UNITED STATES
NUCLEAR REGULATORY COMMISSION
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November 2, 1993

Docket Nos. 50-390
and 50-391

MEMORANDUM FOR: Docket Files

FROM: Peter S. Tam, Senior Project Manager
Project Directorate II-4
Division of Reactor Projects - I/II
Office of Nuclear Reactor Regulation

SUBJECT: WATTS BAR NUCLEAR PLANT - PROVIDING MISSING PAGES OF DOCUMENT IDENTIFIED AS ACCESSION NUMBER 9209020332 (TAC M77553, M84410)

The Watts Bar Offsite Dose Calculation Manual (ODCM) transmitted by letter dated August 27, 1992 to the NRC, and assigned Accession Number 9209020332, is missing a number of pages. TVA (Becky Mays) telecopied those pages to me. By this memorandum, I am docketing those missing pages (86, 101, 103, 118, 123, 125, 128, 137, 139, and 141), and making them publicly available.

Peter S. Tam, Senior Project Manager
Project Directorate II-4
Division of Reactor Projects - I/II
Office of Nuclear Reactor Regulation

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OFFSITE DOSE CALCULATION/ENVIRONMENTAL MONITORING METHODOLOGIES

6.7 LIQUID DOSE FACTOR EQUATIONS

6.7.1 Water Ingestion Dose Factors
(mrem/hr per μCi/ml)

$$A_{Wit} = \frac{DF_{Liat}\ U_{wa}\ 10^6\ 10^3}{8760}$$

where:

DF_{Liat} = ingestion dose conversion factor for nuclide i, age group a, organ t, mrem/pCi, (Table 6.4).
U_{wa} = water consumption rate for age group a, l/year, (Table 6.3).
10^6 = conversion factor, pCi/μCi.
10^3 = conversion factor, ml/l.
8760 = conversion factor, hours per year.

6.7.2 Fish Ingestion Dose Factors
(mrem/hr per μCi/ml)

$$A_{Fit} = \frac{DF_{Liat}\ U_{fa}\ B_i\ 10^6\ 10^3}{8760}$$

where:

DF_{Liat} = ingestion dose conversion factor for nuclide i, age group a, organ t, mrem/pCi, (Table 6.4).
U_{fa} = fish consumption rate for age group a, kg/year, (Table 6.3).
B_i = bioaccumulation factor for nuclide i, pCi/kg per pCi/l, (Table 6.5).
10^6 = conversion factor, pCi/μCi.
10^3 = conversion factor, ml/l.
8760 = conversion factor, hours per year.

OFFSITE DOSE CALCULATION/ENVIRONMENTAL MONITORING METHODOLOGIES

Table 6.4 (8 of 8)
INGESTION DOSE FACTORS
(mrem/pCi ingested)

	INFANT						
	bone	liver	t body	thyroid	kidney	lung	gi-lli
Sb-125	1.23E-05	1.19E-07	2.53E-06	1.54E-08	0.00E+00	7.72E-06	1.64E-05
Te-125m	2.33E-05	7.79E-06	3.15E-06	7.84E-06	0.00E+00	0.00E+00	1.11E-05
Te-127m	5.85E-05	1.94E-05	7.08E-06	1.69E-05	1.44E-04	0.00E+00	2.36E-05
Te-127	1.00E-06	3.35E-07	2.15E-07	8.14E-07	2.44E-06	0.00E+00	2.10E-05
Te-129m	1.00E-04	3.43E-05	1.54E-05	3.84E-05	2.50E-04	0.00E+00	5.97E-05
Te-129	2.84E-07	9.79E-08	6.63E-08	2.38E-07	7.07E-07	0.00E+00	2.27E-05
Te-131m	1.52E-05	6.12E-06	5.05E-06	1.24E-05	4.21E-05	0.00E+00	1.03E-04
Te-131	1.76E-07	6.50E-08	4.94E-08	1.57E-07	4.50E-07	0.00E+00	7.11E-06
Te-132	2.08E-05	1.03E-05	9.61E-06	1.52E-05	6.44E-05	0.00E+00	3.81E-05
I-130	6.00E-06	1.32E-05	5.30E-06	1.48E-03	1.45E-05	0.00E+00	2.83E-06
I-131	3.59E-05	4.23E-05	1.86E-05	1.39E-02	4.94E-05	0.00E+00	1.51E-06
I-132	1.66E-06	3.37E-06	1.20E-06	1.58E-04	3.76E-06	0.00E+00	2.73E-06
I-133	1.25E-05	1.82E-05	5.33E-06	3.31E-03	2.14E-05	0.00E+00	3.08E-06
I-134	8.69E-07	1.78E-06	6.33E-07	4.15E-05	1.99E-06	0.00E+00	1.84E-06
I-135	3.64E-06	7.24E-06	2.64E-06	6.49E-04	8.07E-06	0.00E+00	2.62E-06
Cs-134	3.77E-04	7.03E-04	7.10E-05	0.00E+00	1.81E-04	7.42E-05	1.91E-06
Cs-136	4.59E-05	1.35E-04	5.04E-05	0.00E+00	5.38E-05	1.10E-05	2.05E-06
Cs-137	5.22E-04	6.11E-04	4.33E-05	0.00E+00	1.64E-04	6.64E-05	1.91E-06
Cs-138	4.81E-07	7.82E-07	3.79E-07	0.00E+00	3.90E-07	6.09E-08	1.25E-06
Ba-139	8.81E-07	5.84E-10	2.55E-08	0.00E+00	3.51E-10	3.54E-10	5.58E-05
Ba-140	1.71E-04	1.71E-07	8.81E-06	0.00E+00	4.06E-08	1.05E-07	4.20E-05
Ba-141	4.25E-07	2.91E-10	1.34E-08	0.00E+00	1.75E-10	1.77E-10	5.19E-06
Ba-142	1.84E-07	1.53E-10	9.06E-09	0.00E+00	8.81E-11	9.26E-11	7.59E-07
La-140	2.11E-08	8.32E-09	2.14E-09	0.00E+00	0.00E+00	0.00E+00	9.77E-05
La-142	1.10E-09	4.04E-10	9.67E-11	0.00E+00	0.00E+00	0.00E+00	6.86E-05
Ce-141	7.87E-08	4.80E-08	5.65E-09	0.00E+00	1.48E-08	0.00E+00	2.48E-05
Ce-143	1.48E-08	9.82E-06	1.12E-09	0.00E+00	2.86E-09	0.00E+00	5.73E-05
Ce-144	2.98E-06	1.22E-06	1.67E-07	0.00E+00	4.93E-07	0.00E+00	1.71E-04
Pr-143	8.13E-08	3.04E-08	4.03E-09	0.00E+00	1.13E-08	0.00E+00	4.29E-05
Pr-144	2.74E-10	1.06E-10	1.38E-11	0.00E+00	3.84E-11	0.00E+00	4.93E-06
Nd-147	5.53E-08	5.68E-08	3.48E-09	0.00E+00	2.19E-08	0.00E+00	3.60E-05
W-187	9.03E-07	6.28E-07	2.17E-07	0.00E+00	0.00E+00	0.00E+00	3.69E-05
Np-239	1.11E-08	9.93E-10	5.61E-10	0.00E+00	1.98E-09	0.00E+00	2.87E-05

References:

Regulatory Guide 1.109, Table E-14.

Dose Factors for Co-57, Zn-69m, Br-82, Nb-97, Sb-124 and Sb-125 are from NUREG-0172 Age Specific Radiation Dose Commitment Factors for a One Year Chronic Intake., November, 1977, Table 4.

NOTE: The tritium dose factor for bone is assumed to be equal to the total body dose factor.

OFFSITE DOSE CALCULATION/ENVIRONMENTAL MONITORING METHODOLOGIES

Table 6.6 (1 of 2)
EXTERNAL DOSE FACTORS FOR STANDING ON CONTAMINATED GROUND
(mrem/h per pCi/m^2)

Nuclide	Total Body	Skin
H-3	0.0	0.0
C-14	0.0	0.0
Na-24	2.50E-08	2.90E-08
P-32	0.0	0.0
Cr-51	2.20E-10	2.60E-10
Mn-54	5.80E-09	6.80E-09
Mn-56	1.10E-08	1.30E-08
Fe-55	0.0	0.0
Fe-59	8.00E-09	9.40E-09
Co-57	1.77E-09	2.21E-09
Co-58	7.00E-09	8.20E-09
Co-60	1.70E-08	2.00E-08
Ni-63	0.0	0.0
Ni-65	3.70E-09	4.30E-09
Cu-64	1.50E-09	1.70E-09
Zn-65	4.00E-09	4.60E-09
Zn-69	0.0	0.0
Zn-69m	5.50E-09	6.59E-09
Br-82	3.18E-08	3.90E-08
Br-83	6.40E-11	9.30E-11
Br-84	1.20E-08	1.40E-08
Br-85	0.0	0.0
Rb-86	6.30E-10	7.20E-10
Rb-88	3.50E-09	4.00E-09
Rb-89	1.50E-08	1.80E-08
Sr-89	5.60E-13	6.50E-13
Sr-91	7.10E-09	8.30E-09
Sr-92	9.00E-09	1.00E-08
Y-90	2.20E-12	2.60E-12
Y-91m	3.80E-09	4.40E-09
Y-91	2.40E-11	2.70E-11
Y-92	1.60E-09	1.90E-09
Y-93	5.70E-10	7.80E-10
Zr-95	5.00E-09	5.80E-09
Zr-97	5.50E-09	6.40E-09
Nb-95	5.10E-09	6.00E-09
Nb-97	8.11E-09	1.00E-08
Mo-99	1.90E-09	2.20E-09
Tc-99m	9.60E-10	1.10E-09
Tc-101	2.70E-09	3.00E-09
Ru-103	3.60E-09	4.20E-09
Ru-105	4.50E-09	5.10E-09
Ru-106	1.50E-09	1.80E-09
Ag-110m	1.80E-08	2.10E-08
Sb-124	2.17E-08	2.57E-08

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OFFSITE DOSE CALCULATION/ENVIRONMENTAL MONITORING METHODOLOGIES

7.3 DOSE - NOBLE GASES

Doses to be calculated are gamma and beta air doses due to exposure to a semi-infinite cloud of noble gases. These doses will be calculated at the SITE BOUNDARY location with the highest dispersion factor based on 1974-1988 meteorological data (Table 7.2). This location is chosen from the SITE BOUNDARY locations listed in Table 7.1. Dispersion factors are calculated using the methodology described in Section 7.8.2.

No credit is taken for radioactive decay.

7.3.1 Gamma dose to air

The gamma air dose, D_γ in mrad, is calculated for each release using the following equation:

$$D_\gamma = 1.9E\text{-}06\ W_A \sum_i Q_i\ DF_{\gamma i}\ T \qquad (7.9)$$

where:

1.9E-06	= conversion factor, years per minute.
W_A	= dispersion factor, s/m^3. For dose rate calculations, the highest value from the sixteen SITE BOUNDARY locations is used.
	= (X/Q) TAF.
	= 1.03E-05 s/m^3.
X/Q	= relative concentration, s/m^3 (from Table 7.1). Relative air concentrations are calculated for the SITE BOUNDARY in each of the sixteen sectors as described in Section 7.8.2 using the historical meteorological data for the period 1974-1988 given in Table 7.2.
TAF	= site specific terrain adjustment factor (from Table 7.3). Calculated as described in Section 7.8.4.
Q_i	= release rate for nuclide i, µCi/s.
$DF_{\gamma i}$	= dose conversion factor for external gamma for nuclide i (Table 7.4), mrad/year per $\mu Ci/m^3$.
T	= duration of release, minutes.

The gamma-air dose calculated by this method will be used in the cumulative dose calculations discussed in Section 7.3.3.

OFFSITE DOSE CALCULATION/ENVIRONMENTAL MONITORING METHODOLOGIES

7.5 DOSE PROJECTIONS

In accordance with ODCM Surveillance Requirement 2.2.2.4.1, dose projections will be performed. This will be done for the gamma dose, the beta dose and the maximum organ dose.

$$d = \frac{(a + b)}{d_t} * 31 + c$$

where

d = the 31-day dose projection, mrem.
a = the cumulative dose for the quarter, mrem
b = the projected dose for this release (as calculated in Sections 7.4.1, 7.4.2 and 7.4.3), mrem
c = any anticipated additional dose in the next month from other sources, mrem
d_t = current number of days into the quarter up to the time of the release under consideration.

Once per 31 days, these 31-day running totals will be compared to the limits given in ODCM Control 2.2.2.4.1 to determine compliance.

7.5.1 Gaseous Radwaste Treatment System Description

The GASEOUS RADWASTE TREATMENT SYSTEM (GRTS) described in the WBN FSAR shall be maintained and operated to keep releases ALARA. A flow diagram for the GRTS is given in Figure 7.2.

OFFSITE DOSE CALCULATION/ENVIRONMENTAL MONITORING METHODOLOGIES

7.6.2 Noble Gas - Beta Air Dose

Beta air doses due to exposure to noble gases, D_β in mrem, are calculated using the following equation:

$$D_\beta = \sum_i X_{im} \, TAF_m \, DF_{\beta i} \qquad (7.13)$$

where:

X_{im} = annual average concentration of nuclide i at location m, μCi-year/m^3. Calculated as described by Equation 7.16.

TAF_m = site specific terrain adjustment factor for location m. Calculated as described in Section 7.8.4.

$DF_{\beta i}$ = dose conversion factor for external beta for nuclide i, mrad/year per μCi/m^3 (Table 7.4).

7.6.3 Radioiodine, Particulate, and Tritium - Maximum Organ Dose

Organ doses due to radioiodine, particulate and tritium releases, D_{org} ~~in~~ mrem~~/yr~~ are calculated using the following equation:

$$D_{org} = 3.17E\text{-}08\left((W_p)\sum_P R_{PT}Q_T + \sum_i \left[(W_p)\, Q_i \sum_P R_{Pi} + (W_p)R_{Gi} + (W_p)R_{Ii}\right]\right) \qquad (7.14)$$

where:

3.17E-08 = conversion factor, year/second.

W_p = dispersion factor for the location and pathway,
= $(X/Q)_m \, TAF_m$ for the inhalation and tritium ingestion pathways,
= $(D/Q)_m \, TAF_m$ for the food and ground plane pathways,

X/Q_m = relative concentration for location m, s/m^3. Relative air concentrations are calculated for the SITE BOUNDARY in each of the sixteen sectors, and the nearest resident, garden and milk animal locations identified in the most recent land use census. Meteorological data for the calendar quarter in question is used to calculate these dispersion factors using Equation 7.17.

TAF_m = site specific terrain adjustment factor for location m. Calculated as described in Section 7.8.4.

OFFSITE DOSE CALCULATION/ENVIRONMENTAL MONITORING METHODOLOGIES

7.6.4 Population Doses

For determining population doses to the 50-mile population around the plant, each compass sector is broken down into elements. These elements are defined in Table 7.5. For each of these sector elements, an average dose is calculated, and then multiplied by the population in that sector element. Dispersion factors are calculated for the midpoint of each sector element (see Table 7.5).

For population doses resulting from ingestion, it is conservatively assumed that all food eaten by the average individual is grown locally.

The general equation used for calculating the population dose in a given sector element is:

$$Dose_{pop} = \sum_{p} RATIO_p * POPN * AGE * 0.001 * DOSE_p \qquad (7.15)$$

where

$RATIO_p$ = ratio of average to maximum dose for pathway P. (Average ingestion rates are obtained from Regulatory Guide 1.109, Table E-4.)
- = 0.5 for submersion and ground exposure pathways, a shielding/occupancy factor.
- = 1.0 for the inhalation pathway.
- = 0.515, 0.515, 0.5, and 0.355 for milk, for infant, child, teen and adult, respectively. (It is assumed that the ratio of average to maximum infant milk ingestion rates is the same as that for child.)
- = 1.0, 0.90, 0.91, 0.86 for beef ingestion, for infant, child, teen and adult, respectively.
- = 1.0, 0.38, 0.38, 0.37 for vegetable ingestion, for infant, child, teen and adult, respectively. (It is assumed that the average individual eats no fresh leafy vegetables, only stored vegetables.)

POPN = the population of the sector element, persons (Table 7.6).

AGE = fraction of the population belonging to each age group.
- = 0.015, 0.168, 0.153, 0.665 for infant, child, teen and adult, respectively (fractions taken from NUREG/CR-1004, Table 3.39).

0.001 = conversion from mrem to rem.

OFFSITE DOSE CALCULATION/ENVIRONMENTAL MONITORING METHODOLOGIES

7.7.8 Tritium - Stored Feed-cow/goat-milk Dose Factor - R_{CTS} (mrem/year per $\mu Ci/m^3$)

$$R_{CTS} = 10^3\ 10^6\ DFL_{Tao}\ F_{mT}\ Q_f\ U_{ap}\ [0.75(0.5/H)]\ f_s\ \frac{(1-\exp(-\lambda_T t_{csf}))}{\lambda_T\ t_{csf}}\ \exp(-\lambda_T t_{fm})$$

where:

10^3	= conversion factor, grams/kg.
10^6	= conversion factor, pCi/μCi.
DFL_{Tao}	= ingestion dose conversion factor for tritium for age group a, organ o, mrem/pCi (Table 6.4).
F_{mT}	= transfer factor for tritium from animal's feed to milk, days/liter (Table 6.2).
Q_f	= animal's consumption rate, kg/day.
U_{ap}	= milk ingestion rate for age group a, l/year.
0.75	= the fraction of total feed that is water.
0.5	= the ratio of the specific activity of the feed grass water to the atmospheric water.
H	= absolute humidity of the atmosphere, g/m^3.
f_s	= fraction of time animal spends on stored feed, dimensionless.
λ_T	= decay constant for tritium, $seconds^{-1}$ (Table 6.2).
t_{csf}	= time between harvest of stored feed and consumption by animal, seconds.
t_{fm}	= transport time from milking to receptor, seconds.

NOTE: Factors defined above which do not reference a table for their numerical values are listed in Table 6.3.

OFFSITE DOSE CALCULATION/ENVIRONMENTAL MONITORING METHODOLOGIES

7.7.10 Tritium - Stored feed-beef Dose Factor - R_{MTS}
(mrem/year per $\mu Ci/m^3$)

$$R_{MTS} = 10^3\ 10^6\ DFL_{Tao}\ F_{fT}\ Q_f\ U_{am}\ [0.75(0.5/H)]\ f_s\ \exp(-\lambda_T t_s)\ \frac{(1-\exp(-\lambda_T t_{csf}))}{\lambda_T\ t_{csf}}\ \frac{(1-\exp(-\lambda_T t_{cb}))}{\lambda_T\ t_{cb}}$$

where:

10^3 = conversion factor, grams/kg.
10^6 = conversion factor, pCi/μCi.
DFL_{Tao} = ingestion dose conversion factor for H-3 for age group a, organ o, mrem/pCi (Table 6.4).
F_{fT} = transfer factor for H-3 from cow's feed to meat, days/kg (Table 6.2).
Q_f = cow's consumption rate, kg/day.
U_{am} = meat ingestion rate for age group a, kg/year.
0.75 = the fraction of total feed that is water.
0.5 = the ratio of the specific activity of the feed grass water to the atmospheric water.
H = absolute humidity of the atmosphere, g/m^3.
f_s = fraction of time cow spends on stored feed, dimensionless.
λ_T = decay constant for tritium, $seconds^{-1}$ (Table 6.2).
t_s = transport time from slaughter to consumer, seconds.
t_{csf} = time between harvest of stored feed and consumption by cow, seconds.
t_{cb} = time for receptor to consume a whole beef, seconds.

NOTE: Factors defined above which do not reference a table for their numerical values are listed in Table 6.3.

OFFSITE DOSE CALCULATION/ENVIRONMENTAL MONITORING METHODOLOGIES

7.7.12 Tritium - Stored Vegetables Dose Factor - R_{VTS}
(mrem/year per $\mu Ci/m^3$)

$$R_{VTS} = 10^3\ 10^6\ DFL_{Tao}\ [0.75(0.5/H)]\ U_{Sa} f_g \frac{(1-\exp(-\lambda_T t_{sv}))}{\lambda_T\ t_{sv}} \exp(-\lambda_T t_{hc})$$

where:

10^3 = conversion factor, grams/kg.
10^6 = conversion factor, pCi/μCi.
DFL_{Tao} = ingestion dose conversion factor for tritium for age group a, organ o, mrem/pCi (Table 6.4).
0.75 = the fraction of total vegetation that is water.
0.5 = the ratio of the specific activity of the vegetation water to the atmospheric water.
H = absolute humidity of the atmosphere, g/m^3.
U_{Sa} = consumption rate of stored vegetables by the receptor in age group a, kg/year.
f_g = fraction of stored vegetables grown locally, dimensionless.
λ_T = decay constant for tritium, $seconds^{-1}$ (Table 6.2).
t_{sv} = time between harvest of stored vegetables and their consumption and/or storage, seconds.
t_{hc} = time between harvest of vegetables and their storage, seconds.

NOTE: Factors defined above which do not reference a table for their numerical values are listed in Table 6.3.