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Steam Generator Group Project Progress Report

Task 3 - Health Physics

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Pacific Northwest Laboratory
Operated by
Battelle Memorial Institute

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Commission

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ABSTRACT

The gamma radiation fields in and around the retired Surry steam generator were measured extensively with thermoluminescent dosimeters (TLD's) and other standard radiation instruments. The techniques of measurement and the results are described for locations outside the shell, inside the channel head, and inside the secondary side of the steam generator. The gamma fields ranged from more than 10 R/hr in the middle of the tube bundle on the secondary side to less than 5 mR/hr at the bottom of the outside of the shell below the channel head. Co-60 was the only detected gamma emitter. The results of the measurements were used in an analytical model which predicted the Co-60 inventory to be between 70 and 87 curies.

ABSTRACT

The gamma radiation fields in and around the retired Suroy steam generator were measured extensively with thermoluminescent dosimeters (TLD's) and other standard radiation instruments. The techniques of measurement and the results are described for locations outside the shell, inside the channel head, and inside the secondary side of the steam generator. The gamma fields ranged from more than 10 R/hr in the middle of the tube bundle on the secondary side to less than 2 mR/hr at the bottom of the outside of the shell below the channel head. Co-60 was the only detected gamma emitter. The results of the measurements were used in an analytical model which predicted the Co-60 inventory to be between 70 and 85 curies.

INTRODUCTION - STEAM GENERATOR RADIATION MAPPING

The objective of the radiation mapping subtask is to determine the radiation fields inside and around the steam generator, including the Steam Generator Examination Facility (SGEF) and the surrounding environment. External gamma radiation fields are measured and mapped using data gathered from survey instruments and thermoluminescence dosimeters (TLD's). An environmental monitoring study is part of the exterior measurement study. The steam generator interior was examined for isotopic content and field distribution. A computer code developed for cylindrical sources and extended to structures like the steam generator was employed to determine the efficiency of using this computer simulation to predict and map the radiation field measurements.

Initial measurements of the subtask prior to decontamination activities have been completed using conventional radiation survey instruments and thermoluminescence dosimeters. This is an ongoing assignment and additional measurements will be taken as needed to assess the effectiveness of decontamination processes and other operations and to monitor working and environmental dose rates.

Mapping the Exterior

Thermoluminescence dosimeters were used to provide exposure rate profiles along the length, circumference, and other portions of the exterior of the steam generator. Strings of TLD's were attached to the exterior of the steam generator at 1-ft intervals from the top edge to the bottom center of the generator. They were oriented facing north, south, east, and west. A string of TLDs was placed diagonally across the top of the unit and a single TLD string was placed three feet from the northeast side parallel to the exterior shell. The NE to SW orientation corresponds to the lifting trunions on the generator. The maximum dose rates for the surface measurements are (the numbers in parenthesis denote feet down from the top edge of unit): north 160 mR/hr (9), east 157 mR/hr (18), south 144 mR/hr (8), west 155 mR/hr (16) and 252 mR/hr (46), top of unit 504 mR/hr at center and at 3 feet away and parallel to the generator 73 mR/hr (18). See Figures 1-3.

About two-thirds of the way down the unit, the surface readings show an abrupt change from readings around 120-150 mR/hr down to 80-105 mR/hr. This corresponds to a thicker lower section of the steam generator shell providing enhanced shielding. Near the top where the exterior shell flares outward, the readings behave as would be predicted considering the greater distance from the surface to the tubes (Figure 4), and the fact that most radiation is fixed inside the tubes.

TLD readings at points just beyond the exterior were taken in conjunction with interior measurements. Results near the hot leg and cold leg manway holes and outside of penetrations 1, 3, and 4 (P-1, P-2, P-4 in Figure 4) are summarized below:

TLD DOSE RATE READINGS

FIGURE 1.

TLD DOSE RATE READINGS

ALL EXPOSURES IN mR AT CONTACT

FIGURE 2.

DOSE RATE READINGS

FIGURE 3.

SHELL PENETRATIONS LOCATIONS ON SURRY STEAM GENERATOR

FIGURE 4.

	<u>Distance from Surface</u>	<u>R/hr</u>
Cold Leg	11 in.	0.55
	1 ft 11 in.	0.07
Hot Leg	1 ft.	1.5
	2 ft.	0.51
	3 ft.	0.10
	4 ft.	0.05
	5 ft.	0.024
	6 ft.	0.017
P-1	10 ft.	0.012
	1 ft. 10 in.	0.045
	2 ft. 10 in.	0.039
	3 ft. 10 in.	0.037
P-3	5 in.	2.1
	11 in.	1.0
	16 in.	0.55
	21 in.	0.27
P-4	1 in.	1.3
	1 ft. 1 in.	0.11
	2 ft. 1 in.	0.044
	3 ft. 1 in.	0.036

Radiation surveys were conducted from time to time, usually by the radiation monitor assigned to the building, and the information was used to map the fields in the examination room. Surveys were conducted to determine changes in the radiation fields with changing steam generator condition, such as manway opening and channel head decontamination. This provides information which can be used to predict changes in radiation fields for similar operations at commercial plants.

After installation of the generator in the SGEF tower, survey readings were taken with an ion chamber at the manways, the inlet-outlet cover caps and at various points at each floor level of the SGEF tower. The covers measured the following readings at their exterior surfaces:

	<u>mR/hr</u>
Hot Leg	
manway	15
inlet cap	100
Cold Leg	
man way	10
outlet cap	60

Isotopic diagrams from surveys inside the SGEF tower plot the dose range from each of the four floors (Figures 5-8). This information is especially useful for reducing exposure of workers who can perform parts of their tasks in areas away from the steam generator. These profiles change significantly with changes in operations. After the vertical installation of the generator, condensate and other contaminated water remaining in the tubes settled into the bottom of the channel head. This increased the dose rate in the basement from about 60 mR/hr to about 200 mR/hr near the channel head. Removal of the manway covers and penetrations in the sides of the shell walls caused some localized increases in dose rate, though the shielding provided for the penetrations mitigates this problem while it covers the holes.

An additional cause for changing exposure rates occurs during decontamination procedures and during removal of tubes and other material samples from the steam generator. The location of the collection tank in the basement suggests that the basement profile and the grid steps and platform of the 1st floor experience changes as the activity in the tank increases. These changes are apparent in routine surveys.

Surveys from the outside of the SGEF tower were also conducted. Measurements along the roof of the 2nd floor mechanical equipment room facing the steam generator ranged from 2 mR/hr to 2.5 mR/hr. Geiger-Mueller (GM) counts were taken on the outside ground level of the SGEF tower and on the second level mechanical equipment room also facing the structure. Counts from the mechanical equipment room along the south wall ranged from 200-2000 counts per minute (c/m). The readings outside the building ranged from 200 to 300 c/m (Figure 9).

Environmental Monitoring Program

Radiation monitoring at various locations around the Steam Generator Examination Facility (SGEF) began in February 1982 to determine the dose rates at points outside the facility. Ten environmental dosimeters were fabricated and hung in the following locations (Figure 10): 3746D building, 314 Building room 103, 305B annex, 377 trailer and at fence positions north, south east, and west surrounding the 377 (steam generator) building.

Fiscal year quarterly readings from these TLDs (Table 1) show little variation in exposure dose rate at most locations, though some fluctuation in facility activity is reflected in monthly readings. The fourth quarter averages at the north fence and at the 377 trailer show slightly elevated values probably due to the proximity of low-level radioactive shipping containers from the decontamination equipment. High levels in the 305B building during the fourth quarter are probably also due to temporary storage here of the radioactive decontamination equipment when it arrived from offsite.

**RADIOLOGICAL SURVEY DOSE PROFILE
OF SLURRY STEAM GENERATOR**

LEVEL - 1st FLOOR

*DOSE RATES ARE IN mR/hr

FIGURE 5.

**RADIOLOGICAL SURVEY DOSE PROFILE
OF SURRY STEAM GENERATOR**

LEVEL - 2nd FLOOR

*DOSE RATES ARE IN mR/hr

FIGURE 6.

**RADIOLOGICAL SURVEY DOSE PROFILE
OF SURRY STEAM GENERATOR**

LEVEL - 3rd FLOOR

*DOSE RATES ARE IN mR/hr

FIGURE 7.

**RADIOLOGICAL SURVEY DOSE PROFILE
OF SURRY STEAM GENERATOR**

LEVEL - 4th FLOOR

*DOSE RATES ARE IN mR/hr

FIGURE 8.

AREA SURVEY WITH GIEGER-MULLER COUNTER

FIGURE 9.

FIGURE 10.

TABLE 1. Exposure Dose Rate as Determined by Environmental TLD Dosimeters Located Near the Steam Generator Examination Facility (Quarterly Average)

	<u>Q2/82</u>	<u>Q3/82</u>	<u>Q4/82</u>	<u>Q1/83</u>
North Fence	5.3	4.8	8.8*	31.5*
South Fence	726.0	771.4	626.2	761
East Fence	126.0	103.1	83.7	106
West Fence	485.3	441.8	356.9	437
377 Trailer (inside)	3.7	3.6	5.4*	9.1*
305B Building	25.7	22.0	42.7**	22.9
314 Building (inside)	8.3	6.7	4.9	7.7
3746 Building	14.1	14.8	11.8	13.9

NOTE: All readings are in $\mu\text{R/hr}$.

*Low level radioactive shipping containers used by sub-contractor in general vicinity for one month.

**High reading one month prior to decontamination operation - probable explanation is storage of radioactive London Nuclear decontamination equipment in the building.

Environmental Monitoring Data

<u>Location</u>	<u>Total Exposure (mR)</u>	<u>Average Exposure Rate ($\mu\text{R/hr}$)</u>
Exposure from 1/10/82 to 3/11/82 (720 hr. exposure)		
North Fence	4.7	6.5
South Fence	609.1	846
East Fence	101.8	141
West Fence	369.2	513
3746 Building	12.3	17.1
377 Trailer	3.6	5.0
305B Building	19.8	27.5
314 Building	6.2	8.6
Exposure from 3/11/82 to 4/13/82 (816 hr. exposure)		
North Fence	6.2	7.6
South Fence	724.8	888
East Fence	100.4	123
West Fence	413.9	507
3746 Building	13.8	16.9
377 Trailer	4.6	5.6
305B Building	20.8	25.5
314 Building	7.1	8.7

Exposure from 4/13/82 to 5/12/82 (720 hr. exposure)

North Fence	4.4	6.1
South Fence	541.4	752
East Fence	75.3	104
West Fence	313.2	435
3746 Building	11.8	16.4
377 Trailer	4.5	6.3
305B Building	15.6	21.7
314 Building	5.8	8.0

Exposure from 5/12/82 to 6/15/82 (816 hr. exposure)

North Fence	6.0	7.3
South Fence	706.0	865
East Fence	95.4	117
West Fence	413.1	506
3756 Building	14.5	17.8
377 Trailer	4.0	5.0
305B Building	20.9	25.6
314 Building	6.3	7.7

Exposure from 6/15/82 to 7/15/82 (720 hr. exposure)

North Fence	5.4	7.5
South Fence	603.0	837
East Fence	78.4	109
West Fence	329.5	454
3746 Building	13.4	18.6
377 Trailer	3.4	4.7
305B Building	16.8	23.4
314 Building	6.5	9.0

Exposure from 7/15/82 to 8/17/82 (792 hr. exposure)

North Fence	5.0	6.3
South Fence	482.0	609
East Fence	67.4	85
West Fence	265.7	335
3746 Building	8.4	10.6
377 Trailer	6.4	8.1
305B Building	57.7	72.8
314 Building	3.4	4.3

Exposure from 8/17/82 to 9/17/82 (744 hr. exposure)

North Fence	18.8	25.3
South Fence	497.0	668
East Fence	68.3	92
West Fence	281.0	378
3746 Building	10.4	13.9
377 Trailer	8.2	11.0
305B Building	33.7	45.3
314 Building	6.0	8.0

Exposure from 9/17/82 to 10/21/82 (816 hr. exposure)

North Fence	100.1	122.7
South Fence	642.0	787
East Fence	94.4	116
West Fence	371.2	455
3746 Building	18.6	22.8
377 Trailer	--	--
305B Building	18.8	23.1
314 Building	7.0	8.5

Exposure from 10/21/82 to 11/17 & 19*/82 (620 and 672* hr. exposure)

North Fence	8.1*	12.0
South Fence	535.1*	796
East Fence	71.7*	107
West Fence	308.0*	458
3746 Building	8.5	13.8
377 Trailer	--	--
305B Building	15.4	24.8
314 Building	5.9	9.5

Exposure from 11/17/82 to 12/20/82 (796 hr. exposure)

North Fence	11.9	15.0
South Fence	586.0	736
East Fence	80.1	101
West Fence	329.9	414
3746 Building	9.0	11.3
377 Trailer	7.1	9.0
305B Building	17.3	21.7
314 Building	4.3	5.5

Exposure from 12/20/82 to 1/17/83 (672 hr. exposure)

North Fence	9.0	13.4
South Fence	480.1	715
East Fence	69.6	104
West Fence	286.5	426
3746 Building	7.1	10.6
377 Trailer	6.2	9.2
305B Building	14.2	21.1
314 Building	5.2	7.8

Mapping the Interior

Shell Penetrations - Penetrations P-1, P-3, and P-4 and the uncovering of the manways initiated the internal measurements portion of the health physics task. In-place measurements of exposure rates from the channel head tube sheet, tubes and channel head partition plate provide the basis for predicting personnel exposure for decontamination and tube nondestructive testing (NDT) tasks. These profiles provide information about the distribution of activity within the steam generator and aid in

assessing the effectiveness of decontamination efforts. They also were used to determine contamination levels, the isotopic content of the contamination, and the components which contribute to dose rate in and around the steam generator.

TLD-700 dosimeters inside of a rigid plastic tube were inserted into the steam generator at the following locations: Shell penetrations P-1, P-3, P-4, (Figure 4), and the two hand holes located between the tube sheet and first support plate (designated L-1 in Southwest orientation and L-2 in Northeast orientation), and 8 cm below the tube sheet. Co-60 is the only radionuclide above detection limits in the steam generator. Since the most energetic beta from Co-60 can penetrate only about 0.1 inches of plastic and the average energy beta can penetrate less than 0.02 inches, the rigid tubing shielded the TLDs from any beta dose. The doses given below therefore represent the gamma ray dose only. For the P-1 sample, TLDs were placed at six inch intervals within the tube. The tube was exposed for 4 hours and rested on top of a tube support plate during this period. Dose rates ranged from 9.0 R/hr in the middle of the generator to 11.1 R/hr at about one half radius from the center of the tube bundle. Another measurement was made at the P-1 penetration using a tube suspended one foot above the support plate to show the shielding effect of the support plate. A 7-in. TLD tube exposed for 4 hours produced a 9.27 R/hr reading for the P-3 penetration. This penetration is out of the tube lane and it was not possible to place dosimeters through the tube bundle in this orientation, due to close spacing. Rod dosimeter measurements at the P-4 penetration had a maximum reading of 10.9 R/hr. The "hand hole" openings on the first floor varied between 6.0 and 8.5 R/hr. Summaries of these internal measurements are given below:

Sampling Site	Average	Maximum	Minimum
P-1	9.9 R/hr	11.1 R/hr	8.2 R/hr
(above plate)	12.1	13.5	8.8
P-3	9.7	---	---
P-4	10.1	10.9	8.3
Hand Hole			
L-1 (SW)	7.1	8.6	5.5
L-2 (NE)	6.9	8.5	5.6
Tube Sheet	5.8	6.2	5.6

All of the TLD readings, showing the complete profiles are shown in Tables 2 through 9. Note the readings through the hand holes are lower than through penetrations P-1 and P-4, due to reduced shine from one direction.

TABLE 2. TLD Insertion Measurements Taken at P-1
Opening into the Surry Steam Generator
on 2/8/82 at the SGEF Facility

Depth	Exposure in R/hr
8'9"	10.22
8'3"	9.69
7'9"	9.22
7'3"	9.85
6'9"	9.25
6'3"	9.46
5'9"	9.00
5'3"	9.60
4'9"	10.12
4'3"	11.06
3'9"	11.04
3'3"	10.38
2'9"	10.88
2'3"	10.97
1'9"	10.09
1'3"	8.20
9"	6.00
3" inside*	3.69
3" outside*	1.65
9" outside	0.68
15" outside	0.38

*Shell surfaces used as 0 baseline.

TABLE 3. First Floor Insertion (P-1, second run 2/24/82),
Surry Steam Generator, Dosimeter Package Elevated
1 Foot Above Support Plate

<u>Depth</u>	<u>Exposure in R/hr</u>
6'2"	12.12
5'8"	12.07
5'2"	12.33
4'8"	12.77
4'2"	13.43
3'8"	12.62
3'2"	12.35
2'8"	13.53
2'2"	12.86
1'8"	10.61
1'2"	8.84
8"	5.77
2" inside*	2.08
4" outside*	0.57
10"	0.12
1'4"	0.06
1'10"	0.05
2'4"	0.04
2'10"	0.04
3'4"	0.04
3'10"	0.04

TABLE 4. Second Floor P-3 "Rod Dosimeter" Insertion
Measurements, Surry Steam Generator,
Exposure of 2/24/82

<u>Depth</u>	<u>Exposure in R/hr</u>
7"	9.66
1" inside*	4.83
5" outside*	2.11
11"	1.03
16"	0.56
21"	0.27

*Shell surface used as 0 baseline.

TABLE 5. Third Floor Insertion (P-4) "Rod Dosimeter"
Measurements, Surry Steam Generator,
Exposure 3/12/82

<u>Depth</u>	<u>Exposure in R/hr</u>
6'11"	9.9
6'5"	10.1
5'11"	10.0
5'5"	10.4
4'11"	10.4
4'5"	10.9
3'11"	10.6
3'5"	10.0
2'11"	10.4
2'5"	9.7
1'11"	10.2
1'5"	8.3
11"	6.6
5" inside*	3.4
1" outside*	1.3
7"	0.53
1'1"	0.11
1'7"	0.57
2'1"	0.44
2'7"	0.39
3'1"	0.36

*Shell surface used as 0 baseline.

TABLE 6. First Floor (Southwest Hand Hole)
"Rod Dosimeter" Measurements, Surry
Steam Generator, Exposure of 3/15/82

<u>Depth</u>	<u>Exposure in R/hr</u>
9'8"	6.3
9'2"	6.0
8'8"	6.4
8'2"	6.4
7'8"	6.5
7'2"	6.6
6'8"	6.7
6'2"	7.0
5'8"	7.0
5'2"	7.4
4'8"	7.9
4'2"	8.0
3'8"	8.2
2'8"	8.6
2'2"	7.9
1'8"	6.8
1'2"	5.5
8"	3.9
2" inside*	1.5
4" outside*	0.21

*Shell surface used as 0 baseline.

TABLE 7. First Floor (Northeast Hand Hole)
"Rod Dosimeter" Measurements, Surry
Steam Generator, Exposure 3/23/82

Depth	Exposure in (R/hr)
10'	4.8
9'6"	5.7
9'	6.3
8'6"	6.3
8'	6.3
7'6"	6.0
7'	6.1
6'6"	6.5
6'	6.3
5'6"	7.0
5'	7.5
4'6"	7.6
4'	8.2
3'6"	7.8
3'	8.3
2'6"	8.3
2'	8.5
1'6"	7.3
1'	5.6
6"	3.2
Surface	0.7

Two 2-foot rods were placed 3 inches under the tube sheet in both the hot leg and cold leg before decontamination.

TABLE 8. Rod Measurements in Hot Leg Channel Head

<u>Identification</u>	<u>TLD Location in Rod</u>	<u>1 hr Exposure</u>
Rod No. 1 Right	End	5.7 R
	6"	5.6 R
	1'	5.3 R
	1'6"	5.2 R
	End	5.6 R
Rod No. 2 Left	End	6.1 R
	6"	5.8 R
	1'	5.6 R
	1'6"	5.8 R
	End	5.8 R

TABLE 9. Rod Measurements in Cold Leg Channel Head

<u>Identification</u>	<u>TLD Location in Rod</u>	<u>Exposure in (R/hr)</u>
Rod No. 1 Right	End	6.2
	6"	5.8
	1'	5.6
	1'6"	5.7
	End	5.6
Rod No. 2 Left	End	5.7
	6"	5.8
	1'	5.9
	1'6"	5.6
	End	5.7

Channel Head Measurements

Rod dosimeter measurements were made in the hot and cold legs of the channel head by inserting a plastic tube containing TLD's through the manway to the far upper corner (see Figures 11a and 11b). This gave a depth profile along the rods ranging from 1.6 to 4.1 R/hr in the cold leg side and from 2.3 to 4.9 in the hot leg:

**INITIAL RADIATION READINGS
(COLD LEG - R/h)**

FIGURE 11a.

**INITIAL RADIATION READINGS
(HOT LEG - R/h)**

FIGURE 11b.

<u>Depth</u>	<u>Cold Leg</u>	<u>Hot Leg</u>
9 ft.	4.1 R/hr	4.9 R/hr
8 ft.	3.9 R/hr	4.2 R/hr
7 ft.	3.8 R/hr	4.0 R/hr
6 ft.	3.7 R/hr	3.8 R/hr
5 ft.	3.2 R/hr	3.5 R/hr
4 ft.	3.2 R/hr	3.2 R/hr
3 ft.	2.8 R/hr	3.1 R/hr
2 ft.	2.9 R/hr	2.9 R/hr
1 ft.	3.6 R/hr	2.7 R/hr
surface	1.6 R/hr	2.3 R/hr

A second study of the dose inside the channel head using rods inserted to different depths near the midpoint of the intersection of the channel head bowl and tube sheet from the manway (see Figure 12) provided slightly higher results:

<u>Depth</u>	<u>Cold Leg</u>	<u>Depth</u>	<u>Hot Leg</u>
6 ft. 1 in.	5.2 R/hr	3 ft. 6 in.	6.3 R/hr
5 ft. 1 in.	4.1 R/hr	3 ft.	4.7 R/hr
4 ft. 1 in.	3.5 R/hr	2 ft.	3.3 R/hr
3 ft. 1 in.	3.2 R/hr	1 ft.	2.8 R/hr
2 ft. 1 in.	3.3 R/hr	surface	3.5 R/hr
1 ft. 1 in.	3.5 R/hr		
1 in.	2.1 R/hr		

Lead bricks were used to estimate the exposure due to the channel head bowl surfaces. TLDs were taped to a machined recess in the lead brick and placed dosimeter side down next to the inner channel head surface 1 ft. from the manway hole. Since some of the dose to the TLDs might be from the beta component of the radiation fields, while dose to TLDs in rods or tubes would not, it is only valid to compare these results with other measurements made the same way. The measured doses were:

Hot Leg	2.7 R/hr
Cold Leg	3.2 R/hr

Other Sample Measurements

The exposure rate from the inner surfaces of the hot and cold leg manways and manway cover plate inserts were measured using an ion chamber with these results:

Manway	R/hr
Hot leg manway	3.6
Cold leg manway	3.8
Hot leg cover plate	2.0
Cold leg cover plate	3.6

LOCATION OF TLD STRINGS FOR SECOND STUDY (LOOKING DOWN ON CHANNEL HEAD)

FIGURE 12.

Coupon samples cut from the cold leg manway cover insert ranged from 396 to 503 mR/hr (see Table 10). Additionally a disk dosimeter consisting of 202 chips was used on both manway plate inserts to obtain the dose distribution. The dose rate ranged from 2.3 R/hr to 7.9 R/hr on the cold leg insert and from 1.3 R/hr to 2.6 mR/hr on the hot leg insert (see Table 11 and Figure 13).

A section of a tube at the P-4 penetration (row 1, column 94, cold leg) was cut out for further study and use in the channel head decontaminations. A TLD "train" was inserted into the open end of the remaining tube (above the 6th support plate) and the dose rate inside the tube measured. The dose rate proved to be quite evenly distributed:

<u>Depth Inside Tube</u>	<u>R/hr</u>	<u>Depth Inside Tube</u>	<u>R/hr</u>
1 ft. (outside)	2.7	10 ft.	7.9
cut off end	7.6	11 ft.	7.9
1 ft.	7.9	12 ft.	6.9
2 ft.	7.7	13 ft.	7.8
3 ft.	7.8	14 ft.	8.1
4 ft.	7.5	15 ft.	7.9
5 ft.	7.8	16 ft.	6.3
6 ft.	8.1	17 ft.	7.9
7 ft.	7.8	18 ft.	7.8
8 ft.	7.4		
9 ft.	7.8		

TABLE 10. Exposure Rates of Coupons Cut From Cold Leg Manway Cover Insert Plate

<u>Coupon ID</u>	<u>Exposure mR/hr</u>
CA-8	396.0
CA-9	443.0
CA-10	501.0
CB-8	503.0
CB-9	464.0
CB-10	477.0

LOCATIONS IN DISKS

SURRY STEAM GENERATOR DISK DOSIMETER FOR MAN WAY PLATE

FIGURE 13.

TABLE 11. Manway Cover Plate Insert Radiation Measurements

Location (see Figure 13)	Exposure (R/hr)	
	Cold Leg	Hot Leg
1	3.8	1.4
2	4.1	1.6
3	3.8	1.3
4	4.1	1.5
5	4.3	1.4
6	3.8	1.5
7	3.5	1.6
8	3.2	1.6
9	2.8	1.5
10	3.4	1.6
11	3.9	1.7
12	4.0	1.6
13	4.2	1.5
14	3.3	1.6
15	3.7	1.8
16	3.4	1.9
17	3.1	1.8
18	3.4	1.9
19	3.2	1.8
20	3.2	1.9
21	3.1	1.8
22	4.2	1.6
23	5.0	1.6
24	3.5	1.6
25	2.5	1.9
26	3.6	2.1
27	3.9	1.9
28	3.9	2.0
29	3.4	2.0
30	3.5	2.1
31	3.1	1.9
32	3.1	1.9
33	3.2	1.8
34	4.0	1.8
35	4.2	1.8
36	3.5	1.8
37	3.2	1.8
38	2.8	1.7
39	3.6	1.9
40	3.9	2.1
41	4.3	2.0
42	4.3	1.9
43	3.8	2.1
44	3.3	2.2
45	3.4	1.9
46	3.4	1.9
47	3.5	1.9

TABLE 11. (Continued)

Location (see Figure 13)	Exposure (R/hr)	
	Cold Leg	Hot Leg
48	4.0	2.0
49	3.8	1.7
50	3.4	1.9
51	3.3	2.0
52	2.6	2.0
53	4.2	2.0
54	3.9	2.0
55	3.9	2.2
56	3.8	2.1
57	3.4	2.1
58	3.7	2.1
59	3.2	1.9
60	3.1	2.1
61	3.2	2.1
62	3.3	1.8
63	7.1	2.0
64	3.7	1.9
65	3.4	2.0
66	3.2	2.0
67	2.7	1.9
68	4.0	2.0
69	4.2	2.2
70	4.1	2.2
71	3.5	2.2
72	3.7	2.3
73	3.7	2.0
74	3.6	2.1
75	3.1	2.0
76	2.8	2.1
77	3.2	2.1
78	4.4	2.2
79	7.9	2.1
80	4.2	2.0
81	3.3	2.0
82	3.3	2.0
83	2.8	2.1
84	4.0	2.3
85	4.2	2.1
86	4.4	2.3
87	3.7	2.5
88	3.9	2.2
89	3.9	2.3
90	3.4	2.0
91	3.3	2.2
92	3.1	2.0
93	3.6	2.2
94	5.0	2.3

TABLE 11. (Continued)

Location (see Figure 13)	Exposure (R/hr)	
	Cold Leg	Hot Leg
95	5.0	2.1
96	3.6	1.9
97	3.2	2.1
98	3.7	1.8
99	2.7	1.9
100	3.8	2.1
101	4.0	2.3
102	4.4	2.4
103	4.0	2.6
104	4.0	2.5
105	3.9	2.3
106	3.9	2.2
107	3.3	2.0
108	3.0	2.2
109	3.2	2.1
110	3.8	2.4
111	4.1	2.0
112	3.8	2.0
113	3.4	2.0
114	3.7	1.9
115	2.9	2.1
116	4.2	2.0
117	4.1	2.4
118	3.9	2.3
119	4.1	2.2
120	4.0	2.3
121	3.4	2.2
122	4.0	2.0
123	3.4	2.2
124	2.9	2.1
125	3.5	2.3
126	3.6	2.3
127	3.4	1.9
128	3.4	2.0
129	3.3	2.0
130	3.4	1.9
131	2.9	1.8
132	3.8	2.0
133	3.8	2.2
134	3.9	2.2
135	4.0	2.0
136	3.7	2.1
137	3.5	2.0
138	3.4	2.1
139	3.8	2.0
140	3.2	1.9
141	3.2	1.9

TABLE 11. (Continued)

Location (see Figure 13)	Exposure (R/hr)	
	Cold Leg	Hot Leg
142	3.7	2.1
143	3.3	1.9
144	3.6	2.0
145	3.3	1.9
146	2.6	2.0
147	3.5	2.0
148	3.7	2.1
149	3.9	2.0
150	3.8	1.9
151	3.7	2.1
152	3.6	1.9
153	3.3	2.0
154	2.9	1.9
155	3.2	1.9
156	3.1	1.9
157	3.6	2.4
158	2.7	2.0
159	2.9	1.9
160	2.5	1.9
161	3.5	2.0
162	3.6	2.0
163	3.8	1.9
164	3.7	1.8
165	3.4	1.9
166	3.6	1.9
167	3.2	1.8
168	3.0	1.8
169	2.3	1.9
170	3.0	1.9
171	3.6	2.3
172	3.3	1.9
173	2.8	2.0
174	3.4	1.8
175	3.6	1.9
176	3.8	1.9
177	3.8	1.8
178	3.4	1.7
179	3.2	1.9
180	3.1	1.8
181	2.7	1.7
182	3.0	1.9
183	3.8	2.3
184	3.6	2.0
185	3.6	1.8
186	3.6	1.9
187	3.7	1.9
188	3.7	1.8

TABLE 11. (Continued)

Location (see Figure 13)	Exposure (R/hr)	
	Cold Leg	Hot Leg
189	3.4	1.8
190	3.5	1.6
191	2.9	1.7
192	3.1	1.8
193	3.3	2.2
194	3.7	2.1
195	3.7	2.2
196	3.9	1.8
197	3.9	1.9
198	4.1	1.7
199	3.9	1.7
200	3.0	1.8
201	4.4	2.0
202	5.4	1.7

SUMMARY AND CONCLUSIONS

The inventory of Co-60 deposited on the inside of the tubes at and above the tube sheet was estimated by calculations done by a computer code to be between 69 and 85 curies as of March 1, 1982. The curie content of the channel head was estimated by hand calculations to be between 1.1 and 1.8 curies, assuming uniform distribution throughout the channel head.

These inventory estimates and the measurements provided the baseline to determine the effectiveness and completeness of subsequent decontamination efforts.

TABLE 11 (Continued)

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The assistance of the Virginia Electric and Power Company (VEPCO) in obtaining the use of the research generator removed from service at their Surry Nuclear Station Unit 2 is hereby acknowledged. VEPCO has also provided valuable assistance with historical information on the generator's operation inspection and maintenance.

SUMMARY AND CONCLUSIONS

The inventory of Co-60 deposited on the inside of the tubes at and above the tube sheet was estimated by calculations done by a computer code to be between 62 and 65 curies as of March 1, 1982. The curie content of the channel head was estimated by hand calculations to be between 1.1 and 1.8 curies, assuming uniform distribution throughout the channel head.

These inventory estimates and the measurements provided the basis to determine the effectiveness and completeness of subsequent decontamination efforts.

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