

2nd Edition

FORMULAS and CALCULATIONS for Drilling Operations

$$\text{HP} = \frac{\text{force (lbf)} \times \text{distance (ft)}}{550 \times \text{time (sec)}}$$

James G. Speight

$$\bar{V}_{ca} = \bar{V}_{cr} + \bar{V}_{cs}$$

$$\text{pH} = -\log([H^+])$$

$$\text{pH} = -\log([OH^-])$$

$$V = \frac{\text{Flow rate}}{\text{Cross sectional area}} = \frac{Q}{A}$$

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for Drilling Operations
Second Edition**

James G. Speight



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Preface

Drilling engineers design and implement procedures to drill wells as safely and economically as possible. Drilling engineers are often degreed as petroleum engineers, although they may come from other technical disciplines (such as mechanical engineering, geology, or chemical engineering) and subsequently be trained by an oil and gas company. The drilling engineering also may have practical experience as a rig hand or mud-logger or mud engineer.

The drilling engineer, whatever his/her educational background, must work closely with the drilling contractor, service contractors, and compliance personnel, as well as with geologists, chemists, and other technical specialists. The drilling engineer has the responsibility for ensuring that costs are minimized while getting information to evaluate the formations penetrated, protecting the health and safety of workers and other personnel, and protecting the environment. Furthermore, to accomplish the task associated with well drilling and crude oil (or natural gas production) it is essential that the drilling engineers has a convenient source of references to definitions, formulas and examples of calculations.

This Second Edition continues as an introductory text for drilling engineers, students, lecturers, teachers, software programmers, testers, and researchers. The intent is to provide basic equations and formulas with the calculations for downhole drilling. In addition, where helpful, example calculations are included to show how the formula can be employed to provide meaningful data for the drilling engineer.

The book will provide a guide to exploring and explaining the various aspects of drilling engineering and will continue to serve as a tutorial guide for students, lecturers, and teachers as a solution manual and is a source for solving problems for drilling engineers.

For those users who require more details of the various terms and/or explanation of the terminology, the book also contain a comprehensive

bibliography and a Glossary for those readers/users who require an explanation of the various terms. There is also an Appendix that contains valuable data in a variety of tabular forms that the user will find useful when converting the various units used by the drilling engineer.

Dr. James Speight,
Laramie, Wyoming.
January 2018.

1

Standard Formulas and Calculations

1.01 Abrasion Index

The abrasion index (sometimes referred to as the *wear index*) is a measure of equipment (such as drill bit) wear and deterioration. At first approximation, the wear is proportional to the rate of fuel flow in the third power and the maximum intensity of wear in millimeters) can be expressed:

$$\delta pl = \alpha \eta k m \omega^3 \tau$$

δpl – maximum intensity of plate wear, mm.

α – abrasion index, mm s³/g h.

η – coefficient, determining the number of probable attacks on the plate surface.

k – concentration of fuel in flow, g/m³.

m – coefficient of wear resistance of metal;

w – velocity of fuel flow, meters/sec.

τ – operation time, hours.

2 FORMULAS AND CALCULATIONS FOR DRILLING OPERATIONS

The resistance of materials and structures to abrasion can be measured by a variety of test methods (Table 1.1) which often use a specified abrasive or other controlled means of abrasion. Under the conditions of the test, the results can be reported or can be compared items subjected to similar tests. These standardized measurements can be employed to produce two sets of data: (1) the *abrasion rate*, which is the amount of mass lost per

Table 1.1 Examples of Selected ASTM Standard Test Method for Determining Abrasion*.

| | |
|-------------|--|
| ASTM B611 | Test Method for Abrasive Wear Resistance of Cemented Carbides |
| ASTM C131 | Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine |
| ASTM C535 | Standard Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine |
| ASTM C944 | Standard Test Method for Abrasion Resistance of Concrete or Mortar Surfaces by the Rotating-Cutter Method |
| ASTM C1353 | Standard Test Method for Abrasion Resistance of Dimension Stone Subjected to Foot Traffic Using a Rotary Platform, Double-Head Abraser |
| ASTM D 2228 | Standard Test Method for Rubber Property – Relative Abrasion Resistance by the Pico Abrader Method |
| ASTM D4158 | Standard Guide for Abrasion Resistance of Textile Fabrics, see Martindale method |
| ASTM D7428 | Standard Test Method for Resistance of Fine Aggregate to Degradation by Abrasion in the Micro-Deval Apparatus |
| ASTM G81 | Standard Test Method for Jaw Crusher Gouging Abrasion Test |
| ASTM G105 | Standard Test Method for Conducting Wet Sand/Rubber Wheel Abrasion Tests |
| ASTM G132 | Standard Test Method for Pin Abrasion Testing |
| ASTM G171 | Standard Test Method for Scratch Hardness of Materials Using a Diamond Stylus |
| ASTM G174 | Standard Test Method for Measuring Abrasion Resistance of Materials by Abrasive Loop Contact |

*ASTM International, West Conshohocken, Pennsylvania; test methods are also available from other standards organizations.

1000 cycles of abrasion, and (2) the *normalized abrasion rate*, which is also called the *abrasion resistance index* and which is the ratio of the abrasion rate (i.e., mass lost per 1000 cycles of abrasion) with the known abrasion rate for some specific reference material.

1.02 Acid Number

The *acid number* (*acid value*, *neutralization number*, *acidity*) is the mass of potassium hydroxide (KOH) in milligrams that is required to neutralize one gram of the substance (ASTM D664, ASTM D974).

$$AN = (V_{eq} - b_{eq})N(56.1/W_{oil})$$

V_{eq} is the amount of titrant (ml) consumed by the crude oil sample and 1 ml spiking solution at the equivalent point, b_{eq} is the amount of titrant (ml) consumed by 1 ml spiking solution at the equivalent point, and 56.1 is the molecular weight of potassium hydroxide.

1.03 Acidity and Alkalinity

pH is given as the negative logarithm of $[H^+]$ or $[OH^-]$ and is a measurement of the acidity of a solution and can be compared by using the following:

$$pH = -\log([H^+])$$

$$pH = -\log([OH^-])$$

$[H^+]$ or $[OH^-]$ are hydrogen and hydroxide ion concentrations, respectively, in moles/liter. Also, at room temperature, $pH + pOH = 14$. For other temperatures:

$$pH + pOH = pK_w$$

K_w is the ion product constant at that particular temperature. At room temperature, the ion product constant for water is 1.0×10^{-14} moles/liter (mol/L or M). A solution in which $[H^+] > [OH^-]$ is acidic, and a solution in which $[H^+] < [OH^-]$ is basic (Table 1.2).

Table 1.2 Ranges of Acidity and Alkalinity.

| <i>pH</i> | $[H^+]$ | <i>Property</i> |
|-----------|---------------------------------|-----------------|
| <7 | $>1.0 \times 10^{-7} \text{ M}$ | Acid |
| 7 | $1.0 \times 10^{-7} \text{ M}$ | Neutral |
| >7 | $<1.0 \times 10^{-7} \text{ M}$ | Basic |

1.04 Annular Velocity

Three main factors affecting annular velocity are size of hole (bigger ID), size of drill pipe (smaller OD) and pump rate. Thus:

$$\text{Annular velocity, ft/min} = \text{Flow rate, bbl/min} \div \text{annular capacity, bbl/ft}$$

For example, with a flow rate of 10 bbl/min and an annular capacity of 0.13 bbl/ft, the annular velocity is:

$$10 \text{ bbl/min} \div 0.13 \text{ bbl/ft which is } 76.92 \text{ ft/min.}$$

Other formulas include:

$$\text{Annular velocity, ft/min} = (24.5 \times Q) \div (D_h^2 - D_p^2)$$

where Q is the flow rate in gpm, D_h is inside diameter of casing or hole size in inches, and D_p is outside diameter of pipe, tubing or collars in inch. Thus, for a flow rate of 800 gpm, a hole size of 10 inches, a drill pipe OD of 5 inches, the annular velocity is

$$\text{Annular velocity} = (24.5 \times 800) \div (10^2 - 5^2) = 261 \text{ ft/min}$$

Another formula used is:

$$\text{Annular Velocity, ft/min} = \text{Flow rate (Q), bbl/min} \times 1029.4 \div (D_h^2 - D_p^2).$$

Thus, for a flow rate equal to 13 bbl/min, a hole size of 10 inches, and a drill pipe OD of 5 inches, the annular velocity is:

$$13 \text{ bbl/min} \times 1029.4 \div (10^2 - 5^2) = 178.43 \text{ ft/min}$$

1.05 Antoine Equation

The Antoine equation is a correlation used for describing the relation between vapor pressure and temperature for pure components. The Antoine constants A, B, and C (Table 1.3) are component specific constants for the Antoine equation:

$$\log_{10} P = A - (B/C + T)$$

$$T = [B/(A - \log_{10} P) - C]$$

P is the vapor pressure, mm Hg, and T is the temperature, °C.

1.06 API Gravity – Kilograms per Liter/Pounds per Gallon

The American Petroleum Institute gravity (API gravity) is a measure of how heavy or light a petroleum liquid is compared to water: if the API gravity is greater than 10, it is lighter than water and floats on water. On the other hand, if the API gravity is less than 10, it is heavier than water and sinks. The formula to calculate API gravity from the specific gravity is:

$$\text{API gravity} = (141.5/\text{specific gravity}) - 131.5$$

Conversely, the specific gravity of petroleum liquids can be derived from their API gravity value by the equation:

$$\text{Specific gravity at } 60^\circ\text{F} = 141.5/(\text{API gravity} + 31.5)$$

Table 1.3 Example of the Antoine Constants.

| | A | B | C | T _{min} , °C | T _{max} , °C |
|---------|---------|---------|---------|-----------------------|-----------------------|
| Water | 8.07131 | 1730.63 | 233.426 | 1 | 100 |
| Water | 8.14019 | 1810.94 | 244.485 | 99 | 374 |
| Ethanol | 8.20417 | 1642.89 | 230.3 | -57 | 80 |
| Ethanol | 7.68117 | 1332.04 | 199.2 | 77 | 243 |

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Using the API gravity, it is possible to calculate the approximate number of of crude oil per metric ton. Thus:

$$\text{Barrels of crude oil per metric ton} = \frac{(\text{API gravity} + 131.5)}{(141.5 \times 0.159)}$$

The relationship between the API gravity of crude oil and kilograms per liter or pounds per gallon is presented in the table (Table 1.4) below.

Table 1.4 API Gravity Conversion to Kilograms per Liter/Pounds per Gallon

| API gravity | Specific gravity | Kilograms per liter | Pounds per gallon |
|-------------|------------------|---------------------|-------------------|
| 1 | 1.0679 | 1.0658 | 8.8964 |
| 1.5 | 1.0639 | 1.0618 | 8.863 |
| 2 | 1.0599 | 1.0578 | 8.8298 |
| 2.5 | 1.056 | 1.0539 | 8.7968 |
| 3 | 1.052 | 1.0499 | 8.7641 |
| 3.5 | 1.0481 | 1.0461 | 8.7317 |
| 4 | 1.0443 | 1.0422 | 8.6994 |
| 4.5 | 1.0404 | 1.0384 | 8.6674 |
| 5 | 1.0366 | 1.0346 | 8.6357 |
| 5.5 | 1.0328 | 1.0308 | 8.6042 |
| 6 | 1.0291 | 1.027 | 8.5729 |
| 6.5 | 1.0254 | 1.0233 | 8.5418 |
| 7 | 1.0217 | 1.0196 | 8.511 |
| 7.5 | 1.018 | 1.0159 | 8.4804 |
| 8 | 1.0143 | 1.0123 | 8.45 |
| 8.5 | 1.0107 | 1.0087 | 8.4198 |
| 9 | 1.0071 | 1.0051 | 8.3898 |
| 9.5 | 1.0035 | 1.0015 | 8.3601 |
| 10 | 1 | 0.998 | 8.3306 |
| 10.5 | 0.9965 | 0.9945 | 8.3012 |
| 11 | 0.993 | 0.991 | 8.2721 |
| 11.5 | 0.9895 | 0.9875 | 8.2432 |

(Continued)

Table 1.4 Cont.

| API gravity | Specific gravity | Kilograms per liter | Pounds per gallon |
|-------------|------------------|---------------------|-------------------|
| 12 | 0.9861 | 0.9841 | 8.2144 |
| 12.5 | 0.9826 | 0.9807 | 8.1859 |
| 13 | 0.9792 | 0.9773 | 8.1576 |
| 13.5 | 0.9759 | 0.9739 | 8.1295 |
| 14 | 0.9725 | 0.9706 | 8.1015 |
| 14.5 | 0.9692 | 0.9672 | 8.0738 |
| 15 | 0.9659 | 0.9639 | 8.0462 |
| 15.5 | 0.9626 | 0.9607 | 8.0189 |
| 16 | 0.9593 | 0.9574 | 7.9917 |
| 16.5 | 0.9561 | 0.9542 | 7.9647 |
| 17 | 0.9529 | 0.951 | 7.9379 |
| 17.5 | 0.9497 | 0.9478 | 7.9112 |
| 18 | 0.9465 | 0.9446 | 7.8848 |
| 18.5 | 0.9433 | 0.9414 | 7.8585 |
| 19 | 0.9402 | 0.9383 | 7.8324 |
| 19.5 | 0.9371 | 0.9352 | 7.8064 |
| 20 | 0.934 | 0.9321 | 7.7807 |
| 20.5 | 0.9309 | 0.9291 | 7.7551 |
| 21 | 0.9279 | 0.926 | 7.7297 |
| 21.5 | 0.9248 | 0.923 | 7.7044 |
| 22 | 0.9218 | 0.92 | 7.6793 |
| 22.5 | 0.9188 | 0.917 | 7.6544 |
| 23 | 0.9159 | 0.914 | 7.6296 |
| 23.5 | 0.9129 | 0.9111 | 7.605 |
| 24 | 0.91 | 0.9081 | 7.5805 |
| 24.5 | 0.9071 | 0.9052 | 7.5562 |
| 25 | 0.9042 | 0.9023 | 7.5321 |
| 25.5 | 0.9013 | 0.8995 | 7.5081 |
| 26 | 0.8984 | 0.8966 | 7.4843 |
| 26.5 | 0.8956 | 0.8938 | 7.4606 |

(Continued)

8 FORMULAS AND CALCULATIONS FOR DRILLING OPERATIONS

Table 1.4 Cont.

| API gravity | Specific gravity | Kilograms per liter | Pounds per gallon |
|-------------|------------------|---------------------|-------------------|
| 27 | 0.8927 | 0.891 | 7.4371 |
| 27.5 | 0.8899 | 0.8882 | 7.4137 |
| 28 | 0.8871 | 0.8854 | 7.3904 |
| 28.5 | 0.8844 | 0.8826 | 7.3673 |
| 29 | 0.8816 | 0.8799 | 7.3444 |
| 29.5 | 0.8789 | 0.8771 | 7.3216 |
| 30 | 0.8762 | 0.8744 | 7.2989 |
| 30.5 | 0.8735 | 0.8717 | 7.2764 |
| 31 | 0.8708 | 0.869 | 7.254 |
| 31.5 | 0.8681 | 0.8664 | 7.2317 |
| 32 | 0.8654 | 0.8637 | 7.2096 |
| 32.5 | 0.8628 | 0.8611 | 7.1876 |
| 33 | 0.8602 | 0.8585 | 7.1658 |
| 33.5 | 0.8576 | 0.8559 | 7.1441 |
| 34 | 0.855 | 0.8533 | 7.1225 |
| 34.5 | 0.8524 | 0.8507 | 7.101 |
| 35 | 0.8498 | 0.8482 | 7.0797 |
| 35.5 | 0.8473 | 0.8456 | 7.0585 |
| 36 | 0.8448 | 0.8431 | 7.0375 |
| 36.5 | 0.8423 | 0.8406 | 7.0165 |
| 37 | 0.8398 | 0.8381 | 6.9957 |
| 37.5 | 0.8373 | 0.8356 | 6.975 |
| 38 | 0.8348 | 0.8331 | 6.9544 |
| 38.5 | 0.8324 | 0.8307 | 6.934 |
| 39 | 0.8299 | 0.8283 | 6.9136 |
| 39.5 | 0.8275 | 0.8258 | 6.8934 |
| 40 | 0.8251 | 0.8234 | 6.8733 |
| 40.5 | 0.8227 | 0.821 | 6.8533 |
| 41 | 0.8203 | 0.8186 | 6.8335 |
| 41.5 | 0.8179 | 0.8163 | 6.8137 |

(Continued)

Table 1.4 Cont.

| API gravity | Specific gravity | Kilograms per liter | Pounds per gallon |
|-------------|------------------|---------------------|-------------------|
| 42 | 0.8156 | 0.8139 | 6.7941 |
| 42.5 | 0.8132 | 0.8116 | 6.7746 |
| 43 | 0.8109 | 0.8093 | 6.7551 |
| 43.5 | 0.8086 | 0.807 | 6.7358 |
| 44 | 0.8063 | 0.8047 | 6.7167 |
| 44.5 | 0.804 | 0.8024 | 6.6976 |
| 45 | 0.8017 | 0.8001 | 6.6786 |
| 45.5 | 0.7994 | 0.7978 | 6.6597 |
| 46 | 0.7972 | 0.7956 | 6.641 |
| 46.5 | 0.7949 | 0.7934 | 6.6223 |
| 47 | 0.7927 | 0.7911 | 6.6038 |
| 47.5 | 0.7905 | 0.7889 | 6.5853 |
| 48 | 0.7883 | 0.7867 | 6.567 |
| 48.5 | 0.7861 | 0.7845 | 6.5487 |
| 49 | 0.7839 | 0.7824 | 6.5306 |
| 49.5 | 0.7818 | 0.7802 | 6.5126 |
| 50 | 0.7796 | 0.7781 | 6.4946 |
| 50.5 | 0.7775 | 0.7759 | 6.4768 |
| 51 | 0.7753 | 0.7738 | 6.459 |
| 51.5 | 0.7732 | 0.7717 | 6.4414 |
| 52 | 0.7711 | 0.7696 | 6.4238 |
| 52.5 | 0.769 | 0.7675 | 6.4064 |
| 53 | 0.7669 | 0.7654 | 6.389 |
| 53.5 | 0.7649 | 0.7633 | 6.3717 |
| 54 | 0.7628 | 0.7613 | 6.3546 |
| 54.5 | 0.7608 | 0.7592 | 6.3375 |
| 55 | 0.7587 | 0.7572 | 6.3205 |
| 55.5 | 0.7567 | 0.7552 | 6.3036 |
| 56 | 0.7547 | 0.7532 | 6.2868 |
| 56.5 | 0.7527 | 0.7512 | 6.2701 |

(Continued)

10 FORMULAS AND CALCULATIONS FOR DRILLING OPERATIONS

Table 1.4 Cont.

| API gravity | Specific gravity | Kilograms per liter | Pounds per gallon |
|-------------|------------------|---------------------|-------------------|
| 57 | 0.7507 | 0.7492 | 6.2534 |
| 57.5 | 0.7487 | 0.7472 | 6.2369 |
| 58 | 0.7467 | 0.7452 | 6.2204 |
| 58.5 | 0.7447 | 0.7432 | 6.2041 |
| 59 | 0.7428 | 0.7413 | 6.1878 |
| 59.5 | 0.7408 | 0.7394 | 6.1716 |
| 60 | 0.7389 | 0.7374 | 6.1555 |
| 60.5 | 0.737 | 0.7355 | 6.1394 |
| 61 | 0.7351 | 0.7336 | 6.1235 |
| 61.5 | 0.7332 | 0.7317 | 6.1076 |
| 62 | 0.7313 | 0.7298 | 6.0918 |
| 62.5 | 0.7294 | 0.7279 | 6.0761 |
| 63 | 0.7275 | 0.7261 | 6.0605 |
| 63.5 | 0.7256 | 0.7242 | 6.045 |
| 64 | 0.7238 | 0.7223 | 6.0295 |
| 64.5 | 0.7219 | 0.7205 | 6.0141 |
| 65 | 0.7201 | 0.7187 | 5.9988 |
| 65.5 | 0.7183 | 0.7168 | 5.9836 |
| 66 | 0.7165 | 0.715 | 5.9685 |
| 66.5 | 0.7146 | 0.7132 | 5.9534 |
| 67 | 0.7128 | 0.7114 | 5.9384 |
| 67.5 | 0.7111 | 0.7096 | 5.9235 |
| 68 | 0.7093 | 0.7079 | 5.9086 |
| 68.5 | 0.7075 | 0.7061 | 5.8939 |
| 69 | 0.7057 | 0.7043 | 5.8792 |
| 69.5 | 0.704 | 0.7026 | 5.8645 |
| 70 | 0.7022 | 0.7008 | 5.85 |
| 70.5 | 0.7005 | 0.6991 | 5.8355 |
| 71 | 0.6988 | 0.6974 | 5.8211 |
| 71.5 | 0.697 | 0.6957 | 5.8068 |

(Continued)

Table 1.4 Cont.

| API gravity | Specific gravity | Kilograms per liter | Pounds per gallon |
|-------------|------------------|---------------------|-------------------|
| 72 | 0.6953 | 0.6939 | 5.7925 |
| 72.5 | 0.6936 | 0.6922 | 5.7783 |
| 73 | 0.6919 | 0.6905 | 5.7642 |
| 73.5 | 0.6902 | 0.6889 | 5.7501 |
| 74 | 0.6886 | 0.6872 | 5.7361 |
| 74.5 | 0.6869 | 0.6855 | 5.7222 |
| 75 | 0.6852 | 0.6839 | 5.7083 |

Table 1.5 API Gravity and Sulfur Content of Selected Heavy Oils.

| | API | Sulfur % w/w |
|------------------|------|--------------|
| Bachaquero | 13.0 | 2.6 |
| Boscan | 10.1 | 5.5 |
| Cold Lake | 13.2 | 4.1 |
| Huntington Beach | 19.4 | 2.0 |
| Kern River | 13.3 | 1.1 |
| Lagunillas | 17.0 | 2.2 |
| Lloydminster | 16.0 | 2.6 |
| Lost Hills | 18.4 | 1.0 |
| Merey | 18.0 | 2.3 |
| Midway Sunset | 12.6 | 1.6 |
| Monterey | 12.2 | 2.3 |
| Morichal | 11.7 | 2.7 |
| Mount Poso | 16.0 | 0.7 |
| Pilon | 13.8 | 1.9 |
| San Ardo | 12.2 | 2.3 |
| Tremblador | 19.0 | 0.8 |
| Tia Juana | 12.1 | 2.7 |
| Wilmington | 17.1 | 1.7 |
| Zuata Sweet | 15.7 | 2.7 |

Table 1.6 API Gravity at Observed Temperature Versus API Gravity at 60 °F

| Observed temperature (°F) | 18.0 | 19.0 | 20.0 | 21.0 | 22.0 | 23.0 | 24.0 | 25.0 | 26.0 | 27.0 |
|---------------------------|------|-------|------|------|------|------|------|------|------|------|
| 70 | 17.5 | 18.4 | 19.4 | 20.4 | 21.4 | 22.4 | 23.4 | 24.4 | 25.4 | 26.3 |
| 75 | 17.2 | 18.2 | 19.1 | 20.1 | 21.1 | 22.1 | 23.1 | 24.1 | 25.0 | 26.0 |
| 80 | 16.9 | 17.9 | ia.9 | 19.a | 20.a | 21.a | 22.S | 23.7 | 24.7 | 25.7 |
| 85 | 16.6 | 17.6 | ia.6 | 19.6 | 20.5 | 21.5 | 22.5 | 23.4 | 24.4 | 25.4 |
| 90 | 16.4 | 17.3 | is.3 | 19.3 | 20.2 | 21.2 | 22.2 | 23.1 | 24.1 | 25.1 |
| 95 | 16.1 | 17.1 | 13.0 | 19.0 | 20.0 | 20.9 | 21.9 | 22.S | 23.S | 24.S |
| 100 | 15.9 | 16.a | 17.8 | 18.7 | 19.7 | 20.6 | 21.6 | 22.5 | 23.5 | 24.4 |
| 105 | 15.6 | 16.5 | 17.5 | 18.7 | 19.4 | 20.3 | 21.3 | 22.2 | 23.2 | 24.1 |
| 110 | 15.3 | 16.3 | 17.2 | 18.2 | 19.1 | 20.1 | 21.0 | 21.9 | 22.9 | 23.B |
| 115 | 15.1 | 16.0 | 17.0 | 17.9 | 1a.a | 19.a | 20.7 | 21.6 | 22.6 | 23.5 |
| 120 | 14.8 | 15.8a | 16.7 | 17.6 | 1a.6 | 19.5 | 20.4 | 21.3 | 22.3 | 23.2 |
| 125 | 14.6 | 15.5 | 16.4 | 17.4 | 1a.3 | 19.2 | 20.1 | 21.1 | 22.0 | 22.9 |
| 130 | 14.3 | 15.2 | 16.2 | 17.4 | 1a.0 | 1S.9 | 19.9 | 20.S | 21.7 | 22.6 |
| 135 | 14.1 | 15.0 | 15.9 | 16.B | 17.7 | 1S.7 | 19.6 | 20.5 | 21.4 | 22.6 |
| 140 | 13.S | 14.7 | 15.6 | 16.6 | 17.5 | 1S.4 | 19.3 | 20.2 | 21.1 | 22.0 |

Table 1.7 Selected Crude Oils Showing the Differences in API Gravity and Sulfur Content Within a Country.

| Country | Crude oil | API | Sulfur % w/w |
|------------------|---------------------|------|-----------------|
| Abu Dhabi (UAE) | Abu Al Bu Khoosh | 31.6 | 2.00 |
| Abu Dhabi (UAE) | Murban | 40.5 | 0.78 |
| Angola | Cabinda | 31.7 | 0.17 |
| Angola | Palanca | 40.1 | 0.11 |
| Australia | Barrow Island | 37.3 | 0.05 |
| Australia | Griffin | 55.0 | 0.03 |
| Brazil | Garoupa | 30.0 | 0.68 |
| Brazil | Sergipano Platforma | 38.4 | 0.19 |
| Brunei | Champion Export | 23.9 | 0.12 |
| Brunei | Seria | 40.5 | 0.06 |
| Cameroon | Lokele | 20.7 | 0.46 |
| Cameroon | Kole Marine | 32.6 | 0.33 |
| Canada (Alberta) | Wainwright-Kinsella | 23.1 | 2.58 |
| Canada (Alberta) | Rainbow | 40.7 | 0.50 |
| China | Shengli | 24.2 | 1.00 |
| China | Nanghai Light | 40.6 | 0.06 |
| Dubai (UAE) | Fateh | 31.1 | 2.00 |
| Dubai (UAE) | Margham Light | 50.3 | 0.04 |
| Egypt | Ras Gharib | 21.5 | 3.64 |
| Egypt | Gulf of Suez | 31.9 | 1.52 |
| Gabon | Gamba | 31.4 | 0.09 |
| Gabon | Rabi-Kounga | 33.5 | 0.07 |
| Indonesia | Bima | 21.1 | 0.25 |
| Indonesia | Kakap | 51.5 | 0.05 |
| Iran | Aboozar (Ardeshir) | 26.9 | 2.48 |
| Iran | Rostam | 35.9 | 1.55 |
| Iraq | Basrah Heavy | 24.7 | 3.50 |
| Iraq | Basrah Light | 33.7 | 1.95 |
| Libya | Buri | 26.2 | 1.76 |
| Libya | Bu Attifel | 43.3 | 0.04 |

(Continued)

Table 1.7 Cont.

| Country | Crude oil | API | Sulfur % w/w |
|--------------------|--------------------------|------|--------------|
| Malaysia | Bintulu | 28.1 | 0.08 |
| Malaysia | Dulang | 39.0 | 0.12 |
| Mexico | Maya | 22.2 | 3.30 |
| Mexico | Olmecca | 39.8 | 0.80 |
| Nigeria | Bonny Medium | 25.2 | 0.23 |
| Nigeria | Brass River | 42.8 | 0.06 |
| North Sea (Norway) | Emerald | 22.0 | 0.75 |
| North Sea (UK) | Innes | 45.7 | 0.13 |
| Qatar | Qatar Marine | 36.0 | 1.42 |
| Qatar | Dukhan (Qatar Land) | 40.9 | 1.27 |
| Saudi Arabia | Arab Heavy (Safaniya) | 27.4 | 2.80 |
| Saudi Arabia | Arab Extra Light (Berri) | 37.2 | 1.15 |
| USA (California) | Huntington Beach | 20.7 | 1.38 |
| USA (Michigan) | Lakehead Sweet | 47.0 | 0.31 |
| Venezuela | Leona | 24.4 | 1.51 |
| Venezuela | Oficina | 33.3 | 0.78 |

Table 1.8 API Gravity and Sulfur Content of Selected Heavy Oils and Tar Sand Bitumen.

| Country | Crude oil | API | Sulfur % w/w |
|------------------|--------------|------|--------------|
| Canada (Alberta) | Athabasca | 8.0 | 4.8 |
| Canada (Alberta) | Cold Lake | 13.2 | 4.11 |
| Canada (Alberta) | Lloydminster | 16.0 | 2.60 |
| Canada (Alberta) | Wabasca | 19.6 | 3.90 |
| Chad | Bolobo | 16.8 | 0.14 |
| Chad | Kome | 18.5 | 0.20 |
| China | Qinhuangdao | 16.0 | 0.26 |
| China | Zhao Dong | 18.4 | 0.25 |
| Colombia | Castilla | 13.3 | 0.22 |
| Colombia | Chichimene | 19.8 | 1.12 |

(Continued)