents otherwise disseminated or used for purposes other than specified above before patent approval for such release or use has been secured, upon request, from the Chief, Chicago Patent Group, U. S. Atomic Energy Commission, 9800 So. Cass Ave., Argonne, Illinois.

PACIFIC NORTHWEST LABORATORY
RICHLAND, WASHINGTON

MASTER

DISTRIBUTION RESTRICTED TO U.S. ONLY

RESULTS OF RESEARCH CONCERNING PHOSPHORUS-32
IN REACTOR EFFLUENT

INTRODUCTION

Staff members of the Radiological Chemistry Unit have been involved in research concerning reactor effluent water for many years. This work was intensified in 1960 when the Division of Production, A.E.C., initiated sponsorship of a program to investigate methods for reducing the concentration of biologically-significant radioisotopes discharged to the Columbia River in the effluent water.

An isotope of major concern is phosphorus-32, and in the course of these studies, much has been learned about the origin, production, and behavior of this isotope. While most of these data have been published at one time or another, some information is not documented. It is the purpose of this presentation to summarize and review our findings together with pertinent facts obtained by others.

SUMMARY

Several processes for reducing the concentration of radioisotopes in reactor effluent water have been developed and evaluated. Application of the high alum process for the treatment of reactor cooling water has resulted in a reduction in P^{32} concentration by a factor of 2.3 from pre-1961 levels. An additional factor of 2 could be obtained by substituting nitrate salts for the sulfates currently employed in the process. Addition of sodium silicate to the cooling water was demonstrated to provide a factor of three reduction in the effluent concentration of P^{32} . Passage of reactor effluent water through a bed of aluminum turnings removed half of the P^{32} by adsorption on the aluminum corrosion film. The benefits from these treatments are cumulative; thus, by adoption of both sodium silicate addition and substitution of nitrate salts in the water treatment process the P^{32} concentration could be reduced to about 10% of the 1960 levels.

Prior to 1961, it was shown that two-thirds of the P^{32} in-reactor effluent water resulted from activation of inert phosphorus, but that currently, 80% results from n,p reaction on S^{32} . Phosphate ions were

found to engage in complex reactions with the film on in-reactor surfaces and are retained for extended lengths of time, while sulfate ions are rapidly released from the film surfaces. Roughly two-thirds of the P^{32} was produced on the surface of aluminum fuel elements, and one-third on the aluminum tube wall. Zirconium components did not provide significant sites for the retention and neutron activation of P^{32} parent isotopes. The chemical form of radiophosphorus in reactor effluent water was determined, both during normal operation and during reactor shutdown.

Production of Phosphorus-32

Phosphorus-32 can be produced by one of the three reactions shown in Table I, all of which are possible in the reactor environment.⁽¹⁰⁾ From consideration of the relative concentrations of the reactants and the reaction cross-section, chlorine was eliminated from consideration as a major source of radiophosphorus.

TABLE I
REACTIONS FOR P^{32} FORMATION

<u>Reaction</u>	<u>Cross Section (millibarns)</u>
$P^{31}(n,\gamma)P^{32}$	230
$S^{32}(n,p)P^{32}$	67
$Cl^{35}(n,\alpha)P^{32}$	3

The relative contributions of P^{31} and S^{32} were calculated from data available, both prior to 1961 and subsequent to this time, during which period the water treatment process was altered. Measurement prior to 1961, of the concentrations of S^{32} and P^{31} in the process tubing film, together with knowledge of the neutron spectrum and flux, showed S^{32} would be responsible for about 85% of the P^{32} formation, if both sulfur and phosphorus ions were retained on the corrosion film for equal lengths of time.⁽¹⁰⁾ It was shown, however, by addition of sulfate and phosphate to the cooling water, that the retention times for these two ions were markedly different. The retention of sulfate ion on the corrosion film was for a relatively short period as evidenced by the rapid attainment of a higher P^{32} concentration during continued addition of sulfate to the

coolant.⁽¹⁸⁾ On the other hand, when the phosphate concentration in the coolant was increased, the buildup of P^{32} extended over a considerable length of time, and increased by a series of exponential functions.⁽¹⁸⁾ From these data, it was concluded that only one-third of the P^{32} was produced from the sulfur reaction. Another experiment, in which the sulfate ion concentration in the reactor coolant was decreased by substituting nitrate salts for the sulfates normally employed in water treatment, showed the total contribution of P^{32} from the sulfur parent to be 30%.⁽¹⁹⁾

Since adoption of the "high alum" process of treatment of reactor cooling water the relative production of P^{32} by these two reactions has been drastically altered. As is shown in a subsequent section of this report, only 20% of the P^{32} is currently produced by activation of P^{31} with the remaining 80% derived from S^{32} . This reversal in contribution is due to increased phosphorus removal efficiency by the improvement in water treatment process, in addition to an increased sulfate concentration resulting from maintenance of a lower pH of the coolant.

Kinetics of Phosphate and Sulfate Retention

Kinetics of the retention reaction of both phosphate and sulfate ions with the film on process tubes and fuel elements were measured from the rate of change of the P^{32} concentration in the effluent from a process tube that was cooled with water containing an added amount of the respective parent.

The inert phosphorus concentration in the water cooling two single pass process tubes was increased by addition of $NaH_2PO_4 \cdot 2H_2O$ for a period of about 30 days.⁽¹⁸⁾ Radiochemical analyses of effluent from these tubes were performed during the addition and for some time after the addition was discontinued. The kinetics of phosphate retention were evaluated according to the model described by Nicholson⁽²⁰⁾, which assumed chemical identity of inert and radioactive phosphorus. These data indicated three components with the reaction half-periods and attachment probabilities shown in Table II. The attachment probability is defined as that fraction of the incoming phosphate ions that were retained within the flux zone.

TABLE II
KINETICS OF PHOSPHATE RETENTION

<u>Reaction Half-Period</u>	<u>Attachment Probability</u>	<u>Fraction of p³² at Equilibrium</u>
7 hours	2.06×10^{-3}	.17
30 hours	9.2×10^{-4}	.31
27 days	1.9×10^{-4}	.52

Extrapolation of these data to infinite time predicted an increase in p³² concentration that was proportional to the increased influent phosphate concentration. The film, therefore, had not attained saturation with respect to phosphate ion, and the sum of the calculated attachment probabilities should be a valid estimation of the fraction of the influent phosphate ions that entered into reaction with the corrosion films.

The sulfate ion concentration in the coolant for two reactor process tubes was increased from the normal 17.5 ppm to 104.2 ppm by addition of ammonium sulfate.⁽¹⁹⁾ The p³² concentration increased immediately when the sulfate addition was started and also decreased immediately when the addition was stopped. The average change in the p³² activity density during these periods was 31%. The fact that the changes were rapid, and the new concentrations were maintained until the experimental conditions were altered was interpreted to reflect a very short retention period for sulfate ion on the corrosion film.

Production Site

Estimates of the relative contribution of tube and fuel element surfaces to the production of p³² were possible during an operational sequence in which both zirconium and aluminum clad fuel pieces were exposed in an aluminum and zirconium tube.^(21,22) It was found that zirconium surfaces did not provide significant sites for the production of radiophosphorus when deionized water was employed as the coolant. Three percent of the effluent p³² was produced by activation of parent material dissolved in the cooling water while the parents retained on aluminum tube and fuel element surfaces accounted for 30% and 67%, respectively.

Analysis of film from downstream dummy fuel pieces showed that p³² was equally distributed with depth within the film. The radiophosphorus

was tightly bound to the film and transferred to water very slowly in contrast to the behavior of several cationic species.⁽²⁸⁾

In 1958, the film materials removed from the aluminum surface of process tubes and fuel elements, by a purge with Turco 4306 B, was analyzed for P^{32} . These measurements showed a large reservoir of radiophosphorus, amounting to 7 mCi/tube was contained in the film.⁽¹¹⁾ A measurement of the radioisotopes contained by the film on a fuel element column showed that the inventory had increased to 28 mCi/tube in 1963.⁽¹⁴⁾

Chemical and Physical Forms

Phosphorus-32 in reactor effluent water is predominately in the orthophosphate form during normal operation.^(7,23) Under conditions of reactor shutdown, the relative concentrations of the various chemical forms of P^{32} are altered, with high concentrations occurring as polymers containing as many as five or more phosphorus atoms.⁽²³⁾

Electrodialysis of Columbia River water from Vancouver, Washington showed that P^{32} at this location was anionic.⁽²⁷⁾ About 10% of the isotope was found on the exchange membrane, which was believed to result from deposition of particulate or colloidal material with which this fraction of P^{32} was associated.

Activation analysis of filtered samples of reactor process water revealed that 4% of the P^{32} precursor materials were insoluble.⁽¹²⁾ Four percent of the P^{32} in the reactor effluent water was particulate; however, after transport by the Columbia River to Pasco, 43% of the P^{32} had associated with particulate material.⁽¹²⁾ The fraction of insoluble radiophosphorus in the river water was, however, dependent on the turbidity of the river.⁽⁵⁾ During a clear water period, the Whatman #1 filterable content was 1.1 mg of ash/liter and contained about 1.5% of the P^{32} . In water taken during a turbid period there was 32.2 mg of ash/liter, which contained 48% of the radiophosphorus.

Methods for Reduction of the Effluent P^{32} Concentration

Effluent Treatment

Trenching. Disposal of reactor effluent water to a series of trenches located in the proximity of the river was proposed.⁽⁸⁾ Infiltration of the water and subsequent flow toward the river would permit soil retention

of the radionuclides in addition to the decay during the transit time required to reach the river. Calculation from the adsorption constants for the soil in the vicinity of the trenching predicted p^{32} removals of 93% and 99.9% at water travel times of 5 days and 15 days, respectively. No increased radioactivity was detected at the river during a two month evaluation of this process, in which 10% of the effluent from one reactor was diverted to a trench.⁽⁹⁾

Aluminum Bed Decontamination

This concept of post reactor decontamination was based on adsorption of the radioactive species on the continually regenerated aqueous corrosion film of aluminum. The amount of p^{32} removed from the effluent was shown to be an exponential function of the surface area of the aluminum.⁽²⁴⁾ A pilot scale bed of aluminum turnings, 20 ft. long, 6 ft. high, and 3 ft. wide, was operated with reactor effluent at varying flow velocities. The p^{32} decontamination efficiencies obtained are reported in Table III below.⁽¹⁵⁾

TABLE III

PHOSPHORUS-32 REMOVED BY ALUMINUM TURNINGS

<u>Superficial Velocity ft/min.</u>	<u>p^{32} Removal Percent</u>
2.7	55
3.8	45
6.0	37

Silicate Addition

Laboratory tests showed that retention of p^{32} on aluminum was markedly decreased when 20 to 100 ppm of SiO_2 (as sodium silicate) was added to the influent.⁽¹³⁾ Addition of 20 ppm of silicate to the cooling water of a single pass process tube for a period of three weeks reduced the effluent concentration of p^{32} by a factor of 2.⁽¹⁶⁾

The benefits obtainable under production conditions were evaluated in a half-pile test, in which 20 ppm SiO_2 , as sodium silicate, was added to the cooling water supplied to one-half of a reactor. This test, which is still being conducted, has shown that reduction of the effluent concentration of various radionuclides improved over a long period of time.

It seems likely that this is due to the beneficial effect resulting from reaction of the silicate with the surfaces of new fuel elements, and the ultimate improvement will be attained only after complete replacement of the reactor fuel charge. A reduction of the effluent P^{32} concentration of about a factor of 3 was observed by comparing the respective concentrations from the test and control sides of the reactor.⁽¹⁷⁾ The ultimate reduction would be somewhat greater if the treatment was applied to the total reactor coolant, due to cross-mixing of water between the two sides of the cooling system, which increased the apparent P^{32} concentration in the test side, with an accompanying decrease in the control side effluent.

Further evidence of the importance of sulfur as a P^{32} precursor can be implied from the fact that a reduction in radioarsenic of a factor of 6 was obtained by the silicate treatment. In laboratory tests, arsenate and phosphate ions behaved similarly, and presumably would also be nearly identical in behavior in the reactor test.⁽²¹⁾ The difference in concentration reductions for As^{76} and P^{32} was therefore attributed to the dual production route of P^{32} , and that amount of P^{32} derived from P^{31} accounted for the observed concentration change.

Addition of activated silica to reactor cooling water duplicated the P^{32} reductions obtained by addition of sodium silicate.⁽²⁵⁾ It was therefore reasoned that the sodium silicate underwent reaction to colloidal silica within the environment of the reactor. The deposition of the negatively charged colloidal silica on the in-reactor cooling surfaces inhibited deposition and retention of the phosphates and arsenates from the coolant.

Water Treatment Processes

One of the concepts in reduction of effluent radioisotopes is to remove the respective parents from the water prior to its use as a coolant. Considerable effort was devoted toward optimizing the water treatment process to accomplish this aim.⁽¹⁹⁾ This process, which utilizes flocculation with aluminum sulfate, was originally controlled to provide water with low turbidity. Prior to 1961, a flocculant dosage of 3 to 5 ppm was applied to fulfill this requirement. The removal of the negatively charged raw water colloids is accomplished by mutual coagulation with

the positively charged hydrous aluminum oxide. The net surface charge of the coagulum was highly negative at an alum dosage of 5 ppm. Under these conditions, roughly 40% of the negatively charged ions of phosphorus and arsenic were removed from the raw water by adsorption on the floc. When the surface potential of the coagulum was made more positive by increased addition of alum, or decreasing the pH of the medium, the removal of these anions was increased to about 95%. This led to the development of the "high alum" process. This process was developed to take advantage of this increased removal efficiency, and has been utilized by the reactor area water treatment plants since July 1961. Confirmation of the benefits obtainable by increased coagulant concentration was first obtained in two half plant tests in which the water supplying half of a reactor was treated with 18 to 20 ppm of either aluminum nitrate or aluminum sulfate, while the water supplying the other half was treated with the standard 3 to 5 ppm of coagulant. The measured reductions of P^{32} and As^{76} concentration obtained in these two tests, together with the calculated reductions assuming 10% cross-mixing of the water between the two sides of the reactor are tabulated in Table IV.

TABLE IV

REDUCTION IN EFFLUENT RADIOISOTOPE CONCENTRATIONS

	<u>Aluminum Sulfate</u>		<u>Aluminum Nitrate</u>	
	<u>% Observed</u>	<u>% Calculated</u>	<u>% Observed</u>	<u>% Calculated</u>
P^{32}	63	73	77	88
As^{76}	72	86	76	87

As a result of these tests, the use of 18 ppm of alum was adopted in mid-1961 as a standard for treatment of reactor coolant. It was subsequently determined, by electrophoretic measurements, that this concentration of coagulant was in excess of that required at those treatment plants operating at lower pH, and the alum dosage was subsequently reduced according to these findings. Later work illuminated the need to vary the alum dosage, according to the requirements of the raw water turbidity, to provide a neutral or slightly negative electrical charge on the coagulum.⁽²⁶⁾ Although this was successfully demonstrated in water

treatment pilot plant operation, application to reactor water treatment plants has not been made to date.

The fact that use of the high alum treatment has proven effective is substantiated by several independent analyses and tests. Radiochemical analysis of raw and treated water from the treatment plant at 100F Area showed respective depletions of 91 and 90% for p^{32} and As^{76} .⁽⁶⁾ Routine chemical analysis of raw and treated water from 100B Area has shown a consistent reduction of phosphate ion by a factor of 10 or greater.⁽³⁾ Occasional reductions of only a factor of 6 were reported, but these results represented less than 10% of the values reported. One set of data was also reported in which the inert arsenic concentration was reduced greater than a factor of 5 by the water treatment process,⁽⁴⁾ the arsenic concentration in the treated water being less than the detection limit of the procedure employed.

The measured concentrations of reactor effluent radioisotopes from 100KF Area, during the twelve month periods both before and after application of the high alum treatment, are summarized in Table V.

TABLE V
RELATIVE As^{76} AND p^{32} CONCENTRATIONS
IN KE REACTOR EFFLUENT

	<u>Period</u>		<u>Reduction Factor</u>
	<u>5/60-5/61</u>	<u>5/64-5/65</u>	
As^{76}	1.0	.30	3.3
p^{32}	1.0	.43	2.3

This reduction in the concentrations of these radioisotopes has provided concurrent decreases in the discharge rate of p^{32} to the river (Ci/day) of about a factor of 2. This has been maintained in spite of increased coolant flow and reactor power level, both of which contribute to higher discharge rates.⁽¹⁾

The result of these production improvements on effluent radioisotope concentrations has been speculative, however, factual data were lacking until a recent reactor production test was conducted. In this test, the treatment plant supplying the coolant for the KW Reactor was operated with a reduced coagulant feed rate, while the plant supplying

the KE Reactor maintained a "normal" alum feed of 14 to 18 ppm. The alum dosage at KW was first reduced to 8 ppm in early 1965, and was further decreased to 3 ppm during September and October, which approximated the conditions existent prior to application of the "high alum" process. The effluent concentrations of P^{32} and As^{76} increased each time that the coagulant concentration was diminished.⁽²⁾ The data obtained during the terminal two week portion of the treatment with 3 ppm are summarized below in Table VI.

TABLE VI
RELATIVE RADIOISOTOPE CONCENTRATIONS AT DIFFERENT ALUM FEED

<u>Reactor</u>	<u>Alum Concentration</u>	<u>As^{76}</u>	<u>p^{32}</u>
KE	14 to 18 ppm	1.0	1.0
KW	3 ppm	9.3	2.7

These data, when compared with those from the preceding table, show that the production improvements would have increased the effluent concentration of P^{32} and As^{76} by factors of 1.2 and 2.8, respectively, had the water treatment process used in 1960 been continued. These increases are probably on the conservative side, due to the fact that the test was not of sufficient duration to insure attainment of steady state equilibrium of the parent isotope concentration on the film in KW Reactor.

If the reactor operating conditions had been maintained at 1960 levels, the "high alum" process would provide reduction of at least factors of 10 and 3 in the respective effluent concentration of As^{76} and p^{32} .

The differences in effectiveness of reduction of As^{76} and p^{32} is due in part to the dual production path for P^{32} . From the data in Table VI, it was calculated that only 20% of the P^{32} is currently produced by activation of P^{31} , and the remaining 80% resulted from reaction with S^{32} . It is obvious, from these values that to accomplish a further reduction in the effluent P^{32} concentration will require significant depletion of the sulfate concentration in the coolant.

The purpose of this review was to summarize the current knowledge pertaining to radioactive phosphorus in the effluent from Hanford reactors.

By necessity, many details were omitted and the reader is referred to the original publications for these data. It is apparent, however, that much information has been obtained about P^{32} , not only in development of methods for reducing its concentration in reactor effluent, but also in more fundamental studies such as the kinetics of formation and the physiochemical nature of the radioisotopes. Effort will be continued in an effort to devise new means of providing additional reductions in the amounts of radioisotopes released to the river, and at present the most promising approach appears to be in the treatment of the film, or addition of materials to the coolant to prevent retention of the radioisotope parent materials in the reactor.

REFERENCES:

1. Anderson, B. V., J. W. Healy, J. K. Soldat, and C. M. Unruh. "Environmental Consequences of Proposed Process Changes in Reactor Operations." HW-54953, February 1958.
2. Frymier, J. W. Private Communication, November 1965.
3. Geier, R. G. "Monthly Reports, Contamination Control - Columbia River." 1964-1965.
4. Geier, R. G. "Monthly Reports, Contamination Control - Columbia River." RL-REA-1098, April 1965. (SECRET)
5. Healy, J. W. "Quarterly Progress Report, Research and Development Activities in the Field of Radiological Sciences January-March 1957." HW-49793, April 1957.
6. Hall, R. B. Letter to W. N. Koop, July 8, 1963.
7. Henkins, R. W. and D. R. Kalkwarf. "The Chemical Forms of Radioactive Ions in Reactor Effluent Water." HW-68533, p. 47, January 1961.
8. Nelson, J. L., and G. J. Alkire. "A Concept and Proposed Field Test for Decontamination of Reactor Effluent." HW-80022, December 1963.
9. Nelson, J. L. Private Communication, November, 1965.
10. Perkins, R. W. "The Origin of Reactor Effluent Radioisotopes. I. The Effect of Turco Purging on the Radioisotope Concentration in Reactor Effluent and Radioisotope Deposition on Metal Surfaces." HW-60890. June 1959.
11. Perkins, R. W. "Interim Report on the Origin of Reactor Effluent Water Radioisotopes. Analysis of Turco Purge Materials." HW-56242. June 1958.
12. Perkins, R. W. "The Origin of Reactor Effluent Radioisotopes." HW-63824, p. 39. March 1960.
13. Perkins, R. W., and D. E. Robertson. "The Effect of Chemical Additives and Coating Materials on the Adsorption of Radionuclide Parent Elements on Aluminum Surfaces." HW-75976. December 1963.
14. Perrigo, L. D. "Radionuclide Distribution in Fuel Column Films: Progress Report." HW-79130. October 1963.
15. Rieck, H. G. "Pilot Scale Aluminum Bed Decontamination of Reactor Effluent." HW-72215. March 1962.
16. Robertson, D. E., and R. W. Perkins. "Reduction of Effluent Water Radionuclides by Addition of Sodium Silicate to Process Water." HW-75782. December 1962.

17. Robertson, D. C., Unpublished Data.
18. Silker, W. B. "On the Origin of Radiophosphorus in Hanford Reactor Effluent Water." HW-69083. April 1961.
19. Silker, W. B. "Reducing Radioisotope Concentrations in Reactor Effluent by High Coagulant Feed." Jour. AWWA. Vol. 55, pp. 355-368 (1963).
20. Silker, W. B. "Kinetics of Arsenic Retention in Hanford Reactor Cooling Systems." HW-63633. February 1960.
21. Silker, W. B., and C. W. Thomas. "The Effect of Deionized Water on Reactor Effluent Water Activities. Part 1: New Tubes and New Fuel Charges." HW-81412. September 1964.
22. Silker, W. B., and C. W. Thomas. "The Effect of Deionized Water on Reactor Effluent Activities. Part 2: Zirconium and Aluminum Clad Fuel." HW-81413. October 1964.
23. Silker, W. B. "The Chemical Form of Phosphorus-32 in Hanford Reactor Effluent Water." HW-60154. April 1959.
24. Silker, W. B. "The Effect of Temperature and Flow Velocity on the Decontamination of Reactor Effluent Water with Aluminum." HW-62874. December 1959.
25. Silker, W. B. To be published. 1965-1966.
26. Silker, W. B. "Optimum Alum Feed Rates at 100K Reactors." HW-72926. March 1962.
27. Thomas, C. W. "Analytical Application of Electrodialysis: Preliminary Report." HW-68533, pp. 7-11. January 1961.
28. Thomas, C. W., and W. B. Silker. "Concentrations of Radionuclides in Reactor Film." HW-81746, p. 3.37. January 1964.
29. Unpublished Date, Purex Analytical Laboratory.

ONSITE DISTRIBUTION

Copy Number

Pacific Northwest Laboratory

1	F. W. Albaugh
2	G. J. Alkire
3	J. A. Ayres
4	S. M. Bush
5	R. L. Dillon
6	J. R. Divine
7	S. L. Fawcett
8	R. F. Foster
9	R. B. Hall
10	W. A. Haney
11	E. R. Irish
12	R. L. Junkins
13	A. R. Keene
14	J. M. Nielsen
15	H. M. Parker
16	R. S. Paul
17	D. W. Pearce
18	R. W. Perkins
19	A. M. Platt
20	R. B. Richman
21	D. E. Robertson
22	C. A. Rohrmann
23	W. B. Silker
25	C. W. Thomas
26	E. E. Voiland
27	M. T. Walling
28 - 32	Central Files

Douglas United Nuclear

33	T. W. Ambrose
34	R. S. Bell
35	J. W. Frymier
36	R. G. Geier
37	S. M. Graves
38	C. D. Harrington/S. P. Smith
39	R. Nilson
40	O. C. Schroeder

General Electric Company

41	W. E. Johnson
----	---------------

Richland Operations Office

42	A. T. Gifford
43	P. G. Holsted
44	H. H. Schipper
45	R. B. St. John
46	R. D. Wildman
47	D. G. Williams

END

DATE
FILMED

01/17/92

I