

DOSE ASSESSMENT AROUND TR-2 REACTOR DUE TO MAXIMUM CREDIBLE ACCIDENT

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ABSTRACT

The revision of safety analysis report of TR-2 research reactor had been initiated in 1995. The whole accident analysis and accepted scenario for maximum credible accident has been revised according to the new safety concepts and the impact to be given to the environment due to this scenario has been assessed. This paper comprises all results of these calculations.

The accepted maximum credible accident scenario is the partial blokage of the whole reactor core which resulted in the release of 25% of the core inventory. The DOSER code which uses very conservative modelling of atmospheric distributions were modified for the assessment calculations. Pasquill conditions based on the local weather observations, topography, and building affects were considered. The thyroid and whole body doses for 16 sectors and up to 10 km of distance around ÇNAEM were obtained. Release models were puff and a prolonged one of two hours of duration. Release fractions for the active isotopes were chosen from literature which were realistic.

INTRODUCTION

Dose and risk assesment calculations have been carried out before and after the installation of TR-2 reactor [1, 2]. The chosen maximum credible accident scenario assumes a release of 25 % of the core inventory due to partial blokage of the reactor core. Two different release models, namely puff and a prolonged one were used. 16 wind directions and 10 km of distances in each direction have been used. The thyroid and whole body doses have been calculated.

DIFFUSION MODELS

The active isotopes that were released from the reactor will diffuse in the atmosphere. The release is assumed to occur from a chimney of height “h”, and the plume has a Gaussian form in 3D. The activity at any point in the direction of wind is assumed to be given by Sutton’s formula [3].

a) Controlled release

One can simplify that formula according to the duration of exposure [4]. For less than 2 hours of exposure, this concentration formula becomes :

$$\chi = \frac{Q}{\pi \bar{u} \sigma_x \sigma_y} \cdot \exp\left(-\frac{h^2}{2\sigma_z^2}\right)$$

where χ is the concentration [Ci / m³], Q is the source term [Ci / sec], σ_x , σ_y , σ_z are the standard deviations [m], h is the height of the chimney [m], $\bar{u}$ is the average wind speed [m/sec].

Between 2 hours and 24 hours of exposure, the cloud was assumed to be spreaded into the whole segment of 22.5° and the concentration formula becomes :

$$\chi(x) = \frac{2.032Q}{\bar{u} \sigma_x} \cdot \exp\left(-\frac{h^2}{2\sigma_z^2}\right)$$

where, x is the distance between the point of release and point of exposure.

b) Puff Model

In this model, it is assumed that all of the activity accumulated in the reactor hole was released as a puff due to an accident. The source activity is constant in this

case. The space and time dependent concentration will be :

$$\chi(x, y, z, t) = \frac{Q}{\sqrt{2\pi} \pi^{3/2} \sigma_x \sigma_y \sigma_z} \cdot \exp\left[-\left(\frac{(x-ut)^2}{2\sigma_x^2} + \frac{y^2}{2\sigma_y^2} + \frac{z^2}{2\sigma_z^2}\right)\right]$$

where, $\chi(x, y, z, t)$ is the concentration [Ci / m³], Q is the total released activity [Ci], t is the time passed after the release [sec]. The time dependent distribution is Gaussian also and the width of the Gaussian changes according to the distance of exposure point and the wind speed. This width is quite small, that is Gaussian is very narrow in time domain.

DOSE CALCULATION FORMULAS

The received dose levels of different organs due to radiation source for an exposure time τ can be calculated easily by using atmospheric diffusion model.

a) Controlled release

Different formula is given for every organ in the literature. A few of them will be given in this study. For the thyroid dose :

$$D_{th} = \left(\frac{\chi}{Q}\right)_\tau \cdot B \cdot \sum_{i=1}^N Q_{ti} \cdot (DFC)_i$$

where D_{th} is the thyroid dose at point x for an exposure time τ [rem], τ is the dose integration time [sec], $[\chi / Q]_\tau$ is the atmospheric dispersion factor [sec / m³], Q_{ti} is the total activity of the released isotope i for a time τ [Ci], B is the inhalation rate [m³ / sec], $(DFC)_i$ is the dose conversion factor for isotope i [rem / Ci]. For the whole body dose :

$$D_g(\tau) = 0.25 \left(\frac{\chi}{Q} \right)_{\tau} \sum_{i=1}^N Q_{\tau} E_{gi}$$

where $D_g(\tau)$ is the whole body gamma dose for an exposure time τ [rem], E_{gi} is the average gamma energy per disintegration for isotope i [MeV / dis.]. The χ / Q values were calculated

$$Q_{\tau} = \frac{\lambda_L}{\lambda_L + \lambda_i} C_{i0} F_P F_B [1 - \exp(-(\lambda_L + \lambda_i)\tau)]$$

for short and long term releases at different atmospheric conditions. The total activities for each isotope can be calculated from :

where F_P is the release fraction into the reactor building , F_B is the release percent to the atmosphere from the reactor building, λ_L is the constant of release rate [sec^{-1}], λ_i is the decay constant of isotope i [sec^{-1}], C_{i0} is the activity of isotope i [Curie].

b) Puff Model

Here only the whole body dose formula will be given :

$$D_g(x) = 0.25 E_g \frac{\exp\left(-\frac{h^2}{2\sigma_z^2}\right)}{\pi \bar{u} \sigma_x \sigma_z} \sum_{i=1}^N C_{i0} \exp(-\lambda_i t_0)$$

where t_0 is the time to arrive to point of exposure for plume.

INPUT DATA

The fission product inventories were calculated with ORIGEN code[5] for two different operational regimes of the reactor together with 100 and 300 days of full power operations. Only the gaseous isotopes, that is Kr83m, Kr85m, Kr85, Kr87, Kr88, Kr89, Xe131m, Xe133m, Xe133, Xe135m, Xe135, Xe138, I131, I132, I133, I134, I135 were taken as the inventory, and the others were assumed to be retained in the pool.

The standart deviations of the plume dispersion at every point x were calculated by an analitical model called Briggs polynomial formulas given for the type of terrain and Pasquill's stability conditions [6]. The reactor is cited at an elevation of 55 m on an open terrain. The height, h of every point was calculated according to it's topographical position plus a building height of 10 meters.

Standart deviations are calculated to include building effects. The meteorologi-cal data obtained from Atatürk Airport Meteorology Station are processed to find ave-rage wind speeds for 16 directions. The controlled leakage rates from the reactor building are found by using the pumping rates of the ventilation pumps and the volume of the rector building . The population distributions around the ÇNAEM were investigated and fortunately the intensity is found to be quite low for a radius of 2.5 km's from the reactor.

DOSE CALCULATIONS

The assumptions made in these calculations can be summarized as :

- 25 % of the core were melted due to the accident scenario,
- The release fractions of noble gases are assumed as 60 % from fuel matrix to pool water, and 30 % from water to building atmosphere,
- The corresponding fractions for halogens are taken as 40 % from fuel to water, and 5×10^{-4} from water to atmosphere,
- no cooling for the inventories,
- inventories for 100 days of operation were used,
- no plate-out was assumed for the halogens,
- in controlled release total fission inventories were taken,
- no filter efficiency is assumed for building ventilation system in case of prolonged release,
- building effect is considered only for prolonged release.

The release scenarios after accident are assumed as follows:

- 1- Reactor is shutdown, and building is severely breaced (that is, it is assumed that there is no building effect) and the gaseous inventory is released as a puff to the environment.
- 2- Reactor is shutdown, building is intact and the whole volatile inventory are released in two hours of duration.

RESULTS

The whole body and the thyroid dose values obtained for the above scenarios by DOSER code [7] are given in Tables -1 and -2. It is seen that the thyroid doses at 500 meter distance for all directions except the directions N and NNW are below 0.5 rem for

Table-1 : Thyroid dose distribution around ÇNAEM for average wind speeds [rem]*

Dis- tance (km)	Sectors															
	1 N	2 NNE	3 NE	4 ENE	5 E	6 ESE	7 SE	8 SSE	9 S	10 SSW	11 SW	12 WSW	13 W	14 WNW	15 NW	16 NNW
0.50	1.97	0.54	0.44	0.4	0.3	0.3	0.6	0.07	0.5	0.34	0.3	0.07	0.33	0.37	0.96	2.3
	1.01	0.33	0.26	0.23	0.16	0.17	0.34	0.06	0.3	0.2	0.17	0.06	0.2	0.23	0.54	1.19
0.75	0.97	0.25	0.21	0.18	0.20	0.18	0.19	0.03	0.23	0.16	0.14	0.03	0.16	0.18	0.5	1.02
	0.5	0.15	0.12	0.11	0.12	0.10	0.11	0.03	0.13	0.09	0.08	0.03	0.09	0.11	0.3	0.54

*) The numbers in the first line are for puff model and the second are for controlled release model

Table-2 : Whole body dose distribution around ÇNAEM for average wind speeds[rem]*

Dis- tance (km)	Sectors															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
0.50	3.47	0.96	0.8	0.7	0.5	0.5	0.99	0.13	0.9	0.6	0.5	0.1	0.6	0.7	1.7	4.05
	0.55	0.17	0.14	0.12	0.09	0.09	0.18	0.03	0.15	0.1	0.09	0.03	0.1	0.12	0.3	0.6
0.75	1.72	0.43	0.37	0.32	0.32	0.31	0.33	0.06	0.4	0.3	0.24	0.05	0.3	0.32	0.9	1.79
	0.28	0.08	0.07	0.057	0.063	0.055	0.058	0.01	0.07	0.05	0.04	0.01	0.05	0.06	0.2	0.3

*) The numbers in the first line are for puff model and the second are for controlled release model

both puff and prolonged releases. The higher results of N and NNW are coming from the topographical elevations of those directions. But the 500 meter boundary limit points are still in the ÇNAEM's campus area and there are nothing but empty fields along these directions. Actually campus boundary starts at 750 meters radius at the north direction. At this distance all thyroid doses are below or around 500 mrem for prolonged release. But the doses along these two direction are still higher than 500 mrem for puff release model.

Prolonged release model gives low whole body doses at the site boundary, that is 500 meter radius for all directions except N and NNW directions. At 750 meter distance all doses are less than 300 mrem. Puff release model gives higher doses, namely below 1 rem at 500 meter distance. The N, NW, and NNW directions have doses greater than 1 rem. At 750 meter away the higher dose values drops, but those at N, and NNW directions are still above 1 rem.

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