LESSON

A HOME STUDY COURSE ISSUED BY
PETROLEUM EXTENSION SERVICE
THE UNIVERSITY OF TEXAS AT AUSTIN

9

WELL SERVICING

CONTROL OF FORMATION PRESSURE

AESC

AND WORKOVER

PETEX

LESSONS IN WELL SERVICING AND WORKOVER

Lesson 1: Introduction to Oilwell Service and Workover

Lesson 2: Petroleum Geology and Reservoirs

Lesson 3: Well Logging Methods

Lesson 4: Well Completion Methods

Lesson 5: Artificial Lift Methods

Lesson 6: Production Rig Equipment

Lesson 7: Well Servicing and Repair

Lesson 8: Well Cleanout and Repair Methods

Lesson 9: Control of Formation Pressure

Lesson 10: Fishing Tools and Techniques

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CONTROL OF FORMATION PRESSURE

INTRODUCTION

Producing wells are valuable only if they permit the controlled flow of gas and oil from an underground reservoir. Any well that is connected to a formation where gas, oil, or salt water exists under pressure may blow out of control if the pressure is sufficient to raise the fluid in the well to the surface. An uncontrolled flow of gas, oil, or salt water from a well is called a "blowout." Blowouts can cause loss of life, property damage, waste of oil and gas, and damage to the producing formation.

Rig crewmen can be injured or killed by flying debris or by fire in a blowout. The rig may be a total loss, and wells may be damaged beyond salvage. Oil that escapes from a well is usually wasted and often causes serious pollution that is expensive to clean up; gas vented in a blowout is gone forever. In addition, heavy vapors can accumulate in shallow depressions or low ground around the well and cause an explosion and fire. Besides the dollar value of oil or gas that is wasted, the loss of formation pressure may considerably reduce the producing capability of an oil or gas pay zone.

Blowouts may occur before casing is set in a well, or they may take place while the well is being serviced or repaired, long after it was drilled. Wells on artificial lift sometimes blow out when being serviced because of crew error or equipment failure. Wells being repaired, recompleted, or deepened may blow out because of excessive formation pressure. Even though formation pressure may not be enough to raise a column of oil to the surface, gas may enter the well bore and escape to the surface if the fluid column is removed. As will be explained further, 1000 psi of formation pressure may be balanced by a fluid column only 2000 to 3000 feet in height, but gas will blow out if the fluid is removed.

Production rig personnel must be alert to the hazard of a blowout; they must recognize the preliminary indications and be ready and able to close in a well to stop an impending flow. They must realize that a flow of fluid from a well is positive evidence that a "kick" is about to happen. A bubble of gas will float up the hole and expand as it nears the surface; finally, it will blow a slug of fluid out of the well. Quiet will follow as another bubble forms, gathers momentum, and spews another slug of fluid from the hole. These intermittent eruptions are called "kicks." Kicks get stronger and stronger as fluid is emptied from a well. If a blowout is to be avoided, the well head must be closed completely, at least momentarily, to obtain pressure readings. Devices to shut off the well while it is being worked on are called blowout preventers.

Blowout preventers may be simple plug-shaped arrangements—the so-called boll weevil preventers—that seat in the casing head, or they may be elaborate assemblies of fluid-actuated devices that will enable the well to be closed in with or without pipe in the well. The usual provisions for blowout prevention on production rigs are manually operated ram preventers, with one set of rams to shut off around the pipe and another set to enable a complete shutoff when the pipe is out of the hole. High-pressure blowout preventers are usually hydraulically operated to insure faster closure and a more positive shutoff than with manual equipment.

Blowout preventers are for emergencies. They are useful only if they are in good condition and then only if they are manipulated by crewmen who understand their operation. A column of fluid, whether oil, water, or mud, is the ordinary means of containing formation pressure when working on a well. Blowout preventers, despite their name, do not keep a blowout from happening. The bottom-hole pressure developed below a column of fluid in a well must be greater than the pressure in the formation if fluid entry is to be avoided.

WELL PRESSURES

Pressure at the bottom of a column of fluid increases as the fluid's height becomes greater. This pressure is caused by the density or specific gravity of the fluid. The increase of pressure with depth is termed the pressure gradient of a given fluid. Mud that weighs 10 ppg (pounds per gallon) will develop a pressure gradient of 0.520 psi per foot of depth. Salt water, such as that usually found in Gulf Coast wells, will have a pressure gradient of 0.465 psi per foot. The pressure gradient for fresh water is 0.433 psi per foot. Medium gravity crude oil may have a gradient of 0.380 per foot if associated gas is not considered. Figure 1 shows that formation pressure of 1000 psi can be balanced by fluid columns of different heights varying from 1920 feet to 2630 feet, depending on the pressure gradient of the fluid. Each column will develop exactly 1000 psi at the bottom of the hole. Gas, of course, has only a negligible pressure gradient. If a gas well contains no liquid, surface pressure when the well is shut in will be considerable, though somewhat lower than formation pressure, because gas has a small pressure gradient.

The pressure developed at the bottom of a well—or at any intermediate point, for that matter—by a column of fluid at rest is called static pressure. Various types of fluids, as given in the previous example, may be employed to "load" a well and thus to control formation pressure. Fluid density may vary from 8.0 ppg to more than 20.0 ppg. Figure 2 shows the pressure gradients of various fluids in terms of psi per foot of depth. For any point in a well, static pressure—usually called hydrostatic pressure—may be determined by multiplying the depth in feet by the pressure gradient of the fluid. For example, a 10.0 ppg

PRESSURE GRADIENTS FOR FLUIDS OF VARIOUS WEIGHTS

Specific Gravity	*lb./cu. ft.*	*lb./gal.*	*Pressure Gradient psi/ft.*
1.00	62.4	8.34	0.433
1.02	63.6	8.5	0.442
1.08	67.4	9.0	0.468
1.14	71.0	9.5	0.494
1.20	74.8	10.0	0.520
1.26	78.6	10.5	0.546
1.32	82.2	11.0	0.572
1.38	86.0	11.5	0.598
1.44	89.8	12.0	0.624
1.50	93.4	12.5	0.650
1.54	95.7	12.8	0.666
1.56	97.2	13.0	0.676
1.62	101.0	13.5	0.702
1.68	104.7	14.0	0.728
1.74	108.4	14.5	0.754
1.80	112.2	15.0	0.780
1.86	115.9	15.5	0.806
1.92	119.7	16.0	0.832
1.98	123.3	16.5	0.858
2.04	127.1	17.0	0.884
2.10	130.9	17.5	0.910
2.16	134.6	18.0	0.935
2.22	138.3	18.5	0.961
2.31	144.0	19.25	1.000

Figure 2. Conversion Units for Various Mud Weights

fluid has a pressure gradient of 0.520 psi/foot and will exert the following pressures at the depths indicated:

Depth		*Fluid Pressure of Static Columns*
5,000 ft. x 0.520	=	2600 psi
10,000 ft. x 0.520	=	5200 psi
15,000 ft. x 0.520	=	7800 psi

Static pressures at the bottom of a well can be developed in different ways as illustrated in Figure 3. Column A represents a 10,000-foot well filled with mud, which has a pressure gradient of 0.520 psi per foot; the hydrostatic pressure at the bottom of the hole is 5200 psi. Column B, containing 15 ppg mud, will have 7800 psi at 10,000 feet.

INDICATIONS OF A BLOWOUT

Formation pressure open to the well that is greater than the hydrostatic pressure of the fluid column in the hole will give advance evidence of its presence to an observant crew. Sometimes this evidence is very obvious; for example, when rapid flow from the well occurs. At other times, it may be obscure and show up only as a very slow gain of fluid in the pit. These indications may occur after a mechanical operation has been performed; for example, when the casing has been perforated or after a plug has been drilled out, both of which can expose the well bore to a formation pressure greater than can be controlled by the fluid column. Sometimes, after a high-pressure zone has been opened to the hole, formation fluid is swabbed into the well bore by pulling pipe too fast, and the crew fails to note that the hole is not taking the right amount of fluid as pipe is removed. At other times, particularly with water in the hole, fluid is lost to open perforations and the level of the column falls, allowing formation pressure to follow the pipe out of the hole. The crew thinks the well is under control until a kick hits them.

Figure 6 shows that gas will enter the borehole or casing unless the preventers are closed when formation pressure greater than bottom-hole pressure of the drilling fluid is encountered.

Some of the preliminary events that may

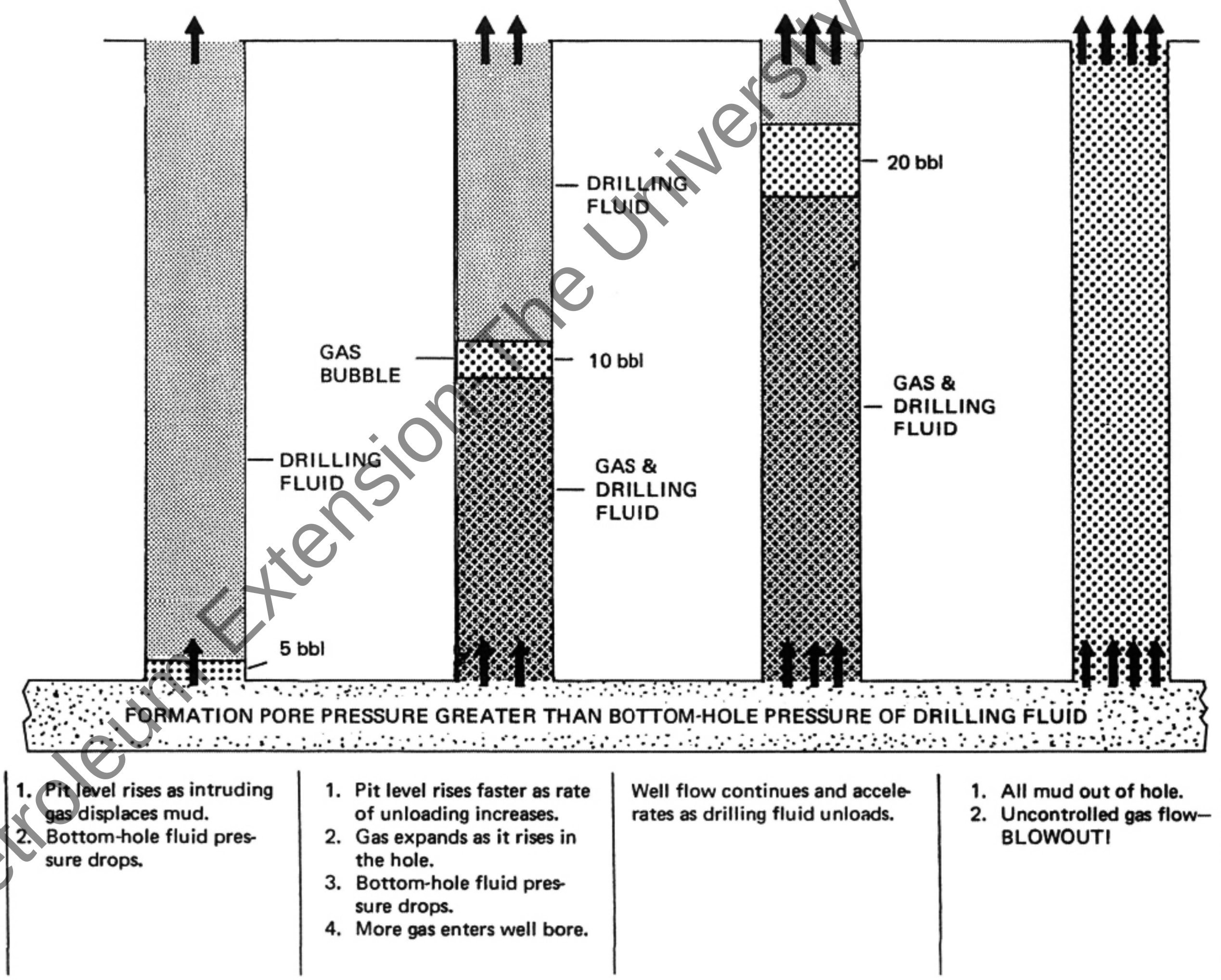

Figure 6. Gas enters the well bore unless the blowout preventers are closed.

BLOWOUT PREVENTER STACK ARRANGEMENTS

BLOWOUT PREVENTERS

The preferred arrangement of blowout preventer equipment properly becomes a function of risk exposure and the degree of protection desired. Where the risk is small, a simple, low-cost blowout preventer stack may suffice. Where the risk is greater, the stack likely will be more elaborate and more expensive.

Risk exposure involves two important factors, viz., pressure and environment. Formation pressures to be encountered may be high or low, known or unknown, normal, subnormal, or abnormal. The environment of the operation may be urban, rural, wasteland, or even isolated at sea on a platform or a barge with heavy concentration of men and equipment.

The API classification of blowout preventers is based on service pressure ratings. Fig. 1 through 11 (p. 4-6, incl.) illustrate alternate stack arrangements which, with normal environment, should prove adequate for API Classes 2M, 3M, 5M, 10M, and 15M. Arrangements other than those illustrated may be equally adequate. Each stack arrangement is identified by code.

The code adopted for the designation of stack arrangement, reading upward from the uppermost piece of permanent wellhead equipment, is as follows:

R = single-ram-type preventer with one set of rams, either blank or for pipe, as operator prefers.

Rd = double-ram type preventer with two sets of rams, positioned in accord with operator's choice.

A = annular-type blowout preventer.

S = drilling spool with side outlet connections for choke and kill lines.

G = rotary stripper head for gas/air or aerated drilling.

A blowout preventer stack, therefore, may be fully identified by a very simple designation, such as:

5M — 13⅝ — RSRA

This hookup would be rated 5,000 psi working pressure, would have a throughbore of 13⅝ in., arranged as in Fig. 6.

Since pipe rams and blank rams are readily interchangeable and since their relative position is optional, it is not considered necessary that the code be complicated further merely to show type of rams to be used in each of the ram-type preventers.

Two basic types of blowout preventers currently are available, viz: *1*, ram type and *2*, annular type. Ram-type preventers are available both in single units and in "double" units. Fig. 1 through 11 illustrate stack arrangements for the various service classifications.

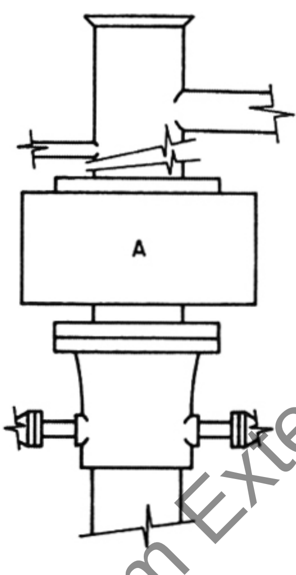

Fig. 1
ARRANGEMENT A

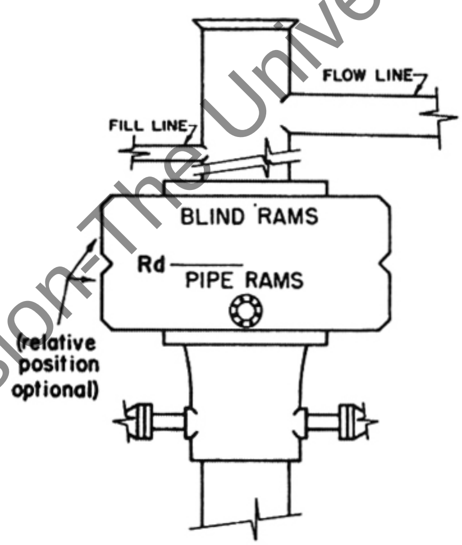

Fig. 2
ARRANGEMENT Rd
Separate Ram-Type Preventers
(Arrangement RR) Optional

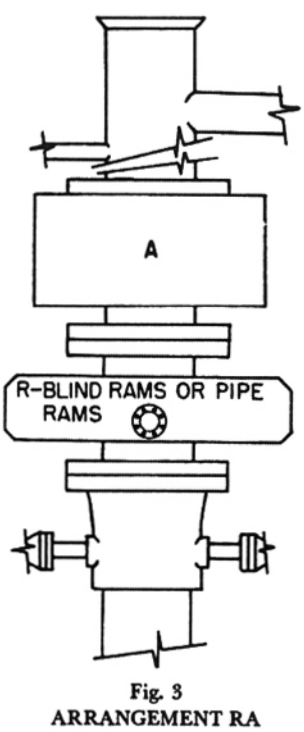

Fig. 3
ARRANGEMENT RA

Source: Bulletin D13: Installation and Use of Blowout-Preventer Stacks and Accessory Equipment, American Petroleum Institute.

Figure 30. API Blowout Preventer Stack Arrangements

To obtain additional training materials, contact:

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