

H 6/26/63

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Equivalent Residual Dose Calculations At Vincent 25 June 63

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

The important point is to compare the ERD(t_k) to the ERD(t_{k-1}) and to see if the dose rate is decreasing. The ERD(t_k) is the sum of the irreparable injury at time t_k plus the repair of the injury at time t_{k-1}. The repair of the injury at time t_{k-1} is given by (1-β)I_{k-1}^r. The repair of the injury at time t_{k-2} is given by (1-β)²I_{k-2}^r. The repair of the injury at time t_{k-3} is given by (1-β)³I_{k-3}^r. The repair of the injury at time t_{k-4} is given by (1-β)⁴I_{k-4}^r. The repair of the injury at time t_{k-5} is given by (1-β)⁵I_{k-5}^r. The repair of the injury at time t_{k-6} is given by (1-β)⁶I_{k-6}^r. The repair of the injury at time t_{k-7} is given by (1-β)⁷I_{k-7}^r. The repair of the injury at time t_{k-8} is given by (1-β)⁸I_{k-8}^r. The repair of the injury at time t_{k-9} is given by (1-β)⁹I_{k-9}^r. The repair of the injury at time t_{k-10} is given by (1-β)¹⁰I_{k-10}^r. The repair of the injury at time t_{k-11} is given by (1-β)¹¹I_{k-11}^r. The repair of the injury at time t_{k-12} is given by (1-β)¹²I_{k-12}^r. The repair of the injury at time t_{k-13} is given by (1-β)¹³I_{k-13}^r. The repair of the injury at time t_{k-14} is given by (1-β)¹⁴I_{k-14}^r. The repair of the injury at time t_{k-15} is given by (1-β)¹⁵I_{k-15}^r. The repair of the injury at time t_{k-16} is given by (1-β)¹⁶I_{k-16}^r. The repair of the injury at time t_{k-17} is given by (1-β)¹⁷I_{k-17}^r. The repair of the injury at time t_{k-18} is given by (1-β)¹⁸I_{k-18}^r. The repair of the injury at time t_{k-19} is given by (1-β)¹⁹I_{k-19}^r. The repair of the injury at time t_{k-20} is given by (1-β)²⁰I_{k-20}^r. The repair of the injury at time t_{k-21} is given by (1-β)²¹I_{k-21}^r. The repair of the injury at time t_{k-22} is given by (1-β)²²I_{k-22}^r. The repair of the injury at time t_{k-23} is given by (1-β)²³I_{k-23}^r. The repair of the injury at time t_{k-24} is given by (1-β)²⁴I_{k-24}^r. The repair of the injury at time t_{k-25} is given by (1-β)²⁵I_{k-25}^r. The repair of the injury at time t_{k-26} is given by (1-β)²⁶I_{k-26}^r. The repair of the injury at time t_{k-27} is given by (1-β)²⁷I_{k-27}^r. The repair of the injury at time t_{k-28} is given by (1-β)²⁸I_{k-28}^r. The repair of the injury at time t_{k-29} is given by (1-β)²⁹I_{k-29}^r. The repair of the injury at time t_{k-30} is given by (1-β)³⁰I_{k-30}^r. The repair of the injury at time t_{k-31} is given by (1-β)³¹I_{k-31}^r. The repair of the injury at time t_{k-32} is given by (1-β)³²I_{k-32}^r. The repair of the injury at time t_{k-33} is given by (1-β)³³I_{k-33}^r. The repair of the injury at time t_{k-34} is given by (1-β)³⁴I_{k-34}^r. The repair of the injury at time t_{k-35} is given by (1-β)³⁵I_{k-35}^r. The repair of the injury at time t_{k-36} is given by (1-β)³⁶I_{k-36}^r. The repair of the injury at time t_{k-37} is given by (1-β)³⁷I_{k-37}^r. The repair of the injury at time t_{k-38} is given by (1-β)³⁸I_{k-38}^r. The repair of the injury at time t_{k-39} is given by (1-β)³⁹I_{k-39}^r. The repair of the injury at time t_{k-40} is given by (1-β)⁴⁰I_{k-40}^r. The repair of the injury at time t_{k-41} is given by (1-β)⁴¹I_{k-41}^r. The repair of the injury at time t_{k-42} is given by (1-β)⁴²I_{k-42}^r. The repair of the injury at time t_{k-43} is given by (1-β)⁴³I_{k-43}^r. The repair of the injury at time t_{k-44} is given by (1-β)⁴⁴I_{k-44}^r. The repair of the injury at time t_{k-45} is given by (1-β)⁴⁵I_{k-45}^r. The repair of the injury at time t_{k-46} is given by (1-β)⁴⁶I_{k-46}^r. The repair of the injury at time t_{k-47} is given by (1-β)⁴⁷I_{k-47}^r. The repair of the injury at time t_{k-48} is given by (1-β)⁴⁸I_{k-48}^r. The repair of the injury at time t_{k-49} is given by (1-β)⁴⁹I_{k-49}^r. The repair of the injury at time t_{k-50} is given by (1-β)⁵⁰I_{k-50}^r. The repair of the injury at time t_{k-51} is given by (1-β)⁵¹I_{k-51}^r. The repair of the injury at time t_{k-52} is given by (1-β)⁵²I_{k-52}^r. The repair of the injury at time t_{k-53} is given by (1-β)⁵³I_{k-53}^r. The repair of the injury at time t_{k-54} is given by (1-β)⁵⁴I_{k-54}^r. The repair of the injury at time t_{k-55} is given by (1-β)⁵⁵I_{k-55}^r. The repair of the injury at time t_{k-56} is given by (1-β)⁵⁶I_{k-56}^r. The repair of the injury at time t_{k-57} is given by (1-β)⁵⁷I_{k-57}^r. The repair of the injury at time t_{k-58} is given by (1-β)⁵⁸I_{k-58}^r. The repair of the injury at time t_{k-59} is given by (1-β)⁵⁹I_{k-59}^r. The repair of the injury at time t_{k-60} is given by (1-β)⁶⁰I_{k-60}^r. The repair of the injury at time t_{k-61} is given by (1-β)⁶¹I_{k-61}^r. The repair of the injury at time t_{k-62} is given by (1-β)⁶²I_{k-62}^r. The repair of the injury at time t_{k-63} is given by (1-β)⁶³I_{k-63}^r. The repair of the injury at time t_{k-64} is given by (1-β)⁶⁴I_{k-64}^r. The repair of the injury at time t_{k-65} is given by (1-β)⁶⁵I_{k-65}^r. The repair of the injury at time t_{k-66} is given by (1-β)⁶⁶I_{k-66}^r. The repair of the injury at time t_{k-67} is given by (1-β)⁶⁷I_{k-67}^r. The repair of the injury at time t_{k-68} is given by (1-β)⁶⁸I_{k-68}^r. The repair of the injury at time t_{k-69} is given by (1-β)⁶⁹I_{k-69}^r. The repair of the injury at time t_{k-70} is given by (1-β)⁷⁰I_{k-70}^r. The repair of the injury at time t_{k-71} is given by (1-β)⁷¹I_{k-71}^r. The repair of the injury at time t_{k-72} is given by (1-β)⁷²I_{k-72}^r. The repair of the injury at time t_{k-73} is given by (1-β)⁷³I_{k-73}^r. The repair of the injury at time t_{k-74} is given by (1-β)⁷⁴I_{k-74}^r. The repair of the injury at time t_{k-75} is given by (1-β)⁷⁵I_{k-75}^r. The repair of the injury at time t_{k-76} is given by (1-β)⁷⁶I_{k-76}^r. The repair of the injury at time t_{k-77} is given by (1-β)⁷⁷I_{k-77}^r. The repair of the injury at time t_{k-78} is given by (1-β)⁷⁸I_{k-78}^r. The repair of the injury at time t_{k-79} is given by (1-β)⁷⁹I_{k-79}^r. The repair of the injury at time t_{k-80} is given by (1-β)⁸⁰I_{k-80}^r. The repair of the injury at time t_{k-81} is given by (1-β)⁸¹I_{k-81}^r. The repair of the injury at time t_{k-82} is given by (1-β)⁸²I_{k-82}^r. The repair of the injury at time t_{k-83} is given by (1-β)⁸³I_{k-83}^r. The repair of the injury at time t_{k-84} is given by (1-β)⁸⁴I_{k-84}^r. The repair of the injury at time t_{k-85} is given by (1-β)⁸⁵I_{k-85}^r. The repair of the injury at time t_{k-86} is given by (1-β)⁸⁶I_{k-86}^r. The repair of the injury at time t_{k-87} is given by (1-β)⁸⁷I_{k-87}^r. The repair of the injury at time t_{k-88} is given by (1-β)⁸⁸I_{k-88}^r. The repair of the injury at time t_{k-89} is given by (1-β)⁸⁹I_{k-89}^r. The repair of the injury at time t_{k-90} is given by (1-β)⁹⁰I_{k-90}^r. The repair of the injury at time t_{k-91} is given by (1-β)⁹¹I_{k-91}^r. The repair of the injury at time t_{k-92} is given by (1-β)⁹²I_{k-92}^r. The repair of the injury at time t_{k-93} is given by (1-β)⁹³I_{k-93}^r. The repair of the injury at time t_{k-94} is given by (1-β)⁹⁴I_{k-94}^r. The repair of the injury at time t_{k-95} is given by (1-β)⁹⁵I_{k-95}^r. The repair of the injury at time t_{k-96} is given by (1-β)⁹⁶I_{k-96}^r. The repair of the injury at time t_{k-97} is given by (1-β)⁹⁷I_{k-97}^r. The repair of the injury at time t_{k-98} is given by (1-β)⁹⁸I_{k-98}^r. The repair of the injury at time t_{k-99} is given by (1-β)⁹⁹I_{k-99}^r. The repair of the injury at time t_{k-100} is given by (1-β)¹⁰⁰I_{k-100}^r.

$$ERD(t_k) = \int_0^{t_k} g(t) dt + (1-\alpha) \left[\sum_{i=1}^k (1-\beta)^{k+1-i} \int_{t_{i-1}}^{t_i} g(t) dt \right] \quad (1)$$

$$\frac{I_k^i}{R_0} + \frac{I_k^r}{R_0} \quad (2)$$

ERD(t_k) = Equivalent Residual dose at time t_k

α = irreparable fraction = .15

g(t) = t^{-1.2} = ~~the~~ dose rate at time t / R₀

R₀ = (H+1) dose rate

β' = daily repair rate = .15

β = $\frac{\Delta t \beta'}{24}$

Δt = t_j - t_{j-1} = 4 hrs, j = 1, 2, ..., k

I_kⁱ = irreparable injury at time t_k

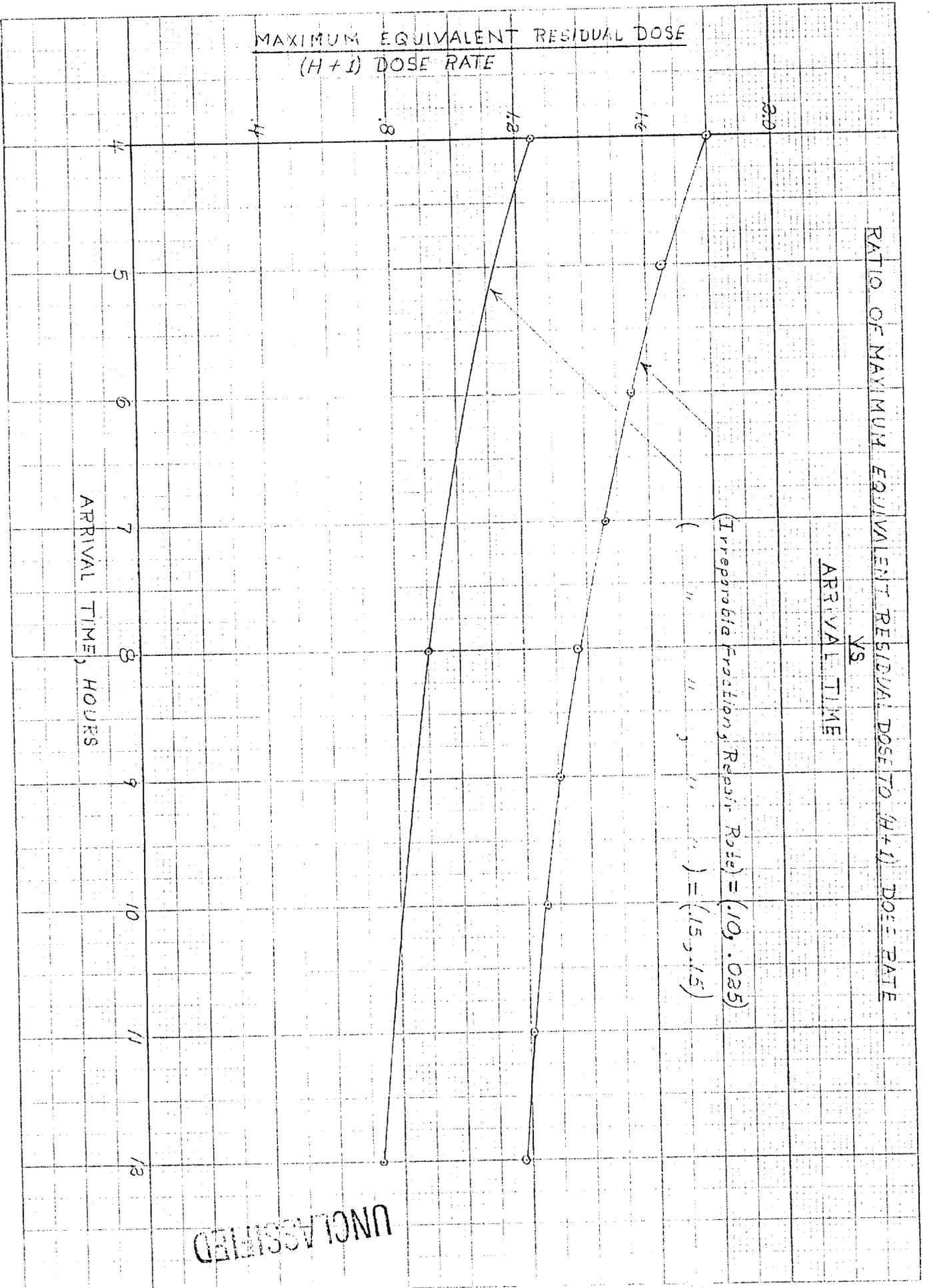
I_k^r = reparable injury at time t_k which has not been repaired

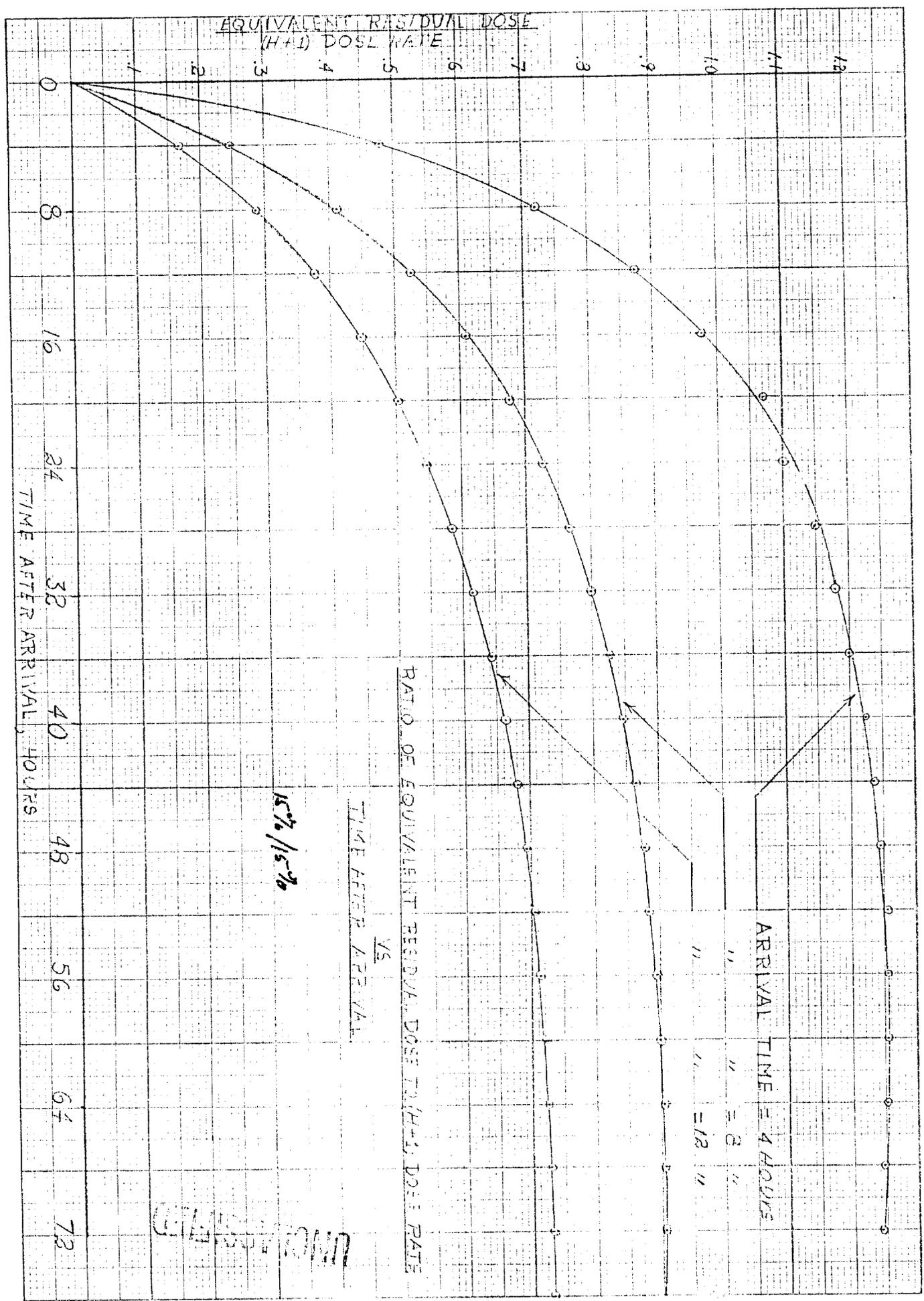
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Note:
$$\frac{I_k^r}{R_0} = (1-\beta) \left[\frac{I_{k-1}^r}{R_0} + (1-\alpha) \int_{t_{k-1}}^{t_k} g(t) dt \right] \quad (3)$$

where I₀^r = 0

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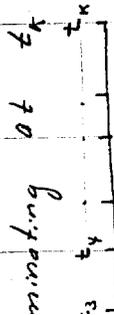


15% / 15-90

Equivalent Residual Dose Calculations

irreparable repair rate
 action of injury which is irreparable
 time for fall-out

the time period commencing at t_0



t_{j-1} = constant for $j = 1, 2, \dots, k$

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

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

I_{j-1} dose rate

I_{k-1} : Equivalent Residual Dose at time t

irreparable injury at time t_k

reparable injury which at time t_k
 which has not been repaired.

$= 0$

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

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

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

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

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

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

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

$$ERD(t_k) = \alpha \int_{t_0}^{t_k} g(t) dt + (1-\beta) \left[\frac{I_{k-1}^i}{R_0} + (1-\alpha) \int_{t_{k-1}}^{t_k} g(t) dt \right]$$

$$= \frac{I_k^i}{R_0} + \frac{I_k^r}{R_0}$$

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

Equivalent Residual Dose Calculations

β' = daily repair rate

d = fraction of injury which is irreparable

t_0 = Arrival time for fall-out

Consider the time period commencing at t
and terminating at t_k



$\Delta t = t_j - t_{j-1} = \text{Constant for } j = 1, 2, \dots, k$

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

$f(t) = R_0 g(t) = \text{dose rate at time } t$

$R_0 = (H+1) \text{ dose rate}$

$ERD(t) = \text{Equivalent Residual Dose at time } t$

$I_k^i = \text{irreparable injury at time } t_k$

$I_k^r = \text{reparable injury which at time } t_k \text{ which has not been repaired.}$

$I_0^r = I_0^i = 0$

$\frac{ERD(t)}{R_0} =$

$\frac{ERD(t)}{R_0}$

$\frac{ERD(t)}{R_0}$

$ERD(t)$

Note:

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

$$= \alpha \int_{t_0}^{t_k} g(t) dt + (1-\alpha) \left[\sum_{i=1}^k (1-\beta)^{k+1-i} \int_{t_{i-1}}^{t_i} g(t) dt \right]$$

α = Fraction of injury which is irreparable
 β = repair rate per day
 $\beta = (\beta' \Delta t / 24)$

	①	②	③	④	⑤	⑥	⑦	⑧	
K	t_k	$\int_{t_0}^{t_k} g(t) dt$	$\int_{t_{k-1}}^{t_k} g(t) dt$	$(1-\alpha) \times$ ③	$I_{k-1}^r +$ ④	$I_k^r = (1-\beta) \times$ ⑤	$\alpha \times$ ②	$\frac{⑥+⑦}{R_0}$	K
	$t_0 = \text{Ancestral Time} = 4 \text{ hrs}$								
0	4	.000	0	0	0	0	0		
1	8	.492	.492	.4133	.4182	.4077	.0738	.4815	0
2	12	.747	.255	.2168	.6245	.6089	.1121	.7210	1
3	16	.919	.172	.1462	.7551	.7363	.1379	.8742	2
4	20	1.044	.125	.1063	.8426	.8215	.1566	.9781	3
5	24	1.142	.098	.0823	.8823	.9048	.1713	1.0761	4
6	28	1.222	.080	.0680	.9502	.9264	.1833	1.1097	5
7	32	1.284	.067	.0569	.9833	.9587	.1933	1.1526	6
8	36	1.346	.057	.0485	1.0072	.9820	.2019	1.1839	7
9	40	1.396	.050	.0425	1.0245	.9989	.2094	1.2083	8
10	44	1.440	.044	.0374	1.0363	1.0104	.2160	1.2264	9
11	48	1.479	.039	.0332	1.0436	1.0175	.2219	1.2394	10
12	52	1.514	.035	.0297	1.0472	1.0210	.2271	1.2481	11
13	56	1.546	.032	.0272	1.0482	1.0220	.2319	1.2539	12
14	60	1.574	.028	.0238	1.0458	1.0197	.2361	1.2558	13
15	64	1.60	.026	.0221	1.0418	1.0157	.2400	1.2557	14
16	68	1.623	.023	.0196	1.0353	1.0095	.2434	1.2529	15
17	72	1.645	.022	.0187	1.0282	1.0025	.2467	1.2492	16
18	76	1.665	.020	.0170	1.0195	.9940	.2497	1.2437	17
19	80	1.683	.018	.0153	1.0092	.9840	.2526	1.2366	18
20	84	1.70	.017	.0145					19
21	88								
22	90								

Note: $\int_{t_0}^{t_k} g(t) dt$ were read from Nicks Nannograms

$\Delta z = 4 \text{ hrs}$

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

$\beta = 15\% \Rightarrow \beta = \frac{.15 \times 4}{2.4} = .25 \Rightarrow (1-\beta) = .75$

$I^r = \text{reparable injury which has not been repaired}$

$g(t)dt$

$F(t) = R_0 g(t)$

$f(t) = \text{dose rate at time } t$

① t_k	② $\int_0^{t_k} g(t)dt$	③ $\int_{t_{k-1}}^{t_k} g(t)dt$	④ $(1-\alpha) \times ③$	⑤ $I_{k-1}^r + ④$	⑥ $I_k^r = (1-\alpha) \times ⑤$	⑦ $\alpha \times ②$	⑧+⑦ FRD(t_k)
$t_0 = \text{Arrival time} = 8 \text{ hrs}$							
8	0	0	0	0	0	0	0
12	.255	.255	.2168	.2168	.2114	.0383	.3497
16	.427	.172	.1462	.3576	.3486	.0641	.4127
20	.552	.125	.1063	.4549	.4436	.0523	.5234
24	.650	.098	.0833	.5269	.5137	.0775	.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	.8826
64	1.108	.026	.0221	.7484	.7297	.1662	.8959
68	1.131	.023	.0196	.7493	.7305	.1697	.9003
72	1.153	.022	.0187	.7443	.7305	.1736	.9035
76	1.173	.020	.0170	.7475	.7288	.1760	.9048
80	1.191	.018	.0153	.7441	.7255	.1787	.9043
84	1.208	.017	.0145	.7400	.7215	.1812	.9027

$t_0 = \text{Arrival Time} = 12 \text{ hrs}$

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

$(1-\alpha) = .85$

$(1-\beta) = .975$

$K_0 = 1141 \text{ dose rate}$

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	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
	K	t_k	$\int_{t_0}^k g(t) dt$	$\int_{t_{k-1}}^k g(t) dt$	$(1-\alpha) \times (3)$	$\sum_{k=1}^n (4)$	$(1-\beta) \times (6)$	$\alpha \times (7)$	(6)+(7) ERD(t_k)
0	12	0	0	0	0	0	0	0	0
1	16	.173	.173	.173	.1463	.1463	.1463	.0358	.1633
2	20	.247	.247	.073	.1063	.2486	.2486	.0446	.2872
3	24	.311	.311	.068	.0833	.3259	.3259	.0593	.3711
4	28	.375	.375	.050	.0680	.3858	.3858	.0713	.4474
5	32	.439	.439	.037	.0569	.4330	.4330	.0813	.5035
6	36	.503	.503	.027	.0485	.4707	.4707	.0898	.5487
7	40	.567	.567	.020	.0425	.5014	.4889	.0974	.5863
8	44	.631	.631	.015	.0374	.5263	.5131	.1040	.6171
9	48	.695	.695	.011	.0332	.5463	.5327	.1098	.6425
10	52	.759	.759	.008	.0297	.5624	.5482	.1151	.6634
11	56	.823	.823	.006	.0272	.5755	.5611	.1199	.6810
12	60	.887	.887	.004	.0253	.5849	.5703	.1241	.6944
13	64	.951	.951	.003	.0238	.5924	.5776	.1279	.7055
14	68	.1015	.1015	.002	.0196	.5972	.5823	.1314	.7137
15	72	.1079	.1079	.001	.0187	.6010	.5859	.1347	.7206
16	76	.1143	.1143	.001	.0170	.6039	.5879	.1377	.7256
17	80	.1207	.1207	.001	.0153	.6032	.5881	.1404	.7285
18	84	.1271	.1271	.001	.0145	.6026	.5875	.1430	.7305
19	88	.1335	.1335	.001	.0136	.6011	.5861	.1454	.7315
20	92	.1399	.1399	.001	.0128	.5989	.5839	.1476	.7315