ROTARY DRILLING

The Drawworks and the Compound

First Edition

UNIT I • LESSON 6

ROTARY DRILLING SERIES

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Lesson 2: The Bit
Lesson 3: Drill String and Drill Collars
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Lesson 10: Marine Riser Systems and Subsea Blowout Preventers

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The Drawworks and the Compound

Unit I, Lesson 6
First Edition

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By Kate Van Dyke

Published by

PETROLEUM EXTENSION SERVICE
Continuing Education
The University of Texas at Austin
Austin, Texas

in cooperation with

INTERNATIONAL ASSOCIATION
OF DRILLING CONTRACTORS
Houston, Texas

1995

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Twin Disc Inc.
1328 Racine St.
Racine, Wisconsin 53403
David H. Johnson, manager of marketing communications

Library of Congress Cataloging-in-Publication Data

Van Dyke, Kate, 1951–
The drawworks / by Kate Van Dyke. — 1st ed.
p. cm. — (Rotary drilling series ; unit I, lesson 6)
"In cooperation with International Association of Drilling Contractors, Houston, Texas."
ISBN 0-88698-171-9
1. Oil well drilling rigs. 2. Hoisting machinery. I. University of Texas at Austin. Petroleum Extension Service. II. International Association of Drilling Contractors. III. Title. IV. Series: Rotary drilling series; unit 1, lesson 6.
TN871.5.V27 1994
622'.3382—dc20 94-37140
CIP

First Edition published 1995. Fifth impression 2008
Printed in the United States of America

Catalog no. 2.106101
ISBN 0-88698-171-9

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Foreword

For many years, the Rotary Drilling Series has oriented new personnel and further assisted experienced hands in the rotary drilling industry. As the industry changes, so must the manuals in this series reflect those changes.

The revisions to both text and illustrations are extensive. In addition, the layout has been "modernized" to make the information easy to get; the study questions have been rewritten; and each major section has been summarized to provide a handy comprehension check for the student.

PETEX wishes to thank industry reviewers—and our readers—for invaluable assistance in the revision of the Rotary Drilling Series. On the PETEX staff, Deborah Caples designed the layout; Doris Dickey proofread innumerable versions; Sheryl Horton saw production through from idea to book; Ron Baker served as content editor for the entire series.

Although every effort was made to ensure accuracy, this manual is intended to be only a training aid; thus, nothing in it should be construed as approval or disapproval of any specific product or practice.

Kathy Bork

Acknowledgments

The revising of the 1982 edition of *The Hoist* into this new edition entitled *The Drawworks and the Compound* was a challenging journey. My thanks to several people who generously gave of their time and expertise and provided drawings, photos, and written resources: Ken Fischer of IADC; Wes Morrow of National Oilwell; Otis Danielson, retired; Dick Evans-Lombe of Diamond Chain Co.; and Kent Greenwald of Twin Disc.

Thanks also to eagle-eyed reviewers of the draft: John Altermann of Reading and Bates, Jim Arnold of Salem Investment, Joey Hopewell of Delta Drilling, and Ken Fischer.

Finally, thanks to the director of PETEX, Ron Baker for his good-humored explanations of convoluted reference material, to Sheryl Horton for providing referrals and acting as a sounding board, to Jonell Clardy for new illustrations, and to Terry Gregston for new photographs for this edition.

Kate Van Dyke

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.

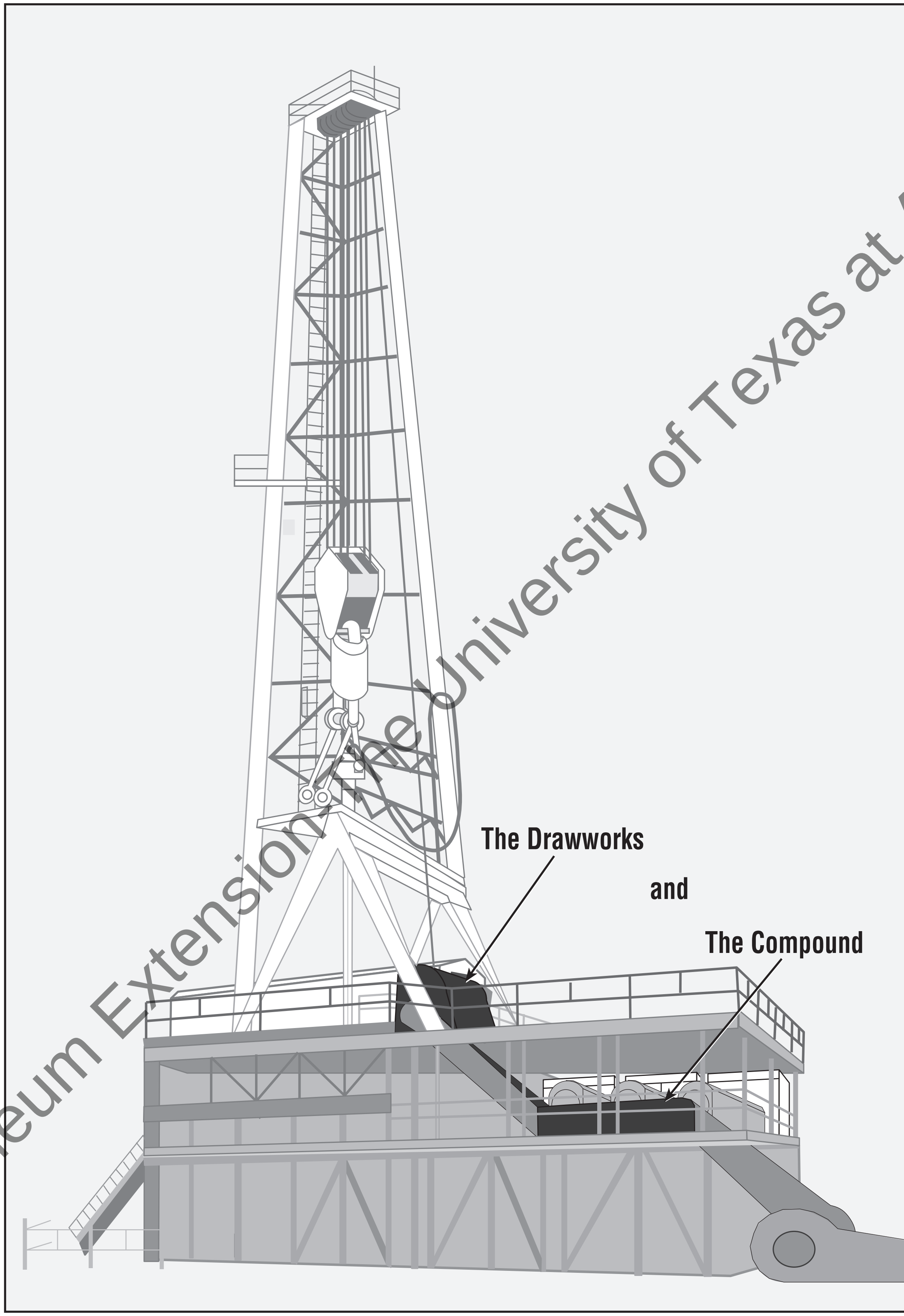
In the late 1970s, the Eleventh General Conference on Weights and Measures described and adopted the Système International (SI) d'Unités. Conference participants based the SI system on the metric system and designed it as an international standard of measurement.

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 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)


The Drawworks
and
The Compound

Introduction

The drawworks is a part of the system that rotary drilling rigs use for hoisting, or lifting, the drill stem and casing out of the hole. The earliest hoist, a windlass or winch, was a simple drum, or spool, sitting horizontally between two posts with one end of a rope attached to it (fig. 1). The other end of the rope was attached to something a person wanted to lift, such as a bucket. When someone turned the drum with a crank, the rope wound around the drum and lifted the bucket. The windlass enabled people to lift a heavy load of water, for instance, much more easily than they could have by pulling the bucket straight up. Of course, enterprising laborers were always looking for power greater than human strength to turn the drum and hoist heavier loads, and they used animals and, eventually, engines for the purpose.

Early rigs used steam engines to power the hoist. Today they use diesel engines and electric motors. But the basic principle of using a mechanical device to do the work of lifting continues to be the basis of hoisting.

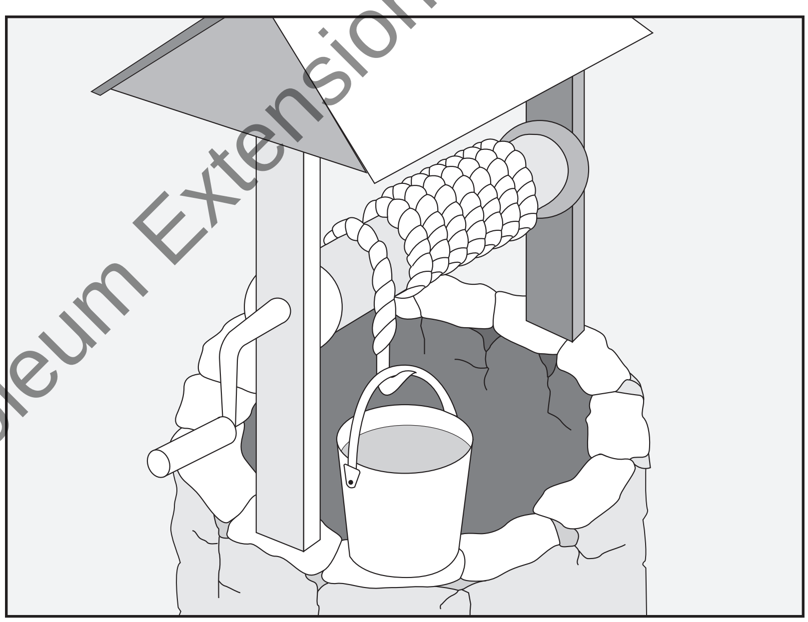


Figure 1. Windlass

The Hoisting System

The hoisting system of a drilling rig is a collection of machines that work together. Broadly speaking, a simple machine does one of the following things:

1. It converts energy from one form to another.

   Energy comes in several forms. Everything that moves has mechanical energy, and mechanical energy is the type most important to the hoisting system. Some other types of energy are heat, light, and electricity. An example of a machine that converts energy is a generator, which turns mechanical energy into electricity.

2. It transfers energy from one place to another.

   The steering wheel and its linkages are a machine that transfers mechanical energy (motion) from the driver's arm to the wheels of a car.

3. It controls energy.

   A machine can control mechanical energy in three ways to make it more usable: (a) switch it on and off. A clutch in a car interrupts the power from the engine to the wheels so that you don't have to turn off the engine at a stoplight; (b) change its direction. A pulley changes the direction of motion of a rope from linear (in a straight line) to rotary (in a circle) and back again (fig. 2); (c) change its power. Power is a combination of force and speed. Force and speed are always related—a machine that increases one will decrease the other. When you are driving on a flat road, stepping on the gas in high gear makes the car move faster—increases its speed. But when going up a hill, you change to a lower gear so that stepping on the gas increases the force instead of the speed. Gears are one type of machine for changing force and speed relationships.

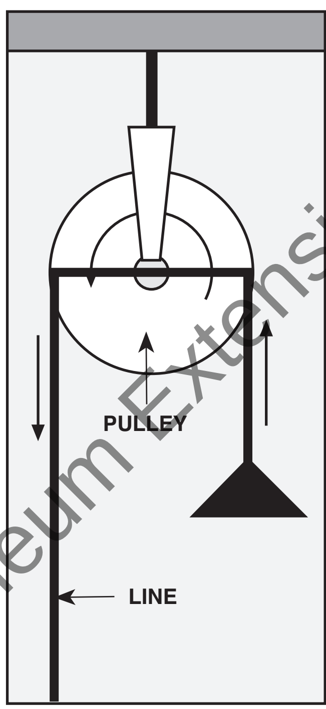


Figure 2. Hoisting with a pulley and line

A complex machine, like the hoisting system, does all of these kinds of work. It helps to think of the hoisting system as a complex machine made up of several other complex machines. Each of these in turn is made up of simpler machines that do one of the basic kinds of work described above.

Components of the Drawworks

Most of the rest of this book will describe the components of the drawworks, how they are constructed and powered, and what they do. The people who work with the drawworks must be able to operate and maintain it well so that the machinery lasts as long as possible and is safe to use.

Figure 5a shows a front view of a drawworks, with the coverings of the frame removed:

(1) driller's console and brake lever
(2) low drum drive
(3) main brake
(4) drum
(5) high drum drive
(6) catshaft and optional sand reel
(7) rotary drive countershaft (optional)
(8) auxiliary brake

The back of the drawworks is sometimes called the power side because it is the side nearest the engines that supply power to the drawworks (see Getting Power to the Drawworks). Figure 5b shows the uncovered back of the drawworks:

(1) high drum drive
(2) electric motors
(3) drum
(4) optional sand reel
(5) catshaft drive
(6) low drum drive
(7) output shaft
(8) input shaft

The chains in the rear are part of the transmission.

Getting Power to the Drawworks

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Power for running the drawworks, and therefore the whole hoisting system, comes from the rig's *prime movers*. The prime movers are the basic power source. Most rigs use two to four internal-combustion engines as prime movers. These are the same type of engine that a car has, but rig engines are much bigger and more powerful. Most use diesel fuel because a diesel engine has more turning power, or *torque*, than a gasoline engine. Torque is important because the engine directly spins a shaft to produce mechanical energy that powers everything else.

Mechanical and Electric Drives

Engine power is then transmitted to run the various working parts of the rig in one of two ways. A *mechanical-drive* rig uses a compound, a mechanical transmission made up of sprockets and chains (fig. 7). On an *electric-drive* rig, the prime movers drive generators mounted right on each diesel engine (fig. 8). A generator converts the mechanical energy from the engine shaft into electricity. The electricity then flows through electric cables to electric motors attached to the drawworks and other parts of the rig that need power. Each motor directly powers one of these parts (see electric motors in fig. 5b).

Transmissions

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Rotating shafts are the basis of a transmission. The rest of the transmission consists of an arrangement of mechanical parts, such as gears, sprockets and chains, belts and pulleys, and clutches, that connect the rotating shafts to each other. All together these parts constitute a machine that transmits power from a power source to another machine to make it work.

On a mechanical-drive rig, a *compounding transmission*, or *compound*, sends power from the engines to the drawworks and the rotary table, and sometimes to the mud pumps. Electric-drive rigs, where the engines run generators, do not have a compound. Here, the cables transmit electric power to motors near the components that need it.

Once the drawworks receives power from either the compound or electric motors, it must have its own system for sending that power to its various parts. A *selective transmission* does this job, allowing the driller to select how the power is distributed (torque/speed combinations) to various components of the drawworks. The drawworks on both mechanical-drive and electric-drive rigs have a selective transmission.

Compounding Transmission

Many rigs need more than one prime mover to provide enough power, so in a mechanical-drive rig, the compounding transmission combines, or compounds, the energy from two to four engine shafts to make them act as one power source (fig. 9). The output shafts from the engines do not connect directly to the compound, however. Between each rotating shaft and the compound is either a torque converter or a hydraulic coupling to smooth the transfer of power.

Clutches

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Clutches are the components of a mechanical assembly that connect or disconnect driving shafts from driven shafts. When a clutch is engaged, it makes the connection so that the driving shaft moves the driven shaft. When a clutch is disengaged, it breaks such a connection. Then, even though the driver continues to move, the driven shaft stops moving. A clutch works like an on/off switch for the transmission.

Locations

The hoisting system has clutches wherever two drives are connected and the driller needs to be able to disconnect them (see fig. 18). An exception to this is when a hydraulic coupling or a torque converter replaces the mechanical clutch. Some of the places that need clutches are—

1. between the compound and the mud pumps;
2. between the compound and the selective transmission (master clutch);
3. inside the selective transmission, for example, to the high and low drum drives (high clutch and low clutch), to the sand reel;
4. between the selective transmission and the rotary drive.

The type of clutch used in each location depends on its position in the machinery, the space available, the conditions under which it must function, the possibility for misalignment, and the work that must be done. Three types of clutches in the drawworks are the positive clutch, the friction clutch, and the overrunning clutch.

Main Brake

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The main brake is crucially important to a drilling rig because it slows or stops the drum. It is also called a mechanical brake, because it uses only mechanical energy rather than electricity or water power to work. The crew must adjust it, service it, and reline it regularly and should therefore be thoroughly familiar with its construction and operation.

Design

Figure 44 shows the main brake. The figure does not include the drum and its rims, which are also a part of the brake, so that the other parts are easier to see. The bands wrap around the rims of the drum and have a lining of brake blocks to increase friction. The driller applies the brake by pulling down on the brake lever, which is next to the console.

Brake Flanges and Bands

The drawworks drum is just a cylinder to start with. The manufacturer bolts steel rims to the ends of the cylinder that make it into a spool, and these rims are half of the mechanical brake (see fig. 6). The rims are also called *flanges*. These flanges have a hardened layer on the surface that does not wear out quickly.

The other half of the brake is the *brake bands.* These are two flexible steel bands that wrap around the flanges. One end of each band (the *dead end*) is anchored to the drawworks frame and does not move. The other end (the *live end*) is attached to a brake lever by means of a linkage. Moving the brake lever pulls the live end down, and the whole band tightens around the flange. This slows or stops the drum by friction. The main brake, like the friction clutch, takes advantage of useful friction, where the energy of the moving drum is transferred to the immovable brake bands. This mechanical energy from motion has to go somewhere; here it changes into heat. Remember that converting energy from one form to another is one of the things machines can do.

Auxiliary Brake

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The auxiliary brake works in combination with the main brake to slow the rate of descent of the traveling block with a heavy load. It functions only when the block is descending. The auxiliary brake ensures that the load descends slowly and smoothly and it lessens wear on the main brake by taking the heavy shock loads (sudden jerking) and continual dead weight off the brake bands.

Always be careful, however, to lower the traveling block slowly enough that the mechanical brake alone could stop it, because the auxiliary brake could fail. The auxiliary brake cannot stop the drum by itself.

The auxiliary brake can be either a hydrodynamic brake (activated by water) or an electrodynamic brake (activated by electricity). It sits next to the drum on the drawworks framework (see fig. 5a). The two types look very similar on the outside.

Catshaft

The *catshaft* is a long axle that sits on heavy-duty roller bearings in the frame of the drawworks. It runs along the top of the drawworks and sticks out on both sides of it (fig. 54). The catshaft has two catheads on each end and often a sand reel in the middle. Each cathead is a winch that can spool up a wire rope, fiber rope, or chain. The catheads are an integral part of the catshaft and rotate with it.

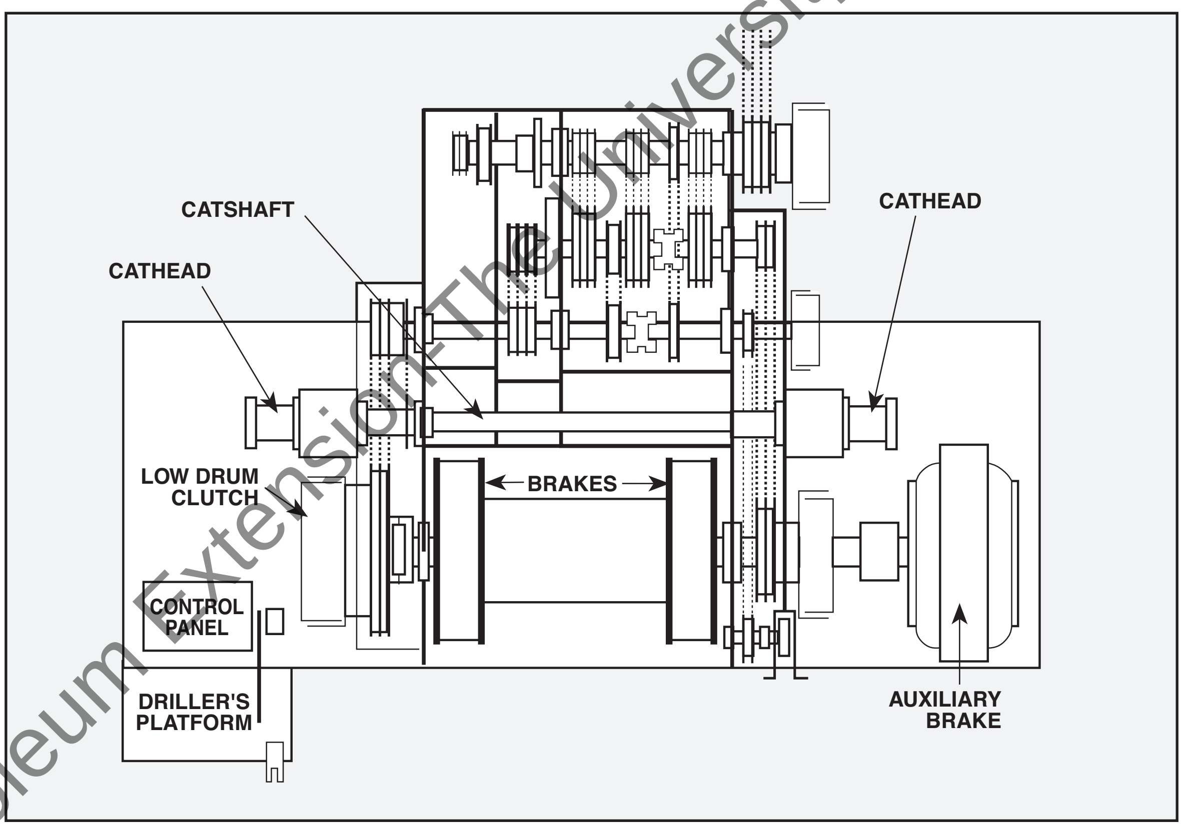

Figure 54. The catshaft, catheads, and sand (coring) reel

Lubrication

The greatest contribution the rig crew can make to the general benefit of the drilling contractor is to learn and practice good techniques of rig lubrication. Every place on the drawworks where metal rubs against metal needs lubrication. Good lubrication helps the equipment to last as long as possible before breaking. Not only does this mean less expense for replacement parts, but it also means that there is less time when the rig is not drilling because of repairs.

Every tour, the operator provides a certain amount of time for inspecting and servicing the rig. The driller keeps a maintenance record, called a tour report, that includes, for example, when the crew measured oil levels, changed oil, checked oil pressure gauges, serviced and replaced filters, and greased fittings.

Some parts of the drawworks, such as the transmission, need oil lubrication and some parts need grease. Figure 56 shows an

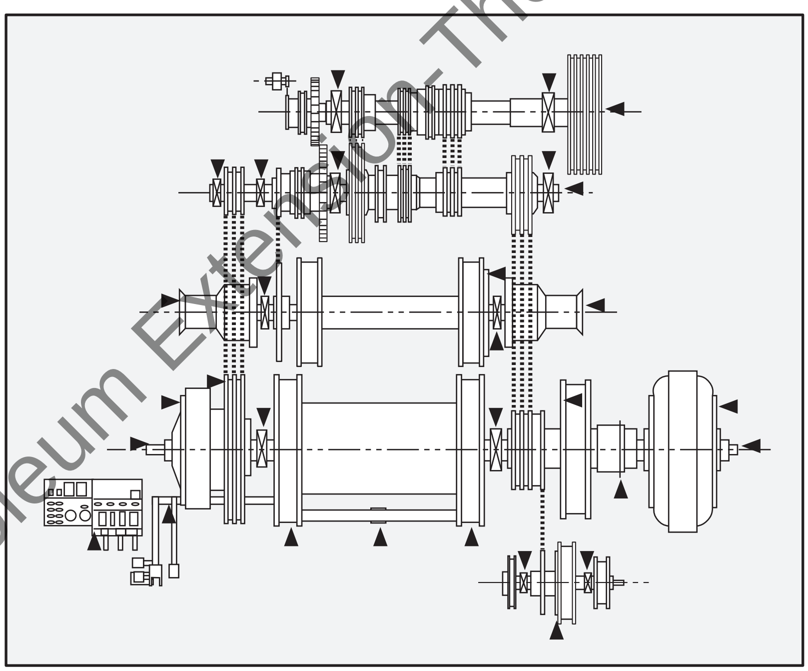

Figure 56. Grease fitting locations

Glossary

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A

air hoist *n:* a hoist operated by compressed air; a pneumatic hoist. Air hoists are often mounted on the rig floor and are used to lift joints of pipe and other heavy objects.

American National Standards Institute (ANSI) *n:* serves as clearinghouse for nationally coordinated voluntary standards for fields ranging from information technology to building construction. Address: 11 W. 42d St., 13th floor; New York, NY 10036; (212) 642-4900.

angle of wrap *n:* the distance that the brake band wraps around the brake flange. Drawworks have an angle of wrap of 270° or more.

angular misalignment *n:* one type of misalignment in a chain-and-sprocket drive. The shafts are not parallel to each other (they form an angle) in either the horizontal or the vertical plane. This pulls the link plates on one side tighter than those on the other side; thus, one side of the chain and sprockets wears faster than the other. Link plates on only one side of the chain break because of fatigue.

ANSI *abbr:* American National Standards Institute.

automatic cathead *n:* see *breakout cathead*, *cathead*, *makeup cathead*.

auxiliary brake *n:* a braking mechanism on the drawworks, supplemental to the mechanical brake, that permits the lowering of heavy hook loads safely at retarded rates without incurring appreciable brake maintenance. There are two types of auxiliary brake—the hydrodynamic and the electrodynamic. In both types, work is converted into heat, which is dissipated through liquid cooling systems. See *electrodynamic brake*, *hydrodynamic brake*.

B

block *n*: any assembly of pulleys on a common framework; in mechanics, one or more pulleys, or sheaves, mounted to rotate on a common axis. The crown block is an assembly of sheaves mounted on beams at the top of the derrick or mast. The drilling line is reeved over the sheaves of the crown block alternately with the sheaves of the traveling block, which is raised and lowered in the derrick or mast by the drilling line. When elevators are attached to a hook on the traveling block and drill pipe is latched in the elevators, the pipe can be raised or lowered. See *crown block*, *traveling block*.

brake band *n:* a part of the brake mechanism consisting of a flexible steel band lined with a material that grips a drum when tightened. On a drilling rig, the brake band acts on the flanges of the drawworks drum to control the lowering of the traveling block and its load of drill pipe, casing, or tubing.

Review Questions

LESSONS IN ROTARY DRILLING

Unit I, Lesson 6: The Drawworks and the Compound

1. Name five components of the hoisting system.

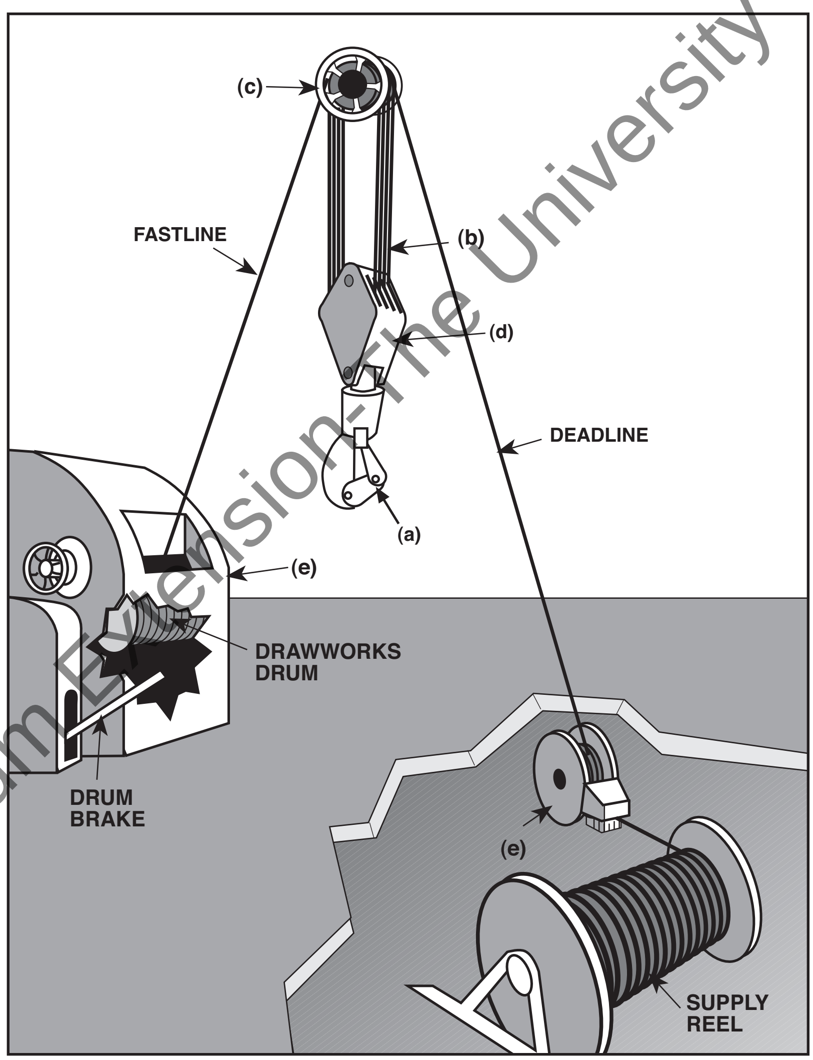
   (a)

   (b)

   (c)

   (d)

   (e)



Answers to Review Questions

LESSONS IN ROTARY DRILLING

Unit I, Lesson 6

The Drawworks and the Compound

1. (a) Drilling hook
   (b) Drilling line
   (c) Crown block
   (d) Traveling block
   (e) Drawworks
2. (a) Driller's console and brake lever
   (b) Low drum drive
   (c) Main brake
   (d) Drum
   (e) High drum drive
   (f) Catshaft and optional sand reel
   (g) Rotary drive countershaft (optional)
   (h) Auxiliary brake
3. (a) High drum drive
   (b) Electric motors
   (c) Drum
   (d) Optional sand reel
   (e) Catshaft drive
   (f) Low drum drive
   (g) Output shaft
   (h) Input shaft
4. T
5. T
6. T
7. mechanical; auxiliary
8. The basic power source; diesel-powered internal-combustion engines
9. compound
10. generators; motors
11. (a) Shafts
    (b) Sprockets
    (c) Roller chain
12. driving; driven
13. T
14. (a), (b), (c) Chain-and-sprocket drives for three speeds
    (d) Gears for reverse speed
    (e) Low drum chain-and-sprocket drive
    (f) High drum chain-and-sprocket drive
    (g) Chain-and-sprocket drive to the catshaft ____
    (h) Chain-and-sprocket drive to the rotary drive countershaft ____
15. roller; pin
16. connector; offset
17. even
18. F
19. F
20. angular; offset
21. Too much
22. T
23. It connects and disconnects two rotating shafts.
24. jaw; spline
25. drum; plate (disk)
26. automatically
27. T
28. rims (flanges); bands; blocks
29. live; dead
30. descending
31. F

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