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Exhibit No. ______
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From: Lockett, Tim
Sent: Tue Jun 29 11:32:28 2010
To: Hill, Trevor
Cc: MC252_Email_Retention
Subject: Top kill simulation cases
Importance: Normal
Attachments: Post event simulation of the Top Kill procedure.doc

Trevor
I have now looked at TopKill #1 and 2 using the same resistances and well PI as are needed to get a first pass 'reasonable' match to TopKill#3.
The results are not bad. TopKill#1 shows some interesting features, and the suggestion that the flow resistance increased during the top kill procedure. TopKill#2 only seemed to use a low mud rate and had an odd pressure build over the procedure.
Attached is my previous write-up extended with these latest results. Could we maybe get some time later to talk through the value in taking these further with this premise. I would also value some discussion on:
- the timing of when the test rams were opened before TopKill#1 and when they were closed at the end of TopKill#'3
- the 966 psi fixed offset over and above the column labelled "Lower BOP" in the xls databooks,
- and confimation of the junk shot application in TopKill#3 as there is a time when the pressure rises when the mud rate is constant and this is not represented by OLGA.
<<...>>
From the discussion with Henry it seems that up until yesterday his model was not yet working, at least with his fluid files. I believe his premise is different (since his model includes the annuli in detail) so there should not be duplication between our work. It would therefore be beneficial to see if his model can show similar or better levels of agreement with the data.
Best regards

Tim

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Calibration of the well model with a dual flow path

Data

Top Kill transient data referenced in this section are from the following sources:

- Top Kill #3: "052810 SS BP Kill Job Blue Dolphin TJH.xls"
- Top Kill #2: "052710 SS BP Kill Job Blue Dolphin.xls"
- Top Kill #1: "052610 BJ Data.xls"

Premise

The premise on which this section of work is based is that there is flow up the drill string and also up the casing and through the BOP rams.

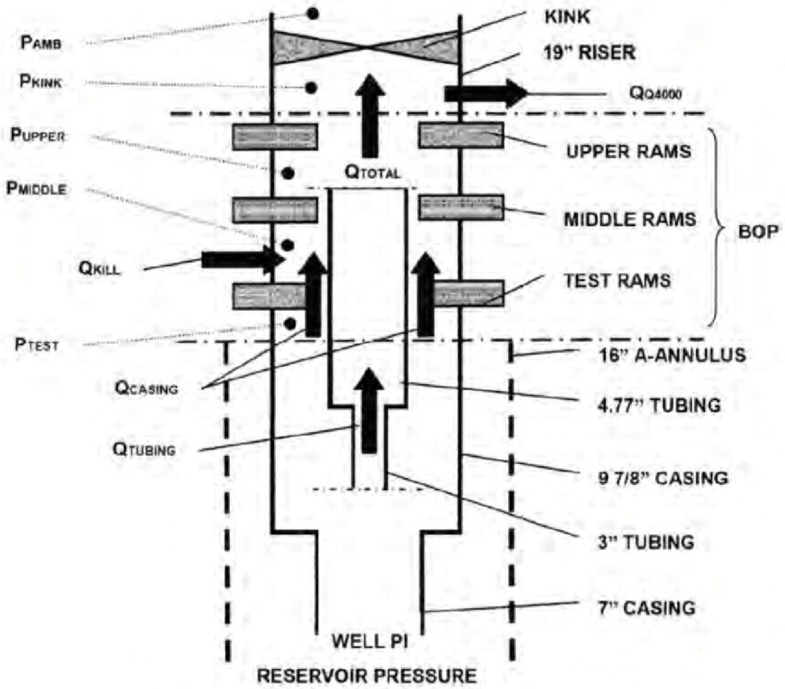

Figure 1: Subsurface and BOP premise for top kill simulation

Model

The model is summarised as having flow up the liner and casing as far as the base of the drill-pipe, and then two parallel flow paths:

- Up the drillpipe to the topmost section of the BOP stack, then through the last rams and out to the riser, kink and sea ambient pressure

- Up the remaining height of the casing, through the test rams, middle rams (which represent more than one set), ,then out to the riser, kink and sea ambient pressure

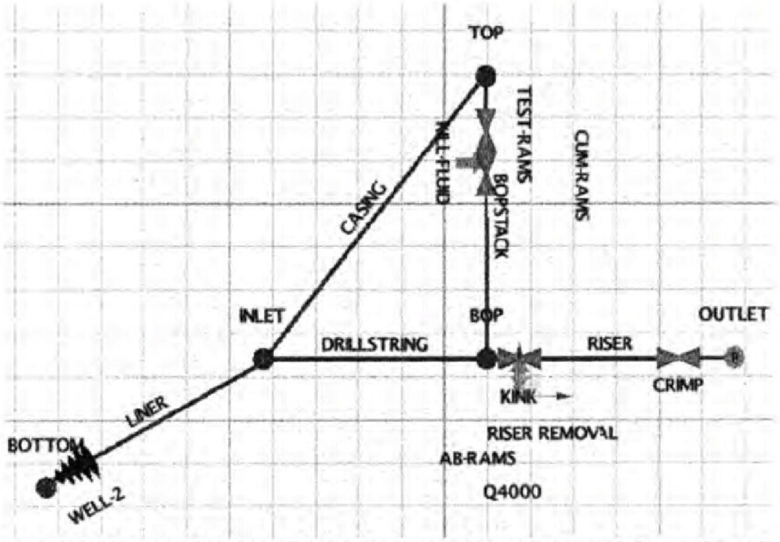

Figure 2: OLGA model of the well including flow up the drill pipe and also up the casing

Drilling Fluid

Drilling fluid was represented as having a density of 16.4 ppg (1972 kg/m^3) and being a Bingham fluid with yield stress of 15 lb/100ft^2 (7 Pa) and a plastic viscosity of 30 cPoise. Due to lack of data, no variation with temperature or pressure was included. With this non-Newtonian description, the effective viscosity of the mud as a function of shear rate is shown below.

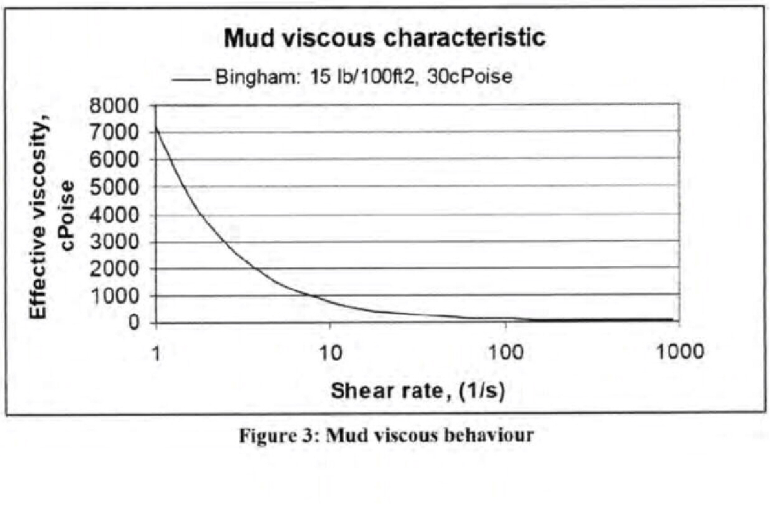

Figure 3: Mud viscous behaviour

Calibration against current operating state

The model was initially calibrated by allowing the pressures at the following locations to be matched:

- Pressure below the test rams: 4400 psia
- Pressure below the middle rams: 3760 psia
- Pressure below the upper rams: 2550 psia

In order to match these pressures, the open area of the test rams, middle rams and upper rams was adjusted to represent a leak path through the rams. In the case of the test rams and middle rams, this leak path is external to the drill-pipe.

The parameter of the case is the well PI. Values of 4, 5 and 6 sbbl/d/psi were tested and found to be insufficient to achieve the pressure of 4400 psia at the test rams.

A well PI of 10 sbbl/d/psi was tested and was found to be sufficient to achieve this pressure, and generated an excess flow through the BOP rams of 18000 bbl/d in addition to a flow of 25800 sbbl/d through the drill pipe (Total 43900 sbbl/d). The open area of the rams for this case were as follows:

A/B rams	5.8	sq in
C M U rams	1.1	sq in
Test rams	1.3	sq in

Higher well PI values would generate larger flows while meeting this pressure, well PIs between 7 and 10 would generate lower flows and may still be able to meet this pressure.

Difference from the state prior to the top kill procedure

Two differences exist in the state of the well at the time of the top kill procedure:

- The test rams were opened to allow the top kill attempt to proceed. This change was included in the model
- At the time that the top kill was attempted, the old riser, including the kink, was in place. This aspect has not been included in the model for all cases. If this resistance is included then the top kill case will generate higher pressures in the BOP stack and it is more likely that the case would result in killing the well.

Top Kill Simulation

The top kill simulation was tested for the highest rate of mud, 78 bbl/min (this was incorrectly modelled as 366 kg/s which corresponds to a mud rate of 70 bbl/min) with the expectation of generating a pressure in the region of 6000 psia at the BOP stack.

Case 1: PI = 10 sbbl/d//psi

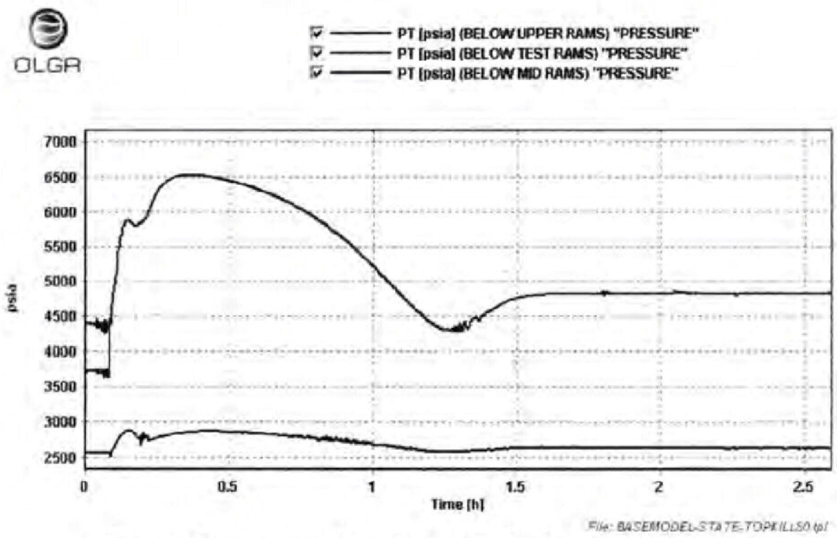

Figure 4: Pressure trace during the top kill simulation, PI = 10 sbbl/d/psi

The initial pressures in the BOP stack prior to starting the top kill can be seen on the far left hand side - the top kill starts after 300 s of simulation. The peak pressure during the top kill is understood to be approximately 6000 psia. This case therefore exceeds the measured pressure, suggesting that the resistance of the rams has been over-estimated and in fact the rams allow a greater flowrate to pass. Had the kink resistance also been included the pressure would have been still higher (approx another 200 psi).

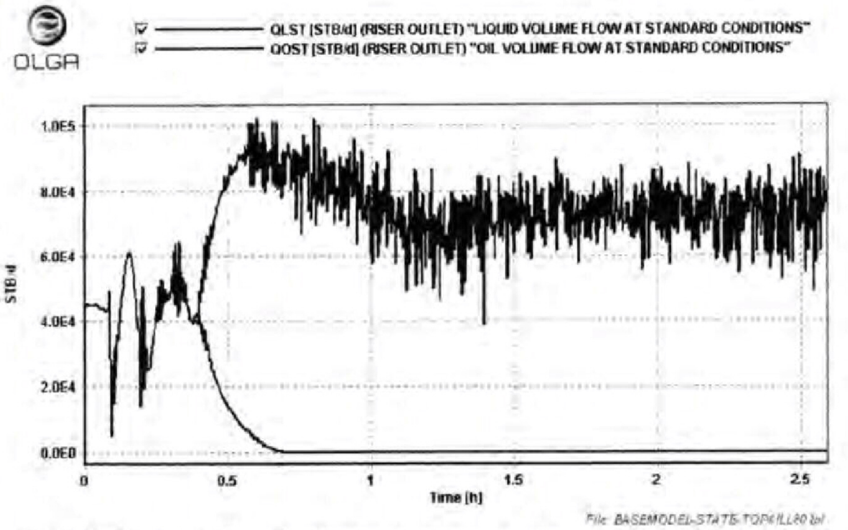

Figure 5: Flowrate trace exiting through the riser during the top kill (total liquid and oil, the difference being mud), PI = 10 sbbl/d/psi

In this case the top kill is successful, the oil rate falls to zero allowing a mud column to be built. This behaviour deviates from actual events.

The additional conclusion for this case is that if the kink resistance had been included then the well would have also been killed (killed more easily) and hence there is no requirement to re-run this case including the kink resistance.

Case 2: PI = 20 sbbl/d/psi

The calibration of the rams given the pressures for current operation was completed for a well PI of 20 sbbl/d/psi. With this calibration, the flowrates were found to be:

- 25200 sbbl/d up the drill pipe
- 51800 sbbl/d up the casing and up through the rams
- Total: 77100 sbbl/d

The open area of the rams for this case were as follows:

A/B rams	10.9	sq in
C M U rams	3.25	sq in
Test rams	3.6	sq in

For this case, the kink resistance was then calibrated, before the top kill case was undertaken. In order to do this calibration, it was assumed that the resistances derived from the current operating state (test, middle and upper rams) would have applied with the same effective open areas. This uses the assumption that the top kill operation did not itself materially effect the integrity of the rams (eg through erosion).

This assumption is weak and if incorrect would imply that more flow is coming from the well after the top kill than would have been the case before the top kill.

The kink and riser was therefore added and the open area was calibrated to give:

- Pressure of 2700 psia upstream of the kink.
- The leaks on the kink itself were not modelled. This has no impact on the results since the pressure measured upstream of the kink does not influence the split of flow between the leaks at the kink compared with the flow along the old riser.

The open area of the kink for this case was 8.16 sq in. Because the leaks at the kink were not separately modelled, this area would include both the 'kink' area (for flow along the riser, assuming there is no other restriction) and the area of the 3 or 4 leaks at the kink combined.

As a consequence of including the kink restriction, the pressures in the BOP stack were increased to the following values:

- Below the test rams: 4562 psia
- Below the middle set of rams (C/M/U rams): 3890 psia
- Below the upper set of rams (A/B rams): 2928 psia

This increased backpressure reduced the flowrate from the well to the following values:

- 24000 sbbl/d up the drill pipe
- 50400 sbbl/d up the casing and up through the rams
- Total: 74400 sbbl/d

Comparing the flowrates with and without the kink restriction, the flowrate increase due to removing the kink is around 3.5%.

With the model calibrated in this way, the top kill was simulated at the highest flowrate (80 gpm) with the test rams opened.

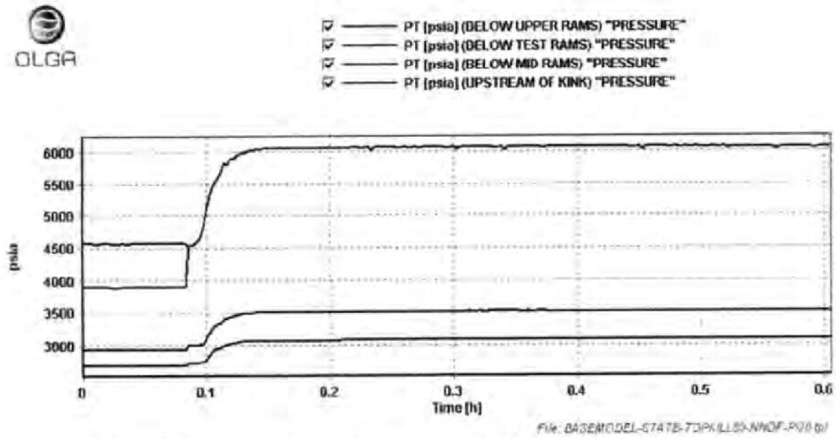

Figure 6: Pressure trace during the top kill simulation, PI = 20 sbbl/d/psi

The initial pressures in the BOP stack prior to starting the top kill can be seen on the far left hand side - the top kill starts after 300 s of simulation. The pressure rises to 6000 psia and does not change with time indicating that a mud column is not being built in the well.

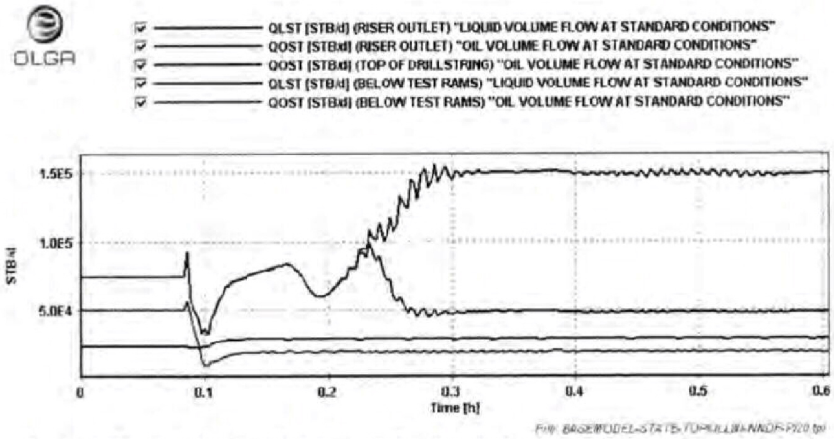

Figure 7: Flowrate trace exiting through the riser during the top kill (total liquid and oil, the difference being mud), PI = 20 sbbl/d/psi

Conclusions at this time (from PI = 10 and 20 cases)

The following conclusions are therefore indicated based on the following two key assumptions:

- the model with two paths for flow is a valid representation of what is happening in the well

- and that the resistances derived from the current operation can be retrospectively applied to the conditions before the top kill event (which might not be true if the top kill mud caused additional erosion of the rams).

On this basis it is concluded that it is highly likely that the actual operation lies between these the two cases modelled here, and so it can be inferred that the PI of the well is probably in the range 10 - 20 sbbl/d/psi. The implication is that the flowrate from the well is now probably in the range 44000 - 77000 sbbl/d, of that approximately 25000 bbl/d would be expected to come through the drill pipe and the remainder through the casings/rams in the BOP stack.

Options for further study:

- Intermediate well PI values
- Model top kill rates lower than 80 bbl/min (for additional checks vs pressure)

PI = 12.5 and 15

Cases were repeated with PI values of 12.5 and 15. In both cases the well was not killed (albeit with the slightly lower mud rate of 70 bpm in place of the intended 79 bpm used). Of the 4 cases run, the results from the PI=15 case looked to be a close match to the actual pressure data. Further work will therefore be run using the PI=15 well description.

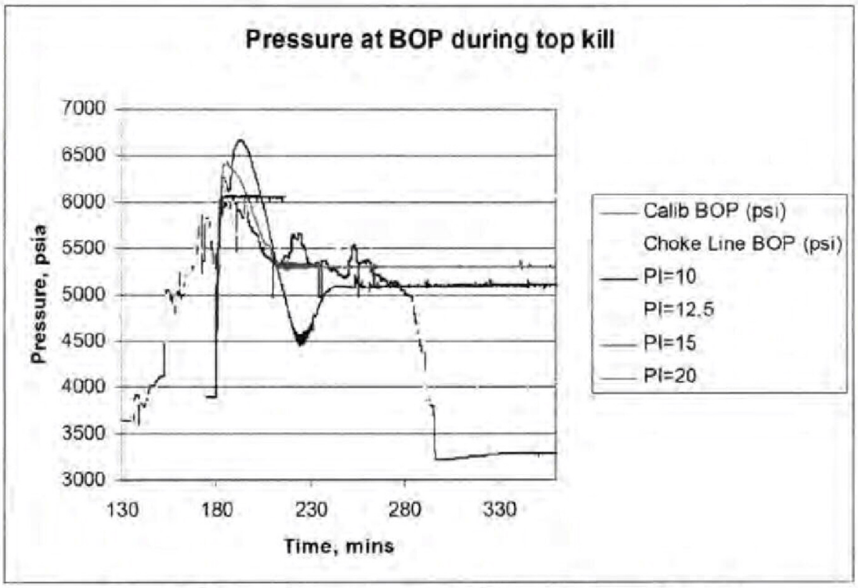

Figure 8: Pressure response during top kill, across the range of well PIs

PI = 15

For this case, the procedure above was repeated but with the following changes:

- Mud rate to mimic the actual delivery (ignoring the delay inherent in the volume delivery at sea surface compared with sea bed)
- Kink opening adjusted to set a pressure of 2700 psia at the same time that the middle set of rams is adjusted to set a pressure of 3670 psia.
- Upper rams set to be 100% open because the pressure basis on which to set these rams has now been lost by including the kink at this time.

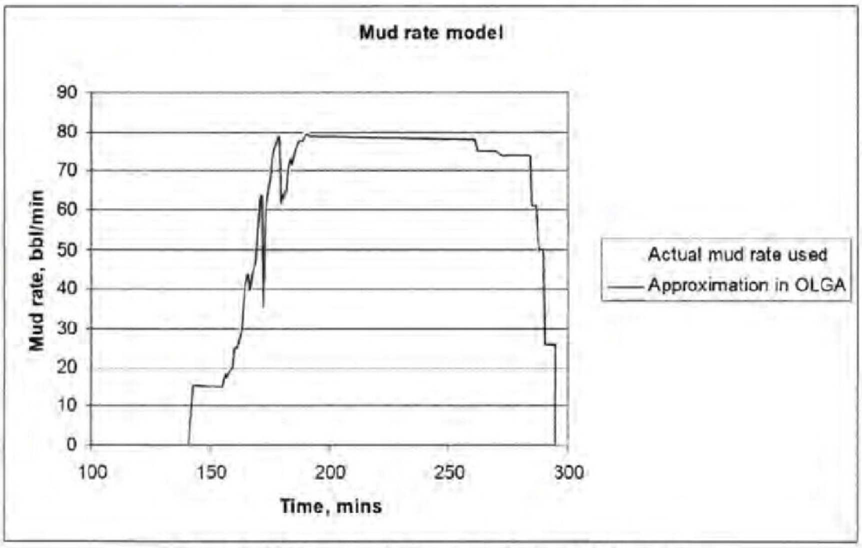

Figure 9: Mud rate modelling (input to the OLGA model)

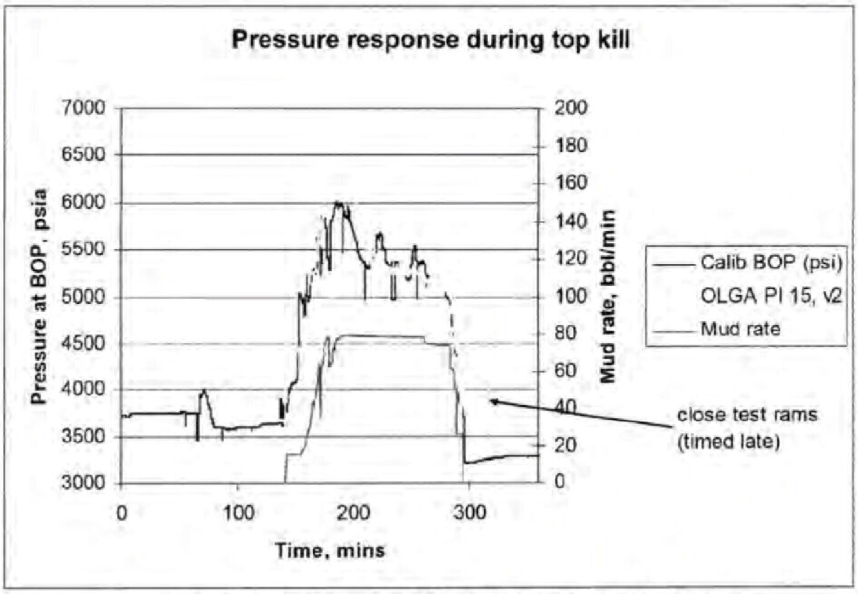

Figure 10: Pressure at the BOP (OLGA result) with PI = 15 sbbl/d/psi

This case shows a good deal of promise in matching the actual results, with the following areas of possible deficiency:

- The holes in the kink were not modelled. This may well impact the peak pressure of 6400 psia vs the actual peak of 6000 psia. This can be included in the model.
- The test rams were not closed when the mud supply was turned off. This impacts the pressure at time = 310 mins onwards. This aspect was considered by restarting the simulation. The simulation is then symmetric in that the pressure at the end is essentially the same as the pressure at the start, which differs from the actual result where a 315 psi decline is seen across the top kill operation (start to finish).
- The decision to model the upper rams as being fully open in this case should be revisited. Current operation (with the kink removed) suggests a differential pressure of 300 psi exists across these rams. Other options for modelling this condition are:
    - Retain the open area from a case which models the current condition (without the kink) and apply it to this case.
    - Retain a 300 psi differential even with the kink in place, such that the pressure below the upper rams is 3000 psia.

Kink resistance removed:

The pressure below the upper rams was set to be 2560 psia before starting the top kill. In doing this, the upper rams were set to represent the flow resistance of the rams and kink combined.

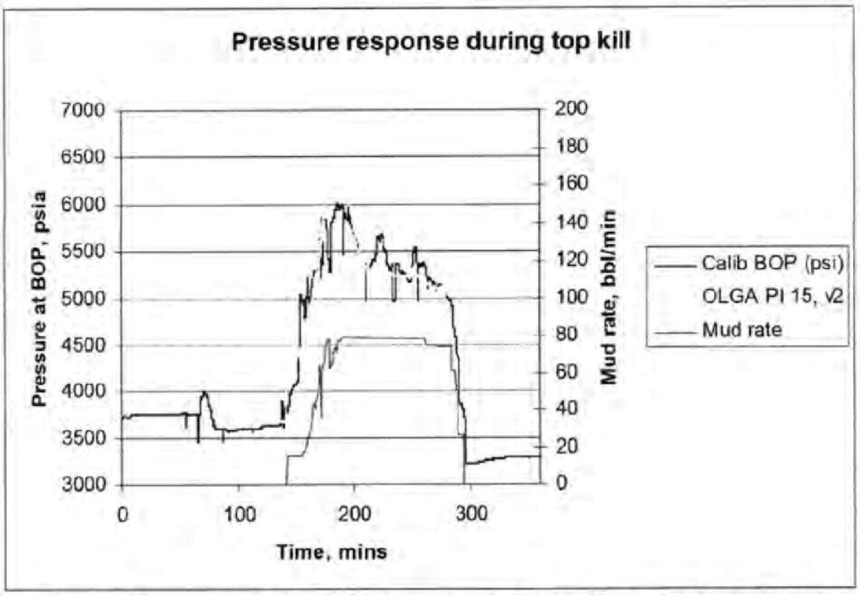

Figure 11: Pressure at the BOP (OLGA result) with PI = 15 sbbl/d/psi and with the kink resistance removed (encompassed within the setting of the resistance for the upper rams)

The early pressure rise in this case (time = 146 - 157 mins) exceeded the actual result. It was deduced that this is associated with the test rams being opened in the model to allow the top kill to proceed. In practice, the test rams were already open at this time. The model was therefore re-based such that the pressure below the middle rams (3670 psia) and upper rams (2550 psia) was set with the test rams open, with the following result:

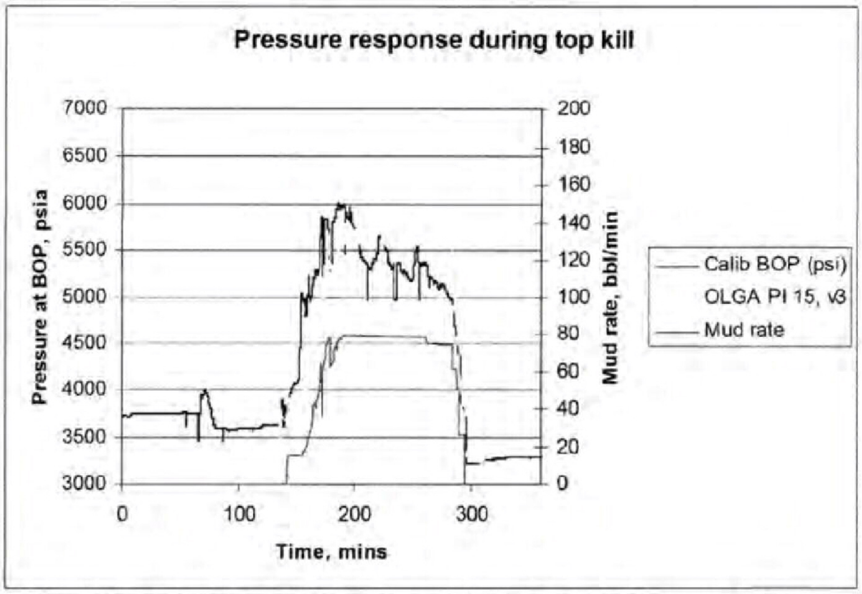

Figure 12: Top kill#3 with Test Rams Open while setting the initial pressure of 3670 psia

This case shows a better match to the early pressure increase than the previous case, and possibly also the peak pressure, at the expense of a worse match for the pressure through the later stages. The relatively flat pressure response late in the top kill event corresponds to little/no mud column. In order to gain a better match this case was re-run with a lower well productivity index of 12 sbbl/d/psi.

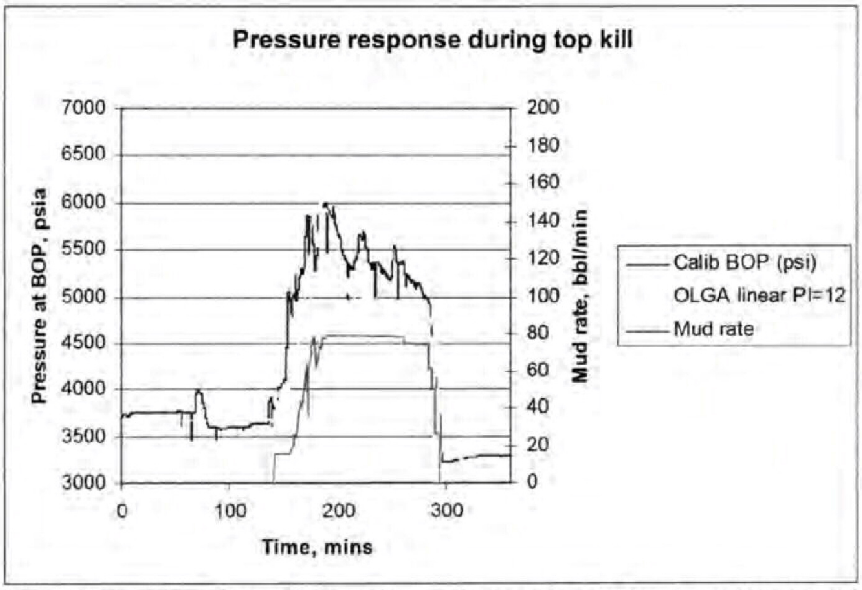

Figure 13: Simulation of Top Kill #3, resistances calibrated to give 3670 psia and 2550 psia with the test rams open, well PI = 12 sbbl/d/psi

In this case the initial pressure rise (to ~4100 psia) is well captured.

The junk shot was applied during the early stages of Top Kill #3 and this may in part explain the significant rise in pressure at a time of 152 minutes whereas the OLGA result has a pressure increase as the mud rate is ramped up starting at a time of 158 minutes.

The peak pressure is well captured (6000 psia), and the subsequent decline in peak pressure corresponds in the OLGA model to building a mud column in the casing.

The two 'humps' in the pressure decline are not reproduced by this OLGA model but in the context of building a mud column in the casing such a pressure response might correspond to shedding part of the column before it is complete down the casing, and then rebuilding it. In this context it is important to recognise that the OLGA model includes a *linear* well productivity to describe the inflow.

The case ends at a lower pressure than it started because the test rams are closed (in the model) when the mud flow is turned off. The timing of the closure of the test rams in practice is not known (at this time).

The mud column formed in this case is shown below:

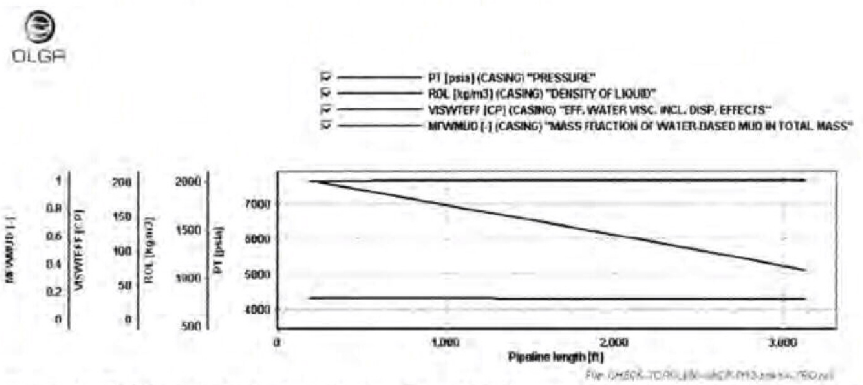

Figure 14: Fluid properties in the casing at time = 236 minutes, showing a complete mud column in the casing

In contrast the mud column in the drillstring is incomplete, with mud occupying around 60% of the volume. Hydrocarbons continue to be produced, which also corresponds with observations at the time.

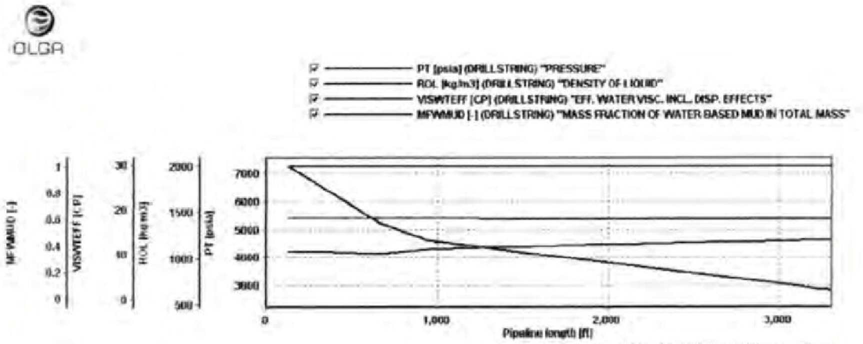

Figure 15: Fluid properties in the drill string at time = 236 minutes, showing a partial (60%) mud column in the drill string

For completeness, the case was re-run with a well PI of 10 sbbl/d/psi, with the following result:

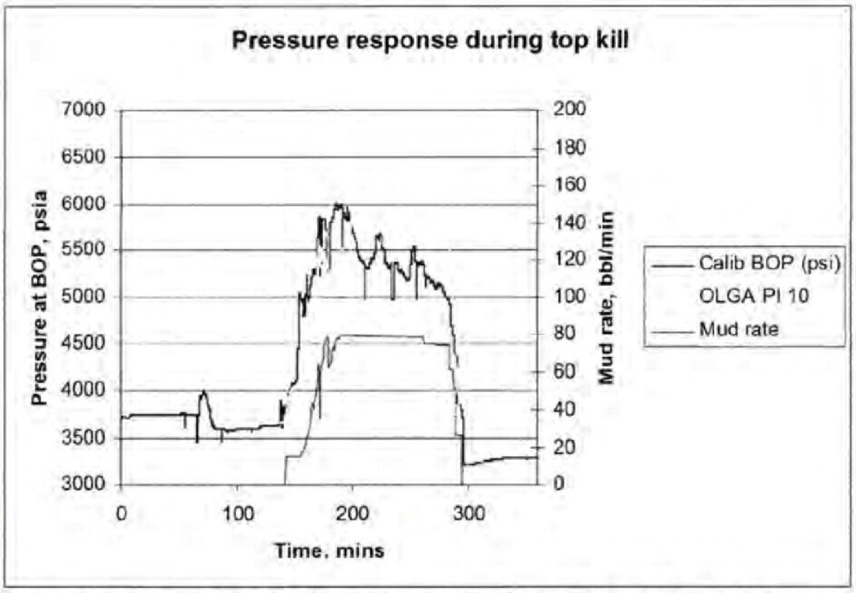

Figure 16: Simulation of Top Kill #3, resistances calibrated to give 3670 psia and 2550 psia with the test rams open, well PI = 10 sbbl/d/psi

As previously identified, this case succeeds in killing the well. The failure of the OLGA result to capture the timing of the second pressure peak at time = 190 minutes reflects the mud column that is built in the casing during the first peak (time = 180 minutes).

Conclusions for Top Kill #3

This analysis concludes that:

- The starting condition for the top kill has been set such that
    - The test rams are open
    - The pressure in the BOP stack is 3670 psia
    - The pressure in the upper portion of the BOP stack (below the upper rams) is 2550 psia, and this includes the flow resistance of the kink
- A reasonable representation has been developed for top kill #3 using a well PI is ~12 sbbl/d/psi, whereby:
    - The peak pressures are reasonably well represented,
    - The well is not killed at the mud rates which were used,
    - The pressure response declines as a result of building a mud column in the casing (behind the drill string)
    - Hydrocarbons continue to flow up through the drill string throughout the procedure (as observed)
- Certain features of the pressure response (humps) are not represented by the model. These features could be explained by a lack of stability in the mud column (shedding and subsequent rebuilding).
- The model suggests that with a well PI of 10 the well would have been expected to be killed. Equally, with a well PI of 15 the pressure response

would have been expected to be constant at constant mud rate, indicating that no mud column was built in the casing.

Overall the model is considered to be robust enough to apply it to the other top kill datasets.

Other Top Kill data sets

Three top kill attempts were made over the time 26, 27, 28 May 2010. The intent is to define a model using Top Kill #3 (above) and then test it unchanged on TopKill#1 and #2. The well PI should remain constant. The resistances in the BOP rams will be treated as being constant but may well in practice have eroded. To gain a good match with this model it is therefore anticipated that the resistances applied in TopKill#3 would be less (larger leak path) than would be needed to get a good match in TopKill#1.

Top kill #2

The data used in this comparison is "BOP, psi", which is formed from the data recorded in column "Lower BOP" with an additional 966 psi added. This offset is carried forward from the TopKill#3 spreadsheet.

The mud rate is taken from a column headed "Mech rate, bpm".

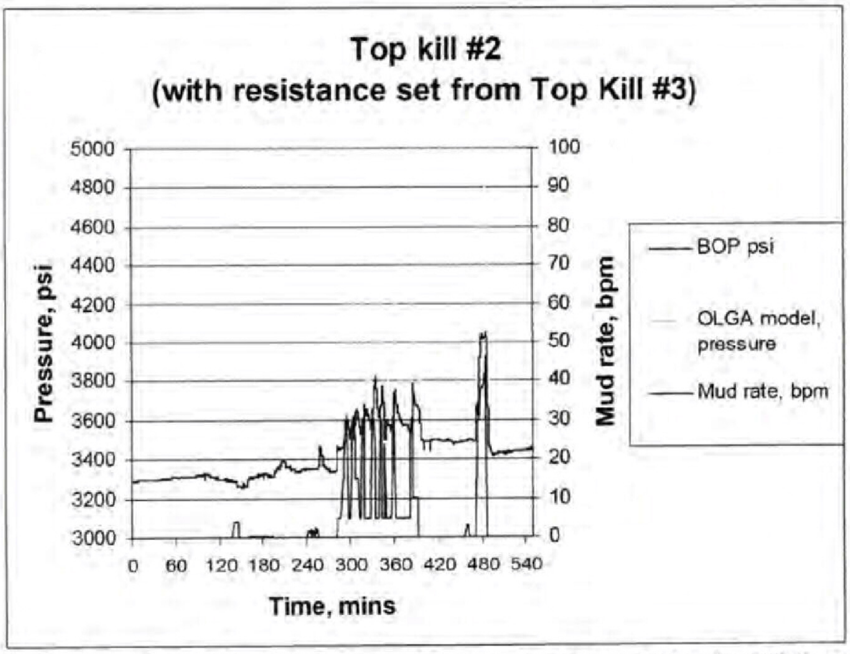

Figure 17: Simulation of Top Kill #2 using model with resistances defined from Top Kill #3 and a well PI = 12 sbbl/d/psi

Figure 17 shows the following:

- the initial pressure in the OLGA model (3670 psia) is significantly higher than the pressure which was recorded.
- The peaks in pressure in the OLGA model are significantly graeter in amplitude in the OLGA model than was recorded.
- The mud rate in this top kill attempt was quite low and the OLGA model does not indicate the formation of a mud column.

Across the top kill procedure, OLGA returns to the same pressure that it started with. The data shows a gain in pressure of ~300 psi. This behaviour might be consistent with gradual flushing out of a mud column formed during top kill #1.

Top kill #1

The data used in this comparison is "BOP, psi", which is formed from the data recorded in column "Lower BOP" with an additional 966 psi added. This offset is carried forward from the TopKill#3 spreadsheet. For comparison, data headed "Kill line BOP" is also plotted.

The mud rate is taken from a column headed "Combined rate".

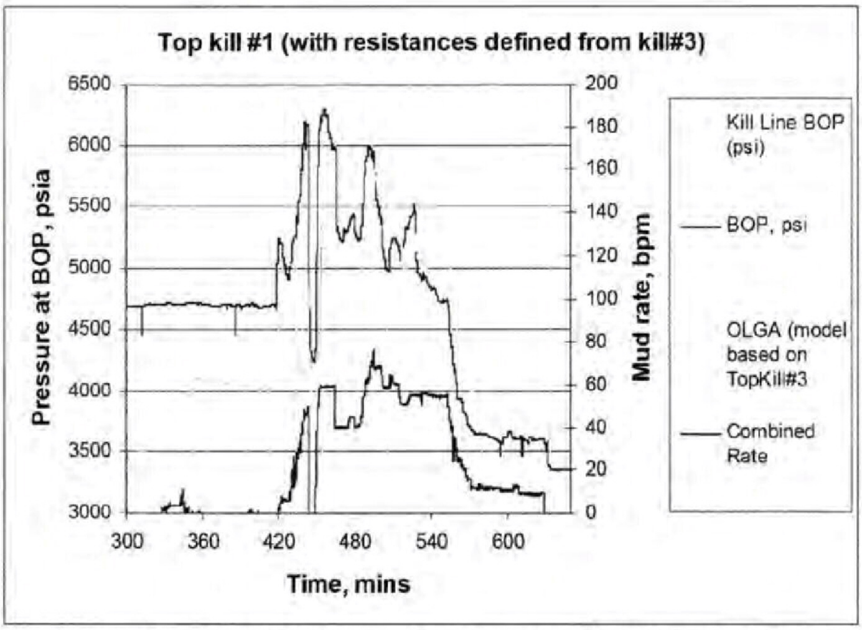

Figure 18: Simulation of Top Kill #1 using model with resistances defined from Top Kill #3 and a well PI = 12 sbbl/d/psi

Figure 18 shows the following features:

- The OLGA model pressure starts at a pressure (3670 psia) which is significantly lower than the "BOP" pressure but is more consistent with the pressure in the kill line during the short period of mud injection which preceded the main top kill attempt (time = 300 - 350). The pressure recorded as "Lower BOP" is 966 psi lower than the "BOP" pressure.

- From a time of 420 minutes onwards, the "BOP" pressure and the kill line pressure are in good agreement with each other. The reliability of "BOP" pressure before a time of 420 minutes is therefore uncertain. A possible explanation is that this higher reading would be consistent with the test rams being closed at this time, and if modelled as such, the OLGA model would reproduce this.
- During the initial stages of the top kill, the first two peaks in pressure are significantly under-predicted by the OLGA model. This suggests that the flow resistance was greater during this time.
- The third peak is better represented by the OLGA model.
- Across the three peaks, the OLGA model is largely mimicking the mud rate, in that the first and second peaks in pressure have lower mud rates than the third peak. It is therefore surprising that the third pressure peak is lower than the first and second, and suggests that a resistance that was present during the first two peaks was removed prior to the third peak.

The OLGA model for this case does not form a mud column in the casing although a small amount of mud (7% volume) does collect towards the top of the casing when flowing at the peak rate (third peak, 77 bpm).

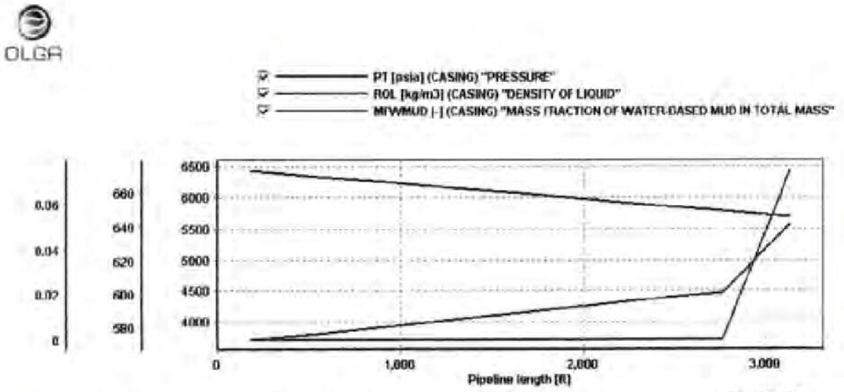

Figure 19: Fluid properties in the drill string at time = 493 minutes, showing a small (7%) mud collection towards the top of the casing

Having failed to form a mud column, the pressure in the OLGA model remains relatively stable with time while flowing at a constant mud rate of 60 bpm (time = 530 - 553 mins). In contrast the actual result over this time period shows a declining pressure at constant mud rate which would be consistent with a mud column being formed.

Further work with this case:

- Ascertain the additional resistance that would be required to bring the first and second peaks to the pressure levels that were recorded.

- Ascertain the additional resistance that would be required to bring the third peak closer to 6000 psi AND would lead to some formation of mud column in the casing during the time period 530 - 553 mins.