Designation: D341 – 17 D341 – 20

Standard Practice for Viscosity-Temperature Equations and Charts for Liquid Petroleum or Hydrocarbon Products[1]

This standard is issued under the fixed designation D341; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This practice covers kinematic viscosity-temperature equations and charts (see Figs. 1 and 1-23), which are a convenient means to ascertain the kinematic viscosity of a petroleum oil or liquid hydrocarbon at any temperature within a limited range, provided that the kinematic viscosities at two temperatures are known.

1.2 The charts are designed to permit petroleum oil kinematic viscosity-temperature data to plot as a straight line. The charts have been derived from the equations shown in Section 5. The charts here presented provide a significant improvement in linearity over the charts previously available under Method D341D341 – 03. 43. This increases the reliability of extrapolation to higher temperatures.

1.3 The values provided in SI units are to be regarded as standard.

1.3.1 *Exception*—The values given in parentheses are provided for information only.

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

NOTE 1—Any ASTM standard that measures kinematic viscosity at multiple temperatures is applicable to D341. Some examples are given below.

D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)

D7042 Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)

D7279 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids by Automated Houillon Viscometer

2.2 *ASTM Adjuncts:*[3]

Viscosity-Temperature Charts 1–7

3. Technical HazardMethod Limitations

3.1 **Warning—**The charts should be used only in that range in which the hydrocarbon or petroleum fluids are homogeneous liquids. The suggested range is thus between the cloud point at low temperatures and the initial boiling point at higher temperatures. The charts provide improved linearity in both low kinematic viscosity and at temperatures up to 340 °C (approximately 650 °F) or higher. Some high-boiling point materials can show a small deviation from a straight line as low as 280 °C (approximately 550 °F), depending on the individual sample or accuracy of the data. Reliable data can be usefully plotted in the high temperature region even if it does exhibit some curvature. Extrapolations into such regions from lower temperatures will lack accuracy, however. Experimental data taken below the cloud point or temperature of crystal growth will generally not be of reliable repeatability for interpolation or extrapolation on the charts. It should also be emphasized that fluids other than hydrocarbons will

[1] This practice is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and are the direct responsibility of Subcommittee D02.07 on Flow Properties.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from ASTM International Headquarters. Order Adjunct No. ADJD0341CS. Original adjunct produced in 1965.

***A Summary of Changes section appears at the end of this standard**

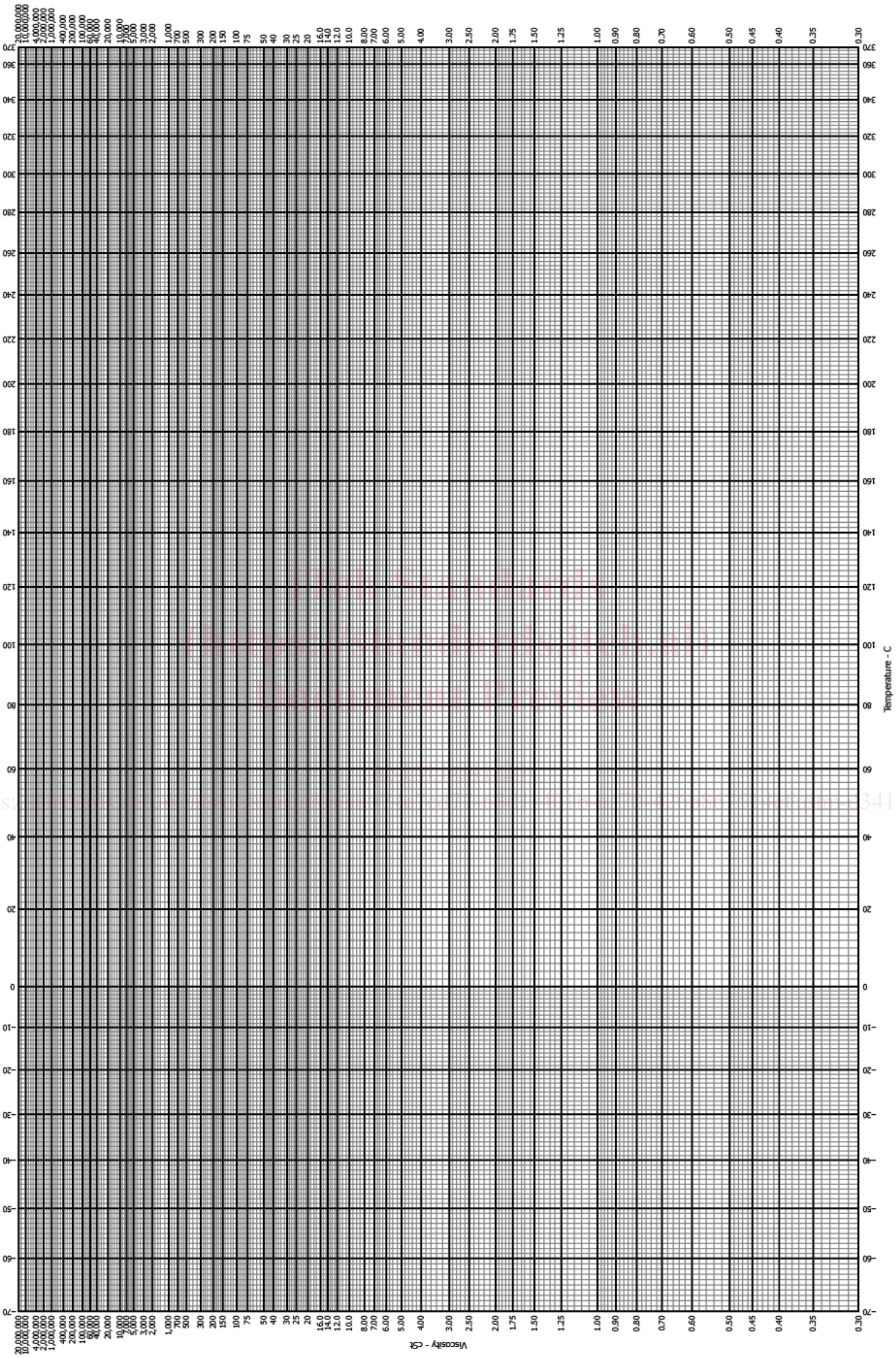
Viscosity - cSt
Temperature - C

FIG. 1 Facsimile of Kinematic Viscosity-Temperature Chart I High Range (Temperature in degrees Celsius)

usually not plot as a straight line on these charts.

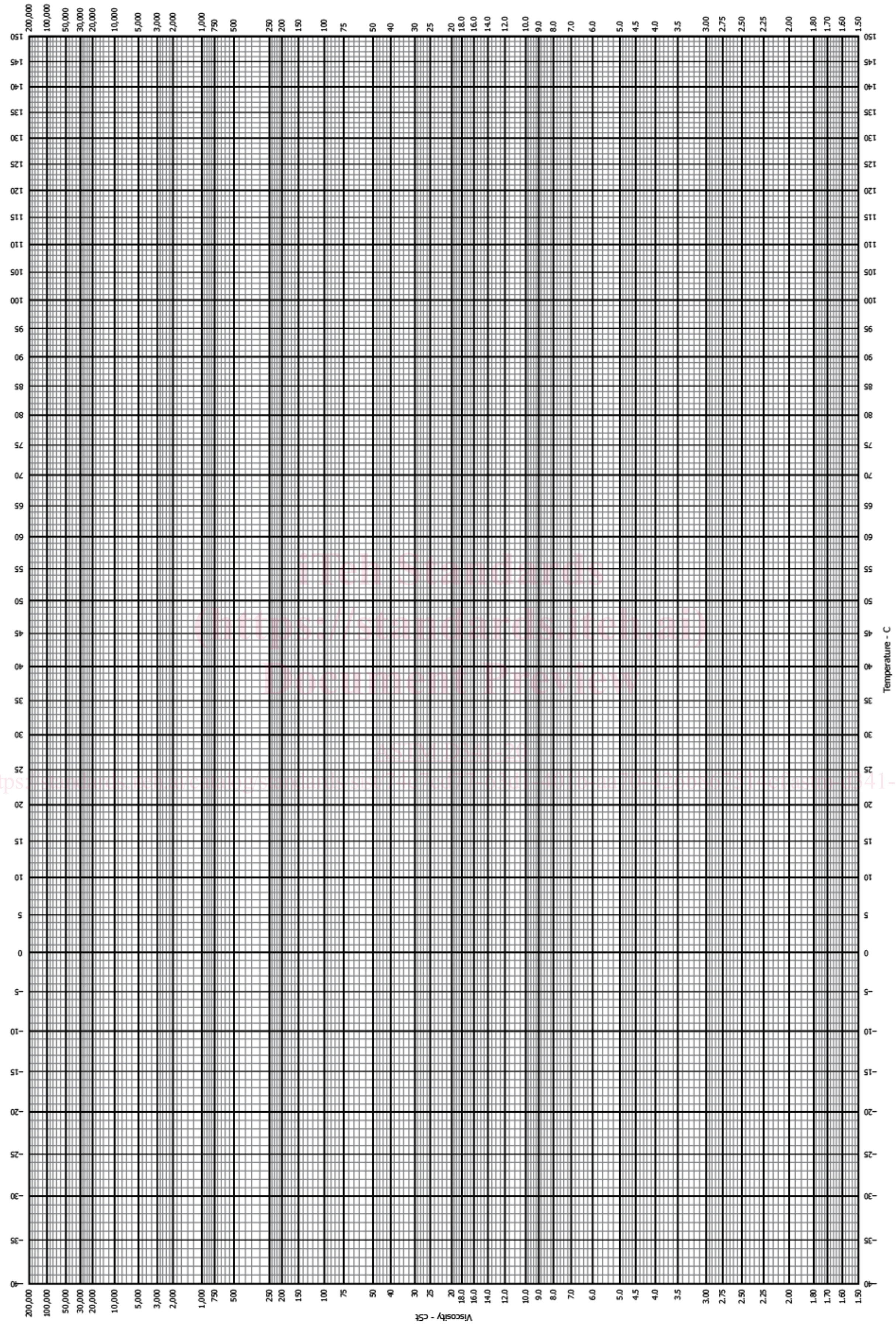
Viscosity - cSt
Temperature - C
200,000
100,000
50,000
30,000
20,000
10,000
5,000
3,000
2,000
1,000
750
500
250
200
150
100
75
50
40
30
25
20
18.0
16.0
14.0
12.0
10.0
9.0
8.0
7.0
6.0
5.0
4.5
4.0
3.5
3.00
2.75
2.50
2.25
2.00
1.80
1.70
1.60
1.50

FIG. 2 Facsimile of Kinematic Viscosity-Temperature Chart II LowI Medium Range (Temperature in degrees Celsius)

3.2 These charts are derived from the equations shown in Section 5 and are applicable over the following ranges:

Fig. 1	0.30 cSt to 20 000 000 cSt and –70 °C to 370 °C
Fig. 2	1.50 cSt to 200 000 cSt and –40 °C to 150 °C
Fig. 3	0.18 cSt to 7.0 cSt and –70 °C to 370 °C

4. Description

4.1 The charts are designed to permit kinematic viscosity-temperature data for a petroleum oil or fraction, and hydrocarbons in general, to plot as a straight line over a wide range. Seven charts are available as follows:[3]

Chart I—Kinematic Viscosity, High Range:
Kinematic Viscosity: 0.3 cSt to 20 000 000 cSt
Temperature: –70 °C to +370 °C
Size: 680 mm by 820 mm (26.75 in. by 32.25 in.)
Pad of 50
ADJD034101
Chart II—Kinematic Viscosity, Low Range:
Kinematic Viscosity: 0.18 cSt to 6.5 cSt
Temperature: –70 °C to +370 °C
Size: 520 mm by 820 mm (20.5 in. by 32.25 in.)
Pad of 50
ADJD034102
Chart III—Kinematic Viscosity, High Range:
Kinematic Viscosity: 0.3 cSt to 20 000 000 cSt
Temperature: –70 °C to +370 °C
Size: 217 mm by 280 mm (8.5 in. by 11.0 in.)
Pad of 50
ADJD034103
Chart IV—Kinematic Viscosity, Low Range:
Kinematic Viscosity: 0.18 cSt to 6.5 cSt
Temperature: –70 °C to +370 °C
Size: 217 mm by 280 mm (8.5 in. to 11.0 in.)
Pad of 50
ADJD034104
Chart V—Kinematic Viscosity, High Range:
Kinematic Viscosity: 0.3 cSt to 20 000 000 cSt
Temperature: –100 °F to +700 °F
Size: 680 mm by 820 mm (26.75 in. by 32.25 in.)
Pad of 50
ADJD034105
Chart VI—Kinematic Viscosity, Low Range:
Kinematic Viscosity: 0.18 cSt to 3.0 cSt
Temperature: –100 °F to +700 °F
Size: 520 mm by 820 mm (20.5 in. by 32.25 in.)
Pad of 50
ADJD034106
Chart VII—Kinematic Viscosity, Middle Range:
Kinematic Viscosity: 3 cSt to 200 000 cSt
Temperature: –40 °C to +150 °C
Size: 217 mm by 280 mm (8.5 in. by 11.0 in.)
Pad of 50
ADJD034107

4.2 Charts I, II, V, and VI are preferred when convenience and accuracy of plotting are desired. Chart VII is the middle range section of Chart I at somewhat reduced scale. It is provided for convenience in connection with reports and data evaluation. Charts III and IV are the same as Charts I and II and are provided in greatly reduced scale for convenience in connection with reports or quick evaluation of data. These latter charts are not recommended for use where the most accurate interpolations or extrapolations are desired.

4. Procedure for Use of the Charts

4.1 Plot two known kinematic viscosity-temperature points on the chart. Draw a sharply defined straight line through them. A point on this line, within the range defined in Section 3, shows the kinematic viscosity at the corresponding desired temperature and vice versa.

NOTE 2—If the kinematic viscosities are not known, they should be determined in accordance with Test Method D445 or D7042. Test Method D7042 results shall be bias-corrected by the application of the correction described in Test Method D7042 for the specific sample type. In case of dispute, Test Method D445 shall be the referee method.

4.2 Alternatively, the interpolated and extrapolated kinematic viscosities and temperatures may be calculated as described in Annex A14.3, within the range identified for the charts in Section 3.

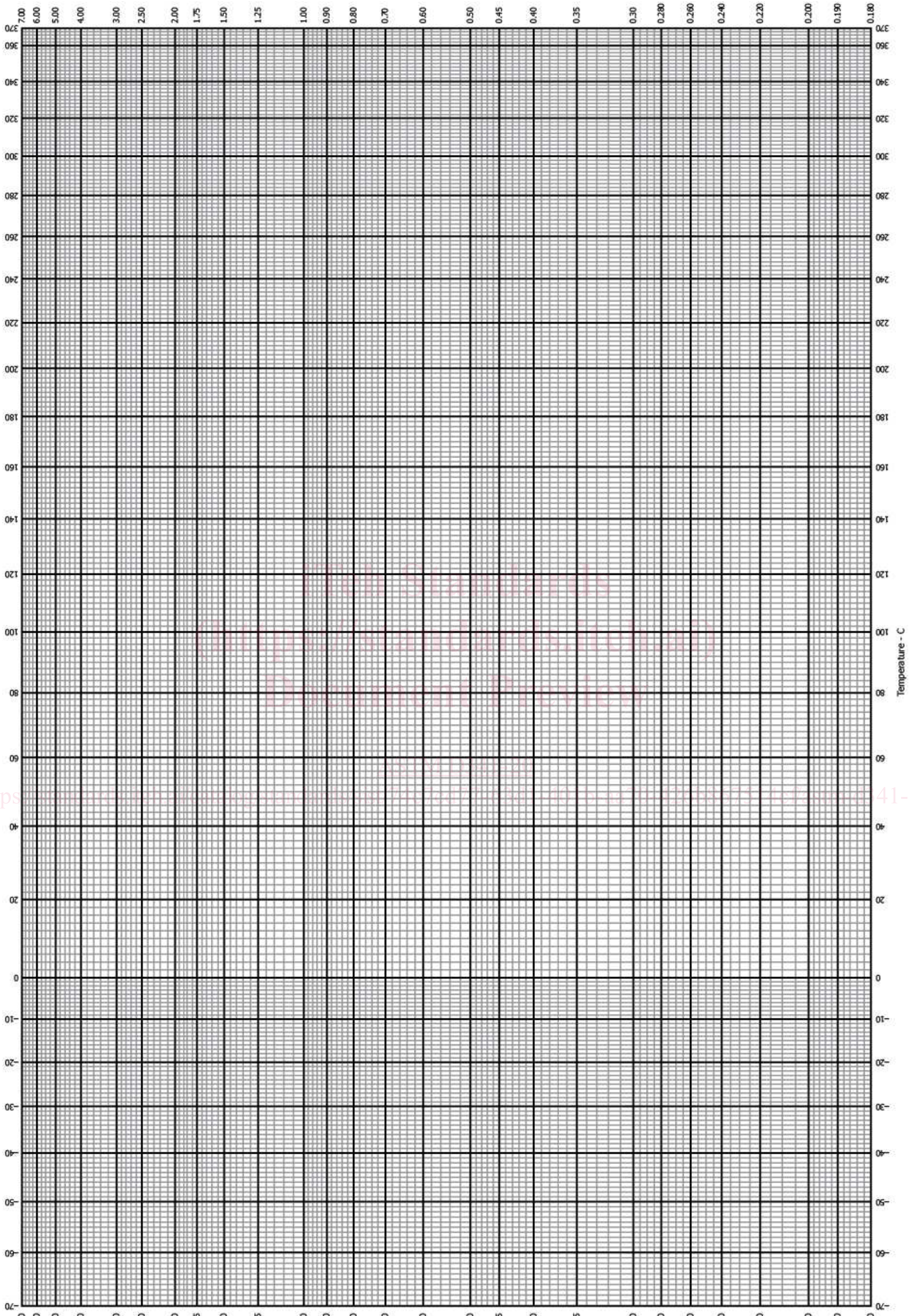
Viscosity - cSt
7.00
6.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.25
1.00
0.90
0.80
0.70
0.60
0.50
0.45
0.40
0.35
0.30
0.280
0.260
0.240
0.220
0.200
0.190
0.180
Temperature - C
370
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
−10
−20
−30
−40
−50
−60
−70

FIG. 3 Facsimile of Kinematic Viscosity-Temperature Chart I Low Range (Temperature in degrees Celsius)

Fig. 1	0.30 cSt to 20 000 000 cSt and –70 °C to 370 °C
Fig. 2	1.50 cSt to 200 000 cSt and –40 °C to 150 °C
Fig. 3	0.18 cSt to 7.0 cSt and –70 °C to 370 °C

4.3 *Extrapolation*—Kinematic viscosity-temperature points on the extrapolated portion of the line, but still within the range defined in Section 3 and 4, are satisfactory provided the kinematic viscosity-temperature line is located quite accurately. For purposes of extrapolation, it is especially important that the two known kinematic viscosity-temperature points be far apart. If these two points are not sufficiently far apart, experimental errors in the kinematic viscosity determinations and in drawing the line may seriously affect the accuracy of extrapolated points, particularly if the difference between an extrapolated temperature and the nearest temperature of determination is greater than the difference between the two temperatures of determination. In extreme cases, an additional determination at a third temperature is advisable.

5. ~~Extrapolation~~ Viscosity Temperature Equation and Use

5.1 The current viscosity-temperature equation derived by MacCoull has a general relationship as follows:

$$\log\log(Z) = A - B\log(T) \tag{1}$$

where:

$$Z = v + 0.7 + \exp(-1.47 - 1.84v - 0.51v^2) \tag{2}$$

and:

$$v = [Z - 0.7] - \exp(-0.7487 - 3.295[Z - 0.7] + 0.6119[Z - 0.7]^2 - 0.3193[Z - 0.7]^3) \tag{3}$$

where:

log = logarithm to base 10,
Z = defined in Eq 2,
A and B = constants,
T = temperature, K (or t + 273.15, where t is °C), and
v = kinematic viscosity, mm^2/s (or cSt).

5.1.1 Inserting Eq 2 into Eq 1 will permit solving for the constants A and B. Once A and B are known, Z can be calculated at any specified temperature and then Eq 3 can be used to calculate kinematic viscosity.

5.2 *Example of Calculation of A and B*—Assume a fluid has a 40 °C (313.15 K) kinematic viscosity of 70.0 mm^2/s and a 100 °C (373.15 K) kinematic viscosity of 10.0 mm^2/s.

5.2.1 Z can be calculated using Eq 2:

5.2.1.1 Z at 40 °C (313.15 K) and 100 °C (373.15 K) are 70.7 and 10.7, respectively.

5.2.1.2 log log (Z) at 40 °C (313.15 K) and 100 °C (373.13 K) are 0.267 and 0.013, respectively.

5.2.1.3 log (T) at 40 °C (313.15 K) and 100 °C (373.15 K) are 2.496 and 2.572, respectively.

5.2.1.4 Remember that T in this equation is in K.

5.2.2 Eq 1 can be rearranged to solve for A using data at 40 °C resulting in the following equation:

$$A = 0.267 + B*2.496 \tag{4}$$

5.2.3 Eq 4 can be substituted into Eq 1 along with log log (Z) and log (T) at 100 °C which results in the following equation:

$$0.013 = 0.267 + B*2.496 - B*2.572 \tag{5}$$

5.2.4 Eq 5 can be rearranged to solve for B which is 3.342. This value for B can be substituted into Eq 4 to solve for A which is 8.609.

5.3 ~~Kinematic viscosity-temperature points on the extrapolated portion of the line, but still within the range defined in Section 3, are satisfactory provided the kinematic viscosity-temperature line is located quite accurately. For purposes of extrapolation, it is especially important that the two known kinematic viscosity-temperature points be far apart. If these two points are not sufficiently far apart, experimental errors in the kinematic viscosity determinations and in drawing the line may seriously affect the accuracy of extrapolated points, particularly if the difference between an extrapolated temperature and the nearest temperature of determination is greater than the difference between the two temperatures of determination. In extreme cases, an additional determination at a third temperature is advisable.~~ *Example of Calculation of v:*

5.3.1 Values A = 8.609 and B = 3.342 for the fluid described in 5.2 can be substituted into Eq 1 which results in the following equation:

$$\log\log(Z) = 8.609 - 3.342*\log(T) \tag{6}$$

5.3.2 Using Eq 6 we can calculate log log (Z) at a desired temperature, for example 70 °C (343.15 K):

5.3.2.1 log (T) at 70 °C (343.15 K) is 2.535