ROTARY DRILLING

SPREAD MOORING SYSTEMS

Second Edition

UNIT V • LESSON 2

ROTARY DRILLING SERIES

Unit I: The Rig and Its Maintenance

Lesson 1: The Rotary Rig and Its Components
Lesson 2: The Bit
Lesson 3: Drill String and Drill Collars
Lesson 4: Rotary, Kelly, Swivel, Tongs, and Top Drive
Lesson 5: The Blocks and Drilling Line
Lesson 6: The Drawworks and the Compound
Lesson 7: Drilling Fluids, Mud Pumps, and Conditioning Equipment
Lesson 8: Diesel Engines and Electric Power
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Preface

The use of dynamically positioned vessels has certainly increased dramatically in recent years, but spread moorings still play a vital role in the offshore drilling industry. Innovations in mooring line materials, anchor holding power, and deployment and retrieval methods have improved the efficiency of mooring systems since the original text of this book was written over thirty years ago.

While the subject of spread mooring systems and equipment is necessarily quite complex, this updated text attempts to explain the main principles and applications to participants of the drilling industry in an understandable way. It is intended to give readers a basic overview of the topic from a historical and an operational viewpoint, while touching on the technical details in sufficent depth to understand their importance and relevance.

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Morlan, who contributed his significant expertise to enhancing this new edition of Spread Mooring Systems, has several years of experience reviewing and analyzing floating offshore structures including semisubmersibles, jackups, drillships, barges, and various small vessels. His background also includes experience with drilling rig layout, design, weight control, and vessel interface; and extensive experience in stability analysis, motions response analysis, mooring analysis, riser analysis, and design and weight management. He has conducted inclining experiments and deadweight surveys on jackups, semisubmersibles, and drillships.

Units of Measurement

Throughout the world, two systems of measurement dominate: the English system and the metric system. Today, the United States is one of only a few countries 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, 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.

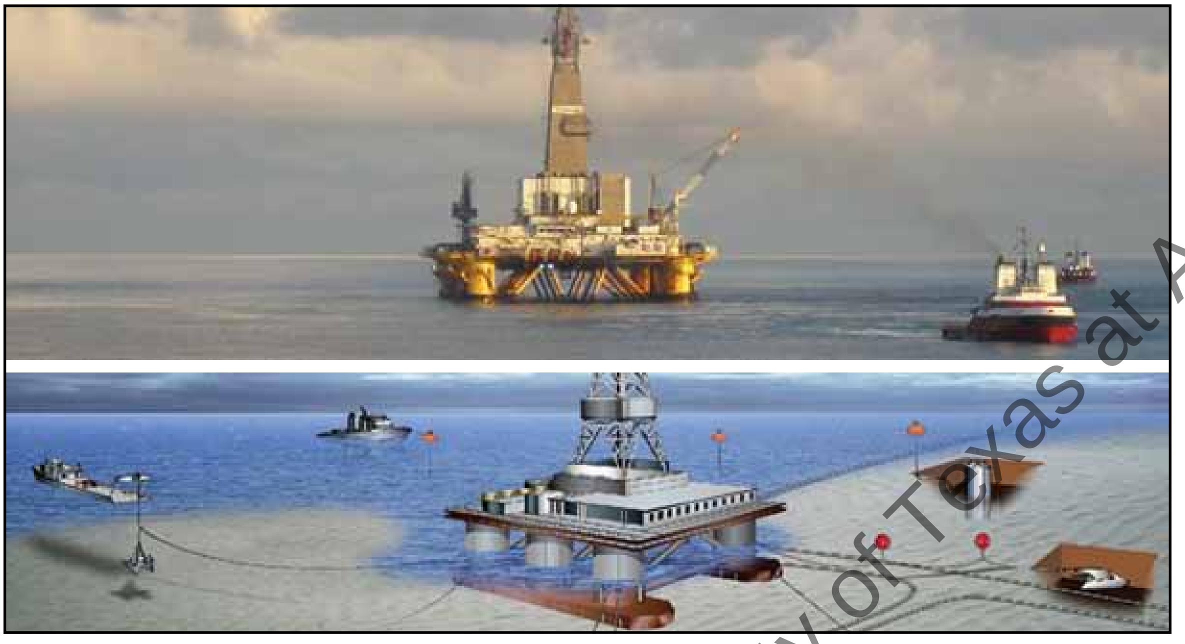
In the late 1970s, the Eleventh General Conference on Weights and Measures described and adopted the Système International (SI) d'Unités. Conference participants based the SI system on the metric system and designed it as an international standard of measurement.

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 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)



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Mooring system. *Surface and underwater views of a typical spread mooring system in offshore operations*

Holding Floating Vessels

In this chapter:

- Anchors and mooring lines used for offshore operations
- Typical mooring system patterns
- Principles of anchor and mooring line behavior
- Balancing and counterbalancing horizontal forces

Holding a floating vessel near a fixed location on the surface of the sea, called *mooring*, is an age-old challenge. Basic principles and concepts have changed little since ancient times; however, technologies and applications have improved markedly. As oil and gas exploration has moved increasingly offshore, more permanent mooring systems have been developed to keep floating operations in place.

Early Mooring Systems

The earliest mooring systems consisted of natural fiber ropes attached to anchor stones. Various types of anchor stones, dating back as far as 1600 B.C., have been recovered from Egyptian tombs and the Mediterranean Sea floor. Metal anchors were introduced by the year 800 B.C., when bronze anchors were cast on the island of Malta. By 300 B.C., iron anchors were common to ships of the Athenian navy. As shown in figure 1, some of these early anchors contain the features of relatively modern anchors. Rapid development of anchors in the years following the Industrial Revolution culminated in the *stockless anchor* of the early twentieth century.

Components of Mooring Systems

In this chapter:

- Mooring line arrangements
- Types of anchors
- Wire rope, chain, connectors, and fittings
- Anchor-handling equipment
- Tension measurement

Mooring Line Arrangements

Figures 17 and 18 show two mooring line arrangements that are used. One is a chain configuration commonly used in shallow water; the other is a composite wire rope and chain configuration commonly used in deeper water. Both arrangements contain practically all components found in spread mooring systems: anchors, wire rope, chain, end fittings, buoys, and handling equipment such as *winches* and *windlasses*. Not shown are anchor-handling boats that deploy and retrieve the anchors.

Main components of a spread mooring system:

- Buoys to mark locations
- Anchors to drop weight to hold a vessel
- Wire rope and chain to make up the mooring line
- End fittings to add holding power
- Winches to handle and store rope
- Windlasses to propel the line

Placing and Recovering Moorings

In this chapter:

- Companies involved in mooring operations
- Moving on and off location
- Running and setting mooring patterns
- Pulling up anchors
- Function of anchor-handling boats

Planning a Successful Mooring Operation

A successful mooring operation requires considerable planning and organization. The well site should be marked and surveyed and the bottom conditions established before the rig moves onto location. When water depths are known, pendant lines can be checked for correct lengths. It is important to inventory and inspect all mooring components and handling equipment to ensure they are available and in good condition. Any missing or damaged items should be replaced or repaired. All participating personnel should review and understand all equipment and procedures to ensure safe and efficient operations (fig. 61).

Constant and close coordination between the drilling rig and the anchor-handling boat is essential during the mooring operation. Clear lines of communication should be established beforehand to avoid any confusion on the job. This task is complicated by the fact that multiple companies, organizations, and individuals might be involved.

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