Considerations for various methods for density and specific gravity

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1. Introduction

During the execution of the numerous proficiency tests for petrochemicals and petroleum products like gasoline, diesel, fuel oil and crude oil, it was observed that a significant number of laboratories encountered difficulties with the density determination. Sometimes the various density definitions gave problems and in other cases the necessary calculations and conversions were a problem. Therefore the Institute for Interlaboratory Studies decided to prepare a guidance document on this item to assist the participating laboratories in this matter.

A number of density (or Specific Gravity or API) test methods are discussed in this report. The methodologies discussed are: hydrometer method and oscillating U-tube method. For each of the methods the scope of the method is quoted together with some of the "critical points" that needs extra attention.

This paper has been sent to the members of the Technical Committee of i.i.s. for review, but the actual contents remain the responsibility of the author.
When you wish to comment or when you disagree with some of the contents of this paper please you are welcome to add your respons.

The reader is strongly advised to carefully read the valid versions relevant analytical standard methods himself / herself in the original format as published.

2. Definitions of Density, apparent density, relative density, specific gravity

From the discussions concerning the reported results in the Round Robin Program of the Institute of Interlaboratory Studies, it appeared that some aspects of the reporting of density results are not clear to all participating laboratories due to differences in the various definitions. Also in the ASTM different terminology is used in various standards (see par. XI.5 in appendix of E12). This chapter tries to make these things clear for every day's practice.

ASTM D1298
One of the methods most frequently used is ASTM D1298. In paragraph 3 of this method the terminology used in this standard is stated quite clearly:
density (acc. to D1298): the mass (weight in vacuo) of liquid per unit volume at 15°C in kg/l.
relative density or specific gravity (acc. to D1298): the ratio of the mass of a given volume of liquid at 15 °C to the mass of an equal volume of pure water at the same temperature.

ASTM D4052
Another often used method is ASTM D4052. Here about the same terminology as in D1298 is used, although the definitions mentioned in paragraphes 3.1.1 and 3.1.2 of this standard are less precise compared to the ones of D1298: The temperature does not have to be 15 °C; any temperature between 15 °C and 35 °C can be used. The temperature used, must be reported.

ASTM E12
In this less known standard all valid definitions of density were present. However, this standard was discontinued in 1996 and has been replaced by ASTM E 1547. As in E1547 less information (and less explanatory text) on the various density definitions is present, one will find here a substract from the obsolete E12, together with the meaning for a laboratory.

Density: 'The mass of a unit volume of a material at a specified temperature'; One can read this as the mass (in vacuo) of liquid per unit volume in kg/l at a specified temperature.

Apparent density: 'The weight in air of a unit volume of a material at a specified temperature'; One can read this as the weight (in air) of liquid per unit volume in kg/l at a specified temperature. For animal and vegetable oils the term litre-weight is used in stead of apparent density.

Specific gravity (equal to relative density): 'The ratio of the mass of a unit volume of a material at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature.' One can read this as the ratio of the mass (in vacuo) of liquid per unit volume at a specified temperature to the mass (in vacuo) of the same volume of pure water at a specified temperature.

In the appendix of E12 the differences between the definitions are discussed: Density and specific gravity (= relative density) are based on mass (= in vacuo) and should be constant. Apparent density (together with litre-weight, bulk density, apparant specific gravity and bulk specific gravity) are based on weight in air, and therefore are subject to change with atmosferic conditions, locality and altitude.

3. Standard methods for the determination of Density

From the discussions concerning the reported results in the Round Robin Program of the Institute of Interlaboratory Studies, it appeared that some aspects of the reporting of density results are not clear to all participating laboratories due to differences in the various standard methods. This chapter tries to make these things clear for every day's practice. In the next paragraphs for each of the methods the scope of the method is quoted together with some of the "critical points" that needs extra attention.

3.1 ASTM D 287 – 92

API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)

quote

1. Scope

1.1 This test method covers the determination by means of a glass hydrometer of the API gravity of crude petroleum and petroleum products..... Gravities are determined at 60°F (15.56°C), or converted to values at 60°F, by means of standard tables.

3. Terminology

3.1.1 No statement of reference temperature is required, since 60°F is included in the definition.

7. Temperature of the test

7.1 The gravity ... is most accurate at or near the standard temperature of 60 °F. Use this or any other temperature between 0 and 195°F, so far as it is consistent with the type of sample and the necessary limiting conditions shown in Table 1.

Sample Type	Gravity Limits	IBP Limits	Other limits	Test Temperature
Highly volatile	lighter than 70° API			Cool to 35°F or lower in original closed container
Moderately volatile	heavier than 70° API	below 250°F (120°C)		Cool to 35°F or lower in original closed container
Moderately volatile and viscous	heavier than 70° API	below 250°F (120°C)	Viscosity too high at 65°F	Heat to minimum temperature for sufficient fluidity
Nonvolatile	heavier than 70° API	above 250°F (120°C)		Any temperature between 0 and 195°F as convenient
Mixtures of nonpetroleum products or pure hydrocarbons				60 +- 0.25°F

Table 1: Limiting Conditions and Testing Temperatures

8. Procedure

8.2 Adjust the temperature of the sample in accordance with Table 2.

8.3 Transfer the sample into the clean hydrometer cylinder without splashing, so as to avoid the formation of air bubbles and to reduce to a minimum the evaporation of the lower boiling constituents of the more volatile samples.....

8.7 Observe the temperature of the sample to the nearest 0.25°F immediately before and after the observation of the gravity ..... Should these temperature readings differ by more than 1°F , repeat the temperature and gravity observations.....
Record the mean of the thermometer reading before and after the final hydrometer reading, to the nearest 1°F, as the temperature of the test.

9. Calculation
9.1 When gravities have been observed on opaque liquids using the procedure given in 8.6, subtract the correction from the hydrometer reading observed.
unquote

Critical points for attention:

A volatile sample must be cooled in the original closed container. Do NOT transfer the sample to the hydrometer cylinder before cooling otherwise some light ends will be lost.
You will also loose light ends when excess air bubbles are formed during transfer of the sample.
A viscous sample must be heated so as to make certain that the hydrometer floats freely and the reading is not influenced by the sample viscosity.
Record the temperature reading both before AND after the hydrometer reading. Should these readings differ by more than 1°F, repeat BOTH the temperature and gravity observations. It is a common error to average wrongly observed readings.
Hydrometers for Density or Specific Gravity read from top to bottom from low value to high value.
Hydrometers for °API read the other way around: from top to bottom from high to low. Thus, when using D 287 the correction for an opaque sample must not be added but subtracted.
Refer Item 3.1 of the method > "No statement of reference temperature is required, since 60°F is included in the definition."
Therefore, do not report the result as == 45.5 °API at 60°F == or == API Gravity at °60F ==, but simply as == 45.5 °API ==, or == API Gravity ==.

3.2 ASTM D 891 - 95

Standard Test Methods for Specific Gravity, Apparent, of Liquid Industrial Chemicals

quote
Scope
1.1 These test methods cover the determination of the specific gravity, apparent, of liquid industrial chemicals.
1.1.1 Test Method A, specific gravity, apparent, by means of a hydrometer.
1.2 In common usage the term specific gravity, apparent, is understood to mean specific gravity. Since this test method is to be in conformity with Terminology E12 (replaced by E1547 since 1996), all terms reading specific gravity were changed to specific gravity, apparent, without altering the meaning of specific gravity, and the term apparent could be dropped in every day operations after establishing the use term equivalency.

3. Terminology
3.1 Descriptions of Terms Specific to This Standard:[6]
3.1.1 specific gravity, apparent - the ratio of the weight in air of a unit volume of a material at a stated temperature to the weight in air of equal density of an equal volume of gas-free distilled water (see Note2) at a stated temperature. It shall be stated as follows:

Specific gravity, apparent, x/y°C

where x is the temperature of the material and y is the temperature of the water.

Note 2 - Gas-free distilled water is distilled water that has been boiled to eliminate dissolved gasses.
Note 6 - These definitions conform to those in Terminology E 12 (replaced by E1547 since 1996), with this explanation modified as follows: specific gravity corresponds to apparent specific gravity as defined in Terminology E 12 (replaced by E1547 since 1996), and absolute specific gravity corresponds to specific gravity as defined in Terminology E 12 (replaced by E1547 since 1996),.

7. Apparatus
7.1 Hydrometer - The hydrometers to be used shall be those specified in Specifications E 100.

Note 3 - The ASTM hydrometers prescribed in Test Method A, 7.1, are calibrated as if all weights are in vacuum. Equivalent values at the same temperature for all weights in air may be approximated for ambient conditions as follows:

apparent specific gravity = 1.00120 x (sp gr) - 0.00120

where:
sp gr = specific gravity determined by ASTM hydrometer

9. Report
9.1 Report the reading obtained plus any calibration correction as the specific gravity, apparent, of the sample to the nearest 0.0001 unit.
unquote

Critical points for attention:

ASTM E 12 (terminology) was discontinued in 1996 and has been replaced by ASTM E 1547.

The terminology used in D 891 may be somewhat confusing. Refer item 1.2 above.
In daily practice when we use the term Specific Gravity most of the times what actually is meant is: Specific Gravity, apparent.
And there is a significant difference between the two. Refer to chapter 1 and ASTM E 1547.

Specific Gravity (thus without the " apparent") is the ratio of the mass of a unit volume.
Specific Gravity, apparent is the ratio of the weight in air of a unit volume.
Thus Specific Gravity is "in vacuum" whilst Specific Gravity, apparent is "in air".

Now refer to Note3. It says that the hydrometers to be used in ASTM D 891 are calibrated in vacuum. Therefore, readings taken by these hydrometers must be converted to equivalent "apparent" values using the given formula before same can be reported as Specific Gravity, apparent.

SG	SG app	Difference
0.6666	0.6662	0.0004
0.7777	0.7774	0.0003
0.8888	0.8887	0.0001
0.9999	0.9999	0.0000

There is a small difference between these two values

3.3 ASTM D 1298 - 85 (Reapproved 1990)e1

Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method.

quote

1. Scope

1.1 This practice covers the laboratory determination, using a glass hydrometer, of the density, relative density (specific gravity), or API Gravity of crude petroleum, petroleum products, or mixtures ..... normally handled as liquids, and having a RVP of (179 kPa) 26 lb or less.

3. Terminology

3.1.1 density - for the purpose of this practice, the mass (weight in vacuo) of liquid per unit volume at 15°C. .....in units of ..... kilograms per litre at 15 °C

3.1.2 relative density (specific gravity) - for the purpose of this practice, the ratio of the mass of a given volume of liquid at 15°C (60°F) to mass of an equal volume of pure water at the same temperature. .....relative density (specific gravity) 60/60°F.

3.1.3 API Gravity - a special function of relative density (specific gravity) 60/60°F ..... No statement of reference temperature is required, since 60°F is included in the definition.

4. Field of application

4.1 When used in connection with bulk oil measurements, volume correction errors are minimized by observing the hydrometer reading at a temperature close to that of the bulk oil temperature.

7. Apparatus

7.3 Hydrometer Cylinder, ...The inside diameter of the cylinder shall be at least 25 mm greater than the outside diameter of the hydrometer used in it. The height of the cylinder shall be such that the appropriate hydrometer floats in the sample with at least 25 mm clearance between the bottom of the hydrometer and the bottom of the cylinder.

Note 1 ..... In cases where the instrument is provided with a calibration certificate ..... the appropriate correction listed shall be applied to the observed readings.

8 Temperature of Test

8.1 The density ..... by the hydrometer method is most accurate at or near the reference temperature of 15°C or 60°F. Use these or any other temperatures between -18 and +90°C (0 and 195°F), so far as it is consistent with the type of sample and necessary limiting conditions shown in Table 3.

8.2 When the hydrometer value is to be used to select multipliers for correcting volumes to standard temperatures, the hydrometer reading should be made preferably at a temperature within +-3°C (+-5°F) of the temperature at which the bulk volume of the oil was measured (Note 2). However, in cases when appreciable amounts of light fractions may be lost during determinations at the bulk oil temperature, the limits given in Table 2 should be applied.

Sample type	Initial Boiling Point	Other Limits	Test Temperature
Highly volatile		RVP below 26 lb (179 kPa)	Cool in original closed container to 2°C (35°F) or lower
Moderately volatile	120°C (250°F) and below		Cool in original closed container to 18°C (65°F) or lower
Moderately volatile and viscous	120°C (250°F) and below	viscosity too high at 18°C (65°F)	Heat to minimum temperature to obtain sufficient fluidity
Nonvolatile	Above 120°C (250°F)		Use any temperature between -18 and 90°C (0 and 195°F) as convenient
Mixtures with nonpetroleum products			Test at 15 +- 0.2°C (60 +-0.5°F)

TABLE 2 Limiting Conditions and Test Temperatures

Note 2 - Volume and density .... correction tables are based on an average expansion for a number of typical materials. Since the same coefficients were used in computing both sets of tables, corrections made over the same temperature interval minimize errors arising from possible differences between the coefficients of the materials under test and the standard coefficients.

9. Procedure

9.4 ..... As soon as a steady reading is obtained, record the temperature of the sample to the nearest 0.25°C (0.5°F) and then remove the thermometer.

9.7 With an opaque liquid ..... This reading, at the top of the meniscus, requires correction..... The correction for the particular hydrometer in use may be determined by observing the maximum height above the principal surface of the liquid to which the oil rises on the hydrometer scale when the hydrometer in question is immersed in a transparent oil having a surface tension similar to that of the sample under test.

Note 5 - Alternatively, corrections as given in Table 3 may be applied.

Specification	Units	Interval	Meniscus correction
BS 718:1960 L50 SP	density, kg/litre at 15°C	0.0005	+ 0.0007
BS 718:1960 M50 SP	density, kg/litre at 15°C	0.001	+ 0.0014
BS 718:1960 L50 SP	relative density (specific gravity) 60/60°F	0.0005	+ 0.0007
BS 718:1960 M50 SP	relative density (specific gravity) 60/60°F	0.001	+ 0.0014
E 100, Nos 82H to 90H	relative density (specific gravity) 60/60°F	0.0005	
E 100, Nos 1H to 10H	API	0.1	

TABLE 3 Recommended hydrometers

9.8 ..... Record the temperature of the sample to the nearest 0.2°C (0.5°F). Should this temperature differ from the previous reading by more than 0.5°C (1°F), repeat the hydrometer test and then thermometer observations until the temperature becomes stable within 0.5°C (1°F).

10. Calculations and Report

10.1 Apply any relevant corrections..... Record to the nearest 0.0001 density or relative density (specific gravity) or 0.1°API the final corrected hydrometer scale reading. After application of any relevant corrections record to the nearest 0.5°C or 1°F, the mean of the temperature values observed immediately before and after the final hydrometer reading.

unquote

Critical points for attention:

Terminology. (See also chapter 2 of this report)
The definition of density is clear: "mass (weight in vacuo).... ". Same as the definition for Specific Gravity: "ratio of the mass.....".
Thus by definition density is always in vacuo. It is not correct to report values as "Density in vacuo" or "Density in air" or "Specific Gravity in vacuo" or "Specific Gravity in air".

A volatile sample must be cooled in the original closed container. Do NOT transfer the sample to the hydrometer cylinder before cooling otherwise some light ends will be lost.
You will also loose light ends when excess air bubbles are formed during transfer of the sample.

A viscous sample must be heated so as to make certain that the hydrometer floats freely and the reading is not influenced by the sample viscosity. For black oils with high pour points the test temperature should be at least above 48 °C (with reference to ASTM D 97 Pour Point).

Refer to item 4.1 Field of application: "volume correction errors are minimized by observing the hydrometer reading at a temperature close to that of the bulk oil temperature."
Densities are normally reported at 15°C. When readings are taken at high temperatures there may be calculation errors when converting to 15°C. Make certain that the correct tables are used and that the tables are used in the correct manner.

Refer also to Note 2 above:
"Volume and density .... correction tables are based on an average expansion for a number of typical materials. Since the same coefficients were used in computing both sets of tables, corrections made over the same temperature interval minimize errors arising from possible differences between the coefficients of the materials under test and the standard coefficients."
When the exact coefficient of expansion is known for the temperature interval for the product under test it is preferred to use this coefficient rather than the tables.

Record the temperature reading both before AND after the hydrometer reading. Should these readings differ by more than 0.5°C, repeat BOTH the temperature and density observations. It is a common error to average wrongly observed readings.

Hydrometer readings on opaque sample require a correction for the meniscus. Always add this correction to the observed reading. Do not subtract.

When taking readings of viscous samples make certain that the sampe does not contain entrained air bubbles. This is especially valid for opaque samples at elevated temperatures.

Make certain that the dimensions of the hydrometer cylinder meet the requirements stated at Item 7.3.
The clearance between the hydrometer and the cylinder must be at least 25 mm. Otherwise the hydrometer may not float freely. This is especially valid for viscous samples.

3.4 ASTM D 4052 – 96

Density and Relative Density of Liquids by Digital Density Meter

quote

1. Scope

1.1 This test method covers the determination of the density or relative density of petroleum distillates and viscous oils that can be handled in a normal fashion as liquids at test temperatures 15 and 35°C.

Its application is restricted to liquids with vapour pressures below 600 mmHg (80 kPa) and viscosities below about 15000 cSt (mm2/s) at the temperature of the test.
1.2 This test method should not be applied to samples so dark in color that the absence of air bubbles in the sample cell cannot be established with certainty. For the determination of density in crude oil samples use Test Method D 5002.
1.3 The accepted units of measure for density are grams per millilitre or kilograms per cubic metre.

10. Calibration of apparatus
10.1 Calibrate the instrument .... whenever the test temperature is changed. Thereafter, conduct calibration checks at weekly intervals during routine operation.
10.3.1 If the display does not exhibit the correct density for air at the temperature of test, repeat the cleaning procedure .....

11. Procedure
11.3 ..... Make sure that no bubbles are trapped in the tube, and that it is filled just beyond the suspension point on the right-hand side.

Note 6 - If the sample is too dark in color to determine the absence of bubbles with certainty, the density cannot be measured within the stated precision limits....

11.4 Turn the illumination light off immediately after sample introduction, because the heat generated can affect the measurement temperature.

12. Calculation
12.3 If it is necessary to convert a result obtained using the density meter to a density or relative density at another temperature, Guide 1250 can be used only if the glass expansion factor has been excluded.

unquote

Critical points for attention:

Scope of the method:
"oils that can be handled in a normal fashion as liquids at test temperatures 15 and 35°C."
Thus the test method would be applicable only between 15 and 35 °C.

"restricted to liquids with vapour pressures below 600 mmHg (80 kPa) and viscosities below about 15000 cSt (mm2/s) at the temperature of the test.
Vapour pressure of gasolines is normally expressed at 100°F (RVP). At the temperature of the density test the vapour pressure will be much lower. Therefore samples with high RVP may still be analyzed with this method.

Take care to record readings only when it is absolutely certain that air bubbles are absent. This is especially valid when analyzing samples that are dark in color.

This method is **NOT** applicable for crude oil > use Test Method D 5002.

The instrument MUST be calibrated when the temperature settings are changed.

The heat of the illumination light may effect the measurement temperature. Turn it off immediately after making certain that that U-tube does not contain air bubbles.

Glass expansion factor. Item 12.3 above.
"Guide 1250 can be used only if the glass expansion factor has been excluded."

Refer ASTM D 1250 Tables 53A and 53B Item 11.1.53.1
The formula used for glass expansion factor is:
Quote
$HYC = 1 - 0.000023 * (t - 15°C) - 0.00000002 * (t - 15°C)^2$
Unquote

Unfortunately the foreword of the table does not specify how to exactly apply this HYC factor. It can be deduced from the computer procedures described in Volume X Item 11.1.53.2. In these procedures the observed values are multiplied by the HYC.
Thus, to exclude this factor, the observed density value should be multiplied by the reciprocal of the HYC to obtain the corrected reading for entry in Table 53B.

The procedure would then be as follows:
1. Record the observed reading from the instrument.
2. Record the temperature of the test.
3. Find the applicable factor in the HYC table, see appendix 1 (or use a calculator)
4. Multiply the observed value for the density with the factor
5. Enter the ASTM table with the corrected observed value to find the Density at 15 C

Calculation example:

Observed density	997.0	kg/m3
Temperature	34.0	°C
Hydrometer correction HYC	0.999556	
Corrected reading for table entry	997.4	kg/m3

An elaborate explanation of the Hydrometer Correction HYC can be found in Annex A of IP 365/97 (ISO 12185:1996).

3.5 ASTM D 5002 – 94

Density and Relative Density of Crude Oils Liquids by Digital Density Analyzer

quote
1. Scope
1.1 This test method covers the determination of the density or relative density of crude oils that can be handled in a normal fashion as liquids at test temperatures 15 and 35°C. This test method applies to crude oils with high vapor pressures provided appropriate precautions are taken to prevent vapor loss during transfer of the sample to the density analyzer.
1.2 This test method was evaluated in round robin testing using crude oils in the 0.75 to 0.95 g/mL range. Lighter crude oil can require special handling to prevent vapor losses. Heavier crudes can require measurements at higher temperatures to eliminate air bubbles in the sample.
1.3 The accepted units of measure for density are grams per millilitre or kilograms per cubic metre.

10. Calibration of apparatus
10.1 Calibrate the instrument .... whenever the test temperature is changed. Thereafter, conduct calibration checks at least weekly during routine operation or more frequently as may be dictated by the nature of the crude oils being measured (see 10.3).
10.2.1 ..... In cases where saline components can be deposited in the cell, flush with distilled water followed by acetone and dry air. Contaminated or humid air can affect the calibration. When these conditions exist in the laboratory, pass the air used for calibration through a suitable purification and drying train. In addition. the inlet and outlet ports for the U-tube must be plugged during measurement of the calibration to prevent ingress of moist air.
10.3 Since some crude oils can be difficult to remove from the sample tube, frequent calibration checks are recommended.....

11. Procedure
11.1 Introduce about 0.7 mL ... using a suitable syringe. Leave the syringe in place and plug the exit port.
11.2 Turn on the illumination light and examine the sample tube carefully..... Turn the illumination light off immediately after inspection ..... since the heat generated affects the measurement temperature.
11.3 Allow the sample to equilibrate to the test temperature before proceeding to evaluate the test sample for the presence of unseen air or gas bubbles.
11.4 ..... If stable values are not observed after a few minutes, then repeat the injection of a new sample into the tube.
11.6 ..... check the calibration .... prior to introducing another sample.

12. Calculation
12.3 If it is necessary to convert a result obtained using the density analyzer to a density or relative density at another temperature, Guide 1250 can be used only if the table values have not been corrected for the glass expansion factor.

13. Report
13.3 Report the final result to four significant figures.
Unquote

Critical points for attention:

Most of the critical points are the same as given for ASTM D 4052. These are not repeated here.

ASTM D 5002 differs from D 4052 a.o. on the following:

Scope: D 5002 applies to crude oils with high vapour pressures.

Procedure:
D 5002 Item 11.1 "Leave the syringe in place and plug the exit port"
D 5002 does NOT mention the possibility of entering the sample by siphoning, whereas D 4052 does.

Report:
D 4052 item 13.3 "Report the final result to the fourth decimal place".
D 5002 item 13.3 "Report the final result to four significant figures".

3.6 IP 160/96

Determination of density - Hydrometer method

quote
1. Scope
This standard specifies a method for the laboratory determination, using a glass hydrometer, of the density of crude petroleum, liquid petroleum products, and mixtures of petroleum and non petroleum products normally handled as liquids and having a Reid vapour pressure (RVP) of 90 kPa or less.

This standard is suitable for determining the density of mobile transparent liquids. It can also be used for viscous liquids by carrying out the determinations at temperatures above ambient using a suitable liquid bath for temperature control. It may also be used for opaque liquids.....

Note 2 The procedure given in this standard may not be appropriate for obtaining density data necessary for fiscal or custody transfer accounting of volatile crude oils containing free and/or suspended water and sediments. This is due to the sample mixing which may result in the loss of light components. ..... if further reduction in light end loss or if a ' dry oil density ' is required, it is recommended that a test method such as IP PM BK is used.

5 Apparatus
5.1 Hydrometer cylinder, ...with an inside diameter at least 25 mm greater than the outside diameter of the hydrometer and a height such that the hydrometer floats in the test portion with at least 25 mm clearance between the bottom of the hydrometer and the bottom of the cylinder.....

7.2 Test temperature
7.2.1 Bring the sample to the test temperature which shall be such that the sample is sufficiently fluid, but not so high as to cause the loss of light ends, nor so low as to result in the presence of wax in the test sample.

Note 13 The density determined by the hydrometer method is most accurate at or near the reference temperature of 15°C.
Note 14 When used in conjunction with bulk oil measurements, errors due to volume correction are minimized by determining the density at the bulk oil temperature.

9 Procedure
9.3 ..... When testing at temperatures above or below ambient temperature, a constant-temperature bath shall be used to avoid excessive temperature changes.
9.10 ..... Record the temperature of the test portion to the nearest 0.1°C. If this temperature differs from the reading taken at the start of the test by more than 0.5°C, repeat the hydrometer observations, and then thermometer observations until the temperature becomes stable within 0.5°C. ...

10 Calculation
10.1 Apply any thermometer correction to the temperature reading observed and record the temperature to the nearest 0.1 °C.
10.2 For opaque liquids, apply the relevant meniscus correction as given in table 1 to the observed hydrometer reading, ...

Note 18 The correction for the particular hydrometer in use is determined by observing the maximum height above the principal surface of the liquid to which oil rises on the hydrometer scale when the hydrometer in question is immersed in a transparent oil having a surface tension similar to that of the sample under test. For hydrometers specified in this method, see Table 4

Units	Density range	Scale interval	Meniscus correction
kg/m^3 at 15°C	600 to 1100 600 to 1100	0.5 1.0	+ 0.7 + 1.4
g/ml at 15°C	0.600 to 1.100 0.600 to 1.100	0.000 5 0.001 0	+ 0.000 7 + 0.001 4

Table 4 - Requirements for hydrometers

10.3 Apply any hydrometer correction to the observed hydrometer reading and record to the nearest 0.1 kg/m^3 (0.0001 g/ml)

Note 20 To convert a hydrometer reading from one unit to another, use either table 3 or table 51....

unquote

Critical points for attention:

Although ASTM D 1298 and IP 160 are joint methods they are not equal. However, the final test result of the two methods should be the same.

Most of the critical points are the same as given for ASTM D 1298. These are not repeated here.

A difference exists in the scope of the methods:
ASTM D 1298 : "having a RVP of 129 kPa or less".
IP 160 : "having a RVP of 90 kPa or less".

3.7 ISO 12185:1996

Crude petroleum and petroleum products - Determination of density - Oscillating U-tube method.

quote

1. Scope

This International Standard specifies a method for the determination, using an oscillating U-tube density meter, of the density of crude petroleum and related products within the range 600 kg/m^3 to 1 100 kg/m^3 which can be handled as single-phase liquids at the test temperature and pressure.

This International Standard is applicable to liquids of any vapour pressure as long as suitable precautions are taken to ensure that they remain in single phase composition, and density during both the sample handling and the density determination.

3 Definitions

3.1 density: Mass of the substance, expressed in kilograms, divided by its volume, expressed in cubic metres.

3.2 reference temperature: Temperature at which the sample density is to be reported.

note 2 This temperature should be either 15°C or 20°C.

9 Apparatus preparation

9.1 Test temperature

9.1.1 Sample density shall, wherever possible, be determined at the reference temperature.
If this is not possible, a temperature shall be chosen which is 3 °C above the cloud point or wax appearance temperature or 20 °C above the pour point and below the temperature at which gas appears in the sample.

9.2 Cell cleaning

.....
After testing crude oils containing dissolved salts, clean the cell with water after first washing with the flushing solvent.

If the cell shows signs of organic deposits, clean the cell by injecting ammonium peroxidisulfate solution into the cell. After removal of the ammonium peroxidisulfate solution, flush the cell with water followed by a water-miscible solvent and blow dry with clean dry air.

10.1

.....
The density-meter calibration shall be verified within a period of not more than seven days prior to use.

11 Test procedure
11.1 Check that the density-meter reading when the cell is filled with ambient air is within +- 1 of the least significant digit compared to the reference value achieved during calibration. If it is not, reclean and dry the cell and repeat the check. If the reading still differs recalibrate the meter.
11.3 When using an autosampler, either run samples in duplicate or introduce check samples, ...
11.4 Do not apply suction to samples prone to light-end loss at any stage. .....
11.5 When making a manual injection, switch on the cell illumination before injecting, check the cell for bubbles

unquote

Critical points for attention:

All the critical points that are given at ASTM 4052 and ASTM 5002 are also applicable for this method.

An elaborate explanation of the Hydrometer Correction HYC can be found in Annex A of IP 365/97 (ISO 12185:1996).

3.8 IP 365

This method is identical to ISO 12185:1996
Refer to the discussion of ISO 12185 in this paper.

3.9 EN ISO 12185

The text of ISO 12185:1996 was approved in 1996 by CEN as an European Standard without any modification. Refer to the discussion of ISO 12185 in this paper.

4. Appendix 1

HYC table

Test Temperature	HYC
50.0	0.999171
49.0	0.999195
48.0	0.999219
47.0	0.999244
46.0	0.999268
45.0	0.999292
44.0	0.999316
43.0	0.999340
42.0	0.999364
41.0	0.999388
40.0	0.999413
39.0	0.999436
38.0	0.999460
37.0	0.999484
36.0	0.999508
35.0	0.999532
34.0	0.999556
33.0	0.999580
32.0	0.999603
31.0	0.999627
30.0	0.999651
29.0	0.999674
28.0	0.999698
27.0	0.999721
26.0	0.999745
25.0	0.999768
24.0	0.999791
23.0	0.999815
22.0	0.999838
21.0	0.999861
20.0	0.999885
19.0	0.999908
18.0	0.999931
17.0	0.999954
16.0	0.999977
15.0	1.000000