This info was for 1963-I
H 6/26/63

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Equivalent Residual Dose Calculations

Al Vincent 25 June 63

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

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

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

The important point is not to mix discrete and continuous models in the same calculation. The error due to the discrete nos. used for lack of time, hopefully the errors associated with discreteness are cancelled out in the comparison of interest which was the purpose of this exercise. H.

[illegible]

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

α = irreparable fraction = .15

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

R_o = (H+1) dose rate

β' = daily repair rate = .15

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

$\Delta t = t_j - t_{j-1}$ = 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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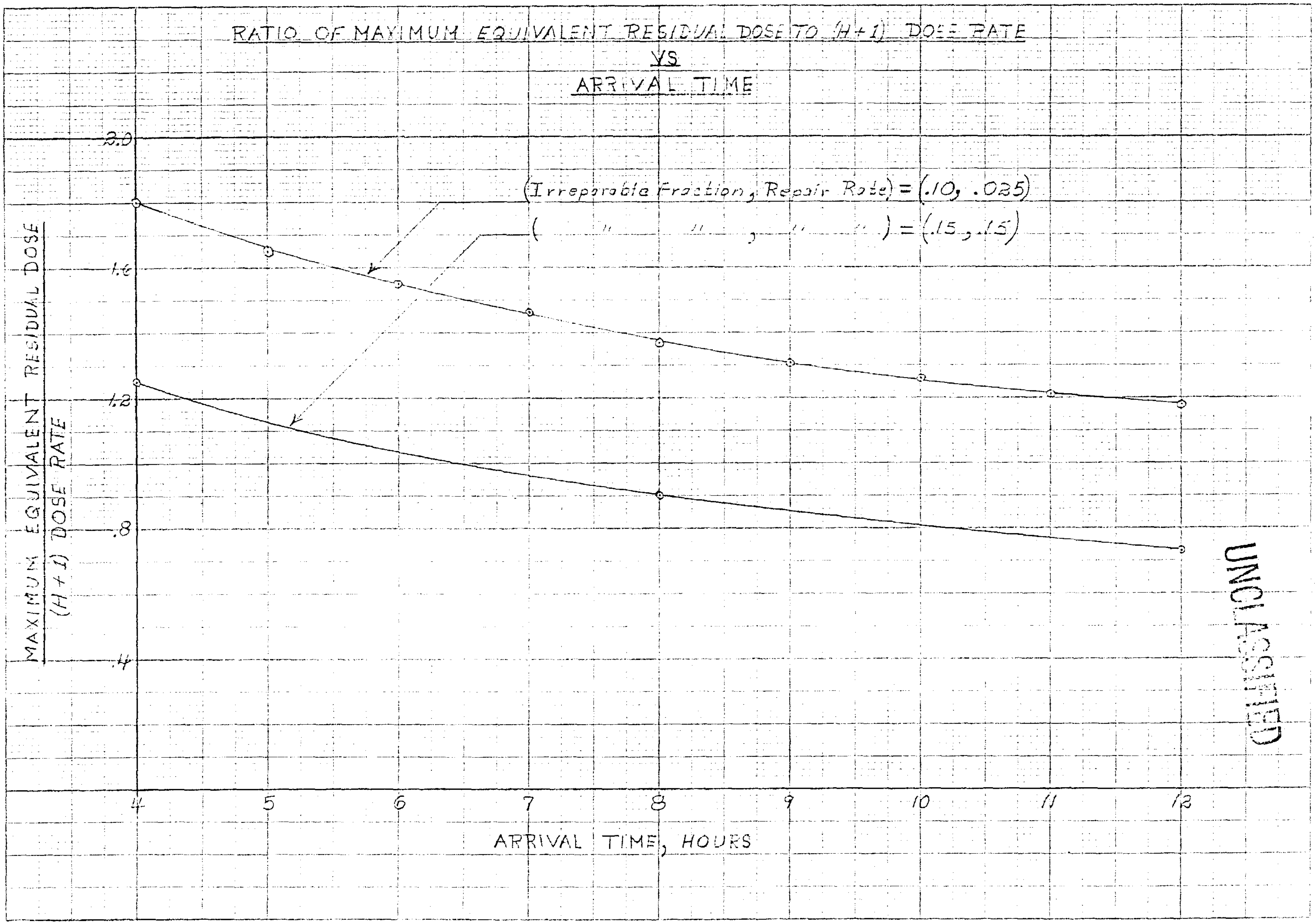
RATIO OF MAXIMUM EQUIVALENT RESIDUAL DOSE TO (H+1) DOSE RATE
VS
ARRIVAL TIME
(Irreparable Fraction, Repair Rate) = (.10, .025)
(" " , " ") = (.15, .15)
MAXIMUM EQUIVALENT RESIDUAL DOSE / (H+1) DOSE RATE
2.0
1.6
1.2
.8
.4
4
5
6
7
8
9
10
11
12
ARRIVAL TIME, HOURS
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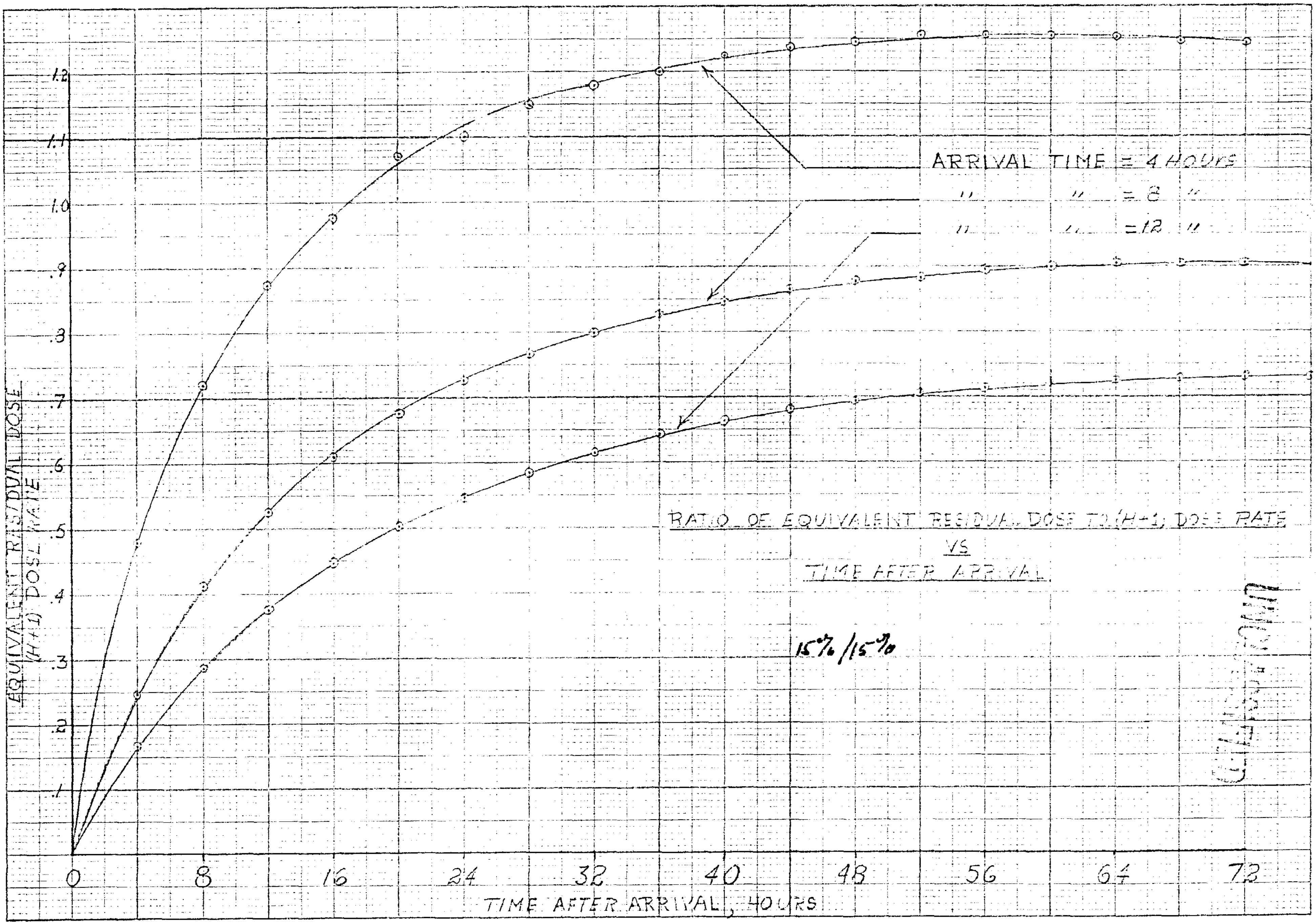
EQUIVALENT RESIDUAL DOSE
(H+1) DOSE RATE
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
0
8
16
24
32
40
48
56
64
72
TIME AFTER ARRIVAL, HOURS
ARRIVAL TIME = 4 HOURS
" " = 8 "
" " = 12 "
RATIO OF EQUIVALENT RESIDUAL DOSE TO (H+1) DOSE RATE
VS
TIME AFTER ARRIVAL
15%/15%

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

$t_3 \quad t_4 \quad \cdot \quad \cdot \quad \cdot \quad t_K$

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

$(+1)$ dose rate

: Equivalent Residual Dose at time t

irreparable injury at time t_K

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

$= 0$

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

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

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

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

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

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

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

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

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

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

Equivalent Residual Dose Calculations

$\beta' =$ daily repair rate

$\alpha =$ 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

$t_o \quad t_1 \quad t_2 \quad t_3 \quad t_4 \quad \cdot \quad \cdot \quad \cdot \quad t_K$

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

$\beta = \dfrac{\beta' \Delta t}{24} =$ 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.

$I_o^r = I_o^i = 0$

$\dfrac{ERD(t_1)}{R_o} =$

$\dfrac{ERD(t_2)}{R_o}$

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

$ERD($

Note:

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

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

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	$I^r_{K-1}+$④	$I^r_K=(1-\beta)\times$⑤	$\alpha\times$②	⑥+⑦ $\frac{ERD(t_K)}{R_0}$	K
	t_0 = Arrival Time = 4 hrs								
0	4	.000	0	0	0	0	0		
1	8	.492	.492	.4183	.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	.0833	.8822	.9048	.1713	1.0761	4
6	28	1.222	.080	.0680	.9502	.9264	.1833	1.1097	5
7	32	1.289	.067	.0569	.9833	.9587	.1933	1.1520	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	$\boxed{1.2558}$	13
15	64	1.60	.026	.0221	1.0418	1.0157	.2400	$\boxed{1.2557}$	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	[illegible]								
22	[illegible]								

Note: $\int_{t_0}^{t_K} g(t)\,dt$ were read from Nicks Nomograms

$\Delta t = 4$ hrs

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

$\beta' = 15\% \Rightarrow \beta = \frac{.15 \times}{24} = .025 \Rightarrow \boxed{(1-\beta) = .975}$

I^r = reparable Injury which has not been repaired

$\frac{\ldots}{R_0} = \ldots_{k-1} \ldots \int_{t_{k-1}} g(t)\,dt$

$\dot{\rho}(t) = R_0\, g(t)$

$\dot{\rho}(t)$ = dose rate at time t

①	②	③	④	⑤	⑥	⑦	8
t_k	$\int_{t_0}^{t_k} g(t)dt$	$\int_{t_{k-1}}^{t_k} g(t)dt$	$(1-\alpha)\times$③	$I^r_{k-1}+$④	$I^r_k=(1-\beta)\times$⑤	$\alpha\times$②	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
[illegible]	.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	.9002
72	1.153	.022	.0187	.7493	.7305	.1730	.9035
76	1.173	.020	.0170	.7475	.7288	.1760	$\boxed{.9048}$
80	1.191	.018	.0153	.7411	.7255	.1787	.9042
84	1.208	.017	.0145	.7400	.7215	.1812	.9027

t_0 = Arrival Time = 12 hrs

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

K_0 = H+1 dose rate

$(1-\alpha) = .85$

$(1-\beta) = .975$

	(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} + (4)	$I_i = (1-\beta) \times$ (5)	$\alpha \times$ (2)	(6) + (7) ERD (t_K)
0	12	0	0	0	0	0	0	0
1	16	.172	.172	.1462	.1462	.1425	.0258	.1683
2	20	.297	.125	.1063	.2488	.2426	.0446	.2592
3	24	.390	.093	.0833	.3239	.3178	.0593	.3771
4	28	[illegible]	.080	.0680	.3858	.3761	.0713	.4474
5	32	.542	.067	.0569	.4330	.4223	.0813	.5035
6	36	.599	.057	.0485	.4707	.4589	.0898	.5487
7	40	.649	.050	.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	.5483	.1151	.6634
11	56	.799	.032	.0223	.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	.898	.022	.0187	.6010	.5859	.1347	.7206
16	76	.918	.020	.0170	.6029	.5879	.1377	.7256
17	80	.936	.018	.0153	.6032	$\boxed{.5881}$	.1404	.7285
18	84	.953	.017	.0145	.6026	.5875	.1430	.7305
19	88	.969	.016?	.0136	.6011	.5861	.1454	$\boxed{.7315}$
20	92	.984	.015?	.0128	.5989	.5839	.1476	$\boxed{.7315}$