BNWL-711

3-

DECONTAMINATION OF THE PLUTONIUM
RECYCLE TEST REACTOR (PRTR)
PRIMARY SYSTEM

R. D. Weed

MARCH 1968

AEC RESEARCH &
DEVELOPMENT REPORT

SEARCHED	SERIALIZED	INDEXED	FILED	ROUTE	DATE
<i>CE King</i>	<i>30788</i>	<i>37012</i>	<i>JUL 10 1968</i>		

BATTELLE
BATTTELLE MEMORIAL INSTITUTE

NORTHWEST
PACIFIC NORTHWEST LABORATORY

3000 STEVENS DRIVE, P. O. BOX 999, RICHLAND, WASHINGTON 99352

BNWL-711

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

PACIFIC NORTHWEST LABORATORY

RICHLAND, WASHINGTON

operated by

BATTELLE MEMORIAL INSTITUTE

for the

UNITED STATES ATOMIC ENERGY COMMISSION UNDER CONTRACT AT(45-1)-1830

PRINTED BY/ FOR THE U. S. ATOMIC ENERGY COMMISSION

BNWL-711

UC-80,
Reactor Technology

DECONTAMINATION OF THE PLUTONIUM
RECYCLE TEST REACTOR (PRTR) PRIMARY SYSTEM

By

Ronald D. Weed

Surface and Coolant Chemistry Section
CHEMISTRY AND CHEMICAL ENGINEERING DEPARTMENT

RECEIVED
FEBRUARY 1968

168

March, 1968

Cutaway View of PRTR with Decontamination Tank Truck

DECONTAMINATION OF THE PLUTONIUM
RECYCLE TEST REACTOR (PRTR) PRIMARY SYSTEM

ABSTRACT

The Plutonium Recycle Test Reactor primary system was successfully decontaminated in late December, 1965. An improved decontamination process consisting of alkaline permanganate followed by an inhibited oxalic-citrate mixture was used. The decontaminating solutions effectively removed more than 31 Ci of radioactivity with an effective primary system decontamination factor of 24. Corrosion of carbon steel and stainless steels during the decontamination process and development data for the decontamination process are discussed.

TABLE OF CONTENTS

ABSTRACT	ii
LIST OF TABLES	iv
INTRODUCTION	1
SUMMARY	1
DISCUSSION	2
Background	2
PRTR Primary System Description and Operating History	2
Decontamination Procedure	3
PRTR Primary System Decontamination Data	5
Radioactivity Measurements	5
Corrosion Measurements	10
Additional Laboratory Data	14
Comparison with Previous Decontaminations	16
Comparison with Previous PRTR Decontamination	16
Comparison with Shippingport PWR Decontamination	17
CONCLUSIONS	20
ACKNOWLEDGEMENTS	20
REFERENCES	21
APPENDIX A - Pertinent Development Data for the Decontamination Process	A-1
Laboratory Evaluations	A-2
Decontamination of G7 M3 Loop Facility, Engineering Test Reactor (ETR), Idaho Falls, Idaho	A-5
DISTRIBUTION	22-

LIST OF TABLESTable

I	Radioactivity Levels on the Primary System Before and After Decontamination.
II	Radioactivity Levels on a Top Face Process Tube Connector Before and After Decontamination.
III	Radiochemical Data Obtained from the Decontamination Samples.
IV	Corrosion of Samples and Probes During the PRTR Primary System Decontamination.
V	Additional Cleaning of Top Face Connector Samples.
VI	Stepwise Comparison of Both PRTR Decontaminations.
A-I	Comparison of the Decontamination Effectiveness of Three Acid Decontaminants Preceded by Modified Alkaline Permanganate.
A-II	Comparison of the Uniform Penetration of Structural Metals in Three Decontaminant Acid Solutions.
A-III	Process and Procedure for G7/M3 Loop Decontamination.
A-IV	Radioactivity Levels (mR/hr) on the BNW G7/M3 System.
A-V	Radioactivity Levels of Various Decontaminant Samples.

DECONTAMINATION OF THE PLUTONIUM
RECYCLE TEST REACTOR PRIMARY SYSTEM

R. D. Weed

INTRODUCTION

The decision to decontaminate the primary system of the Plutonium Recycle Test Reactor (PRTR) was made after the radioactivity levels had increased gradually following the chemical decontamination in October, 1962.⁽¹⁾ These levels hindered contact maintenance on portions of the primary system.

The Rupture Loop incident^(2,3) in late September, 1965, slowed the pace of decontamination preparation but did not affect the selection of the decontamination process. The actual decontamination was conducted December 28-29, 1965.

SUMMARY

The decontamination procedure involved circulation of an alkaline permanganate (10% NaOH, 3% KMnO_4) pretreatment solution followed by the inhibited acid solution (RDW-3) with appropriate water rinsing between solutions and after decontamination.

The decontamination factors obtained around the system varied from 11 to 360. The highest decontamination factors were obtained on the primary heat exchanger (HX-1). The effective primary system decontamination factor was 24, excluding HX-1, which does not affect accessibility for maintenance.

More than 31 Ci of activity were removed from the primary system during the decontamination. The RDW-3 solution removed 18 Ci of ^{60}Co , 0.1 Ci of ^{124}Sb , and 13 Ci of beta activity. Insignificant amounts of activity were removed by the alkaline permanganate and the water rinses.

Gamma scan analyses of top face jumper samples before and after decontamination gave the following values:

<u>Isotope</u>	<u>Before</u>	<u>After</u>
^{60}Co	$0.5\mu\text{ Ci/cm}^2$	$0.19\mu\text{ Ci/cm}^2$
^{124}Sb	$8 \times 10^{-3} \mu\text{ Ci/cm}^2$	None

Assuming uniform distribution of ^{60}Co over the top face, these values indicate 62% removal of the ^{60}Co on the reactor top face.

The corrosion of AISI type 304 stainless steel during decontamination was negligible, less than 0.01 mil. The carbon steel corrosion was 1.5 to 1.7 mils for the exposure period of the coupons (December 10, 1965 to January 3, 1966). Corrosion probe data defined the greatest attack (~ 0.7 mil) as occurring during the period of RDW-3 circulation.

Corrosion of the 400 series stainless steels varied from 0.02 mil for type 416 to 1.7 mils for type 440-C, both steels in the mill-finish condition. The corrosion probe of type 410 SS indicated that most of the attack occurred during the acid step, 0.47 mils per 3 hours versus 0.55 mil for the total period--December 10, 1965 to January 3, 1966. The corrosion rates of carbon steel and 400 series SS in laboratory beaker studies (zero velocity) varied between 0.1 to 0.2 mil per 24-hour exposure in the acid solution. The increase from about 0.01 mil/hr at zero velocity to about 0.2 mil/hr at 13 ft/sec velocity indicates a marked velocity effect on the corrosion rates of carbon steel and the 400 series SS.

DISCUSSION

BACKGROUND

PRTR Primary System Description and Operating History

The PRTR primary system was described briefly by J. A. Ayres et al.,⁽⁴⁾ and in detail elsewhere.⁽⁵⁾ The heavy water coolant is recirculated at approximately 10,000 gal/min by three pumps in the primary system. To review briefly, the primary system was constructed of AISI type 304 SS

pipng and tubing; Zircaloy-2 process tubes; and other materials found in valves and gaskets such as Haynes Stellite alloys, 17-4PH SS, and asbestos. The reactor core outlet temperature was approximately 540 °F and the pressure, approximately 1100 psi. The coolant was maintained at pH-10 with addition of lithium hydroxide. Operation during the period December 1962 to late September 1965 (time of rupture-loop incident) was 35,000 megawatt days. Normal full power operation was 70 MW.

The schematic diagram (Figure 1) of the PRTR primary system during decontamination presented by J. A. Ayres et al.,⁽⁴⁾ was modified slightly for the decontamination in December 1965. Chemicals for decontamination were pumped from a tank truck through the lower ring header, rather than by gravity flow from a mix tank to the reactor top face as in 1962. The solutions, supplied by tank truck, were from mix tanks located in the separations plant area about 20 miles away.

Decontamination Procedure

In October 1962 the decontamination objective was to remove the maximum possible amount of plutonium oxide and activated corrosion film from the internal piping surfaces.

Since fuel rupture debris was not present, the single objective of this decontamination was to remove the radioactive corrosion film. Therefore, the chemical procedure was greatly shortened and consisted of only two solutions with the appropriate water rinses between the solutions. The general procedure is described briefly below. A more detailed discussion of the operational procedures, scheduling, chemical procurement, and preparation is being prepared by PRTR operations personnel.

- Step 1. Remove all fuel elements, drain and store primary system heavy water, and modify the system as necessary.
(Connect the following: drain hoses, fill and pump out lines, angle valve and pump seal back flush lines; and isolate all instrumentation lines possible.)
- Step 2. Following extensive personnel training, completely drain the light water from the primary system.

FIGURE 1
PRTR Primary System Schematic During Decontamination

- Step 3. Introduce the alkaline permanganate solution and circulate at 100 to 105 °C for 2 hours.
- Step 4. Drain the system and rinse the water until a pH of 10.5 or less is obtained.
- Step 5. Introduce the acid solution and circulate at 80 °C for 3 hours.
- Step 6. Drain the system and rinse with water to a specific resistance of 10,000 ohm/cm(100 μ hos).
- Step 7. Use ion exchange cleanup to achieve a specific resistance of 100,000 ohm/cm or greater (≤ 10 μ hos).

The chemical solutions used for this decontamination and the maximum acceptable concentrations for chloride and fluoride in the makeup chemicals are listed below:

<u>Material</u>	<u>Concentration</u>	<u>Analyses (ppm)</u>	
	g/liter	Cl ⁻	F ⁻
<u>Alkaline Permanganate Solution (AP)</u>			
Sodium hydroxide	100	400	2.5
Potassium permanganate	30	<5 ^(a)	<10 ^(a)
<u>Inhibited Acid Solution (RDW-3)</u>			
Oxalic acid	25	<5 ^(a)	<10 ^(a)
Dibasic ammonium citrate	50	2.5	<3 ^(a)
Ferric sulfate	2	<5 ^(a)	<4 ^(a)
Diethyl thiourea	1	3	1.5

(a) Determination limit of analytical procedure.

PRTR PRIMARY SYSTEM DECONTAMINATION DATA

Radioactivity Measurements

The chemical decontamination of the PRTR primary system began at 0800 hours on December 28, 1965 and the final chemical solution was drained from the system by 1500 hours on December 29, 1965. Four water rinses were conducted until 0800 hours on December 30, 1965;

at this time ion exchange units were valved into the system to obtain greater than 1,000,000 ohm/cm specific resistance ($<1 \mu\text{mho}$ conductivity) water in the system prior to adjusting the pH to 10 with LiOH.

Radioactivity levels at various points on the primary system were recorded before and after decontamination; the activity levels are presented in Table I with the decontamination factors for each point.

The decontamination factors obtained on the primary system ranged from a low value of 11 measured at the pressurizer to a high of 360 measured on the secondary side of the HX-1 tube bundle. Because the moderator and dry gas systems were still contaminated from the September incident, it is important to note that the general dose rate inside the HX-1 (5 mR/hr) was much less than the general dose rate (25 mR/hr) on the enclosure grating around the HX-1. About 70% of the general dose rate was contributed by contaminated portions of the moderator and dry gas systems in the proximity of the HX-1 enclosure grating.

The general dose rate readings taken in the work areas of cells A, B, and C before and after decontamination also showed a substantial decrease in radioactivity. Three gamma scan probes placed at different points on the primary system indicated decontamination factors of 48 on the lower ring header, 10 on the upper ring header, and 3 on the DT-2 tank.

Prior to decontamination, a process tube connector from the top face of the reactor was removed, and the activity levels at various points were recorded. The connector was replaced and decontaminated. It was removed following the decontamination and monitored for the change in activity levels. The results are shown in Table II.

The results shown in Table II indicate satisfactory decontamination of the PRTR top face process tube connector and indicate a background activity level of about 25 mR/hr for the primary system.

Samples of the decontaminating solutions were drawn every 15 min during the period of recirculation, including the periods for heat-up and cool-down. Following decontamination, selected samples were submitted for complete gamma-scan analysis to identify the radioactive isotopes present and to determine the relative quantities of individual

isotopes. The analytical data presented in Table III indicate that very little change in activity level occurred after the first hour of circulation. Additional circulation would not have removed appreciably more activity.

TABLE I
RADIOACTIVITY LEVELS ON THE PRIMARY SYSTEM
BEFORE AND AFTER DECONTAMINATION^(a)

<u>System Location</u>	Before mR/hr	After mR/hr	Decontamination Factor (DF)
1. Bottom of DT-2 tank	130	5	26
2. Inlet to lower ring header, point 1	300	10	30
3. Volute, primary pump #2	150	5	30
4. Volute, primary pump #3	120	5	24
5. Pressurizer inlet piping	120	10	12
6. Six-foot level on pressurizer	110	10	11
7. Inlet to degasser	100	5	20
8. Bottom of HX-5 header	190	5	38
9. Inlet header, injection pumps	60	5	12
10. Outlet header, injection pumps	100	5	20
11. Outlet line from DT-2 tank	90	5	18
12. Inlet line to DT-2 tank	100	5	20
13. Side of DT-2 tank, point 1	90	5	18
14. Pressurizer outlet piping	190	5	38
15. Header to primary pump #2	220	5	44
16. Inlet to primary pump #1	210	5	42
17. Inlet to lower ring header, point 2	300	10	30
18. By-pass around HX-1 and pressurizer	100	5	20
19. Piping from HX-1 to pressurizer	110	5	22
20. Side of pressurizer, point 1	90	5	18
21. Side of pressurizer, point 2	100	5	20
22. Side of DT-2 tank, point 2	60	5	12
Secondary side of HX-1			
23. 6 in. inside manhole	1,200	5	240
24. 12 in. from tubes	1,800	5	360
25. Maximum reading on tubes	4,500	25	180

(a) Readings taken by Radiation Monitoring Section (RMS), using a shielded C. P. Instrument.

Point	Levels Before		Levels After		Decontamination Factor	
	wo (a) mrad/hr	wc (b) mR/hr	wo mrad/hr	wc mR/hr	wo	wc
1	800	350	21	6	38	58
2	---	60	19	19	--	3.2
3	---	60	20	19	--	3.2
4	---	70	20	20	--	3.5
5	---	70	21	20	--	3.5
6	---	60	20	20	--	3.0
7	---	60	18	16	--	3.8
8	800	400	40	7	20	57

(a) wo - C.P. Window Open Readings

(b) wc - C.P. Window Closed Readings

TABLE II
Radioactivity Levels on a Top Face Process Tube Connector
Before and After Decontamination

TABLE III

RADIOCHEMICAL DATA OBTAINED FROM THE DECONTAMINATION SAMPLES

Sample	Total Ci of Activity Removed ^(a) ($\beta + \gamma$)	Total Activity (μ Ci/liter)	Isotopic γ Activity (μ Ci/liter)					C. P. Reading (mR/hr)
			⁶⁰ Co	¹²⁴ Sb	¹³⁷ Cs	⁶⁵ Zn	⁵⁴ Mn	
1 Alkaline permanganate at pump-out	0.4	6	0 ^(b)	0.6	18	1.8	0.04	2
2 RDW-3 at start of circulation	19	5.4×10^2	7.8×10^2	3.1	0	0	0	70
3 RDW-3 after 1 hour of circulation, temperature 159 °F	29	8.6×10^2	1.1×10^3	6.4	0	0	0	130
4 RDW-3 after 2 hours of circulation, temperature 170 °F	30	8.8×10^2	1.2×10^3	9.3	0	0	0	150

(a) Values based on 3800 gallon volume.

(b) None detected.

The analyses by gamma scan of a small section of a top face process tube connector before decontamination showed the presence of $0.5 \mu\text{Ci}/\text{cm}^2$ ^{60}Co and $8 \times 10^{-3} \mu\text{Ci}/\text{cm}^2$ ^{124}Sb . The analyses from a second connector showed only the presence of $0.2 \mu\text{Ci}/\text{cm}^2$ ^{60}Co after decontamination. Based on these two measurements from different top face process tube connectors, and assuming uniform distribution over the top face of the reactor, approximately 60% of the ^{60}Co was removed from the top face area. Data obtained by J. L. Glesener indicate 100% removal of the ^{60}Co from the lower ring header.

The alkaline permanganate and RDW-3 solutions removed about 31 Ci of beta-gamma activity from the primary system. The total activity removed during the decontamination was greater than 31 Ci because additional quantities of activity, though small, were removed in the water rinses.

Corrosion Measurements

During decontamination, the corrosion was monitored as well as decontamination effectiveness. The corrosion data obtained from the coupons are tabulated in Table IV; the corrosion probe* data are presented graphically in Figures 2 and 3.

The data from the corrosion probes generally agreed with the coupon data. Corrosion was not measurable on the 304 and 316 SS samples, or on the 304SS corrosion probe. The corrosion of the carbon steel probe, the carbon steel samples, the 410 stainless steel probe, and the 400 series stainless steel samples were more varied than expected.

The corrosion probe readings plotted in Figure 3 show that the principal corrodant was the acid solution of Step 5 in the procedure. It was also noted that the sharp increase in the corrosion of the carbon steel and the 410 stainless steel probes occurred immediately upon starting the three primary pumps on high speed. The increased velocity (from 0 to 13.5 ft/sec) in the test section accelerated corrosion of the carbon steel and 400 series stainless steel more than had been expected from laboratory stirred beaker studies.

* Manufactured by Magna Corporation

TABLE IV

CORROSION OF SAMPLES AND PROBES DURING THE PRTR
PRIMARY SYSTEM DECONTAMINATION

<u>Type of Material</u>	<u>mils Penetration</u> (a)
<u>A. Coupons</u>	
304 SS, sensitized	0.001
304 SS, as-received	0.0015
316 SS, sensitized	0.005
316 SS, as-received	0.001
416 SS, heat treated	0.065
416 SS, as-received	0.016
440-C SS, heat treated	0.406
440-C SS, as-received	1.67
302 SS, sensitized	0.014
302 SS, as-received	0.004
A-245 CS, as-received	1.52
A-106 Grade B-CS, as-received	1.75
Zircaloy-2, as-received	(b)
304 SS with Stellite overlay	0.006
17-4PH SS, as-received	0.021
Inconel-600, as-received	0.307
Inconel-X, as-received	0.165
<u>B. Probes</u>	
304 SS	(b)
1010 CS	1.02
410 SS	0.55

(a) Charged 12-10-65, removed 1-3-66.

(b) Not measurable.

FIGURE 2
 Total Corrosion Recorded from Corrosion Probes
 (See Figure 3 for Expanded View Between December 28 - 30)

FIGURE 3
Corrosion Recorded During Decontamination and Rinsing. (Expanded Section from Figure 2)

The Zircaloy-2 coupons did not undergo any detectable weight change. The 17-4PH stainless steel was also corroded very little (0.02 mil total).

In the primary system, the 440-C stainless steel injection pump plungers probably sustained the most corrosion. Approximately 85% of the corrosion occurred during the 3-hour circulation of the acid step.

The top face piping connector, which was removed for monitoring activity levels, was visually inspected for surface appearance before and after decontamination. The original corrosion film was a very dark brown to black color before decontamination. Following decontamination the visual appearance of the surface was a light reddish-brown color. This film was residual high-temperature water film which had not been completely removed during decontamination; it was loose, smearable, and could be completely removed by wiping.

Additional Laboratory Data

Additional laboratory evaluations were performed with sections (approximately 3 to 4 in.²) of this piping connector. One sample was cleaned further in one liter of acid solution taken from the reactor at the completion of the decontamination. A second sample was cleaned further in a newly made-up liter of acid solution, RDW-3. The drop in activity levels and the decontamination factors are presented in Table V. Both acid treatments were for one hour at 80 °C.

Complete removal of the residual process film was accomplished in both solutions during the additional hour of acid exposure. The visual appearance of the samples after these exposures was: (1) a dull metallic grey color after the used acid cleaning, and (2) a bright, shiny new-metal appearance after the new acid cleaning.

The beaker decontamination of portions of the top face connector, previously decontaminated in situ, must be further clarified. The studies indicate that significant additional decontamination could be obtained with either new acid solution or the acid solution removed from the reactor. The action of the used solution is of particular interest because it indicates that the solution either regained some of its effectiveness after removal from the reactor or that additional time of contact would have cleaned the system more completely.

An unequivocal choice between these alternatives cannot be made at this time because there were some differences between the beaker and reactor tests. The beaker test was conducted after a period of time which could allow slow processes to come to equilibrium, and since the solution was exposed to air the oxidation state of some of the dissolved materials may have changed. However, the decontamination of the top face jumpers was not as complete as many other areas of the reactor (compare Tables I and II). This observation is supported by laboratory tests shown in Table A-I (in Appendix A) which indicated the top face jumpers were more difficult to decontaminate than the bottom face jumpers. Presumably this is caused by the higher temperature water of the top face when compared to the bottom face. Thus, the decrease in the rate of activity removal with time, which is shown in Table III, simply may be a decrease in area with removable contamination rather than an approach to equilibrium in the stripping solution. If this is the case, an extended time of contact would have increased the removal of the more obdurate oxide surface layers. The use of a fresh acid solution would have improved the decontamination effectiveness even further according to Table V.

TABLE V

ADDITIONAL CLEANING OF TOP FACE CONNECTOR SAMPLES^(a)

Solution	<u>Sample Activity</u>		<u>Decontamination Factor</u>
	<u>Before Treatment</u>	<u>After Treatment</u>	
Pump-out sample of acid ($\beta+\gamma$)	65 mrad/hr	5 mrad/hr	13
γ	4 mR/hr	1 mR/hr	4
Newly made up sample of ($\beta+\gamma$)	70 mrad/hr	2.5 mrad/hr	28
acid γ	3 mR/hr	1 mR/hr	3

(a) Samples were 1/2 sections of 1 1/2 in. rings cut from the connector.

COMPARISON WITH PREVIOUS DECONTAMINATIONS

When reporting and discussing decontamination data, inherent problems exist, more especially when comparing data from different sources. In an earlier report,⁽⁴⁾ J. A. Ayres et al., very aptly described the problems:

"In the discussion of decontamination, the efficiency of the removal of the contamination will usually be expressed as the decontamination factor, or the ratio of initial activity to final activity. Actually, the effectiveness of decontamination may be expressed in any of several different ways: amount of activity removed (in curies of β, γ, α , Pu, ...) amount of crud removed, degree of film removal, residual activity, or decontamination factor. In laboratory and pilot plant experiments, the most popular method is by decontamination factors. In a reactor, this method may be somewhat academic because the reading at one spot may be affected by high levels of activity in surrounding areas. Further, if the initial activity level is near background level, even complete removal of activity would result only in a low decontamination factor. Conversely, in those regions where initial activity is high and background levels are low, the same degree of removal of activity would result in a very high decontamination factor. The decontamination factors, to be of value, must be interpreted in light of these considerations.

"There is no simple method of stating how effective or satisfactory the reactor decontamination is. An average decontamination factor is misleading, since it depends on the number and location of points. For example, if all or most readings are taken at points with high general background the decontamination factor will tend to be low."

In light of the above discussion by J. A. Ayres, the decontamination factors, which are used as a method of expressing the effectiveness of decontaminations, must be interpreted with caution. To compare different processes, a common basis must be used for sampling the system and the process, and for calculating the decontamination factors.

Comparison with Previous PRTR Decontamination

Both decontaminations of the PRTR primary system, October 1962 and December 1965, accomplished the established objectives. Since

the objectives were somewhat different, the two decontaminations are not directly comparable. Only those portions of the decontaminations which were similar can be compared. Probably the most striking comparison between the two decontaminations, then, is the comparison of lapsed time from beginning to end of the cleanup (see Table VI beginning with Step 5).

The total lapsed time used for chemical decontamination and stripping the corrosion film was 216 hr in 1962 compared to 48 hr in 1965. Several reasons account for this shorter time period: (1) an improved process for decontamination, (2) increased efficiency in handling the chemical solutions, and (3) detailed operational procedures improved by experience gained from the first decontamination.

The improved decontamination process removed more activity from the primary system than the previous procedure and accomplished it in less time. The initial pretreatment solution, alkaline permanganate, was revised from 18% NaOH in 1962 to 10% NaOH in 1965; the potassium permanganate concentration was constant at 3%. The lower caustic concentration tends to reduce the possibility of caustic stress corrosion cracking.

More curies of radioactivity were removed in 1965 by a single application of the process than was removed by three applications of similar chemical solutions in 1962 (see Table III). However, it also must be remembered that more activity was present initially in the corrosion film in 1965 than was present in the film in 1962, though a comparison of the relative amounts is not available.

Comparison with Shippingport Pressurized Water Reactor (PWR) Decontamination

The decontamination of the PWR at Shippingport, Pennsylvania, in March 1964, provides an interesting contrast to the procedures used for the 1962 and 1965 PRTR decontaminations. Abrams and Saiterelli⁽⁶⁾ have described the PWR decontamination system and process as well as the results obtained.

TABLE VI

STEPWISE COMPARISON OF PRTR DECONTAMINATION PROCESSES

<u>Operational Step of Decontamination</u>	<u>PRTR 1962</u>		<u>PRTR 1965</u>	
	<u>Time</u>	<u>Date</u>	<u>Time</u>	<u>Date</u>
1. Began addition of oxalic-peroxide peracetic solution	1400	10-10-62		
2. Completed circulation and rinsing	2315	10-10-62		
3. Began addition of oxalic-peroxide-gluconic solution	2315	10-10-62		
4. Completed circulation and rinsing	2100	10-11-62		
5. Began addition of first alkaline permanganate solution	2100	10-11-62	0800	12-28-65
6. Completed circulation, draining and rinsing	1400	10-12-62	0700	12-29-65
7. Completed addition circulation, and rinsing of 1% oxalic acid solution	0300	10-13-62		
8. Began addition of oxalic acid cleaning solution	0300	10-13-62	0820	12-29-65
9. Completed circulation of acid solution	0800	10-13-62	1400	12-29-65
10. Completed rinsing of system	0700	10-14-62		
11. Began addition of second alkaline permanganate solution	0700	10-14-62		
12. Completed circulation and draining of alkaline permanganate solution	1500	10-14-62		
13. Completed rinsing of system and deadlegs	0200	10-15-62		
14. Completed 1% oxalic acid rinse and water rinse	1130	10-15-62		
15. Completed addition, circulation, and draining of second oxalic acid cleaning solution	1530	10-15-62		
16. Completed rinsing and laboratory analyses	2030	10-18-62		
17. Completed addition, circulation and draining of third alkaline permanganate solution	0300	10-19-62		
18. Completed rinsing of system and deadlegs	2300	10-19-62		
19. Completed addition, circulation, and draining ammonium citrate solution	0530	10-20-62		
20. Completed rinsing system to coolant conductivity of approximately 5 μ mbos/cm	2130	10-20-62	0600	12-30-65
Total ^(a) lapsed time in hours	247		48	
Total ^(a) lapsed time for corrosion film removal and decontamination	216		48	

(a) This is not total reactor down time.

The PWR decontamination was accomplished using dilute acid solutions (1% to 3%) instead of concentrated acid solutions (7% to 10%) such as used in both PRTR decontaminations. The use of dilute solutions had the stated purpose of minimizing the volume of solid radioactive waste requiring disposal. However, dilute solutions, as used at Shippingport, are more susceptible than concentrated solutions to the formation of precipitates which may be insoluble and which may scavenge the activity. The collection of radioactive precipitates in low velocity areas or deadlegs can seriously prejudice the effectiveness of the decontamination. Abrams and Salterelli⁽⁶⁾ observed deposited particulate activity which probably resulted from a precipitation-scavenging reaction in the dilute acidic solution. Precipitation in the dilute acid solution was also observed by Stice and Weed during decontamination of the irradiated rupture prototype loop.⁽⁷⁾

The objective of this PWR decontamination was accomplished, namely, reduced radioactivity levels for contact maintenance. The few remaining areas with high radioactivity levels were further reduced by either rinsing, removal of component, local decontamination, or installation of temporary shielding.

Abrams and Salterelli⁽⁶⁾ reported decontamination factors ranging from 4 to 50 for the over all system; the total time requirement was approximately 325 hr. In comparison, the 1965 PRTR decontamination factors ranged from 11 to 360 at various points on the primary system, and the total time required was 48 hr. Since the amount and type of activity to be removed, as well as the system geometries were different, comparisons concerning the effectiveness of the two decontaminating processes can be only qualitative; both processes achieved effective removal of radioactivity.

CONCLUSIONS

The following conclusions about the decontamination and the procedure were drawn:

- More than 31 Ci of beta-gamma activity were removed from the system.
- The 304 SS system was corroded less than 0.01 mil; the 440-C alloy (injection pump plungers) was corroded about 0.4 mil during the decontamination.
- RDW-3 solution in contact with the primary system piping approached an equilibrium state in solution activity and would not have increased the decontamination effectiveness appreciably if circulated longer.
- A second treatment with RDW-3 solution probably would have reduced activity levels in the primary system to a range of from 5 to 10 mR/hr versus 20 to 30 mR/hr.
- The decontamination process and procedure used at PRTR can be recommended for stainless steel reactor systems.

ACKNOWLEDGEMENTS

J. L. Glesener, G. A. Halseth, J. Holt, W. R. Lewis, and R. B. Richman of PRTR operations and planning, Pacific Northwest Laboratory; D. A. Dodd, Redox Analytical Operation, Isochem, now Atlantic Richfield Hanford Company; E. R. Wood, Corrosion and Coolant Chemistry Section, Pacific Northwest Laboratory; and G. L. Erickson, Instruments and Electrical Development, Douglas-United Nuclear, are gratefully thanked for their help in obtaining the data presented in this report.

REFERENCES

1. L. D. Perrigo, Jr. Transport and Buildup of Radioactive Materials in Reactor Systems as Determined by Shutdown Radiation Measurements, BNWL-SA-35. Pacific Northwest Laboratory, Richland, Washington, March 5, 1965.
2. R. H. Purcell. Plutonium Recycle Test Reactor Experience, 1962-1966, BNWL-SA-557. Pacific Northwest Laboratory, Richland, Washington, April 15, 1966.
3. W. B. Cottrell and W. H. Jordan. "Rupture-Loop Failure in Plutonium Recycle Test Reactor", Nuclear Safety, vol. 7, no. 2, pp 242-247. Winter 1965-1966.
4. J. A. Ayres, Tom Demmit, K. D. Hayden, L. D. Perrigo, and R. D. Weed. Decontamination of the Plutonium Recycle Test Reactor, HW-75557-REV. General Electric Company, Richland, Washington, May 1963.
5. Joseph R. Dietrich and Walter H. Zinn, Editors, Solid Fuel Reactors, Addison-Wesley Publishers, 1958. Chapter 8.
6. C. S. Abrams and E. A. Salterelli, Editors. Decontamination of the Shippingport Atomic Power Station, WAPD-299. Westinghouse Electric Corporation, Bettis Plant, Pittsburgh, Pennsylvania, January 1966.
7. N. D. Stice and R. D. Weed. Unpublished data. General Electric Company, Richland, Washington, March 1962. (Pilot Plant Observation)
8. R. D. Weed, Invention Report - Dissolution and Removal of Radioactive Corrosion Films in Stainless Steel Reactor Systems, BNIR-23. Pacific Northwest Laboratory, Richland, Washington, October 1965.

BNWL-711

APPENDIX A

APPENDIX A

PERTINENT DEVELOPMENT DATA FOR THE DECONTAMINATION PROCESS

The radioactive corrosion films characteristic of circulating water-cooled nuclear reactors must be periodically removed to permit contact maintenance and continuity of operation. Before these systems can be cleaned, procedures and processes must be developed which are suitable for use in the system. These decontamination processes must meet certain criteria which are discussed below though not necessarily in order of importance.

A decontamination reagent must dissolve the radioactive corrosion film and remove it from the system. Large nuclear plants are no exception to other types of plants; they are built with inherent low velocity areas and other traps where particulate material will settle out. The particulates in these areas must be dissolved for successful removal. Therefore a successful decontamination reagent must dissolve as well as remove the radioactive corrosion film because, if it is only removed from the piping surfaces and not dissolved, it will settle out in the low velocity areas and traps.

A successful decontamination reagent must remove and dissolve radioactive films formed during extended periods of continuous operation. From the limited data available in the AEC literature, it is probable that cleaning will not be required more often except under unusual circumstances or demands. In power reactor operation it is desirable to keep the down-time at a minimum and possibly reach five years or more of continuous operation before cleaning. Therefore, the removal of these long term films is an essential requirement.

A successful decontamination reagent must not deposit a secondary film on the surface of the system piping. This secondary film deposit contains a considerable amount of radioactivity and thus, will render a decontamination procedure unsuccessful. The deposit can also be in the form of a precipitate settling out in the low velocity areas and deadlegs.

To be successful, a decontamination reagent must not be excessively corrosive to the materials of construction in the primary system. The reactor system will be constructed primarily of one or two materials, but there will be small quantities of many other materials found in such places as valves, sampling devices, and instrumentation. Such materials must be compatible with the reagent if they are in contact with the solution. This is particularly true if the components are in a critical location, e.g., a drain valve plug, seat, or stem.

After numerous compoundings, beaker evaluations, and loop studies, a mixture of oxalic acid, dibasic ammonium citrate, and inhibitors was formulated that met the above criteria. It was termed the RDW-3 solution and had the following composition:

Oxalic Acid	25 g/liter
Dibasic Ammonium Citrate	50 g/liter
Ferric Sulfate	2 g/liter
Diethyl thiourea	1 g/liter

LABORATORY RESULTS

The decontamination process consisted of two chemical treatments: a pretreatment with alkaline permanganate followed by treatment with the RDW-3 solution. Both solutions were thoroughly evaluated in the laboratory and in loop tests prior to specifying these solutions for decontamination. The laboratory results indicated that the RDW-3 solution had some advantages over available commercial cleaners.

The effectiveness of radioactive corrosion film removal and decontamination with these acid decontaminants were compared. The two proprietary cleaners (inhibited oxalic acid and inhibited sulfamic acid) were chosen for comparison because they were the most effective chemical decontaminating reagents previously evaluated by Coolant Systems Development Unit at the Pacific Northwest Laboratory. The alkaline permanganate pretreatment was conducted at 105 °C for 1 hr. The acidic treatments were conducted under the following conditions:

Inhibited oxalic acid, 60 g/liter, 85 °C, 1 hr

Inhibited oxalic citrate, 78 g/liter, 85 °C, 1 hr

Inhibited sulfamic acid, 90 g/liter, 60 °C, 1 hr

The samples were small sections, approximately $3/4$ in.², of 304 SS process tube connectors which were removed from the PRTR primary system after various operational exposures. The surface appearance of the samples varied in color from a very light brown to a dark brown to black color. The longer the exposure period the darker the corrosion film became. After decontamination the surface appearance indicated complete film removal from some samples and smaller amounts of film removal from others. These visual observations of film removal are confirmed by the results presented in Table A-I.

The sulfamic acid cleaner did not remove the corrosion film from the samples. Some film was removed but none of the samples had a bright metallic sheen after decontamination. The decontamination factors were also lower for the long exposure samples than for comparable samples using the two oxalic acid procedures.

With both oxalic acid solutions, the appearance was a bright metallic sheen after the sample was cleaned; however, there were some samples which were not entirely cleaned by the decontamination procedure. These samples were grouped between the 12 and 27 months exposure range. The sample surfaces retained some residual film. This observation was very interesting and with further investigation of samples exposed for periods of 27 and 32 months, another difference was noted. The bottom face samples were cleaned more easily than those from the top face of the reactor. Here a temperature gradient is observed, the top face of the reactor being about 50 °F hotter than the bottom face.

From the visual data and the decontamination data of Table A-I, the RDW-3 and proprietary oxalic acid cleaners are comparable. There also were no residues in the solutions used for the tests. Therefore, both oxalic acid cleaners, the RDW-3, and the proprietary cleaner all satisfy two of the initial criteria: (1) to dissolve and remove film instead of sloughing it, and (2) to dissolve film of three years or more operating exposure.

TABLE A-I

COMPARISON OF THE DECONTAMINATION EFFECTIVENESS OF THREE DECONTAMINANTS
PRECEDDED BY MODIFIED ALKALINE PEPHMANGANATE TREATMENTS(a)

Jumper Number			1455	1546	1847-2	1847-1	1356	1249	1253	2049-T(c)	2049-B(d)	1154-B	1746-T	1746-B
Months of Filming			6	6	12	16	20	22	22	27	27	29	32	32
Acid Process	% (b) NaOH	(e)	Decontamination Effectiveness											
PDW-3 78 g/liter 85 °C	1	IA	5	4	31	12	24	28	25	55	48	120	38	180
		FA	1	1	8	2	5	7	4	6	2	<1	12	1
		DF	5	4	4	6	4.8	4	6.3	9.2	24	120	3	180
	5	IA	6	4	32	12	33	28	29	50	70	120	40	190
		FA	1	1	7	2	6	7	7	5	<1	<1	6	<1
		DF	6	4	4.5	6	5.5	4	4	10	70	120	6.7	190
	10	IA	5	4	26	10	38	35	27	45	80	130	35	180
		FA	1	1	4	2	7	8	3	4	<1	<1	2	<1
		DF	5	4	6.5	5	5.5	4.5	9	11.2	80	130	17.5	180
	18	IA	5	4	29	13	24	27	24	50	45	120	39	160
		FA	1	1	1	2	3	4	4	5	<1	<1	1	<1
		DF	5	4	29	6.5	8	6.75	6	10	45	120	39	160
Proprietary oxalic acid cleaner 60 g/liter 85 °C	1	IA	5	4	26	15	36	24	25	50	70	130	37	160
		FA	1	1	1	2	4	3	2	6	<1	<1	4	1
		DF	5	4	26	7.5	9	8	12.5	8.3	70	130	9.25	160
	5	IA	5	4	34	13	30	26	29	50	80	120	38	160
		FA	1	1	2	1	3	2	2	5	<1	<1	3	<1
		DF	5	4	17	13	10	13	14.5	10	80	120	12.7	160
	10	IA	5	4	36	14	34	29	25	50	110	110	39	140
		FA	1	1	1	1	4	2	1	6	<1	<1	3	<1
		DF	5	4	36	14	8.5	14.5	25	8.3	110	110	13	140
	18	IA	5	4	32	12	30	28	27	55	100	120	45	140
		FA	1	1	1	1	3	2	1	7	<1	<1	2	1
		DF	5	4	32	12	10	14	27	7.9	100	120	22.5	140
Proprietary sulfamic acid cleaner 90 g/liter 60 °C	1	IA	6	4	27	14	23	25	22	50	47	120	38	120
		FA	1	1	6	5	6	6	5	11	7	6	9	5
		DF	6	4	4.5	3	4	4	4.5	4.5	7	20	4	24
	5	IA	5	4	31	13	28	30	20	55	100	110	32	160
		FA	1	1	7	4	7	8	5	12	3	5	6	6
		DF	5	4	4.5	3	4	3.7	4	4.6	33	22	5	27
	10	IA	6	4	33	18	19	27	25	40	70	110	30	160
		FA	1	1	9	7	5	7	6	10	9	6	9	7
		DF	6	4	3.7	2.5	4	4	4	4	8	18	4	23
	18	IA	6	4	37	12	27	24	25	60	140	140	47	160
		FA	1	1	10	4	8	6	6	14	5	6	10	6
		DF	6	4	3.7	3	3.5	4	4	4.3	28	23	4.7	27

(a) All solution exposures were 1 hr.

(b) Temperatures were 105 °C for all concentrations. Constant KMnO_4 concentration at 3%.

(c) T, top-face process tube connector.

(d) B, bottom-face process tube connector.

(e) IA, initial activity level (mR/hr).

FA, final activity level (mR/hr).

DF, decontamination factor: IA/FA.

Corrosion evaluation was conducted in three liters of solution with the concentrations and temperatures presented in Table A-II. Samples were discharged at periods of 8, 16, and 24 hr. The twenty-four hour data are given in Table A-II. The visual appearance of the samples was also noted at the time of discharge.

The measured corrosion in both the proprietary sulfamic acid and the oxalic acid cleaners varied from each other but were generally of the same order of magnitude; however, the 416 SS, hardened, presented an example of exfoliation corrosion in the sulfamic acid solution. The corrosion of the samples was less (with the exception of Haynes 25) in the RDW-3 than in the proprietary oxalic acid cleaner.

The samples discharged from the proprietary oxalic acid solution after 24 hr. were coated with a thick yellowish-green deposited film. The beaker of solution contained a thick deposit which had settled to the bottom even with mild agitation. Only faint traces of film deposition were observed on the samples exposed for 24 hr. in the RDW-3 solution. The beaker of RDW-3 solution was extremely clear and transparent after removing the coupons.

Since the sulfamic acid cleaner failed to accomplish the criteria of film removal, and since proprietary oxalic acid cleaner has failed to meet the specification for secondary film deposits, the RDW-3 solution alone remains.

With a cleaning solution which passed the criteria of: (1) dissolving corrosion films, (2) dissolving long exposure period films, (3) depositing no secondary film, and (4) minimal corrosion, the next phase of evaluation was conducted, namely decontamination of an in-reactor loop.

Decontamination of G7/M3 Loop Facility, Engineering Test Reactor (ETR) Idaho Falls, Idaho

The G7/M3 loop facility (Figure 4) is a high-pressure, high-temperature loop for testing material and fuel element performance in recirculating water. The out-of-reactor loop piping is AISI type 347 and 304 SS; the in-reactor sections are composed of Zircaloy-2 and AISI type 347 SS. The loop radioactivity levels were sufficiently high to hinder contact

maintenance and loop modification. Loop decontamination, therefore, was performed September 13-15, 1965; alkaline permanganate and slightly modified RDW-3 solutions were specified to decontaminate the facility.

Since the specified inhibitor, diethylthiourea, was not available when the decontamination was required, a proprietary inhibitor was used for this loop decontamination. This inhibitor had been previously evaluated in the laboratory and had satisfactorily inhibited the corrosiveness of the RDW-3 solution.⁽⁸⁾ A pretreatment of alkaline permanganate (18% NaOH, 3% KMnO_4) was used. The actual process included heating, circulating and cooling times. Temperatures and final rinse limits are described in Table A-III.

The final results of the loop decontamination confirmed the cleaning results obtained in the laboratory tests. The radioactivity levels monitored at various points on the system are tabulated in Table A-IV. The average overall loop decontamination factor was 13, based on the fourteen points in Table A-IV.

The solutions were sampled during decontamination. Two samples were scanned for gamma activity; the principle isotope observed was ^{60}Co . The total beta-gamma activity for typical samples are presented in Table A-V. The second acid rinse removed a small amount of activity (5.7 % of the total removed), which demonstrated that an additional acid rinse is beneficial in obtaining lower activity levels in the system.

TABLE A-II

COMPARISON OF THE UNIFORM PENETRATION OF STRUCTURAL
METALS IN THREE DECONTAMINANT ACID SOLUTIONS^(a)

<u>Alloy Evaluated</u>	Sulfamic ^(b) Acid Cleaner, 90 g/liter, 70 °C, <u>mils Corrosion</u>	Oxalic Acid ^(b) Cleaner, 60 g/liter, 85 °C, <u>mils Corrosion</u>	RDW-3 78 g/liter, 82 °C, <u>mils Corrosion</u>
Haynes 25	0.001	0.002	0.017
304 SS, stressed	0.03	0.17	0.007
304 SS, sensitized	0.02	0.041	0.007
316 SS	0.01	0.072	0.006
17-4 PH SS	0.07	0.27	0.021
416 SS	2.6	2.24	0.085
440-A SS	0.16	2.37	0.11
440-C SS	0.63	1.16	0.198
Stellited A-212 CS	1.4	0.61	0.21
A212 CS welded to 304 SS	0.12	0.48	0.045
A245 CS	0.08	0.31	0.092
A106 CS	0.59	0.58	0.103

(a) Tests conducted for 24 hr. with mild stirring and reflux to minimize concentration and temperature gradients.

(b) Proprietary materials.

FIGURE A-I
G7/M3 Facility System Schematic During Decontamination

A-8

BNWL-711

TABLE A-III

PROCESS AND PROCEDURE FOR ETR G7/M3 LOOP DECONTAMINATION

<u>Process</u>	<u>Procedure</u>	<u>Time</u>	<u>Temperature</u>
Alkaline permanganate	heating	7 hr	105 °C
	circulating	1.25 hr	
	cooldown	0.75 hr	
Water rinses ^(a)	-	0.50 hr	ambient
1st RDW-3 solution	heating	3.5 hr	85 °C
	circulating	1.5 hr	
2nd RDW-3 solution	heating	1.75 hr	85 °C
	circulating	1.25 hr	
Water rinses ^(b)	-	0.50 hr	ambient

(a) 3 water rinses to pH 10.8.

(b) 3 water rinses to 10,000 ohm/cm specific resistance.

TABLE A-IV

RADIOACTIVITY LEVELS^(a) (mR/hr) ON THE BNW G7/M3 SYSTEM

System Location	Activity Levels					DF
	Before Decontami- nation	After Certain Decontamination Steps				
		Alkaline Permanganate	1st Acid Rinse	2nd Acid Rinse	Final Rinse	
1 Pump-3, volute	270	290	110	50	40	6.8
2 Pump-2, volute	330	350	135	50	50	6.6
3 Pump-1, volute	315	330	150	70	60	5.3
4 Pressurizer shell	160	160	100	65	60	2.7
5 Pressurizer heaters	150	150	95	65	65	2.3
6 TCV ^(b) -M3	1700	1750	290	150	100	17.0
7 TCV-G7	700	650	100	45	30	23.2
8 M3 heat exchanger head	800	800	140	60	40	20.0
9 M3 heat exchanger shell	400	310	130	60	22	18.2
10 Pump-3, strainer	850	850	250	55	45	18.9
11 Pump-2, strainer	1300	1250	285	90	60	20.2
12 Pump-1, strainer	1000	1100	270	110	70	14.3
13 Entry at cubicle door	140	140	85	37	26	5.4
14 Elbow below heat exchanger	800	780	165	100	50	16.0

(a) Readings taken at surface of piping covered with 3 in. of lagging.

(b) Temperature control valve.

TABLE A-V

RADIOACTIVITY LEVELS OF VARIOUS DECONTAMINANT SAMPLES

<u>Solution Sample</u>	<u>mR/hr</u>	<u>Beta-Gamma Counts/min/ml</u>	<u>Alpha Counts/min/ml</u>
Alkaline permanganate	-	17,000	0.6
1st water rinse	-	3,000	0.3
2nd water rinse	-	2,200	-
1st acid solution	260 ^(a)	1,980,000	-
2nd acid solution	35 ^(a)	120,000	-

(a) Reading of 1 liter liquid sample taken at surface of bottle.

ONSITE DISTRIBUTIONCopy Number

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26-35
36
37
38-40

Battelle-Northwest

J. A. Ayres
J. D. Berger
R. E. Burns
E. W. Christopherson
D. R. de Halas
W. L. Delvin
R. L. Dillon
J. R. Fishbaugher
B. Griggs
G. A. Halseth
H. Harty
R. S. Hope
D. C. Kaulitz
R. A. Kennedy
A. P. Larrick
W. R. Lewis
J. E. Mendel
L. D. Perrigo
R. H. Purcell
R. B. Richman
W. D. Richmond
L. D. Turner
E. E. Voiland
P. C. Walkup
R. F. Warnick
R. D. Weed
R. E. Westerman
K. L. Young
Technical Information Files

Douglas United Nuclear

41
42
43
44
45
46
47
48
49

T. W. Ambrose
W. D. Bainard
R. G. Geier
H. F. Jensen
W. K. Kratzer
M. C. Leverett
Milton Lewis
J. V. Olson
J. W. Riches

Atlantic Richfield

50
51
52

W. C. Schmidt
M. L. Short
P. J. Wiater

OFFSITE DISTRIBUTIONCopy Number

53	Atomic Energy Commission, Washington F. Brannigan
54	Consolidated Edison Indian Point, New York I. B. Dick
55	Consolidated Edison New York, New York Jack Robe
56	Dairyland Power Cooperative P. O. Box 135 Genoa, Wisconsin 54632 M. J. Wise
57	The Dow Chemical Company, Rocky Flats E. D. Erickson
58	Dow Industrial Service Midland, Michigan C. M. Loucks
59	DuPont Company, Aiken A. B. Carlson
60	General Atomic Division R. M. Watkins
61	General Dynamics/Fort Worth T. F. D'Muhala
62	General Electric Company, San Jose N. Micheal
63	Michigan State University Dept. Chemical Engineering College of Engineering East Lansing, Michigan 48823 M. F. Obrecht, Ph.D., P.E.
64	Oak Ridge National Laboratory A. B. Meservey
65	Southern California Edison Company Los Angeles, California J. B. Henderson
66	Turco Products, Inc. 24600 S. Main Street Wilmington, California

OFFSITE DISTRIBUTION (Cont.)Copy Number

67

Wyandotte Chemicals Corporation
J. B. Ford Division
8921 Dice Road
Los Nietos, California
J. J. Schneider

68

Wyandotte Chemicals Corporation
J. B. Ford Division
Wyandotte, Michigan
P. N. Burkard

69

Yankee Atomic Electric Company
Rowe, Massachusetts
R. F. Jones

70-74

Division of Technical
Information Extension

75-76

Atomic Energy Commission
Chicago
Patent Group

G. H. Lee
R. K. Sharp

77-78

Atomic Energy Commission
Richland, Washington

C. L. Robinson
Technical Library

79-80

Atomic Energy Commission
Washington
Reactor Development and
Technology

P. G. Holsted (2)