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BRINGING FORWARD DISCOVERY
IN AUSTRALIA'S NORTHERN TERRITORY
AUSTRALIAN AQUITAINE PETROLEUM
WELL SAFETY PROCEDURES
ONSHORE DRILLING

N. CAMPBELL
M. IMBERT
SEPTEMBER, 1981
AQUITAINE WELL SAFETY PROCEDURES

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AQUITAINE WELL SAFETY PROCEDURES

1) GENERAL
During all operations being conducted on Aquitaine operated wells, the following well safety procedures will be followed. Personnel experienced and inexperienced will familiarise themselves with these procedures so that a well can be efficiently controlled at any time.

2) DRILLS
Once weekly kick/blowout safety drills will be conducted by each crew in the presence of the Contractor Toolpusher and the Aquitaine Representative. Safety drills will also be conducted before drilling out the cement in the 13 3/8" and 9 5/8" casing strings. These drills will consist of raising the kelly above the rotary table, shutting the pump down, closing the BOP and circulating at a reduced flow rate with returns entering the mud tank via the choke manifold and degasser.

3) LEAK OFF TESTS
Leak off Tests to test the resistance of the formation at the casing shoe depth and to verify the casing cementation will be conducted after 13 3/8" and 9 5/8" casing strings are set. The procedure for conducting Leak off Tests and the necessary calculations are detailed in Annexe I. The properties of maximum allowable pressures and mud weights derived from these tests will be adhered to, or unless otherwise rectified by the Aquitaine Representative.

4) PERSONNEL
Personnel of each crew shall be assigned specific tasks during safety drills, so that in the event of an actual kick/blowout situation occurring there is no confusion amongst the crew regarding their specific job assignment.
Example: Driller - at the drawworks controls to raise kelly, shut down pumps, close the BOP and open the hydraulic valve on the choke line, commence circulation and controlling surface pressure.
Derrickman - at the choke manifold to ensure that return flow of mud is not restricted by closed valves, assuring that BOP is closed and choke line is open and operation of adjustable choke.

Motorman - at the hydraulic closing unit (BOPs) to ensure that unit operates efficiently. Ensure that spark arrestors on motors are working.

Roughneck - on the mud tanks. Ensure that returns are in order and to measure mud tank level.

Roughneck - on the rig floor to assist the driller or derrickman.

It must be assured that the choke line and choke manifold are completely and fully open before re-commencing the circulation in order that the formation is not broken down by sudden pressure loading.

5) DRILLERS INSTRUCTIONS CHART

A Drillers Instructions Chart which is self-explanatory, will be provided and must be displayed in the doghouse or any other prominent position in proximity to the driller. - Refer AnnexeII.

Comments on the Chart

5.1) Maximum pressure admissible on annulus: M. Ad. P
The Aquitaine Representative will define the M. Ad. P after each casing job or after any change in the mud weight. This figure will be derived from the Leak off Test, or by making the necessary calculations.

5.2) Maximum pressure on annulus: M.W.P.
The Aquitaine Representative will define M.W.P., which corresponds to the service pressure of the BOP or the burst pressure of the casing whichever is the smaller.

5.3) Reduced flow rate to be used in control: Qr
The reduced flow rate Qr, which is the flow rate to be used in the control of a well during a kick/blowout situation is to be calculated at the start of each shift or after changing the bit. This is to be calculated at half the flow rate normally used during drilling. The new pressure loss (gauge surface pressure) at the reduced rate will be noted on the chart under CCP.
5.4) Observation of pressures
The observation of pressures on the drill pipe and casing annulus with the well closed in are required for a duration of ten to twenty minutes. These should be recorded minute by minute. After the pressure rises rapidly to a point of equilibration, a slow rise of pressure is generally observed, which corresponds to the gas rising through the annulus mud column in a chimney effect. Refer Annexe III, form for calculations for controlling a well.

6) WELL VOLUMES
A form to calculate the volume of mud in circulation will be displayed in the doghouse - Refer Annexe IV for example form. This form must be updated every 100 meters drilled or at the end of each shift if that shift drills more than 100 metres. During the controlling of a well in a kick/blowout situation it is necessary to know the approximate volumes of mud in circulation for the evacuation of gas and treatment of the mud with mud weighting material.

7) DRILLERS RESPONSIBILITIES
It often happens that a kick/blowout occurs during the night hours when the driller and his crew are the only people on the well site. It is for this reason that crews must be sufficiently aware of the dangers that exist in drilling into any unexpected high pressure zone. Efficient training in safety drills, job assignments and the correct filling out of the Drillers Instructions Chart and Well Volumes form be carried out by the driller, or by another crew member under the driller's supervision. The most frequent blowouts occur during tripping, either running in or pulling out of the hole. Swabbing and incorrect filling of the hole during pulling out, and pressure surges and incorrect mud returns during running in can reduce the hydrostatic pressure, damage formations and induce a well to flow with serious consequences.
While pulling out of the hole, care should be paid to see that the well is not Swabbing (balled-up stabilizers or bit) and that the well is filled every 5/8 stands with a volume of mud
equal to the amount of metal removed from the hole. It is advisable that a small trip tank of 1m$^3$ in volume equipped with a volume gauge is used during tripping out. If this is not available, measurements of the mud tank used to fill the hole should be made every 5/8 stands to ensure that hole is filling properly.

During running in excessive pressure surges should be avoided even at the expense of lowering the pipe more slowly. The mud returns and volume should be checked every 10 stands.

To obtain better control of filling a hole while tripping out a pill of 1/2m$^3$ (6/12 bbls) of heavy mud should be injected prior to starting the trip.

The driller is the "man on the job" and must be made to realise his responsibilities to the safety of his crew and to the safety of the equipment and the well. This can only be done by efficient training, commmonsense and a thorough knowledge of correct safety procedures.

8) **DERRICKMAN OR MUDMAN RESPONSIBILITIES**

Proper control, knowledge and reporting of the mud system and mud properties is essential to an efficient operation.

A form for mud control is detailed in Annexe V.

During drilling the derrickman or mudman must carry out the following duties: - Take the mud weight and viscosity every 15 minutes.

- Measure mud tank levels every 15 minutes.
- Take a water loss every 2 hours.
- Notify driller and mud logger of any transfer of mud to other tanks.
- Notify driller and mud logger of any change in volumes (losses or gains) or rheological properties of the mud.

During tripping (to be carried out by a designated roughneck)
- Control and measure volumes of mud required to fill the hole while pulling out, and to control volume of mud returned during running in.
During kill procedures -
- Operation of choke manifold by derrickman or a designated roughneck.
- Take mud weight every 5 minutes.
- Measure mud tank levels every 5 minutes.
- Ensure that everything is in order to commence adding barytes to the mud.

9) **MUD ENGINEER/TECHNICIAN**
Where a mud engineer/technician is contracted from a mud company (e.g. Baroid, Magcobar) he will supervise and provide instructions to the derrickman/mudman.
He will also provide to the Aquitaine Representative a Daily Mud Report in which is listed the rheological properties of the mud, materials added, relative hydraulic and volume data and daily mud cost.
The mud engineer should also be present during the conducting of blowout safety drills, and assume responsibility for tasks carried out on the mud tanks.

10) **MUD LOGGERS**
Where a mud logging company is contracted to carry out mud logging duties under the supervision of an Aquitaine Geologist the technicians shall be aware of the duties to be carried out in a kick/blowout situation.
If possible mud tank level recorders installed with read-outs shall be available in the mud loggers cabin. Equipment continuously recording the mud weight returning from the well is also recommended. Co-ordination and co-operation between the mud loggers and the derrickman is essential.
Any "drilling break" should not be penetrated by more than 3 meters and all gas shows and "drilling breaks" should be reported to the Aquitaine Representative immediately.
It is preferable to stop drilling and circulate any "drilling break" or shows even if time is lost, than to continue drilling into a reservoir with unexpected high pressures which may result in a blowout.
11) CEMENTING OPERATOR/UNIT
Where a cementing Operator and unit are located on the wellsite and where a kick/blowout situation occurs, the operator must be called immediately, the machine started and pumps primed. The unit will previously have been hooked up to the kill line. Cement will be readied. Operator and unit will remain on standby until further orders are issued by the Aquitaine Representative.

12) EQUIPMENT FOR DETECTION OF INTRUDING FLUIDS &/OR GASES
11.1) Rate of penetration recorder
11.2) Mud density recorder
11.3) Shale density equipment
11.4) Chromatograph
11.5) Gas detector
11.6) Mud tank level indicators
11.7) Weight indicator
11.8) Pressure gauges
11.9) Mud return indicator

13) EQUIPMENT AVAILABLE FOR CONTROLLING A WELL
12.1) BOP stack - drawing to be displayed for each phase of drilling.
12.2) Choke manifold - drawing to be displayed
12.3) Lower kelly cock - placed between kelly and Saver sub.
12.4) Upper kelly cock - placed between kelly and swivel
12.5) Drop-in type non-return valve during drilling of the 8½" phase to be placed at top of drill collars.
12.6) Inside BOP valve to be situated on rig floor at all times
12.7) High pressure circulating head with swivel joint with chiksan connection.
12.8) Sufficient number of 2" 5000/1000 psi chiksan joints situated on rig floor able to be connected from standpipe to drill string circulating head.
12.9) Degasser
12.10) Cementing unit (if on service contract)
12.11) Flare line
12.12) Trip tank of $1m^3$ (5/6 Bbls) to control fill up and return on trips
12.13) 80 $^\text{T}$ Barytes (For offshore operations, pressure tanks to be full at all times)
12.14) 20 $^\text{T}$ Cement
12.15) 9 $^\text{T}$ Lost circulation material
12.16) One tank of mud in reserve weighted to a density of 1.40/1.50 SG (11.6/12.5 PPG)

14) CONCLUSIONS
It is nearly impossible to follow any safety procedures by letter as each case has different characteristics.
The Aquitaine Well Safety Procedures will however be followed as closely as possible.
The ultimate responsibility for controlling a well is with the Aquitaine Representative at the well site and with the Tool-pusher and Driller of the Contractor Company.
It is with this aim that the Aquitaine Well Safety Procedures has been drawn up, to provide information and assistance to the personnel on the well site.
It also must be remembered that it is not too soon to stop drilling on the "drilling break", mud losses or gains, or shows, and to circulate or put the well on security. It is much better to lose some drilling time rather than have a dangerous kick/blowout situation occur.
ANNEXE I

LEAK OFF TEST PROCEDURE
1) **PURPOSE:**

To test the resistance of the formation at the casing shoe depth.

To establish a maximum allowable pressure.

To verify the casing cementation.

2) **NOMENCLATURE**

- The measured depth is the drilled length of the well bore measured from the rotary table.

- The vertical depth is equal to the projection of the measured depth onto the vertical passing through the rotary table.

- The weak point is the part of the open hole taking up mud when pressure testing. In homogeneous formations, this point is located just below the last casing shoe.

- "Re" is the burst strength of the weakest casing section. If the mud density inside the casing is higher than the one on the outside, the maximum permissible pressure at surface is equal to the smallest value:

\[
\frac{\text{RE} - \gamma d_e - d_i}{1.10} 10
\]

Computed for each casing section, \(Z(m)\) being the vertical depth of each section end, \(\text{Re} (\text{Kg/cm}^2)\) being the burst strength of each section.

- \(W_{\text{inj.}}\) is the mud weight (expected, measured or real) at which the mud leaks off into the formation.

- \(\text{E.M.W.}\) is the equivalent mud weight at which the cement or the formation will be tested.

- \(\text{T.P.}\) is the pressure to be applied at surface either to test the casing or to obtain the required \(\text{E.M.W.}\). For example, if the well is full of \(W = 1.15\) mud, and if the casing shoe, located at \(Z_s = 1500\) m, must be tested at the \(\text{E.M.W.} = 1.60\), the \(\text{T.P.} \) to be applied will be:

\[
\text{T.P.} = (1.60 - 1.15) \times \frac{1500}{10} = 67.5 \text{ Kg/cm}^2
\]
- I.P. is the pressure at surface at which the mud starts to leak off into the formation or into the cement behind the shoe.
- F.P. is the pressure at surface at which the formation (or cement) may be fractured. Formation fracture is always followed by a sharp pressure drop.

**NOTA**
I.P. and F.P. are measured with the pump running at reduced flow rate to minimize and neglect the pressure losses.

3) **PROCEDURE**

- Pressure test must be done using the H.P. unit, at reduced and constant flow rate. Volumes must be measured and plotted with the corresponding pressures on the attached diagram.
- During the operation, watch the annulus between casings and bleed-off in case of pressure increase. Compare the pumped volumes with the calculated volumes.
- The pump must be stopped:
  - either when T.P. is reached.
  - or when 3 or 4 consecutive plots are located off the normal pressure increase line. The point of divergence is I.P.,
  - or, if by inadvertence, fracture is reached (F.P.)
- After the pump is stopped, watch the pressure during 3 to 5 minutes for cement and formation tests, and 15 minutes after stabilization for casing test. Plot the pressure drop versus time on the diagram.
- Bleed-Off slowly while measuring the released volume.

4) **RESULTS**

- A casing pressure test is positive if the pressure is stabilized during 15 minutes at a value higher or equal to:
  - 90% of test pressure for pressures ≤ 400 kg/cm²
  - test pressure minus 40 kg/cm² for pressures ≥ 400 kg/cm².
- Regarding formation or cement test, make sure that the pressure stabilizes or tends to stabilize after 3 or 5 minutes. This stabilized value will be taken to calculate the corresponding E.M.W.

- The result of any pressure test is given as an equivalent mud weight (W test or W injection or W fracture).

Ex 1 - Cement test

\[
\begin{align*}
Z\text{ shoe: } & 1500 \text{ m;} \ W = 1.15; \ TP = 67.5 \text{ kg/cm}^2 \\
W\text{ test: } & 1.15 + \frac{10 \times 67.5}{1500} = 1.60
\end{align*}
\]

EX 2 - Leak off test

\[
\begin{align*}
Z\text{ weak point: } & 1850 \text{ m;} \ IP: 40 \text{ kg/cm}^2 \text{ with } W = 1.18 \\
W\text{ inj.: } & 1.18 + \frac{10 \times 40}{1850} = 1.40
\end{align*}
\]

Ex 3 - Unexpected fracture at shoe depth

\[
\begin{align*}
Z\text{ shoe } & = 1500 \text{ m;} \ W = 1.15; \ FP = 85 \text{ kg/cm}^2 \\
W\text{ frac: } & 1.15 + \frac{10 \times 85}{1500} = 1.72
\end{align*}
\]
# PRESSURE TEST REPORT

**WELL** | **RIG** | **R.K.B. ELEVATION** |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ground or M.L. M.S.L.</td>
</tr>
</tbody>
</table>

**DATE OF TEST:** | **HOLE DEPTH:**  

**MUD CHARACTERISTICS DURING TEST**  
Type = | AV = | YP = | Gels 0/10 | Mud weight |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>W: kg/l</td>
</tr>
</tbody>
</table>

**PLANNED TEST TYPE**  
Max. Perm. Press. \(\frac{\text{Re}}{1.10}\): | Estimated W inj.: | Desired EMW(2) = |
<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>kg/cm²</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**PLANNED INJECTION LINE:**  
PUMP: | FLOW RATE: | MUD VOLUME: |

**TIME**  
Pumped (or released) volume by step cumulated  
Pressure  
Results Total pumped volume: Total released volume:  
Cement or formation test T.P. = kg/cm²  
I.P. = kg/cm²  
F.P. = kg/cm² |

**COMMENTS:**  
1) Specify here  
Bottom hole  
Top of cement  
Packer or plug  
2) Equivalent mud weight

Reference Note: DPRO/FOR 9 378  
Inno: 582 SNEAIP - RGM N° 959 004 024
Mud should be homogeneous, clean and not gas-cut.

Pump flow rate should be adjusted between 50 and 100 l/min (max. 300 l/min).

Theoretical compression is 4 to 5 l by kg/cm² and by 100 m³ compressed.

Be careful not to confine an air plug in the circuit.

Release the pressure slowly while measuring return volume.

Well:

Measured depth:

Ø Casing:

Shoe measured depth:

Minutes after the pump is stopped

Pumped volume
ANNEXE 2

COMPANY

DRILLER'S PROCEDURES
for well control
(DRILLING FROM LAND OR FIXED SUPPORT)

1. At every bit change or crew change:

| Circulate off bottom for 5 minutes at reduced flow rate and record pressures. |
|----------|----------|----------|----------|----------|----------|
| Pressure | Flow     | Pressure | Flow     | Pressure | Flow     |
| [in psi]  | [gpm]    | [in psi] | [gpm]    | [in psi] | [gpm]    |
| [in psi]  | [gpm]    | [in psi] | [gpm]    | [in psi] | [gpm]    |
| [in psi]  | [gpm]    | [in psi] | [gpm]    | [in psi] | [gpm]    |

2. If any of the following occurs during drilling, coring, or circulating:

- Increase in drilling rate
- Increase of fluid across shale sliver
- Increase in pit level
- Gas cut mud
- Increase in mud chloride content
- Partial or total mud loss

- Pack up Kelly until T.IJ is 3 ft above rotary table
- Shut off mud pump - check for well flow or losses
- Notify operator and contractor Tool pusher

IF WELL IS MINE

- Resume circulation
- Check for mud level, mud weight, and shows
- Resume operations

IF WELL IS FLOWING

- Open the choke, the choke being fully open
- Close the by-pass
- Slowly close the tool, and record casing and well bore pressure for 15 minutes

IF CASING PRESSURE REACHES $P_c$:

- Calculate $P_c$ as follows
  - $P_c = P_{1/2}$
  - $P_{1/2} = \frac{1}{2} \times SP_{1/2}$
  - $SP_{1/2} = \frac{1}{2} \times SP_{1/2}$

- Open the by-pass and record new and final pressures
- If the well is flowing, close the by-pass
- If the well is stable, open the tool, and close the by-pass

The casing pressure must never be higher than $P_c$

(1) If the well is flowing, set the tool at the bottom of the hole and close the by-pass

(2) $P_c$ can be determined above, depending on the amount of bottom pressure equal to $P_c - 5$ for a period of time. The bottom pressure should be close to the $P_c$ calculated above

3. If the well is not taking mud on trip, or flowing while out of the hole:

IF THE WELL IS MINE

- Run pipe back to bottom. In case of losses keep annulus full of fluid
- Resume circulations at reduced flow rate, eventually under control at constant BP pressure (Casing same gas may enter the well later)

IF THE WELL IS FLOWING

- Make up annular back pressure equal to 1.2
- With maximum delay, run pipe back to bottom. Check mud gun
- On bottom proceed as above 4.2

NOTE: The Operator Supervisor must fill up the above shadowed spaces as often as necessary.
ANNEXE III

DRILLERS PROCEDURES

AND WELL CONTROL WORK SHEETS
**Driller’s procedures and well control work sheets**

**IMPORTANT NOTES**

The drilling crew are often alone at the well site when a well kicks, and the driller must act quickly and correctly. It is therefore essential that he be given simple, clear orders that he understands perfectly.

The “driller’s procedures” proposed here apply to onshore or fixed platform drilling. When drilling from floating vessels these procedures must be modified to take account of the special circumstances relating to the sub-sea BOP stack, the type of vessel and its environment. These factors are discussed in Chapter 7.

The control procedure given here cannot be guaranteed to succeed unless the closed in annulus pressure is lower than $P_a$ and the bit is close to bottom. Chapter 8 discusses the procedures required when these conditions cannot be met.

The assumption that the gas bubble is at the bottom of the hole is only justified if the kick is detected immediately (for example by a drilling break).

An acceleration in return flow rate or a pit level increase often corresponds to the expansion of a gas bubble as it nears the surface. If this occurs one mud cycle after the bit gets on bottom or after making a connection, it is generally a small bubble which can be circulated out without back-pressure (well wide open or on a large choke). If not, the well should be closed in, the drill pipe pressure determined, and, if it is not zero, the normal control procedure put into action.

It should be noted that the presence of gas near the surface will increase $P_a$ to such an extent that it may exceed $P_m$ without fracture pressure being achieved at the casing shoe.

If an oil-based mud is used, any gas entering the well bore may dissolve completely in the mud. In this case the kick may not be detected until it almost reaches the surface, when the gas is liberated and the kick reveals itself violently. This dangerous situation is handled by closing in the BOP’s and disposing of the gas through the flare line.
6.3. NOTES ON THE DRILLER'S PROCEDURES

6.3.1. Initial allowable casing pressure ($P_{ia}$)

The company drilling supervisor will set the initial allowable casing head pressure $P_{ia}$ after setting each casing string, after any change in mud weight or when any new information on formation strength becomes available.

It is not possible to lay down a standard procedure to be followed if $P_{ia}$ is reached, and the drilling supervisor must therefore select a procedure suited to the particular circumstances and ensure that this is added to the "driller's procedures".

6.3.2. Shut-in period and pressure measurements

A 10 to 20 min shut-in period is normally sufficient to obtain the stabilised drill pipe pressure.

After a rapid rise to the stabilised pressure there is generally a period during which the pressure rises slowly and steadily as gas bubbles percolate upwards in the annulus and the mud in the well heats up.

The drill pipe and casing head pressures should be recorded every minute, using sensitive pressure gauges with a full scale range of no more than 1.5 to 2 times $P_{ia}$.

6.3.3. Maximum casing head (annulus) pressure ($P_{max}$)

The company drilling supervisor will set the value of $P_{max}$ at the lower of the working pressure of the BOP stack or the bursting strength of the casing (see Chapter 2, Section 2.2).
TABLE IV

COMPANY DRILLER'S PROCEDURES for well control
(NEW FROM LAND OR FIXED SUPPORT)

1. At every bit change or crew change:
   - Circulate off bottom for 5 minutes at reduced flow rate and record pressure loss (Δ_P).

2. If any of the following occurs during drilling, coring, or circulating:
   - Increase in drilling rate.
   - Increase in flow across shale shaker.
   - Increase in pit level.
   - Gas cut mud.
   - Increase in mud Chrisile content.
   - Partial or total mud losses.

   - Open the choke valve, the choke being fully opened.
   - Close the bag type.
   - Slowly close the choke and record casing and end bar pressure for 15 minutes.

3. If casing pressure reaches P_1:
   - Calculate P_1 as follows:
     - Record the pressure
     - Add the pump pressure
     - Add the manifold pressure
     - Add the fluid level
   - Circulate and maintain a constant pressure equal to P_1.

4. If well is flowing:
   - Check for losses.
   - Notify operator and contractor Tool pusher.

5. If the well is not taking mud on trip, or flowing while out of the hole:
   - Stop tripping.
   - Check for well flow.
   - Notify operator and contractor Tool pusher.

NOTE: The Operator Supervisor must fill in the above shadowed spaces as often as necessary.
6.3.4 Keeping the well full while tripping

Depending on circumstances the annulus will be filled after each stand is pulled, or at the most after five stands are pulled. The cumulative volume taken by the well should be calculated every 5 or 10 stands, and should be compared with the records of previous trips.

It is most important to measure the volumes accurately. If the drill pipe tends to pull wet it should be slugged with heavy mud before pulling out.

6.3.5 Kick occurring with no drill pipe in the hole

The pipe should be run in the hole immediately with a back-pressure valve in the first stand, even if the flow is very slight. The subsequent procedure is the same as that given for a kick occurring while tripping.

If it is impossible to get any pipe into the hole, close the blind rams, ensure that the pressure does not exceed $P_{\text{max}}$ and wait for instructions.

6.4 WELL CONTROL WORK SHEET AND PUMPING PRESSURE PLOT

See Tables V and VI

6.5 REMARKS ON THE WORK SHEET

The well control work sheet is usually completed by the company drilling representative and the toolpusher. The work sheet shown in this book is a composite of various such sheets used in the industry.

Calculation of circulating volumes.

To avoid making any mistakes it is advisable to prepare sketches of the well and the drill string.

It is also recommended that the times and pump strokes required to reach particular changes in section are calculated in advance. The pressure changes occurring as the weighted mud reaches these points can then be anticipated.
TABLE V. WELL CONTROL WORK SHEET

I. BASIC DATA

<table>
<thead>
<tr>
<th>DEPTH</th>
<th>SELECTED PUMP</th>
<th>CONTROL PUMP RATE</th>
<th>INITIAL MUD WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEASURED MD (m)</td>
<td>VERTICAL Z (m)</td>
<td>Qf (l/min)</td>
<td>PUMP SPEED (St/min)</td>
</tr>
<tr>
<td>N*</td>
<td>LINE</td>
<td>MILLIMETERS / INCHES</td>
<td></td>
</tr>
<tr>
<td>INITIAL</td>
<td>CIRCULATING PRESSURE LOSSES FOR Qf AND Wf THROUGH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIRCULATING PRESSURE LOSSES FOR Qf AND Wf THROUGH CHOKES LINE AND MANIFOLD (CHOKE FULLY OPEN)</td>
<td>Apf (kg/cm²)</td>
<td>SAFETY</td>
<td></td>
</tr>
<tr>
<td>PL1</td>
<td>Pl = Δps</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>PL2</td>
<td>Pl = Δps</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

II. CALCULATION OF VOLUMES AND PUMPING TIMES

<table>
<thead>
<tr>
<th>ANNULAR SPACES</th>
<th>LENGTH</th>
<th>ARRAYS MATERIALS (L/2)</th>
<th>TOTAL ANNULAR VOLUME (LITERS)</th>
<th>DOLL x 10</th>
<th>DOLL x 10</th>
<th>DOLL x 10</th>
<th>DOLL x 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIPS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DIAPHRAGM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SURFACE TO BIT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BIT TO SURFACE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL CIRCULATING VOLUME</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

III. CALCULATION OF CONTROL PARAMETERS

<table>
<thead>
<tr>
<th>REQUALED MUD WEIGHT</th>
<th>Wf = Wf + 100/2 + S</th>
</tr>
</thead>
<tbody>
<tr>
<td>PUMP PRESSURE BEFORE BARTING MUD</td>
<td>PRi = Pi + Pfi + S</td>
</tr>
<tr>
<td>PUMP PRESSURE WHEN THE MUD REACHES THE BI</td>
<td>PRf = Pi + wi</td>
</tr>
<tr>
<td>PUMP PRESSURE DECREASE VERSUS INCREASING DEGREE OF MUD</td>
<td>ΔPr = PR1 - PRf</td>
</tr>
<tr>
<td>QUANTITY OF BARIUM REQUIRED</td>
<td>A = L2 - Wf - Wf - Wf - Wf</td>
</tr>
<tr>
<td>TOTAL WEIGHT OF BARIUM</td>
<td>Wf = Vf x A</td>
</tr>
<tr>
<td>MUD IN MIX WEIGHT PER CYCLE</td>
<td>ΔWf = Wf - Wf</td>
</tr>
<tr>
<td>BLOW-DOWN</td>
<td>C = A x Qf</td>
</tr>
<tr>
<td>MUD PRESSURE WHEN MUD REACHES THE BI</td>
<td>Wf = Wf + ΔWf</td>
</tr>
<tr>
<td>MUD PRESSURE WHEN MUD REACHES THE BI</td>
<td>Wf = Wf + ΔWf</td>
</tr>
</tbody>
</table>

IV. Calculation of pump pressure at the end of the control period

<table>
<thead>
<tr>
<th>PUMP PRESSURE</th>
<th>Wf = Wf + 100/2 + S</th>
</tr>
</thead>
<tbody>
<tr>
<td>REACHED THE BI</td>
<td>PRf = PRi + ΔPr x ΔWf</td>
</tr>
<tr>
<td>REACHED THE BI</td>
<td>PRf = PRi + ΔPr x ΔWf</td>
</tr>
</tbody>
</table>

V. Check that open hole is not fractured with the chosen 'S' margin

<table>
<thead>
<tr>
<th>REQUIRED VOLUME</th>
<th>Wf = Wf - 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>THROUGH ONE LINE</td>
<td>Wf = Wf - 10</td>
</tr>
<tr>
<td>THROUGH TWO LINES</td>
<td>Wf = Wf - 10</td>
</tr>
<tr>
<td>THROUGH ONE LINE</td>
<td>Wf = Wf - 10</td>
</tr>
<tr>
<td>THROUGH TWO LINES</td>
<td>Wf = Wf - 10</td>
</tr>
</tbody>
</table>

VI. Weighting-up the mud in the riser (before opening the BOP's)

<table>
<thead>
<tr>
<th>RISER VOLUME</th>
<th>Vr = Vr</th>
</tr>
</thead>
<tbody>
<tr>
<td>REQUIRED WEIGHT OF BARIUM</td>
<td>B1 = Vr x 4.2 - Wf - Wf - Wf</td>
</tr>
</tbody>
</table>

NB: SHADED AREAS MUST ONLY BE FILLED IN FOR FLOATING RIG.
DRILLER'S PROCEDURES AND WELL CONTROL WORK SHEETS

**TABLE VI**

**PUMPING PRESSURE PLOT FOR THE PERIOD DURING WHICH THE WEIGHTED MUD TRAVELS FROM SURFACE TO THE BIT**

1. On the vertical pressure axis plot the value of $P_{R1}$. For the second cycle $P_{R2}$, etc.
2. On the horizontal pump strokes axis plot the number of strokes required to pump the mud from surface to the bit. Draw a vertical line from this point.
3. On this vertical plot the value of $P_{R2}$ for the second cycle $P_{R1}$, etc.
4. Join the points plotted in 1 and 3.
5. Select the number of pressure steps desired and calculate the number of pump strokes for each step, plot these values on the horizontal axis and draw a vertical line from each point.
6. On the line drawn in 4 read off the drill pipe pressure to be maintained from the start of each step and write these figures on the plot.

If it is desired to minimise the pressure overbalance at the formation, the drill pipe pressure to be maintained should be the average of the pressures at the start and end of each step. In this case the difference between the two pressures must be less than twice the safety margin ($S$) used in the calculations.

<table>
<thead>
<tr>
<th>$P_R$ ($kg/cm^2$)</th>
<th>pump strokes</th>
<th>time</th>
</tr>
</thead>
</table>
Calculation of circulating pressure at reduced rate.

If the circulating pressure at the reduced rate has not been measured, an approximate value can be obtained from Fig. 37, using the circulating pressure at normal pump rate as a reference point.

If \( P_{RI} \) was obtained directly using the initial annulus pressure method:

\[
P_{LI} = P_{RI} - (P_{dI} + S)
\]

Fig. 37. — Calculation of circulating pressure \( (P_{LI}) \) at a reduced pump rate.

This chart may be entered with either pumping rate (litres min) or pump speed (strokes min).

Example. Circulating pressure 150 kg/cm\(^2\) at 2000 litres/min.
1. Find the point corresponding to 150 kg/cm\(^2\) and 2000 litres/min.
2. Through this point draw a line parallel to those shown on the chart.
3. For a pump rate of 1000 litres/min using the normal circulating path, the circulating pressure would be a little over 40 kg/cm\(^2\).

Weighting the mud.

Barite should be added to the mud at a constant rate. The best method of controlling the procedure is to use a pneumatic silo and mud weight indicators.
The following procedure may be used if two circulating tanks are available:

1. While circulating the original mud using one of the circulating tanks, weight up the mud in the second tank to the density required for the first cycle \( W_2 \) at the rate calculated. This gives the opportunity of adjusting the equipment to the required weighting rate.

2. When the weighted mud reaches the density \( W_2 \), switch circulating tanks and note the pump stroke counter reading.

3. Reduce the pumping pressure following the first line on the plot. Check the mud density in the suction pit to verify that the weighting-up rate is correct.

4. When the weighted mud reaches the bit, keep the pumping pressure \( P_{R2} \) constant until the mud of density \( W_2 \) has reached surface and the mud in the suction tank has reached the next higher density \( W_3 \).

5. Reduce the pumping pressure following the second line on the plot. Repeat steps 3 and 4.

**Note.** In certain situations the kick is circulated out before weighting up the mud, but the same weighting procedure is followed in either case.

### 6.6 EXAMPLES

Two completely different situations will be examined: a deep onshore well and a shallow well from a fixed platform.

**Example 1: Onshore well.**

- Well depth, \( Z \): 6120 m
- 9 5/8" casing shoe at 4534 m
- 7" liner shoe at 5688 m
- Hole diameter: 5 3/4"
- Mud weight: 1.76

BOP's 10,000 psi WP.  
Equivalent fracture density (leak-off test): 1.90.

The drill string comprises:

- 910 m of 5" 25.6 lb/ft drill pipe
- 1179 m of 3 1/2" 15.5 lb/ft drill pipe
- 3864 m of 3 1/2" 13.3 lb/ft drill pipe
- 167 m of 4 1/2" OD x 2" ID drill collars.

A control rate of 400 litres/min has been chosen (pump speed 102 strokes/min at 3.92 litres/stroke).

The circulating pressure measured at this rate was 70 kg/cm².

Upon closing in the well after detecting the kick the stabilised well-head pressures were:

\[ P_{d1} = 28 \text{ kg/cm}^2 \]
\[ P_{a1} = 57 \text{ kg/cm}^2 \]

A safety margin of 15 kg/cm² will be used.
COMPANY  
DRILLER'S PROCEDURES  
for well control  

(DRILLING FROM LAND OR FIXED SUPPORT)  

WELL:  

<table>
<thead>
<tr>
<th></th>
<th>5 1/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>5688m</td>
</tr>
<tr>
<td>Mud level</td>
<td>17.6</td>
</tr>
<tr>
<td>Max. rate</td>
<td>95</td>
</tr>
<tr>
<td>Max. pres.</td>
<td></td>
</tr>
</tbody>
</table>

1. At every bit change or crew change :  
   - Circulate off bottom for 5 minutes at reduced flow rate and record pressure loss ($P_{1}$).  
   - Keep the bag type pump running and check for well flow or losses.  
   - Notify operator and contractor Tool pusher.  

2. If any of the following occurs during drilling, coring, or circulating :  
   - Increase in drilling rate.  
   - Increase of flow across shale shaker.  
   - Increase in pit level.  
   - Gas cut mud.  
   - Increase in mud chloride content.  
   - Partial or total mud losses.  

   - Fill up Kelly valve.  
   - Shut off mud pump.  
   - Increase in drilling rate.  

   IF WELL IS STABLE  
   - Resume circulation.  
   - Check for mud pit level, mud weight, and shows.  
   - Resume operations.  

   IF WELL IS FLOWING  
   - Open the choke line, the choke being fully open.  
   - Close the bag type.  
   - Slowly close the choke and record casing and drill pipe pressure for 15 minutes.  

   IF WELL IS LOUSING  
   - Circulate at reduced flow rate.  
   - Check for losses.  
   - Wait for orders.  

   IF CASING PRESSURE REACHES $P_{c}$  
   - Follow the instructions here under:  
   - Check for pressure loss ($P_{p}$)  
   - Calculate $P_{c}$ as follows:  
     - $P_{c} = \frac{57.14}{\text{hours}}$  
     - Keep running the Kelly valve down.  
     - Keep up the flow into the drill string.  
     - Wait on orders.  
     - Rig up to pump a plug of heavy mud.  

   IF CASING PRESSURE IS LESS THAN $P_{c}$  
   - Open the bag type to keep pressure.  
   - Keep running mud.  
   -随 the pressure loss at reduced flow rate.  
   - Add in the top.  

   ($P_{c}$ is a measureable and theoretically, start pump at reduced flow rate, inject drill at normal pressure, stop and reduce the pressure in the bag type to less than $P_{c}$).  

3. If the well is not taking mud on trip, or flowing while out of the hole :  
   - Stop tripping.  
   - Check for well flow or losses.  
   - Notify operator and contractor Tool pusher.  

   IF THE WELL IS STABLE  
   - Run pipe back in bottom, in case of losses keep annulus full if possible.  
   - Resume circulating at reduced flow rate, eventually under control at constant DP pressure (Caution: same gas may enter the well bore).  

   IF THE WELL IS FLOWING  
   - Make up an inside bag pressure valve in drill string.  
   - With minimum delay, run pipe back to bottom.  
   - Close the bag type.  
   - Wait for orders.  

NOTE: The Operator must fill up the above shallowed spaces as often as necessary.
### I. Basic Data

<table>
<thead>
<tr>
<th>Depth</th>
<th>Selected Pump</th>
<th>Control Pump Rate</th>
<th>Initial Mud Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>6120</td>
<td>HP 3&quot;</td>
<td>3.92</td>
<td>40.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Circulating Pressure Loss for Qa and WI</th>
<th>Drill String Pressure</th>
<th>Safety Margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>thru one line</td>
<td>thru two lines</td>
<td></td>
</tr>
<tr>
<td>Pua (kg/cm²)</td>
<td>Pua (kg/cm²)</td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>70</td>
<td>2.8</td>
</tr>
</tbody>
</table>

### II. Calculation of Volumes and Pumping Times

#### Annulus Spaces

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Length</th>
<th>Annulus Volume Per Meter (ft³/m)</th>
<th>Total Annulus Volume (Cubic Meters)</th>
<th>Drill String Length (ft)</th>
<th>Internal Volume Per Meter (ft³/m)</th>
<th>Total Internal Volume (Cubic Meters)</th>
<th>Circulating Volume Per Meter (ft³/m)</th>
<th>Total Circulating Volume (Cubic Meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5½x4¾</td>
<td>517</td>
<td>167</td>
<td>4.153</td>
<td>175</td>
<td>305</td>
<td>1755</td>
<td>4.153</td>
<td>1755</td>
</tr>
<tr>
<td>5¼x3½</td>
<td>275</td>
<td>390</td>
<td>14.78</td>
<td>175</td>
<td>386</td>
<td>13,075</td>
<td>3.862</td>
<td>13,075</td>
</tr>
<tr>
<td>6¾x5½</td>
<td>1154</td>
<td>114.8</td>
<td>13617</td>
<td>175</td>
<td>96.6</td>
<td>13,258</td>
<td>96.6</td>
<td>13,258</td>
</tr>
<tr>
<td>9½x8</td>
<td>3624</td>
<td>31.7</td>
<td>116,800</td>
<td>175</td>
<td>13.9</td>
<td>112,660</td>
<td>13.9</td>
<td>112,660</td>
</tr>
<tr>
<td>9x7½</td>
<td>916</td>
<td>24.3</td>
<td>22,660</td>
<td>175</td>
<td>13.3</td>
<td>21,377</td>
<td>13.3</td>
<td>21,377</td>
</tr>
<tr>
<td>10½x9½</td>
<td>6120</td>
<td>61.2</td>
<td>6170</td>
<td>175</td>
<td>13.8</td>
<td>61,100</td>
<td>13.8</td>
<td>61,100</td>
</tr>
</tbody>
</table>

#### Annulus Volume Vₐ

- Calculated over the Mid-point
- Includes the Mid Point
- Total Volume to be Weighed Vₐ = 155192

### III. Calculation of Control Parameters

#### Required Mud Weight

\[ W_f = \frac{W_f + W_w}{2} \]

#### Pump Pressure before Bariting

\[ P_{R1} = P_{R1} + \Delta P R = 28.70 - 45 \]

#### Pump Pressure when the Weighted Mud Reaches the Bit

\[ P_{R1} = P_{R1} + \Delta P \]

#### Pump Pressure Increase versus Increasing Weight of Mud

\[ \Delta P = \frac{P_{R1} - P_{R2}}{10} \]

#### Quantity of Barite Required

\[ A = \frac{W_f + W_w}{2} \]

#### Increase in Mud Weight per Cycle

\[ \Delta W = \frac{W_f + W_w}{2} \]

#### Increase in Pump Pressure

\[ \Delta P = \frac{P_{R1} - P_{R2}}{10} \]

### IV. Calculation of Pump Pressure at the End of the Control Period

**Through One Line**

\[ \frac{W_f}{10} \]

**Through Two Lines**

\[ \frac{W_f + W_w}{10} \]

### V. Check that open hole is not fractured with the chosen 'S' margin

#### Pumping Rate

\[ W_{eq} = W_f + 10 \]

### VI. Weighting-up the Mud in the Riser (before opening the BOP’s)

- **Riser Volume**

\[ V_r = \frac{W_r}{G} \]

- **Required Weight of Barite**

\[ W_r = V_r \times 4.3 \times 42 = \frac{W_r}{10} \text{ kg} \]
DRILLER'S PROCEDURES AND WELL CONTROL WORK SHEETS

PUMPING PRESSURE PLOT FOR THE PERIOD DURING WHICH THE WEIGHTED MUD TRAVELS FROM SURFACE TO THE BIT

FIRST EXAMPLE

1. On the vertical pressure axis plot the value of \( P_{R1} \)
   For the second cycle \( P_{R2} \), etc.
2. On the horizontal pump strokes axis plot the number of strokes required to pump the mud from surface to the bit. Draw a vertical line from this point.
3. On this vertical plot the value of \( P_{R1} \) for the second cycle \( P_{R2} \), etc.
4. Join the points plotted in 1 and 3.
5. Select the number of pressure steps desired and calculate the number of pump strokes for each step, plot these values on the horizontal axis and draw a vertical line from each point.
6. On the line drawn in 4 read off the drill pipe pressure to be maintained from the start of each step and write these figures on the plot.

If it is desired to minimize the pressure overbalance at the formation, the drill pipe pressure to be maintained should be the average of the pressures at the start and end of each step. In this case the difference between the two pressures must be less than twice the safety margin \( S \) used in the calculations.

### Example No. 1

<table>
<thead>
<tr>
<th>( P_R ) (kg/cm²)</th>
<th>example no. 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>125</td>
<td></td>
</tr>
<tr>
<td>113</td>
<td>70,660 strokes</td>
</tr>
<tr>
<td>110</td>
<td>1h 30 min</td>
</tr>
<tr>
<td>107</td>
<td>73,150 strokes</td>
</tr>
<tr>
<td>104</td>
<td>23 h</td>
</tr>
<tr>
<td>101</td>
<td>6,832 strokes</td>
</tr>
<tr>
<td>98</td>
<td>67 min</td>
</tr>
<tr>
<td>95</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** When using a mixed drill string this graphical method, which assumes the string to be of constant ID, may still be used providing that the mud weight increments are not too great. It is however recommended that calculations be made to check that this is indeed the case. In this example, with 910 m of 5" drill pipe at the top of the string, the pump pressure will be reduced by 6 kg/cm² after 2,000 strokes (7,840 litres). At this point, however, the weighted mud will only have reached a depth of 1,048 m, corresponding to an increase in bottom-hole pressure of 3.7 kg/cm². The net effect will therefore be a fall in bottom-hole pressure of 2.3 kg/cm². Since the chosen safety margin is 15 kg/cm² this error will be of no significance and the use of this simplified graphical method is justified.
Example 2: Fixed platform well. Water depth 115 m.

Well depth, \( Z \) 1300 m

20" casing shoe at 600 m

Hole diameter \( 17 \frac{1}{2}" \)

Mud weight 1.2

BOP's 2000 psi WP.

Equivalent fracture density (leak-off test) 1.70.

The drill string comprises:

- 1165 m of 5" 19.5 lb/ft drill pipe
- 135 m of 8" OD \( \times \) 3" ID drill collars

A control rate of 1500 litres/min has been chosen (pump speed 30 strokes/min at 50 litres/stroke).

The circulating pressure measured at this rate was 40 kg/cm\(^2\).

Upon closing in the well after the kick the stabilised wellhead pressures were:

\[ P_{d1} = 20 \text{ kg/cm}^2 \]

\[ P_{a1} = 25 \text{ kg/cm}^2 \]

A safety margin of 10 kg/cm\(^2\) will be used.
SECOND EXAMPLE

COMPANY
DRILLER'S PROCEDURES
for well control
(DRILLING FROM LAND OR FIXED SUPPORT)

WELL: 6000 ft. (1829 m)

1. At every bit change or crew change:
   a. Circulate off bottom for 5 minutes at reduced flow rate and record pressure loss (P1).

   - Increased in drilling rate.
   - Increase in flow across shaker.
   - Increase in pit level.
   - Gas cut mud.
   - Increase in mud chloride content.
   - Partial or total mud losses.

   Circulate at reduced flow rate.
   Resume operations.

2. If any of the following occurs during drilling, coring, or circulating:

   - Pick up Kelly until T.J. is 3 ft above rotary table.
   - Shut off mud pump - check for well flow or losses.
   - Notify operator and contractor Tool pusher.

   IF WELL IS STABLE
   - Resume circulation.
   - Check for mud pit level, mud weight, and shunt.
   - Resume operations.

   IF WELL IS FLOWING
   - Open the choke line, the choke being fully open.
   - Close the bag type.
   - Slowly close the choke and record casing and drill pipe pressure for 15 minutes.

   IF WELL IS LOOSING
   - Circulate at reduced flow rate.
   - Check for losses.
   - Wait for orders.

   IF CASING PRESSURE REACHES $P_{\text{m}}$

   - Follow the instructions hereunder:
     - Open the choke to half the annular pressure at or below 5000 psi.
     - Break circulation at 1500 psi.
     - Check weighting up the mud in circulation immediately.

   IF CASING PRESSURE IS LESS THAN $P_{\text{m}}$

   - Record the pressure $P_{\text{m}}$
   - Circulate $P_{\text{m}}$ as follows:
     - Close the annular and drill pipe pressure.
     - Add the pressure loss or reduced flow rate.
     - Add the top margin.

   - Open the choke and simultaneously open a pump at reduced flow rate, until the choke is at a constant pressure equal to $P_{\text{m}}$.
   - Do not reset the casing pressure to less than $P_{\text{m}}$.

3. If the well is not taking mud on trip, or flowing while out of the hole:

   - Stop tripping.
   - Check for well flow or losses.
   - Notify operator and contractor Tool pusher.

   IF THE WELL IS STABLE
   - Unless otherwise notified:
     - Run pipe back to bottom.
     - Resume circulating at reduced flow rate, eventually under control at constant DP pressure (Caution: some gas may enter the well bore).

   IF THE WELL IS FLOWING
   - Make up an inside back pressure valve in drill string.
     - With minimum delay, run pipe back to bottom. Check mud gain.
     - On bottom proceed as above 1.2.

   IF THE FLOW IS INCREASING OR IF THE BORE IS FREE
   - Stop tripping.
   - Close the bag type.
   - Wait for orders.
   - Bleed off if casing pressure reaches $P_{\text{m}}$.

NOTE: The Operator Supervisor must fill up the above shadowed spaces as often as necessary.
**WELL CONTROL WORK SHEET**

**SECOND EXAMPLE**

### I. BASIC DATA

<table>
<thead>
<tr>
<th>DEPTH (ft)</th>
<th>SELECTED PUMP</th>
<th>CONTROL PUMP RATE</th>
<th>INITIAL MUD WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1300</td>
<td>4X6</td>
<td>50</td>
<td>1500</td>
</tr>
</tbody>
</table>

### II. CALCULATION OF VOLUMES AND PUMPING TIMES

<table>
<thead>
<tr>
<th>Diameters (in)</th>
<th>Length (m)</th>
<th>Annulus Volume (l)</th>
<th>Total Annulus Volume</th>
<th>Drill String Length (m)</th>
<th>Internal Volume of Line (l)</th>
<th>Internal Volume of Choke Line (l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>17/8</td>
<td>8</td>
<td>155</td>
<td>1655</td>
<td>5</td>
<td>115</td>
<td>65</td>
</tr>
<tr>
<td>15/8</td>
<td>5</td>
<td>414.19</td>
<td>80173</td>
<td>8</td>
<td>3</td>
<td>135</td>
</tr>
</tbody>
</table>

### III. CALCULATION OF CONTROL PARAMETERS

- **Required Mud Weight**
  
  
  \[ W_r = \frac{W_f}{1 + \frac{P_{	ext{Res}} - P_{	ext{mud}}}{2}} \]

- **Pump Pressure Before Barriers**
  
  \[ P_{	ext{R1}} = P_{	ext{inj}} - P_{	ext{mud}} \]

- **Pump Pressure When the Weighted Mud Reaches the Bit**
  
  \[ P_{	ext{R2}} = P_{	ext{inj}} - P_{	ext{mud}} \]

- **Pump Pressure Decrease Versus Increasing Weight of Mud**
  
  \[ \Delta P = \frac{P_{	ext{R1}} - P_{	ext{R2}}}{W_{	ext{mud}} - W_{	ext{inj}}} \]

- **Weight of Barite Required**
  
  \[ A = \frac{W_{	ext{inj}} - W_{	ext{mud}}}{\Delta P} \]

- **Total Weight of Barite**
  
  \[ B = A \times 1.25 \]

- **Mud of Mud Cycles to be Used**
  
  \[ \text{N} = 3 \]

- **Increase in Mud Weight, per Cycle**
  
  \[ \Delta W = \frac{W_{	ext{inj}} - W_{	ext{mud}}}{\Delta P} \]

- **Bearing Rate**
  
  \[ C = \frac{A \times 1.25}{3} \]

### IV. Calculation of Pump pressure at the End of the Control Period

- **Pressure at End of Control Period**
  
  \[ P_{\text{end}} = P_{	ext{R1}} + \Delta P \times \Delta W \]

### V. Check that open hole is not fractured with the chosen 8m margin

### VI. Weighing up the mud in the riser (before opening the BOP's)

**NB: SHADED AREAS MUST ONLY BE FILLED IN FOR FLOATING RIG**
DRILLER'S PROCEDURES AND WELL CONTROL WORK SHEETS

PUMPING PRESSURE PLOT FOR THE PERIOD DURING WHICH THE WEIGHTED MUD TRAVELS FROM SURFACE TO THE BIT

SECOND EXAMPLE

1. On the vertical pressure axis plot the value of \( P_{RI} \). For the second cycle \( P_{RI} \) etc.
2. On the horizontal pump strokes axis plot the number of strokes required to pump the mud from surface to the bit. Draw a vertical line from this point.
3. On this vertical plot the value of \( P_{RI} \) for the second cycle \( P_{RI} \) etc.
4. Join the points plotted in 1 and 3.
5. Select the number of pressure steps desired and calculate the number of pump strokes for each step, plot these values on the horizontal axis and draw a vertical line from each point.
6. On the line drawn in 4 read off the drill pipe pressure to be maintained from the start of each step and write these figures on the plot. If it is desired to minimise the pressure overbalance at the formation, the drill pipe pressure to be maintained should be the average of the pressures at the start and end of each step. In this case the difference between the two pressures must be less than twice the safety margin (S) used in the calculations.

Steps drawn at the average of the pressures at the start and end of each step.
ANNEXE IV

WELL VOLUMES FORM
PHASE: DEPTH: metres DATE:

Volume mud in circulation: $d_1$:
Volume mud in reserve: $d_2$:

Volume Casing (int') =
Volume open hole =

**VOLUME WELL EMPTY**

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Drill Collars</td>
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</tr>
<tr>
<td>Vol. ext'</td>
<td>(bbls/ft)(1/m)</td>
<td>(m)(ft)</td>
<td></td>
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<td>Vol. int'</td>
<td>(bbls/ft)(1/m)</td>
<td>(m)(ft)</td>
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</tr>
<tr>
<td>Vol. metal</td>
<td>(bbls/ft)(1/m)</td>
<td>(m)(ft)</td>
<td></td>
</tr>
<tr>
<td>Drill Collars</td>
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<tr>
<td>Vol. ext'</td>
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<td>Vol. int'</td>
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<td>Vol. metal</td>
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<td>Drill Pipe</td>
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<tr>
<td>Vol. ext'</td>
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<td></td>
</tr>
<tr>
<td>Vol. int'</td>
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<tr>
<td>Vol. metal</td>
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</tr>
<tr>
<td>Displacement drill string (Vol ext')</td>
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</tr>
<tr>
<td>Volume Interior</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Volume metal</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**VOLUME ANNULUS**

**VOLUME INTERIOR**

**VOLUME MUD IN WELL**

Author: N. CAMPBELL  Date: SEPTEMBER, 1978  Dwg. No: 16285
Drafting: J.M.B  Report No: Base: Plan:
ANNEXE V

MUD CONTROL FORM
<table>
<thead>
<tr>
<th>TIME</th>
<th>WEIGHT (MARSH)</th>
<th>VISCOSITY (CC/30')</th>
<th>FILTRATE</th>
<th>SAND CONTENT</th>
<th>TANK 1</th>
<th>TANK 2</th>
<th>TANK 3</th>
<th>LOSSES</th>
<th>GAINS</th>
<th>SURFACE OR SUBSURF</th>
<th>ADDED MUD PRODUCTS AND COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

**DRILLER:**

**DERRICKMAN:**

**PUMP NO** | **LINER** | **SPM** | **FLOW RATE** | **DESAND (HRS)** | **DESILT (HRS)**
ANNEXE VI

KILLING A WELL

"DRILLERS METHOD"
Where:


debug abbreviations

\[\begin{align*}
\text{SIDPP} &= \text{Shut in drill pipe pressure} \\
\text{SICP} &= \text{Shut in casing pressure (annulus)} \\
\text{di} &= \text{Initial mud weight (SG or PPG)} \\
\text{dr} &= \text{Mud weight required (SG or PPG)} \\
\text{Z} &= \text{Depth (metres or feet)} \\
\text{Q} &= \text{Flow rate during drilling} \\
\text{Qr} &= \text{Reduced flow rate (normally half of drilling flow rate)} \\
\text{CCP} &= \text{Pressure loss at reduced flow rate (constant Circulating Pressure)} \\
\text{M.Ad.P} &= \text{Maximum admissible pressure under a closed BOP in respect to fracturing the formation at last casing shoe depth.} \\
\text{M.W.P} &= \text{Maximum well pressure allowable under a closed BOP in relation to BOP pressure rating or casing burst pressure. May also be M.Ad.P.} \\
\text{SG} &= \text{Mud weight in Specific Gravity} \\
\text{PPG} &= \text{Mud weight in Pounds per Gallon (US)} \\
\text{Kg/cm}^2 &= \text{Kilograms per square centimeter.} \\
\text{l/m} &= \text{Litres per metre.} \\
\text{bbls/ft} &= \text{Barrels per foot} \\
\text{Vint} &= \text{Volume interior} \\
\text{Van} &= \text{Volume annulus} \\
\text{Vtot} &= \text{Volume total in circulation} \\
\text{CDPP} &= \text{SIDPP + CCP + S = Pressure loss at reduced flow rate plus shut in drill pipe pressure plus pressure safety factor = Pressure required on stand pipe to begin killing the well.} \\
\text{S} &= \text{Pressure safety factor. Usually 14 Kg/cm}^2 (200 \text{ psi}) \text{ or 5 Kg/cm}^2 (70 \text{ psi}) \text{ per 1000 metres (3300 feet) of depth.} \\
\text{CDPPr} &= \text{Surface pressure loss after addition of barytes when such new mud is at bit.} \\
\text{PR} &= \text{Pressure reduction by each point mud is raised.} \\
\text{A} &= \text{Quantity of barytes required to raise initial mud weight to required mud weight} \\
\text{B} &= \text{Total volume of barytes required.} \\
\text{N} &= \text{Number of cycles of circulation choses to kill the well.} \\
\text{d} &= \text{Number of points mud weight is raised each cycle of circulation.} \\
\text{C} &= \text{Rate at which barytes is added to the mud system.} \\
\text{deqv} &= \text{Mud weight to pressure at given depth.} \\
4.2 &= \text{Density of barytes in SG.}
\end{align*}\]
KILLING A WELL BY USING THE "DRILLERS METHOD" AFTER SHUT IN PRESSURES

HAVE BEEN OBTAINED

1) EVACUATION OF FLUID AND/OR GAS THAT HAS ENTERED A WELL (SEE NOTE BELOW)
   1.1) Open the choke manifold
   1.2) Recomence circulation at half the normal flow rate as that used in drilling and keep this flow rate constant (see Drillers Instructions Chart for: Qr).
   1.3) Simultaneously operate the adjustable choke to maintain a constant back pressure on the annulus equal to the SICP plus a safety factor of 200 psi (14 kg/cm²)
   1.4) When the annulus pressure is stabilised note the pressure on the drill pipe and maintain at a constant pressure by using the adjustable choke until one cycle of circulation is completed and the intruding fluid and/or gas is evacuated from the well.

2) CALCULATE THE MUD WEIGHT REQUIRED TO CONTROL A WELL
   2.1) Pressure on drill pipe with well shut in = SIDPP in kg/cm²
       Safety factor: 200 psi (14 kg/cm²)
       Depth of well: Z in meters
       Weight of mud in circulation: Initial mud weight: di
       Weight of mud required: dr
       Therefore: \( dr = di + 10 \frac{SIDPP + 14}{Z} \) in Specific Gravity
   2.2) Fabricate a volume of mud equal to the volume of mud in circulation at the mud weight calculated at dr.

3) KILLING THE WELL
   3.1) Pump the mud at mud weight dr, maintaining a constant pressure on the annulus equal to SIDPP + 14 kg/cm² by using the adjustable choke.
   3.2) When the volume of the interior of the drill pipe has been pumped note the pressure on the drill pipe and maintain at a constant pressure during the rest of the circulation and until the well has been killed.
NOTE: It is important to evacuate the fluid and/or gas that has entered the well before adding barytes to the mud.

4) PRESSURES

Pore pressure can be calculated as:

\[ P_{pore} = \frac{Z \times d_i}{10} + \frac{SIDPP}{10} \text{ in kg/cm}^2 \]

or \[ P_{pore} = Z \times d_i \times 0.052 = SIDPP \text{(Psi) in psi} \]

Mud weight required can be calculated as:

\[ dr = d_i + 10 \times \frac{SIDPP}{Z} \]

in Specific Gravity

or \[ dr = d_i + \frac{SIDPP + 200}{0.052 Z} \]

in P.P.G.

Circulation pressure required to kill a well

\[ CDPP = CCP + SIDPP + S \]

Quantity of Barytes required to kill a well

\[ A = \frac{4.2 \times (dr - d_i)}{4.2 - dr} \]

in kilograms per litre

or \[ A = \frac{4.2 \times (dr - d_i)}{4.2 - dr} \times 350 \]

in lbs per bbl.

Total Barytes required

\[ B = V_{tot} \times A \]

in kilograms if \( V_{tot} \) is in litres

or \[ B = V_{tot} \times A \]

in pounds if \( V_{tot} \) is in bbls.

Where:

- \( P_{pore} \) = Pore pressure
- \( Z \) = Depth in meters
- \( SIDPP \) = Shut in drill pipe pressure
- \( d_i \) = Initial mud weight
- \( dr \) = Required mud weight
- \( CDPP \) = Circulation pressure required
- \( CCP \) = Pressure loss at reduced flow rate
- \( S \) = Safety factor, usually 200 psi (14 kg/cm\(^2\))
- \( A \) = Quantity of Barytes required Kg/l or lbs/bbl
- \( B \) = Total quantity of Barytes required kg or lbs
- \( V_{tot} \) = Total volume of mud in circulation

NOTE 1 kg/cm\(^2\) = 14.2233 psi 1 psi = 0.0703 kg/cm\(^2\).
ANNEXE VII

12" 3000 PSI WELLHEAD
Australian Aquitaine Petroleum Pty Ltd.

RECOMMENDED WELLHEAD ARRANGEMENT

12" 3000 FOR DRILLING 12 1/4" HOLE

Hydril GK
12" 3000

Pipe rams
Shaffer/Cameron Double
12" 3000

Blind rams

Kill line 2" 3000
Mud Cross 4" or 3" 3000
Choke line

Spacer Spool

2" plug
2" valve
Casing spool 13 3/8" x 9 5/8" 3000

13 3/8" Casing

Flow nipple 8" or 10"

Line to rig floor (Drillers position)
with Martin Decker gauge or
similar to monitor annulus pressure
if well is shut in.

Drafting: S. W. S.
Report No.: S100 P10

ANNEXE VII

Author: N. CAMPBELL
Date: SEPT 1978
Dwg. No.: 16286
ANNEXE VIII

12" 3000/10" 3000 WELLHEAD
RECOMMENDED WELLHEAD ARRANGEMENT

12" 3000 / 10" 3000 FOR DRILLING 8 1/2" HOLE

Flow nipple 8" or 10"

NOTE: Adapter flange or mud cross may be used as cross-over from 10" 3000 or 12" 3000

Hydri 12" 3000

Pipe rams
Shaffer / Cameron Double
12" 3000
Blind rams

Kill line 2" 3000

Mud Cross
10" 3000

4" or 3" 3000 choke line

Line to rig floor (Drillers' position) or above cellar level with Martin Decker gauge or similar to monitor annulus pressure if well is shut in.

Casing spool 9 5/8" x 7"/5 1/2"
10" 3000

Conductor 13 3/8"

9 5/8" Casing

Author: N. CAMPBELL
Date: SEPT 1976
Doc No: 16287
ANNEXE VIII
ANNEXE IX

10" 5000 PSI WELLHEAD
Australian Aquitaine Petroleum Pty. Ltd.

RECOMMENDED WELLHEAD ARRANGEMENT

10" 5000 FOR DRILLING 8\frac{1}{2}" HOLE

- Hydri G K 10" 5000
- Ring gasket R54
- Pipe rams
- Shaffer / Cameron Double 10" 5000
- Blind rams
- Mud Cross 10" 5000
- R54
- 2" plug
- Spool 2" 10" 5000 x 12" 3000
- 2" 5000
- R54
- Testing flange 12" 3000
- R57
- R57
- 2" plug
- Casing spool 13\frac{3}{8}" x 9\frac{5}{8}" 3000
- 9\frac{3}{8}" casing
- Line to rig floor (Drillers position)
- with Martin Decker gauge or similar to monitor annulus
- pressure if well is shut in.

Avtto: N. CAMPBELL
Date: SEPT. 1978
Drafting: S.W.S.
Report No.

Dwg. No. 16 288
SAFETY CONTROL FORM

To be completed each week and at after each change in the BOP or H.P. System.

A. DISPLAYS

Are the following documents displayed at indicated places:

1. Well drilling program chart (except for tight hole).
2. BOP's and choke manifold drawings.
3. Driller's procedures (model F 8 bis) filled in by Operator's Supervisor.
4. Mud system drawings.
5. Pump liners, maximum pressure, volume per stroke.
6. Mud volumes and inventory.
   6.1 Volume and weight of active mud.
   6.2 Volume and weight of reserve mud.
   6.3 Barite inventory (or Calcium Carbonate).
   6.4 Bentonite inventory.
   6.5 Lost circulation materials inventory.
   6.6 Cement inventory.
7. Mud pit level control instructions.
8. Alert instructions for the on-site geologist.
9. Addresses and telephone numbers of Operator's and Contractor's Supervisors.

B. CONTROL EQUIPMENT

1. Can gas separated from the mud be safely discharged and flared?
2. Is the flare located outside the restricted area?
3. Are the flare stack and flare line well anchored?
4. Has the degasser been operated in the last two weeks or at specified intervals?
5. On each trip or every two days, are the ram-type BOP's operated with reduced flow rate established through chokes?
6. Is the annular preventer operated no more than once a week?
7. Are both main and remote BOP hydraulic control systems in working condition?
8. Is the BOP emergency closing system in working condition?
9. If this system is hand operated, are the number of turns clearly labeled on the hand wheels?
10. Are valves on BOP's, choke manifold and fittings greased and operated once a week?
11. Is the kelly-cock operated and greased on each trip?
12. Are BOP bolted flanges checked every month?
13. Are BOP's correctly centered and anchored (no vibration)?
14. Are BOP's, fittings and choke manifold tested under pressure after work on this equipment, after a casing job, before entering a reservoir or periodically (every month unless otherwise specified)?
15. Are extra parts for chokes available?
16. Does the accumulator capacity permit one closing and one opening of the entire BOP components?
17. Can all preventers be closed in less than 20 seconds?
18. Can accumulators be recharged in less than 10 minutes?
19. Can the annular preventer closing pressure be adjusted?
20. Are there devices to ignite the flare (flare gun)?
21. Are explosimeters available to check cellar and sub-structure atmosphere?
22. On the rig floor, are two inside BOP's available and are they properly maintained, and provided with the right subs to be stabbed on drill pipes and drill collars?
23. Is there one properly maintained high pressure circulating head with right subs?

24. Are there five (5) 5,000 psi WP (or more) chiksan units with fittings to be nipped up to the stand pipe, the circulating head or the choke manifold?

25. Is there a device to cut the logging cable?

26. Is there a pair of bronze sledge hammers?

C. DETECTION EQUIPMENT

1. Is the possum belly tank nipped up and in use?

2. Is the mud pit level recorder working?

3. Is the total-gas detector properly nipped up?

4. Is the drilling rate recorder working?

5. Is the extra detection equipment provided for in the drilling and mud-logging contracts in working condition?

D. PERSONNEL TRAINING

1. In order to check competence and skill of mud-logging crews, mud engineers and drilling crews, are alert drills held once a week, times and recorded on the daily report?

   If not held weekly, indicate frequency.

E. TRANSPORTATION

Means of transportation and time necessary to supply the following items to the rig:

1. H.P. pumping unit.

2. Mud products.

3. Cement.
### SAFETY CONTROL SHEET

FOR BLOW OUT PREVENTION ON LAND RIG

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<thead>
<tr>
<th>PERIOD:</th>
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<tr>
<td>FROM</td>
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<td>WELL:</td>
<td>COUNTRY:</td>
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#### A. DISPLAY

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<td>CONTRACTOR OFFICE</td>
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<td>DOG HOUSE</td>
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<tr>
<td>GEOLOGY LAB.</td>
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<tr>
<td>MUD TANKS</td>
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#### B. CONTROL EQUIPMENT

<table>
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<tr>
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#### C. DETECTION EQUIPMENT

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#### D. PERSONNEL TRAINING

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<th>FREQUENCY:</th>
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#### E. TRANSPORT

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<tr>
<td></td>
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</table>

#### REMARKS - SUGGESTIONS:

______________________________
______________________________
______________________________
______________________________
______________________________

DATE AND SIGNATURE OPERATOR'S SUPERVISOR

______________________________
ANNEXE XI

GENERAL SAFETY RULES
1. **SMOKING**

   After spudding in, smoking will not be permitted within a radius of 100 feet of the wellhead. Smoking on rig floor, mud tanks, around BOP and mud pumps will not be permitted.

2. **WELDING**

   Permission for welding and oxy-acetylene cutting within a radius of 100 feet of the wellhead must be obtained from the Aquitaine representative.

3. **EQUIPMENT**

   Safety guards where provided, must be installed on moving machinery.

4. **ENGINES**

   The main rig engines must be equipped with spark arrestors and have automatic shut down.

5. **PERSONNEL**

   Safety hats and safety boots must be worn at all times. No unauthorised personnel will be permitted on the well site without approval from the Aquitaine representative at the well site.

Encl. Hydrill Testing and Rotating/stripping pressures
HYDRIL BLOW-OUT-PREVENTERS TESTING PRESSURES

(from Hydril information)

The indicated pressures are average required pressures and are listed only as a guide to the proper setting of the regulator valve. The actual pressure required to make a seal will vary slightly for each individual packing unit. The pipe sizes listed are the optimum causing the least strain on the packing unit.

WHEN ROTATING OR STRIPPING THROUGH A HYDRIL BOP:-

Use only the minimum closing pressure required to hold well pressure. When stripping, a small amount of leakage should occur around the drill pipe for lubrication purposes. The small amount of leakage also assures the operator that the light holding pressure is being applied. Leakage is especially important when rotating for the purpose of removing heat produced by friction of pipe rotation on packing unit.
<table>
<thead>
<tr>
<th>Size Blowout Preventer</th>
<th>Recommended size pipe on which to close</th>
<th>Recommended closing pressure for listed pipe</th>
<th>Recommended closing pressure on open hole</th>
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<tbody>
<tr>
<td>MSP-6-2000</td>
<td>2.7/8&quot;</td>
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