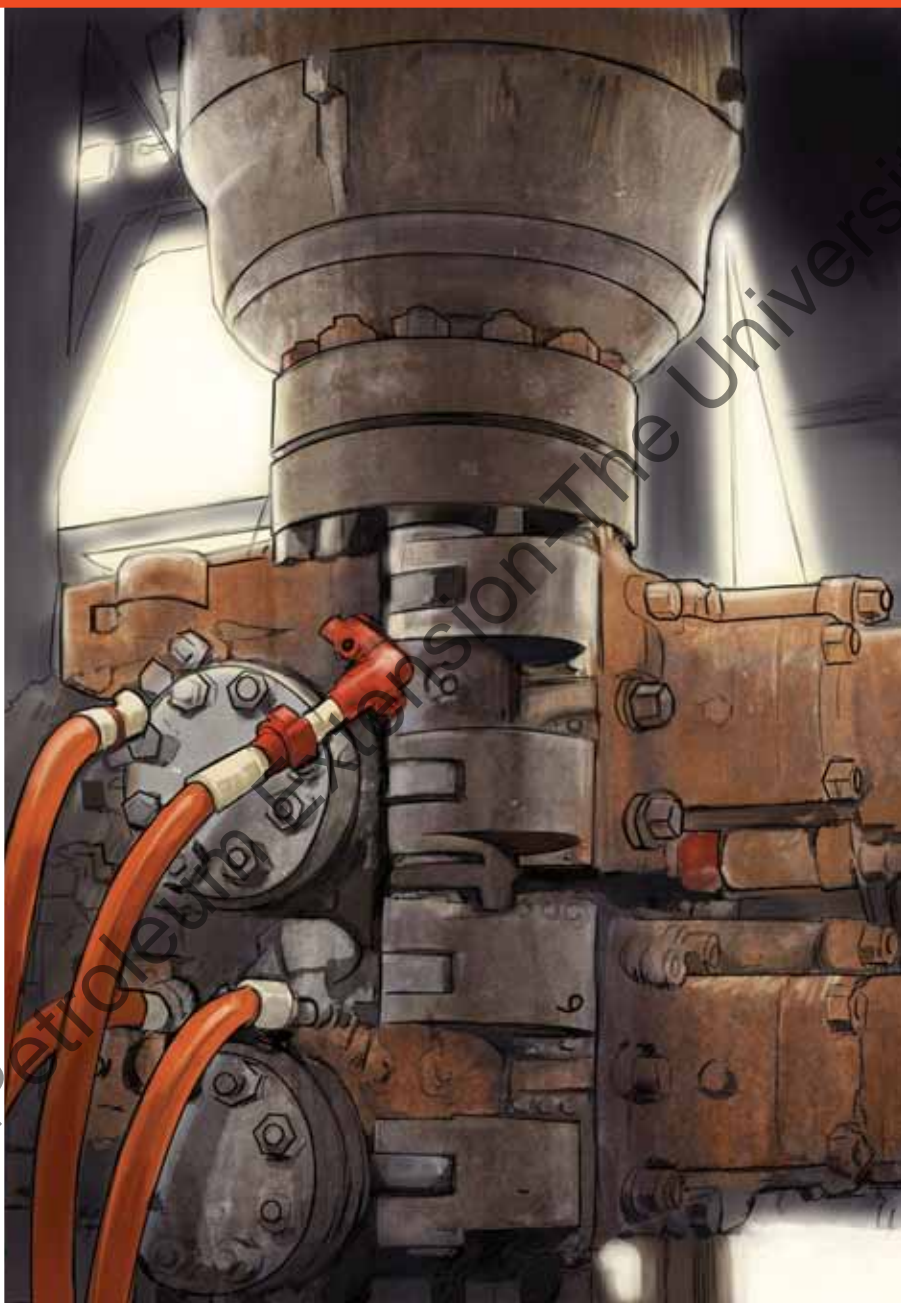


ROTARY DRILLING

Blowout Prevention



Fourth Edition

UNIT III • LESSON 3



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
- Lesson 9: The Auxiliaries
- Lesson 10: Safety on the Rig

Unit II: Normal Drilling Operations

- Lesson 1: Making Hole
- Lesson 2: Drilling Fluids
- Lesson 3: Drilling a Straight Hole
- Lesson 4: Casing and Cementing
- Lesson 5: Testing and Completing

Unit III: Nonroutine Operations

- Lesson 1: Controlled Directional Drilling
- Lesson 2: Open-Hole Fishing
- Lesson 3: Blowout Prevention

Unit IV: Man Management and Rig Management

Unit V: Offshore Technology

- Lesson 1: Wind, Waves, and Weather
- Lesson 2: Spread Mooring Systems
- Lesson 3: Buoyancy, Stability, and Trim
- Lesson 4: Jacking Systems and Rig Moving Procedures
- Lesson 5: Diving and Equipment
- Lesson 6: Vessel Inspection and Maintenance
- Lesson 7: Helicopter Safety
- Lesson 8: Orientation for Offshore Crane Operations
- Lesson 9: Life Offshore
- Lesson 10: Marine Riser Systems and Subsea Blowout Preventers

Contents



Figures	vi
Tables	viii
Acknowledgments	ix
About the Authors	x
Units of Measurement	xiv
Overview	1
To summarize	4
Formation Pressure	5
Formation Pressure Gradients	7
Normal and Abnormal Pressures	9
Hydrostatic Pressure versus Formation Pressure	11
Circulating Pressure	14
Pressure Surges and Swabbing	15
Hole Filling	17
Formation Fracture and Lost Circulation	20
To summarize	24
Abnormal-Pressure Formations	25
Shale Compaction	25
Detection of Abnormal Pressure	28
Drilling Rate Changes	28
Sloughing Shale	30
Shale Density	30
Gas-Cut Mud	31
Chloride Increases	31
Mud Temperature Increase	32
Electric Log Data	32
To summarize	34
Kick Detection	37
Pit Gain	39
Mud Flow from the Well	41
Increase in Flow While Circulating	42
Drilling Break	42
Decrease in Circulation Pressure	43
Shows of Gas, Oil, or Salt Water	44
Gas Behavior and Gas-Cut Mud	45
To summarize	48
Killing a Well Kick Onshore	49
Steps to Control an Onshore Well Kick if on Bottom While Drilling	50

Controlling a Well Kick While Making a Trip	51
Drill Pipe as a Bottomhole Pressure Gauge	51
Slow Pump Rate	54
Driller's Method	55
Wait-and-Weight Method (Engineer's Method)	62
Concurrent Method	67
Bullhead Kill Method	67
Dynamic Kill Method	68
Momentum Kill Method	69
Kicks with Drill Pipe off Bottom	70
Top Kill (Volumetric)	70
Reverse Circulation	71
Mistakes in Well Control	72
Pulling into the Casing	72
Constant Pit-Level Method	72
Excessive Mud Weight	73
Constant Choke-Pressure Method	73
To summarize	74
Kick Control in Offshore Operations	77
Diverter BOP Systems	78
Procedure to Control the Well with a Diverter System	79
Controlling Kick from a Floating Rig with Competent	
Casing Set	79
To summarize	80
Special Problems in Kick Control	81
Shallow Gas Formations	81
Kicks with the Drill Pipe Out of the Hole	82
Stripping into the Hole	86
Surface Pressure Conditions	86
Preliminary Procedures for Stripping In	86
Stripping In with the Annular Preventer	87
Stripping with Ram Preventers (Ram-to-Ram	
Stripping)	91
Volumetric Displacement Correction for Casing	
Pressure	92
Stripping Out of the Hole	94
Hole in the Drill Pipe	94
Plugged Pipe or Bit	94
Snubbing Operations	96
Lost Circulation	98
To summarize	100

Preventer Equipment	103
Pressure Ratings	106
Flanges and Fittings	106
Casing and Wellheads	110
Annular Preventers	115
Pipe Ram Preventers	117
Drilling Spools/Flow Cross	122
Mud Riser and Fill-up Connections	125
Rotating Heads	127
Operating Equipment	128
Flow and Choke Fittings	134
Kill Lines	136
Mud-Handling Equipment	137
Auxiliaries	140
Kelly Cock	140
Inside Blowout Preventer	142
Accessories	144
Degasser	144
Trip Tank	145
Pit-level Indicator and Pit-volume Recorder	146
Pump Stroke Counter	148
Mud-Flow Indicator	149
To summarize	150
Preventer Tests and Drills	153
Testing Procedures	154
Testing on Casing	154
Testing with a Hanger Plug	156
Cup or Packer Tests	157
Blowout Preventer Drills	158
To summarize	160
Appendix	161
Glossary	167
Review Questions	189
Index	195
Answers	205

About the Authors



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Tim Bell is a Senior Well Control Engineer for Cudd Well Control. Tim has over eight years experience in the oil and gas industry. He is involved in all phases of well-control engineering, including blowout contingency planning, dynamic well-kill design and execution, underground blowout control, rig equipment inspections, engineering, and field operations.

Tim has experience in the majority of petroleum producing states in the United States. He also has experience with international blowouts, firefighting operations, on- and offshore events, inland barge blowouts, H₂S wells, oil-based mud kicks, and high-pressure and geothermal wells. Tim has been involved with special service projects including ROV assisted subsea hot tapping, freeze jobs and post-event consulting. Tim has held several positions in well control, drilling, completions, production and workovers as an operations engineer and wellsite supervisor. In addition to blowouts and well-control jobs, Tim's past projects have included horizontal wells, coalbed methane exploration and development, deep gas wells, and unconventional tight gas reservoirs.

Tim graduated from Texas Tech University with a Bachelor's degree in Petroleum Engineering. Upon graduation, he was hired by Devon Energy as an operations engineer. In the fall of 2004, Tim left Devon to become Vice President of Operations for Quest Resources. Tim made the move to Cudd Well Control in January of 2007 and currently holds the position of Senior Well Control Engineer. Tim is involved in all aspects of well-control engineering, blowout intervention and firefighting operations and recovery. Tim is a member of the Society of Petroleum Engineers and is IADC WellCAP certified.



Dan Eby is the Vice President of Operations and Engineering Manager for Cudd Well Control. Dan has 29 years of experience in the petroleum industry with several major oil companies and well-control service providers. As Vice President of Operations, Dan is in charge of the daily operation of Cudd Well Control, including all technical field work and business decision making.

As Engineering Manager, he is involved in all phases of well-control engineering including blowout contingency planning, relief well planning, dynamic kill design and execution, and field operations.

Dan has worked in over 30 different countries with diverse assignments in well control, drilling, completions, and workover. He has acted as both project engineer and well site supervisor. In addition to blowouts, the projects include deepwater exploration, HPHT sour gas wells, horizontal wells, subsea completions, coalbed methane exploration, and hazardous waste disposal wells.

In addition to work on well-control jobs and blowouts, Dan's experience includes well-control instruction, development of well-control technical manuals, development of recommended practices for unconventional well-control problems, acting as MMS liaison, and the design and supervision of high-pressure snubbing jobs, both onshore and offshore.

Dan graduated from Texas A&M University with a B.S. in Building Construction in 1977, followed by a B.S. in Civil Engineering in 1979. Dan is a licensed professional engineer in the state of Texas and a member of the Society of Petroleum Engineers, National Society of Professional Engineers, Texas Society of Professional Engineers, and the International Association of Drilling Contractors Well Control Committee.



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Jace Larrison is a Senior Well Control Engineer for Cudd Well Control. Upon graduation, Jace began work for Cudd Pressure Control, now Cudd Energy Services (CES), as a field engineer for snubbing and coiled tubing. Jace has an extensive background in snubbing operations that includes operational soundness with 170K hydraulic rig-assist units as well as all sizes of CES Stand-Alone (HWO) units. Special Service experience includes hot tapping, cryogenic freezing, conventional dry-ice freezing, and valve drilling operations. Jace has well-control operational experience on projects including onshore, inland water, and offshore critical pressure control situations, onshore blowouts, geothermal blowouts, inland water blowouts, high volume H₂S blowouts and numerous other special projects related to well control. Jace has worked in most oil and gas producing areas of the United States as well as many international locations such as Australia, Saudi Arabia, Qatar, Turkmenistan, Kazakhstan, Libya, and Egypt.

Jace is involved in all aspects of well-control engineering, including Blowout Contingency Planning (BCP), well-control equipment inspections, recommendations for special well-control problems, kill design and execution, kick resolution and modeling, and all aspects of field operations. Jace has also taught several industry classes related to well-control subject matter and has been involved in giving numerous presentations at industry-related events such as case histories and well-control topic discussions.

Jace is a graduate of Texas Tech University with a B.S. in Petroleum Engineering. In 2002, he received the Texas Tech SPE outstanding member of the year award and was a TTUSPE officer for the 2002–2003 academic year. Jace is a member of the American Association of Drilling Engineers and the Society of Petroleum Engineers.



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BHAVESH RANKA

He has been involved in all aspects of well-control engineering including blowout contingency plans, well-control equipment inspection, drilling plan reviews, gas dispersion modeling, and kick simulation. His work in field operations includes blowouts, rig fires, and well-control operations.

Bhavesh has worked offshore and at onshore locations in Texas, Louisiana, Oklahoma, Colorado, New Mexico, Montana, and Wyoming. He has also been involved in well-control training. His special services experiences include hot-tap, valve drilling, and freeze operations.



Petroleum Extension-The University of Texas at Austin

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 employ 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 Systeme International (SI) d'Unites. 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 system, we include the table on the next page.

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)
	2.895	kilograms per cubic metre (kg/m ³)	
	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)

Overview



In this chapter:

- The history of the Lucas well at Spindletop
 - The probable causes of the blowout at the Lucas well
 - The signs of an imminent well kick that can lead to a blowout
-

On January 10, 1901, the *blowout* of the Lucas well at Spindletop near Beaumont, Texas, was spectacular and widely publicized. Before the development of *blowout preventers (BOP)*, blowouts were common. They were called *gushers* if they produced oil.

The Hamill brothers had started drilling the Lucas well three months earlier using a new tool called a *rotary drill*. Because of their experience using the rotary drill, the Hamills had been hired by Anthony F. Lucas and his partners to come to Beaumont to try drilling through the sand and rock at Spindletop (fig. 1).

A 6-inch (15.24 centimetres) diameter *casing* was set at 880 feet (268 metres), where it was expected that oil would be found. When no oil was struck, the well was deepened to 1,020 feet (310.9 metres). The final 140 feet (42.67 metres) of drilling proceeded quickly – much faster than had been drilled before. The crew was preparing a new *bit* with 700 feet (213.4 metres) of *drill pipe* in the hole when the well started to unload; that is, drilling mud started flowing from the casing.



Figure 1. Anthony Lucas, chief engineer at Spindletop

Formation Pressure



In this chapter:

- Rock formations that can trap oil
- The difference between and causes of formation pressure and hydrostatic pressure
- The causes of formation pressure gradients
- How to calculate hydrostatic pressure
- The differences among normal, abnormal, and subnormal hydrostatic pressures
- The interdependence of formation and hydrostatic pressure in well control
- The measurement and control of circulating pressures caused by drilling fluid and equipment

To classify layers of rock, geologists use a basic subdivision called a *formation*. A formation is a rock unit that is distinctive and consists of a certain number of rock strata with comparable or similar properties. Therefore, the characteristics of formations result in differences in the way fluids are trapped (fig. 4).

Formation pressure is the force exerted by fluids in an underground rock formation. In drilling operations, formation pressure is measured and recorded using a drilled hole at the depth of the formation with the well's surface valves completely closed or *shut-in*. It is sometimes referred to as reservoir pressure. Formation pressure must be carefully monitored and controlled during drilling operations. This is an important factor in blowout prevention.

Abnormal-Pressure Formations



In this chapter:

- Shale compaction as a cause of abnormal formation pressure
 - Common signs and detection methods used to locate abnormal formation pressures
-

Abnormal formation pressure and lost circulation in *unconsolidated formations* are related problems. Higher than normal formation pressure gradients are encountered at varying depths in many locations. These areas require extra care to be productive and incur additional drilling expense. Costly blowouts can occur when abnormal pressure zones are unexpectedly penetrated.

A rock with *pores* or open spaces is called *porous*. Hydrocarbons can occur only in porous reservoir rocks. A porous rock has a measurable quality called *porosity*. Porosity can be very low, almost zero or, in theory, it can be as high as 55% for extremely well-sorted (same diameter) rock grains. Because most rocks have grains of varying sizes, the practical limit of porosity is usually around 30% for sandstone.

Shale Compaction

Kick Detection



In this chapter:

- Preliminary events that indicate a kick has been taken
- Well-control equipment used to assess and detect a kick
- Some corrective measures used to stop a kick

Drilling abnormally-pressured formations is known to be hazardous, but many well-control problems also happen in normal formation pressures. Some problems occur while pipe is being moved in or out of the borehole (fig. 22).

When the first stands of pipe are pulled or tripped out, there can be a reduction in bottomhole pressure. This may be caused by the cessation of circulation, and perhaps because of swabbing. If there is any indication of flow, the well should be shut-in and circulated by following standard well-control practices to remove any influx and fill the well with clean drilling fluid. If necessary, the mud weight should be increased before subsequent attempts to trip the pipe.

Sometimes, the preliminary indications of a kick are almost unmistakable. These “positive” indicators include:

- Unexplained mud-pit gain
- Mud flow with the pumps off
- Increase in flow while circulating

In other cases, the indications of a possible kick are ambiguous. These “possible” indicators include:

- A drilling break, a sudden increase in *ROP* (rate of penetration)
- Decrease in circulating pressure
- Shows of gas, oil, or salt water

Strong indicators of a kick include:

- Unexplained mud-pit gain
- Mud flow with the pumps off
- Increase in flow while circulating

Killing a Well Kick Onshore



In this chapter:

- Steps to control an onshore well kick
- Steps to control a well kick while making a trip
- Various methods, procedures and calculations used to kill a kick
- Killing a well kick with the pipe off the bottom of the borehole
- Common mistakes made in killing a well kick

By taking immediate action, the driller can minimize the size of a kick. Minimizing the size of the kick and can greatly enhance the ability of a drilling crew to handle the kick properly. Quick action can prevent the situation from escalating into a blowout.

When a kick is detected, following the proper sequence of steps is critical to successful emergency control. Depending on the cause, differing methods and procedures may be used to kill a well kick.

Kick Control in Offshore Operations



In this chapter:

- Procedures in controlling a kick offshore from a floating rig
- Diverter BOP systems
- Procedures for well control with a diverter system

The procedures for controlling kicks in offshore drilling from a floating rig are similar to those for onshore as discussed in the previous chapter. Offshore may refer to any body of water, including inland lakes, seas, and rivers. There are additional steps and additional equipment with which crewmembers must be familiar (fig. 36).



Courtesy of Cudd Well Control

Figure 36. A subsea ram-type blowout preventer

Special Problems in Kick Control



In this chapter:

- The dangers of shallow gas formations
- Procedures and calculations required to control kicks with the drill pipe out of the hole
- Well-control problems encountered when stripping into the hole
- Well-control problems encountered when stripping out of the hole
- The procedures and equipment used in snubbing operations
- The procedures used to control lost circulation

Shallow gas formations present a danger because:

- The gas pocket is generally at a depth that allows a potential kick to rapidly unload the mud from the wellbore, and
- Shutting in the well might cause the formation to fracture and the wellbore fluids to broach all the way to the mud line.

Either of these possibilities can result in a serious well-control problem. If a shallow gas kick occurs before enough casing is set, the diverter system will divert the flow away from the rig. For a kick in a shallow gas formation, the offshore crew should take the same steps as those listed for diverting the well in the previous chapter.

Shallow Gas Formations

Preventer Equipment



In this chapter:

- The main pieces of equipment used in well control and blowout prevention
 - The purpose and function of each piece of equipment
 - Auxiliary and accessory rig equipment that contributes to well control
-

The hydrostatic pressure of the drilling fluid column on the formation is the primary barrier in preventing a well from blowing out. When formation pressure is greater than the hydrostatic pressure of the mud column, BOPs and related equipment shut in a well at the surface and serve as a second barrier.

In addition to BOPs, other equipment is used to assist in the control of well pressure. Chokes and choke manifolds allow a controlled removal of the intruded formation fluids from the wellbore. Mud-gas separators help conserve drilling fluids while removing the gas from the drilling fluids and discharging the gas to the atmosphere. *Rotating heads* permit drilling to continue at an increased ROP in formations with high-pressure/low-volume gas flow.

Preventer Tests and Drills



In this chapter:

- The reasons for BOP pressure testing
 - The methods for testing various BOP components
-

Blowout preventers are emergency equipment. The BOPs are only effective if they:

- Can handle the pressure involved
- Are in good operating condition, and
- Are used correctly

The decision to provide adequate BOPs involves the operating company, the drilling contractor and the drilling crews. The drillers on the rig are key in the responsibility, but every crewmember should know how to operate the preventer equipment and be alert to the signs of a well kick. Function testing of the preventers and careful pressure testing ensures that everything is in good operating condition and ready for use.

Testing of the BOPs to their rated pressure (if equal to or below the rating of the wellhead) should be conducted to confirm that the equipment will hold under the given test pressure. All preventers and valves, including the choke manifold, should be tested with pressure from the upstream side. Therefore, test pressure is applied to the preventer or valve from the side normally originating the pressure in a kill situation.

Frequent operational checks and regular pressure tests ensure that valves and other components are in good working order. Lubrication, as necessary, ensures easy operation of the equipment in an emergency. Regular maintenance is less expensive than replacement of an item or the possibly drastic consequences incurred when equipment does not function properly.

Index



- abnormal formations, 42
- abnormal pressure, 28
- abnormal-pressure formations
 - detection of, 28–35
 - shale compaction, 25–27
- accumulators, 128, 132, 133
- acoustic travel time, 32
- adapter spools, 108
- adjustable chokes, 89, 135
- American National Standards Institute (ANSI), 109
- American Petroleum Institute (API), 106, 109.
See also API RP 53 (American Petroleum Institute standards)
- annular blowout preventers, 50, 87–90, 115–117
- annular space, 13
- annulus, 14
- ANSI (American National Standards Institute), 109
- API RP 53 (American Petroleum Institute standards)
 - accumulator pressure level in blowout preventer control unit, 133
 - blowout preventer working pressure test schedule, 154
 - closing systems speed, 128
 - for flanges and gaskets, 109
 - for operating equipment, 128
 - pressure ratings, 109
 - recommendations and ratings for blowout preventers, 106
 - for wellhead equipment, 109
 - working pressures, 136
- assemblies
 - blowout preventers (BOPs), 104, 111, 112, 113, 128, 150, 154
 - choke manifold, 145
 - connection to, 106
 - high pressure, 108
 - skid-mounted, 130
 - testing, 154
 - valve, 87
 - working pressure of, 106, 110–111
- associated gas, 73
- A-suction, 114
- auxiliaries
 - degassers, 144
 - inside blowout preventers, 142–143
 - kelly cock, 140–141
 - mud-flow indicators/sensors, 149
 - pit-level indicators and pit-volume recorders, 146–147
 - pump stroke counter, 148
 - trip tanks, 145
- back-pressure, 18
- back-pressure valves, 140
- balled up bits, 14
- barite, 7
- bell nipples, 125–126
- bits, 1, 14, 94–95
- blanket sands, 10
- blind flange, 106
- blind rams, 89, 121, 122

BLOWOUT PREVENTION

- blowout assemblies
 - high pressure, 108
 - working pressure of, 110–111
- blowout preventers (BOPs). *See also under preventers*
 - annular, 50, 87–90, 115–117
 - auxiliaries, 142–143
 - Cameron Type U, 118–119
 - capabilities of, 104
 - closure of, 41
 - components of, 105
 - control unit, 133
 - dart type, 142–143
 - drop type, 142–143
 - history of, 1
 - hydraulic fluids for operation of, 129
 - Hydril-Type GK, 116
 - Hydril-Type V, 119–120
 - inside (IBOPs), 142–143
 - NL Shaffer type, 119–120
 - pipe ram, 91–92, 115, 117–122
 - stack, 89
- blowouts, 1, 3
- borehole, 7
- bottomhole pressure (BHP), 3, 12, 84
- Boyle, Robert, 45
- Boyle's law, 45
- bullhead kill method (bullheading), 67–68, 82
- bull plug, 106

- Cameron Type U ram preventers, 118–119
- cap rock, 42
- casing and wellheads, 110–114
- casing pressure, 46
- casings, 1
- casing seats, 22
- casing shoes, 20, 110–111
- cellar, 114

- cementing, 20, 110
- cementing unit, 89, 94
- cement plugs, 148
- centrifugal degassers, 138, 144
- centrifugal pumps, 18
- chloride increases, 31
- choke adjustments, 62
- choke lines, 106
- choke-manifold friction, 66
- chokes. *See also constant choke-pressure method*
 - adjustable, 89, 135
 - adjustments, 62
 - fittings, 134–135
 - manifold assemblies, 55, 134, 145
- circulate-and-weight method, 67
- circulating pressure, 14–15
- circulation pressure, 94
- closed in well, 50
- closed reservoirs, 10
- closing systems, 128
- closing time, 128
- closing unit pumps, 87
- concurrent method, 67
- conductivity, 32
- conductor pipe, 44, 78, 113, 117
- conductor pipe outlet, 125
- connection gas, 31
- constant choke-pressure method, 73
- constant pit-level method, 72
- controlling a well kick while making a trip, 51
- controlling kick from a floating rig with competent casing set, 79
- cross-flow, 98
- cup packers, 157–158
- cup testers, 157–158
- cuttings, 71

- dart type inside blowout preventers, 142–143
 decrease in circulating pressure, 43–44
 degassers, 138, 144
 delay timing, 58
 density (unit weight), 7, 8
 derrickhand, 3
 detection of abnormal pressure, 28–35
 - chloride increases, 31
 - drilling rate changes, 28–29
 - electric log data, 32–33
 - gas-cut mud, 31
 - mud temperature increase, 32
 - shale density, 30
 - sloughing shale, 30
 detection of high formation pressures, 28
 d-exponent factor, 29
 differential pressure, 28
 displacement monitoring, 89
 ditches, 125
 diverter bop systems, 78
 drill collars, 19
 drilled show gas, 31, 44
 drilled shows, 44
 driller's method, 55–61
 drilling break, 3, 28, 42
 drilling fluid density, 12
 drilling fluids, 7
 drilling rate changes, 28–29
 drilling spools/flow cross, 114, 122–124
 drill pipe. *See also* blowout preventers (BOPs);
 circulation pressure; full-opening safety
 valves (FOSVs); lost circulation; shut-in
 drill pipe pressure (SIDPP); trips
 - as a bottomhole pressure gauge, 51–53, 83
 - displacement, 19, 92
 - fishing operations, 121
 - hydrostatic pressure, 13, 44
 - out of the hole, 82
 - pipe ram preventers, 117
 - pressures, 134
 - pulling/pulled, 44, 145–146
 - shearing, 118
 - at Spindletop, Texas, 1–3
 drill pipe pressure, 12, 44
 drill pipe pressure gauge, 62
 drill pipe rubbers, 91
 drill-stem (full-opening safety) valves
 (FOSVs), 143
 drill stems, 121
 drill string, 14, 51–53
 drop type inside blowout
 preventers, 142–143
 dynamic kill method, 68
- electric log, 28
 electric log data, 32–33, 35
 detection of abnormal pressure, 32–33
 engineer's method, 62–67
 entrained gas, 54
 equivalent circulating density (ECD), 78
 excessive mud weight, 73
- fill-up line connections, 126
 final circulating pressure (FCP), 62
 fishing operations, 121
 flanges and fittings, 106–109
 float in drill string, 51–53
 flow and choke fittings, 134–135
 flow check, 16
 flow checks, 41
 flow line, 44
 flow-line temperatures, 32
 fluid pressure, 7
 formation fluids, 2
 formation fracture, 67
 formation fracture and lost circulation, 20–24

BLOWOUT PREVENTION

formation integrity. *See* formation fracture and lost circulation

formation pressure

about, 5–6

formation fracture and lost circulation, 20–24

formation pressure gradients, 7–8

hole filling, 17–19

vs. hydrostatic pressure, 11–15

hydrostatic pressure vs., 11–15

monitoring, 6

normal and abnormal pressures, 9–10

pressure surges and swabbing, 15–16

formation pressure gradients, 7–8

formations, 5

formation types and mud loss, 23

fracture pressure, 20

free water, 27

full-opening safety valves (FOSVs), 51, 70, 105, 143

gas behavior and gas-cut mud, 45–47

gas charge, 133

gas-cut mud, 31, 45–47

gaskets, 109

gas migration, 61, 82, 86

gel strength, 14–15

glycol, 129

gradients, 51–53

gravity-flow trip tanks, 145

guide shoes, 110–111

gushers, 1

hanger plugs, 156

hangers, 112

hard shut-in, 79

hard shut-in well, 50

high formation pressure detection, 28

high pressure blowout assemblies, 108

hole in the drill pipe, 94

hook load, 3

hydraulic accumulators, 132

hydraulically-operated valves, 108

hydraulic high-pressure choke manifold, 134

hydraulic rig assist snubbing units, 96

hydraulic workover (HWO) unit, 96–97

Hydril-Type GK blowout preventers, 116

Hydril-Type V ram preventers, 119–120

hydrostatic head, 14

hydrostatic pressure, 2, 7, 8

circulating pressure, 14–15

vs. formation pressure, 11–15

hydrostatic pressure gradient, 8

ideal gas, 45

increase in flow while circulating, 42

induced kicks, 83

initial circulating pressure (ICP), 62

inside blowout preventers (IBOPs)

dart type, 142–143

drop type, 142–143

internal blowout preventers. *See* inside blowout preventers (IBOPs)

internal diameter (ID), 13

International Association of Drilling Contractors (IADC), 60

jet nozzles, 14

joints. *See* tool joints

kelly, 41

kelly cocks, 140–141

test sub, 155

kick

causes of, 15

defined, 2

signs of, 4

- kick control, offshore operations
 - about, 77
 - controlling kick from a floating rig with competent casing set, 79
 - diverter bop systems, 78
 - procedure to control the well with a diverter system, 79
- kick control, special problems, 81–101
- kicks with the drill pipe out of the hole, 82–86
 - shallow gas formations, 81
 - in snubbing operations, 96–99
 - stripping into the hole, 86–93
 - stripping out of the hole, 94–95
- kick detection, 37–48
 - decrease in circulating pressure, 43–44
 - drilling break, 42
 - gas behavior and gas-cut mud, 45–47
 - increase in flow while circulating, 42
 - mud flow from the well, 41
 - pit gain, 39–40
 - shows of gas, oil, or salt water, 44
- kick indicators, 37–38
- kicks with drill pipe off bottom, 70–71
 - reverse circulation, 71
 - top kill (volumetric), 70–71
- kicks with the drill pipe out of the hole, 82–86
- killing a well kick
 - about, 49
 - bullhead kill method, 67–68
 - concurrent method, 67
 - controlling a well kick while making a trip, 51
 - driller's method, 55–61
 - driller's method for, 55
 - drill pipe as a bottomhole pressure gauge, 51–53
 - dynamic kill method, 68
 - engineer's method, 62–67
 - kicks with drill pipe off bottom, 70–71
 - mistakes in well control, 72–73
 - momentum kill method, 69
 - slow pump rate, 54
 - steps to control an onshore well kick if on bottom while drilling, 50
 - wait-and-weight method, 62–67
- kill lines, 106, 136
- kill sheet, 62
- kill-weight mud, 55–56, 66
- leak-off test, 20
- liners, 18
- logs, 28, 32–33, 35
- loss zone, 23
- lost circulation, 20, 23, 98–99
- lost-circulation material, 99
- lost returns, 20
- lower kelly cock, 140–141
- lube-and-bleed method, 70, 82
- Lucas Anthony F., 1
- make hole, 3
- managed pressure drilling (MPD), 127
- Marine Riser System and Subsea Blowout Preventers (PETEX)*, 78
- master control panels, 128
- mistakes in well control
 - constant choke-pressure method, 73
 - constant pit-level method, 72
 - excessive mud weight, 73
 - pulling into the casing, 72
- momentum kill method, 69
- mud, 7, 13–24, 28–29, 32–34, 37–47, 51–59, 61–62, 65–67
- mud flow, 41
- mud-flow indicators/sensors, 149
- mud-gas separator, 54
- mud-handling equipment, 137–139
- mud logs, 28, 31
- mud loss and formation types, 23

- mud pits, 18
- mud return flow rate, 42
- mud return line, 38
- mud riser and fill-up connections, 125–127
- mud risers, 125
- mud temperature increase, 32
- mud-weight
 - calculations of, 74–75
 - concurrent method, 67
 - differential pressure, 25
 - equivalent, 20
 - excessive, 73
 - fluid density, 8, 24
 - formation pressure control, 22, 53
 - fracture pressure, 23, 31
 - kick and, 37
 - killing a well kick, 50, 70, 82–83
 - loss of, 47
 - maximum, 23
 - mud temperature increase, 32
 - normalized penetration rate, 29
 - pressure surging, 15
 - stripping in procedure, 90, 93
 - wait-and-weight method, 62–67
- naturally-fractured formation, 98
- nipped-up connection, 114
- nitrogen, 133
- NL Shaffer ram preventers, 119–120
- nomographs, 90
- normalized penetration rate (d-exponent), 29
- normal-rate trend, 28
- nozzles, 14
 - offshore, 77
- open hole, 83
- operating equipment, 128–133
- operating pressure control, 56
- operating pressure source, 128
 - operating pressure standards, 133
 - outer diameter (OD) drill collars, 13
 - “out-running the well” kills, 69
 - overbalance, 9
 - overburden, 10
 - overburden pressure, 10
 - overkill, 73
 - overpressurized formations, 28, 42
 - oxygen, 133
- packers, 117
- permeability, 26
- permeable rocks, 26
- pipe ram blowout preventers, 117–122
- pipe rams, 117
- pit gain, 3, 39–40
- pit level, 40
 - pit-level change, 17
 - pit-level indicators, 40
 - pit-level indicators and pit-volume recorders, 146–147
 - pit-volume increase, 65
- plugged pipe or bit, 94–95
- plugs, 94, 106, 148, 156
- pores, 26–27
- porosity, 25
- porous rocks, 25
- positive-displacement meters, 18
- pounds per gallon (ppg), 8
- pounds per square inch (psi), 47
- pounds per square inch per foot (psi/ft), 8
- power rigs, 128
- preliminary procedures for stripping in, 86
- pressure, 2
 - pressure changes, 15
 - pressure gradient, 7
 - pressure loss, 13
 - pressure overbalance, 9

- pressure ratings, 106
- pressure surges and swabbing, 15–16
- pressure surging, 15
- preventer equipment, 103–152
- about, 103–105
 - annular blowout preventers, 115–117
 - auxiliaries, 140–143
 - casing and wellheads, 110–114
 - drilling spools/ flow cross, 122–124
 - flanges and fittings, 106–109
 - flow and choke fittings, 134–135
 - kill lines, 136
 - mud-handling equipment, 137–139
 - mud riser and fill-up connections, 125–127
 - operating equipment, 128–133
 - pipe ram blowout preventers, 117–122
 - pressure ratings, 106
 - rotating heads, 127–128
- preventer operating pumps, 130
- preventer tests and drills
- about, 153–154
 - blowout preventer drills, 158–159
 - cup or packer tests, 157–158
 - testing on casing, 154–155
 - testing procedures, 154
 - testing with a hanger plug, 156
- procedure to control the well with a diverter system, 79
- pulling into the casing, 72
- pump stroke count, 17
- pump stroke counters, 148
- rams, 87
- ram-to-ram stripping, 91–92
- ram-type blowout preventers, 115
- rate of penetration (ROP), 28
- reciprocating pumps, 18
- Recommended Practices for Blowout Prevention Equipment Systems for Drilling Wells* (API).
See API RP 53 (American Petroleum Institute standards)
- reduced circulating pressure, 65
- regulator valves, 87
- remote choke panels, 135
- remote control panels, 131, 135
- reservoir pressure, 2
- resistivity, 32
- reverse circulation, 71
- ring gaskets, 114
- ring-joint flanges, 109
- roller cone bit, 94
- rotary, 41
- rotary drills/drilling, 1, 2
- rotary tables, 128
- rotating heads, 103, 127–128
- seismic data, 28
- settling pit, 139
- shale, 10
- shale characteristics, 32
- shale compaction, 25–27
- shale density, 30
- shale shakers, 56
- shallow gas formations, 81
- shearing
- of drill pipe, 118
 - of tubing, 118
- shear rams, 118
- short way, 71
- show, 44
- show gas, 31
- show of gas, oil, or salt water, 44
- shut-in, 50, 79
- shut-in casing pressure (SICP), 53, 55, 65
- shut-in drill pipe pressure (SIDPP), 51–53, 65
- signs of blowouts, 3, 79
- siphons, 139

BLOWOUT PREVENTION

- skid-mounted assemblies, 130
- slips, 96, 143
- sloughing shale, 30
- slow pump rate, 54
- snubbing, 71, 82
- snubbing operations, 96–99
- snubbing units, 89, 96
- soft shut-in, 50, 79
- soft shut-in well, 50
- Spindletop, Texas, 1
- squeeze cementing, 20
- stack, 89
- stand-alone unit, 96, 97
- standpipe, 56
- stands of pipe, 16
- starter heads, 114
- stationary slips, 96
- steps to control an onshore well kick if on bottom while drilling, 50
- stripping in, 71
- stripping into the hole
 - with annular preventer, 87–90
 - preliminary procedures for stripping in, 86
 - ram-to-ram stripping, 91–92
 - stripping with ram preventers, 91–92
 - surface pressure conditions, 86
 - volumetric displacement correction for casing pressure, 92–93
- stripping out, 94
- stripping out of the hole
 - hole in the drill pipe, 94
 - plugged pipe or bit, 94–95
 - stripping with ram preventers, 91–92
- strokes per minute (spm), 54
- stuck pipe, 61
- subsea blowout preventers (BOPs), 77–78
- subsea wells, 99
- suction pit, 62
- surface casing, 110, 117
- surface pressure conditions, 86
- surge bottles, 88
- surging, 15
- swab, 158
- swabbed shows, 44
- swabbing, 15
- swivel, 140. *See also* kelly
- targets, 106
- tees, 106
- test packers, 157–158
- test sub, 155
- TIW valve, 70
- tool joints
 - annular blowout preventers (BOPs), 115
 - pipe rams, 118, 121
 - snubbing operations, 87, 96
 - stripping the joint, 87, 91–92, 100
- top kill (volumetric), 70–71
- total friction losses. *See* circulation pressure
- tour, 54
- traveling slips, 96
- trip gas, 31
- triplex pumps, 18
- trip margin, 16
- trips, 16
- trip shows, 44
- trip tanks, 17, 145
- true vertical depth (TVD), 7
- tubing, 71
 - shearing of, 118
- tubing head fittings, 71
- unconsolidated formation, 25
- underbalanced drilling (UBD), 9, 128
- underbalanced wells, 9
- underground blowout, 98
- upper kelly cock, 140
- U-tube, 54

- vacuum degassers, 138, 144
- variable bore rams (VBRs), 117
- vent lines, 78–79, 105, 124, 139, 144
- viscosity, 14
- volumetric correction, 92
- volumetric displacement correction for casing pressure, 92–93
- volumetric method, 16
- vugular formation, 98
- wait-and-weight method, 62–67. *See also*
 - engineer's method
 - disadvantages of, 66
- warning signs, 79
- wellbores, 2
- well-control problems, 42
- wellheads, 46, 112–113
- well pressure, 2
- wireline, 94
- workover service, 39–40

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