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RADIOACTIVE EFFLUENT CONTROL PROGRAM
DOUGLAS UNITED NUCLEAR
OPERATED
AEC FACILITIES

by

Staff of
Douglas United Nuclear

Edited by

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January 25, 1971

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TABLE OF CONTENTS

	<u>Page</u>
I. INTRODUCTION	4
II. SUMMARY	4
III. RADIOACTIVE EFFLUENT CONTROL STATUS	5
A. Quantities	5
1. K Area	5
a. Liquid	5
b. Gaseous	5
2. N Area	11
a. Liquid	11
b. Gaseous	11
3. 300 Area	11
a. Liquid	11
b. Gaseous	13
B. Overall Performance Evaluation	13
IV. RADIOACTIVE EFFLUENT CONTROL PROGRAMS	16
A. Past Plant and Process Programs	16
B. Ongoing Programs	17
1. K Area	17
a. Decontamination	17
2. N Area	17
a. Decontamination	17
b. Contaminated Coolant Treatment Facility	18
c. Low Level Radioactive Drains	18
d. Confinement Filters	19
3. 300 Area Activity	19
C. Deferred Programs	20
1. KE Reactor Effluent Diversion	20
2. Effluent Treatment	21
3. K Reactor Inland Canal and Lake Disposal System	22
4. Noble Gas Entrapment	22
V. CONCLUSIONS AND RECOMMENDATIONS	23
VI. REFERENCES	24

RADIOACTIVE EFFLUENT CONTROL PROGRAM
DOUGLAS UNITED NUCLEAR
OPERATED
AEC FACILITIES

I. INTRODUCTION

This report is addressed to the radioactive effluent control program of AEC facilities operated by Douglas United Nuclear, Inc. It was prepared in response to an inquiry from AEC Division of Operational Safety via AEC-RL regarding quantities of radionuclides released. The current status, measurement, and activity of the program are described. In addition, other related efforts which have been deferred due to lack of funding are highlighted.

II. SUMMARY

Douglas United Nuclear operates for the Atomic Energy Commission at Hanford the KE Reactor (single pass production), the N Reactor (dual purpose), and facilities to manufacture fuel for each. Control of radioactive effluents, liquid and gaseous, are a daily part of the program of each facility. The release of all effluents are well within manual chapter requirements. The quantities of all radionuclides released total only a few percent of the MC-0524 limits. This enviable posture has been developed over the years through extensive R&D programs aimed at reducing effluent activity in the production reactors, designing N Reactor with a closed primary coolant system, and development of optimized waste control procedures in the fuel fabrication processes.

Although funding has been severely limited in recent years, a viable monitoring program persists as well as several intensive efforts to reduce quantities of radionuclides released in support of N Reactor regulatory activities. Of the latter, the most significant effort is the development of a contaminated coolant treatment facility concept. It is anticipated that this facility will place N Reactor effluent releases in the range of less than 3% of 10 CFR 20 limits.

There appear to be no additional efforts over those currently being pursued that could be undertaken in the next three months and/or within currently available resources to reduce radioactive effluents further. However, several rather extensive programs in support of this cause have been deferred or dropped in recent years due to lack of funding. These include:

K Reactor Effluent Treatment
K Reactor Inland Lake
KE Fuel Rupture Debris Diversion
Noble Gas Entrapment Studies

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-5-

DUN-7521

These could all be re-activated with adequate funding with the potential of further reducing radioactive effluent releases.

III. RADIOACTIVE EFFLUENT CONTROL STATUS

Radioactive effluents from Douglas United Nuclear operated AEC facilities at Hanford are strictly controlled by and are an integral part of a more encompassing Waste Management Program. The current status of control of these effluents is as follows:

A. Quantities

1. K Area

a. Liquid

The KE Reactor uses treated Columbia River water as a coolant on a once-through basis. Thus, radionuclides are formed largely by the neutron activation of naturally occurring river salts. The raw river water is treated to remove some materials by $Al(OH)_3$ flocculation. The salts found in the river at the average river flow are shown in Table 1. The quantities of salts added to the river by the water treatment process¹² are also shown in this table. The radionuclides added to the river by the KE Reactor during normal operation are shown in Table 2. In the event of a fuel failure, the coolant stream from the reactor can be diverted to existing tanks (associated with the shutdown KW facility) where most of the radionuclides will be caught. However, during the required valving time about 20% of the effluent containing rupture debris would go directly to the river. Additional funds would be required to improve this situation.

The concentrations of radionuclides in the river decrease downstream as shown in Table 3 because of decay and adsorption on soil particles.¹⁴ The radionuclide concentrations found in the river compared to 10 CFR 20 are shown in Table 4. Two radionuclides, ^{56}Mn and ^{133}I are the greatest contributors to the concentration at Ringold divided by the maximum permissible concentration. Even with these, the reactor releases, on the average, only 12.6% of the limit under the "unit" rule. (10CFR20)

b. Gaseous

The gas discharge from KE Reactor is filtered by high efficiency particulate filters and this process is followed by charcoal adsorbers for radioiodine removal. This ensures that radioactive gases are not discharged directly to the atmosphere. Filter efficiencies are routinely measured at 99.95+ percent. Air dissolved in the river water used as reactor coolant

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TABLE 1

COLUMBIA RIVER MINERAL CONTENT

Ave. river flow⁶ = 133,000 ft³/sec. = 3.6 x 10⁸ tons water/day

Material	Priest Rapids Ave. ppm (Ref. 7)	Tons/day Natural	Tons/day Added by KE Reactor	Discharge to River ppm in Effluent
Ca	20	7200	0	**
SO ₄	12	4300	18	22
P	--	10	0	**
Filterable Solids (SiO ₂)	6	2160	0	**
Mg	5	1800	0	**
Na	--	1.1	0.092	0.075
Cl	0.5	180	1.1	0.86
Fe	0.1	36	0	**
Mn	0.05	18	0	**
Zn	--	7.2	0	**
Al(OH) ₃	--	*	5	6-11
Cu	--	0.002	0	**
As	--	0.001	0	**
La	--	0.0008	0	**
U	--	0.0006	0	**
Cr	--	2.52	0.22	0.0175
Co	--	0.00002	0	**
Sc	--	0.000003	0	**
Polyacrylamides	--	0	0.035	0.1 intermittent

*Only significant during periods of high turbidity.

**Not analyzed, normal river burden present unless removed by water treatment.

TABLE 2
SIGNIFICANT RADIONUCLIDES ADDED TO COLUMBIA RIVER
BY KE REACTOR*

<u>Radionuclide</u>	<u>1/2 Life</u>	<u>Reactor Output</u>	
		<u>Ci/d</u>	<u>Equilibrium Ci</u>
^3H	12.3 y	0.5	2700
^{24}Na	15 h	600	520
^{32}P	14.3 d	5	100
^{41}Ar	1.8 h	1000**	100
^{46}Sc	84 d	4.8	560
^{51}Cr	28 d	77	2900
^{56}Mn	2.6 h	5200	780
^{64}Cu	13 h	600	500
^{65}Zn	244 d	6.5	2200
^{76}As	26 h	66	106
^{89}Sr	50 d	0.3	30
^{90}Sr	28 y	0.01	45
^{131}I	8 d	0.33	3.7
^{239}Np	2.3 d	55	180

*Calculated values for radionuclides added to the river by a 4000 MW_t single-pass reactor from the observed measurements at other reactor powers reported in references 9 and 14.

** ^{41}Ar from ^{40}Ar dissolved in water. This exchanges with the atmosphere rapidly.

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TABLE 3

SIGNIFICANT RADIONUCLIDES OBSERVED IN COLUMBIA RIVER FROM KE REACTOR*

Radio-nuclide	1/2 Life	Priest Rapids pCi/ml	(0.75 hrs) Complete Mixing at Reactor pCi/ml	(8 hrs) Complete Mixing at Ringold pCi/ml	(15 hrs) at Richland pCi/ml	(150 hrs) Bonneville Dam pCi/ml
³ H	12.3 y	1.9**	1.9	1.9	1.9	1.9
²⁴ Na	15 h	0	2.0	1.5	1.0	****
³¹ Si	2.6 h	0	1.9	0.3	****	****
³² P	14.3 d	****	0.017	0.017	0.017	0.007
⁴¹ Ar***	1.8 h	****	***	***	***	***
⁴⁵ Ca	163 d	****	0.0026	0.0026	****	****
⁴⁶ Sc	84 d	****	0.016	0.016	0.016	****
⁵¹ Cr	28 d	****	0.26	0.26	****	0.12
⁵⁶ Mn	2.6 h	0	17	2.1	0.31	****
⁶⁴ Cu	13 h	0	2.2	1.5	****	****
⁶⁵ Zn	244 d	****	0.022	0.022	0.022	0.014
⁷² Ga	14 h	0	0.09	0.06	****	****
⁷⁶ As	26 h	****	0.23	0.18	0.15	****
⁸⁹ Sr	50 d	****	0.0015	0.0015	****	****
⁹⁰ Sr	28 y	0.5**	0.000075	0.000075	****	****
⁹¹ Sr	97 h	****	0.038	0.038	****	****
⁹² Sr	2.7 h	0	0.15	0.028	****	****
⁹⁰ Y	3.2 h	0	0.007	0.0015	****	****
⁹³ Y	10 h	0	0.018	0.011	****	****
¹²² Sb	2.8 d	0	0.041	0.038	****	****
¹³¹ I	8 d	****	0.0011	0.0011	0.001	****
¹³² I	2.3 h	0	0.075	0.0075	****	****
¹³³ I	21 h	****	0.075	0.06	****	****
¹³⁴ I	53 m	0	0.11	0.0004	****	****
¹³⁵ I	6.7 h	0	0.035	0.017	****	****
¹⁴² Pr	19 h	0	0.014	0.011	****	****
¹⁵² Eu	9 h	0	0.22	0.12	****	****
¹⁵³ Sm	47 h	****	0.08	0.08	****	****
¹⁶⁵ Dy	2.3 h	0	0.15	0.015	****	****
²³⁹ Np	2.3 d	0	0.16	0.16	0.13	****

*Calculated values for radionuclides added to the river by a 4000 MW_t single-pass reactor from the observed measurements at other reactor powers reported in references 9 and 14.

**³H in river above and below reactor area as reported in reference 10. Reactor would add less than 0.01 pCi/ml. Concentration varies over a wide range due to weapons testing in other countries.

***⁴¹Ar from ⁴⁰Ar dissolved in water; this exchanges with the atmosphere rapidly.

****Analyses not made as data was not available.

TABLE 4
RIVER CONCENTRATION COMPARED TO 10 CFR 20 FOR KE REACTOR

Radio-nuclide	1/2 Life	10 CFR 20 MPC General Population pCi/ml	Complete Mixing at Reactor/MPC	Concentration at Ringold/MPC
³ H	12.3 y	3000	0.0006	0.0006
²⁴ Na	15 h	200	0.01	0.0075
³¹ Si	2.6 h	900	0.0021	0.0003
³² P	14.3 d	20	0.0008	0.0003
⁴¹ Ar*	1.8 h	*	*	*
⁴⁵ Ca	163 d	9	0.0003	0.0003
⁴⁶ Sc	84 d	40	0.0004	0.0004
⁵¹ Cr	28 d	2000	0.0001	0.0001
⁵⁶ Mn	2.6 h	100	0.17	0.021
⁶⁴ Cu	13 h	300	0.0074	0.005
⁶⁵ Zn	244 d	100	0.0002	0.0002
⁷² Ga	14 h	40	0.0023	0.0015
⁷⁶ As	26 h	20	0.011	0.009
⁸⁹ Sr	50 d	3	0.0005	0.0005
⁹⁰ Sr	28 y	0.3	0.0002	0.0002
⁹¹ Sr	97 h	70	0.0005	0.0005
⁹² Sr	2.7 h	70	0.002	0.0004
⁹⁰ Y	3.2 h	20	0.00035	0.00007
⁹³ Y	10	30	0.0006	0.0004
¹²² Sb	2.8 d	30	0.0014	0.0013
¹³¹ I	8 d	0.3	0.004	0.004
¹³² I	2.3 h	8	0.0094	0.0001
¹³³ I	21 h	1	0.075	0.06
¹³⁴ I	53 m	20	0.0055	0.0002
¹³⁵ I	6.7 h	4	0.0087	0.0042
¹⁴² Pr	19 h	30	0.0005	0.0003
¹⁵² Eu	9 h	60	0.0037	0.002
¹⁵³ Sm	47 h	80	0.001	0.001
¹⁶⁵ Dy	2.3 h	400	0.0004	0.00004
²³⁹ Np	2.3 d	100	0.0016	0.0016
			0.32	0.126

*⁴¹Ar from ⁴⁰Ar dissolved in water; this exchanges with the atmosphere rapidly.

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-10-

DUN-7521

contains argon which becomes activated in the neutron flux. After the water passes through the reactor, and enters the 107 basin, a rapid transfer of the ^{41}Ar is observed. There is discharged about 1000 Ci/d (Table 2) of this material, but, because of the half life, the equilibrium value of ^{41}Ar is only about 100 Ci/d.

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2. N Area

a. Liquid

N Reactor is cooled by recirculating demineralized water. This is used to produce steam for the WPPSS power plant. The heat is transferred to the river water via surface condensers. Hence, radionuclides are not released by this process. However, in the event of a fuel failure, primary coolant from the tube involved is diverted to a crib. Also flowing to the crib is the normal release of water (~1000 gpm) from the primary coolant system feed and bleed system. The water in the crib percolates through the soil and enters the river through springs at the river bank. In this process, much of the radionuclide burden is removed as shown in Table 5.

b. Gaseous

All gases leaving the reactor zones are filtered with moisture separators, high efficiency particulate filters, and charcoal adsorbers for iodine removal. All filtering units are routinely tested to continually assure their capability to meet their design requirements.

3. 300 Area

In the 300 Area, Douglas United Nuclear operates the fuel fabrication facilities and supporting fuel development and analytical laboratories. The research and development facilities of the Hanford Engineering Development Laboratory and Pacific Northwest Laboratory are the responsibility of WADCO and BNW, respectively. Liquid wastes containing radioactive materials from all these facilities are dumped to a common process sewer. Effluent from the process sewer is dumped to ponds where it enters the soil and eventually enters the local water table or through river bank springs enters the Columbia River. A sanitary sewer is maintained separately. The Douglas United Nuclear contribution of radioactive material to the process sewer is limited to uranium, both natural and slightly enriched. The economic value of uranium and the need to account for all losses have placed added emphasis on the desirability to minimize releases of uranium to the environs. Thus, there has been a continuing program to quantitatively identify all releases of uranium in waste liquid streams, as well as atmospheric releases, and to minimize releases from these sources.

a. Liquid

Liquid wastes containing uranium originate primarily within the main fuel fabrication process - single-pass reactor (AlSi) and N Reactor fuel. Most process liquids containing significant quantities of uranium are routed to the uranium

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TABLE 5

SIGNIFICANT RADIONUCLIDES ADDED TO COLUMBIA RIVER
BY N REACTOR FOR 1969*

Radionuclide	1/2 Life	10 CFR 20 MPC General Population ρ Ci/ml	N Reactor		After Complete Mixing in River ρ Ci/ml	Concentration in River/MPC
			Crib Ave. Ci/d	Springs Ave. Ci/d		
^3H	12.3 y	3000	11	**	**	**
^{32}P	14.3 d	20	0.029	0.00019	6×10^{-5}	3×10^{-6}
^{51}Cr	28 d	2000	0.44	0.12	4×10^{-4}	2×10^{-7}
^{90}Sr	28 y	0.3	0.020	0.002	6×10^{-6}	2×10^{-5}
^{99}Mo	67 h	200	--	0.011	3×10^{-5}	1×10^{-7}
^{131}I	8 d	0.3	0.28	0.007	2×10^{-5}	1×10^{-4}

*Data from reference 11.

**No analysis of this radionuclide made as data was not available.

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recovery process. Here uranium bearing acids and caustics are mixed, the uranium precipitated, and the precipitate pressed and recovered. The effluent of this process is then released to the process sewer.

Uranium releases from the process sewer have been monitored at a concentration up to 0.5 ppm which converts to a few hundred pounds per year. Uranium concentrations in the Columbia River measured at Priest Rapids Dam (upstream of Hanford Project) when coupled with annual river flows indicate that approximately 240,000 pounds of uranium as a natural river burden pass the Hanford Project each year. Hence, the quantity of uranium released to the ponds (if assumed to enter the river) represents less than 1 percent of the background.

b. Gaseous

Gaseous or atmospheric releases of uranium are quite small. Airborne activity from the fabrication process originates primarily in sawing and lathe operations. In these operations, coolant plays on the metallic uranium thereby effectively eliminating airborne releases. In addition, exhaust systems for these operations include filters which are either the absolute or scrubber type. The combined effect of these preventative measures is to minimize the quantity of uranium released to the atmosphere. The main sources of airborne releases are routinely monitored.

Solid scrap metallic uranium is recovered by converting the material to an oxide by controlled burning. The quantity of uranium released to the environs is small. However, the nature of this operation is such that careful attention and effort are required to maintain the release concentrations within limits. Efforts are underway to eliminate this process and use a better method for scrap control and shipment.

B. Overall Performance Evaluation

In addition to the DUN internal monitoring program, the performance of all Hanford contractors in regard to environmental control, including radioactive release, is evaluated annually by BNW. This evaluation not only concerns itself with radioactive release concentrations and quantities but with dose to the offsite population as well.

The dose standards for evaluation are governed by the AEC Manual Chapters 0524 and RL-0524 for permissible radiation exposure in uncontrolled areas as shown in Table 6. The total effect for the year 1969 (reference 10) is shown in Table 7. As can be seen, it was only a few percent of the standard. A preliminary evaluation for 1970 indicates that these radiation doses are even lower, only

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-14-

DUN-7521

TABLE 6
RADIATION PROTECTION STANDARDS
FOR EXTERNAL AND INTERNAL EXPOSURE

<u>Type of Exposure</u>	<u>Based on Dose to Critical Individuals at Points of Maximum Probable Exposure</u>	<u>Based on an Average Dose to a Suitable Sample of the Exposed Population*</u>
Whole body, gonads, or bone marrow	0.5	0.17
Other organs**	1.5	0.5

---

* See Par. 5.4, FRC Report No. 1, for discussion on concept of suitable sample of exposed population.

** An acceptable alternate standard for bone for individuals is the ICRP standard of 0.003 μg of radium-226 or its biological equivalent. The alternate standard for populations would be one-third this ICRP standard.

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TABLE 7
SUMMARY OF RADIATION DOSES*
IN THE HANFORD ENVIRONS - 1969

<u>Organ</u>	<u>Annual Dose, mrem</u>	<u>Standard, mrem</u>	<u>% of Standard</u>
<u>Maximum Individual</u>			
Bone	140	1500	9
Whole Body	18	500	4
GI Tract	40	1500	3
Thyroid (infant)	60	1500	4
<u>Average Richland Resident</u>			
Bone	15	500	3
Whole Body	4	170	2
GI Tract	19	500	4
Thyroid (infant)	23	500	5

---

* Doses from fallout and natural background not included.

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about one-half of the 1969 doses. The dose evaluation is made for the average individual, conservatively using the average Richland resident, including the infant with a two gram thyroid and a hypothetical maximum individual found in the Tri-Cities (Richland, Kennewick, and Pasco) and surrounding area. The basis for the evaluation comes from long-term studies of the local population habits which would bring them in contact with released radionuclides. Possible contact sources include the atmosphere, the Columbia River, local drinking water, local fish, gamebirds, milk, produce, and coast shell fish.

Recent efforts that have contributed to the lowering of the potential dose include the following. On-site trenches in use for incidental, but important, radioactive releases have been covered to prevent migratory fowl from entering and feeding there. Likewise, ponds and tanks that are no longer used or that are associated with shutdown facilities have been filled in to cover residual radioactivity and marked in accordance with AEC requirements.

IV. RADIOACTIVE EFFLUENT CONTROL PROGRAMS

A. Past Plant and Process Programs

Until the advent of N Reactor, all plutonium production reactors at Hanford used treated Columbia River water as a coolant on a once-through basis. Thus, as was indicated in the previous section, radionuclides form largely by the activation of river salts and are returned to the river following activation. These radionuclides have been monitored and studied since the startup of the Hanford site. Through the years, as the number of reactors and reactor power levels increased, the quantities of radionuclides released increased. Likewise, interest in the subject increased. Monitoring and analytical techniques were developed and improved and studies were conducted to determine the source of the isotopes and the chemical and physical forms in which they exist.

By 1960 the radionuclide release had increased to a point where, although not a problem with respect to nationally established limits, it appeared prudent to markedly increase emphasis on means of reducing them. To this end, many thousands of dollars worth of research and development has been sponsored by AEC-Division of Production. The long-range goal of the program was the development of economical processes capable of achieving major reductions in the biologically significant radionuclides in the reactor effluents.

Numerous documents have been published relating the technical and economical merits of these R&D efforts.²³ They have resulted in considerable advances being made to chemical treatment and filtration of reactor influent, chemical treatment of reactor effluent, process tube corrosion, fuel clad corrosion and structural integrity, plant decontamination techniques, and improved operating and maintenance procedures.

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This effort has now essentially all been terminated due to a lack of financial support. Further reduction in quantities of radionuclides released could be realized if programs were re-instituted as is discussed in Section IV.C. However, the return may not be justifiable on a purely economic basis but would be in harmony with being a leader in reducing radioactive effluents to levels as low as practicable.

B. Ongoing Programs

In addition to the routine monitoring program conducted in all areas of contaminated waste streams, several other programs are being actively pursued by DUN in an effort to reduce total releases to as low a level as practicable. These include the following.

1. K Area

a. Decontamination

The decontamination wastes from KE Reactor are primarily those associated with rear face decontaminations and to a small degree those associated with fuel spacer decontaminations. The rear face decontaminations, performed at approximately yearly intervals, consist of washing the rear face piping with inhibited organic acids at a concentration of 2-5 oz./gal. and a temperature of 80-95 C. Total volume ranges from 30,000 to 200,000 gallons of solution per decontamination. The fuel spacer decontaminations consist of immersion of spacers in tanks containing approximately 500 gallons nitric acid. All wastes are routinely routed to a crib for disposal. Solution activities for a typical rear face decontamination are 0.6 $\mu\text{Ci/liter}$ and total releases are approximately 20 curies/year.¹⁶

The ongoing program in this regard is to stay alert for new methods and procedures to better decontaminate the facility. This, of course, could result in greater quantities of contaminated solution of which to dispose. Hence, an integral part of the program is to consider alternate methods of disposal.

2. N Area

a. Decontamination

The N Reactor decontamination wastes are from three primary sources: single-pass, through-reactor decontaminations with inhibited phosphoric acid; recirculating decontaminations of the primary system steam generators with inhibited oxalic-citric acid mixtures; and recirculating decontaminations of graphite cooling system heat exchangers with inhibited oxalic-citric acid. Since the first steam generator decontamination in 1965, a total of five steam generator

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cells have been decontaminated, three graphite heat exchangers have been decontaminated, and four single-pass decontaminations have been conducted. For all of these decontaminations, the waste streams have been collected in storage tanks and then later shipped to Atlantic Richfield Hanford Company for concentration and permanent storage. A typical steam generator decontamination consists of 4,000 gallons of inhibited acid solutions containing about 56 curies of radioactivity. A typical single-pass decontamination consists of 250,000 gallons of 10 percent phosphoric acid containing 150-200 curies of radioactivity.¹⁷ Graphite cooling system heat exchanger decontaminations are similar to steam generator decontaminations except on a much smaller scale - total activity does not exceed 10 curies. None of the above wastes are released to the environment. In all, over 4,000,000 gallons of decontamination waste originating at N Reactor have been shipped and processed.¹⁸ The waste has contained approximately 1,500,000 pounds of chemicals and an estimated 1,000 curies of radioisotopes, more than half of which has been cobalt-60.¹⁸

An integral part of the decontamination program is to seek out better ways of disposing of the contaminated waste. There are economic as well as environmental incentives for doing this. In addition, new decontaminants are under study that result in low net volume contaminated residue.

b. Contaminated Coolant Treatment Facility

In an effort to reduce the quantity of radioactive material released from N Reactor to the environment to the lowest practicable, a presently funded program is underway to obtain basic information needed for the design of a radioactive waste processing system. This system, identified as the Contaminated Coolant Treatment Facility (CCTF), will process and/or recycle selected liquid effluent streams containing radioactive material. These streams at present are released to a ground retention basin (crib) and percolates through the soil. It is anticipated that the CCTF will cause a reduction of ~750% in the quantity of radioactive material released to the Columbia River. If the CCTF is indeed successful, the release of radioactive material from N Area to water and air will effectively be zero or at most only a few percent of the 10 CFR 20 release guides.

c. Low Level Radioactive Drains

Investigation of the feasibility of upgrading equipment that would allow the disposal of low level radioactive liquids from radioactive drains to a ground disposal facility rather than directly to the river is underway.

The goal of this program is to help decrease the radioactive burden to the river, thereby supporting compliance with the request to keep radioactive releases as low as practicable.

d. Confinement Filters

Both particulate and charcoal confinement filters are routinely inspected and tested. Experience has shown that a surveillance program is necessary to continually assure filter integrity. Filter test efficiencies of 99.95+ percent for both the particulate filters and iodine adsorbers are quite routine. This degree of filtration is near perfect and is the result of intensive efforts to monitor and maintain filter performance.^{19,20,21,22} To the extent possible within very limited operating funds, some charcoal "aging" and "weathering" studies are planned to be conducted in the future.

3. 300 Area Activity

The quantity of uranium contained in waste liquid streams from the fuel fabrication facilities is reported monthly to the AEC-Richland Operations Office. The basic data for their reports are obtained from various daily processing reports. Each year the accountability system is reviewed to assure current accuracy. These accountability reports thus pinpoint those steps in the process which result in significant releases. Routine process effort is directed toward assuring adequate information to identify quantitatively the releases. Currently, engineering effort is being directed toward the development of an improved scrap metallic uranium recovery process and the development of a process to recover both copper and uranium contained in the nitric acid solution used to remove copper lubricant from the coextruded N Reactor fuel. Like other programs described above, these programs are also hampered by the continuing trend of reduced AEC budgets for DUN development activities. Nonetheless, slow but definite progress is being made toward achieving the program objectives.

Recently, as a result of this continuing effort, piping additions and process changes were implemented to route the spent acid from the prebraze acid etch station in N Fuels fabrication process to the uranium recovery process.

As previously indicated, uranium concentration in the process sewer effluent is approximately a factor of 100 below limits. Further, the actual quantity of uranium released is a few hundredths of 1 percent of the total material processed. In view of these conditions, development of techniques for further reduction in the quantity of uranium released has been evaluated on an economic basis. The economic criteria has been that the

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net cost savings in the recovered product must be equal to or greater than the cost of implementation. Within existing development funding, efforts will continue to refine individual process steps so as to minimize releases from the existing process. Development effort will continue to explore techniques for recovery of uranium from the copper stripping operation and improved solid scrap processing. However, any significant process equipment modifications resulting from such development effort would require future supplemental implementation funding. At present, justification for the additional funding would be evaluated using the above noted economic criteria.

Other than those ongoing program efforts noted above, this review and those previously conducted by DUN have not identified any other practicable means for further reducing uranium releases to the environs.

C. Deferred Programs

The following projects and programs which are addressed to the reduction of radioactive releases to the environs have all been discontinued due to lack of funding. However, they are all programs which could be re-activated if supplemental funds should become available. They are all individually too costly and extensive to pursue within currently available program resources and within the next three months.

1. KE Reactor Effluent Diversion

The 107-K Retention Tank Bypass system consists of a 72-inch bypass line around the existing 107 Retention Tanks for the transport of routine effluent discharge directly to the river. New bypass lines could be tied to the existing 72-inch effluent line just ahead of the Retention Tanks and to the tank outlet lines going to the outfall structure. The new system could then be valved such that effluent could be automatically diverted to the empty 107 Retention Tanks for holdup purposes. Storage capacity of the three-tank system, per reactor, would accommodate full reactor effluent flow for a minimum period of two hours. This would significantly reduce the very small quantity of fission products dumped to the river after a fuel rupture.

During normal reactor operating conditions, the reactor coolant effluent flow would be routed directly to the Columbia River through the new 72-inch bypass line. The 107 Retention Tanks would remain empty during this period (except for maintaining a nominal water "heel" in each tank) and tank inlet valves would be in the open position. Upon fuel rupture detection, automatic closure of the butterfly valve in the 72-inch bypass line would be initiated with complete closure effected within a maximum time period of 60 seconds subsequent to the closure initiation.

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The new bypass lines for both K Reactors are estimated to cost \$540,000. The cost for a single K Reactor bypass line would be approximately \$300,000.

2. Effluent Treatment

The total quantity of radionuclides released from KE Reactor was discussed in Section III.A.1.a. Numerous plant operating improvements, as described in Section IV.A, have been implemented over the years to reduce the amount of this release. Almost all of these measures have involved changes in operating chemistry or other operating parameters associated with the influent water treatment process. Laboratory tests indicate that the most promising method for further radioisotope release reductions is by flocculation of the effluent water. The laboratory tests showed that the solubility of hydrous aluminum oxide (alum), the flocculant currently used in treating influent water, is too high at effluent temperatures to form an adequate floc. However, both ferric chloride and ferrous sulfate-potassium permanganate formed precipitates capable of removing radioactive isotopes as shown in the table below.¹⁵

REMOVAL OF RADIOISOTOPES FROM REACTOR EFFLUENT WATER

Treatment	% Associated with Insolubles					
	Cr ⁵¹	Zn ⁶⁵	La ¹⁴⁰	Np ²³⁹	As ⁷⁶	p ³²
FeCl ₃ · 6H ₂ O 5 ppm	0	82	61	20	89	91
FeCl ₃ · 6H ₂ O 7.5 ppm	0	81	65	30	95	94
FeCl ₃ · 6H ₂ O 10 ppm	0	67	--	10	93	96
FeCl ₃ · 6H ₂ O 20 ppm	0	83	60	26	97	98
FeSO ₄ 1.35 ppm - KMnO ₄ 0.5 ppm	0	94	27	22	50	36
FeSO ₄ 3.39 ppm - KMnO ₄ 1.25 ppm	0	91	40	30	91	88
FeSO ₄ 6.76 ppm - KMnO ₄ 2.50 ppm	0	94	38	75	98	90

It is clear from these data that, with the exception of Cr⁵¹, significant decontamination of both the anionic and cationic radioactive components can be obtained under most of the treatment conditions. Pilot plant tests in the Water Treatment Pilot Plant (WTPP) were scheduled for FY-1970 to evaluate the laboratory results under prototypical conditions but were deferred because of lack of funds. The WTPP tests were to have involved the use of ferric chloride or ferrous sulfate-potassium permanganate as a flocculating agent, passing the flocculated water through settling basins, and then filtering the product. Various parameters, including chemical concentration and pH, would have been investigated to determine optimum conditions.

Upon the successful completion of the pilot plant tests, scoping studies would be required to determine the best methods of treating the effluent water on a full-reactor scale.

Total costs for the WTPP flocculation pilot plant tests would be approximately \$175,000 and for the studies on waste disposal methods approximately \$150,000. Any pilot plant demonstrations of the waste disposal methods selected would be at additional costs.

3. K Reactor Inland Canal and Lake Disposal System

As a means of reducing both the thermal and radioactivity burden to the Columbia River, various alternate methods of K Reactor effluent have been investigated. One potential disposal system consists of a canal from 100-K Area to an inland sump near Gable Mountain (the approximate center of the reservation).

The Inland Lake System would be expected to remove 90 percent of the radionuclides and achieve a thermal reduction of 50 percent at a cost of approximately \$11,000,000 for two K Reactors. The cost of a single K Reactor canal and lake system would not be significantly lower since the reduction of excavation for a single K Reactor canal would be minimal.

4. Noble Gas Entrapment

The fission products released from a reactor as a result of a reactor accident can be removed quite efficiently by filters except for the noble gases. The exhaust air filter system of production reactors is capable of removing 99.95 percent of the particles larger than 0.3 microns and elemental halogens. The current filtration systems do little, if anything, to reduce the release of the noble fission gases to the atmosphere.

Noble gas control methods developed to date for use in the nuclear power industry operate at extremely low flow rates, in some instances are recirculatory, and would not be economically feasible if applied to the 140,000 cfm KE Reactor system or even the 4000 cfm N Reactor emergency exhaust system.

Other methods must, therefore, be developed for the trapping and controlled release of the noble fission gases to the atmosphere. If the method would also remove particulates and halogens, such as methyl iodide, that may penetrate the filtration system, a containment/confinement system with improved reliability and additional nuclear safety features may be derived which is efficient and lower in cost than any that has been demonstrated to date.

The noble gas entrapment program was to investigate, on a development scale, two possible methods of controlling the

DECLASSIFIED

DECLASSIFIED

-23-

DUN-7521

releases of chemically inert gaseous, fission products (xenon and krypton) which would occur as a result of fuel melting accidents. The methods investigated were encapsulation in a high expansion foam, and adsorption in a porous cryogenic bed.

The original experiment conducted during the deactivation of F Reactor at Hanford in the summer of 1965 provided results supporting the concept that large-scale foam encapsulation of reactor exhaust air bearing highly radioactive noble gas and iodine may be accomplished either in a reactor facility or in the open atmosphere.

A follow-up noble gas confinement study program was proposed and initiated in FY-70. The FY-70 program was successful in the quest of a long-lived, high-expansion, water-based foam product, as well as several families of additional products indicating potential value.

This very promising work was terminated in FY-71 due to lack of adequate funding.

V. CONCLUSIONS AND RECOMMENDATIONS

It is the conclusion of Douglas United Nuclear that radioactive effluents are in excellent control being only a few percent of limits. It is further our conclusion that all prudent activities which can be done within currently budgeted funds and stated priorities are in place to keep quantities of radioactive effluents as low as practicable. It is strongly recommended that the currently ongoing programs described be continued. If limited additional funds should become available, more monitoring equipment is desirable in both the 100 Areas and the 300 Area. If substantial additional funds should become available, further reductions in quantities of radioactive effluents, particularly at KE Reactor, could be realized; however, economic justification is marginal.

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-25-

DUN-7521

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