Tikrit University

The College of Petroleum Processes Engineering

Petroleum Systems Control Engineering Department

Properties of Petroleum & Natural Gas

Third Class

Lecture 7

By

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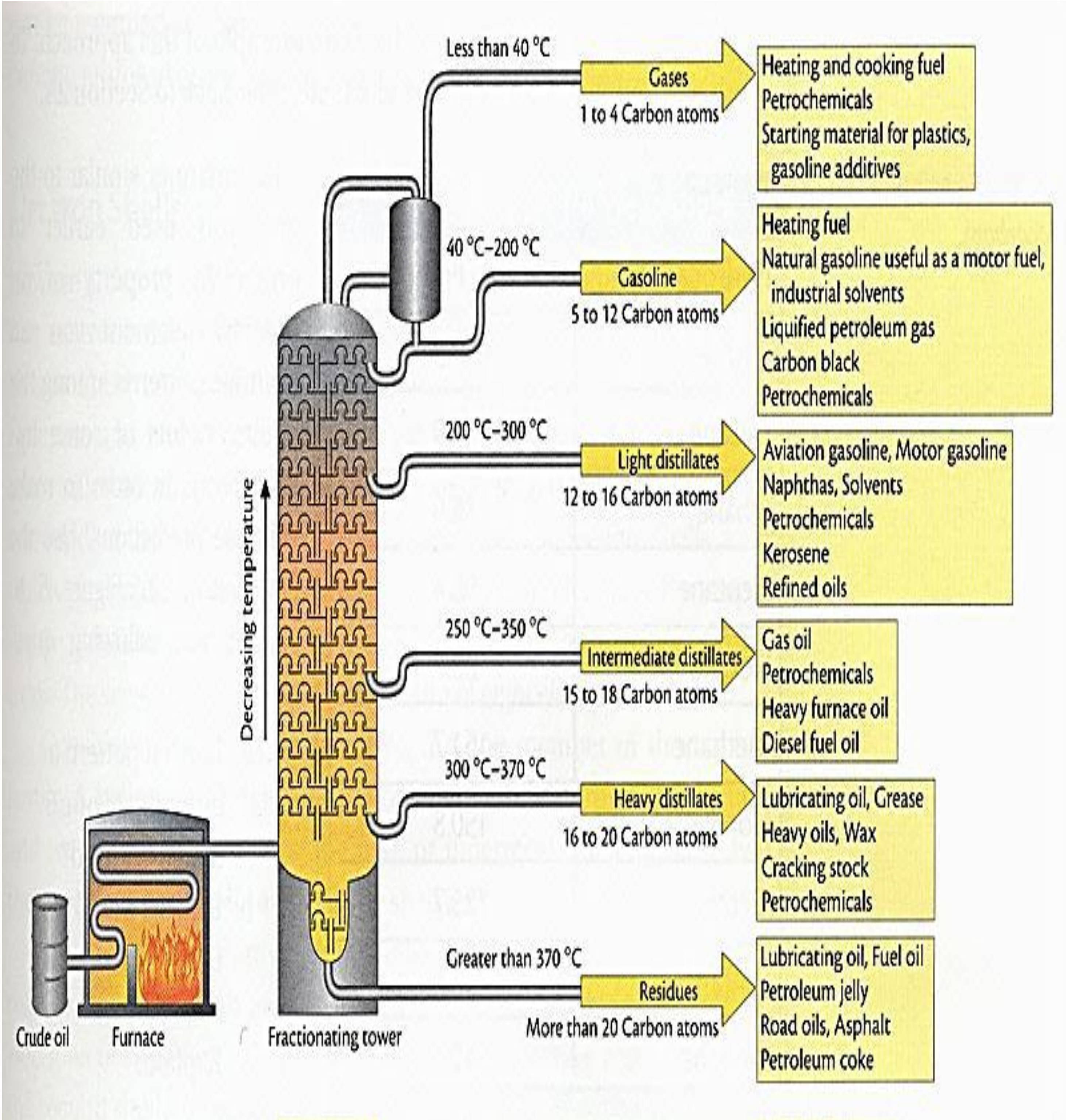
Petroleum fractions from crude distillation unit

Typical petroleum products with their carbon atom and boiling ranges:



Kerosene (C10 – C14)

- **Kerosene** is a fraction of crude oil boiling between **174 and 260°C**.
- It is heavier than naphtha and gasoline cut but lighter than diesel cut.
- The yield of kerosene from a medium gravity crude oil such as light Arabian is approximately 16 vol %.

Physical Description: A pale yellow or clear oily liquid.

Chemical Description:

• Kerosene is a complex mixture of hydrocarbons, usually containing C**10 to C16 carbon atoms** per molecule with the **average being C12**. The average chemical composition by percent is: 35 **percent alkanes (paraffins), 60 percent cyclic alkanes (naphthenes) and 15 percent aromatics**.

• Flash point: l00°F-165°F (38-74°C).

• Auto-ignition temperature: 444°F (229°C).

• Density range: 0.73 to 0.820

• Vapor density: 4.5 times that of air.

• Pour point: 0°F (-18°C).

• Average boiling range: 345-510°F (174-260°C)

• **Kerosene** used in space heaters, cook stoves, water heaters and suitable for use as a light source.

- **Kerosene** used in aircrafts is called **"aviation turbine fuel." Kerosene was considered as aviation fuel because of:**

• its high flash point: A higher flash point allowed safer handling, transportation, and storage of fuel.

• lower volatility compared with that of naphtha.

• **Kerosene** has a very low freezing point, allowing planes to fly at great altitudes.

Two main grades of turbine fuels are in use for civil commercial aircrafts:

Jet A-1 and Jet A. Another grade of jet fuel called **Jet B** is a wide-cut kerosene (a blend of naphtha and kerosene) that is used only in very cold ambient conditions.

Jet A-1 is a kerosene cut suitable for most turbine engine aircrafts. It has a minimum flash point of 100°F and a maximum freeze point of –47°C (–52.6°F). Jet A-1 meets the specifications of ASTM D 1655 (Jet A-1).

Jet A is identical to Jet A-1 except that it has a higher freeze point maximum of –40°C. It meets ASTM D 1655 (Jet A) specifications. Jet A is used within the United States by domestic and international airlines.

Jet B is a wide-cut distillate fuel containing naphtha and kerosene fractions.

• It can be used as an alternative to Jet A-1, but it has a lower flash point and higher flammability.

• It is more difficult to handle. It is used in very cold weather operations.

• It is generally produced to Canadian specifications CAN/CGSB 3.23.

Military Jet Fuel Specifications

The major difference between U.S. military fuels and commercial fuels is the use of certain additives, such as anti-icing, corrosion inhibitors, lubricity improvers, antioxidants, thermal stability
improvers, and conductivity improvers.

JP-4: blend of 60 vol % light straight run naphtha, medium straight naphtha, and 40 vol % straight run kerosene. JP-4 has corrosion inhibitor and anti-icing additives. It meets the requirements of U.S. military specifications MIL-DTL-5624U grade JP-4. It also meets requirements of British specifications DEF STN 91-88 AVTAG/FSII. JP-4 can be considered the military equivalent of Jet B.

JP-5: is a high flash kerosene meeting the requirements of U.S. military specifications MIL–DTL-5624U grade JP-5. JP-5 also meets the requirements of British specifications DEF STN 91-87 AVTUR /FSII. JP-5 is mainly used by the U.S. Navy for its aircrafts based on aircraft carriers. Its high flash point provides a higher degree of safety in fuel handling.

JP-7: is a highly refined, high thermal stability fuel developed in the 1960s to meet the high heat sink demand of supersonic air crafts and **missiles.**

• It is thermally stable to 550°F.

• It has high flash, **very low aromatic content** (maximum 5 percent), a high hydrogen content, and a high heat of combustion.

• It is blended from kerosene coming from distillate hydrocracker and straight run desulfurized kerosene blend components. A U.S. study showed that a turbine fuel with thermal stability near that of JP-7 can be made from a 50:50 blend of naphthalic straight run kerosene and hydrocracker kerosene.

Diesel Fuel (C12 – C20) Gasoil (LGO and HGO)

(boiling range 260-425°C)

The term diesel is used for motor vehicle fuel used in compression-ignited engines. Rudolf Diesel invented the compression-ignited engine in 1892.

High-speed diesel engines (1200 r/min and greater) are used to power trucks, buses, tractors, farm machinery, railroad locomotives, passenger cars, yachts, pumps, compressors and small electric generators.

• **Physical Description**: A yellow viscous liquid.

• **Chemical Description**: A complex mixture of hydrocarbons with C**12 to C20** carbon atoms per molecule, with the average being C15. The average chemical composition, by percent, is: 30 percent alkanes (paraffins), 45 percent cyclic alkanes (naphthenes) and 25 percent aromatics.

• The quality of diesel fuels can be **expressed as cetane number or cetane index**. The cetane number (CN) is expressed in terms of the volume percent of cetane ($C_{16}H_{34}$) which has high ignition (CN = 100) in a mixture with alpha-methyl-naphthalene ($C_{11}H_{10}$) which has low ignition quality (CN = 0).

Diesel fuel includes:

No.1 diesel (Super-diesel) which has cetane number of 45 and it is used in high speed engines, trucks and buses.

No.2 diesel has CN: 40. It is especially suitable for use in applications with conditions of varying speed and load.

No.4 a heavy distillate fuel or blend of distillate and residual oil, for use in low and medium speed diesel engines in applications involving predominantly constant speed and load have higher boiling ranges up to 400 °C and lower cetane numbers.

Fuel Oil (LFO and HFO) C20+

Physical Description: Very viscous, dark colored liquid.

Chemical Description: A complex mixture of heavy molecular weight hydrocarbons, averaging **about 30 carbon atoms per molecule**. The average chemical composition is: 15 percent alkanes (paraffins), 15 percent polar compounds, containing nitrogen, oxygen, or sulfur, 25 percent aromatics, 45 percent cyclic alkanes (naphthenes).

The fuel oils are mainly:

No. 1 fuel oil is similar to kerosene.

No. 2 fuel oil is very similar to No. 2 diesel fuel.

Heavier grades of No. 3 and 4 are also available.

Residual Fuel Oil

It is mainly composed of vacuum residue. Critical specifications are viscosity and sulphur content. Low sulphur residues are in more demand in the market.

Lube Oil

Lubricants are based on the viscosity index. Paraffinic and naphthenic lubricants have a finished viscosity index of more than 75.

Asphalt

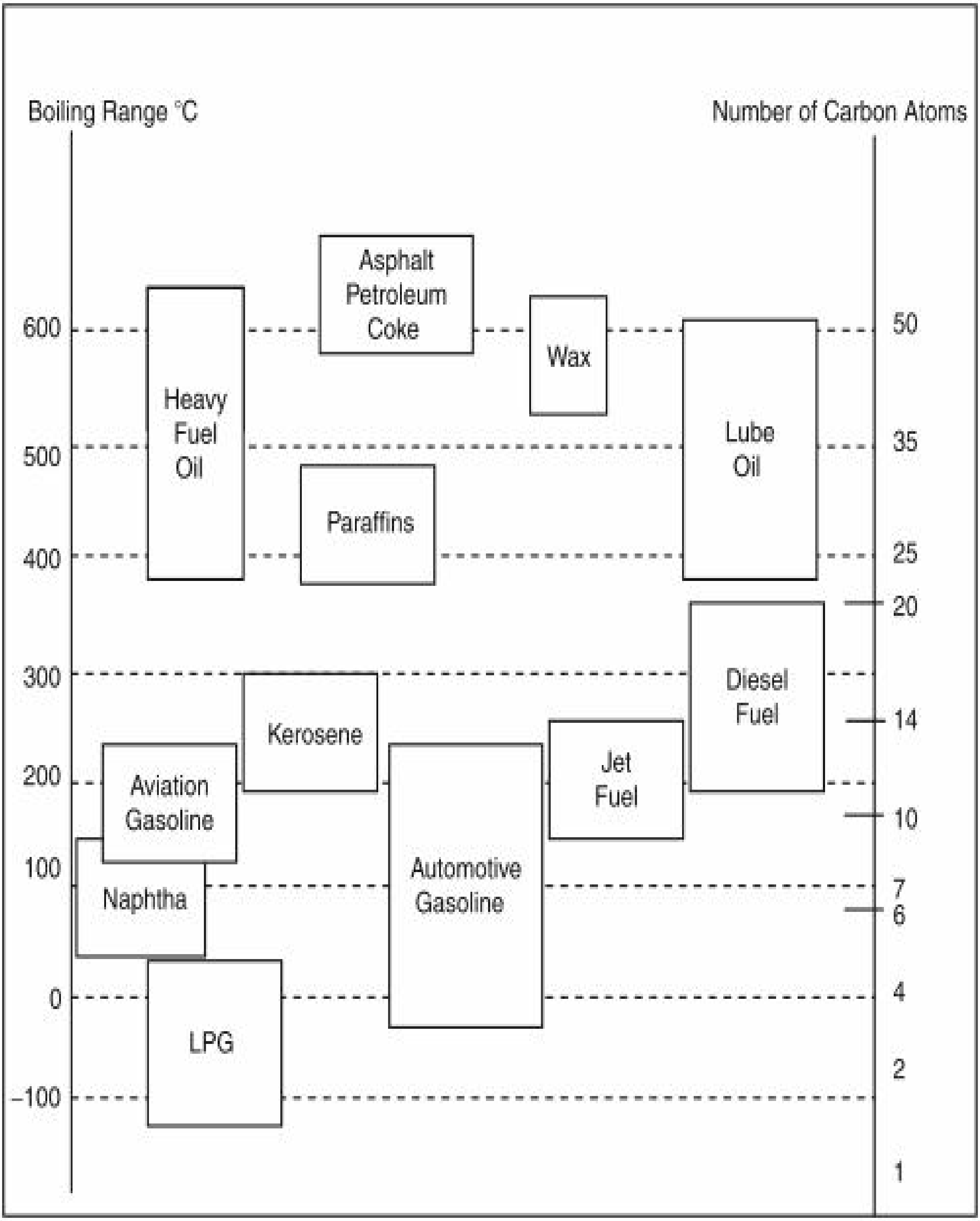
Asphalt is an important product in the construction industry and comprises up to 20% of products. It can be produced only from crude containing asphaltenic material.

Petroleum Coke

Carbon compounds formed from thermal conversion of petroleum containing resins and asphaltenes are called petroleum cokes. Fuel grade coke contains about 85% carbon and 4% hydrogen. The balance is made up of sulphur, nitrogen, oxygen, vanadium and nickel.

Disadvantages of the presence of asphaltenes in crude oil

- Precipitate inside the pores of rock formations, well heads and surface processing equipment
- Transportation problems because they contribute to gravity and viscosity increases of crude oils
- Coke formation and metal deposition on catalyst surface causing catalyst deactivation


Boiling Range °C
Number of Carbon Atoms
600
500
400
300
200
100
0
–100
50
35
25
20
14
10
7
6
4
2
1
Heavy Fuel Oil
Asphalt Petroleum Coke
Wax
Lube Oil
Paraffins
Diesel Fuel
Kerosene
Aviation Gasoline
Naphtha
Automotive Gasoline
Jet Fuel
LPG

Crude Oil Properties (Petroleum Assay)

Important Characterization Properties

Numerous important feed and product characterization properties in refinery engineering include:

- API gravity
- Watson Characterization factor
- Viscosity
- Sulfur content
- True boiling point (TBP) curve
- Pour point
- Flash and fire point
- ASTM distillation curve
- Octane number

1- Density and Specific Gravity

- ❖ **Density is defined as mass per unit volume**.
- ❖ **Density** is a state function depends on both temperature and pressure.
- ❖ **Liquid densities** decrease as temperature increases but the effect of pressure on liquid densities at moderate pressures is usually negligible.
- ❖ **Liquid density** for hydrocarbons is usually reported in terms of specific gravity (SG) or relative density .
- ❖ **Specific gravity (SG):** This is the ratio of the density of a substance to that of water at the same temperature. The temperature usually specified is 15.5 °C. SG defined as:

$$SG\ @\ 60°F = \frac{\rho \text{ of liquid at } T}{\rho \text{ of water at } T}$$

- **Specific gravities** of liquid hydrocarbons are normally reported at the standard conditions adopted by the petroleum industry i.e. **60 °F (15.5 °C) and 1 atm**.
- **The specific gravity** is useful in terms of API gravity, characterization factor and indication of fluid flow of petroleum.
- **API gravity** API gravity of petroleum fractions is a measure of density of the stream. Usually measured at 60 ^{o}F, the API gravity is expressed as:

$$API = \frac{141.5}{Sp.Gr.@\ 60°F} - 131.5$$

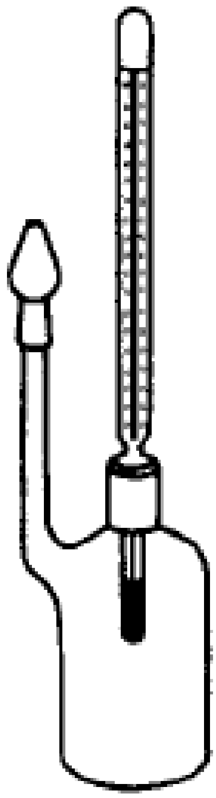
Where specific gravity is measured at 60 ^{0}F

- In the U.S., specific gravity of oil is often expressed as degrees **A.P.l. (American Petroleum Institute)**.
- Lighter **API** gravity value is desired as more amount of gas fraction, naphtha and gas oils can be produced from the lighter crude oil than with the heavier crude oil. Therefore, crude oil with high values of API gravity is expensive to procure due to their quality.

Crude Category	Gravity
Light crudes	API > 38
Medium crudes	38 > API > 29
Heavy crudes	29 > API > 8.5
Very heavy crudes	API < 8.5

Specific-Gravity Bottle

The most accurate method of determining the specific gravity of an oil is to weigh a known volume in a specific-gravity bottle at 15.5 °C. I fit is not convenient to carry out the determination at 15.5 °C, a correction may be applied by measuring the specific gravity at some convenient temperature near 15.5 °C and adding or subtracting 0.00063 per °C above or below 15.5 °C. A convenient specific-gravity bottle for doing this, with ground-in thermometer for measuring temperature, is illustrated in Figure below.



Specific-gravity bottle.

Hydrometer

- The most rapid method is by means of a set of hydrometers.
- **Density ASTM D 287-92, relative density (specific gravity), or API gravity of crude oil and liquid petroleum products by hydrometer method.**
- A hydrometer (a calibrated floating device) is placed in the sample at the specified temperature (15.5 °C) and allowed to come to rest.
- The specific gravity is shown on the scale at the point coincident with the surface of the oil.
- The depth to which the hydrometer sinks and comes to rest in the liquid indicates the relative weight of the liquid.
- The specific gravity is read directly from the calibrations on the hydrometer.
- The hydrometer value is converted to density at 15.6◦C or API gravity at 60◦F using standard tables.