

## TABLES FOR USE IN NSD CALCULATIONS

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The concept of Nominal Standard Dose (NSD) is finding increasing use in radiation therapy and while slide rules (WINSTON et coll. 1969, RAO 1972) and tables (KROENING & DEITERMAN 1971) have been prepared to aid in the calculation of NSD, the tables presented here do provide greater versatility and ease of use than those previously published. The work reported here was done before the report by ORTON & ELLIS (1973) describing the time, dose and fractionation factor (TDF) and represents an alternative approach which is, perhaps, not so far removed from the original NSD concept.

The concept of NSD was recently introduced in the output of a computer program (JONES & WASHINGTON 1973) for external beam calculations and the following is extracted from a manual describing the service. It is intended as a guide to the therapist who is already acquainted with original papers describing the NSD concept and its limitations (ELLIS 1968, 1969, 1971, FOWLER 1971, LIVERSAGE 1971, PROBERT 1971).

The NSD is defined as follows:

$$\text{NSD} = \frac{\text{T.D.}}{N^{0.24} \times T^{0.11}}$$

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**Table 1**  
*Three fractions per week*

Treat	Mon, Wed, Fri						Mon, Tue, Thu		
Start	Mon		Wed		Fri		Mon		Tue
N	T	$\frac{N^{0.76}}{T^{0.11}}$	T	$\frac{N^{0.76}}{T^{0.11}}$	T	$\frac{N^{0.76}}{T^{0.11}}$	T	$\frac{N^{0.76}}{T^{0.11}}$	T
4	7	2.32	7	2.32	7	2.32	7	2.32	7
5	9	2.67	9	2.67	10	2.64	8	2.70	9
6	11	3.00	12	2.97	12	2.97	10	3.03	13
7	14	3.28	14	3.28	14	3.28	14	3.28	14
8	16	3.58	16	3.58	17	3.56	15	3.61	16
9	18	3.86	19	3.84	19	3.84	17	3.89	20
10	21	4.12	21	4.12	21	4.12	21	4.12	21
11	23	4.38	23	4.38	24	4.36	22	4.40	23
12	25	4.64	26	4.62	26	4.62	24	4.66	27
13	28	4.87	28	4.87	28	4.87	28	4.87	28
14	30	5.11	30	5.11	31	5.09	29	5.13	30
15	32	5.35	33	5.33	33	5.33	31	5.37	34
16	35	5.56	35	5.56	35	5.56	35	5.56	35
17	37	5.79	37	5.79	38	5.77	36	5.81	37
18	39	6.01	40	5.99	40	5.99	38	6.03	41
19	42	6.21	42	6.21	42	6.21	42	6.21	42
20	44	6.43	44	6.43	45	6.41	43	6.44	44
21	46	6.64	47	6.62	47	6.62	45	6.65	48
22	49	6.83	49	6.83	49	6.83	49	6.83	49
23	51	7.03	51	7.03	52	7.02	50	7.05	51
24	53	7.23	54	7.22	54	7.22	52	7.25	55
25	56	7.42	56	7.42	56	7.42	56	7.42	56
26	58	7.61	58	7.61	59	7.60	57	7.62	58
27	60	7.80	61	7.79	61	7.79	59	7.82	62
28	63	7.98	63	7.98	63	7.98	63	7.98	63
29	65	8.17	65	8.17	66	8.15	64	8.18	65
30	67	8.35	68	8.34	68	8.34	66	8.36	69
31	70	8.52	70	8.52	70	8.52	70	8.52	70
32	72	8.70	72	8.70	73	8.69	71	8.72	72
33	74	8.88	75	8.87	75	8.87	73	8.89	76
34	77	9.05	77	9.05	77	9.05	77	9.05	77
35	79	9.22	79	9.22	80	9.21	78	9.23	79
36	81	9.39	82	9.38	82	9.38	80	9.41	83
37	84	9.55	84	9.55	84	9.55	84	9.55	84
38	86	9.72	86	9.72	87	9.71	85	9.74	86
39	88	9.89	89	9.88	89	9.88	87	9.91	90
40	91	10.05	91	10.05	91	10.05	91	10.05	91
41	93	10.21	93	10.21	94	10.20	92	10.23	93
42	95	10.38	96	10.37	96	10.37	94	10.39	97

Table 1 (cont.)

Tue, Thu, Fri									
Thu		Tue		Thu		Fri		N	
$\frac{N^{0.76}}{T^{0.11}}$	T	$\frac{N^{0.76}}{T^{0.11}}$	T	$\frac{N^{0.76}}{T^{0.11}}$	T	$\frac{N^{0.76}}{T^{0.11}}$	T	$\frac{N^{0.76}}{T^{0.11}}$	N
2.32	7	2.32	7	2.32	7	2.32	7	2.32	4
2.67	11	2.61	9	2.67	8	2.70	11	2.61	5
2.94	12	2.97	10	3.03	12	2.97	13	2.94	6
3.28	14	3.28	14	3.28	14	3.28	14	3.28	7
3.58	18	3.53	16	3.58	15	3.61	18	3.53	8
3.82	19	3.84	17	3.89	19	3.84	20	3.82	9
4.12	21	4.12	21	4.12	21	4.12	21	4.12	10
4.38	25	4.34	23	4.38	22	4.40	25	4.34	11
4.60	26	4.62	24	4.66	26	4.62	27	4.60	12
4.87	28	4.87	28	4.87	28	4.87	28	4.87	13
5.11	32	5.08	30	5.11	29	5.13	32	5.08	14
5.31	33	5.33	31	5.37	33	5.33	34	5.31	15
5.56	35	5.56	35	5.56	35	5.56	35	5.56	16
5.79	39	5.76	37	5.79	36	5.81	39	5.76	17
5.98	40	5.99	38	6.03	40	5.99	41	5.98	18
6.21	42	6.21	42	6.21	42	6.21	42	6.21	19
6.43	46	6.40	44	6.43	43	6.44	46	6.40	20
6.61	47	6.62	45	6.65	47	6.62	48	6.61	21
6.83	49	6.83	49	6.83	49	6.83	49	6.83	22
7.03	53	7.00	51	7.03	50	7.05	53	7.00	23
7.20	54	7.22	52	7.25	54	7.22	55	7.20	24
7.42	56	7.42	56	7.42	56	7.42	56	7.42	25
7.61	60	7.58	58	7.61	57	7.62	60	7.58	26
7.77	61	7.79	59	7.82	61	7.79	62	7.77	27
7.98	63	7.98	63	7.98	63	7.98	63	7.98	28
8.17	67	8.14	65	8.17	64	8.18	67	8.14	29
8.32	68	8.34	66	8.36	68	8.34	69	8.32	30
8.52	70	8.52	70	8.52	70	8.52	70	8.52	31
8.70	74	8.68	72	8.70	71	8.72	74	8.68	32
8.85	75	8.87	73	8.89	75	8.87	76	8.85	33
9.05	77	9.05	77	9.05	77	9.05	77	9.05	34
9.22	81	9.20	79	9.22	78	9.23	81	9.20	35
9.37	82	9.38	80	9.41	82	9.38	83	9.37	36
9.55	84	9.55	84	9.55	84	9.55	84	9.55	37
9.72	88	9.70	86	9.72	85	9.74	88	9.70	38
9.87	89	9.88	87	9.91	89	9.88	90	9.87	39
10.05	91	10.05	91	10.05	91	10.05	91	10.05	40
10.21	95	10.19	93	10.21	92	10.23	95	10.19	41
10.35	96	10.37	94	10.39	96	10.37	97	10.35	42

Where T.D. is the total dose  
 N is the number of fractions  
 T is the total elapsed days; the first treatment  
 is given on day zero

The unit of NSD is the ret: rad equivalent therapy.  
 It is known that

$$\text{T.D.} = d \times N$$

Where d is the dose per fraction

The assumption of equal increments is implicit in these relationships. Substituting and rearranging the equation the following is obtained:

$$\text{NSD} = \frac{\text{T.D.}}{N} \times \frac{N^{0.76}}{T^{0.11}} \quad (1)$$

$$\frac{\text{NSD}}{d} = \frac{N^{0.76}}{T^{0.11}} \quad (2)$$

Tables 1 and 2 present the relationship between the number of days (T) that will elapse given a treatment plan for N fractions, starting on a particular day at three and five fractions per week. The ratio of  $N^{0.76}$  to  $T^{0.11}$  also appears. Similar tables have been generated for other fractionation techniques.

*Determination of the NSD.* Basic to an understanding of NSD is the fact that this term must be reserved for a treatment that continues to tolerance level and any other solution to equation 1 is simply a number. If tolerance has not been achieved then the partial tolerance is obtained by the proportion of the fractions given to the number of fractions required to achieve the NSD at the same fractionation and daily dose. The volume of tissue irradiated or the spatial distribution of the dose is not accounted for in the NSD relationship, while it is known that this does affect tolerance. Thus, it should be realized that NSD is a specific quantity and is specified in relation to the therapist's philosophy as to what is tolerable and the treatment technique. At the outset the therapist has to translate his current practice into NSD terms.

Suppose the standard practice at an institution for treating a certain stage of carcinoma of the bladder is to treat to a total dose of 5200 rad in 26 fractions, treating 5 times per week then, from Table 2 and using equation 1, it is seen that

$$\text{NSD} = \frac{5200}{26} \times 8.05 = 1610 \text{ ret.}$$

At some institutions, the standard practice is to give a split course treatment involving a rest and repeat.

Suppose that the prescription reads as follows:

d rad/day	N fractions	T days
	Rest G days	
d rad/day	N fractions	T days

As a statement: a dose of rad per day is delivered for N fractions which at the number of fractions per week used is seen to take T days followed by a rest of G days then a repeat of the therapy given in the first part.

If the treatments would continue to the NSD then

$$\frac{\text{NSD}}{d} = \frac{N_t^{0.76}}{T_t^{0.11}}$$

it can be shown that

$$N_t = N \left[ 1 + \left( \frac{T}{T+G} \right)^{0.11} \right]$$

from these equations the NSD may be calculated.

Consider the following example.

400 rad/day	6 fractions	at 3 fractions/week
	Rest 31 days	
400 rad/day	6 fractions	at 3 fractions/week

$$N_t = 6 \left[ 1 + \left( \frac{11}{11+31} \right)^{0.11} \right] = 11.17$$

The value of  $\left( \frac{11}{11+31} \right)^{0.11}$  is obtained from Table 3.

To the nearest integer this is 11 fractions, thus

$$\text{NSD} = 400 \times \frac{11^{0.76}}{23^{0.11}} = 1752 \text{ ret.}$$

The value of  $\frac{11^{0.76}}{23^{0.11}}$  is obtained from Table 1.

By comparison, if no rest were given:

400 rad/day	12 fractions	3 F/week
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which, using Table 1, gives:

$$\text{NSD} = 400 \times 4.64 = 1856 \text{ ret.}$$

To summarize, before the NSD concept is used routinely in a department, it is first necessary to determine the NSD for the current practice and it is a

**Table 2**  
*Five fractions per week*

Treat	Mon, Tue, Wed, Thu, Fri									
Start	Mon		Tue		Wed		Thu		Fri	
N	T	$\frac{N^{0.76}}{T^{0.11}}$	T	$\frac{N^{0.76}}{T^{0.11}}$	T	$\frac{N^{0.76}}{T^{0.11}}$	T	$\frac{N^{0.76}}{T^{0.11}}$	T	$\frac{N^{0.76}}{T^{0.11}}$
4	3	2.54	3	2.54	5	2.40	5	2.40	5	2.40
5	4	2.92	6	2.79	6	2.79	6	2.79	6	2.79
6	7	3.15	7	3.15	7	3.15	7	3.15	7	3.15
7	8	3.49	8	3.49	8	3.49	8	3.49	10	3.41
8	9	3.81	9	3.81	9	3.81	11	3.73	11	3.73
9	10	4.12	10	4.12	12	4.04	12	4.04	12	4.04
10	11	4.42	13	4.34	13	4.34	13	4.34	13	4.34
11	14	4.63	14	4.63	14	4.63	14	4.63	14	4.63
12	15	4.91	15	4.91	15	4.91	15	4.91	17	4.84
13	16	5.18	16	5.18	16	5.18	18	5.11	18	5.11
14	17	5.44	17	5.44	19	5.38	19	5.38	19	5.38
15	18	5.70	20	5.63	20	5.63	20	5.63	20	5.63
16	21	5.88	21	5.88	21	5.88	21	5.88	21	5.88
17	22	6.13	22	6.13	22	6.13	22	6.13	24	6.07
18	23	6.37	23	6.37	23	6.37	25	6.31	25	6.31
19	24	6.61	24	6.61	26	6.55	26	6.55	26	6.55
20	25	6.84	27	6.78	27	6.78	27	6.78	27	6.78
21	28	7.01	28	7.01	28	7.01	28	7.01	28	7.01
22	29	7.23	29	7.23	29	7.23	29	7.23	31	7.18
23	30	7.45	30	7.45	30	7.45	32	7.40	32	7.40
24	31	7.67	31	7.67	33	7.62	33	7.62	33	7.62
25	32	7.89	34	7.83	34	7.83	34	7.83	34	7.83
26	35	8.05	35	8.05	35	8.05	35	8.05	35	8.05
27	36	8.25	36	8.25	36	8.25	36	8.25	38	8.20
28	37	8.46	37	8.46	37	8.46	39	8.41	39	8.41
29	38	8.66	38	8.66	40	8.61	40	8.61	40	8.61
30	39	8.86	41	8.81	41	8.81	41	8.81	41	8.81
31	42	9.01	42	9.01	42	9.01	42	9.01	42	9.01
32	43	9.21	43	9.21	43	9.21	43	9.21	45	9.16
33	44	9.40	44	9.40	44	9.40	46	9.36	46	9.36
34	45	9.60	45	9.60	47	9.55	47	9.55	47	9.55
35	46	9.79	48	9.74	48	9.74	48	9.74	48	9.74
36	49	9.93	49	9.93	49	9.93	49	9.93	49	9.93
37	50	10.11	50	10.11	50	10.11	50	10.11	52	10.07
38	51	10.30	51	10.30	51	10.30	53	10.26	53	10.26
39	52	10.48	52	10.48	54	10.44	54	10.44	54	10.44
40	53	10.66	55	10.62	55	10.62	55	10.62	55	10.62

Table 2 (cont.)

Treat	Mon, Tue, Wed, Thu, Fri									
Start	Mon		Tue		Wed		Thu		Fri	
N	T	$\frac{N^{0.76}}{T^{0.11}}$	T	$\frac{N^{0.76}}{T^{0.11}}$	T	$\frac{N^{0.76}}{T^{0.11}}$	T	$\frac{N^{0.76}}{T^{0.11}}$	T	$\frac{N^{0.76}}{T^{0.11}}$
41	56	10.80	56	10.80	56	10.80	56	10.80	56	10.80
42	57	10.98	57	10.98	57	10.98	57	10.98	59	10.94
43	58	11.15	58	11.15	58	11.15	60	11.11	60	11.11
44	59	11.33	59	11.33	61	11.29	61	11.29	61	11.29
45	60	11.50	62	11.46	62	11.46	62	11.46	62	11.46
46	63	11.64	63	11.64	63	11.64	63	11.64	63	11.64
47	64	11.81	64	11.81	64	11.81	64	11.81	66	11.77
48	65	11.98	65	11.98	65	11.98	67	11.94	67	11.94
49	66	12.15	66	12.15	68	12.11	68	12.11	68	12.11
50	67	12.31	69	12.27	69	12.27	69	12.27	69	12.27
51	70	12.44	70	12.44	70	12.44	70	12.44	70	12.44
52	71	12.60	71	12.60	71	12.60	71	12.60	73	12.57
53	72	12.77	72	12.77	72	12.77	74	12.73	74	12.73
54	73	12.93	73	12.93	75	12.89	75	12.89	75	12.89
55	74	13.09	76	13.06	76	13.06	76	13.06	76	13.06
56	77	13.22	77	13.22	77	13.22	77	13.22	77	13.22
57	78	13.38	78	13.38	78	13.38	78	13.38	80	13.34
58	79	13.54	79	13.54	79	13.54	81	13.50	81	13.50
59	80	13.69	80	13.69	82	13.66	82	13.66	82	13.66
60	81	13.85	83	13.81	83	13.81	83	13.81	83	13.81
61	84	13.97	84	13.97	84	13.97	84	13.97	84	13.97
62	85	14.12	85	14.12	85	14.12	85	14.12	87	14.09
63	86	14.28	86	14.28	86	14.28	88	14.24	88	14.24
64	87	14.43	87	14.43	89	14.40	89	14.40	89	14.40
65	88	14.59	90	14.55	90	14.55	90	14.55	90	14.55
66	91	14.70	91	14.70	91	14.70	91	14.70	91	14.70
67	92	14.85	92	14.85	92	14.85	92	14.85	94	14.82
68	93	15.00	93	15.00	93	15.00	95	14.97	95	14.97
69	94	15.15	94	15.15	96	15.12	96	15.12	96	15.12
70	95	15.30	97	15.27	97	15.27	97	15.27	97	15.27

mistake to take NSD values quoted in the literature unless the treatment techniques described in the reports are precisely followed.

*Partial tolerance.* During the course of a treatment, a calculation can be made to see if tolerance has been reached or possibly exceeded.

For example, if NSD is considered 1 770 ret and 25 fractions of 200 rad have been given treating five fractions a week, starting on Monday, from Table 2 it is seen that the number obtained is, using equation 1,  $200 \times 7.89 = 1\,578$ , which is less than that considered tolerance. According to ELLIS (1968) this represents a partial tolerance which is defined by the ratio of the number of fractions given to that required to achieve the NSD. At the rate specified,

$$\frac{\text{NSD}}{d} = \frac{1\,770}{200} = 8.85$$

from Table 2 it is seen that this ratio is closely obtained for 30 fractions hence the Partial Tolerance (PT) =  $\frac{25}{30} \times 1\,770 = 1\,475$  ret.

*Planning a treatment to give the NSD.* If the number of fractions is decided then the daily dose may be calculated to give the NSD. For example, if treating 5 times a week starting on a Monday, the number of fractions chosen is 38 and NSD for the department is 1 800 ret. The daily dose required is, using a rearrangement of equation 2 and Table 2

$$1\,800/10.30 = 174.8 \text{ rad.}$$

More usually, the dose per fraction is known and the number of fractions required to give the NSD are sought for. For example, say the NSD at an institution is considered 1 780 ret and it is planned to give a daily dose of 180 rad five times per week starting on Thursday. The ratio of NSD to daily dose is  $1\,780/180 = 9.89$  and by inspection of Table 2 the nearest integer number of fractions giving this ratio is 36 fractions in 49 days, which has a ratio of 9.93. The daily dose needs to be modified slightly to achieve the exact NSD and actually  $1\,780/9.93 = 179.3$  rad should be delivered daily.

*Changing the prescription.* The NSD concept may be employed as a guide in changing or modifying the prescription following a gap in the course of a treatment.

Consider the following example. The prescription of 6 000 rad in 29 fractions over 38 days treating 5 times per week is made, starting on October 16. After 12 fractions, 15 days, for some reason, the patient cannot be treated until Wednesday, November 29th. The elapsed days since the start of treatment is 44 days.

The partial tolerance achieved by the first part of the treatment is proportioned by the number of fractions

**Table 3**

Ratio days,  $\left(\frac{T}{T+G}\right)^{0.11}$

$\frac{T}{T+G}$	$\left(\frac{T}{T+G}\right)^{0.11}$	$\frac{T}{T+G}$	$\left(\frac{T}{T+G}\right)^{0.11}$	$\frac{T}{T+G}$	$\left(\frac{T}{T+G}\right)^{0.11}$	$\frac{T}{T+G}$	$\left(\frac{T}{T+G}\right)^{0.11}$
0.01	0.603	0.26	0.862	0.51	0.929	0.76	0.970
0.02	0.650	0.27	0.866	0.52	0.931	0.77	0.972
0.03	0.680	0.28	0.869	0.53	0.933	0.78	0.973
0.04	0.702	0.29	0.873	0.54	0.934	0.79	0.974
0.05	0.719	0.30	0.876	0.55	0.936	0.80	0.976
0.06	0.734	0.31	0.879	0.56	0.938	0.81	0.977
0.07	0.746	0.32	0.882	0.57	0.940	0.82	0.978
0.08	0.757	0.33	0.885	0.58	0.942	0.83	0.980
0.09	0.767	0.34	0.888	0.59	0.944	0.84	0.981
0.10	0.776	0.35	0.891	0.60	0.945	0.85	0.982
0.11	0.784	0.36	0.894	0.61	0.947	0.86	0.984
0.12	0.792	0.37	0.896	0.62	0.949	0.87	0.985
0.13	0.799	0.38	0.899	0.63	0.950	0.88	0.986
0.14	0.806	0.39	0.902	0.64	0.952	0.89	0.987
0.15	0.812	0.40	0.904	0.65	0.954	0.90	0.988
0.16	0.817	0.41	0.907	0.66	0.955	0.91	0.990
0.17	0.823	0.42	0.909	0.67	0.957	0.92	0.991
0.18	0.828	0.43	0.911	0.68	0.958	0.93	0.992
0.19	0.833	0.44	0.914	0.69	0.960	0.94	0.993
0.20	0.838	0.45	0.916	0.70	0.962	0.95	0.994
0.21	0.842	0.46	0.918	0.71	0.963	0.96	0.996
0.22	0.847	0.47	0.920	0.72	0.965	0.97	0.997
0.23	0.851	0.48	0.922	0.73	0.966	0.98	0.998
0.24	0.855	0.49	0.925	0.74	0.967	0.99	0.999
0.25	0.859	0.50	0.927	0.75	0.969	1.00	1.000

$$1\ 792 \times 12/29 = 741 \text{ ret.}$$

The partial tolerance will have 'decayed' when treatment is resumed and the partial tolerance on resumption of treatment is obtained from a ratio of the elapsed days,

$$\begin{aligned} \text{i.e. Partial Tolerance on resumption} &= 741 \times (15/44)^{0.11} \\ &= 658 \text{ ret} \end{aligned}$$

Since on November 29th 658 ret have been given, the residual tolerance is

$$1\ 792 - 658 = 1\ 134 \text{ ret.}$$

It is now decided to complete the course treating about 220 rad per day, three times per week, Monday, Wednesday and Friday, starting on Wednes-

day. It is first necessary to determine how the NSD would be achieved using this fractionation scheme

$$\text{i.e. } 1\,792/220 = 8.15.$$

From Table 1, it is seen that this is approximated by 29 fractions. To achieve the NSD exactly, the daily dose should be

$$1\,792/8.17 = 219 \text{ rad.}$$

Since an NSD of 1 792 ret is delivered in 29 fractions a residual tolerance of 1 134 ret is delivered in

$$1\,134/1\,792 \times 29 = 18.3$$

i.e. 18 fractions to the nearest integer

In conclusion, this work was prompted by a belief that a parameter describing a radiation therapy is a worthwhile objective and that existing techniques for the calculation of NSD had not gained wide acceptance. The form of the tables presented here do have a marginal advantage in the development of the concept since if the exponents in the relationship are a function of the number of treatments per week as proposed by PROBERT (1971), the tables will be easy to modify.

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### SUMMARY

The NSD concept has been introduced in the dose calculation service provided by the Northwest Medical Physics Center. Tables have been generated relating the elapsed time to the number of fractions together with the ratio  $\frac{N^{0.76}}{T^{0.11}}$ . The use of these tables is illustrated by examples.

### ZUSAMMENFASSUNG

Das NSD Konzept wurde in den Dosis-Berechnungs-Service des Northwest Medical Physics Center eingeführt. Es wurden Tabellen aufgestellt, um das Verhältnis der verflossenen Zeit zur Anzahl von Fraktionen zusammen mit dem Verhältnis  $\frac{N^{0.76}}{T^{0.11}}$  in Beziehung zu stellen. Die Anwendung dieser Tabellen wird am Beispiel verdeutlicht.

## RÉSUMÉ

Le concept de NSD a été introduit dans le service de calcul de dose fourni pour le Centre de Physique Médicale du Northwest. Des tables ont été établies reliant le temps écoulé au nombre de fractions et au rapport  $\frac{N^{0.76}}{T^{0.11}}$ . L'utilisation de ces tables est illustrée par des exemples.

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