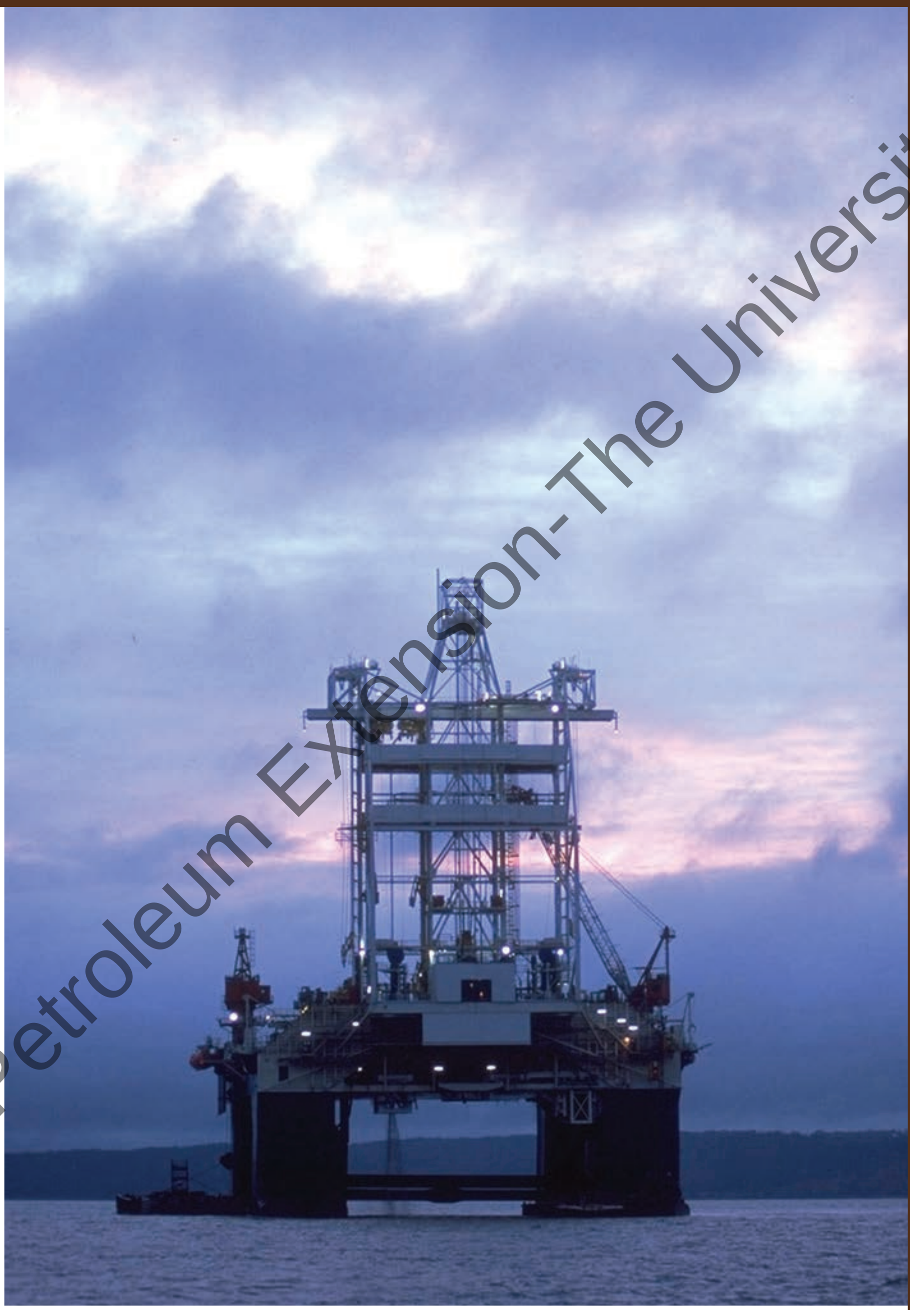
ROTARY DRILLING

BUOYANCY, STABILITY, AND TRIM



Second Edition

UNIT V • LESSON 3

ROTARY DRILLING SERIES

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Units of Measurement

Throughout the world, two systems of measurement dominate: the English system and the metric system. Today, the United States is almost the only country that employs the English system.

The English system uses the pound as the unit of weight, the foot as the unit of length, and the gallon as the unit of capacity. In the English system, for example, 1 foot equals 12 inches, 1 yard equals 36 inches, and 1 mile equals 5,280 feet or 1,760 yards.

The metric system uses the gram as the unit of weight, the metre as the unit of length, and the litre as the unit of capacity. In the metric system, for example, 1 metre equals 10 decimetres, 100 centimetres, or 1,000 millimetres. A kilometre equals 1,000 metres. The metric system, unlike the English system, uses a base of 10; thus, it is easy to convert from one unit to another. To convert from one unit to another in the English system, you must memorize or look up the values.

In the late 1970s, the Eleventh General Conference on Weights and Measures described and adopted the Système International (SI) d'Unités. Conference participants based the SI system on the metric system and designed it as an international standard of measurement.

The *Rotary Drilling Series* gives both English and SI units. And because the SI system employs the British spelling of many of the terms, the book follows those spelling rules as well. The unit of length, for example, is *metre*, not *meter*. (Note, however, that the unit of weight is *gram*, not *gramme*.)

To aid U.S. readers in making and understanding the conversion to the SI system, we include the following table.

English-Units-to-SI-Units Conversion Factors

Quantity or Property	English Units	Multiply English Units By	To Obtain These SI Units
Length, depth, or height	inches (in.)	25.4	millimetres (mm)
		2.54	centimetres (cm)
	feet (ft)	0.3048	metres (m)
	yards (yd)	0.9144	metres (m)
	miles (mi)	1609.344	metres (m)
		1.61	kilometres (km)
Hole and pipe diameters, bit size	inches (in.)	25.4	millimetres (mm)
Drilling rate	feet per hour (ft/h)	0.3048	metres per hour (m/h)
Weight on bit	pounds (lb)	0.445	decanewtons (dN)
Nozzle size	32nds of an inch	0.8	millimetres (mm)
Volume	barrels (bbl)	0.159	cubic metres (m^3)
		159	litres (L)
	gallons per stroke (gal/stroke)	0.00379	cubic metres per stroke (m^3/stroke)
	ounces (oz)	29.57	millilitres (mL)
	cubic inches ($in.^3$)	16.387	cubic centimetres (cm^3)
	cubic feet (ft^3)	28.3169	litres (L)
		0.0283	cubic metres (m^3)
	quarts (qt)	0.9464	litres (L)
	gallons (gal)	3.7854	litres (L)
	gallons (gal)	0.00379	cubic metres (m^3)
	pounds per barrel (lb/bbl)	2.895	kilograms per cubic metre (kg/m^3)
	barrels per ton (bbl/tn)	0.175	cubic metres per tonne (m^3/t)
Pump output and flow rate	gallons per minute (gpm)	0.00379	cubic metres per minute (m^3/min)
	gallons per hour (gph)	0.00379	cubic metres per hour (m^3/h)
	barrels per stroke (bbl/stroke)	0.159	cubic metres per stroke (m^3/stroke)
	barrels per minute (bbl/min)	0.159	cubic metres per minute (m^3/min)
Pressure	pounds per square inch (psi)	6.895	kilopascals (kPa)
		0.006895	megapascals (MPa)
Temperature	degrees Fahrenheit (°F)	$\frac{°F - 32}{1.8}$	degrees Celsius (°C)
Thermal gradient	1°F per 60 feet	—	1°C per 33 metres
Mass (weight)	ounces (oz)	28.35	grams (g)
	pounds (lb)	453.59	grams (g)
		0.4536	kilograms (kg)
	tons (tn)	0.9072	tonnes (t)
	pounds per foot (lb/ft)	1.488	kilograms per metre (kg/m)
Mud weight	pounds per gallon (ppg)	119.82	kilograms per cubic metre (kg/m^3)
	pounds per cubic foot (lb/ft^3)	16.0	kilograms per cubic metre (kg/m^3)
Pressure gradient	pounds per square inch per foot (psi/ft)	22.621	kilopascals per metre (kPa/m)
Funnel viscosity	seconds per quart (s/qt)	1.057	seconds per litre (s/L)
Yield point	pounds per 100 square feet (lb/100 ft^2)	0.48	pascals (Pa)
Gel strength	pounds per 100 square feet (lb/100 ft^2)	0.48	pascals (Pa)
Filter cake thickness	32nds of an inch	0.8	millimetres (mm)
Power	horsepower (hp)	0.75	kilowatts (kW)
Area	square inches ($in.^2$)	6.45	square centimetres (cm^2)
	square feet (ft^2)	0.0929	square metres (m^2)
	square yards (yd^2)	0.8361	square metres (m^2)
	square miles (mi^2)	2.59	square kilometres (km^2)
	acre (ac)	0.40	hectare (ha)
Drilling line wear	ton-miles (tn•mi)	14.317	megajoules (MJ)
		1.459	tonne-kilometres (t•km)
Torque	foot-pounds (ft•lb)	1.3558	newton metres (N•m)

Introduction

Seaworthiness

Just as a ship must be seaworthy, so must a *floating offshore drilling rig*. A floating rig, as the name suggests, floats on or just below the water's surface. It is not in contact with the seafloor (except possibly with anchors) when it is in the *drilling mode*—or when it is at an offshore location drilling a well. A floating offshore drilling rig is a type of *mobile offshore drilling unit* (*MODU*). MODUs not only include floating rigs, but also *bottom-supported offshore drilling rigs*.

A bottom-supported rig has a part of its structure in contact with the seafloor when it is in the drilling mode. The remainder of the rig is supported above the water. However, when it is time for personnel to move a bottom-supported rig, they can make it float on the water's surface, which allows them to tow the rig from one drill site to another. Thus, bottom-supported rigs must also be seaworthy, especially when crewmembers move them from one drill site to another.

Bottom-Supported Rigs

Bottom-supported units include *submersible rigs* and *jackup rigs*. A submersible rig has several compartments that crewmembers intentionally flood to cause the structure to submerge and rest on the seafloor. However, when a rig is not drilling, crewmembers make it float on the water's surface so it can be towed from one drill site to another.

A jackup rig is another type of a mobile, bottom-supported offshore drilling rig. It has columnar or open-truss legs that support a *hull*. The hull is the watertight body of the rig on which the drilling and other equipment are mounted. When crewmembers move a jackup rig, it floats on its hull and towboats move it to a drilling site. When positioned over the drilling site, crewmembers lower the jackup's legs to the seafloor and elevate, or jack up, the hull above the water's surface.

Floating Rigs

Floating units include *drill barges*, *drillships*, and *semisubmersibles*. A drill barge is an offshore drilling vessel built in the shape of a ship.

Buoyancy

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Preview

An offshore floating rig such as a semisubmersible or a drillship, which is made of steel and weighs hundreds of tons, floats easily in the ocean. However, many items the rig carries on board weigh much less and sink if they fall overboard.

Before designing a rig, naval architects carefully consider such physical properties as weight and shape, mathematical principles used in the design, and the national and international regulations established to assure seaworthiness. This section looks at how these design components affect buoyancy and why some items that weigh much less than the rig sink after falling overboard.

Displacement

Displacement, which means to push or move something away, is the scientific principle that explains why something floats. Archimedes, a Greek considered the greatest mathematician of ancient times (fig. 13), discovered the principle of displacement over 2,000

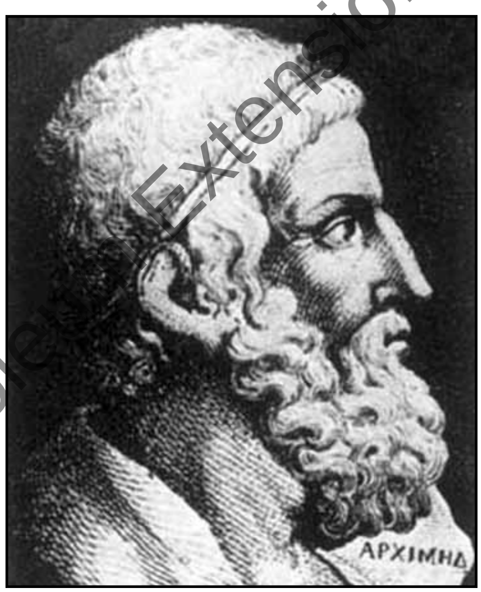

Figure 13. Portrait of Archimedes

Stability

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Preview

Imagine that a large and powerful wave strikes an offshore floating rig. The rig leans to one side, appearing to follow the wave into the ocean. But suddenly, before the rig has tilted too far, it reverses direction and rights itself. This righting action demonstrates *stability*, the tendency of an offshore rig or ship to return to its original position. The vessel's automatic response to a powerful wave or some other environmental force is repeated so often that those working on board, if they even notice, think little of it. Large waves, strong currents, or heavy winds are all environmental forces that affect the offshore workday.

Principles of Motion

Some important definitions relating to motion and stability are—

- *Gravity* is the downward force that pulls any object toward the center of the earth.
- *Mass* is what makes up an object. It is a quantity of matter. Mass can be liquid, solid, or both.
- *Weight* is a downward force resulting from gravity's pull. Weight is measured in pounds or grams.
- *Acceleration* is the tendency of an object in motion to remain in motion and move faster the farther it travels.
- *Inertia* is the tendency of an object at rest to remain at rest. It is the resistance to motion or a change in direction.
- *Force* is the push or pull on any object. Force causes motion. Force is the result of mass and acceleration.
- *Vector* represents the strength and direction of force in drawings or calculations. A vector is shown as an arrow (fig. 30). A fat arrow represents a stronger force than a skinny arrow. A fat arrow can also represent forces that have joined together.

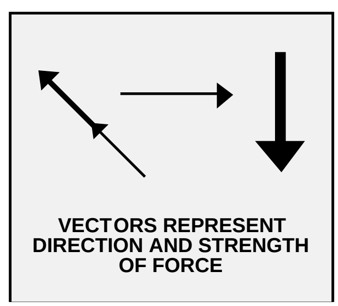

Figure 30. A vector is an arrow used in drawings and formulas relating to stability. It shows both direction and magnitude, or power.

Trim

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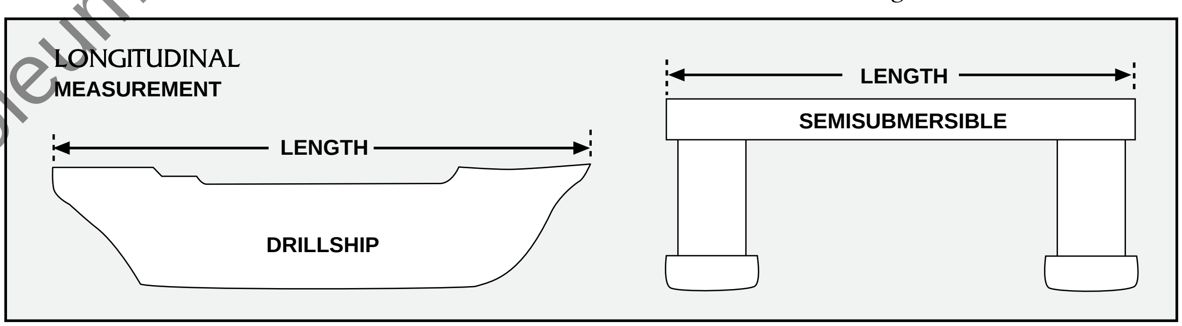
Preview

Imagine a semisubmersible on location in the Gulf of Mexico where it is drilling a well in over 7,500 feet (2,200 metres) of water. The well is nearing a depth where the crew will stop drilling, pull the drill string from the hole, and run several thousand feet (metres) of casing into the well. At present, the roustabouts are unloading dozens of joints of large-diameter casing from a supply boat tied up along side the rig. As they unload the casing and stack it on one side of the deck, that side of the rig submerges a little more deeply into the water than the other side of the rig. Before the side of the rig where the casing is stacked submerges too much into the water, crewmembers skilled in buoyancy, stability, and trim take action to bring the rig back to level. How they level the rig while it is floating and why it is important is the subject of this section.

Trim

As you learned earlier, trim is the difference between the fore and aft draft readings of a floating offshore rig. And, to trim a vessel means to minimize the difference between the fore and aft draft readings. Personnel can determine the trim by measuring the draft, which is the height from the keel to the waterline, at both the bow and stern of the vessel. Also, trim relates to the longitudinal length of the vessel from the bow to the stern (fig. 67). A rig has no trim

Figure 67. The lengthwise measure of a vessel is the longitudinal measure.



Drilling Unit Operations

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This section offers situations to be aware of and think about when working offshore. These practical examples are based on the ideas already discussed in this lesson. While based on real situations, these examples are not intended to replace the operating instructions for a particular offshore rig. Operating instructions are developed specifically for a unique hull design and stability features and should never be ignored.

Weight

An offshore rig carries two kinds of weight. Its lightship weight, or permanent weight, includes the steel structure, built-in machinery and the attached equipment, such as cranes and derrick. Everything else on board is *variable load*. Variable load includes all items that can be added or removed. Ballast, payloads, food and water, casing and casing equipment, drill pipe and drill collars, and hook and rotary loads, fall into this category. The upper deck is where many heavy items are stored and it is built to hold various weights. The rig builder prepares a diagram showing the strongest portions of the upper deck and places it on the rig (fig. 71). The information is based on the amount of pressure that the deck can sustain. It is given in pounds per square inch (psi) and kilopascals (kPa) (fig. 72).

Specially-trained offshore rig crewmembers keep track of the consumables on board and take the proper steps to manage the loads as they are brought on board and are consumed. The specialists are usually members of the *barge-engineering department* on the rig. Usually, they keep a load list on a computer database and update it each day. Even with this list, all crewmembers should be aware of the maximum assigned-load line and maximum draft for the rig. Daily checks of the rig's load line and draft marks should be a routine duty. The only time maximum draft can be exceeded is on a submersible when it is being lowered onto the seafloor. Floating rigs should never exceed maximum draft.

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