Lessons learned from deepwater well kick study

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SEVERAL DEEPWATER KICKS were investigated over the past few years in water depths ranging from 2,000 ft to 6,100 ft. The wells were drilled by major operators in the Gulf of Mexico from semisubmersibles and dynamically-positioned drillships.

Each kick is described here in general detail and a "template" of lessons learned is provided. The information from each event was obtained through on-board interviews with the operator and contractor personnel and from study of pertinent well logs, reports, etc.

KICK #1: "BALLOONING"

This kick is called ballooning because the company drilling representative stated that ballooning masked the kick to the point that it was undetectable.

This kick occurred in a water depth of about 4,500 ft in a well with a total depth of about 20,000 ft. Mud weight was 13.0 ppg and the kick size was estimated to be about 80 bbl.

Well flow was (finally) noted on a connection and the well subsequently shut in. A cause for worry is that well flow occurred during the previous two connections. This can be clearly noted from the log of pvt/flow show.

Kick detection during connections had been relegated to the shaker man who had to make a judgment call as to whether a 1-2 in. stream—common on connections—was increasing or decreasing!

Upon inspection of the trip tank used to monitor connection flow-back it was noted to be very awkward to physically get into position to see the returning flow.

On previous jobs the rig had been successful in allowing flow-back during connections due to ballooning so that flow, up to this point, was not too alarming.

It was also useful to note that the drilling program had specifically indicated that a mud weight of 13.8 ppg was required at this depth.

Severe mud loss occurred during well killing operations and the well eventually "packed off" and the drillstring stuck. Loss of well and abandonment of potential targets made this a financially costly event.

KICK #2: "1-BBL PIT GAIN"

The rig reported that this kick was detected and the well shut in with a 1-bbl pit gain. Thus the kick name.

Note that the reported shut-in drill pipe and shut-in casing pressures were 220 psi and 300 psi respectively. The kick was detected because a change in the measurement-while-drilling (MWD) resistivity log piqued the company man's interest and a prolonged flow check was called on during a "simulated" connection (1 joint down on the stand). This flow check proved positive and hence the very small influx volume.

Details of this kick include a water depth of 6,100 ft and total well depth of 16,700 ft (TVD/TMD). Mud weight was 12.5 ppg (SOBM) and choke line friction pressure was 300 psi at 20 strokes per minute.

The effect of the reduced temperature of the mud in the choke and kill line in deepwater was investigated on this rig with interesting results.

The cold mud caused a 700-psi "spike" that endured for some time prior to slowly declining to a choke line friction pressure measurement of 220 psi at 10 spm. Of special concern is the effect this would have on pump start-up operations.

Of course, most well control events in deepwater report much mud loss during start-up.

"NO-FLOW KICK"

This kick exhibited behavior that defies logic! Several flow-checks all proved negative but while circulating between the checks the well would flow like "gangbusters!" This strange behavior was never understood satisfactorily.

Lessons learned from deepwater well kicks

Well control preparation

1. Designate a pore pressure detection team, have them on location during critical well intervals.
2. Consider potential impact of high ECDs associated with synthetic oil base mud and the importance of catching the kick on connections to prevent riser entry.
3. Consider the significance of mud compressibility.
4. Measure choke line friction pressure by pumping down choke (or kill) line and up riser.
5. Plan for jug testing in lieu of testing to leak-off; with SOBM it makes the fractures downhole less prone to open.
6. Clear drillstring of weighted hole cleaning sweeps prior to drilling ahead.

Kick detection

1. Flow check all connections, implement simulated connections.
2. Time ballooning/compressibility flow returns to establish connection "signatures."
3. Monitor MWD/LWD changes, flow check pore pressure indications.
4. U-tube effects of weighted pills will not cause flow increase during normal drilling.

Well kill procedures

1. Use the Driller's Method to begin circulating immediately.
2. Avoid working pipe to prevent stuck pipe with the well shut in.
3. Sweep kill and choke lines prior to pump startup (circulate sufficient for "bottoms up" from stack to determine if influx may have entered riser, measure gas units or chlorides check).
4. Take returns up both choke and kill lines to reduce impact of choke line friction.
5. Use kill line monitor or wellhead monitor to account for choke line friction pressure.

Kick behavior

1. Much loss of OBM on pump startup.
2. Kick behavior can defy logic; stay focused on well control and circulation/pressure control.

Equipment notes

1. Wellhead pressure and temperature sensors were in use and should be installed and used on all deepwater rigs.
2. Working pipe through annular causes rapid wear in the cold temperature environment common in deep water.
3. Caution is advised when planning to flush stack gas with light weight fluids; avoid topside differential pressures across BOPs.

This kick occurred in a water depth of about 2,000 ft in a well with a total depth of 19,100 ft. Mud weight was 15.0 ppg (SOBM); shut-in casing pressure was 420 psi (initially!?).

While drilling ahead at approximately 19,100 ft, the driller noted a substantial increase in the flow returns (normal 45%, instantaneous increase to 53%). Reacting correctly, he shut down and checked for flow. The flow check was positive and the well was shut in with 420 psi on the casing gage. (During the next 24 hr there was never a reported attempt at measuring the shut-in drillpipe pressure.)

Estimated pit gain at this point was 15 bbl. Complicating matters was the fact that the drillstring had just been slugged with 150 bbl of 16.5 ppg hole cleaning sweep and the calculated U-tube resulted in 410 psi!

Of course the hole was packing off and actions were ordered to prevent stuck pipe. The well was opened up and a stand of pipe was pulled. This resulted in an additional 35 bbl of well flow.

The original event began at 4:00 pm and for the next 9 hours the well was circulated (with the pits gaining constantly), was flow-checked (with no flow indicated!) and the pipe was rotated, reciprocated, and stands pulled in an attempt to keep it free.

Finally, there was no doubt that the well was flowing and it was shut in with 1,910 psi on the casing gauge. Estimated total pit gain at this point was 800 bbl. This event took several days out of normal operations and the prolonged working of pipe through the annular caused severe wear to the point that the annular would not fully open.

KICK #4: "ORDINARY"

There was nothing out of the ordinary reported with this kick. It is discussed here because of the many similarities with the other well kicks investigated.

Details surrounding this kick include a water depth of about 3,900 ft and a well total depth of approximately 22,400 ft (TVD/TMD). Mud weight was 15.0 ppg (SOBM); kill mud weight was 15.3 ppg.

The arrangement of shakers and possum belly volumes was such that normally some 80 bbl of mud volume flowed back into the active pit system during connections. The time for the flow-back volume to occur is what made this kick difficult to detect rapidly.

The estimated initial kick volume was 12 bbl but subsequent mishandling and misinterpretation resulted in about 150 bbl of influx! In 4 of the 5 kicks reported on here, the MWD had quit working just prior to the kick. It failed here as well and, as in the other instances, the decision was made to drill ahead without it. Also, the hole was packing off in each case, resulting in pipe becoming stuck.

PORE PRESSURE = FRAC GRAD

Deepwater drilling offers many challenges. One difficult challenge is how to successfully drill wells having such a small margin between pore pressure gradient and fracture gradient.

Hopefully, the research being done on riser-less drilling and other techniques will make drilling in extreme water depths more routine.

This kick took place in a water depth of about 4,200 ft in a well with a total depth of about 20,000 ft MD/19,400 ft TVD. Mud weight was 14.1 ppg (SOBM) and the pit gain was 20 bbl. Casing had just been set at 19,200 ft TVD and a LOT of 15.2 ppg was obtained (194 units of gas was reported from the LOT bottoms-up).

Ballooning and hole pack off problems began immediately after drilling out with gas units increasing to 250 units.

The resulting low differential of equivalent mud weight with the well shut in—and fracture opening pressure and minimum horizontal stress (fracture closing pressure)—caused 135 bbl of mud loss while attempting to bring the pump online for the well kill!

Working the drillstring to prevent stuck pipe (hole packing-off) also contributed to the mud losses while circulating the influx from the well. Essentially, drillpipe pressure control was impossible and the well—and un-logged targets—were abandoned.

OF SPECIAL NOTE

In each of these incidents, the driller and drill crew detected the kicks and promptly shut the well in with minimum kick volumes (less than 20 bbl in all but one case).

However, ballooning, stuck pipe conditions and mud compressibility issues influenced personnel to open the well and distract attention from the real problem at hand—well control.

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