This info was for 1963-I

R 408413

H 6/26/63

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Equivalent Residual Dose Calculations

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The data for the attached graphs were computed, except where noted, based on ~~a~~ irreparable fraction = .15 and a daily repair rate = .15. The following relation was used for this calculation:

$$\frac{ERD(t_K)}{R_o} = \alpha \int_{t_{K-1}}^{t_K} g(t)\,dt + (1-\alpha)\left[\sum_{i=1}^{K} (1-\beta)^{K+1-i} \int_{t_{i-1}}^{t_i} g(t)\,dt\right] \qquad (1)$$

$$= \frac{I_K^i}{R_o} + \frac{I_K^r}{R_o} \qquad (2)$$

where $ERD(t_k)$ = Equivalent Residual dose at time t_k

α = irreparable fraction = .15

$g(t) = t^{-1.2}$ = ~~dose~~ dose rate at time t / R_o

R_o = (H+1) dose rate

β' = daily repair rate = .15

$\beta = \frac{\Delta t\, \beta'}{24}$

$\Delta t = t_j - t_{j-1}$ = 4 hrs, $j = 1, 2, \ldots, K$

I_K^i = irreparable injury at time t_k.

I_K^r = reparable injury at time t_k which has not been repaired

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Note:
$$\frac{I_K^r}{R_o} = (1-\beta)\left[\frac{I_{K-1}^r}{R_o} + (1-\alpha)\int_{t_{K-1}}^{t_K} g(t)\,dt\right] \qquad (3)$$

where $I_o^r = 0$

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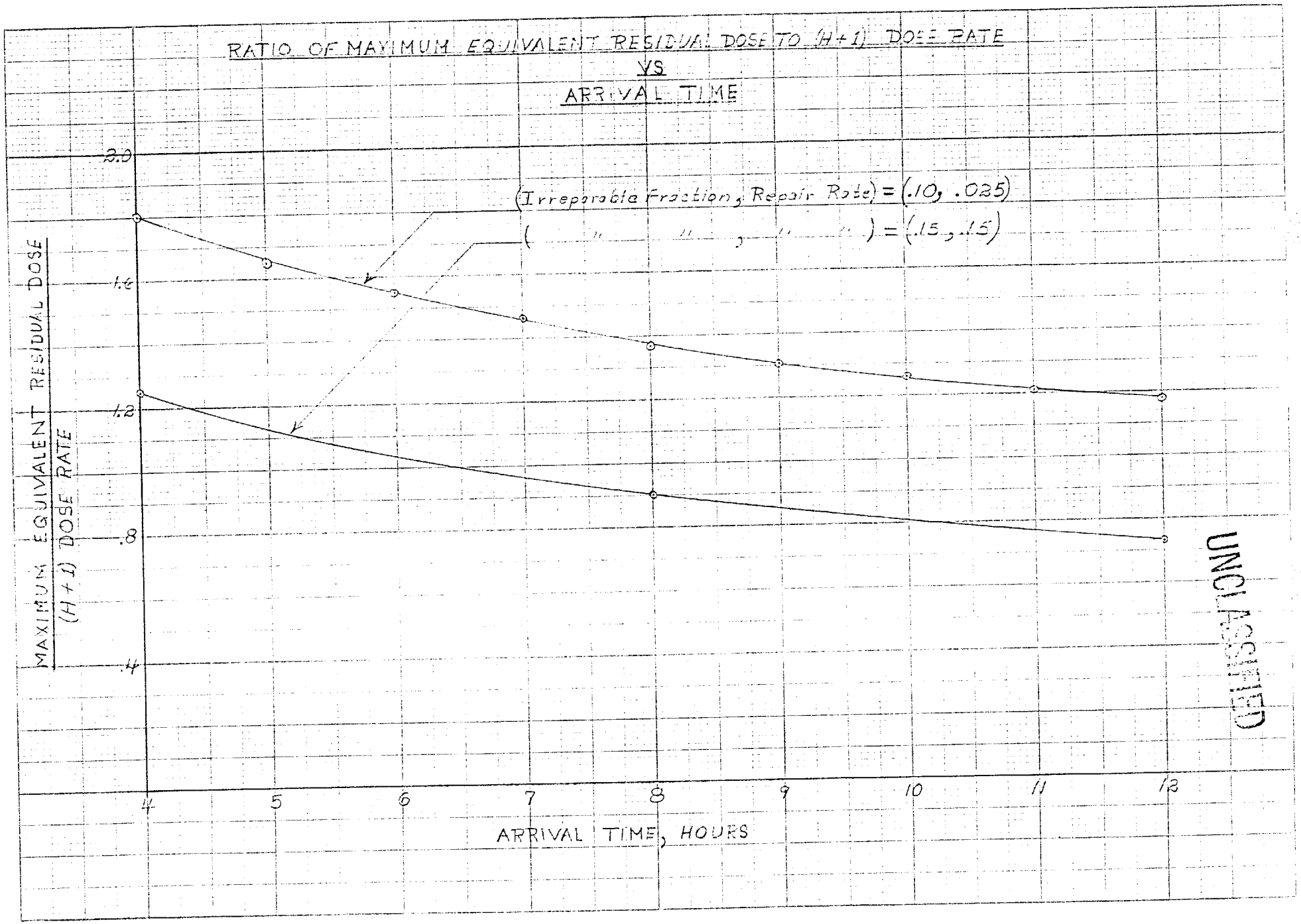

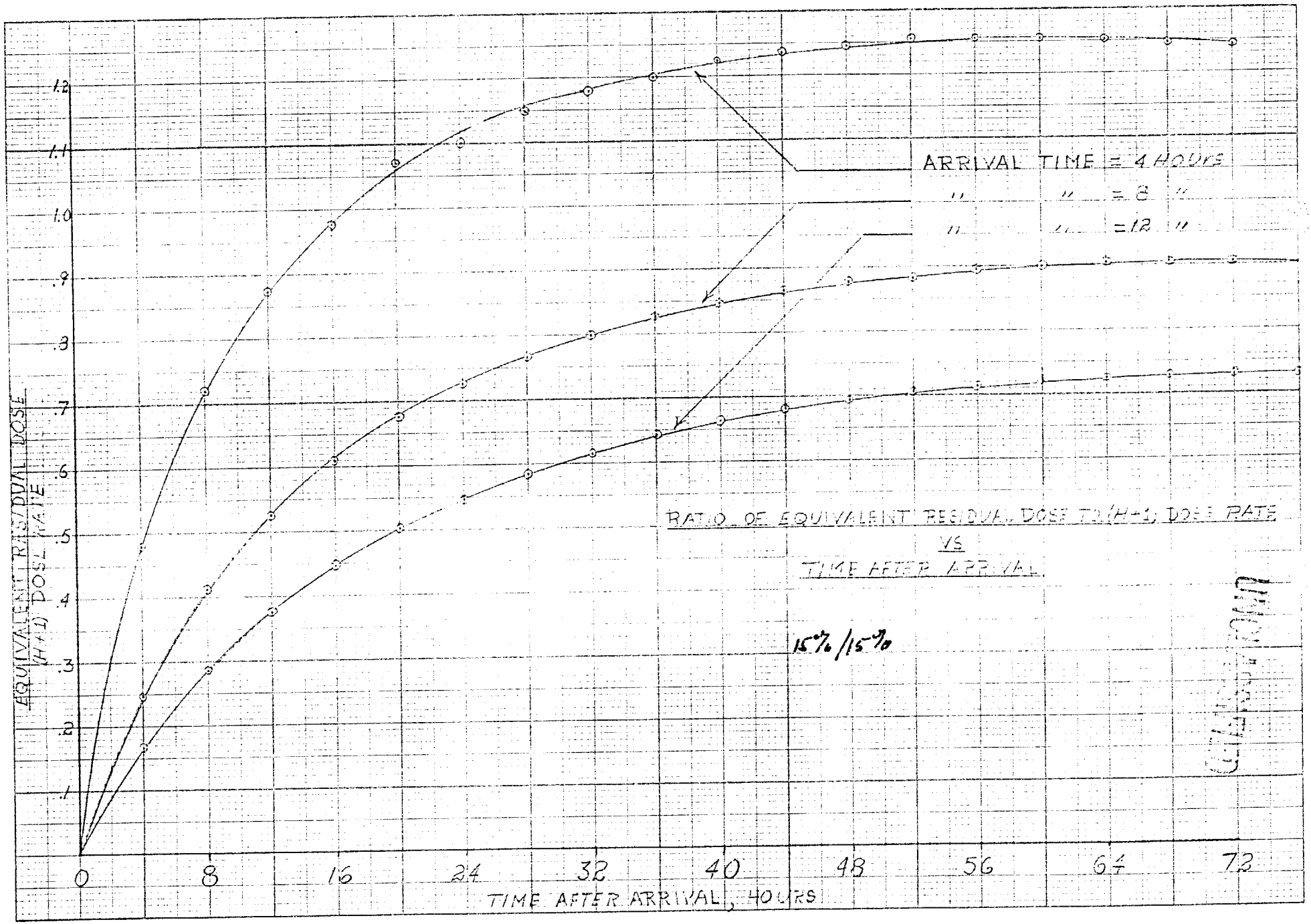

Equivalent Residual Dose Calculations

ily repair rate

action of injury which is irreparable

ival time for fall-out

the time period commencing at t_0

minating at t_K

t_{j-1} = Constant for $j = 1, 2, \ldots, K$

$\frac{\Delta t}{4}$ = repair rate for the time interval Δt

$g(t)$ = dose rate at time t

$(i+1)$ dose rate

: Equivalent Residual Dose at time t

irreparable injury at time t_K

reparable injury ~~which~~ at time t_K which has not been repaired.

$= 0$

$$\frac{ERD(t_1)}{R_0} = \alpha \int_{t_0}^{t_1} g(t)\,dt + (1-\alpha)\int_{t_0}^{t_1} g(t)\,dt - \beta(1-\alpha)\int_{t_0}^{t_1} g(t)\,dt$$

$$= \alpha \int_{t_0}^{t_1} g(t)\,dt + (1-\alpha)(1-\beta)\int_{t_0}^{t_1} g(t)\,dt$$

$$\equiv \frac{I_1^i}{R_0} + \frac{I_1^r}{R_0}$$

$$\frac{ERD(t_2)}{R_0} = \alpha \int_{t_0}^{t_2} g(t)\,dt + (1-\beta)\left[\frac{I_1^r}{R_0} + (1-\alpha)\int_{t_1}^{t_2} g(t)\,dt\right]$$

$$\equiv \frac{I_2^i}{R_0} + \frac{I_2^r}{R_0}$$

$$\frac{ERD(t_3)}{R_0} = \alpha \int_{t_0}^{t_3} g(t)\,dt + (1-\beta)\left[\frac{I_2^r}{R_0} + (1-\alpha)\int_{t_2}^{t_3} g(t)\,dt\right]$$

$$\equiv \frac{I_3^i}{R_0} + \frac{I_3^r}{R_0}$$

$$\vdots$$

$$ERD(t_K) = \alpha \int_{t_0}^{t_K} g(t)\,dt + (1-\beta)\left[\frac{I_{K-1}^r}{R_0} + (1-\alpha)\int_{t_{K-1}}^{t_K} g(t)\,dt\right]$$

$$\equiv \frac{I_K^i}{R_0} + \frac{I_K^r}{R_0}$$

Note: $$\frac{I_K^r}{R_0} = (1-\beta)\left[\frac{I_{K-1}^r}{R_0} + (1-\alpha)\int_{t_{K-1}}^{t_K} g(t)\,dt\right] = (1-\alpha)\sum_{i=1}^{K}(1-\beta)^{(K+1)-i}\int_{t_{i-1}}^{t_i} g(t)\,dt$$

Equivalent Residual Dose Calculations

β' = daily repair rate

α = fraction of injury which is irreparable

t_o = Arrival time for fall-out

Consider the time period commencing at t_o and terminating at t_K

$\Delta t = t_j - t_{j-1}$ = Constant for $j = 1, 2, \ldots, K$

$\beta = \frac{\beta' \Delta t}{24}$ = repair rate for the time interval Δt

$f(t) = R_o\, g(t)$ = dose rate at time t

R_o = (H+1) dose rate

$ERD(t)$ = Equivalent Residual Dose at time t

I_K^i = irreparable injury at time t_K

I_K^r = reparable injury ~~which~~ at time t_K which has not been repaired.

$I_o^r = I_o^i = 0$

$\frac{ERD(t_j)}{R_o}$ =

$\frac{ERD(t_j)}{R_o}$

$\frac{ERD(t_3}{R_o}$

$ERD($

Note:

$$\frac{ERD(t_K)}{R_o} = \alpha \int_{t_o}^{t_K} g(t)dt + (1-\beta)\left[I_{K-1}^r + (1-\alpha)\int_{t_{K-1}}^{t_K} g(t)dt\right]$$

$$= \alpha \int_{t_o}^{t_K} g(t)dt + (1-\alpha)\left[\sum_{i}^{K} (1-\beta)^{K+1-i} \int_{t_{i-1}}^{t_i} g(t)dt\right]$$

α = Fraction of injury which is irreparable

β' = repair rate per day

$\beta = (\beta' \Delta t/24)$

K	t_K	① $\int_{t_o}^{t_K} g(t)dt$	② $\int_{t_{K-1}}^{t_K} g(t)dt$	③ $(1-\alpha)\times$ ②	④ $I_{K-1}^r +$ ③	⑤ $I_K^r = (1-\beta)\times$ ④	⑥ $\alpha \times$ ①	⑦ ⑤+⑥ $\frac{ERD(t_K)}{R_o}$	K
	t_o = Arrival Time = 4 hrs								
0	4	.000	0	0	0	0	0		
			.492						
1	8	.492		.4183	.4182	.4077	.0738	.4815	0
			.255						
2	12	.747		.2168	.6245	.6089	.1121	.7210	1
			.172						
3	16	.919		.1462	.7551	.7363	.1379	.8742	2
			.125						
4	20	1.044		.1063	.8426	.8215	.1566	.9781	3
			.098						
5	24	1.142		.0833	.9259	.9028	.1713	1.0741	4
			.080						
6	28	1.222		.0680	.9502	.9264	.1833	1.1097	5
			.067						
7	32	1.289		.0569	.9833	.9587	.1933	1.1520	6
			.057						
8	36	1.346		.0485	1.0072	.9820	.2019	1.1839	7
			.050						
9	40	1.396		.0425	1.0245	.9989	.2094	1.2083	8
			.044						
10	44	1.440		.0374	1.0363	1.0104	.2160	1.2264	9
			.039						
11	48	1.479		.0332	1.0436	1.0175	.2219	1.2394	10
			.035						
12	52	1.514		.0297	1.0472	1.0210	.2271	1.2481	11
			.032						
13	56	1.546		.0272	1.0482	1.0220	.2319	1.2539	12
			.028						
14	60	1.574		.0238	1.0458	1.0197	.2361	1.2558	13
			.026						
15	64	1.60		.0221	1.0418	1.0157	.2400	1.2557	14
			.023						
16	68	1.623		.0196	1.0353	1.0095	.2434	1.2529	15
			.022						
17	72	1.645		.0187	1.0282	1.0025	.2467	1.2492	16
			.020						
18	76	1.665		.0170	1.0195	.9940	.2497	1.2437	17
			.018						
19	80	1.683		.0153	1.0092	.9840	.2526	1.2366	18
			.017						
20	84	1.70		.0145					19
21									
22									

Note: $\int_{t_o}^{t_K} g(t)dt$ were read from Nicks Nomograms

Δt = 4 hrs

$\alpha = 15\% \Rightarrow \boxed{(1-\alpha) = .85}$

$\beta' = 15\% \Rightarrow \beta = \frac{.15 \times .4}{2.4} = .025 \Rightarrow \boxed{(1-\beta) = .975}$

I^r = reparable Injury which has not been repaired

$f(t) = R_0 g(t)$

$f(t)$ = dose rate at time t

(1) t_K	(2) $\int_{t_0}^{t_K} g(t)dt$	(3) $\int_{t_{K-1}}^{t_K} g(t)dt$	(4) $(1-\alpha) \times$ (3)	(5) $I^r_{K-1} \div$ (4)	(6) $I^r_K = (1-\beta) \times$ (5)	(7) $\alpha \times$ (2)	8 (6) + (7) $ERD(t_K)$
t_0 = Arrival time = 8 hrs							
8	0	0	0	0	0	0	0
12	.255	.255	.2168	.2168	.2114	.0383	.2497
16	.427	.172	.1462	.3576	.3486	.0641	.4127
20	.552	.125	.1063	.4549	.4436	.0828	.5264
24	.650	.098	.0833	.5269	.5137	.0975	.6112
28	.730	.080	.0680	.5817	.5672	.1095	.6767
32	.797	.067	.0569	.6241	.6085	.1196	.7281
36	.854	.057	.0485	.6570	.6405	.1281	.7686
40	.904	.050	.0425	.6830	.6660	.1356	.8016
44	.948	.044	.0374	.7034	.6858	.1422	.8280
48	.987	.039	.0332	.7190	.7010	.1481	.8491
52	1.022	.035	.0297	.7307	.7124	.1533	.8657
56	1.054	.032	.0272	.7396	.7211	.1581	.8792
60	1.082	.028	.0238	.7449	.7263	.1623	.8886
64	1.108	.026	.0221	.7484	.7297	.1662	.8959
68	1.131	.023	.0196	.7493	.7305	.1697	.9002
72	1.153	.022	.0187	.7493	.7305	.1730	.9035
76	1.173	.020	.0170	.7475	.7288	.1760	.9048
80	1.191	.018	.0153	.7441	.7255	.1787	.9042
84	1.208	.017	.0145	.7400	.7215	.1812	.9027

t_0 = Arrival Time = 12 hrs

$P(t) = K_0 g(t) = K_0 t^{-1.2}$

$(1-\alpha) = .85$

$(1-\beta) = .975$

K_0 = unit dose rate

K	t_K	① $\int_{t_0}^{t_K} g(t)dt$	② $\int_{t_{K-1}}^{t_K} g(t)dt$	③ $(1-\alpha)\times$②	④ ⑤$_{K-1}$ + ③	⑤ $(1-\beta)\times$④	⑥ $\alpha\times$②	⑦ ⑤ + ⑥ ERD(t_K)
0	12	0	0	0	0	0	0	0
1	16	.172	.172	.1463	.1463	.1425	.0258	.1683
2	20	.297	.125	.1062	.2488	.2426	.0446	.2872
3	24	.395	.098	.0833	.3459	.3372	.0593	.3971
4	28	.471	.076	.0646	.3858	.3761	.0713	.4474
5	32	.542	.067	.0569	.4230	.4123	.0813	.5035
6	36	.594	.057	.0485	.4707	.4589	.0898	.5487
7	40	.647	.053	.0425	.5014	.4889	.0974	.5863
8	44	.693	.044	.0374	.5263	.5131	.1040	.6171
9	48	.732	.039	.0332	.5463	.5327	.1098	.6425
10	52	.767	.035	.0297	.5624	.5482	.1151	.6634
11	56	.799	.032	.0272	.5755	.5611	.1199	.6810
12	60	.827	.028	.0238	.5849	.5703	.1241	.6944
13	64	.853	.026	.0221	.5924	.5776	.1279	.7055
14	68	.876	.023	.0196	.5972	.5823	.1314	.7137
15	72	.895	.019	.0162	.6010	.5859	.1347	.7206
16	76	.913	.018	.0170	.6027	.5874	.1377	.7256
17	80	.930	.017	.0153	.6032	.5881	.1404	.7285
18	84	.943	.013	.0145	.6026	.5875	.1430	.7305
19	88	.956	.013	.0136	.6011	.5861	.1454	.7315
20	92	.968	.012	.0128	.5989	.5839	.1476	.7315