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ABSTRACT

This report is in response to the request by the Hanford Operations Office, United States Atomic Energy Commission, for a comprehensive review of past and present practices with respect to the discharge of reactor effluent water to the Columbia River. It covers 1) a description of the effluent water systems and the use of these systems over the years, 2) a tabulation of effluent water activity data including total beta activity and the activity contributions of specific radioisotopes of concern, over the past 2-1/2 years, 3) the sources of radioisotopes in effluent water and 4) methods by which the activity can be reduced or essentially eliminated.

This report is augmented by HW-63654, "Off-Project Exposure from Hanford Reactor Effluent", by R. F. Foster and R. L. Junkins, February 1, 1960.

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I. EFFLUENT WATER SYSTEMS

The original reactors, 105 B, D and F, were equipped with parallel 107 retention basins for the effluent water. Each half had a capacity of about 6 million gallons. In the beginning the 107 basins were used in parallel, providing detention time of nearly eight hours to permit decay of much of the radioactivity. The technique of using only one side for normal effluent flow was adopted in 1946. When the side in use contained abnormal radioactivity from reactor purges or from fuel element ruptures, the flow was diverted to the empty basin and the unusual effluent pumped to a nearby trench. This technique was used until 1954 and the five newer reactors, 105 DR, H, C, KE and KW, were equipped with 107 basins which would operate in this manner. The 105 DR and H reactors were provided with concrete basins similar to the original reactors except that each half-basin had a capacity of about 9 million gallons, 105 C reactor was provided with two-10 million gallon steel tanks and both K reactors were provided with three-9 million gallon steel tanks.

By 1954 the reactor flow rates had increased to the point that there was concern that further increases would cause the basins to overflow their sides. This coupled with increasing leakage from the full basin into the empty one brought about a change in policy whereby the 107 B, D, F, DR and H basins were operated in parallel permitting unusual effluents from reactor purges and fuel element ruptures to flow into the river. The average effluent flow rate for all reactors from 1948 through 1959 is shown in Figure 1. The same data is broken down by individual reactors for the last three years in order to show recent trends and is shown in Table I.

At 105 C the 107 tanks were used singly until 1958. Cracking of welded seams was caused by the thermal shock when hot effluent water was put into a cold tank. Use of the tanks singly or in parallel has not been consistent. In many cases, but not in every case, unusual effluents are caught and routed to a trench.

When the K reactors were first started up in 1955, the three tanks were used in sequence. Automatic valving routed the flow to an empty tank and dumped the water from a full tank through a valve in the bottom to the river. In the event that a tank contained unusual effluent, it was manually dumped to a trench. However, in April 1955, it was found that air was trapped in the outfall line when a tank dumped and this caused the outfall lines to float and rupture. The lines were anchored and the flow through the 107 tanks changed. At present, two tanks are used in parallel and are allowed to overflow into a flume which leads to the outfall line. When these tanks contain unusual effluent, the flow is routed to the empty tank as soon as the reactor is shut down and the cooling water flow rate reduced. The two full tanks are then dumped to a trench.

The detention time in the present basins and tanks at present flow rates ranges from about 30 minutes to about 3 hours. This reduces the total activity by a factor of 2 to 3, but is not long enough to reduce the activity of those radioisotopes which are of major interest by a significant amount.

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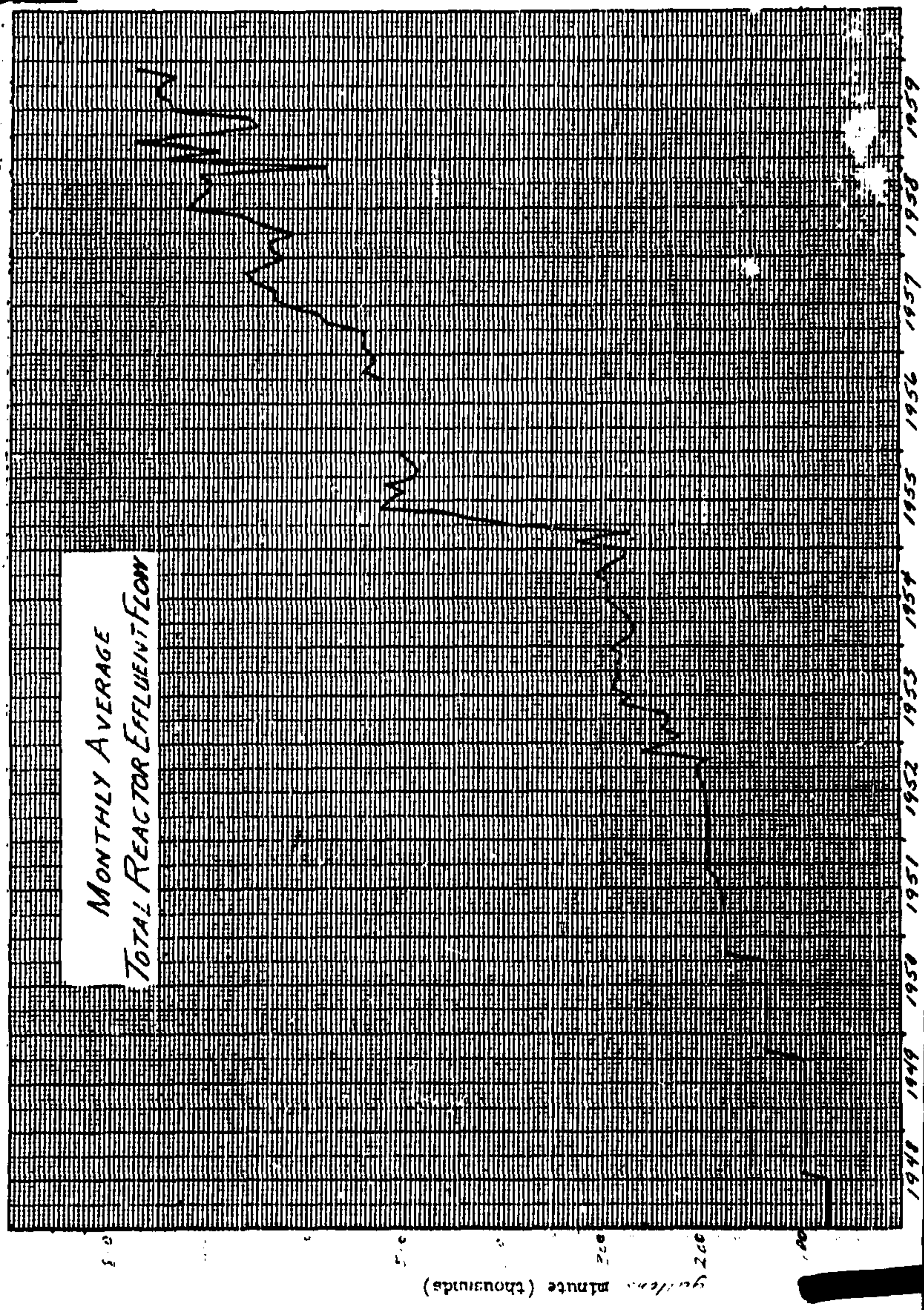

FIGURE 1

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TABLE I

Monthly Average Flow Rate of Reactor Cooling Water (gpm)

1957

	105 B	105 C	105 D	105 DR	105 F	105 H	105 KE	105 KW	Total
Jan.	66600	73860	45400	8700	36839	50341	133600	126400	541740
Feb.	55000	62900	25850	40850	43200	49900	130600	131600	539900
Mar.	50800	65400	24100	63900	36942	46200	117100	139800	544242
Apr.	66500	69600	65600	62900	2510	48200	135100	132400	582810
May	55500	80900	58300	61200	44268	20600	129500	138500	588768
June	59100	81500	64900	61100	60490	18300	133300	139300	617990
July	60200	52400	65700	62200	67302	53600	136800	137900	636102
Aug.	60000	72900	66000	66692	59827	59800	103700	143600	632519
Sept.	59600	69400	59000	60800	60676	60100	144700	142800	654076
Oct.	65800	74400	66800	57600	49173	63500	140800	145300	663373
Nov.	61700	70300	62200	61100	61360	62720	131300	130700	641380
Dec.	62400	71400	62900	45500	60218	60820	125300	135100	623638

1958

	105 B	105 C	105 D	105 DR	105 F	105 H	105 KE	105 KW	Total
Jan.	56800	79400	64940	61807	55009	62950	121000	130400	632306
Feb.	60700	69700	66900	59035	66939	63070	124400	124700	635444
Mar.	55400	73200	63758	58370	61117	61330	114800	124000	611975
Apr.	64900	82600	65770	52033	63702	40520	132000	146200	647725
May	60200	82100	64848	57512	64163	64050	134900	139700	669473
June	64500	85900	64716	68306	67921	63800	146200	162600	723943
July	65876	80164	68848	54983	68153	64400	163600	147300	713324
Aug.	63677	75216	72406	57267	66574	66600	146100	154400	702236
Sept.	57616	79686	70493	58906	63010	61600	152900	154100	698311
Oct.	64683	80467	77022	53390	72881	63800	139100	159300	710643
Nov.	68623	68753	75176	55806	58360	75000	159200	21900	582818
Dec.	69719	82535	74251	64467	78094	79000	148100	145100	741266

1959

	105 B	105 C	105 D	105 DR	105 F	105 H	105 KE	105 KW	Total
Jan.	53300	72261	71316	64100	64082	58460	158200	149800	691519
Feb.	72039	79289	75389	79296	78912	69040	161100	159500	774565
Mar.	72245	80177	66135	67181	59723	80000	138300	154800	718561
Apr.	74910	72450	69156	64743	71749	69700	77900	152400	653008
May	61428	76829	74754	71461	51277	69100	103500	151200	659549
June	69816	76946	65320	67735	70886	69900	158800	161200	740603
July	72542	81729	76716	59780	69718	84000	140800	155800	741085
Aug.	64596	79289	74035	73187	77114	69800	151000	165800	755361
Sept.	75990	66319	78416	78150	65962	71200	156400	159900	752337
Oct.	67954	92503	74280	65764	70689	70900	149400	146300	737790
Nov.	71763	78443	69393	74506	76343	72900	164900	166000	774248

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At each of the reactors the outflow from the 107 basins is carried to or near the main channel of the river by large steel lines called outfall lines. This allows maximum dilution and dispersion of reactor effluent in the river.

The trench which is located near each 107 retention basin was provided to remove much of the radioactivity associated with unusual effluents by filtration and ion exchange. It can be seen from the foregoing discussion of the operation of the basins that at 105 B, D, F, DR, and H, these trenches are not now being used. The trench adjacent to 107 C is used occasionally and the single trench which was provided for both 107 KE and KW is used routinely. Being located on the river bank, the time delay between introduction of effluent into a trench and its emergence at the river shoreline is short, probably a few hours.

II. RADIOACTIVITY

Although more than 60 radioisotopes have been identified in reactor effluent water, not many have half-lives and abundance which is adequate to make them significant contributors to human exposure. Only those few radioisotopes that are of major interest will be discussed. The significance of these radioisotopes off plant is discussed in the companion document.(1)

Because phosphorus-32 is concentrated by river organisms and is subsequently transferred to edible fish and waterfowl, it becomes significant to human exposure. The rate of release in recent years is shown in Table II. In addition to seasonal variations which are due to changes in the river, it can be seen that anomalous values appear rather frequently. These fluctuations cannot be satisfactorily explained at this time. Occasional high values are not considered to be spurious, but rather caused by some undefined variation in reactor plant operation.

Although several radioisotopes contribute measurable amounts to the potential radiation exposure from drinking Columbia River water, arsenic-76 is the most significant. Above the confluence of the Columbia with the Snake River, it contributes more than 75 percent of the potential dose to the gastrointestinal tract. The release rates in recent years are shown in Table III. Seasonal fluctuation is very apparent and unusual measurements seldom occur. Note that the maximum release rate coincides with minimum river flow.

Zinc-65, chromium-51 and neptunium-239 are significant because their presence is detectable at the mouth of the Columbia. Tables IV, V, and VI indicate the rates of release of these radioisotopes in the recent past.

Strontium-90 release is of interest because of the large quantities released in weapons tests. Tabulation of rates of release was not included because the sensitivity of measurement was inadequate to give reliable data or indicate trends.

The monthly average release rate for all reactors at the point of release to the river is shown in Figure 2. Table VII shows the total release rate in terms of beta emitters measured four hours after the effluent left the reactor. The time has a very great

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TABLE II

Monthly Average Release Rates (curies/day)

PHOSPHORUS-32

1957	105 B	105 C	105 D	105 DR	105 F	105 H	105 KE	105 KW	Total
June	2.24	7.75	2.86	2.46	1.52	----	2.43	2.00	21.3
July	2.13	3.44	3.07	3.18	2.16	1.20	2.16	1.79	19.1
Aug.	2.36	4.41	2.85	2.97	2.65	2.94	.709	17.3	36.2
Sept.	2.67	5.53	2.14	3.44	3.99	9.55	2.29	1.25	24.9
Oct.	4.30	6.76	3.35	3.01	8.00	3.14	2.77	1.38	32.7
Nov.	3.74	5.06	3.59	4.00	5.17	3.33	7.89	1.71	34.5
Dec.	3.75	13.7	3.19	3.63	21.1	3.79	6.09	9.42	64.6
1958									
Jan.	4.35	23.4	3.25	5.16	5.22	3.90	11.2	2.62	59.1
Feb.	5.57	11.8	4.00	6.23	6.37	4.80	8.94	6.35	54.1
Mar.	2.53	12.3	5.40	2.97	3.74	4.16	6.34	1.65	39.1
Apr.	4.00	9.59	3.50	3.36	61.6	3.63	4.77	2.85	93.3
May	5.25	8.59	3.74	3.39	19.5	3.49	5.88	3.24	53.1
June	2.76	9.60	2.44	4.03	4.97	2.45	7.54	15.0	48.8
July	2.05	4.04	2.14	2.08	50.0	2.58	7.39	1.05	71.4
Aug.	2.60	4.14	2.30	1.89	54.7	2.76	5.12	1.41	75.0
Sept.	2.73	5.02	3.08	1.88	6.21	2.74	7.46	1.48	30.6
Oct.	4.24	7.25	3.90	1.06	9.35	2.49	10.1	2.14	40.5
Nov.	5.76	5.99	5.58	2.11	2.53	4.91	13.8	.453	41.2
Dec.	6.50	12.3	4.91	2.61	5.35	6.85	80.9	4.48	123
1959									
Jan.	3.42	10.2	4.04	2.94	5.28	3.86	19.9	6.89	56.6
Feb.	6.47	9.08	5.52	4.61	6.01	5.79	15.6	12.3	65.4
Mar.	5.81	8.92	6.25	4.55	3.83	7.64	12.1	9.88	59.0
Apr.	6.27	6.05	5.67	5.21	5.09	6.10	5.01	9.28	48.7
May	4.26	6.14	5.29	5.69	2.16	5.07	4.38	5.15	38.1
June	3.04	5.22	2.66	2.72	2.61	2.63	9.21	3.84	31.9
July	3.12	4.74	3.01	1.94	2.68	2.90	10.6	2.24	31.2
Aug.	3.27	5.13	2.56	3.11	4.22	1.70	6.87	3.74	30.6
Sept.	3.76	4.55	3.63	3.66	3.16	2.57	6.01	4.39	31.7
Oct.	7.07	13.1	4.29	4.33	5.45	2.95	11.6	6.78	55.6
Nov.	6.46	6.30	3.36	4.85	54.5	4.19	7.83	2.94	90.4

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TABLE III

Monthly Average Release Rates (curies/day)

ARSENIC-76

1957	105 B	105 C	105 D	105 DR	105 F	105 H	105 KE	105 KW	Total
June	35.2	106.	43.9	38.3	37.5	----	27.0	35.0	323
July	36.1	44.2	50.7	52.5	54.7	31.6	49.7	23.5	343
Aug.	46.6	76.2	50.8	52.4	50.4	57.3	16.3	35.3	385
Sept.	52.7	122	53.6	34.4	85.9	62.6	47.7	26.7	486
Oct.	79.9	155	48.7	35.2	97.0	52.3	65.3	37.4	591
Nov.	93.1	116	53.8	52.3	155	93.4	124	48.5	736
Dec.	110	320	77.0	91.7	136	104	95.9	205	1140
1958									
Jan.	124	300	109	156	127	118	130	91.6	1160
Feb.	133	244	122	138	111	101	162	131	1140
Mar.	78.6	212	110	85.2	97.1	99.9	93.8	51.9	828
Apr.	85.8	205	72.8	73.3	116	67.7	88.2	71.4	781
May	87.3	152	89.2	74.8	82.3	78.8	115	91.3	771
June	60.6	72.6	38.8	71.6	44.7	46.3	94.2	34.3	463
July	44.1	15.8	39.3	38.6	65.4	54.4	82.8	70.5	411
Aug.	49.6	110	46.5	35.7	118	62.9	100	31.3	554
Sept.	68.3	112	71.8	48.3	83.0	57.1	128	48.7	616
Oct.	86.5	115	97.3	41.5	137	52.0	132	60.9	723
Nov.	120	132	100	50.4	47.8	117	232	9.50	809
Dec.	133	162	91.9	61.2	120	147	161	114	999
1959									
Jan.	63.1	91.5	95.6	75.2	94.6	50.5	192	120	782
Feb.	97.9	136	100	95.3	88.9	110	224	183	[illegible]
Mar.	67.6	135	97.7	81.0	48.2	105	124	120	[illegible]
Apr.	80.7	66.6	71.3	79.1	63.2	81.1	55.5	114	[illegible]
May	62.4	103	65.3	74.7	30.1	66.4	53.9	62.1	[illegible]
June	39.9	62.1	46.0	32.6	28.5	29.4	64.7	43.2	[illegible]
July	47.4	64.1	28.0	25.0	33.4	39.0	39.8	37.8	[illegible]
Aug.	37.0	57.7	28.4	47.6	42.6	37.7	78.6	22.9	[illegible]
Sept.	56.4	68.0	37.7	39.4	30.6	29.4	61.7	52.5	[illegible]
Oct.	73.5	146	48.1	46.3	52.1	55.3	75.1	70.2	[illegible]
Nov.	88.7	72.4	26.7	50.1	38.4	46.6	74.3	65.0	[illegible]

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TABLE IV

Monthly Average Release Rates (curies/day)

ZINC-65

1958	105 B	105 C	105 D	105 DR	105 F	105 H	105 KE	105 KW	Total
Jan.	4.2	8.3	4.7	7.2	9.7	4.8	7.4	7.0	53.3
Feb.	4.3	7.5	5.2	8.2	7.9	5.6	9.7	23.1	71.5
Mar.	3.8	9.9	6.4	6.6	7.3	5.3	5.8	4.6	49.8
Apr.	6.6	9.5	7.4	8.6	59.4	5.1	7.8	9.2	114.0
May	6.6	7.9	7.9	5.8	27.4	7.8	7.2	8.2	78.8
June	2.8	1.8	1.25	5.3	1.09	5.2	13.0	7.7	44.8
July	3.7	3.42	3.68	2.96	7.2	4.5	27.0	7.4	59.9
Aug.	2.84	4.2	3.7	2.1	35.1	3.3	12.3	4.25	67.8
Sept.	2.3	3.7	2.1	1.3	7.1	2.7	9.4	3.6	32.2
Oct.	12.2	4.2	7.6	2.3	38.6	6.3	29.4	6.3	107.
Nov.	4.7	2.6	5.8	2.6	28.8	5.6	11.9	6.6	68.6
Dec.	4.1	4.3	4.7	3.0	5.9	6.6	12.8	7.3	48.7

1959	105 B	105 C	105 D	105 DR	105 F	105 H	105 KE	105 KW	Total
Jan.	3.6	4.4	5.5	2.3	7.6	2.4	10.7	10.4	46.9
Feb.	8.3	7.6	9.1	5.3	9.3	7.2	16.2	15.2	78.2
Mar.	7.5	10.6	9.5	10.8	8.40	11.0	10.7	13.9	82.4
Apr.	10.0	6.3	7.3	8.6	12.6	10.2	6.8	18.1	79.9
May	5.8	10.6	9.6	9.1	5.4	7.7	7.8	19.0	75.0
June	6.1	8.2	5.0	6.6	14.0	4.8	13.5	12.1	70.3
July	3.7	7.0	5.0	2.7	38.0	6.1	11.2	6.3	80.0
Aug.	3.4	7.4	2.7	2.8	6.8	3.2	24.8	6.7	57.8
Sept.	5.9	8.6	26.0	29.2	18.8	5.0	25.8	19.2	138.5
Oct.	6.4	9.8	2.6	3.0	4.3	2.4	9.2	8.9	37.6
Nov.	6.2	13.3	4.4	6.3	84.0	4.2	4.2	26.0	152.2

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TABLE V

Monthly Average Release Rates (curies/day)

CHROMIUM-51

1958	105 B	105 C	105 D	105 DR	105 F	105 H	105 KE	105 KW	Total
Jan.	138	261	124	194	164	149	122	124	1280
Feb.	141	194	148	175	138	150	144	87	1180
Mar.	82	181	140	136	110	124	84	94	950
Apr.	124	200	109	119	308	94	78	102	1130
May	118	181	108	115	191	106	111	113	953
June	116	294	101	150	146	129	173	128	1102
July	72	155	108	113	84	122	134	88	877
Aug.	106	116	165	107	384	123	140	358	1499
Sept.	70	139	121	125	282	68	138	144	1087
Oct.	120	122	143	146	210	129	132	132	1134
Nov.	152	117	127	82	139	159	141	16	933
Dec.	152	130	120	113	123	177	165	82	1062
1959									
Jan.	93	94	131	112	151	111	188	153	1033
Feb.	127	138	98	143	139	151	128	101	1025
Mar.	89	130	97	119	80	304	89	57	965
Apr.	169	105	132	126	157	150	57	136	1032
May	181	270	216	268	93	206	86	158	1478
June	230	204	130	109	113	144	200	167	1297
July	178	189	149	110	180	175	162	120	1263
Aug.	40	139	111	111	78	102	110	26	717
Sept.	54	74	138	142	142	167	150	163	1030
Oct.	139	415	133	248	90	133	153	141	1452
Nov.	142	110	72	87	130	125	167	146	979

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TABLE VI

Monthly Average Release Rates (curies/day)

NEPTUNIUM-239

1957	105 B	105 C	105 D	105 DR	105 F	105 H	105 KE	105 KW	Total
June	122	321	78.8	153	74.7	----	70.2	79.4	899
July	111	126	161	170	102	78.9	111	75.7	936
Aug.	119	238	134	188	96.8	123	36.4	86.5	1020
Sept.	135	275	89.3	178	147	134	127	88.2	1170
Oct.	92.2	167	72.3	77.8	77.7	54.9	79.4	55.7	677
Nov.	106	140	103	110	103	93.4	164	83.6	903
Dec.	135	272	104	119	142	122	126	155	1130
1958									
Jan.	121	284	130	194	128	145	134	128	1270
Feb.	150	226	138	192	109	146	179	135	1270
Mar.	102	215	148	146	115	124	104	75.4	1030
Apr.	98.6	140	97.7	104	110	82.2	125	101	858
May	102	143	101	109	86.7	90.6	70.3	80.7	783
June	67.4	119	71.6	100	51.3	66.2	118	59.3	653
July	74.9	88.1	71.3	74.7	58.8	81.6	121	52.3	623
Aug.	74.4	85.9	82.7	66.0	146	78.7	126	120	780
Sept.	74.7	100	95.6	101	85.7	73.3	157	81.9	769
Oct.	89.8	99.1	119	51.3	175	77.7	166	99.5	877
Nov.	150	129	136	81.6	73.6	157	252	12.4	992
Dec.	132	146	139	104	115	145	250	147	1120
1959									
Jan.	49.2	79.1	77.2	62.7	59.6	53.5	127	116	625
Feb.	110	114	133	109	107	106	181	178	1040
Mar.	80.5	129	89.9	96.3	58.5	112	89.6	92.4	749
Apr.	92.8	77.9	91.3	81.4	78.2	86.5	53.7	104	666
May	59.3	97.0	92.7	87.8	35.8	72.8	56.6	72.7	575
June	63.4	68.9	43.8	51.1	37.2	36.4	68.1	52.1	421
July	67.7	68.4	57.7	45.3	40.7	55.5	62.2	42.0	439
Aug.	48.1	67.3	50.0	60.0	38.8	39.6	80.6	45.3	430
Sept.	68.7	72.4	57.3	63.8	35.6	45.2	105	72.3	520
Oct.	73.6	97.7	41.9	55.5	49.8	55.3	89.0	109	572
Nov.	111	102	36.7	74.3	56.3	63.3	98.0	140	682

[redacted]

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FIGURE 2

RADIOACTIVITY IN REACTOR EFFLUENT
MONTHLY AVERAGE RELEASE RATE

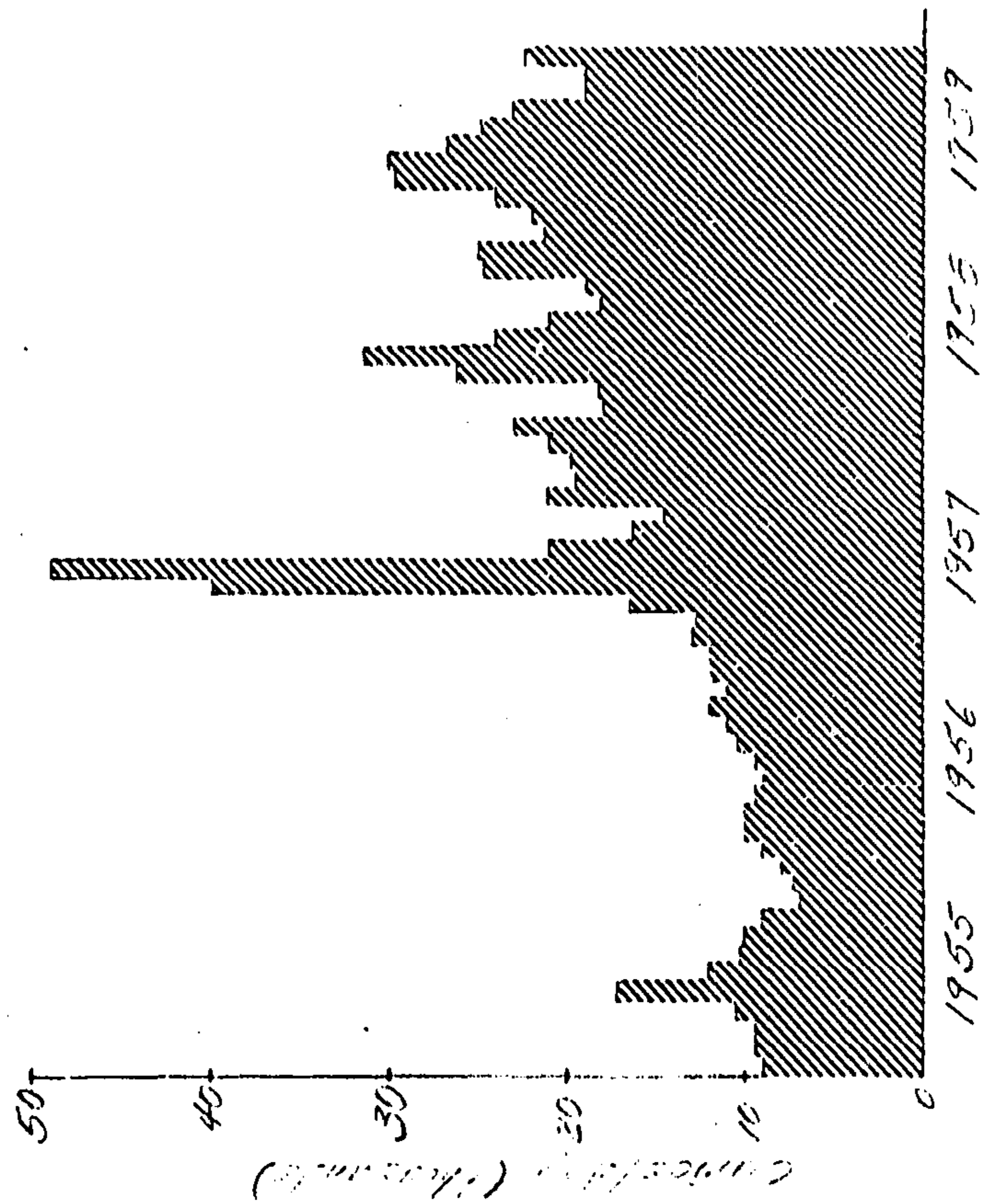

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TABLE VII

Monthly Average Release Rate (curies/day)

TOTAL BETA AT 4 HOURS

1957	105 B	105 C	105 D	105 DR	105 F	105 H	105 KE	105 KW	Total
June	1540	2900	1250	1580	1310	----	2100	3260	13900
July	1380	1110	1450	1450	1060	907	1890	1900	11200
Aug.	1170	1710	1070	1140	796	1250	623	1860	9610
Sept.	1320	1640	922	1440	1290	1310	1450	1520	10900
Oct.	1350	1910	1290	1150	1270	994	1460	1840	11300
Nov.	1390	1280	1560	1280	1550	1230	1660	1950	11900
Dec.	1360	2320	1240	1190	1240	1200	1280	2080	11900
1958									
Jan.	1270	2860	1620	1960	1220	1260	1570	2220	14000
Feb.	1250	2080	1720	1790	1140	1420	2100	1710	13200
Mar.	1020	2350	1770	1510	1230	1440	1520	1410	12300
Apr.	1670	2480	1920	2080	2640	1620	1870	5570	19800
May	1400	1870	1840	1480	1480	1950	1950	3210	15200
June	1110	1670	987	1260	1090	1190	2430	1810	11600
July	1030	1360	977	800	1170	1270	2060	1190	9850
Aug.	1010	805	1050	748	1580	1200	1770	1460	9630
Sept.	1180	1220	1780	839	1260	1430	2270	2390	12400
Oct.	1160	1410	1720	791	1700	1060	1810	2420	12100
Nov.	1490	1030	1960	889	774	1630	2480	227	10500
Dec.	1600	1690	1640	1080	1590	1950	2240	1580	13400
1959									
Jan.	877	1240	1870	1320	1380	1040	2150	1890	11800
Feb.	1710	1590	1890	1890	1900	1630	2880	2870	16400
Mar.	1400	1860	1920	1850	1200	2330	2000	2360	14900
Apr.	2390	1700	2230	2110	3300	2680	1880	3970	20300
May	1830	2490	2110	2140	1220	1840	1470	2640	15700
June	1570	1790	1190	1370	1120	1030	2440	1930	12500
July	1950	2040	1280	876	1110	1460	1680	1710	12100
Aug.	1630	1900	1150	1210	1170	910	2410	2040	12400
Sept.	1470	1030	1430	1360	890	1320	2110	2200	11800
Oct.	1320	1700	1530	1270	1260	1360	2010	2450	12900
Nov.	2040	1370	1150	1500	1370	1510	2310	2060	13300

[redacted]

effect on this figure since the various constituent radioisotopes decay at different rates. This time was chosen in order to permit collection and preparation for counting and to provide a uniform base for evaluation. The significance of this measurement is not great because of the considerable contribution of short lived radioisotopes, especially manganese-56.

III. UNUSUAL EFFLUENTS

The previous section dealt with the results of routine measurements which are made in such a manner that unusual effluents would not be measured. These unusual effluents contain radioactive materials released by fuel element failures, purges of the reactors with diatomaceous earth and chemical decontamination of reactor piping. In each case it can be shown that unusual effluents do not contribute much to the burden of radioactivity in the Columbia River. Their significance lies in the potential release rather than the actual experience to date.

McCormack and Schwendiman have estimated that ruptures contribute 20% of the present strontium-89 plus strontium-90 content of the Columbia at Pasco and about 4% of the gross fission product activity.(2) The average fuel element rupture of those studied released an estimated 30 curies of fission products to the river, as measured at Pasco. On this basis fission products from ruptures contribute less than one percent of the annual average fraction of MPC in the river. The gastro-intestinal tract is the limiting organ. During 1959 the frequency of ruptures dropped sharply.

During operation of reactors with single-pass coolant, a film is built-up on the surfaces of the fuel elements and process tubes. Occasionally this film will build up to sufficient depth that the flow of cooling water through the process tubes is reduced slightly. When this happens a slurry of diatomaceous earth is mixed with the process water. The mild abrasive action reduces the film thickness. This operation is called a purge. This film, basically iron oxides, is fundamental in the process of activation of water impurities and therefore contains all the radioisotopes normally found in reactor effluent water. It has been shown by studies of this film that only a small fraction of the film is removed by a purge. Koop estimated that purging one reactor every other day would increase the gastro-intestinal tract dose in drinking water by less than 5%.(3) Actually an average of two or three purges per month are conducted.

A film also builds up on the surfaces of the effluent piping in the reactor discharge areas. This contributes high radiation dose rate. In order to improve working conditions, a technique was devised to remove this film with a proprietary chemical known as Turco-4306B. This operation is necessarily conducted during a reactor outage. Subsequent experience has supported conclusions reached by Koop(4) following the first large scale effort that release to the river was acceptable. No river pollution problems were encountered in any of the ten decontamination attempts. In all but two the effluent was released to the river. In those two cases, the effluent was neutralized with sodium hydroxide before release to a trench.

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IV. SOURCES OF RADIOISOTOPES

As previously stated, the film which forms on the surfaces of the fuel elements and process tubes plays a fundamental role in the activation of materials which appear as radioisotopes in reactor effluent water. Several tests have been conducted to determine the feasibility of decontamination of in-reactor piping. Although these tests were aimed at the reduction of discharge area radiation dose rates, they afforded an opportunity to study the build-up of radioisotopes in the effluent water and the deposition of radioactive materials on metals.[5] From this and other studies it has been concluded that almost all the radioisotopes found in reactor effluent water have their primary source in the river. These trace elements are not removed by the present water treatment process but are incorporated into the film in the active zone of the reactor for varying lengths of time and are then released to the water.

One notable exception to the previous generality is chromium-51. About 2 ppm of sodium dischromate is added to the process water shortly before it enters the reactor to inhibit the corrosion of aluminum. No other suitable corrosion inhibitors have been found. This chemical also contributes most of the sodium-24 found in reactor effluent water although it is known that sodium-24 is an activation product of aluminum. As much as 25% of the phosphorus-32 may also result from water treatment chemicals. Sulfuric acid is used in large amounts to reduce the pH from 8.0 to 8.6 which is normal for the river water to 7.0 which is desired for the process water. One of the activation products of sulfur is phosphorus-32.

Zinc is an impurity in the aluminum process tubing and fuel element jackets. Perhaps as much as 10% of the zinc-65 in reactor effluent water results from corrosion.

As previously stated, ruptured fuel elements add some 4% to the fission product contamination of the river. Residue left in a process tube following discharge of the offending element may add slightly to the fission products released. In addition traces of uranium have been found on fuel element jackets. By far the largest amount of fission products as well as neptunium-239 result from the irradiation of uranium derived from river water.

V. METHODS FOR REDUCING OR ELIMINATING RADIOACTIVITY IN REACTOR EFFLUENT

The incentive for reducing the amounts of radioisotopes released to the river may best be determined from the companion document[1] and from forecasts of the effects of further increasing production. Varying degrees of reduction could be obtained from methods presently known and possibly from those being studied.

Probably the most direct approach would be to pass the effluent water through an ion exchange resin bed. A rough guess of the cost is $30 to $40 million to equip one reactor with a suitable bed. In addition regeneration of the resin beds would add large sums to operating costs and present large waste disposal problems.

A modified version of this process has been studied. It was shown that significant reduction could be achieved by passing the reactor effluent through a bed of aluminum.[6] In this process, the bed would not be regenerated. Instead

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the radioisotopes collect on the surfaces of the aluminum much as the parent elements did on in-reactor aluminum surfaces. Significant decay occurs before the materials are again released to the water. On a laboratory scale, using lathe turnings the release rate of arsenic-76 was reduced by 65%, zinc-65 by 50%, phosphorus-32 by 43% and neptunium-239 by 25%.

A scope study is currently being made to determine the cost of such a treatment method for the entire effluent stream from a reactor.

Improvement of the influent water treatment process would appear to offer the greatest advantage. The treatment of water for reactor cooling has been geared only to control corrosion on slug can and process tube surfaces and the pressure drop across the reactor. Tests have shown that the usual standard of water quality, turbidity, does not define the potential for formation of radioisotopes in the reactor[7] [8].

Research activities have been started with the goal of tailoring water treatment to also control the output of certain radioisotopes. The sources of the parents of significant isotopes including the critical isotopes have been determined. Perhaps some of those present in process water can be removed by improved water treatment.

The concentration of parent elements entering the reactor in the cooling water is not high enough to account for the concentration of radioisotopes in the effluent if it is assumed that the parent elements pass through the reactor with the water. Knowing that a film is deposited on the surfaces of fuel elements and tubes within the flux zone of the reactor, it is felt that the output of some radioisotopes could be controlled by controlling this film. The scope of the study includes 1) investigation of the source, mechanism of formation, and chemical form of the radioisotopes; 2) the influence of process variables such as water treatment, materials of construction, operating temperature, effect of additives, etc.; and 3) procedures whereby problems associated with these radioisotopes may be eliminated or minimized. In-pile testing with the necessary equipment is required.

Conversion of the reactors from single-pass cooling to recirculation of the coolant would reduce the amounts of radioactive material released to negligible amounts. A study made in 1955 estimated the cost of adapting the H reactor to a recirculating water system at $18,200,000.[9]

Some reduction in the output of chromium-51 and sodium-24 is possible. Although the need for addition of sodium dichromate as a corrosion inhibitor has been established, the minimum acceptable feed rate has not. The feed rate is presently established on the basis that increased corrosion would greatly increase reactor maintenance costs. The effect of reduced chromium feed is being investigated. The ultimate reduction is dependent upon the results of the investigation.

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