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SUBJECT: ESTIMATED GAMMA RADIATION LEVELS AT ACCESS HOLES IN THE HRT SHIELDING

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2.

ESTIMATED GAMMA RADIATION LEVELS AT ACCESS HOLES IN THE HRT SHIELDING

SUMMARY:

An estimate has been made of the gamma radiation levels at access holes in the HRT Shielding when the plugs have been removed to service or maintain the reactor. In every case the radiation level at the holes was greater than the maximum permissible exposure rate of 0.3 roentgens per week. The radiation through the holes can be attenuated to some extent by flooding the reactor cell up to the flange to be disconnected. However, shielding would still be required and it is more practical to provide a small additional shield thickness to compensate for the moderate attenuation that could be gained from flooding.

Where it is necessary to remove the roof shielding to service or maintain equipment after the reactor has been shut down, the top layer of shielding can be removed and the radiation dose rate through the bottom layer of shielding will be in the order of 0.4 milliroentgens per hour⁻¹. Before the bottom layer of roof shielding is removed the cell should be flooded to the 830 foot elevation or other means taken to reduce the radiation.

Radiation can be reduced to the permissible level by developing special procedures and designing shielding and handling equipment to be used when the plugs have been removed from the access holes.

Shielding should be designed so that it can be set in place over the access hole by remote handling immediately following removal of the plug. The tooling should be designed to work through the shielding and must be operated remotely so that the operator is never in a direct line with any opening in the shielding.

Shielded carrier designs should be based on the physical limitations of available handling equipment (crane capacity, etc.), and should provide for the addition of additional shielding to compensate for contingencies.

Shielding thickness should be based on attenuating the radiation to the maximum permissible exposure rate of 0.3 roentgen per 40-hour week. The handling procedures require limiting the exposure to direct radiation from holes in shielding, etc., to the above limit or some slightly larger limit consistent with economic, design, and safety limitations.

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INTRODUCTION:

Curves have been prepared by the Reactor Analysis Section for use in determining the radiation contribution of reactor cell piping and equipment relative to particular access holes². The radiation at the outside of an access hole is given as a function of the hole size, the perpendicular distance from the bottom of the hole to the equipment, the perpendicular distance from the hole axis to the equipment, and the equipment surface area wetted by fuel solution.

A curve has been prepared for each size access hole. In using the curves the two perpendicular distances for each item of equipment are determined and the radiation dose read from the curve in roentgens per hour per square foot of wetted surface area. This figure is multiplied by the wetted surface area of the equipment to give the total radiation from that item. The total radiation at an access hole is then the sum of the contributions from each item considered as a point source.

The curves were based on the assumptions that the holes are opened four hours after shutdown following five megawatt operation, and that 50% of the fission products were deposited on wetted surfaces of fuel equipment.

Access holes considered are those for the fuel sample holder, the blanket sample holder, and the rupture disc assembly; and the six inspection holes in the north wall of the cell. The holes in the north wall are designated as being in the east or west row and first, second or third level from the top.

Equipment and reactor cell piping which contribute the greater part of the radiation and are included in the calculations are shown in Table 1.

Since it is possible to attenuate the radiation by flooding the cell with water, the equipment is considered first with no flooding and then with flooding at various levels.

This analysis deals only with the fuel system, since D_2O is to be used as the initial blanket fluid.

The fuel sample holder is connected to the core by a flange which serves as a shadow shield in attenuating the radiation from the core neck. When the sample holder is actually being taken out, the flange is removed making it necessary to consider the radiation level with and without this flange. The rupture disc assembly is also flanged, and its access hole radiation level is also considered with and without the flange.

TABLE 1

ITEMS CONTRIBUTING MAJORITY OF RADIATION
THROUGH CELL ACCESS OPENINGS

ITEM NO.	DESCRIPTION	ITEM NO.	DESCRIPTION
2	Fuel Pressurizer	50	Storage Cold Trap
3	Fuel Gas Separator	117	Recombiner
4	Fuel Heat Exchanger		Core Neck
5	Fuel Circulating Pump		Line 101
7A & B	Fuel Dump Tank & Evaporator		Line 102
7C	Entrainment Separator		Line 103
9A & B	Fuel Cold Trap		Line 105 & 106
15	Reflux Condenser		Line 107 A, B
16A & B	Fuel Storage Tank & Evaporator		Line 109
19	Fuel Transfer Tank		Line 110
20	Fuel Letdown Heat Exchanger		Line 128 & 129
21A & B	Fuel Feed Pump		Line 166
22	Hold Up Tank		Line 167

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5.

No direct radiation is considered from the core through the blanket sample hole because of the relatively small size of the hole and the attenuation by the D₂O blanket.

The calculations for the rupture disc access hole assume that this hole will only be opened after a disc has ruptured and that the rupture has allowed fuel solution into the top fuel pressurizer header and into the rupture disc assembly with 25% of the fission products being deposited on the walls of the equipment.

The induced activity within the biological shielding at the access hole is ignored since its contribution to the radiation level at the hole is less than 0.2 roentgens per hour³.

RADIATION LEVELS:

The estimated total radiation levels at each access hole for various conditions are tabulated in Table 2.

TABLE 2
RADIATION LEVELS AT CELL ACCESS HOLES

<u>ACCESS HOLE</u>	<u>No Flooding of Cell</u>	<u>Radiation Levels (R/Hr)</u>	
		<u>Cell Flooded to 13'-0" depth</u>	<u>Cell Flooded to 19'-3" depth</u>
1. A. Fuel Sample Hole with Flange on.	1300	750	---
B. Fuel Sample Hole with Flange off.	2900	2400	---
2. Blanket Sample Hole	2300	1700	---
3. A. Rupture Disc hole with Flange on.	3000	2600	560
B. Rupture Disc Hole with Flange off.	4000	3600	1600
4. Inspection Holes in North Wall			
W-1	870	---	---
W-2	230	---	---
W-3	190	---	---
E-1	19	---	---
E-2	24	---	---
E-3	6		

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6.

Radiation through the inspection holes in the north wall would not be attenuated appreciably by flooding the cell since most of the equipment contributing the radiation is located near the top of the cell and the hole itself would be flooded before any appreciable decrease in radiation level would be affected. For this reason the holes in the north wall are considered only for the case where there is no flooding.

The cell can be flooded to a depth of 13'-0" for access to the blanket sample holder. The radiation attenuation from this depth of water is shown in the second column of Table 2.

Access to the fuel sample holder can be made with flooding the cell to a depth of 15'-6". There is no appreciable difference in attenuation of radiation between this depth and the 13'-0" depth of water since no major equipment is located at this elevation.

The rupture discs can be removed with the water at a depth of 19'-3". This depth of water submerges all equipment so that the only significant radiation involved would be that from the rupture disc assembly itself. The attenuation from this depth of water is shown in the third column of Table 2.

To determine the attenuation of the radiation at various distances from the access holes it is assumed that at the hole the radiation is evenly distributed over the surface area of a hemisphere of diameter equal to the hole diameter. The radiation at distance "R" is then calculated using the inverse square law for attenuation with distance.

Table 4 tabulates the radiation at distance "R" from each access hole for the same conditions considered in Table 2.

The radiation present with the cell flooded and the roof shielding removed was investigated using the following formula:

$$\text{Source Term (S)} = 1.76 \times 10^{14} \times A \text{ (area wetted by fuel)}^{(4)}$$

$$\begin{aligned} \text{Where: } S &= \text{gamma photons/sec} \\ A &= \text{ft}^2 \end{aligned}$$

Using units of roentgens per hour this is:

$$\begin{aligned} S &= 1.76 \times 10^{14} A \times 1.4 \times 10^{-6} \\ &= 2.46 \times 10^8 \times A \end{aligned}$$

This source radiation is attenuated by water to the amount given by the formula:

$$R = \left(\frac{S}{4\pi r^2} \right) B e^{-\mu r} \quad (5)$$

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7.

The radiation level was calculated for the point at the water level directly above the piece of equipment. Since there is some distance between pieces of equipment and the radiation must pass through this additional amount of water to the point under consideration, the radiation contribution from adjacent equipment can be ignored. In the case of the fuel cold traps, both are considered at the point midway between them.

Table 3 tabulates the estimated radiation levels from the major items of equipment under less than six feet of water when the cell is flooded to 825' elevation. This is the elevation to the bottom of the roof shielding.

TABLE 3

ITEM NO.	DESCRIPTION	RADIATION LEVEL (ROENTGEN/HR)
2	Fuel Pressurizer	1.1
3	Fuel Gas Separator	1.1
9A & B	Fuel Cold Traps	310
50	Storage Cold Trap	1.60
101	Line	3.4
	Core Neck	.04

It is apparent from Table 3 that the radiation is not attenuated sufficiently by flooding to the 825 ft. elevation to permit access to the equipment. The cell can be flooded to the 830 ft. elevation. To keep the level of water below the floor, the cell could be flooded to 829'-6" with 7 ft. of water above the cold traps which were the most critical items.

Flooding to this elevation attenuates the radiation above the cold traps to 0.3 roentgens/40 hr week which is the allowable exposure rate.

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TABLE 4

RADIATION LEVEL AT DISTANCE "R" FROM ACCESS HOLE (R/HR)

"R" (ft)	NO FLOODING OF CELL										
	Fuel	Fuel	Blanket	Rupture	Rupture	W-1	W-2	W-3	E-1	E-2	E-3
	Sample	Sample	Sample	Disc	Disc						
	Hole- Flange On	Hole- Flange Off	Hole	Hole- Flange On	Hole- Flange Off						
Radiation at hole (Roent/hr)	1300	2900	2300	3000	4000	870	230	190	19	24	6
1	442	984	1030	1320	1800	97.0	25.7	21.4	2.11	2.66	.666
2	110	243	257	330	448	24.3	6.43	5.36	.528	.668	.167
3	49.0	108	117	146	198	10.7	2.85	2.37	.234	.295	.0738
4	27.8	61.2	64.4	82.5	113	6.07	1.61	1.34	.132	.167	.0417
5	17.8	39.3	41.0	52.5	71.7	3.88	1.03	.858	.0846	.107	.0267
6	12.3	27.0	28.5	36.5	49.8	2.70	.717	.596	.0587	.0742	.0185
8	5.78	12.7	16.1	20.6	28.1	1.52	.404	.336	.0330	.0418	.0104
10	4.43	9.75	10.6	13.2	18.0	.970	.257	.214	.0211	.0266	.0066
12	3.07	6.77	7.15	9.17	12.5	.675	.179	.149	.0147	.0185	.0046
14	2.26	5.00	5.23	6.71	9.14	.496	.132	.110	.0108	.0136	.0034
16	1.73	3.82	4.00	5.04	7.00	.378	.100	.0835	.0082	.0104	.0026
18	1.37	3.01	3.09	4.10	5.58	.298	.0791	.0660	.0065	.0082	.0021
20	1.10	2.43	2.57	3.30	4.28	.243	.0648	.0538	.0053	.0067	.0017

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TABLE 4 (Cont'd.)

9.

"R" (ft)	Cell Flooded to 13'-0" Depth					Cell Flooded to 19'-3" Depth	
	Fuel Sample Hole Flange On	Fuel Sample Hole Flange Off	Blanket Sample Hole	Rupture Disc Hole Flange On	Rupture Disc Hole Flange Off	Rupture Disc Hole Flange On	Rupture Disc Hole Flange Off
Radiation at hole	750	2400	1700	2600	3600	560	1600
1	256	807	766	1140	1616	251	728
2	63.7	201	191	285	404	62.7	182
3	28.3	89.3	84.7	126	179	27.7	80.5
4	16.0	50.6	48.0	71.3	101	15.7	45.6
5	10.3	32.5	30.5	45.4	64.4	10.0	29.0
6	7.09	22.3	21.2	31.6	44.8	6.95	20.2
8	3.34	10.5	12.0	17.8	25.3	3.92	11.4
10	2.56	8.07	7.66	11.4	16.2	2.51	7.28
12	1.78	5.60	5.33	7.93	11.2	1.74	5.05
14	1.31	4.13	3.90	5.80	8.23	1.28	3.71
16	1.00	3.16	2.98	4.44	6.30	.977	2.84
18	.791	2.49	2.36	3.54	5.02	.780	2.26
20	.637	2.01	1.91	2.85	4.04	.627	1.82

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DISCUSSION:

Since it is impossible to calculate exactly the amount of radiation from the HRT, the values given in this report are to be regarded only as establishing the order of magnitude of radiation present at various access holes in the reactor shielding. As such the values are useful in establishing the design requirements for shielding and special handling equipment for servicing and maintaining the reactor through the access holes and in developing the necessary procedures.

It is seen that flooding the cell to the depth of the equipment flanges to be opened only attenuates the radiation by a small factor; therefore it is doubtful if it is worth the time and effort involved in flooding the cell when working through the access holes. Shielding must be employed in any case and a small increase in shielding thickness will compensate for the small attenuation contributed by flooding.

Considering the radiation from a hole as a point isotropic source and using lead for shielding, Table 5 indicates the attenuation of gamma radiation for various thicknesses of lead.

TABLE 5
ATTENUATION FACTORS FOR LEAD SHIELDING

<u>THICKNESS OF LEAD</u> <u>(INCHES)</u>	<u>ATTENUATION</u> <u>FACTOR</u>
1	11.6
2	170
3	2.7×10^3
4	4.46×10^4
5	7.69×10^5
6	1.37×10^7

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11.

The highest radiation level is present at the rupture disc access hole when the top flange on the rupture disc assembly has been removed with no flooding of the cell. At this condition the radiation was estimated to be 4000 roentgens per hour. For a person to work directly over the hole and not receive more than 0.3 roentgens per 40 hour week the radiation would be attenuated by a factor of

$$\frac{4000 \times 40}{0.3} = 5.3 \times 10^5$$

It is seen from Table 5 that approximately 5 inches of lead shielding would be required.

Since the attenuation factor for shielding varies exponentially with the thickness of shielding, any error in the estimated radiation level is minimized. It can be seen from the attenuation factors in Table 5 that if the estimated radiation level were as much as 10 times greater than the radiation level under actual operating conditions the excess shielding thickness would only amount to approximately 1/2 inch.

The most practical method for working on equipment requiring removal of the roof shielding seems to be to remove the top layer of shielding and the metal membrane. The cell would then be flooded to the 829'-6" elevation making approximately 15" of water above the bottom layer of shielding. The bottom layer of shielding would then be removed through the water and no personnel would be exposed to more than .08 roentgens/40 hr week.

Although the estimated radiation levels presented here do not represent exactly the amount of radiation likely to be present at the access holes, it is felt that they are conservative figures that can be used for design and planning purposes.

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2. H. C. Claiborne, Memo to W. R. Gall, "Radiation Escaping From Openings in HRT Shield", December 18, 1956.
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5. Rockwell, T., "Reactor Shielding Design Manual".

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