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Aviation fuels — Estimation of net heat of combustion

Carburants aviation — Estimation du pouvoir calorifique inférieur

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FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO Member Bodies). The work of developing International Standards is carried out through ISO Technical Committees. Every Member Body interested in a subject for which a Technical Committee has been set up has the right to be represented on that Committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 3648 was drawn up by Technical Committee ISO/TC 28, *Petroleum products,* and circulated to the Member Bodies in November 1974.

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It has been approved by the Member Bodies of the following countries :

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No Member Body expressed disapproval of the document.

This International Standard should be considered as an interim document, until new correlations can be established exclusively in SI units between the net heat of combustion and the product of the aniline point and density which will give results at least as reliable as the present method.

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Aviation fuels — Estimation of net heat of combustion

1 SCOPE AND FIELD OF APPLICATION

1.1 This International Standard specifies a method for the estimation of the net heat of combustion of aviation fuels, in megajoules per kilogram or British thermal units per pound. It is not applicable to pure hydrocarbons.

1.2 The method is purely empirical and is applicable only to liquid hydrocarbon fuels which conform to the requirements of specifications for aviation gasolines, or aircraft turbine and jet engine fuels of types Aviation turbine fuel, wide cut; Aviation turbine fuel, high flash; and Aviation turbine fuel, kerosine (see note 1). The method is intended for use as a guide in cases where an experimentally determined heat of combustion is not available and cannot be made conveniently, and where an estimate is considered satisfactory. It is not intended, for specifications and similar purposes, that estimated values of the net heat of combustion shall be used in place of experimentally determined values (see note 2).

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NOTES

1 Internationally understood designations used by the air transport industry may be encountered, for example :

JP-4, Avtag and Jet B for Aviation turbine fuel, wide cut;

JP-5 and Avcat for Aviation turbine fuel, high flash;

Jet A, Jet A1 and Avtur for Aviation turbine fuel, kerosine.

2 The estimation of the net heat of combustion of hydrocarbon fuel from its aniline-gravity product is justifiable only when the fuel belongs to a well-defined type for which a relation between heat of combustion and aniline-gravity product has been derived from accurate experimental measurements on representative samples of that type. Even in this case, the possibility that the estimates may be in error by large amounts for individual fuels should be recognized.

2 REFERENCES

ISO/R 91, *Petroleum measurement tables.*

ISO 2192, *Petroleum products — Determination of sulphur — Lamp method.*

ISO 2977, *Petroleum products and hydrocarbon solvents — Determination of aniline and mixed aniline point.*

ISO 3675, *Crude petroleum and liquid petroleum products — Determination of density or relative density — Hydrometer method.* [1)]

ISO 4260, *Petroleum products — Determination of sulphur content — Wickbold combustion method.* [1)]

3 PRINCIPLE

3.1 Correlations have been established between the net heat of combustion and the product of the aniline point in degrees Fahrenheit and API gravity. These relations, assuming the sample to be sulphur-free, are given by the following equations :

3.1.1 Where the net heat of combustion is required in SI units (megajoules per kilogram) :

Type of fuel	Equation	Equation No.
Aviation gasoline, Grades 100 and 115	$Q_{p(net)} = 41{,}955\,7 + 0{,}000\,205\,43\,(A \times G)$	(1)
Aviation turbine fuel, wide cut	$Q_{p(net)} = 41{,}814\,5 + 0{,}000\,245\,63\,(A \times G)$	(2)
Aviation turbine fuel, high flash	$Q_{p(net)} = 41{,}668\,0 + 0{,}000\,245\,63\,(A \times G)$	(3)
Aviation turbine fuel, kerosine	$Q_{p(net)} = 41{,}679\,6 + 0{,}000\,254\,07\,(A \times G)$	(4)

where

$Q_{p(net)}$ is the net heat of combustion, in megajoules per kilogram, on a sulphur-free basis;

A is the aniline point, in degrees Fahrenheit;

G is the API gravity, degrees.

1) At present at the stage of draft.

3.1.2 Where the net heat of combustion is required in U.K. non-metric or U.S. Customary Units (British thermal units per pound) :

Type of fuel	Equation	Equation No.
Aviation gasoline, Grades 100 and 115	$Q_{p(net)} = 18\,037 + 0{,}088\,32\,(A \times G)$	(6)
Aviation turbine fuel, wide cut	$Q_{p(net)} = 17\,977 + 0{,}105\,6\,(A \times G)$	(7)
Aviation turbine fuel, high flash	$Q_{p(net)} = 17\,914 + 0{,}105\,6\,(A \times G)$	(8)
Aviation turbine fuel, kerosine	$Q_{p(net)} = 17\,919 + 0{,}109\,23\,(A \times G)$	(9)

where

$Q_{p(net)}$ is the net heat of combustion, in British thermal units per pound, on a sulphur-free basis;

A is the aniline point, in degrees Fahrenheit;

G is the API gravity, degrees.

3.2 To correct for the effect of the sulphur content of the sample on the net heat of combustion, apply the following equations :

3.2.1 Where the net heat of combustion is required in SI units (megajoules per kilogram) :

$$Q' = Q_{p(net)}\ \text{MJ/kg} \times (1 - 0{,}01\,S) + 0{,}101\,6\,S \quad \ldots (5)$$

where

Q' is the net heat of combustion, in megajoules per kilogram, of the sample containing S % sulphur;

S is the sulphur content of the sample, as a percentage by mass;

0,101 6 is a constant based on the thermochemical data on sulphur compounds.

3.2.2 Where the net heat of combustion is required in U.K. non-metric or U.S. Customary Units (British thermal units per pound) :

$$Q' = Q_{p(net)}\ \text{Btu/lb} \times (1 - 0{,}01\,S) + 43{,}7\,S \quad \ldots (10)$$

where

Q' is the net heat of combustion, in British thermal units per pound, of the sample containing S % sulphur;

S is the sulphur content of the sample, as a percentage by mass;

43,7 is a constant based on the thermochemical data on sulphur compounds.

3.3 The empirical linear equations (1), (2), (3), (4) and (6), (7), (8), (9), for the estimated net heat of combustion were derived by the method of least squares from accurate data on fuels, most of which conformed at least approximately to specifications for aviation gasolines, or aircraft turbine and jet engine fuels of types Aviation turbine fuel, wide cut; Aviation turbine fuel, high flash; and to specifications for Aviation turbine fuels, kerosine.

4 PROCEDURE

4.1 Determine the aniline point of the sample, A', in degrees Celsius to the nearest 0,1 °C as specified in ISO 2977. Obtain the aniline point, A, in degrees Fahrenheit to the nearest 0,2 °F from table 2 referred to in ISO/R 91 or from the relation

$$A = 1{,}8\,A' + 32$$

4.2 Determine the API gravity of the sample, G, to the nearest 0,1 °API as specified in ISO 3675 (sub-clause 8.3 or annex).

4.3 Determine the sulphur content of the sample, S, to the nearest 0,02 % (*m/m*) sulphur as specified in ISO 2192 or ISO 4260, depending upon the volatility of the sample.

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5 EXPRESSION OF RESULTS

5.1 Calculate the product of the aniline point in degrees Fahrenheit and the gravity in degrees API; round off the value obtained to the nearest integer.

5.2 From tables 1, 2, 3, 4 or 5, 6, 7, 8, make a linear interpolation between rows, bracketing the aniline-gravity products, and within columns, bracketing the sulphur content of the sample. The tables used shall be those applicable to the type of product being tested; that is tables 1 or 5 shall be used for Aviation gasolines; tables 2 or 6 shall be used for Aviation turbine fuel, wide cut; tables 3 or 7 shall be used for Aviation turbine fuel, high flash; and tables 4 or 8 shall be used for Aviation turbine fuels, kerosine.

5.3 From the values obtained in accordance with 5.2, make a linear interpolation for the sulphur content within the row for the calculated aniline-gravity product.

Example :

Sample : Aviation turbine fuel, wide cut

Determined values :

Aniline point	$A = 137$ °F
Gravity	$G = 54{,}8$ °API
Sulphur content	$S = 0{,}10$ % (*m/m*)

Calculated value : $A \times G = 7\,508$

By interpolation from table 2

A × *G*	0 % sulphur	0,1 % sulphur	0,2 % sulphur
7 400	43,63		43,57
7 508*	43,66**	43,63***	43,59**
7 600	43,68		43,61

or table 6

A × *G*	0 % sulphur	0,1 % sulphur	0,2 % sulphur
7 400	18 758		18 729
7 508*	18 769**	18 755***	18 740**
7 600	18 779		18 750

* Value calculated from determined values.

** First step : Interpolation between rows in columns bracketing the sulphur content.

*** Second step : Interpolation within a row between columns.

Estimated net heat of combustion : 43,63 MJ/kg
18 755 Btu/lb

6 PRECISION

The precision of the method, as obtained by statistical examination of inter-laboratory test results, is as follows :

6.1 Repeatability

The difference between two test results, obtained by the same operator with the same apparatus under constant operating conditions on identical test material, would in the long run, in the normal and correct operation of the test method, exceed the following value only in one case in twenty :

0,012 MJ/kg (see note in 6.2)
5 Btu/lb

6.2 Reproducibility

The difference between two single and independent results obtained by different operators working in different laboratories on identical test material, would in the long run, in the normal and correct operation of the test method, exceed the following value only in one case in twenty :

0,035 MJ/kg (see note)
15 Btu/lb

NOTE — These values and all other values involved have been calculated using the following equation :

1 Btu/lb = 0,002 326 MJ/kg

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7 TEST REPORT

Report the result in megajoules per kilogram or British thermal units per pound as the estimated net heat of combustion, and make reference to this International Standard.

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TABLE 1 – **Values of Q' for Aviation gasolines, calculated from equations (1) and (5)**

Aniline-gravity product	Net heat of combustion, MJ/kg				
	0 % sulphur	0,1 % sulphur	0,2 % sulphur	0,3 % sulphur	0,4 % sulphur
4 000	42,78	42,74	42,71	42,68	42,65
4 200	42,82	42,79	42,75	42,72	42,69
4 400	42,86	42,83	42,79	42,76	42,73
4 600	42,90	42,87	42,84	42,80	42,77
4 800	42,94	42,91	42,88	42,84	42,81
5 000	42,98	42,95	42,92	42,88	42,85
5 200	43,02	42,99	42,96	42,93	42,89
5 400	43,07	43,03	43,00	42,97	42,93
5 600	43,11	43,07	43,04	43,01	42,97
5 800	43,15	43,11	43,08	43,05	43,02
6 000	43,19	43,16	43,12	43,09	43,06
6 200	43,23	43,20	43,16	43,13	43,10
6 400	43,27	43,24	43,20	43,17	43,14
6 600	43,31	43,28	43,25	43,21	43,18
6 800	43,35	43,32	43,29	43,25	43,22
7 000	43,39	43,36	43,33	43,29	43,26
7 200	43,43	43,40	43,37	43,33	43,30
7 400	43,48	43,44	43,41	43,38	43,34
7 600	43,52	43,48	43,45	43,42	43,38
7 800	43,56	43,52	43,49	43,46	43,42
8 000	43,60	43,57	43,53	43,50	43,47
8 200	43,64	43,61	43,57	43,54	43,51
8 400	43,68	43,65	43,61	43,58	43,55
8 600	43,72	43,69	43,66	43,62	43,59
8 800	43,76	43,73	43,70	43,66	43,63
9 000	43,80	43,77	43,74	43,70	43,67
9 200	43,85	43,81	43,78	43,74	43,71
9 400	43,89	43,85	43,82	43,79	43,75
9 600	43,93	43,89	43,86	43,83	43,79
9 800	43,97	43,94	43,90	43,87	43,83
10 000	44,01	43,98	43,94	43,91	43,87
10 200	44,05	44,02	43,98	43,95	43,92
10 400	44,09	44,06	44,02	43,99	43,96
10 600	44,13	44,10	44,07	44,03	44,00
10 800	44,17	44,14	44,11	44,07	44,04
11 000	44,22	44,18	44,15	44,11	44,08
11 200	44,26	44,22	44,19	44,15	44,12
11 400	44,30	44,26	44,23	44,20	44,16
11 600	44,34	44,30	44,27	44,24	44,20
11 800	44,38	44,35	44,31	44,28	44,24

TABLE 2 – **Values of Q' for Aviation turbine fuel, wide cut, calculated from equations (2) and (5)**

Aniline-gravity product	Net heat of combustion, MJ/kg					
	0 % sulphur	0,2 % sulphur	0,4 % sulphur	0,6 % sulphur	0,8 % sulphur	1,0 % sulphur
5 200	43,09	43,03	42,96	42,89	42,83	42,76
5 400	43,14	43,07	43,01	42,94	42,88	42,81
5 600	43,19	43,12	43,06	42,99	42,93	42,86
5 800	43,24	43,17	43,11	43,04	42,97	42,91
6 000	43,29	43,22	43,16	43,09	43,02	42,96
6 200	43,34	43,27	43,20	43,14	43,07	43,01
6 400	43,39	43,32	43,25	43,19	43,12	43,05
6 600	43,44	43,37	43,30	43,24	43,17	43,10
6 800	43,48	43,42	43,35	43,28	43,22	43,15
7 000	43,53	43,47	43,40	43,33	43,27	43,20
7 200	43,58	43,52	43,45	43,38	43,32	43,25
7 400	43,63	43,57	43,50	43,43	43,36	43,30
7 600	43,68	43,61	43,55	43,48	43,41	43,35
7 800	43,73	43,66	43,60	43,53	43,46	43,39
8 000	43,78	43,71	43,65	43,58	43,51	43,44

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TABLE 3 – **Values of Q' for Aviation turbine fuels, high flash, calculated from equations (3) and (5)**

Aniline-gravity product	Net heat of combustion, MJ/kg					
	0 % sulphur	0,2 % sulphur	0,4 % sulphur	0,6 % sulphur	0,8 % sulphur	1,0 % sulphur
4 200	42,70	42,63	42,57	42,50	42,44	42,37
4 400	42,75	42,68	42,62	42,55	42,49	42,42
4 600	42,80	42,73	42,67	42,60	42,54	42,47
4 800	42,85	42,78	42,72	42,65	42,59	42,52
5 000	42,90	42,83	42,77	42,70	42,63	42,57
5 200	42,95	42,88	42,81	42,75	42,68	42,62
5 400	42,99	42,93	42,86	42,80	42,73	42,67
5 600	43,04	42,98	42,91	42,85	42,78	42,71
5 800	43,09	43,03	42,96	42,90	42,83	42,76
6 000	43,14	43,08	43,01	42,94	42,88	42,81
6 200	43,19	43,12	43,06	42,99	42,93	42,86
6 400	43,24	43,17	43,11	43,04	42,98	42,91
6 600	43,29	43,22	43,16	43,09	43,02	42,96
6 800	43,34	43,27	43,21	43,14	43,07	43,01
7 000	43,39	43,32	43,25	43,19	43,12	43,06

TABLE 4 — **Values of Q' for Aviation turbine fuels, kerosine, calculated from equations (4) and (5)**

Aniline-gravity product	Net heat of combustion, MJ/kg				
	0 % sulphur	0,05 % sulphur	0,10 % sulphur	0,15 % sulphur	0,20 % sulphur
4 200	42,75	42,73	42,71	42,70	42,68
4 400	42,80	42,78	42,76	42,75	42,73
4 600	42,85	42,83	42,82	42,80	42,78
4 800	42,90	42,88	42,87	42,85	42,83
5 000	42,95	42,93	42,92	42,90	42,88
5 200	43,00	42,98	42,97	42,95	42,94
5 400	43,05	43,04	43,02	43,00	42,99
5 600	43,10	43,09	43,07	43,05	43,04
5 800	43,15	43,14	43,12	43,10	43,09
6 000	43,20	43,19	43,17	43,15	43,14
6 200	43,25	43,24	43,22	43,21	43,19
6 400	43,31	43,29	43,27	43,26	43,24
6 600	43,36	43,34	43,32	43,31	43,29
6 800	43,41	43,39	43,37	43,36	43,34
7 000	43,46	43,44	43,42	43,41	43,39
7 200	43,51	43,49	43,48	43,46	43,44
7 400	43,56	43,54	43,53	43,51	43,49
7 600	43,61	43,59	43,58	43,56	43,54
7 800	43,66	43,64	43,63	43,61	43,59
8 000	43,71	43,70	43,68	43,66	43,65
8 200	43,76	43,75	43,73	43,71	43,70
8 400	43,81	43,80	43,78	43,76	43,75
8 600	43,86	43,85	43,83	43,81	43,80
8 800	43,92	43,90	43,88	43,86	43,85
9 000	43,97	43,95	43,93	43,92	43,90
9 200	44,02	44,00	43,98	43,97	43,95
9 400	44,07	44,05	44,03	44,02	44,00
9 600	44,12	44,10	44,08	44,07	44,05
9 800	44,17	44,15	44,14	44,12	44,10
10 000	44,22	44,20	44,19	44,17	44,15

TABLE 5 — **Values of Q' for Aviation gasolines, calculated from equations (6) and (10)**

Aniline-gravity product	Net heat of combustion, Btu/lb				
	0 % sulphur	0,1 % sulphur	0,2 % sulphur	0,3 % sulphur	0,4 % sulphur
4 000	18 391	18 377	18 363	18 349	18 335
4 200	18 409	18 395	18 381	18 367	18 352
4 400	18 426	18 412	18 398	18 384	18 370
4 600	18 444	18 430	18 416	18 402	18 388
4 800	18 462	18 448	18 433	18 419	18 405
5 000	18 479	18 465	18 451	18 437	18 423
5 200	18 497	18 483	18 469	18 455	18 440
5 400	18 515	18 500	18 486	18 472	18 458
5 600	18 532	18 518	18 504	18 490	18 476
5 800	18 550	18 536	18 522	18 507	18 493
6 000	18 568	18 553	18 539	18 525	18 511
6 200	18 585	18 571	18 557	18 543	18 528
6 400	18 603	18 589	18 574	18 560	18 546
6 600	18 621	18 606	18 592	18 578	18 564
6 800	18 638	18 624	18 610	18 595	18 581
7 000	18 656	18 642	18 627	18 613	18 599
7 200	18 674	18 659	18 645	18 631	18 616
7 400	18 691	18 677	18 663	18 648	18 634
7 600	18 709	18 695	18 680	18 666	18 652
7 800	18 727	18 712	18 698	18 684	18 669
8 000	18 744	18 730	18 716	18 701	18 687
8 200	18 762	18 748	18 733	18 719	18 704
8 400	18 780	18 765	18 751	18 736	18 722
8 600	18 797	18 783	18 768	18 754	18 740
8 800	18 815	18 800	18 786	18 772	18 757
9 000	18 833	18 818	18 804	18 789	18 775
9 200	18 850	18 836	18 821	18 807	18 792
9 400	18 868	18 853	18 839	18 824	18 810
9 600	18 886	18 871	18 857	18 842	18 828
9 800	18 903	18 889	18 874	18 860	18 845
10 000	18 921	18 906	18 892	18 877	18 863
10 200	18 939	18 924	18 909	18 895	18 880
10 400	18 956	18 942	18 927	18 912	18 898
10 600	18 974	18 959	18 945	18 930	18 915
10 800	18 992	18 977	18 962	18 948	18 933
11 000	19 009	18 995	18 980	18 965	18 951
11 200	19 027	19 012	18 998	18 983	18 968
11 400	19 045	19 030	19 015	19 001	18 986
11 600	19 062	19 048	19 033	19 018	19 003
11 800	19 080	19 065	19 050	19 036	19 021
12 000	19 098	19 083	19 068	19 053	19 039

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TABLE 6 — **Values of Q' for Aviation turbine fuels, wide cut, calculated from equations (7) and (10)**

Aniline-gravity product	Net heat of combustion, Btu/lb					
	0 % sulphur	0,2 % sulphur	0,4 % sulphur	0,6 % sulphur	0,8 % sulphur	1,0 % sulphur
5 200	18 526	18 498	18 469	18 441	18 413	18 384
5 400	18 547	18 519	18 490	18 462	18 434	18 405
5 600	18 568	18 540	18 511	18 483	18 454	18 426
5 800	18 589	18 561	18 532	18 504	18 475	18 447
6 000	18 611	18 583	18 554	18 526	18 497	18 469
6 200	18 632	18 603	18 575	18 547	18 518	18 489
6 400	18 653	18 624	18 596	18 568	18 539	18 510
6 600	18 674	18 645	18 617	18 598	18 560	18 531
6 800	18 695	18 666	18 638	18 609	18 580	18 552
7 000	18 716	18 687	18 659	18 630	18 601	18 573
7 200	18 737	18 708	18 680	18 651	18 622	18 593
7 400	18 758	18 729	18 700	18 672	18 643	18 614
7 600	18 779	18 750	18 721	18 693	18 664	18 635
7 800	18 800	18 771	18 742	18 714	18 685	18 656
8 000	18 821	18 792	18 763	18 736	18 706	18 677

TABLE 7 — **Values of Q' for Aviation turbine fuels, high flash, calculated from equations (8) and (10)**

Aniline-gravity product	Net heat of combustion, Btu/lb					
	0 % sulphur	0,2 % sulphur	0,4 % sulphur	0,6 % sulphur	0,8 % sulphur	1,0 % sulphur
4 200	18 358	18 330	18 302	18 274	18 246	18 218
4 400	18 379	18 351	18 323	18 295	18 267	18 239
4 600	18 400	18 372	18 344	18 316	18 288	18 260
4 800	18 421	18 393	18 365	18 337	18 309	18 280
5 000	18 442	18 414	18 386	18 358	18 329	18 301
5 200	18 463	18 435	18 407	18 378	18 350	18 322
5 400	18 484	18 456	18 428	18 399	18 371	18 343
5 600	18 505	18 477	18 448	18 420	18 392	18 364
5 800	18 526	18 498	18 469	18 441	18 413	18 384
6 000	18 548	18 520	18 491	18 463	18 435	18 406
6 200	18 569	18 541	18 512	18 484	18 455	18 427
6 400	18 590	18 562	18 533	18 505	18 476	18 448
6 600	18 611	18 583	18 554	18 526	18 498	18 469
6 800	18 632	18 604	18 575	18 547	18 519	18 490
7 000	18 652	18 625	18 596	18 568	18 540	18 511

TABLE 8 — **Values of Q' for Aviation turbine fuels, kerosine, calculated from equations (9) and (10)**

Aniline-gravity product	Net heat of combustion, Btu/lb				
	0 % sulphur	0,05 % sulphur	0,10 % sulphur	0,15 % sulphur	0,20 % sulphur
4 200	18 378	18 371	18 364	18 357	18 350
4 400	18 400	18 393	18 386	18 379	18 372
4 600	18 421	18 414	18 407	18 400	18 393
4 800	18 443	18 436	18 429	18 422	18 415
5 000	18 465	18 458	18 451	18 444	18 437
5 200	18 487	18 480	18 473	18 466	18 459
5 400	18 509	18 502	18 495	18 488	18 481
5 600	18 531	18 524	18 517	18 509	18 502
5 800	18 553	18 545	18 538	18 531	18 524
6 000	18 574	18 567	18 560	18 553	18 546
6 200	18 596	18 589	18 582	18 575	18 568
6 400	18 618	18 611	18 604	18 597	18 590
6 600	18 640	18 633	18 626	18 619	18 611
6 800	18 662	18 655	18 647	18 640	18 633
7 000	18 684	18 676	18 669	18 662	18 655
7 200	18 705	18 698	18 691	18 684	18 677
7 400	18 727	18 720	18 713	18 706	18 699
7 600	18 749	18 742	18 735	18 728	18 720
7 800	18 771	18 764	18 757	18 749	18 742
8 000	18 793	18 786	18 778	18 771	18 764
8 200	18 815	18 807	18 800	18 793	18 786
8 400	18 837	18 829	18 822	18 815	18 808
8 600	18 858	18 851	18 844	18 837	18 829
8 800	18 880	18 873	18 866	18 858	18 851
9 000	18 902	18 895	18 888	18 880	18 873
9 200	18 924	18 917	18 909	18 902	18 895
9 400	18 946	18 938	18 931	18 924	18 917
9 600	18 968	18 960	18 953	18 946	18 938
9 800	18 989	18 982	18 975	18 968	18 960
10 000	19 011	19 004	18 997	18 989	18 982

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