NUCLEAR REACTOR LABORATORY

AN INTERDEPARTMENTAL CENTER OF MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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August 26, 2008

U.S. Nuclear Regulatory Commission
Attn: Document Control Room
Washington, DC 20555

Re: Massachusetts Institute of Technology – Request for Additional Information License Renewal Request (TAC No. MA6084); License No. R-37; Docket No. 50-20

Dear Sir or Madam:

The Massachusetts Institute of Technology hereby provides the response for #13.1.

Please contact the undersigned with any questions.

Sincerely,

John Bernard, Ph.D., PE, CHP
Director of Reactor Operations

I declare under the penalty of perjury that the foregoing is true and correct.

Executed on 8-26-08 (Date) ________ Signature

cc:

w/enclosures	Stephen Pierce, Project Manager Research and Test Reactors Branch A Division of Policy and Rulemaking Office of Nuclear Reactor Regulation
w/enclosures	Senior Project Manager Research and Test Reactors Branch A Division of Policy and Rulemaking Office of Nuclear Reactor Regulation
w/enclosure	Senior Reactor Inspector Research and Test Reactors Branch B Division of Policy and Rulemaking Office of Nuclear Reactor Regulation
w/o enclosure	Document Control Desk

13.1 In order to determine the effective dose to members of the reactor staff, a determination of the containment concentrations at any time must be determined, along with the expected duration of exposure.

In this regard, Table 13-1 presented the total equilibrium core inventory at various assumed power levels up to 10MW. For the Maximum Hypothetical Accident (MHA), only a small fraction of the fuel is assumed to melt from channel blockage and this release would represent 1.76% of the core fission product inventory. This coupled with the fission product release fractions (Table 13-2), the total activity in containment can be calculated. For the case of fission product gases, it is assumed that the release to containment is instantaneous with uniform mixing, that the reactor has scrammed (t=0), and that containment is isolated. For the case of the non-volatile components, a release rate from the primary coolant is stated to be linear out to two (t=2h) hours and is based on the evaporation rate of the primary coolant taking no credit for the reactor lid acting as a barrier to release.

Dose is calculated based on the presumption of a finite cloud for noble gas immersion (DDE) and inhalation dose for the other radionuclides (committed effective dose equivalent). The summation of the two results in the Total Effective Dose Equivalent.

For the case of submersion dose, the mechanism describe in the response *"to Item 65 of the second partial request for addition information"* is used. Specifically, the following equation is adopted as obtained originally from equation 1 of section 4.2.7 of regulatory guide 1.183.

$$DDE_{finite} = \sum_{i=1}^{i=n} DDE_{\infty_i} \frac{V^{0.338}}{1173}$$

For the case of inhalation dose, the CEDE dose is determined as follows:

$$CEDE = \sum_{i=1}^{i=n} \frac{[C_i]}{DAC_i} * DCF_i (mrem\ h^{-1}\ DAC^{-1}) * T$$

Where: DDE_{finite} is the finite deep dose equivalent (rate),
DDE_{∞} is the infinite deep dose equivalent (rate),
V is the volume of the space defined by an effective radius R,
CEDE is the committed effective dose equivalent,
DAC_i is the derived air concentration as listed in 10CFR20,
$[C_i]$ is the concentration of the i^{th} radionuclide,
DCF_i is the dose conversion factor, and

T is the exposure time (h).

Note that for the CEDE dose quantities, the stochastic values are used for determining the total effective dose equivalent, TEDE (effective dose). Non-Stochastic (deterministic) values are presented but the dose is not calculated.

Given that the dose rate will change over time due to decay an integral to the above equations is the more exacting method and the general form is presented as follows:

$$D = \int_{t_1}^{t_2} \dot{D}(t)dt = \dot{D}(0)\left[\frac{e^{-\lambda t}}{\lambda}\right]_0^T = \dot{D}(0)\left[\frac{1-e^{-\lambda T}}{\lambda}\right]$$

where: D is the integral dose whether it be DDE or CEDE, t_1 and t_2 are the limits of integration for the dependent variable t which were set to 0 for the start of release, T is any time post release, and all other terms are as previously defined.

Given the above, dose rate and doses were calculated and are presented. It should be noted that the presumption of Instantaneous release and uniform mixing for equilibrium core inventories following an Instantaneous occurrence of the MHA at full power with no credit for additional barriers or removal processes is extremely conservative and that the calculations presented represents the extreme upper bound for dose considerations.

In reviewing the potentials for non-noble gas release to containment, Iodine as a halogen is reasonable using the presumption of a linear release rate as stated in the SAR out to two hours. However, the release of particulates considering the lack of driving forces (temperature and pressure) is in general not realistic except for those borne from the decay of its noble gas precursors in containment spaces. In reviewing other research reactor SARs no consideration for nuclides other than noble gases and the iodine groups were made. In fact it was presumed by one such facility that only 5% of the iodine would be available due to the formation of CsI and as a particulate would not be released. Another facility took credit for a deposition fraction on surfaces of containment at 75% for Iodides and that the underlying assumption was this was an instantaneous removal at t=0 post onset of the MHA.

An additional point of conservatism used in these calculations is the presumption of an equilibrium core inventory whereas in practicality, all fuel is at some fraction less due in part to operating history and an intensive fuel management program.
Given the above, the following tables and figures are presented.

Tables:

1. Fraction of an Infinite Cloud for Reference Areas within Containment

2. Fission Product Release Fractions (from SAR)
3. Core Fission Product Inventory (from SAR)
4. Instantaneous Fission Product Dose Rate from a Finite Submersion Cloud of Noble Gases
5. Time Dependent Finite Cloud Submersion Dose Rate for the Control Room
6. Integral Time Dependent Dose for a Finite Submersion Case in the Control Room.
7. Listed and Calculated Stochastic and Deterministic ALIs, DACs, and Fraction of DACs for Non-Noble Gas Radionuclides

Figures:

1. Time Dependent Finite Cloud Submersion Dose Rate within the Control Room
2. Integral Dose within the Control Room from a Submersion of Noble Gases as a Function of Time.
3. Submersion Integral dose as a function of time for a finite cloud on the Reactor Floor
4. Time Dependent CEDE Dose Rates for all Non-Noble Gas Radionuclides
5. Time Dependent CEDE Dose Rates for Iodides
6. Integral CEDE Dose as a Function of Time Post Release for Iodides

In evaluating the potential dose to an operator as a result of a MHA condition, it is necessary to determine the stay time for that operator. Conversely, it may be appropriate to determine the maximum stay time for a MHA condition such that the emergency PAGs are not exceeded. In this later case, the maximum stay time without exceeding the 25 rem Emergency PAG would be 30 minutes if only noble gases and iodides are considered and approximately 2 hours if SCBAs are employed.

If all radionuclides were considered (Iodides contributing greater than 60% of the CEDE dose), then the estimated stay time would be on the order of 20 minutes and if the SCBAs were employed, then the submersion dose component would prevail permitting stay times greater than 2 hours.

Note: Contribution in percentage for the CEDE Dose determine at the maximum dose rate at t=2h

I-131	54 %
Cs-137	25 %
I-133	6 %
Cs-134	6 %
Te-132	4 %
Cs-136	1 %
I-135	1 %
Total	**97 %**

Table 1: Fraction of an Infinite Cloud for Reference Areas within Containment

Area	**$R_{effective}$ (meters)**	**$V_{effective}$ (ft^3)**	**f Eq. 1b**
Reactor Top	10.7	85750	0.039
Reactor Floor	9.8	69768	0.037
Fission Converter Medical Therapy Room	3	2000	0.011
Basement Medical Therapy Room	2.7	1510	0.01
Primary Chemistry	2.8	1569	0.01
Secondary Chemistry Area	2.6	1246	0.0095
Control Room	3	1953	0.011
Basement Medical Set up Area	3.1	2279	0.011
Equipment Room	4.8	8139	0.018
From RAI Initial Request Reply Dated: 1/29/2004 Question number 65			

Table 2. Fission Product Release Fractions

Fission Product	Fraction Released from the Melted Fuel	Fraction Released from the Primary Coolant System	Fraction Remaining Airborne in the Containment Atmosphere	Total Fraction from Fuel to Containment Atmosphere
	F_f	F_p *	F_c	F total
Noble Gases	1	1	1	1
I	0.9	0.03	0.3	0.0081
Cs	0.9	0.03	0.3	0.0081
Te	0.23	0.03	0.9	0.00621
Sr	0.01	0.03	0.9	0.00027
Ba	0.01	0.03	0.9	0.00027
Ru	0.01	0.03	0.9	0.00027
La	0.0001	0.03	0.9	0.0000027
Ce	0.0001	0.03	0.9	0.0000027
Others	0.0001	0.03	0.9	0.0000027

Table 3. Equilibrium Core Fission Product Inventory for Various Power Levels

Isotope		Half-life	λi(sec-1)	Yi(%)	Q_s^i (×10^5 Ci)					
					5MW	6MW	7MW	8MW	9MW	10MW
Kr	85m	4.36h	4.41E-05	1.5	0.649	0.7788	0.9086	1.0384	1.1682	1.3
	87	78m	1.48E-04	2.7	1.17	1.404	1.638	1.872	2.106	2.34
	88	2.77h	6.95E-05	3.7	1.6	1.92	2.24	2.56	2.88	3.2
Xe	131m	12.0d	6.68E-07	0.03	0.013	0.0156	0.0182	0.0208	0.0234	0.026
	133m	2.3d	3.49E-06	0.16	0.0692	0.083	0.0969	0.1107	0.1246	0.138
	133	5.27d	1.52E-06	6.5	2.81	3.372	3.934	4.496	5.058	5.62
	135m	15.6m	7.40E-04	1.8	0.778	0.9336	1.0892	1.2448	1.4004	1.56
	135	9.13h	2.11E-05	6.2	0.413	0.4956	0.5782	0.6608	0.7434	0.826
	138	17m	6.79E-04	5.5	2.38	2.856	3.332	3.808	4.284	4.76
I	131	8.05d	9.96E-07	2.9	1.25	1.5	1.75	2	2.25	2.51
	132	2.4h	8.02E-05	4.4	1.9	2.28	2.66	3.04	3.42	3.81
	133	20.8h	9.25E-06	6.5	2.81	3.372	3.934	4.496	5.058	5.62
	134	52.5m	2.20E-05	7.6	3.29	3.948	4.606	5.264	5.922	6.57
	135	6.68h	2.89E-05	5.9	2.55	3.06	3.57	4.08	4.59	5.1
Br	83	2.4h	8.02E-05	0.48	0.208	0.2496	0.2912	0.3328	0.3744	0.415
	84	30m	3.85E-05	1.1	0.476	0.5712	0.6664	0.7616	0.8568	0.951
Cs	134	2.0y	1.10E-08	0.0*	2.86	3.432	4.004	4.576	5.148	5.72
	136	13d	6.17E-07	0.006*	0.414	0.4968	0.5796	0.6624	0.7452	0.828
	137	26.6y	8.27E-10	5.9	2.31	2.772	3.234	3.696	4.158	4.62
Rb	86	19.5d	4.11E-07	2.8E-5*	0.612	0.7344	0.8568	0.9792	1.1016	1.22
Te	127m	90d	8.82E-08	0.056	0.0242	0.029	0.0339	0.0387	0.0436	0.0484
	127	9.3h	2.07E-05	0.25	0.108	0.1296	0.1512	0.1728	0.1944	0.216
	129m	33d	2.43E-07	0.34	0.147	0.1764	0.2058	0.2352	0.2646	0.294
	129	72m	1.60E-04	1	0.432	0.5184	0.6048	0.6912	0.7776	0.865
	131m	30h	6.42E-05	0.44	0.19	0.228	0.266	0.304	0.342	0.381
	131	24.8m	4.66E-04	2.9	1.25	1.5	1.75	2	2.25	2.51
	132	77h	2.50E-06	4.4	1.9	2.28	2.66	3.04	3.42	3.81
	133m	63m	1.83E-04	4.6	1.99	2.388	2.786	3.184	3.582	3.98
	134	44m	2.63E-04	6.7	2.9	3.48	4.06	4.64	5.22	5.8
Sr	91	97h	2.99E-05	5.9	2.55	3.06	3.57	4.08	4.59	5.1
Ba	140	12.8d	6.27E-07	6.3	2.72	3.264	3.808	4.352	4.896	5.45
Ru	103	41d	1.96E-07	2.9	1.25	1.5	1.75	2	2.25	2.51
	105	4.5h	4.28E-05	0.9	0.389	0.4668	0.5446	0.6224	0.7002	0.779
	106	1.0y	2.20E-08	0.38	0.164	0.1968	0.2296	0.2624	0.2952	0.329
Rh	103	36.5h	5.27E-06	0.9	0.389	0.4668	0.5446	0.6224	0.7002	0.779
Tc	99m	6.04h	3.19E-05	0.6	0.259	0.3108	0.3626	0.4144	0.4662	0.519
Mo	99	67h	2.88E-06	6.1	2.64	3.168	3.696	4.224	4.752	5.28
Sb	127	93h	2.07E-06	0.25	0.108	0.1296	0.1512	0.1728	0.1944	0.216
	129	4.6h	4.32E-05	1	4.32	5.184	6.048	6.912	7.776	8.65
Nd	147	11.3d	7.10E-07	2.6	1.12	1.344	1.568	1.792	2.016	2.25
La	140	40.2h	4.79E-06	6.3	2.72	3.264	3.808	4.352	4.896	5.45
Ce	141	32d	2.51E-07	6	2.59	3.108	3.626	4.144	4.662	5.19
	143	32h	6.01E-06	6.2	2.68	3.216	3.752	4.288	4.824	5.36
	144	290d	2.76E-08	6.1	2.64	3.168	3.696	4.224	4.752	5.28
Zr	95	63d	1.27E-07	6.4	2.77	3.324	3.878	4.432	4.986	5.54
	97	17h	1.13E-05	6.2	2.68	3.216	3.752	4.288	4.824	5.36
Nb	95	35d	2.29E-07	6.4	2.77	3.324	3.878	4.432	4.986	5.54

Table 4. Instantaneous Fission Product Dose Rate (rem/h) From a Finite Submersion Cloud of Noble Gases.

DDE (rem/h) from fission product gases in various locations in containment at T=0										
Area	DDE Infinite	Reactor Top	Reactor Floor	Fission Converter Medical Therapy Room	Basement Medical Therapy Room	Primary Chemistry	Secondary Chemistry Area	Control Room	Basement Medical Set up Area	Equipment Room
F equilb	1.00E+00	3.90E-02	3.70E-02	1.10E-02	1.00E-02	1.00E-02	9.50E-03	1.10E-02	1.10E-02	1.80E-02
Isotope	**Dose Rate (rem/h)**									
Kr-85m	3.03E+01	1.18E+00	1.12E+00	3.33E-01	3.03E-01	3.03E-01	2.87E-01	3.33E-01	3.33E-01	5.45E-01
Kr-87	2.18E+02	8.51E+00	8.07E+00	2.40E+00	2.18E+00	2.18E+00	2.07E+00	2.40E+00	2.40E+00	3.93E+00
Kr-88	7.46E+02	2.91E+01	2.76E+01	8.20E+00	7.46E+00	7.46E+00	7.09E+00	8.20E+00	8.20E+00	1.34E+01
Xe-131m	3.03E-02	1.18E-03	1.12E-03	3.33E-04	3.03E-04	3.03E-04	2.88E-04	3.33E-04	3.33E-04	5.45E-04
Xe-133m	6.45E-01	2.51E-02	2.39E-02	7.09E-03	6.45E-03	6.45E-03	6.13E-03	7.09E-03	7.09E-03	1.16E-02
Xe-133m	2.62E+01	1.02E+00	9.69E-01	2.88E-01	2.62E-01	2.62E-01	2.49E-01	2.88E-01	2.88E-01	4.72E-01
Xe-135m	8.06E+01	3.14E+00	2.98E+00	8.87E-01	8.06E-01	8.06E-01	7.66E-01	8.87E-01	8.87E-01	1.45E+00
Xe-135m	3.85E+01	1.50E+00	1.42E+00	4.24E-01	3.85E-01	3.85E-01	3.66E-01	4.24E-01	4.24E-01	6.93E-01
Xe-138	5.55E+02	2.16E+01	2.05E+01	6.10E+00	5.55E+00	5.55E+00	5.27E+00	6.10E+00	6.10E+00	9.99E+00
Total	**1.69E+03**	**6.61E+01**	**6.27E+01**	**1.86E+01**	**1.69E+01**	**1.69E+01**	**1.61E+01**	**1.86E+01**	**1.86E+01**	**3.05E+01**

Table 5. Time Dependent Finite Cloud Submersion Dose Rate rem/h for the Control Room.

Isotope	**Control Room DDE Does Rate (rem/h) as a Function of Time Post Instantaneous Release (hours)**											
	0	0.25	0.5	0.75	1	2	3	4	5	6	7	8
Kr-85m	3.33E-01	3.20E-01	3.07E-01	2.95E-01	2.84E-01	2.42E-01	2.07E-01	1.76E-01	1.50E-01	1.28E-01	1.10E-01	9.34E-02
Kr-87	2.40E+00	2.10E+00	1.84E+00	1.61E+00	1.41E+00	8.27E-01	4.85E-01	2.85E-01	1.67E-01	9.81E-02	5.76E-02	3.38E-02
Kr-88	8.20E+00	7.71E+00	7.24E+00	6.80E+00	6.39E+00	4.97E+00	3.87E+00	3.02E+00	2.35E+00	1.83E+00	1.42E+00	1.11E+00
Xe-131m	3.33E-04	3.33E-04	3.33E-04	3.33E-04	3.32E-04	3.32E-04	3.31E-04	3.30E-04	3.29E-04	3.29E-04	3.28E-04	3.27E-04
Xe-133m	7.09E-03	7.07E-03	7.05E-03	7.03E-03	7.00E-03	6.92E-03	6.83E-03	6.75E-03	6.66E-03	6.58E-03	6.50E-03	6.42E-03
Xe-133m	2.88E-01	2.88E-01	2.87E-01	2.87E-01	2.87E-01	2.85E-01	2.83E-01	2.82E-01	2.80E-01	2.79E-01	2.77E-01	2.76E-01
Xe-135m	8.87E-01	4.55E-01	2.34E-01	1.20E-01	6.18E-02	4.30E-03	3.00E-04	2.09E-05	1.46E-06	1.01E-07	7.06E-09	4.92E-10
Xe-135m	4.24E-01	4.16E-01	4.08E-01	4.00E-01	3.93E-01	3.64E-01	3.37E-01	3.13E-01	2.90E-01	2.69E-01	2.49E-01	2.31E-01
Xe-138	6.10E+00	3.31E+00	1.80E+00	9.76E-01	5.30E-01	4.60E-02	3.99E-03	3.46E-04	3.00E-05	2.61E-06	2.26E-07	1.96E-08
Total	1.86E+01	1.46E+01	1.21E+01	1.05E+01	9.36E+00	6.75E+00	5.20E+00	4.08E+00	3.24E+00	2.61E+00	2.12E+00	1.75E+00

Figure 1. Time Dependent Finite Cloud Submersion Dose Rate within the Control Room.

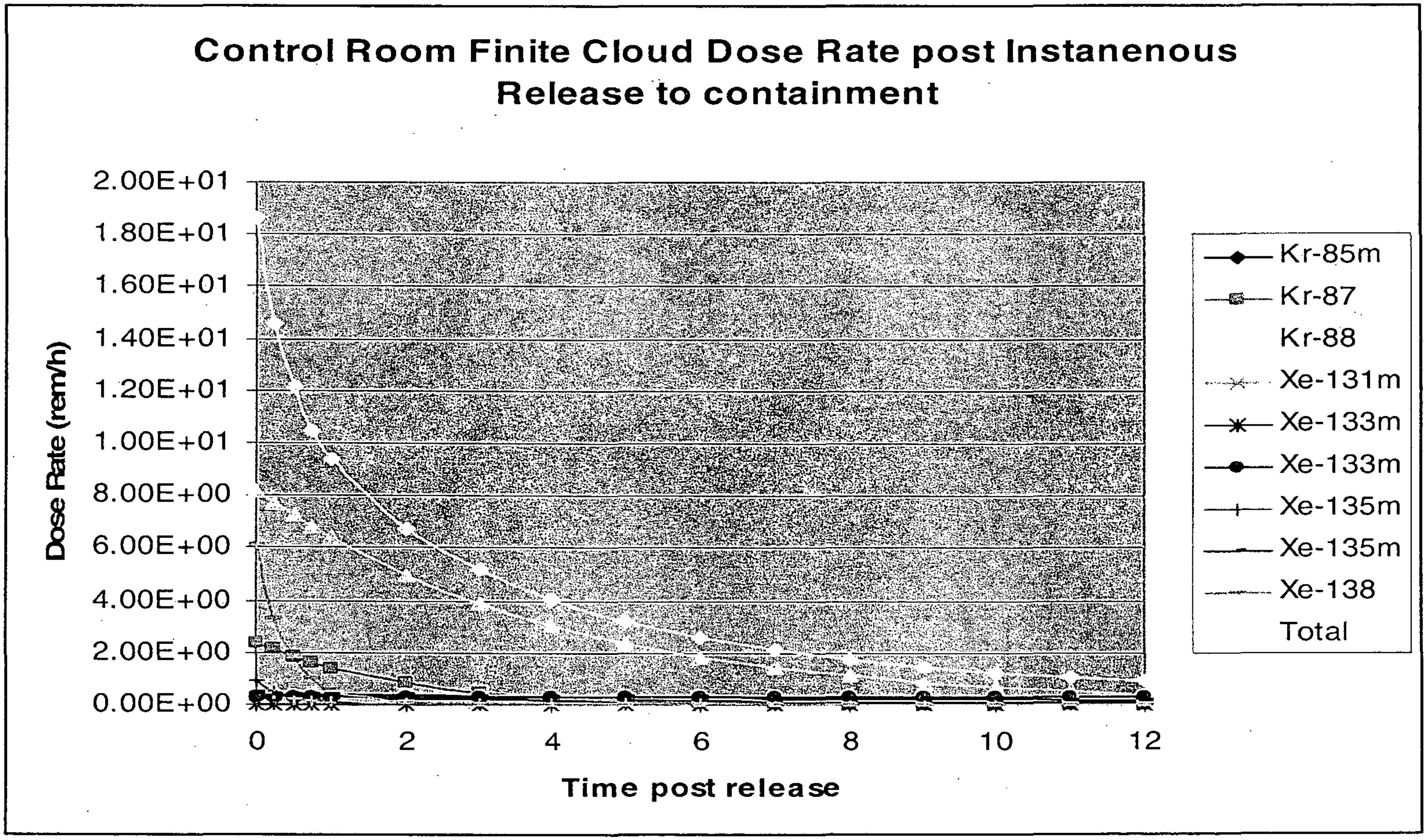

Table 6. Integral Time Dependent Dose (rem) for a Finite Submersion Case in the Control Room.

Isotope	Control Room Noble Gas DDE Integral Dose (rem) as a Function of Time Post Instantaneous Release (hours)											
	0.1	0.25	0.5	0.75	1	2	3	4	5	6	7	8
Kr-85m	3.30E-02	8.16E-02	1.60E-01	2.35E-01	3.08E-01	5.70E-01	7.94E-01	9.85E-01	1.15E+00	1.29E+00	1.41E+00	1.51E+00
Kr-87	2.34E-01	5.62E-01	1.05E+00	1.48E+00	1.86E+00	2.95E+00	3.59E+00	3.97E+00	4.19E+00	4.32E+00	4.40E+00	4.44E+00
Kr-88	8.10E-01	1.99E+00	3.86E+00	5.61E+00	7.26E+00	1.29E+01	1.73E+01	2.07E+01	2.34E+01	2.55E+01	2.71E+01	2.84E+01
Xe-131m	3.33E-05	8.33E-05	1.67E-04	2.50E-04	3.33E-04	6.65E-04	9.96E-04	1.33E-03	1.66E-03	1.99E-03	2.31E-03	2.64E-03
Xe-133m	7.09E-04	1.77E-03	3.54E-03	5.29E-03	7.05E-03	1.40E-02	2.09E-02	2.77E-02	3.44E-02	4.10E-02	4.75E-02	5.40E-02
Xe-133m	2.88E-02	7.20E-02	1.44E-01	2.16E-01	2.87E-01	5.73E-01	8.57E-01	1.14E+00	1.42E+00	1.70E+00	1.98E+00	2.26E+00
Xe-135m	7.78E-02	1.62E-01	2.45E-01	2.88E-01	3.10E-01	3.31E-01	3.33E-01	3.33E-01	3.33E-01	3.33E-01	3.33E-01	3.33E-01
Xe-135m	4.22E-02	1.05E-01	2.08E-01	3.09E-01	4.08E-01	7.86E-01	1.14E+00	1.46E+00	1.76E+00	2.04E+00	2.30E+00	2.54E+00
Xe-138	5.41E-01	1.14E+00	1.76E+00	2.10E+00	2.28E+00	2.48E+00	2.49E+00	2.50E+00	2.50E+00	2.50E+00	2.50E+00	2.50E+00
Total	1.77E+00	4.11E+00	7.43E+00	1.02E+01	1.27E+01	2.06E+01	2.65E+01	3.12E+01	3.48E+01	3.77E+01	4.01E+01	4.20E+01

Figure 2. Submersion Integral dose as a function of time for a finite cloud within the control room

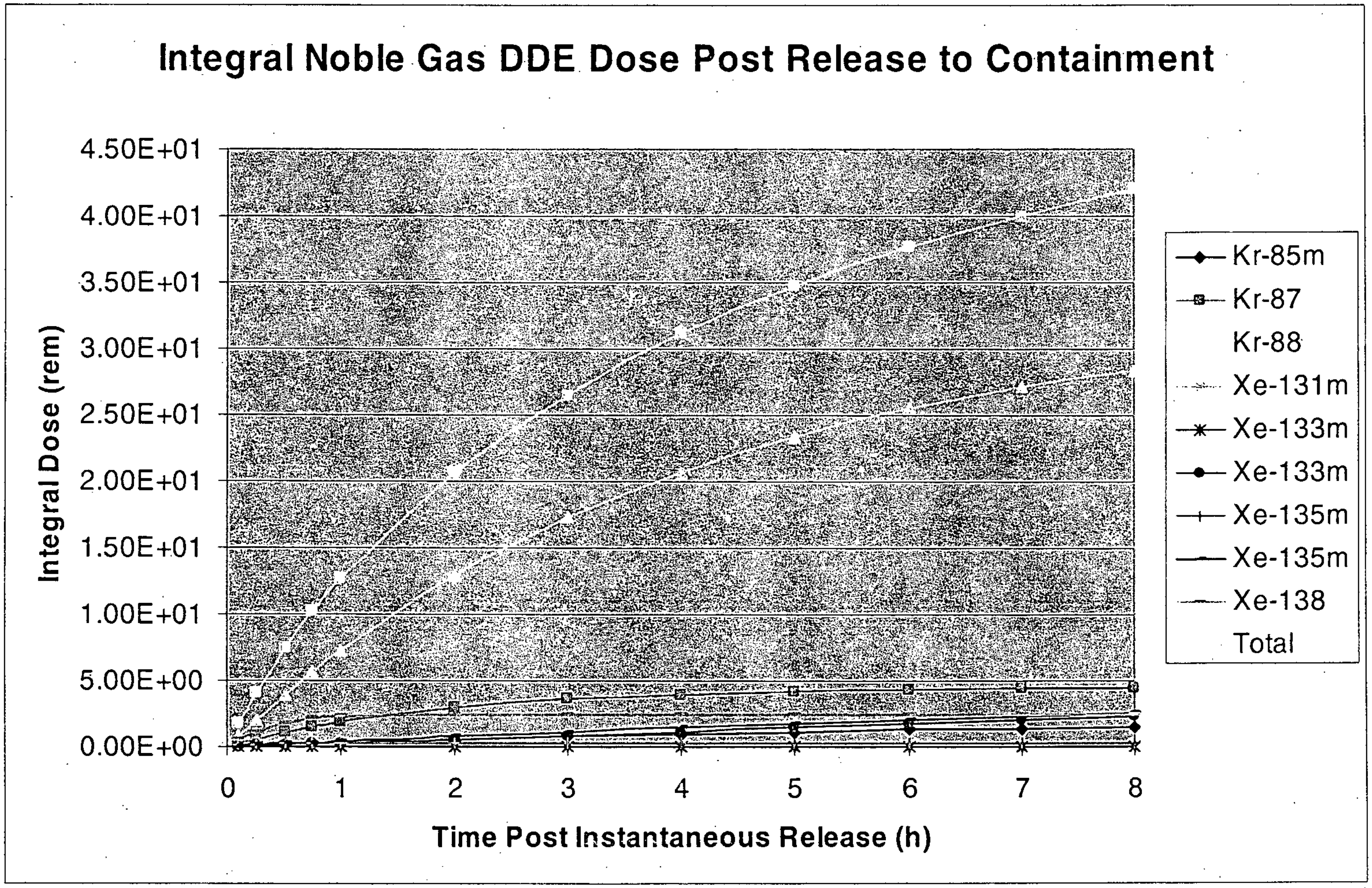

Figure 3. Submersion Integral dose as a function of time for a finite cloud on the Reactor Floor

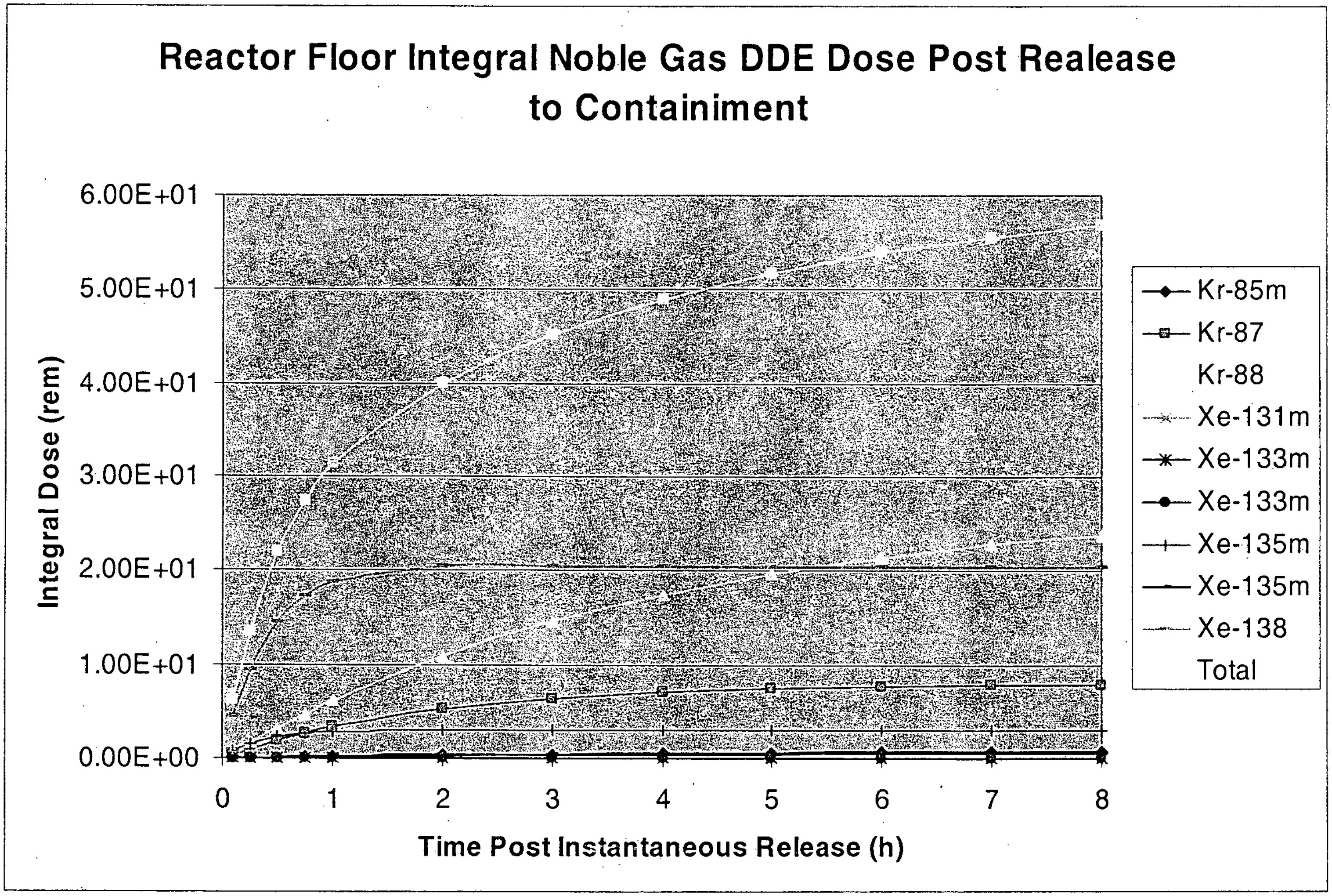

Table 7. Listed and calculated Stochastic and Deterministic ALIs, DACs, and Fraction of DACs for Non-Noble Gas Radionuclides

				Non-Stochsatic			Stochastic		
Isotope	Half-life	Activity Concen. uCi/ml	Listed DAC uCi/ml	Listed ALI uCi	Organ of reference	Fraction DAC	Listed ALI uCi	Calc. DAC uCi/ml	Fraction DAC
I-131	8.05d	3.78E-03	2.00E-08	2.00E+02	Thyroid	1.89E+05	5.00E+01	2.08E-08	1.81E+05
I-132	2.4h	5.74E-03	3.00E-06	8.00E+03	Thyroid	1.91E+03	1.00E+04	4.17E-06	1.38E+03
I-133	20.8h	8.49E-03	1.00E-07	3.00E+02	Thyroid	8.49E+04	9.00E+02	3.75E-07	2.26E+04
I-134	52.5m	9.94E-03	2.00E-05				5.00E+04	2.08E-05	4.77E+02
I-135	6.68h	7.70E-03	7.00E-07	2.00E+03	Thyroid	1.10E+04	4.00E+03	1.67E-06	4.62E+03
Br-83	2.4h	6.28E-04	3.00E-05				6.00E+04	2.50E-05	2.51E+01
Br-84	30m	1.44E-03	2.00E-05				6.00E+04	2.50E-05	5.75E+01
Cs134	2.0y	8.64E-03	5.00E-07				1.00E+03	4.17E-07	2.07E+04
Cs-136	13d	1.25E-03	3.00E-07				7.00E+02	2.92E-07	4.29E+03
Cs-137	26.6y	6.98E-03	6.00E-08				2.00E+02	8.33E-08	8.37E+04
Rb-86	19.5d	6.16E-07	3.00E-07				8.00E+02	3.33E-07	1.85E+00
Te-127m	90d	5.60E-05	1.00E-07	3.00E+02	Bone surf	5.60E+02	4.00E+02	1.67E-07	3.36E+02
Te-127	9.3h	2.50E-04	9.00E-06				2.00E+04	8.33E-06	3.00E+01
Te-129m	33d	3.40E-04	3.00E-07				6.00E+02	2.50E-07	1.36E+03
Te-129	72m	1.00E-03	3.00E-05				6.00E+04	2.50E-05	4.00E+01
Te-131m	30h	4.40E-04	2.00E-07	4.00E+02	Thyroid	2.20E+03	1.00E+03	4.17E-07	1.06E+03
Te-131	24.8m	2.89E-03	2.00E-06	5.00E+03	Thyroid	1.45E+03	1.00E+04	4.17E-06	6.95E+02
Te-132	77h	4.40E-03	9.00E-08	2.00E+02	Thyroid	4.89E+04	8.00E+02	3.33E-07	1.32E+04
Te-133m	63m	4.61E-03	3.00E-06	5.00E+03	Thyroid	1.54E+03	1.00E+04	4.17E-06	1.11E+03
Te-134	44m	6.72E-03	1.00E-05	2.00E+04	Thyroid	6.72E+02	5.00E+04	2.08E-05	3.22E+02
Sr-91	97h	2.57E-04	2.00E-06				5.00E+03	2.08E-06	1.23E+02
Ba-140	12.8d	2.74E-04	6.00E-07				1.00E+03	4.17E-07	6.57E+02
Ru-103	41d	1.26E-04	7.00E-07				2.00E+03	8.33E-07	1.51E+02
Ru-105	4.5h	3.92E-05	6.00E-06				1.00E+04	4.17E-06	9.40E+00
Ru-106	1.0y	1.65E-05	4.00E-08				9.00E+01	3.75E-08	4.40E+02
Tc-99m	6.04h	2.61E-07	6.00E-05				2.00E+05	8.33E-05	3.13E-03
Mo-99	67h	2.66E-06	1.00E-06				3.00E+03	1.25E-06	2.13E+00
Sb-127	93h	1.09E-07	9.00E-07				2.00E+03	8.33E-07	1.30E-01
Sb-129	4.6h	4.35E-06	4.00E-06				9.00E+03	3.75E-06	1.16E+00
Nd-147	11.3d	1.13E-06	4.00E-07				9.00E+02	3.75E-07	3.01E+00
La-140	40.2h	2.74E-06	6.00E-07				1.00E+03	4.17E-07	6.57E+00
Ce-141	32d	2.61E-06	3.00E-07				7.00E+02	2.92E-07	8.94E+00
Ce-143	32h	2.70E-06	8.00E-07				2.00E+03	8.33E-07	3.24E+00
Ce-144	290d	2.66E-06	1.00E-08				3.00E+01	1.25E-08	2.13E+02
Zr-95	63d	2.79E-06	5.00E-08	1.00E+02	Bone surf	5.58E+01	3.00E+02	1.25E-07	2.23E+01
Zr-97	17h	2.70E-06	8.00E-07				2.00E+03	8.33E-07	3.24E+00
Nb-95	35d	2.79E-06	5.00E-07				1.00E+03	4.17E-07	6.69E+00

DAC=ALI(in μCi)/(2000 hours per working year x 60 minutes/hour x 2 x 10^4 ml per minute) = [ALI/2.4x10^9] μCi/ml, where 2x10^4 ml is the volume of air breathed per minute at work by "Reference Man" under working conditions of "light work."

Figure 4. Time Dependent CEDE Dose Rates for all Non-Noble Gas Radionuclides

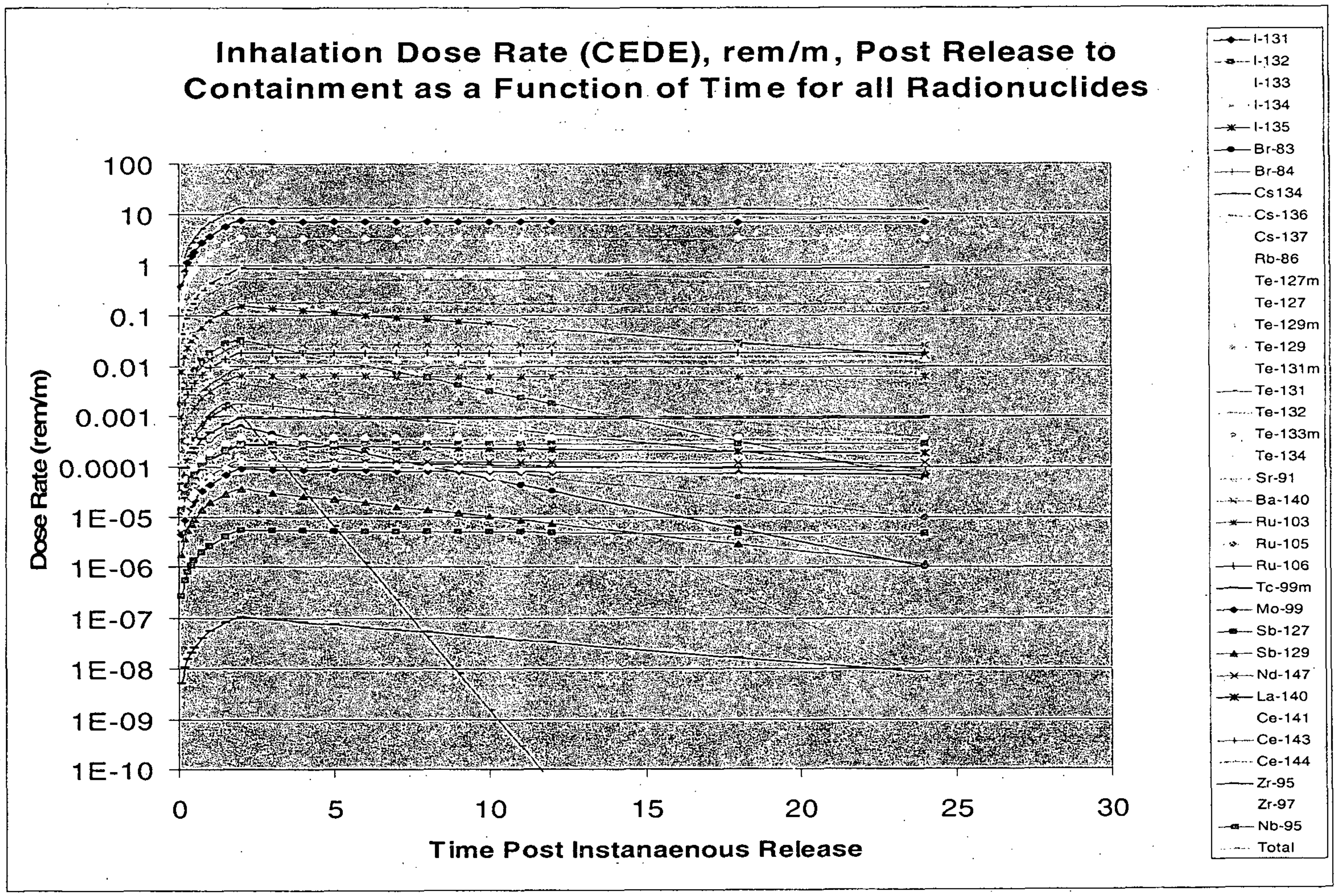

Figure 5. Time Dependent CEDE Dose Rates for Iodides

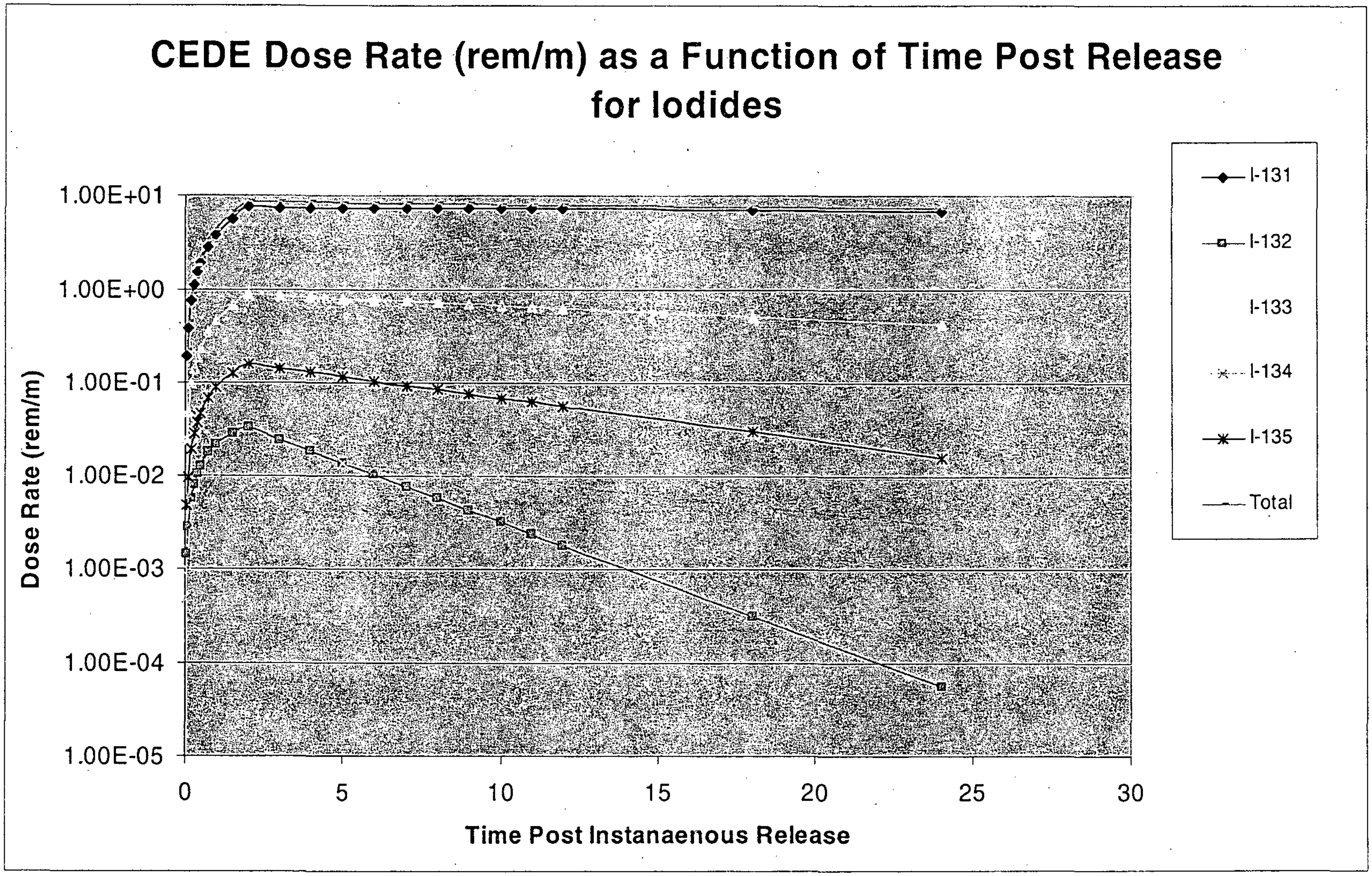

Figure 6. Integral CEDE Dose as a Function of Time Post Release for Iodides