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MANAGEMENT, REGULATION, AND ENFORCEMENT

Buoyancy Casing Analysis

REPORT

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Quality Assurance

The scope of this report is limited to the matters expressly covered. This report is prepared exclusively for and at the request of the BOEMRE. In preparing this report, Keystone Engineering Inc has relied on information provided by the BOEMRE. KEI has made no independent investigation as to the accuracy of the information provided and has assumed the information is accurate and complete.

All findings and conclusions stated in this report are based upon the information as it existed at the time of the report. Changes to the information may affect the findings and conclusions.

In the course of this investigation, KEI had conversations with persons not on the investigation team and this report draws upon the members understanding of those conversations. The investigation team did not record or produce verbatim transcripts of those conversations nor did the team ask the other parties to review or endorse the notes taken by the team members.

Graphics are used to depict information and conditions; these may be simplified or not to scale. They are intended as an aid to the reader in the context of the report.

The view, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Government position, policy or decision, unless so designated by other documentation.

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Section 1 - Introduction

Objective

Keystone Engineering Inc (KEI) was contracted by the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) to review the design of the BP Macondo Well 9-7/8" by 7" production casing and its hanger and to calculate the static forces acting upon the casing to determine if they could lift the casing and hanger from its design location. The deliverables are:

- Calculation of buoyancy force acting on the 9-7/8" by 7" production casing
- Calculation of forces on the
    - Bottom of the 7" casing
    - Crossover of the 9-7/8" by 7" casing
    - 9-7/8" by 7" casing hanger

The BOEMRE provided KEI with data that included a wellbore schematic, a casing crossover schematic, reports from cement service providers and drilling reports. The data is listed in the Appendix B.

Method

A spreadsheet model of the wellbore was developed which considered the properties of the annulus casing, production casing, fluids in both the annulus and production casing, and formation temperatures at wellbore depths. This data was derived from the information provided by BOEMRE.

Several possible operating conditions were considered and eight were chosen for detailed calculations. The conditions are:

- Condition 1 - Wellbore as designed with the cement complete as designed. The design includes 14 ppg mud in the annulus up to the seal/hanger at the 5061 foot depth and the production casing up to the Rig Kelly Bushing (RKB). (See Fig 3.1.)
- Condition 2 - Communication through the cement to the annulus that allows the pressure at the bottom of the annulus to drop to the reservoir pressure. The annulus is still full of 14 ppg mud up to the seal at the 5061 feet. Production casing is full of 14 ppg mud. (See Fig 3.2.)
- Condition 3 - Communication through the cement to the annulus that allows production fluid into the annulus. Annulus is filled with production fluid up to the seal at the 5061 feet. Production casing is full of 14 ppg mud. (See Fig 3.3.)
- Condition 4 - Communication through the cement to the annulus that allows production fluid into the annulus. Annulus is filled with production fluid up to the seal at the 5061 feet. The production casing is filled with gel, seawater and mud. The mud level is at 8367 feet, which is the depth of the drill string in the wellbore schematic. (See Fig 3.4.)
- Condition 5 - Communication through the cement that allows production fluid into the production casing. Annulus is filled with 14 ppg mud up to the seal at the 5061 feet. The production casing is filled with gel, seawater and mud. The mud level is at 8367 feet which is the depth of the drill string in the wellbore schematic. (See Fig 3.5.)
- Condition 6 - Communication through the cement that allows production fluid into the production casing. Annulus is filled with production fluid up to the seal at the 5061 feet. The production casing is filled with static production fluid. (See Fig 3.6.)

- Condition 7 - Communication through the cement that allows production fluid into the production casing. Annulus is filled with 14 ppg mud up to the seal at 5061 feet. The production casing is filled with static production fluid. (See Fig 3.7.)
- Condition 8 - Communication through the cement that allows production fluid into the production casing. Annulus is filled with production fluid up to the seal at 5061 feet. The production casing is filled with static production fluid. The pressure in the casing at 5061feet is set to 2358 psi, which is the pressure from Condition 5 with gel and seawater in the casing above the wellhead. This is a close approximation to the pressure if the production fluid is flowing to the surface. The production fluid is not modeled in HSYS since the flow rate is not known. This condition will give an estimate of the highest pressure in the annulus and the lowest pressure in the casing. (See Figure 3.8)

These conditions are detailed in Section 3 of this report. Diagrams showing the fluid levels and the pressures are included for each condition.

The production casing was considered to have been set on its hanger while the cement was still fluid so the weight of the casing is supported by the hanger only and no axial support is given by the cement or the bottom of the hole. Without this assumption, the forces on the hanger cannot be determined.

The buoyant forces in each condition are developed using the principle of Archimedes that the buoyant force on a submerged object is the weight of the displaced fluid. The force varies depending on the weight of the fluid in the annulus; in this study the fluid is either 14 ppg mud or production fluid from the reservoir. The shape of the object has no effect on the buoyant force, so the pressure differentials at the 9-7/8" by 7" crossover have no effect.

The differential pressure between the annulus and the interior of the production casing will cause the casing dimensions to change from the nominal design. The amount of deformation was calculated to determine the effect. The temperature of the casing will also change the dimensions, and those changes were determined. The calculations are included in Section 4.

The production casing is made of Q-125 steel (9-7/8") and HC-125 steel (7"). These steels are classified as Low Chrome Moly steels. The properties of Chrome Moly steels were taken from the table for "Low Chrome Moly steels, chrome < 3%" from ANSI B31.3. The properties are included in Section 4.

The dimensions of the 9-7/8" by 7" crossover were taken from the drawing by K&B (Appendix B). The weight and volumes of the crossover were calculated separately and entered into the buoyancy calculations as a combined weight and volume. The details are included in Section 4.

Differences in the annular and interior pressures at the crossover will result in net radial forces at the crossover. Also, due to the shape of the crossover (larger top reducing to a smaller bottom), the areas exposed to the annular and interior pressures differ. The crossover is therefore subject to a net vertical force that is calculated in Section 4. Note that this vertical force is included in the buoyancy force and is not additional. The principle of Archimedes uses displacement weights, the shape of the object (hull) is not considered.

The temperature and compressibility properties of the Synthetic Oil Based Mud (SOBM) were not available so a constant 14 ppg density was used.

The density of the production fluid was developed by entering the component analysis from Schlumberger (Appendix B, Item 6) into a HYSYS model for a static column from the bottom of the well to the hanger. The boundary conditions for the column are the bottom hole temperature and pressure and an upper temperature of 110 Deg F at the rig floor. The upper temperature was chosen to match wellhead temperatures commonly observed in production operations. The HYSYS model is detailed in Section 5.

The capacity of the casing strings is calculated in Section 4.

The forces on the bottom of the casing were determined from the following condition. The production casing and its annulus were filled with mud and the cement was pumped into the bottom of the well with the casing elevated above the hanger. The casing was then lowered into the cement, which was still fluid. The casing was then supported by the hanger. The pressures on the annulus and interior sides are equal, and the axial force is that pressure times the area of the 7" 32 lb/ft casing. The axial force is then the hydrostatic pressure (13,200 psi) times the casing metal area (10 sq in). Three conditions are possible:

- The cement seals the casing interior but allows communication between the annulus and the reservoir. The axial force remains the same, 132,000 lb.
- The cement allows communication between the interior and the reservoir but seals the annulus. The hydrostatic force is the reservoir pressure.
- The reservoir communicates with both the annulus and the interior. The hydrostatic force is the reservoir pressure.

The resulting forces and pressures are listed in the results for each condition. Note that these forces are included in the buoyant force calculation and are not to be added to the buoyant force.

Temperatures along the casing string will change with fluid flow from the reservoir. The casing was assumed to be in equilibrium with the formation temperatures when the casing is set. Determination of casing temperatures depends on many factors (e.g. fluid properties, flow rates, cement and annular fluid properties, reservoir properties and time) that are not known. The determination of forces due to temperature expansion in the casing is beyond the scope of the investigation.

Section 2 - Executive Summary

The design of the 9-7/8" by 7" production casing for the Macondo well was reviewed for determination of the buoyant force that would lift the production casing from its hanger. Eight possible operating conditions of the wellbore were examined. The key results are listed below:

- Conditions 5 and 8 result in a net upward force on the hanger.
- The weight of the production casing steel is greater than the weight of the displaced fluid if the fluid is 14 ppg mud. Since the mud is the heaviest of the displaced fluids, the production casing is not buoyant if the pressure forces at the hanger are not considered.
- The weight of the contents of the production casing opposes the buoyant force if the cement at the bottom of the casing seals the casing. The weight of the contents is the largest force in the calculation.
- The net buoyancy of the production casing is:
  - the weight of the displaced fluid
  - minus the weight of the steel
  - minus the weight of the contents of the casing (if the cement seals the contents)
- If the cement at the bottom of the casing does not seal the casing, the weight of the contents has no influence on the buoyant force.
- The net force on the production casing hanger is:
  - the net buoyancy of the casing
  - plus the annulus pressure at the hanger times the projected annular area of the hanger
  - minus the interior pressure of the casing times the projected inside area of the casing
  - This calculation assumes the production casing is set with no support from the cement or the bottom of the hole, i.e. the casing is set on fluid cement.
- The annulus pressure and pressure inside the production casing at the hanger create large forces.
  - If the cement at the bottom of the casing does not seal, the net buoyancy becomes positive (upwards) if the annulus pressure is greater than the interior pressure by a certain amount. This amount changes for each condition depending upon the density of the fluids in the annulus and interior.
  - If the cement seals, the net buoyancy will be negative (downwards) regardless of annulus pressure.
- The temperatures and pressures of the well do not change the radial dimensions of the production casing enough to be significant. The changes are about 0.13% (temperature of 262 Deg F) and 0.18% (differential pressure of 6572 psi).
- The production fluid static column was modeled in HYSYS using reference temperatures of 110 and 160 Deg F to determine sensitivity to the assumed temperature. The net change was 0.36% which is considered negligible.
- Forces due to temperature changes of the production casing were not determined.

Section 3 - Calculations & Figures

Condition 1

Basis
The wellbore is filled with mud fluid and the cement is intact as designed.

The production casing is filled with mud to the Rig Kelly Bushing (RKB).

The annulus is filled with mud to the production casing hanger.

Cement seals the reservoir from the annulus and the production casing, so the pressures in the well are hydrostatic pressures of the mud.

Since the production casing is sealed at the bottom, lifting the casing will lift the contents of the casing up to the RKB, and so the weight of the contents is included in the buoyancy calculation. This weight of the contents will act to oppose the buoyancy force.

The hydrostatic pressure in the annulus at the bottom of the hanger is due to mud fixed in the annulus after cementing when the production casing is lowered into the hanger. This annulus pressure acts upon the exposed annular area of the production casing hanger creating an upward force that adds the buoyant force. This upward force is opposed by the hydrostatic pressure in the production casing acting on the exposed interior area of the hanger.

The area of the production casing hanger exposed to the annulus pressure is the area between the inner diameter of the 18-3/4 inches casing (18.62 inches) and the outer diameter of the production casing hanger (9-7/8 inches). This area was determined to be 195.7 sq. in. (from the Dril-Quip drawing 2-PD-32424-02CP, Appendix B, Item 3).

The area of the production casing hanger exposed to the production casing pressure is the area between the inner diameter of the 18-3/4" hanger (18.62 inches) and the inner diameter of the production casing hanger (8.553 inches). This area was calculated to be 214.8 sq. in. (from the Dril-Quip drawing 2-PD-32424-02CP, Appendix B, Item 3).

The casing shoe was treated as 7" casing.

Friction between the production casing and cement or (annular or interior) fluids was not considered. The production casing does not lift in this condition so friction does not apply.

The ability of the cement to hold the production casing in place was not considered.

The shoe and bottom of the hole formation will resist the lowering of the production casing. Since this effect is applicable only if the casing is lowered by a negative buoyant force and this study is considering the lifting of the casing, the resistance of the shoe and formation is outside the scope of this study.

The buoyancy calculation sheet (Table 3.1) and Figure 3.1 are included in this section.

Area calculations are included in Section 4.

Results

- The buoyancy is a negative 1.63 million lb, so the production casing will not lift.
- The net force on the hanger is a negative 1.70 million lb, so the hanger will not lift
- The resultant of the pressure forces on the hanger is a downward force.
- The casing and hanger will not lift in this condition.
- The weight of the production casing is more than the weight of the displaced mud. Since this condition has the heaviest displaced weight of all the conditions, this indicates that the buoyant force will be positive (cause the casing to lift) only with a high differential between the annulus pressure and the production casing pressure at the hanger.
- The pressures and forces at the crossover due to the pressures and area differences are:
  - Annular pressure 9077 psi
  - Interior pressure 9077 psi
  - Vertical force 73500 lb, upwards
- The pressures and forces at the bottom of the casing are:
  - Annular pressure 13200 psi
  - Interior pressure 13200 psi
  - Vertical force 132000 lb, upwards

Condition 2

Basis

The wellbore is filled with mud fluid. Communication through the annulus cement allows reservoir fluid into the annulus.

The production casing is filled with mud to the RKB.

The annulus is filled with mud to the production casing hanger and is sealed at the hanger. The pressure at the top of the annulus is determined by hydrostatic weight of the mud using the reservoir pressure as the known pressure. The pressure at the bottom of the annulus is reservoir pressure. Mud flows into the reservoir until pressures are equal.

Cement seals the reservoir from the production casing, so the pressure inside the production casing is the hydrostatic pressure of the mud.

Since the production casing is sealed at the bottom, lifting the casing will lift the contents of the casing up to the RKB, and so the weight of the contents is included in the buoyancy calculation. This weight of the contents will act to oppose the buoyancy.

Pressures in the annulus and in the production casing affect the buoyant force on the hanger as described in Condition 1.

The areas of the production casing hanger exposed to the annulus and production casing pressures are as described in Condition 1.

The casing shoe was treated as 7" casing.

Friction between the production casing and cement or annular or interior fluids was not considered. The production casing does not lift in this condition so friction does not apply.
The ability of the cement to hold the production casing in place was not considered.

The ability of the shoe and bottom of the hole formation to resist the lowering of the production casing was ignored per the reasoning stated in Condition 1.

The buoyancy calculation sheet (Table 3.2) and Figure 3.2 are included in this section.

Results

- The buoyancy is a negative 1.63 million lb, so the production casing will not lift.
- The net force on the hanger is a negative 1.84 million lb, so the hanger will not lift
- The decrease in the net force on the hanger from Condition 1 is due to the reduction in annulus pressure at the hanger.
- The resultant of the pressure forces on the hanger is a downward force.
- The casing and hanger will not lift in this condition.
- The pressures and forces at the crossover due to the pressures and area differences are:
    - Annular pressure 8354 psi
    - Interior pressure 9077 psi
    - Vertical force 46078 lb, upwards
- The pressures and forces at the bottom of the casing are:
    - Annular pressure 13200 psi
    - Interior pressure 11844 psi
    - Vertical force 132000 lb, upwards

Condition 3

Basis

Communication through the annulus cement allows reservoir fluid into the annulus. The annulus is filled with production fluid whose properties are determined from a HYSYS model for a static column. The composition of the production fluid was taken from the Schlumberger report (Appendix B, Item 6).

The production casing contains mud to the RKB.

This condition would occur if the reservoir – annulus communication occurred before the seawater was introduced into the production casing.

Cement seals the reservoir from the production casing, so the pressure inside the production casing is the hydrostatic pressure of the gel/seawater/mud column.

Since the production casing is sealed at the bottom, lifting the casing will lift the contents of the casing up to the RKB, and so the weight of the contents is included in the buoyancy calculation. This weight of the contents will act to oppose the buoyancy.

Pressures in the annulus and in the production casing affect the buoyant force on the hanger as described in Condition 1.

The areas of the production casing hanger exposed to the annulus and production casing pressures are as described in Condition 1.

The casing shoe was treated as 7" casing.

Friction between the production casing and cement or annular or interior fluids was not considered. The production casing does not lift in this condition so friction does not apply.

The ability of the cement to hold the production casing in place was not considered.

The ability of the shoe and bottom of the hole formation to resist the lowering of the production casing will be ignored per the reasoning stated in Condition 1

The buoyancy calculation sheet (Table 3.3), HYSYS model description and results, and Figure 3.3 are included in this section.

Results

- The buoyancy is a negative 2.0 million lb, so the production casing will not lift.
- The net force on the hanger is a negative 0.34 million lb, so the hanger will not lift
- The displaced fluid weight is reduced from Condition 1 because the production fluid is lighter than the mud.
- The annulus pressure at the hanger is higher than the interior pressure in the production casing, adding to the buoyant force.
- The net buoyancy force is greater than Condition 1.
- The casing and hanger will not lift in this condition.
- The pressures and forces at the crossover due to the pressures and area differences are:
  - Annular pressure 10540 psi
  - Interior pressure 9077 psi
  - Vertical force 128990 lb, upwards
- The pressures and forces at the bottom of the casing are:
  - Annular pressure 13200 psi
  - Interior pressure 11835 psi
  - Vertical force 132000 lb, upwards

Condition 4

Basis

Communication through the annulus cement allows reservoir fluid into the annulus. The production casing contains a drill string from the RKB to 8367 feet TVD. The production casing contains seawater above 8367 feet through the wellhead to the riser. The riser is filled with seawater to 300 feet below the RKB. The top 300 feet contains a gel with a density of 16.3 ppg.

This condition would occur if the reservoir – annulus communication occurred after the seawater was introduced into the production casing.

The annulus is filled with production fluid with properties per Condition 3.

Cement seals the reservoir from the production casing, so the pressure inside the production casing is the hydrostatic pressure of the mud.

Since the production casing is sealed at the bottom, lifting the casing will lift the contents of the casing up to the RKB, and so the weight of the contents is included in the buoyancy calculation. This weight of the contents will act to reduce buoyancy.

The drill string is supported by the rig and has no effect on the buoyancy of the production casing.

Pressures in the annulus and in the production casing affect the buoyant force on the hanger as described in Condition 1.

The areas of the production casing hanger exposed to the annulus and production casing pressures are as described in Condition 1.

The casing shoe was treated as 7" casing.

Friction between the production casing and cement or (annular or interior) fluids was not considered. The production casing does not lift in this condition so friction does not apply.

The ability of the shoe and bottom of the hole formation to resist the lowering of the production casing will be ignored per the reasoning stated in Condition 1

The buoyancy calculation sheet (Table 3.4), the HYSYS model description and results, and Figure 3.4 are included in this section.

Results

- The buoyancy is a negative 1.56 million lb, so the production casing will not lift
- The net force on the hanger is a negative 0.34 million lb, so the hanger will not lift.
- The weight of the production casing contents is reduced since the gel/seawater/mud column is lighter than that of 14 ppg mud.
- The net buoyancy force is greater than Condition 1.
- The annulus pressure at the hanger is greater than in Condition 1.
- The resultant of the pressure forces on the hanger is an upward force.
- The casing and hanger will not lift in this condition.
- The pressures and forces at the crossover due to the pressures and area differences are:
  - Annular pressure 10540 psi
  - Interior pressure 6818 psi
  - Vertical force 196363 lb, upwards
- The pressures and forces at the bottom of the casing are:
  - Annular pressure 13200 psi
  - Interior pressure 11835 psi
  - Vertical force 132000 lb, upwards

Condition 5

Basis
Communication through the production casing cement allows reservoir fluid into the production casing. The production casing contains a drill string from the RKB to 8367 feet TVD. The production casing contains seawater above 8367 feet through the wellhead to the riser. The riser is filled with seawater to 300 feet below the RKB. The top 300 feet is a gel with a density of 16.3 ppg.

This condition would occur if the production casing – reservoir communication occurred after the seawater was introduced into the production casing.

The annulus is filled with mud from the cementing operations. Pressures in the annulus are the same as Condition 1.

The bottom of the production casing is at reservoir pressure. The pressure profile in the production casing is the hydrostatic head of the gel/seawater/mud combination. The hydrostatic pressure of the gel/seawater/mud column is 11083 psi, less than the reservoir pressure of 11844 psi. The fluid level in the production casing will rise as the higher pressure reservoir flows into the casing.

Since the production casing is not sealed at the bottom, lifting the casing will not lift the contents of the casing up to the RKB. Therefore the weight of the contents is excluded from the buoyancy calculation.

The drill string is supported by the rig and has no effect on the buoyancy of the production casing.

Pressures in the annulus and in the production casing affect the buoyant force on the hanger as described in Condition 1.

The areas of the production casing hanger exposed to the annulus and production casing pressures are as described in Condition 1.

The casing shoe was treated as 7" casing.

Friction between the production casing and cement or annular or interior fluids was not considered because the value of friction force is dependent on many factors that are unknown. Friction, however, will only apply when the casing moves.

The ability of the cement to hold the production casing in place was not considered.

The ability of the shoe and bottom of the hole formation to resist the lowering of the production casing will be ignored per the reasoning stated in Condition 1.

The buoyancy calculation sheet (Table 3.5) and results and Figure 3.5 are included in this section.

The production casing and hanger may lift in this condition. When the hanger lifts, the pressures will equalize between annulus and the interior and the fluid in the annulus will flow to the interior. The amount of lift cannot be determined with the available information.

Results

- The production casing interior is underbalanced by about 756 psi, so the reservoir will flow into the casing.
- The buoyancy is a negative 0.11 million lb, so the production casing will not lift.
- The net force on the hanger is a positive 0.11 million lb, so the production casing can lift. Note the buoyancy force is included in this force.
- The casing and hanger can lift in this condition. Reservoir fluid has already entered the production casing in this condition, so the effect on flowrate of production fluids is small.
- The amount of lift was not determined.
- The pressures and forces at the crossover due to the pressures and area differences are:
  - Annular pressure 9078 psi
  - Interior pressure 6818 psi
  - Vertical force 140896 lb, upwards
- The pressures and forces at the bottom of the casing are:
  - Annular pressure 11835 psi
  - Interior pressure 11835 psi
  - Vertical force 118350 lb, upwards

Condition 6

Basis

Communication through production casing cement allows reservoir fluid into both the annulus and the production casing. The production casing contains production fluid in a static column (a flowing well is outside the study scope due to the uncertainty of the flowrate). The annulus also contains a column of static production fluid.

This condition would occur if reservoir communication occurred and if the communication were established between both the annulus and the production casing.

Production fluid properties were determined as in Condition 3. The bottom of the annulus and the production string are at reservoir pressure.

The pressure profile in the production casing is the combination of hydrostatic head of the production fluid and the friction drop of the flowing fluid. The production fluid has either swept the previous gel/seawater/mud fluid out of the production casing or has flowed around it.

The rate of flow is unknown. Since the pressure in the production casing is used only to determine the downward force on the hanger, intermediate pressures and temperatures are not determined.

Since the production casing is not sealed at the bottom, lifting the casing will not lift the contents of the casing up to the RKB. Therefore the weight of the contents is excluded from the buoyancy calculation.

Pressures in the annulus and in the production casing affect the buoyant force on the hanger as described in Condition 1.

The areas of the production casing hanger exposed to the annulus and production casing pressures are as described in Condition 1.

The casing shoe was treated as 7" casing.

Friction between the production casing and cement or annular or interior fluids was not considered. The production casing does not lift in this condition so friction does not apply.

The ability of the cement to hold the production casing in place was not considered.

The ability of the shoe and bottom of the hole formation to resist the lowering of the production casing will be ignored per the reasoning stated in Condition 1

The buoyancy calculation sheet (Table 3.6) and results and Figure 3.6 are included in this section.

Results

- The buoyancy is a negative 0.47 million lb, so the production casing will not lift.
- The net force on the hanger is a negative 0.64 lb, so the hanger will not lift.
- The resultant of the pressure forces on the hanger is a downward force. This is expected because the two pressures are equal and the interior area is larger than the annulus area.
- The bottom of the production casing is assumed to be open so the weight of the contents is not included in the buoyancy calculation.
- The pressures and forces at the crossover due to the pressures and area differences are:
    - Annular pressure 10540 psi
    - Interior pressure 10540 psi
    - Vertical force 85346 lb, upwards
- The pressures and forces at the bottom of the casing are:
    - Annular pressure 11835 psi
    - Interior pressure 11835 psi
    - Vertical force 118350 lb, upwards

Condition 7

Basis

Communication through production casing cement allows reservoir fluid into the production casing. The production casing contains production fluid in a static column (a flowing well is outside the study scope due to the uncertainty of the flowrate). The annulus contains a mud column from the original cement process.

This condition would occur if the reservoir communication occurred and if communication were established between the production casing but with no communication with the annulus.

Production fluid properties were determined as in Condition 3. The bottom of the production casing is at reservoir pressure. The pressures of the annulus are as in Condition 1.

The pressure profile in the production casing is the combination of hydrostatic head of the production fluid and the friction drop of the flowing fluid. The production fluid has either swept the previous gel/seawater/mud fluid out of the production casing or has flowed around it.

The rate of flow is unknown. Since the pressure in the production casing is used only to determine the downward force on the hanger, intermediate pressures and temperatures were not determined.

Since the production casing is not sealed at the bottom, lifting the casing will not lift the contents of the casing up to the RKB. Therefore the weight of the contents is excluded in the buoyancy calculation.

Pressures in the annulus and in the production casing affect the buoyant force on the hanger as described in Condition 1.

The areas of the production casing hanger exposed to the annulus and production casing pressures are as described in Condition 1.

The casing shoe was treated as 7" casing.

Friction between the production casing and cement or annular or interior fluids was not considered. The production casing does not lift in this condition so friction does not apply.

The ability of the cement to hold the production casing in place was not considered.

The ability of the shoe and bottom of the hole formation to resist the lowering of the production casing will be ignored per the reasoning stated in Condition 1.

The buoyancy calculation sheet (Table 3.7) and results and Figure 3.7 are included in this section.

Results

- The buoyancy is a negative 0.11 million lb, so the production casing will not lift.
- The net force on the hanger is a negative 1.28 million lb, so the hanger will not lift.
- The resultant of the pressure forces on the hanger is a downward force. This is because the interior pressure is higher (8816 psig) than the annulus pressure (3797 psig).
- The pressures and forces at the crossover due to the pressures and area differences are:
  - Annular pressure 9077 psi
  - Interior pressure 10540 psi
  - Vertical force 29872 lb, upwards
- The pressures and forces at the bottom of the casing are:
  - Annular pressure 11835 psi
  - Interior pressure 11835 psi
  - Vertical force 118350 lb, upwards

Condition 8

Basis

Communication through production casing cement allows reservoir fluid into the production casing. The production casing contains production fluid in a static column (a flowing well is out of the study scope due to the uncertainty of the flowrate). The annulus contains a column of production fluid that is static.

This condition would occur if the reservoir communication occurred and if communication were established between the production casing but with no communication with the annulus.

Production fluid properties for the annulus were determined as in Condition 3. The bottom of the production casing is at reservoir pressure. The pressures of the annulus are as in Condition 1.

The pressure profile in the production casing was set at 2358 psi at the TO casing and 11835 psi (reservoir pressure) at the bottom. No attempt was made to model the flowing well fluid and the pressure profile in the casing. The production fluid has either swept the previous gel/seawater/mud fluid out of the production casing or has flowed around it.

The rate of flow is unknown. Since the pressure in the production casing is used only to determine the downward force on the hanger, intermediate pressures and temperatures are not determined.

Since the production casing is not sealed at the bottom, lifting the casing will not lift the contents of the casing up to the RKB. Therefore the weight of the contents is excluded in the buoyancy calculation.

Pressures in the annulus and in the production casing affect the buoyant force on the hanger as described in Condition 1.

The areas of the production casing hanger exposed to the annulus and production casing pressures are as described in Condition 1.

The casing shoe was treated as 7" casing.

Friction between the production casing and cement or annular or interior fluids was not considered. The production casing does not lift in this condition so friction does not apply.

The ability of the cement to hold the production casing in place was not considered.

The ability of the shoe and bottom of the hole formation to resist the lowering of the production casing will be ignored per the reasoning stated in Condition 1.

The buoyancy calculation sheet (Table 3.8) and results and Figure 3.8 are included in this section.

The hanger will lift in this condition. When the hanger lifts, the pressures will equalize between annulus and the interior and the fluid in the annulus will flow to the interior. We could not determine the amount of lift with the current information.

Results

- The buoyancy is a negative 0.47 million lb, so the production casing will not lift.
- The net force on the hanger is a positive 0.75 million lb, so the hanger can lift.
- The resultant of the pressure forces on the hanger is an upward force. This is because the interior pressure is lower (2358 psig) than the annulus pressure (8816 psig).
- The pressures and forces at the crossover due to the pressures and area differences were not determined.
- The pressures and forces at the bottom of the casing are:
  - Annular pressure 11835 psi
  - Interior pressure 11835 psi
  - Vertical force 118350 lb, upwards

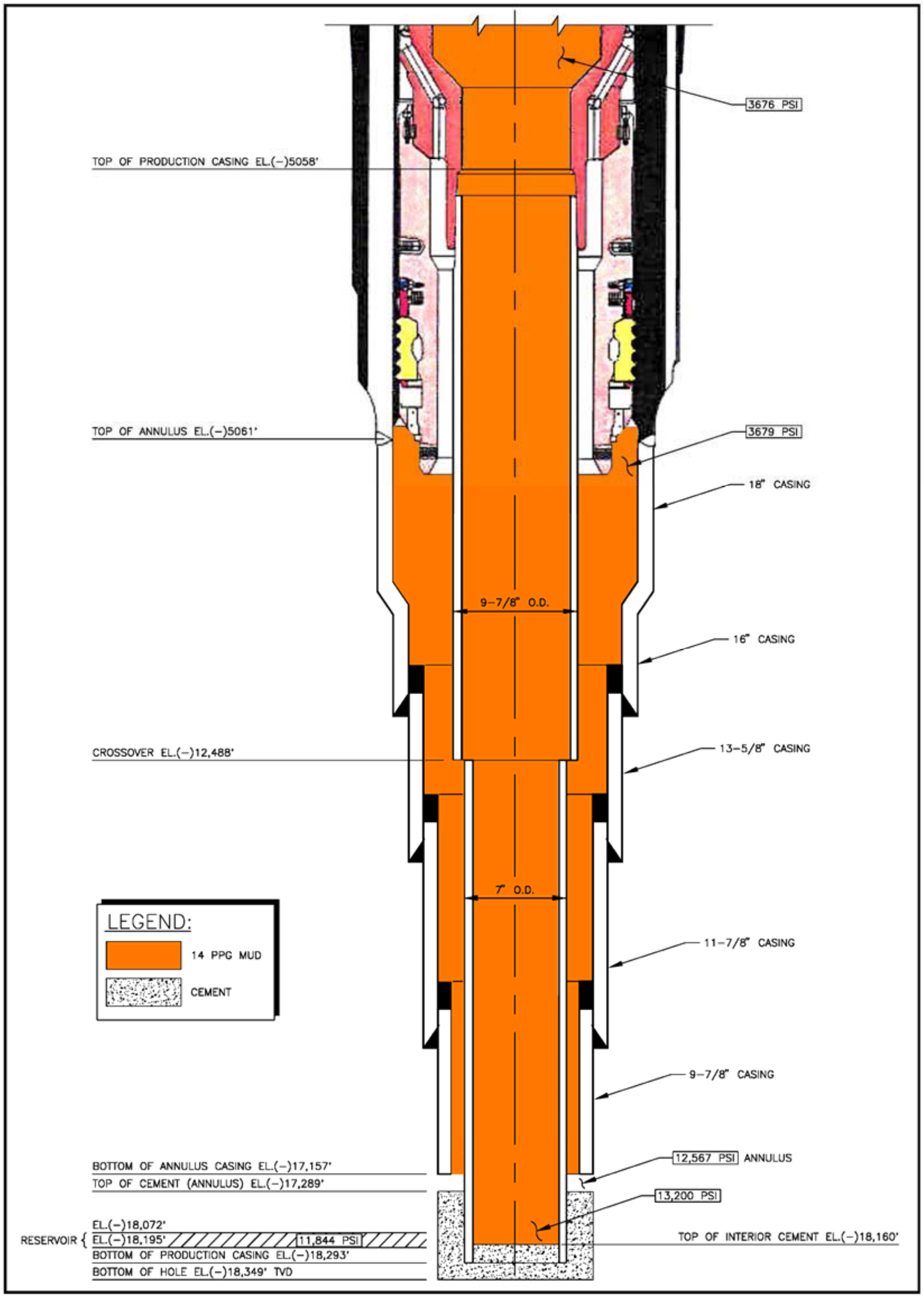

Figure 3.1 – Condition 1

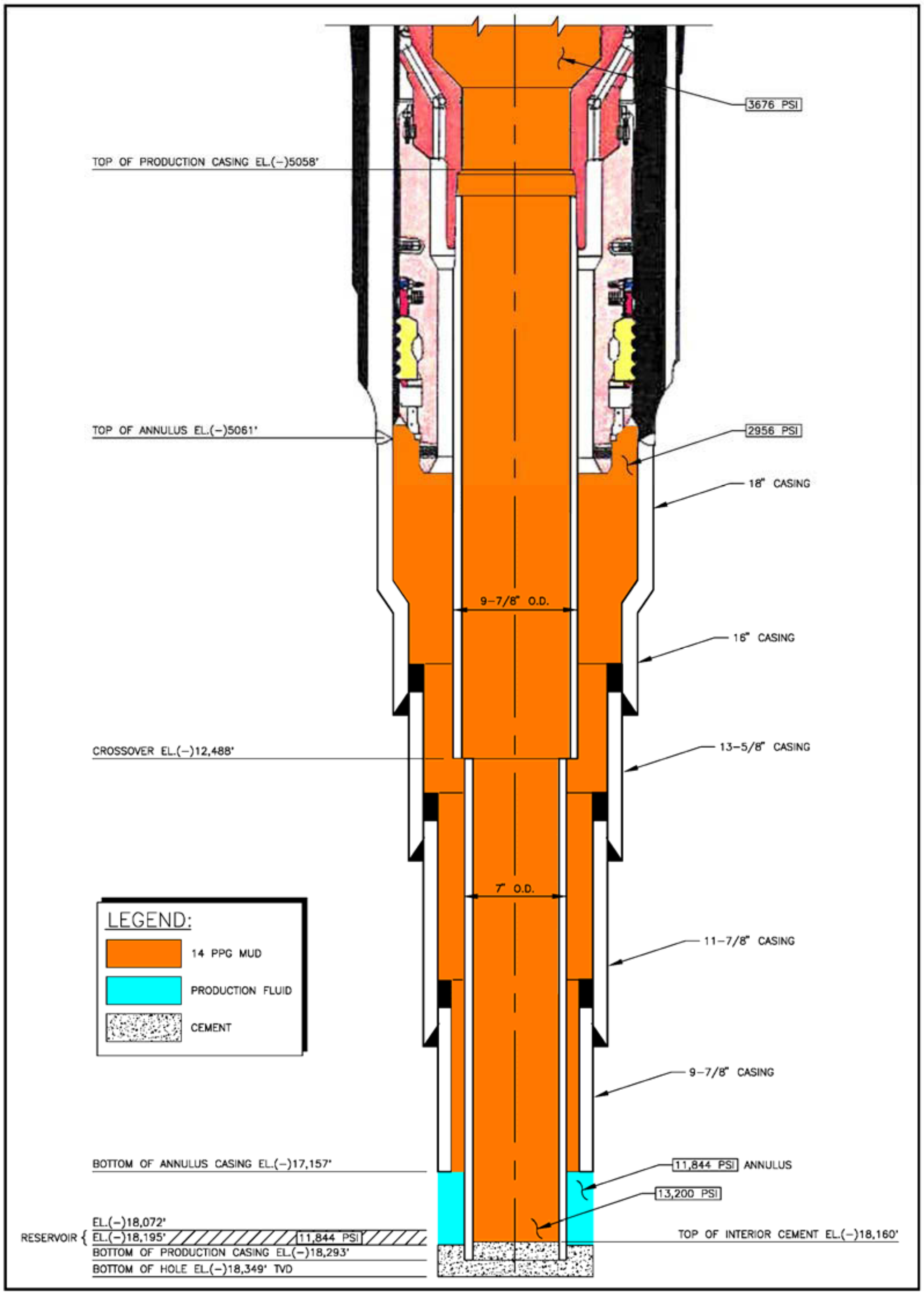

Figure 3.2 – Condition 2

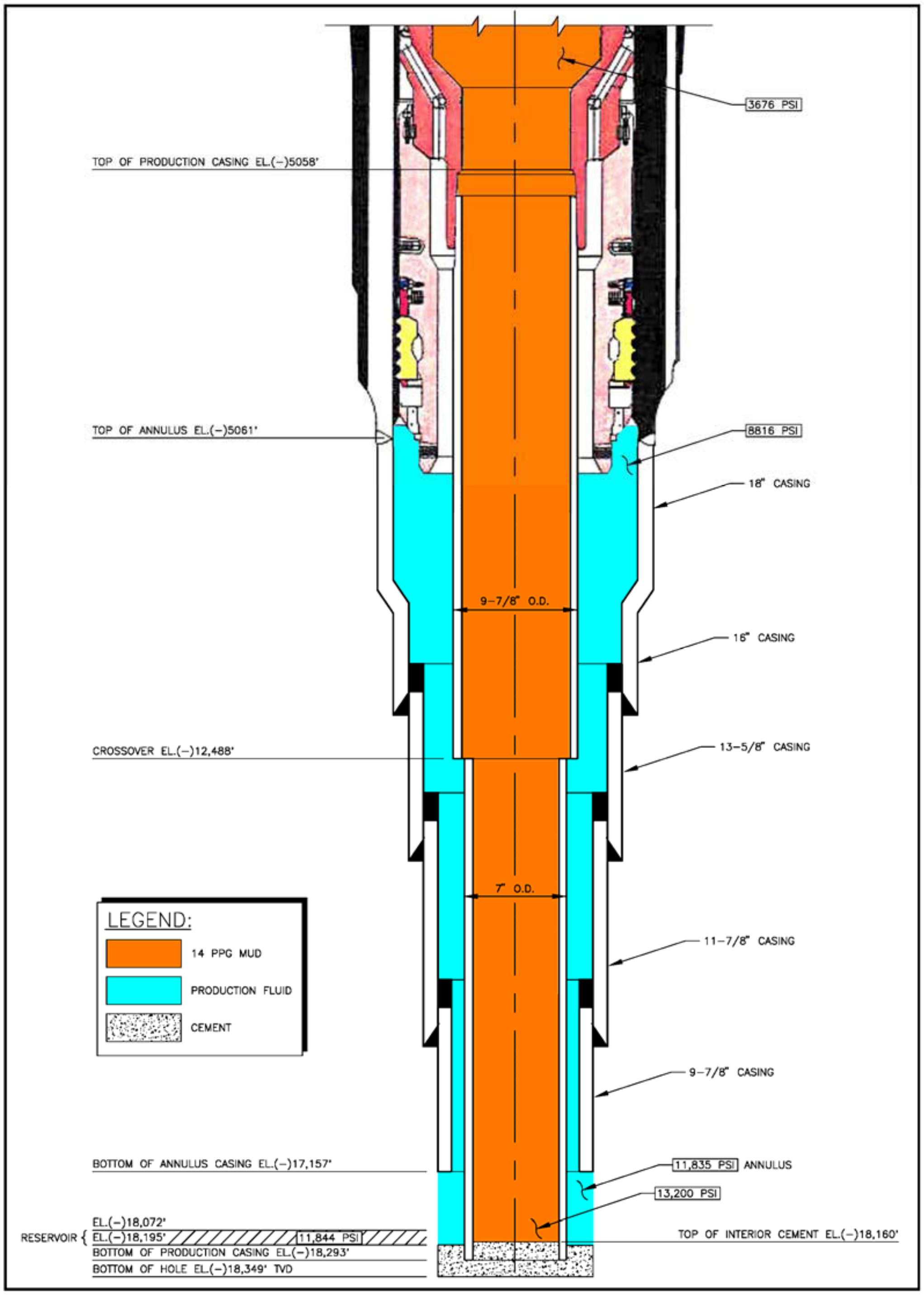

Figure 3.3 – Condition 3

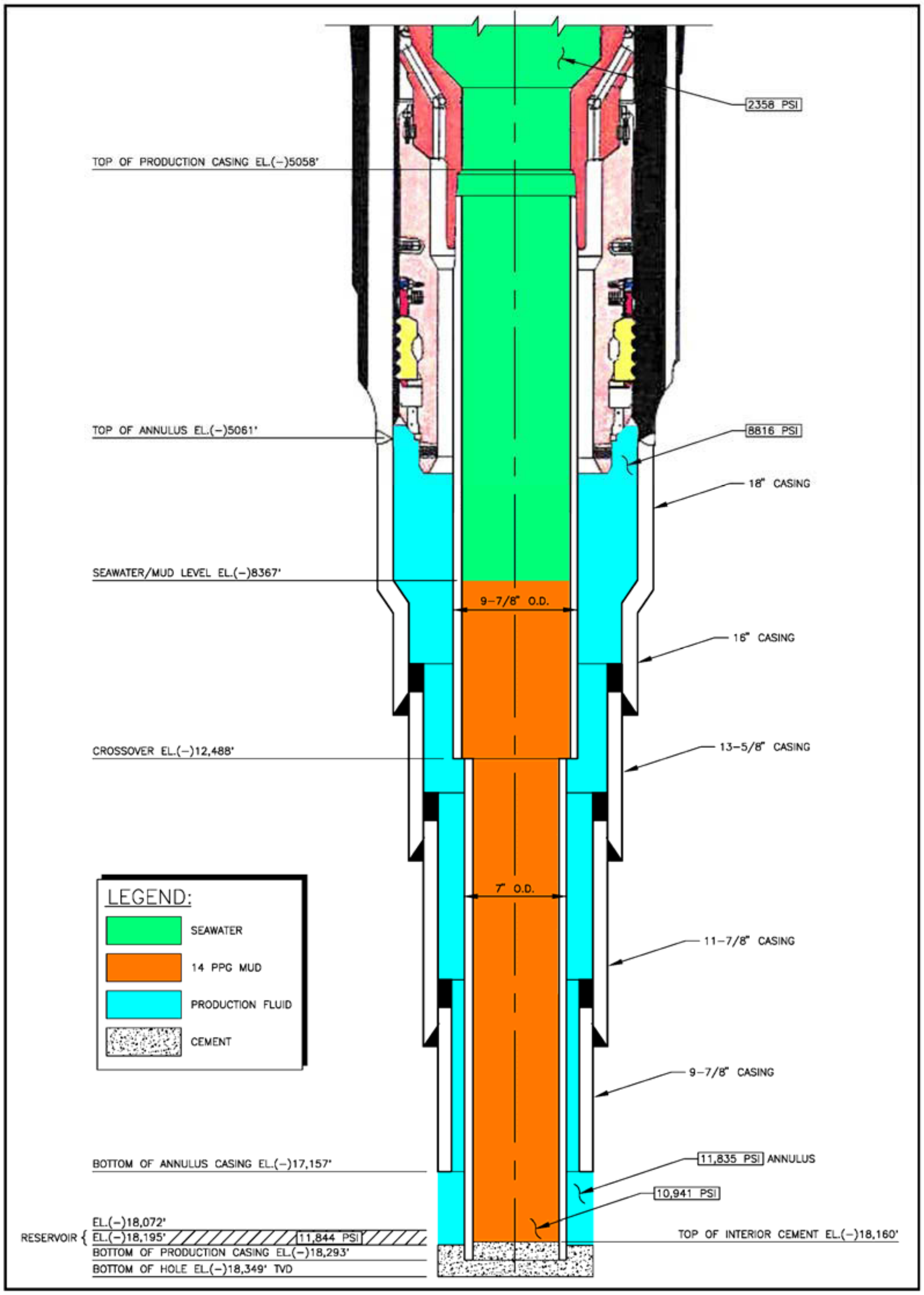

Figure 3.4 – Condition 4

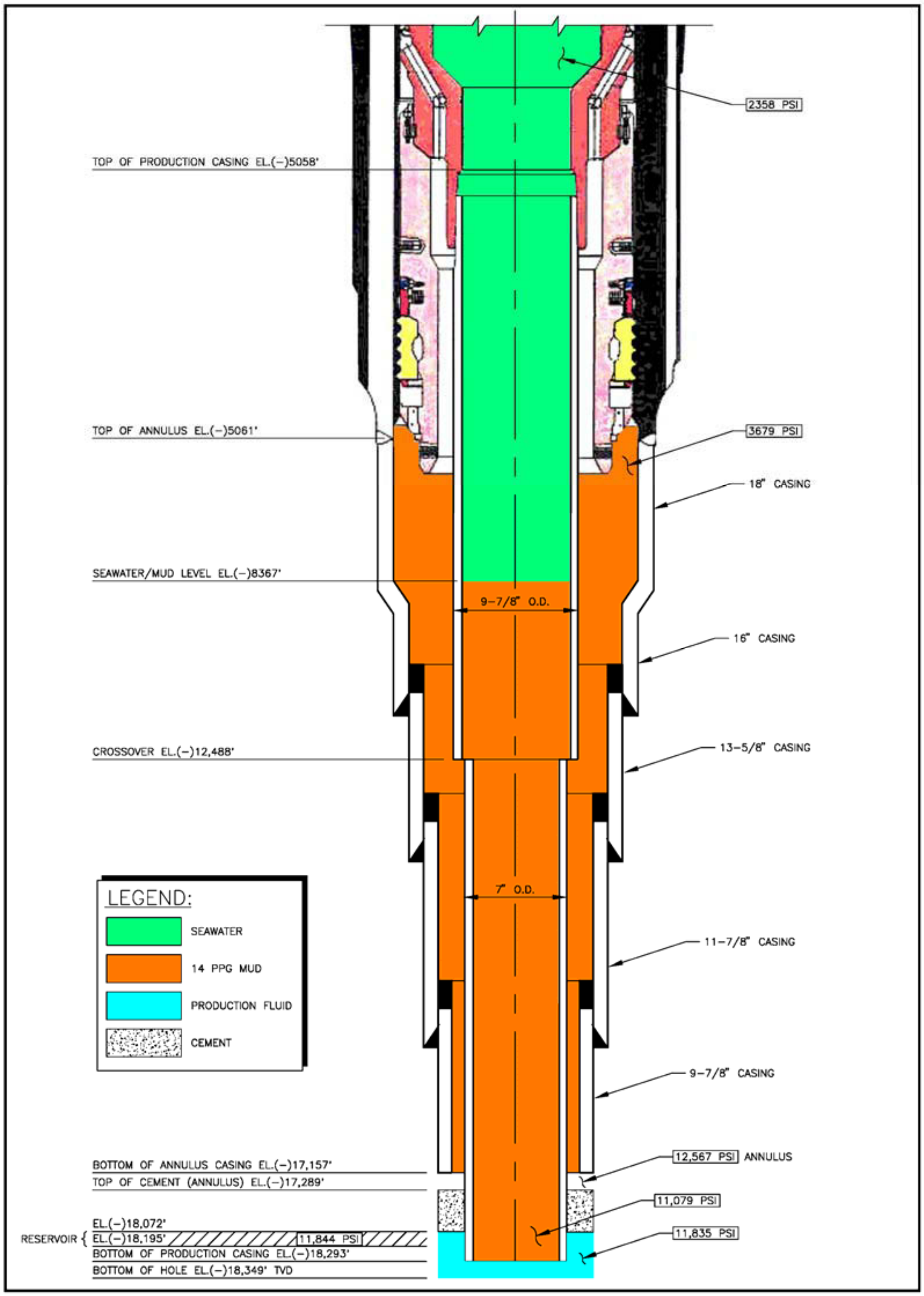

Figure 3.5 – Condition 5

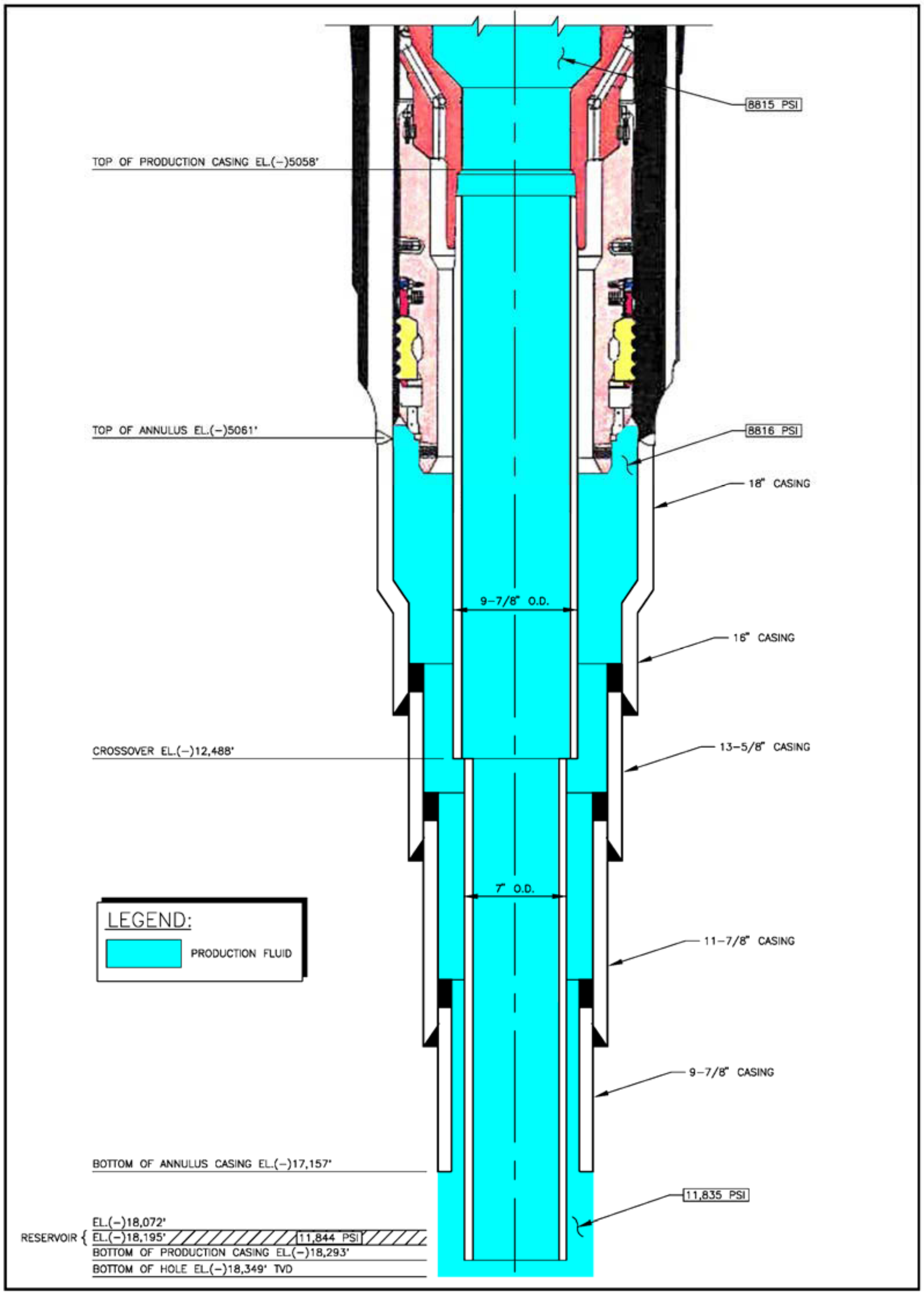

Figure 3.6 – Condition 6

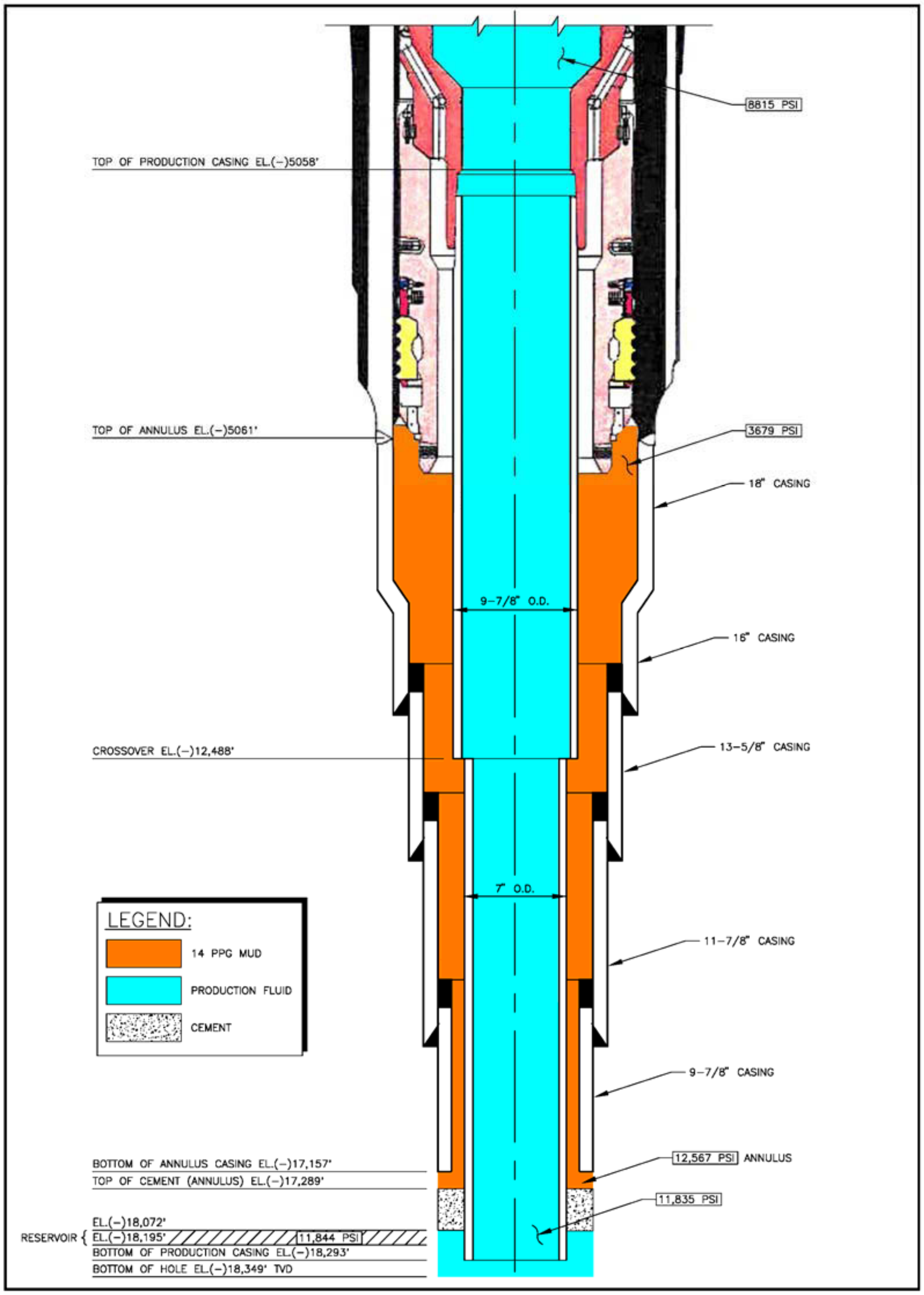

Figure 3.7 – Condition 7

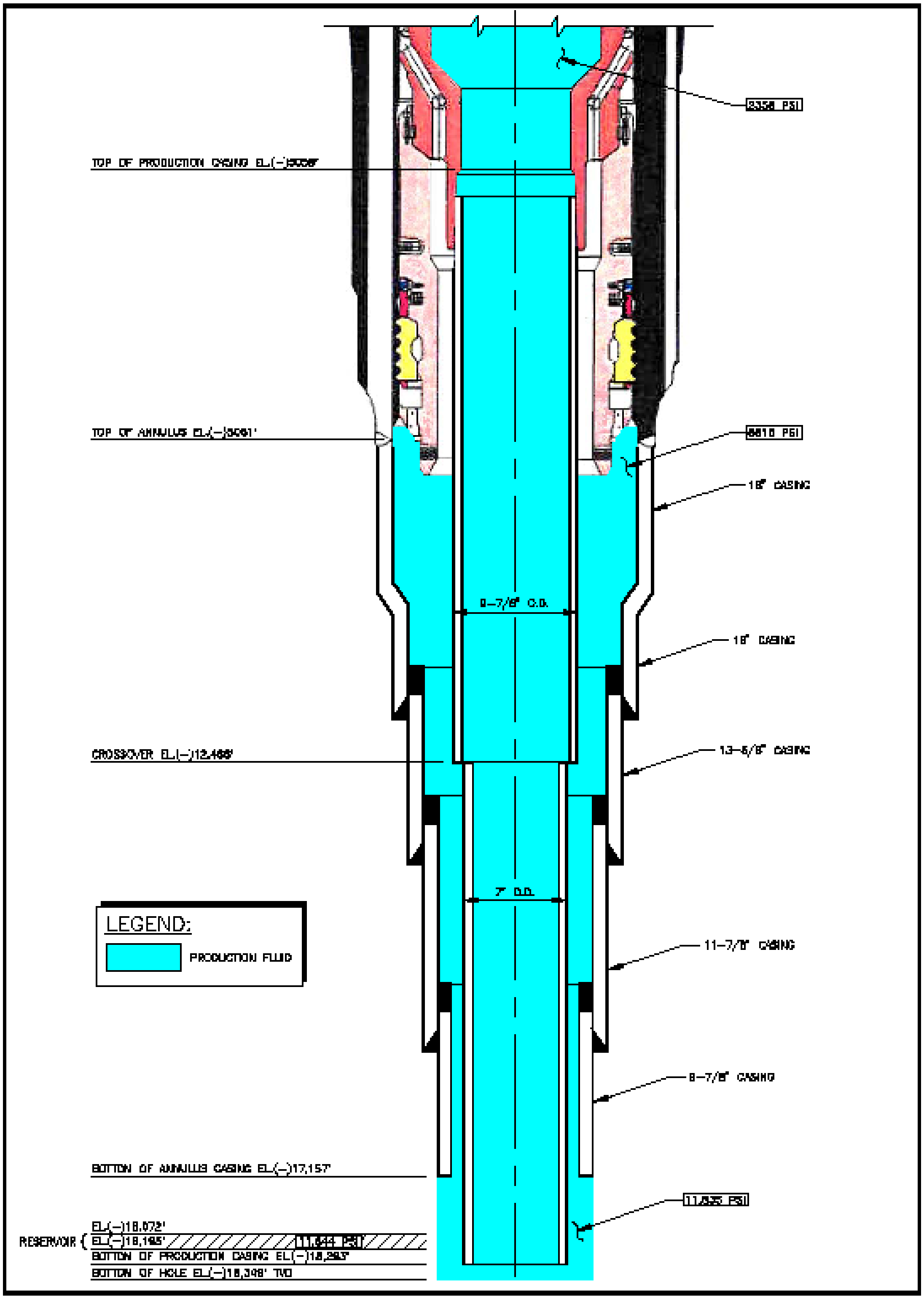

Figure 3.8 – Condition 8

Comments	Start True Vertical Depth	End True Vertical Depth	Production Casing Description	Production Casing ID	Production Casing Fluid	Production Casing Ave Temp. Deg F	Production Casing Fluid ppg	Production Casing Pressure at end of segment	Production Casing Fluid Capacity gal/ft	Production Casing Fluid Capacity wt/section, lb	Production Casing weight, lb/ft	Production Casing weight, lb per segment	Annulus Casing Description	Annulus ID for Displacement	Exterior Fluid	Annulus Fluid Ave Temp. Deg F	Annulus Fluid ppg	Annulus Pressure at end	Production Casing Fluid Displacement gal/ft	Production Casing Fluid Displacement wt/section, lb	Production Casing Fluid Temp gradient, Deg F/ft	Annulus Fluid Temp gradient, Deg F/ft	Production Casing Material
	0	300	Conductor	19.5	Mud	80.0	14	218	15.4188	64759					Mud	80	14	218					
	300	600	Conductor	19.5	Mud	80.0	14	436	15.4188	64759					Mud	80	14	436					
	600	900	Conductor	19.5	Mud	80.0	14	654	15.4188	64759					Mud	80	14	654					
	900	1200	Conductor	19.5	Mud	80.0	14	872	15.4188	64759					Mud	80.0	14	872			-0.0103815	-0.010382	
	1200	1500	Conductor	19.5	Mud	76.9	14	1090	15.4188	64759					Mud	76.9	14	1090			-0.0103815	-0.010382	
	1500	1800	Conductor	19.5	Mud	73.8	14	1308	15.4188	64759					Mud	73.8	14	1308			-0.0103815	-0.010382	
	1800	2100	Conductor	19.5	Mud	70.7	14	1526	15.4188	64759					Mud	70.7	14	1526			-0.0103815	-0.010382	
	2100	2400	Conductor	19.5	Mud	67.5	14	1744	15.4188	64759					Mud	67.5	14	1744			-0.0103815	-0.010382	
	2400	2700	Conductor	19.5	Mud	64.4	14	1963	15.4188	64759					Mud	64.4	14	1963			-0.0103815	-0.010382	
	2700	3000	Conductor	19.5	Mud	61.3	14	2181	15.4188	64759					Mud	61.3	14	2181			-0.0103815	-0.010382	
	3000	3300	Conductor	19.5	Mud	58.2	14	2399	15.4188	64759					Mud	58.2	14	2399			-0.0103815	-0.010382	
	3300	3600	Conductor	19.5	Mud	55.1	14	2617	15.4188	64759					Mud	55.1	14	2617			-0.0103815	-0.010382	
	3600	3900	Conductor	19.5	Mud	52.0	14	2835	15.4188	64759					Mud	52.0	14	2835			-0.0103815	-0.010382	
	3900	4200	Conductor	19.5	Mud	48.9	14	3053	15.4188	64759					Mud	48.9	14	3053			-0.0103815	-0.010382	
	4200	4500	Conductor	19.5	Mud	45.7	14	3271	15.4188	64759					Mud	45.7	14	3271			-0.0103815	-0.010382	
	4500	4800	Conductor	19.5	Mud	42.6	14	3489	15.4188	64759					Mud	42.6	14	3489			-0.0103815	-0.010382	
	4800	5001	Conductor	19.5	Mud	40.5	14	3635	15.4188	43389					Mud	40.5	14	3635			-0.0103815	-0.010382	
TO BOP	5001	5053	BOP	18.375	Mud	40.0	14	3673	13.7760	10029					Mud	40	14	3673			-0.0103815	-0.010382	
	5053	5058	Lock down seal	18.375	Mud	40	14	3676	13.7760	964					Mud	40	14	3676					
TO Prod. Casing	5058	5058					14	3676							Mud		14	3676					
	5058	5059	Hanger	8.626	Mud	48	14	3677	3.0353	42	62.8	62.8			Mud	48	14	3677	3.979	56			
	5059	5061	Prod. Casing	8.626	Mud	48	14	3679	3.0353	85	62.8	125.6			Mud	48	14	3679	3.979	111			
TO 18" x 16" Annulus	5061	5061	Prod. Casing			48	14	3679							Mud	48	14	3679					
	5061	5561	Prod. Casing	8.626	Mud	57	14	4042	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	57	14	4042	3.979	27851			Q-125
	5561	6061	Prod. Casing	8.626	Mud	58	14	4405	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	58	14	4405	3.979	27851			
	6061	6561	Prod. Casing	8.626	Mud	58	14	4769	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	58	14	4769	3.979	27851			
	6561	7061	Prod. Casing	8.626	Mud	59	14	5132	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	59	14	5132	3.979	27851			
	7061	7561	Prod. Casing	8.626	Mud	62	14	5496	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	62	14	5496	3.979	27851			
	7561	8061	Prod. Casing	8.626	Mud	70	14	5859	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	70	14	5859	3.979	27851			
	8061	8367	Prod. Casing	8.626	Mud	90	14	6082	3.0353	13003	62.8	19216.8	Casing	9-7/8	Mud	90	14	6082	3.979	17045			
	8367	8867	Prod. Casing	8.626	Mud	122	14	6445	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	122	14	6445	3.979	27851	0.0124301		
	8867	9367	Prod. Casing	8.626	Mud	128	14	6808	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	128	14	6808	3.979	27851	0.0124301		
	9367	9867	Prod. Casing	8.626	Mud	134	14	7172	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	134	14	7172	3.979	27851	0.0124301		
	9867	10367	Prod. Casing	8.626	Mud	141	14	7535	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	141	14	7535	3.979	27851	0.0124301		
	10367	10867	Prod. Casing	8.626	Mud	147	14	7899	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	147	14	7899	3.979	27851	0.0124301		
	10867	11153	Prod. Casing	8.626	Mud	153	14	8107	3.0353	12154	62.8	17960.8	Casing	9-7/8	Mud	153	14	8107	3.979	15931	0.0124301		
TO 13-5/8"	11153	11585	Prod. Casing	8.626	Mud	162	14	8421	3.0353	18358	62.8	27129.6	Casing	9-7/8	Mud	162	14	8421	3.979	24063	0.0124301		
BO 16"	11585	12085	Prod. Casing	8.626	Mud	171	14	8784	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	171	14	8784	3.979	27851	0.0179115		
	12085	12486	Prod. Casing	8.626	Mud	178	14	9076	3.0353	17040	62.8	25182.8	Casing	9-7/8	Mud	178	14	9076	3.979	22336	0.0179115		
Mid of x-over	12486	12488	x-over		Mud	178	14	9077	1.8674	52		470.6	Casing		Mud	178	14	9077	3.628	102	0.0179115		
	12488	12490	x-over		Mud	178	14	9078	1.8674	52			Casing		Mud	178	14	9078	3.628	102	0.0179115		
	12490	12585	Prod. Casing	6	Mud	180	14	9148	1.5150	2015	32	3040	Casing	7	Mud	180	14	9148	1.999	2659	0.0179115		HCQ-125
	12585	12792	Prod. Casing	6	Mud	184	14	9298	1.5150	4390	32	6624	Casing	7	Mud	184	14	9298	1.999	5794	0.0179115		
TO 11-7/8	12792	13292	Prod. Casing	6	Mud	193	14	9661	1.5150	10605	32	16000	Casing	7	Mud	193	14	9661	1.999	13994	0.0179115		
	13292	13792	Prod. Casing	6	Mud	202	14	10025	1.5150	10605	32	16000	Casing	7	Mud	202	14	10025	1.999	13994	0.0179115		
	13792	14292	Prod. Casing	6	Mud	210	14	10388	1.5150	10605	32	16000	Casing	7	Mud	210	14	10388	1.999	13994	0.0179115		
	14292	14748	Prod. Casing	6	Mud	219	14	10720	1.5150	9672	32	14592	Casing	7	Mud	219	14	10720	1.999	12763	0.0179115		
TO 9-7/8"	14748	15092	Prod. Casing	6	Mud	225	14	10970	1.5150	7296	32	11008	Casing	7	Mud	225	14	10970	1.999	9628	0.0179115		
BO 11-7/8"	15092	15592	Prod. Casing	6	Mud	234	14	11333	1.5150	10605	32	16000	Casing	7	Mud	234	14	11333	1.999	13994	0.0179115		
	15592	16092	Prod. Casing	6	Mud	243	14	11697	1.5150	10605	32	16000	Casing	7	Mud	243	14	11697	1.999	13994	0.0179115		
	16092	16592	Prod. Casing	6	Mud	252	14	12060	1.5150	10605	32	16000	Casing	7	Mud	252	14	12060	1.999	13994	0.0179115		
	16592	17092	Prod. Casing	6	Mud	261	14	12423	1.5150	10605	32	16000	Casing	7	Mud	261	14	12423	1.999	13994	0.0179115		
BO 9-7/8"	17092	17157	Prod. Casing	6	Mud	262	14	12471	1.5150	1379	32	2080	Casing	7	Mud	262	14	12471	1.999	1819	0.0179115		
Open Hole	17157	17289	Prod. Casing	6	Mud	262	14	12567	1.5150	2800	32	4224	Open Hole	7	Mud	262	14	12567	1.999	3695			
TO Annulus Cement	17289	18072	Prod. Casing	6	Mud	262	14	13136	1.5150	16607	32	25056	Cement	7	Cement				1.999				
TO Formation	18072	18104	Prod. Casing	6	Mud	262	14	13159	1.5150	679	32	1024	Cement	7	Cement				1.999				
TO Float Collar	18104	18160	Prod. Casing	6	Mud	262	14	13200	1.5150	1188	32	1792	Cement	7	Cement				1.999				
TO Inside Cement	18160	18195	Prod. Casing	6	Cement	262		13200	1.5150	0	32	1120	Cement	7	Cement								
BO Formation	18195	18349	Prod. Casing	6	Cement	262		13200	1.5150	0	32	4928	Cement	7	Cement	175			1.999				
Shoe	18349	18349	Prod. Casing	6	Cement	262		13200	1.5150	0	32	0	Cement	7	Cement	262			1.999				
Total weight										1526541		654437								548270			

Notes:

Cement seals resevoir.
Cement plug prevents production fluid from flowing into Production Casing.
Mud fills annulus, cement does not fix Production Casing.
Mud fills Production Casing
Since Production Casing is plugged, the contents of the Production Casing affect the buoyancy.
189 feet of cement in Production Casing

Area of Production Casing seal =	195.71	sq in
Pressure at top of Annulus =	3676	psi
Upwards force =	719527	lb
Area of 18" seal =	214.85	sq in
Pressure wellhead =	3676	psi
Downwards force =	789871	lb
Net Force on hanger, lbm = Displaced weight - casing weight+upwards force - downwards force		
-weight of fluid in ProductionCasing =	-1.70E+06	lb

Temperature Criteria:
Above mudline, temperatures are in equilibrium with seawater per pyncocline curve
In wellbore, mud in annulus and production casing are in equilibrium with formations
Annulus Casing Temps from Downhole Temp surveys
Cement density: 5.26 bbl premium H at 16.74 ppg

38.9 bbl Premium H, foamed to 47.75 bbl 14.5 ppg
6.93 bl Premium H 16.74 ppg
20 bbl spacer 14.3 ppg
133 bbl SOBM 14.0 ppg
728.5 bbl SOBM 14.0 ppg (189 ft cement in shoe)

Table 3.1 – Condition 1

Comments	Start True Vertical Depth	End True Vertical Depth	Production Casing Description	Production Casing ID	Production Casing Fluid	Production Casing Ave Temp. Deg F	Production Casing Fluid ppg	Production Casing Pressure at end of segment	Production Casing Fluid Capacity gal/ft	Production Casing Fluid Capacity wt/section, lb	Production Casing weight, lb/ft	Production Casing weight, lb per segment	Annulus Casing Description	Annulus ID for Displacement	Exterior Fluid	Annulus Fluid Ave Temp. Deg F	Annulus Fluid ppg	Annulus Pressure at end	Production Casing Fluid Displacement gal/ft	Production Casing Fluid Displacement wt/section, lbm	Production Casing Fluid Temp gradient, Deg F/ft	Annulus Fluid Temp gradient, Deg F/ft	Production Casing Material
	0	300	Conductor	19.5	Mud	80.0	14	218	15.4188	64759													
	300	600	Conductor	19.5	Mud	80.0	14	436	15.4188	64759													
	600	900	Conductor	19.5	Mud	80.0	14	654	15.4188	64759													
	900	1200	Conductor	19.5	Mud	80.0	14	872	15.4188	64759													
	1200	1500	Conductor	19.5	Mud	80.0	14	1090	15.4188	64759													
	1500	1800	Conductor	19.5	Mud	80.0	14	1308	15.4188	64759													
	1800	2100	Conductor	19.5	Mud	80.0	14	1526	15.4188	64759													
	2100	2400	Conductor	19.5	Mud	80.0	14	1744	15.4188	64759													
	2400	2700	Conductor	19.5	Mud	80.0	14	1963	15.4188	64759													
	2700	3000	Conductor	19.5	Mud	80.0	14	2181	15.4188	64759													
	3000	3300	Conductor	19.5	Mud	80.0	14	2399	15.4188	64759													
	3300	3600	Conductor	19.5	Mud	80.0	14	2617	15.4188	64759													
	3600	3900	Conductor	19.5	Mud	80.0	14	2835	15.4188	64759													
	3900	4200	Conductor	19.5	Mud	80.0	14	3053	15.4188	64759													
	4200	4500	Conductor	19.5	Mud	80.0	14	3271	15.4188	64759													
	4500	4800	Conductor	19.5	Mud	80.0	14	3489	15.4188	64759													
	4800	5001	Conductor	19.5	Mud	80.0	14	3635	15.4188	43389													
TO BOP	5001	5053	BOP	18.375	Mud	40.0	14	3673	13.7760	10029													
	5053	5058	Lock down seal	18.375	Mud	40	14	3676	13.7760	964													
TO Prod. Casing	5058	5058				40	14	3676							Mud	40	14		3.9790	0			
	5058	5059	Hanger	8.626	Mud	48	14	3677	3.0353	42	62.8	62.8			Mud	48	14		3.979	56			
	5059	5061	Prod. Casing	8.626	Mud	48	14	3679	3.0353	85	62.8	125.6			Mud	48	14		3.979	111			
TO 18" x 16" Annulus	5061	5061	Prod. Casing			48	14	3679							Mud	48	14	2956					
	5061	5561	Prod. Casing	8.626	Mud	57	14	4042	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	57	14	3319	3.979	27851			Q-125
	5561	6061	Prod. Casing	8.626	Mud	58	14	4405	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	58	14	3682	3.979	27851			
	6061	6561	Prod. Casing	8.626	Mud	58	14	4769	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	58	14	4046	3.979	27851			
	6561	7061	Prod. Casing	8.626	Mud	59	14	5132	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	59	14	4409	3.979	27851			
	7061	7561	Prod. Casing	8.626	Mud	62	14	5496	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	62	14	4773	3.979	27851			
	7561	8061	Prod. Casing	8.626	Mud	70	14	5859	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	70	14	5136	3.979	27851			
	8061	8367	Prod. Casing	8.626	Mud	90	14	6082	3.0353	13003	62.8	19216.8	Casing	9-7/8	Mud	90	14	5359	3.979	17045			
	8367	8867	Prod. Casing	8.626	Mud	90	14	6445	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	90	14	5722	3.979	27851	0.0124301		
	8867	9367	Prod. Casing	8.626	Mud	85	14	6808	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	85	14	6085	3.979	27851	0.0124301		
	9367	9867	Prod. Casing	8.626	Mud	87	14	7172	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	87	14	6449	3.979	27851	0.0124301		
	9867	10367	Prod. Casing	8.626	Mud	88	14	7535	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	88	14	6812	3.979	27851	0.0124301		
	10367	10867	Prod. Casing	8.626	Mud	95	14	7899	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	95	14	7176	3.979	27851	0.0124301		
	10867	11153	Prod. Casing	8.626	Mud	95	14	8107	3.0353	12154	62.8	17960.8	Casing	9-7/8	Mud	95	14	7384	3.979	15931	0.0124301		
TO 13-5/8"	11153	11585	Prod. Casing	8.626	Mud	92	14	8421	3.0353	18358	62.8	27129.6	Casing	9-7/8	Mud	92	14	7698	3.979	24063	0.0124301		
B O 16"	11585	12085	Prod. Casing	8.626	Mud	95	14	8784	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	95	14	8061	3.979	27851	0.0179115		
	12085	12486	Prod. Casing	8.626	Mud	102	14	9076	3.0353	17040	62.8	25182.8	Casing	9-7/8	Mud	102	14	8353	3.979	22336	0.0179115		
Mid of x-over	12486	12488	x-over		Mud	102	14	9077	1.8674	52		470.6	Casing		Mud	102	14	8354	3.628	102	0.0179115		
	12488	12490	x-over		Mud	102	14	9078	1.8674	52			Casing		Mud	102	14	8355	3.628	102	0.0179115		
	12490	12585	Prod. Casing	6	Mud	102	14	9148	1.5150	2015	32	3040	Casing	7	Mud	102	14	8425	1.999	2659	0.0179115		HCQ-125
	12585	12792	Prod. Casing	6	Mud	105	14	9298	1.5150	4390	32	6624	Casing	7	Mud	105	14	8575	1.999	5794	0.0179115		
TO 11-7/8	12792	13292	Prod. Casing	6	Mud	102	14	9661	1.5150	10605	32	16000	Casing	7	Mud	102	14	8938	1.999	13994	0.0179115		
	13292	13792	Prod. Casing	6	Mud	102	14	10025	1.5150	10605	32	16000	Casing	7	Mud	102	14	9302	1.999	13994	0.0179115		
	13792	14292	Prod. Casing	6	Mud	112	14	10388	1.5150	10605	32	16000	Casing	7	Mud	112	14	9665	1.999	13994	0.0179115		
	14292	14748	Prod. Casing	6	Mud	115	14	10720	1.5150	9672	32	14592	Casing	7	Mud	115	14	9997	1.999	12763	0.0179115		
TO 9-7/8"	14748	15092	Prod. Casing	6	Mud	122	14	10970	1.5150	7296	32	11008	Casing	7	Mud	122	14	10247	1.999	9628	0.0179115		
B O 11-7/8"	15092	15592	Prod. Casing	6	Mud	126	14	11333	1.5150	10605	32	16000	Casing	7	Mud	126	14	10610	1.999	13994	0.0179115		
	15592	16092	Prod. Casing	6	Mud	148	14	11697	1.5150	10605	32	16000	Casing	7	Mud	148	14	10974	1.999	13994	0.0179115		
	16092	16592	Prod. Casing	6	Mud	152	14	12060	1.5150	10605	32	16000	Casing	7	Mud	152	14	11337	1.999	13994	0.0179115		
	16592	17092	Prod. Casing	6	Mud	158	14	12423	1.5150	10605	32	16000	Casing	7	Mud	158	14	11700	1.999	13994	0.0179115		
B O 9-7/8"	17092	17157	Prod. Casing	6	Mud	162	14	12471	1.5150	1379	32	2080	Casing	7	Mud	162	14	11748	1.999	1819	0.0179115		
Open Hole	17157	17289	Prod. Casing	6	Mud	172	14	12567	1.5150	2800	32	4224	Open Hole	7	Mud	172	14	11844	1.999	3695			
TO Annulus Cement	17289	18072	Prod. Casing	6	Mud	172	14	13136	1.5150	16607	32	25056	Cement	7	Cement	172		11844	1.999				
TO Formation	18072	18104	Prod. Casing	6	Mud	176	14	13159	1.5150	679	32	1024	Cement	7	Cement	176		11844	1.999				
TO Float Collar	18104	18160	Prod. Casing	6	Mud	175	14	13200	1.5150	1188	32	1792	Cement	7	Cement	175			1.999				
TO Inside Cement	18160	18195	Prod. Casing	6	Cement	175			1.5150		32	1120	Cement	7	Cement	175							
BO Formation	18195	18349	Prod. Casing	6	Cement	175			1.5150		32	4928	Cement	7	Cement	175			1.999				
Shoe	18349	18349	Prod. Casing	6	Cement	262			1.5150		32	0	Cement	7	Cement	262			1.999				
Total weight										1526541		654437								548270			

Notes:

Communication between the reservoir and the annulus, mud still in the annulus.
Cement plug prevents production fluid from flowing into Production Casing.
Mud fills annulus, cement does not hold Production Casing.
Mud fills Production Casing
Since Production Casing is plugged, the contents of the Production Casing affect the buoyancy.
Pressure at top of Annulus set equal to balance resevoir pressure at bottom.

Area of Production Casing seal = 195.71 sq in
Pressure at top of Annulus = 2956 psi
Upwards force = 578454 lb
Area of 18" seal = 214.846 sq in
Pressure wellhead = 3676.45 psi
Downwards force = 789871 lb
Net Buoyancy, lbm = Displaced weight - casing weight+upwards force - downwards force
+Weight of fluid in ProductionCasing =
Net Buoyancy, lb -1.84E+06

Temperature criteria:
Above mudline, temperatures in equilibrium with seawater per pyncocline curve
In wellbore, mud in equilibrium with formations
Cement density: 5.26 bbl premium H at 16.74 ppg
38.9 bbl Premium H , foamed to 47.75 bbl 14.5 ppg
6.93 bl Premium H 16.74 ppg
20 bbl spacer 14.3 ppg
133 bbl SOBM 14.0 ppg
728.5 bbl SOBM 14.0 ppg (189 ft cement in shoe)

11844 psi Halliburton (H) Pressure Test Survey

Tabl2 3.2 – Condition 2

Comments	Start True Vertical Depth	End True Vertical Depth	Production Casing Description	Production Casing ID	Production Casing Fluid	Production Casing Ave Temp. Deg F	Production Casing Fluid ppg	Production Casing Pressure at end of segment	Production Casing Fluid Capacity gal/ft	Production Casing Fluid Capacity wt/section, lb	Production Casing weight, lb/ft	Production Casing weight, lb per segment	Annulus Casing Description	Annulus ID for Displacement	Exterior Fluid	Annulus Fluid Ave Temp. Deg F	Annulus Fluid ppg	Annulus Pressure at end	Production Casing Fluid Displacement gal/ft	Production Casing Fluid Displacement wt/section, lb	Production Casing Fluid Temp gradient, Deg F/ft	Prod. Casing Material
	0	300	Conductor	19.5	Mud	80.0	14	218	15.4188	64759												
	300	600	Conductor	19.5	Mud	80.0	14	436	15.4188	64759												
	600	900	Conductor	19.5	Mud	80.0	14	654	15.4188	64759												
	900	1200	Conductor	19.5	Mud	80.0	14	872	15.4188	64759											-0.010382	
	1200	1500	Conductor	19.5	Mud	76.9	14	1090	15.4188	64759											-0.010382	
	1500	1800	Conductor	19.5	Mud	73.8	14	1308	15.4188	64759											-0.010382	
	1800	2100	Conductor	19.5	Mud	70.7	14	1526	15.4188	64759											-0.010382	
	2100	2400	Conductor	19.5	Mud	67.5	14	1744	15.4188	64759											-0.010382	
	2400	2700	Conductor	19.5	Mud	64.4	14	1963	15.4188	64759											-0.010382	
	2700	3000	Conductor	19.5	Mud	61.3	14	2181	15.4188	64759											-0.010382	
	3000	3300	Conductor	19.5	Mud	58.2	14	2399	15.4188	64759											-0.010382	
	3300	3600	Conductor	19.5	Mud	55.1	14	2617	15.4188	64759											-0.010382	
	3600	3900	Conductor	19.5	Mud	52.0	14	2835	15.4188	64759											-0.010382	
	3900	4200	Conductor	19.5	Mud	48.9	14	3053	15.4188	64759											-0.010382	
	4200	4500	Conductor	19.5	Mud	45.7	14	3271	15.4188	64759											-0.010382	
	4500	4800	Conductor	19.5	Mud	42.6	14	3489	15.4188	64759											-0.010382	
	4800	5001	Conductor	19.5	Mud	40.5	14	3635	15.4188	43389											-0.010382	
TO BOP	5001	5053	BOP	18.375	Mud	40.0	14	3673	13.7760	10029											-0.010382	
	5053	5058	Lock downseal	18.375	Mud	80	14	3676	13.7760	964												
TO Prod. Casing	5058	5058					14	3676							Prod. Fluid	145	4		3.9787	0		
	5058	5059	Hanger	8.626	Mud	80	14	3677	3.0353	42	62.8	62.8			Prod. Fluid	145	4		3.979	18		
	5059	5061	Prod. Casing	8.626	Mud	80	14	3679	3.0353	85	62.8	125.6			Prod. Fluid	145	4		3.979	36		
TO 18" x 16" Annulus	5061	5061	Prod. Casing				14	3679							Prod. Fluid	145	4	8816	3.9787	0.0000		
	5061	5561	Prod. Casing	8.626	Mud	80	14	4042	3.0353	21247	62.8	31400	Casing		Prod. Fluid	149	4.46		3.979	8872		Q-125
	5561	6061	Prod. Casing	8.626	Mud	80	14	4405	3.0353	21247	62.8	31400	Casing	9-7/8	Prod. Fluid	152	4.455		3.979	8862		
	6061	6561	Prod. Casing	8.626	Mud	65	14	4769	3.0353	21247	62.8	31400	Casing	9-7/8	Prod. Fluid	156	4.455		3.979	8862		
	6561	7061	Prod. Casing	8.626	Mud	80	14	5132	3.0353	21247	62.8	31400	Casing	9-7/8	Prod. Fluid	160	4.453		3.979	8858		
	7061	7561	Prod. Casing	8.626	Mud	80	14	5496	3.0353	21247	62.8	31400	Casing	9-7/8	Prod. Fluid	162	4.451		3.979	8855		
	7561	8061	Prod. Casing	8.626	Mud	80	14	5859	3.0353	21247	62.8	31400	Casing	9-7/8	Prod. Fluid	166	4.449		3.979	8851		
	8061	8367	Prod. Casing	8.626	Mud	80	14	6082	3.0353	13003	62.8	19216.8	Casing	9-7/8	Prod. Fluid	168	4.447		3.979	5414		
	8367	8867	Prod. Casing	8.626	Mud	122	14	6445	3.0353	21247	62.8	31400	Casing	9-7/8	Prod. Fluid	171	4.445		3.979	8843	0.0124301	
	8867	9367	Prod. Casing	8.626	Mud	128	14	6808	3.0353	21247	62.8	31400	Casing	9-7/8	Prod. Fluid	175	4.443		3.979	8839	0.0124301	
	9367	9867	Prod. Casing	8.626	Mud	134	14	7172	3.0353	21247	62.8	31400	Casing	9-7/8	Prod. Fluid	179	4.441		3.979	8835	0.0124301	
	9867	10367	Prod. Casing	8.626	Mud	141	14	7535	3.0353	21247	62.8	31400	Casing	9-7/8	Prod. Fluid	182	4.439		3.979	8831	0.0124301	
	10367	10867	Prod. Casing	8.626	Mud	147	14	7899	3.0353	21247	62.8	31400	Casing	9-7/8	Prod. Fluid	186	4.437		3.979	8827	0.0124301	
	10867	11153	Prod. Casing	8.626	Mud	153	14	8107	3.0353	12154	62.8	17960.8	Casing	9-7/8	Prod. Fluid	188	4.435		3.979	5047	0.0124301	
TO 13-5/8"	11153	11585	Prod. Casing	8.626	Mud	162	14	8421	3.0353	18358	62.8	27129.6	Casing	9-7/8	Prod. Fluid	188	4.434		3.979	7621	0.0124301	
BO 16"	11585	12085	Prod. Casing	8.626	Mud	171	14	8784	3.0353	21247	62.8	31400	Casing	9-7/8	Prod. Fluid	194	4.432		3.979	8817	0.0179115	
	12085	12486	Prod. Casing	8.626	Mud	178	14	9076	3.0353	17040	62.8	25182.8	Casing	9-7/8	Prod. Fluid	197	4.43		3.979	7068	0.0179115	
Mid of x-over	12486	12488	x-over		Mud	178	14	9077	1.8674	52		470.6	Casing	9-7/8	Prod. Fluid	197	4.43	10540	3.628	32	0.0179115	
	12488	12490	x-over		Mud	178	14	9078	1.8674	52			Casing		Prod. Fluid	197	4.43		3.628	32	0.0179115	
	12490	12585	Prod. Casing	6	Mud	180	14	9148	1.5150	2015	32	3040	Casing		Prod. Fluid	198	4.43		1.999	841	0.0179115	HCQ-125
	12585	12792	Prod. Casing	6	Mud	184	14	9298	1.5150	4390	32	6624	Casing	7	Prod. Fluid	199	4.429		1.999	1833	0.0179115	
TO 11-7/8	12792	13292	Prod. Casing	6	Mud	193	14	9661	1.5150	10605	32	16000	Casing	7	Prod. Fluid	203	4.427		1.999	4425	0.0179115	
	13292	13792	Prod. Casing	6	Mud	202	14	10025	1.5150	10605	32	16000	Casing	7	Prod. Fluid	206	4.425		1.999	4423	0.0179115	
	13792	14292	Prod. Casing	6	Mud	210	14	10388	1.5150	10605	32	16000	Casing	7	Prod. Fluid	209	4.423		1.999	4421	0.0179115	
	14292	14748	Prod. Casing	6	Mud	219	14	10720	1.5150	9672	32	14592	Casing	7	Prod. Fluid	213	4.422		1.999	4031	0.0179115	
TO 9-7/8"	14748	15092	Prod. Casing	6	Mud	225	14	10970	1.5150	7296	32	11008	Casing	7	Prod. Fluid	215	4.421		1.999	3040	0.0179115	
BO 11-7/8"	15092	15592	Prod. Casing	6	Mud	234	14	11333	1.5150	10605	32	16000	Casing	7	Prod. Fluid	219	4.419		1.999	4417	0.0179115	
	15592	16092	Prod. Casing	6	Mud	243	14	11697	1.5150	10605	32	16000	Casing	7	Prod. Fluid	222	4.417		1.999	4415	0.0179115	
	16092	16592	Prod. Casing	6	Mud	252	14	12060	1.5150	10605	32	16000	Casing	7	Prod. Fluid	226	4.415		1.999	4413	0.0179115	
	16592	17092	Prod. Casing	6	Mud	261	14	12423	1.5150	10605	32	16000	Casing	7	Prod. Fluid	229	4.413		1.999	4411	0.0179115	
BO 9-7/8"	17092	17157	Prod. Casing	6	Mud	262	14	12471	1.5150	1379	32	2080	Casing	7	Prod. Fluid	230	4.413		1.999	573	0.0179115	
Open Hole	17157	17289	Prod. Casing	6	Mud	262	14	12567	1.5150	2800	32	4224	Open Hole	7	Prod. Fluid	230	4.413		1.999	1165		
TO Annulus Cement	17289	18072	Prod. Casing	6	Mud	262	14	13136	1.5150	16607	32	25056	Open Hole	7	Prod. Fluid	236	4.411		1.999	6905		
TO Formation	18072	18104	Prod. Casing	6	Mud	262	14	13159	1.5150	679	32	1024	Open Hole	7	Prod. Fluid	236	4.41	11835	1.999	282		
TO Float Collar	18104	18160	Prod. Casing	6	Mud	262	14	13200	1.5150	1188	32	1792	Open Hole	7	Prod. Fluid	236	4.41		1.999	494		
TO Inside Cement	18160	18195	Prod. Casing	6	Cement	262			1.5150	0	32	1120	Open Hole	7	Prod. Fluid	236	4.41					
BO Formation	18195	18349	Prod. Casing	6	Cement	262			1.5150	0	32	4928	Cement	7		236			1.999	0		
Shoe	18349	18349	Prod. Casing	6	Cement	262			1.5150	0	32	0	Cement	7		236			1.999	0		
Total weight										1526541		654437		7						181509		

Notes:

Cement fails allowing production fluid to flow into annulus.

Production fluid fills annulus, is trapped by seals at T O Annulus, no flow of production fluid

Pressure at T O annulus is set by reservoir pressure and density of production fluid.

Cement plug prevents production fluid from flowing into Production Casing.

Since Production Casing is plugged, the contents of the Production Casing affect the buoyancy.

Cement does not fix Production Casing.

Mud fills Production Casing

Area of Production Casing seal = 195.71 sq in

Pressure at top of Annulus = 8816 psi

Upwards force = 1725401 lb

Area of 18" seal = 214.85 sq in

Pressure wellhead = 3676.45 psi

Downwards force = 789871 lb

Net Buoyancy, lbm = Displaced weight - casing weight+upwards force - downwards force
+Weight of fluid in ProductionCasing =

Net Buoyancy, lb -1.06E+06

Temperature criteria:

Above mudline, temperatures are in equilibrium with seawater per pyncocline curve

Prodution Fluid densities,pressures and temperatures for annulus from HYSYS calculation for Static column, File name "DensityCalc110Deg F"

Production casing temperatures in equilibrium with formations.

Cement density as footnote

Cement density:

38.9 bbl Premium H at 16.74 ppg

6.93 bl Premium H 16.74 ppg

20 bbl spacer 14.3 ppg

133 bbl SOBM 14.0 ppg

728.5 bbl SOBM 14.0 ppg (189 ft cement in shoe)

Note: 11835 psi (sample pressure) used instead of 11844 psi (reservoir pressure) in HYSYS run.

Table 3.3 – Condition 3

Comments	Start True Vertical Depth	End True Vertical Depth	Production Casing Description	Production Casing ID	Production Casing Fluid	Production Casing Ave Temp. Deg F	Production Casing Fluid ppg	Production Casing Pressure at end of segment	Production Casing Fluid Capacity gal/ft	Production Casing Fluid Capacity wt/section, lb	Production Casing weight, lb/ft	Production Casing weight, lb per segment	Annulus Casing Description	Annulus ID for Displacement	Exterior Fluid	Annulus Fluid Ave Temp. Deg F	Annulus Fluid ppg	Annulus Pressure at end	Production Casing Fluid Displacement gal/ft	Production Casing Fluid Displacement wt/section, lb	Production on Casing Fluid Temp gradient, Deg F/ft	Prod. Casing Material
	0	300	Conductor	19.5	gel	80.0	16.2	252	15.4188	74935												
	300	600	Conductor	19.5	Seawater	80.0	8.52554	385	15.4188	39436												
	600	900	Conductor	19.5	Seawater	80.0	8.52554	518	15.4188	39436												
	900	1200	Conductor	19.5	Seawater	80.0	8.52554	651	15.4188	39436												
	1200	1500	Conductor	19.5	Seawater	80.0	8.52554	783	15.4188	39436												
	1500	1800	Conductor	19.5	Seawater	80.0	8.52554	916	15.4188	39436												
	1800	2100	Conductor	19.5	Seawater	80.0	8.52554	1049	15.4188	39436												
	2100	2400	Conductor	19.5	Seawater	80.0	8.52554	1182	15.4188	39436												
	2400	2700	Conductor	19.5	Seawater	80.0	8.52554	1315	15.4188	39436												
	2700	3000	Conductor	19.5	Seawater	80.0	8.52554	1447	15.4188	39436												
	3000	3300	Conductor	19.5	Seawater	80.0	8.52554	1580	15.4188	39436												
	3300	3600	Conductor	19.5	Seawater	80.0	8.52554	1713	15.4188	39436												
	3600	3900	Conductor	19.5	Seawater	80.0	8.52554	1846	15.4188	39436												
	3900	4200	Conductor	19.5	Seawater	80.0	8.52554	1979	15.4188	39436												
	4200	4500	Conductor	19.5	Seawater	80.0	8.52554	2111	15.4188	39436												
	4500	4800	Conductor	19.5	Seawater	80.0	8.52554	2244	15.4188	39436												
	4800	5001	Conductor	19.5	Seawater	80.0	8.52554	2333	15.4188	26422												
TOBOP	5001	5053	BOP	18.375	Seawater	80.0	8.52554	2356	13.7760	6107												
	5053	5058	Lock down seal	18.375	Seawater	80	8.52554	2358	13.7760	587												
TOProd. Casing	5058	5058					8.52554	2358					Casing	9-7/8	Prod. Fluid	145	4		3.9787			
	5058	5059	Hanger	8.626	Seawater	80	8.52554	2359	3.0353	26	62.8	62.8	Casing	9-7/8	Prod. Fluid	145	4		3.979	18		
	5059	5061	Prod. Casing	8.626	Seawater	80	8.52554	2360	3.0353	52	62.8	125.6	Casing	9-7/8	Prod. Fluid	145	4		3.979	36		
TO18" x 16" Annulus	5061	5061	Prod. Casing				8.52554	2360					Casing	9-7/8	Prod. Fluid	145	4	8816	3.9787	0.0000		
	5061	5561	Prod. Casing	8.626	Seawater	80	8.52554	2581	3.0353	12939	62.8	31400	Casing	9-7/8	Prod. Fluid	149	4.46		3.979	8872		Q-125
	5561	6061	Prod. Casing	8.626	Seawater	80	8.52554	2802	3.0353	12939	62.8	31400	Casing	9-7/8	Prod. Fluid	152	4.455		3.979	8862		
	6061	6561	Prod. Casing	8.626	Seawater	65	8.52554	3024	3.0353	12939	62.8	31400	Casing	9-7/8	Prod. Fluid	156	4.455		3.979	8862		
	6561	7061	Prod. Casing	8.626	Seawater	80	8.52554	3245	3.0353	12939	62.8	31400	Casing	9-7/8	Prod. Fluid	160	4.453		3.979	8858		
	7061	7561	Prod. Casing	8.626	Seawater	80	8.52554	3466	3.0353	12939	62.8	31400	Casing	9-7/8	Prod. Fluid	162	4.451		3.979	8855		
	7561	8061	Prod. Casing	8.626	Seawater	80	8.52554	3688	3.0353	12939	62.8	31400	Casing	9-7/8	Prod. Fluid	166	4.449		3.979	8851		
	8061	8367	Prod. Casing	8.626	Seawater	80	8.52554	3823	3.0353	7919	62.8	19216.8	Casing	9-7/8	Prod. Fluid	168	4.447		3.979	5414		
TOProd Casing Mud	8367	8867	Prod. Casing	8.626	Mud	122	14	4186	3.0353	21247	62.8	31400	Casing	9-7/8	Prod. Fluid	171	4.445		3.979	8843	0.01243	
	8867	9367	Prod. Casing	8.626	Mud	128	14	4550	3.0353	21247	62.8	31400	Casing	9-7/8	Prod. Fluid	175	4.443		3.979	8839	0.01243	
	9367	9867	Prod. Casing	8.626	Mud	134	14	4913	3.0353	21247	62.8	31400	Casing	9-7/8	Prod. Fluid	179	4.441		3.979	8835	0.01243	
	9867	10367	Prod. Casing	8.626	Mud	141	14	5277	3.0353	21247	62.8	31400	Casing	9-7/8	Prod. Fluid	182	4.439		3.979	8831	0.01243	
	10367	10867	Prod. Casing	8.626	Mud	147	14	5640	3.0353	21247	62.8	31400	Casing	9-7/8	Prod. Fluid	186	4.437		3.979	8827	0.01243	
	10867	11153	Prod. Casing	8.626	Mud	153	14	5848	3.0353	12154	62.8	17960.8	Casing	9-7/8	Prod. Fluid	188	4.435		3.979	5047	0.01243	
TO13-5/8"	11153	11585	Prod. Casing	8.626	Mud	162	14	6162	3.0353	18358	62.8	27129.6	Casing	9-7/8	Prod. Fluid	188	4.434		3.979	7621	0.01243	
BO16"	11585	12085	Prod. Casing	8.626	Mud	171	14	6526	3.0353	21247	62.8	31400	Casing	9-7/8	Prod. Fluid	194	4.432		3.979	8817	0.01791	
	12085	12486	Prod. Casing	8.626	Mud	178	14	6817	3.0353	17040	62.8	25182.8	Casing	9-7/8	Prod. Fluid	197	4.43		3.979	7068	0.01791	
Mid of x-over	12486	12488	x-over		Mud	178	14	6818	1.8674	52		470.6	Casing		Prod. Fluid	197	4.43	10540	3.628	32	0.01791	
	12488	12490	x-over		Mud	178	14	6820	1.8674	52			Casing		Prod. Fluid	197	4.43		3.628	32	0.01791	
	12490	12585	Prod. Casing	6	Mud	180	14	6889	1.5150	2015	32	3040	Casing	7	Prod. Fluid	198	4.43		1.999	841	0.01791	HCQ-125
	12585	12792	Prod. Casing	6	Mud	184	14	7039	1.5150	4390	32	6624	Casing	7	Prod. Fluid	199	4.429		1.999	1833	0.01791	
TO11-7/8	12792	13292	Prod. Casing	6	Mud	193	14	7403	1.5150	10605	32	16000	Casing	7	Prod. Fluid	203	4.427		1.999	4425	0.01791	
	13292	13792	Prod. Casing	6	Mud	202	14	7766	1.5150	10605	32	16000	Casing	7	Prod. Fluid	206	4.425		1.999	4423	0.01791	
	13792	14292	Prod. Casing	6	Mud	210	14	8130	1.5150	10605	32	16000	Casing	7	Prod. Fluid	209	4.423		1.999	4421	0.01791	
	14292	14748	Prod. Casing	6	Mud	219	14	8461	1.5150	9672	32	14592	Casing	7	Prod. Fluid	213	4.422		1.999	4031	0.01791	
TO9-7/8"	14748	15092	Prod. Casing	6	Mud	225	14	8711	1.5150	7296	32	11008	Casing	7	Prod. Fluid	215	4.421		1.999	3040	0.01791	
BO11-7/8"	15092	15592	Prod. Casing	6	Mud	234	14	9075	1.5150	10605	32	16000	Casing	7	Prod. Fluid	219	4.419		1.999	4417	0.01791	
	15592	16092	Prod. Casing	6	Mud	243	14	9438	1.5150	10605	32	16000	Casing	7	Prod. Fluid	222	4.417		1.999	4415	0.01791	
	16092	16592	Prod. Casing	6	Mud	252	14	9801	1.5150	10605	32	16000	Casing	7	Prod. Fluid	226	4.415		1.999	4413	0.01791	
	16592	17092	Prod. Casing	6	Mud	261	14	10165	1.5150	10605	32	16000	Casing	7	Prod. Fluid	229	4.413		1.999	4411	0.01791	
BO9-7/8"	17092	17157	Prod. Casing	6	Mud	262	14	10212	1.5150	1379	32	2080	Casing	7	Prod. Fluid	230	4.413		1.999	573	0.01791	
Open Hole	17157	17289	Prod. Casing	6	Mud	262	14	10308	1.5150	2800	32	4224	Open Hole	7	Prod. Fluid	230	4.413		1.999	1165		
TOAnnulus Cement	17289	18072	Prod. Casing	6	Mud	262	14	10877	1.5150	16607	32	25056	Open Hole	7	Prod. Fluid	236	4.411		1.999	6905		
TOFormation	18072	18104	Prod. Casing	6	Mud	262	14	10900	1.5150	679	32	1024	Open Hole	7	Prod. Fluid	236	4.41	11835	1.999	282		
TOFloat Collar	18104	18160	Prod. Casing	6	Mud	262	14	10941	1.5150	1188	32	1792	Open Hole	7	Prod. Fluid	236	4.41		1.999	494		
TOInside Cement	18160	18195	Prod. Casing	6	Cement	262	14.5		1.5150	769	32	1120	Open Hole	7	Prod. Fluid	236	4.41					
BOFormation	18195	18349	Prod. Casing	6	Cement	262	14.5		1.5150	3383	32	4928	Cement	7	Cement	236			1.999	0		
Shoe	18349	18349	Prod. Casing	6	Cement	262	14.5		1.5150	0	32	0	Cement	7	Cement	236			1.999	0		
Total weight										1084776		654437								181509		

Notes:

Communication between the reservoir and the annulus.
Production fluid fills annulus, is trapped by seals at T O Annulus, no flow of production fluid
Pressure at T O annulus is set by reservoir pressure and density of production fluid.
Cement plug prevents production fluid from flowing into Production Casing.
Cement does not fix Production Casing.
Since Production Casing is plugged, the contents of the Production Casing affect the buoyancy.
Area of Production Casing seal = 195.71 sq in
Pressure at top of Annulus = 8816 psi
Upwards force = 1725401 lb
Area of 18" seal = 214.85 sq in
Pressure wellhead = 2358 psi
Downwards force = 506687 lb
Net Buoyancy, lbm = Displaced weight - casing weight+upwards force - downwards force
+Weight of fluid in ProductionCasing =
Net Buoyancy, lb -3.39E+05

Temperature criteria:
Seawater temperature in production casing is 80 Deg F since seawater is pumped fprm the surface.
Mud temperatures in production casing are in equilibrium with formations.
Prodution Fluid densities,pressures and temperatures for annulus from HYSYS calculation for
Static column, File name "DensityCalc110Deg F"
Production casing Temps from Downhole Temp surveys
Cement density: 5.26 bbl premium H at 16.74 ppg
38.9 bbl Premium H , foamed to 47.75 bbl 14.5 ppg
6.93 bl Premium H 16.74 ppg
20 bbl spacer 14.3 ppg
133 bbl SOBM 14.0 ppg
728.5 bbl SOBM 14.0 ppg (189 ft cement in shoe)
Note: 11835 psi (sample pressure) used instead of 11844 psi (reservoir pressure) in HYSYS run.

Table 3.4 – Condition 4

Comments	Start True Vertical Depth	End True Vertical Depth	Production Casing Description	Production Casing ID	Production Casing Fluid	Production Casing Ave Temp. Deg F	Production Casing Fluid ppg	Production Casing Pressure at end of segment	Production Casing Fluid Capacity gal/ft	Production Casing Fluid Capacity wt/section, lb	Production Casing weight, lb/ft	Production Casing weight, lb per segment	Annulus Casing Description	Annulus ID for Displacement	Exterior Fluid	Annulus Fluid Ave Temp. Deg F	Annulus Fluid ppg	Annulus Pressure at end	Production Casing Fluid Displacement gal/ft	Production Casing Fluid Displacement wt/section, lb	Production Casing Fluid Temp gradient, Deg F/ft	Annulus Fluid Temp gradient, Deg F/ft	Production Casing Material
	0	300	Conductor	19.5	gel	80.0	16.2	252	15.4188	74935													
	300	600	Conductor	19.5	Seawater	80.0	8.52554	385	15.4188	39436													
	600	900	Conductor	19.5	Seawater	80.0	8.52554	518	15.4188	39436													
	900	1200	Conductor	19.5	Seawater	80.0	8.52554	651	15.4188	39436													
	1200	1500	Conductor	19.5	Seawater	80.0	8.52554	783	15.4188	39436													
	1500	1800	Conductor	19.5	Seawater	80.0	8.52554	916	15.4188	39436													
	1800	2100	Conductor	19.5	Seawater	80.0	8.52554	1049	15.4188	39436													
	2100	2400	Conductor	19.5	Seawater	80.0	8.52554	1182	15.4188	39436													
	2400	2700	Conductor	19.5	Seawater	80.0	8.52554	1315	15.4188	39436													
	2700	3000	Conductor	19.5	Seawater	80.0	8.52554	1447	15.4188	39436													
	3000	3300	Conductor	19.5	Seawater	80.0	8.52554	1580	15.4188	39436													
	3300	3600	Conductor	19.5	Seawater	80.0	8.52554	1713	15.4188	39436													
	3600	3900	Conductor	19.5	Seawater	80.0	8.52554	1846	15.4188	39436													
	3900	4200	Conductor	19.5	Seawater	80.0	8.52554	1979	15.4188	39436													
	4200	4500	Conductor	19.5	Seawater	80.0	8.52554	2111	15.4188	39436													
	4500	4800	Conductor	19.5	Seawater	80.0	8.52554	2244	15.4188	39436													
	4800	5001	Conductor	19.5	Seawater	80.0	8.52554	2333	15.4188	26422													
TOBOP	5001	5053	BOP	18.375	Seawater	80.0	8.52554	2356	13.7760	6107													
	5053	5058	Lock down seal	18.375	Seawater	80	8.52554	2358	13.7760	587													
TOProd. Casing	5058	5058					8.52554	2358		0	62.8	0	Casing	9-7/8	Mud			3677					
	5058	5059	Hanger	8.626	Seawater	80	8.52554	2359	3.0353	26	62.8	62.8	Casing	9-7/8	Mud	48	14	3678	3.979	56			
	5059	5061	Prod. Casing	8.626	Seawater	80	8.52554	2360	3.0353	52	62.8	125.6	Casing	9-7/8	Mud	48	14	3679	3.979	111			
TO18" x 16" Annulus	5061	5061	Prod. Casing				8.52554	2360					Casing	9-7/8	Mud	48	14	3679				0.0161048	
	5061	5561	Prod. Casing	8.626	Seawater	80	8.52554	2581	3.0353	12939	62.8	31400	Casing	9-7/8	Mud	57	14	4043	3.979	27851		0.0161048	Q-125
	5561	6061	Prod. Casing	8.626	Seawater	80	8.52554	2802	3.0353	12939	62.8	31400	Casing	9-7/8	Mud	58	14	4406	3.979	27851		0.0161048	
	6061	6561	Prod. Casing	8.626	Seawater	65	8.52554	3024	3.0353	12939	62.8	31400	Casing	9-7/8	Mud	58	14	4769	3.979	27851		0.0161048	
	6561	7061	Prod. Casing	8.626	Seawater	80	8.52554	3245	3.0353	12939	62.8	31400	Casing	9-7/8	Mud	59	14	5133	3.979	27851		0.0161048	
	7061	7561	Prod. Casing	8.626	Seawater	80	8.52554	3466	3.0353	12939	62.8	31400	Casing	9-7/8	Mud	62	14	5496	3.979	27851		0.0161048	
	7561	8061	Prod. Casing	8.626	Seawater	80	8.52554	3688	3.0353	12939	62.8	31400	Casing	9-7/8	Mud	70	14	5860	3.979	27851		0.0161048	
	8061	8367	Prod. Casing	8.626	Seawater	80	8.52554	3823	3.0353	7919	62.8	19216.8	Casing	9-7/8	Mud	90	14	6082	3.979	17045		0.0161048	
TOProd Casing Mud	8367	8867	Prod. Casing	8.626	Mud	122	14	4186	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	122	14	6446	3.979	27851	0.0124301	0.0161048	
	8867	9367	Prod. Casing	8.626	Mud	128	14	4550	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	128	14	6809	3.979	27851	0.0124301	0.0161048	
	9367	9867	Prod. Casing	8.626	Mud	134	14	4913	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	134	14	7172	3.979	27851	0.0124301	0.0161048	
	9867	10367	Prod. Casing	8.626	Mud	141	14	5277	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	141	14	7536	3.979	27851	0.0124301	0.0161048	
	10367	10867	Prod. Casing	8.626	Mud	147	14	5640	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	147	14	7899	3.979	27851	0.0124301	0.0161048	
	10867	11153	Prod. Casing	8.626	Mud	153	14	5848	3.0353	12154	62.8	17960.8	Casing	9-7/8	Mud	153	14	8107	3.979	15931	0.0124301	0.0161048	
TO13-5/8"	11153	11585	Prod. Casing	8.626	Mud	162	14	6162	3.0353	18358	62.8	27129.6	Casing	9-7/8	Mud	162	14	8421	3.979	24063	0.0124301	0.0161048	
BO16"	11585	12085	Prod. Casing	8.626	Mud	171	14	6526	3.0353	21247	62.8	31400	Casing	9-7/8	Mud	171	14	8785	3.979	27851	0.0179115	0.0161048	
	12085	12486	Prod. Casing	8.626	Mud	178	14	6817	3.0353	17040	62.8	25182.8	Casing	9-7/8	Mud	178	14	9076	3.979	22336	0.0179115	0.0161048	
Mid of x-over	12486	12488	x-over		Mud	178	14	6818	1.8674	52		470.6	Casing		Mud	178	14	9078	3.628	102	0.0179115	0.0161048	
	12488	12490	x-over		Mud	178	14	6820	1.8674	52			Casing		Mud	178	14	9079	3.628	102	0.0179115	0.0161048	
	12490	12585	Prod. Casing	6	Mud	180	14	6889	1.5150	2015	32	3040	Casing	7	Mud	180	14	9148	1.999	2659	0.0179115	0.0161048	HCQ-125
	12585	12792	Prod. Casing	6	Mud	184	14	7039	1.5150	4390	32	6624	Casing	7	Mud	184	14	9299	1.999	5794	0.0179115	0.0161048	
TO11-7/8	12792	13292	Prod. Casing	6	Mud	193	14	7403	1.5150	10605	32	16000	Casing	7	Mud	193	14	9662	1.999	13994	0.0179115	0.0161048	
	13292	13792	Prod. Casing	6	Mud	202	14	7766	1.5150	10605	32	16000	Casing	7	Mud	202	14	10025	1.999	13994	0.0179115	0.0161048	
	13792	14292	Prod. Casing	6	Mud	210	14	8130	1.5150	10605	32	16000	Casing	7	Mud	210	14	10389	1.999	13994	0.0179115	0.0161048	
	14292	14748	Prod. Casing	6	Mud	219	14	8461	1.5150	9672	32	14592	Casing	7	Mud	219	14	10720	1.999	12763	0.0179115	0.0161048	
TO9-7/8"	14748	15092	Prod. Casing	6	Mud	225	14	8711	1.5150	7296	32	11008	Casing	7	Mud	225	14	10970	1.999	9628	0.0179115	0.0161048	
BO11-7/8"	15092	15592	Prod. Casing	6	Mud	234	14	9075	1.5150	10605	32	16000	Casing	7	Mud	234	14	11334	1.999	13994	0.0179115	0.0161048	
	15592	16092	Prod. Casing	6	Mud	243	14	9438	1.5150	10605	32	16000	Casing	7	Mud	243	14	11697	1.999	13994	0.0179115	0.0161048	
	16092	16592	Prod. Casing	6	Mud	252	14	9801	1.5150	10605	32	16000	Casing	7	Mud	252	14	12061	1.999	13994	0.0179115	0.0161048	
	16592	17092	Prod. Casing	6	Mud	261	14	10165	1.5150	10605	32	16000	Casing	7	Mud	261	14	12424	1.999	13994	0.0179115	0.0161048	
BO9-7/8"	17092	17157	Prod. Casing	6	Mud	262	14	10212	1.5150	1379	32	2080	Casing	7	Mud	262	14	12471	1.999	1819	0.0179115	0.0161048	
Open Hole	17157	17289	Prod. Casing	6	Mud	262	14	10308	1.5150	2800	32	4224	Open Hole	7	Mud	262	14	12567	1.999	3695		0.0161048	
TOAnnulus Cement	17289	18072	Prod. Casing	6	Mud	262	14	10877	1.5150	16607	32	25056	Cement	7	Cement				1.999	0		0.0161048	
TOFormation	18072	18104	Prod. Casing	6	Mud	262	14	10900	1.5150	679	32	1024	Cement	7	Cement				1.999	0		0.0161048	
TOFloat Collar	18104	18160	Prod. Casing	6	Mud	262	14	10941	1.5150	1188	32	1792	Open Hole	7	Cement				1.999	0		0.0161048	
TOInside Cement	18160	18195	Prod. Casing	6	Mud	262	14	10967	1.5150	742	32	1120	Open Hole	7	Cement							0.0161048	
BOFormation	18195	18349	Prod. Casing	6	Mud	262	14	11079	1.5150	3266	32	4928	Open Hole	7	Cement	175			1.999	0		0.0161048	
Shoe	18349	18349	Prod. Casing	6	Mud	262	14	11079	1.5150	0	32	0	Open Hole	7	Cement	262			1.999	0		0.0161048	
Total weight										NA		654437								548270			

Notes:

Communication between reservoir and Production Casing. Gel/seawater/mud still in Production Casing.

Mud is in annulus, cement does not hold Production Casing.

Production Casing contains seawater down to depth of the drill pipe.

Since hole is open, the contents of the Production Casing do not affect the buoyancy.

Area of Production Casing seal = 195.71 sq in

Pressure at top of Annulus = 3679 psi

Upwards force = 720061 lb

Area of 18" seal = 214.85 sq in

Pressure wellhead = 2358 psi

Downwards force = 506687 lb

Net Buoyancy, lbm = Displaced weight - casing weight+upwards force - downwards force

+Weight of fluid in ProductionCasing =

Net Buoyancy, lb 1.07E+05

Seawater temperature in production casing is 80 Deg F since seawater is pumped form the surface.

Mud temperatures in production casing and annulus are in equilibrium with formations.

Cement density as footnote

Cement density: 5.26 bbl premium H at 16.74 ppg

5.26 bbl premium H at 16.74 ppg

38.9 bbl Premium H, foamed to 47.75 bbl 14.5 ppg

6.93 bl Premium H 16.74 ppg

20 bbl spacer 14.3 ppg

133 bbl SOBM 14.0 ppg

728.5 bbl SOBM 14.0 ppg (189 ft cement in shoe)

Pressure at BO Annulus = pressure at cementing = 12567 psi

Table 3.5 – Condition 5

Comments	Start True Vertical Depth	End True Vertical Depth	Production Casing Description	Production Casing ID	Production Casing Fluid	Production Casing Ave Temp. Deg F	Production Casing Fluid ppg	Production Casing Pressure at end of segment	Production Casing Fluid Capacity gal/ft	Production Casing Fluid Capacity wt/section, lb	Production Casing weight, lb/ft	Production Casing weight, lb per segment	Annulus Casing Description	Annulus ID for Displacement	Exterior Fluid	Annulus Fluid Ave Temp. Deg F	Annulus Fluid ppg	Annulus Pressure at end	Production Casing Fluid Displacement gal/ft	Production Casing Fluid Displacement wt/section, lb	Diff. Press. at end of segment	Production Casing Fluid Temp gradient, Deg F/ft	Annulus Fluid Temp gradient, Deg F/ft	Production Casing Material
	0	300	Conductor	19.5					15.4188															
	300	600	Conductor	19.5					15.4188															
	600	900	Conductor	19.5					15.4188															
	900	1200	Conductor	19.5					15.4188															
	1200	1500	Conductor	19.5					15.4188															
	1500	1800	Conductor	19.5					15.4188															
	1800	2100	Conductor	19.5					15.4188															
	2100	2400	Conductor	19.5					15.4188															
	2400	2700	Conductor	19.5					15.4188															
	2700	3000	Conductor	19.5					15.4188															
	3000	3300	Conductor	19.5					15.4188															
	3300	3600	Conductor	19.5					15.4188															
	3600	3900	Conductor	19.5					15.4188															
	3900	4200	Conductor	19.5					15.4188															
	4200	4500	Conductor	19.5					15.4188															
	4500	4800	Conductor						15.4188															
	4800	5001	Conductor						15.4188															
TOBOP	5001	5053	BOP						13.7760															
	5053	5058	Lock down seal						13.7760															
TOProd. Casing	5058	5058			Prod. Fluid	145	4.463	8815	3.0353	0			Casing	9-7/8	Prod. Fluid	145	4		3.9787	0				
	5058	5059	Hanger		Prod. Fluid	145	4.463	8815	3.0353	14	62.8	62.8	Casing	9-7/8	Prod. Fluid	145	4		3.979	18				
	5059	5061	Prod. Casing		Prod. Fluid	145	4.463	8816	3.0353	27	62.8	125.6	Casing	9-7/8	Prod. Fluid	145	4		3.979	36				
TO 18" x 16" Annulus	5061	5061	Prod. Casing		Prod. Fluid	145	4.463	8816					Casing	9-7/8	Prod. Fluid	145	4	8816	3.9787	0.0000				
	5061	5561	Prod. Casing	8.626	Prod. Fluid	149	4.46		3.0353	6769	62.8	31400	Casing	9-7/8	Prod. Fluid	149	4.46		3.979	8872				Q-125
	5561	6061	Prod. Casing	8.626	Prod. Fluid	152	4.455		3.0353	6761	62.8	31400	Casing	9-7/8	Prod. Fluid	152	4.455		3.979	8862				
	6061	6561	Prod. Casing	8.626	Prod. Fluid	156	4.455		3.0353	6761	62.8	31400	Casing	9-7/8	Prod. Fluid	156	4.455		3.979	8862				
	6561	7061	Prod. Casing	8.626	Prod. Fluid	160	4.453		3.0353	6758	62.8	31400	Casing	9-7/8	Prod. Fluid	160	4.453		3.979	8858				
	7061	7561	Prod. Casing	8.626	Prod. Fluid	162	4.451		3.0353	6755	62.8	31400	Casing	9-7/8	Prod. Fluid	162	4.451		3.979	8855				
	7561	8061	Prod. Casing	8.626	Prod. Fluid	166	4.449		3.0353	6752	62.8	31400	Casing	9-7/8	Prod. Fluid	166	4.449		3.979	8851				
	8061	8367	Prod. Casing	8.626	Prod. Fluid	168	4.447		3.0353	4130	62.8	19216.8	Casing	9-7/8	Prod. Fluid	168	4.447		3.979	5414				
	8367	8867	Prod. Casing	8.626	Prod. Fluid	171	4.445		3.0353	6746	62.8	31400	Casing	9-7/8	Prod. Fluid	171	4.445		3.979	8843				
	8867	9367	Prod. Casing	8.626	Prod. Fluid	175	4.443		3.0353	6743	62.8	31400	Casing	9-7/8	Prod. Fluid	175	4.443		3.979	8839				
	9367	9867	Prod. Casing	8.626	Prod. Fluid	179	4.441		3.0353	6740	62.8	31400	Casing	9-7/8	Prod. Fluid	179	4.441		3.979	8835				
	9867	10367	Prod. Casing	8.626	Prod. Fluid	182	4.439		3.0353	6737	62.8	31400	Casing	9-7/8	Prod. Fluid	182	4.439		3.979	8831				
	10367	10867	Prod. Casing	8.626	Prod. Fluid	186	4.437		3.0353	6734	62.8	31400	Casing	9-7/8	Prod. Fluid	186	4.437		3.979	8827				
	10867	11153	Prod. Casing	8.626	Prod. Fluid	188	4.435		3.0353	3850	62.8	17960.8	Casing	9-7/8	Prod. Fluid	188	4.435		3.979	5047				
TO 13-5/8"	11153	11585	Prod. Casing	8.626	Prod. Fluid	188	4.434		3.0353	5814	62.8	27129.6	Casing	9-7/8	Prod. Fluid	188	4.434		3.979	7621				
BO 16"	11585	12085	Prod. Casing	8.626	Prod. Fluid	194	4.432		3.0353	6726	62.8	31400	Casing	9-7/8	Prod. Fluid	194	4.432		3.979	8817				
	12085	12486	Prod. Casing	8.626	Prod. Fluid	197	4.43		3.0353	5392	62.8	25182.8	Casing	9-7/8	Prod. Fluid	197	4.43		3.979	7068				
Mid of x-over	12486	12488	x-over		Prod. Fluid	197	4.43	10540	1.8674	17		470.6	Casing		Prod. Fluid	197	4.43	10540	3.628	32				
	12488	12490	x-over		Prod. Fluid	197	4.43		1.8674	17			Casing		Prod. Fluid	197	4.43		3.628	32				
	12490	12585	Prod. Casing	6	Prod. Fluid	198	4.43		1.5150	638	32	3040	Casing	7	Prod. Fluid	198	4.43		1.999	841				HCQ-125
	12585	12792	Prod. Casing	6	Prod. Fluid	199	4.429		1.5150	1389	32	6624	Casing	7	Prod. Fluid	199	4.429		1.999	1833				
TO 11-7/8	12792	13292	Prod. Casing	6	Prod. Fluid	203	4.427		1.5150	3353	32	16000	Casing	7	Prod. Fluid	203	4.427		1.999	4425				
	13292	13792	Prod. Casing	6	Prod. Fluid	206	4.425		1.5150	3352	32	16000	Casing	7	Prod. Fluid	206	4.425		1.999	4423				
	13792	14292	Prod. Casing	6	Prod. Fluid	209	4.423		1.5150	3350	32	16000	Casing	7	Prod. Fluid	209	4.423		1.999	4421				
	14292	14748	Prod. Casing	6	Prod. Fluid	213	4.422		1.5150	3055	32	14592	Casing	7	Prod. Fluid	213	4.422		1.999	4031				
TO 9-7/8"	14748	15092	Prod. Casing	6	Prod. Fluid	215	4.421		1.5150	2304	32	11008	Casing	7	Prod. Fluid	215	4.421		1.999	3040				
BO 11-7/8"	15092	15592	Prod. Casing	6	Prod. Fluid	219	4.419		1.5150	3347	32	16000	Casing	7	Prod. Fluid	219	4.419		1.999	4417				
	15592	16092	Prod. Casing	6	Prod. Fluid	222	4.417		1.5150	3346	32	16000	Casing	7	Prod. Fluid	222	4.417		1.999	4415				
	16092	16592	Prod. Casing	6	Prod. Fluid	226	4.415		1.5150	3344	32	16000	Casing	7	Prod. Fluid	226	4.415		1.999	4413				
	16592	17092	Prod. Casing	6	Prod. Fluid	229	4.413		1.5150	3343	32	16000	Casing	7	Prod. Fluid	229	4.413		1.999	4411				
BO 9-7/8"	17092	17157	Prod. Casing	6	Prod. Fluid	230	4.413		1.5150	435	32	2080	Casing	7	Prod. Fluid	230	4.413		1.999	573				
Open Hole	17157	17289	Prod. Casing	6	Prod. Fluid	230	4.413		1.5150	883	32	4224	Open Hole	7	Prod. Fluid	230	4.413		1.999	1165				
TO Annulus Cement	17289	18072	Prod. Casing	6	Prod. Fluid	236	4.411		1.5150	5233	32	25056	Cement	7	Prod. Fluid	236	4.411		1.999	6905				
TO Formation	18072	18104	Prod. Casing	6	Prod. Fluid	236	4.41		1.5150	214	32	1024	Cement	7	Prod. Fluid	236	4.41	11835	1.999	282				
TO Float Collar	18104	18160	Prod. Casing	6	Prod. Fluid	236	4.41		1.5150	374	32	1792	Open Hole	7	Prod. Fluid	236	4.41	11835	1.999	494				
TO Inside Cement	18160	18195	Prod. Casing	6	Prod. Fluid	236	4.41	11835	1.5150	234	32	1120	Open Hole	7	Prod. Fluid	236	4.41	11835						
BO Formation	18195	18349	Prod. Casing	6	Prod. Fluid	236	4.411	11835	1.5150	1029	32	4928	Open Hole	7		236			1.999	0				
Shoe	18349	18349	Prod. Casing	6	Prod. Fluid	236	4.411	11835	1.5150	0	32	0	Open Hole	7		236			1.999	0				
Total weight										NA		654437								181509				

Notes:

Communication between reservoir and Production Casing.

Production fluid fills annulus, is trapped by seals at T O Annulus, no flow of production fluid

Pressure at T O annulus is set by reservoir pressure and density of production fluid.

Production fluid is in annulus, cement does not hold Production Casing.

Since hole is open, the contents of the Production Casing do not affect the buoyancy.

Area of Production Casing seal = 195.7 sq in

Pressure at top of Annulus = 8816 psi

Upwards force = 1725401 lb

Area of 18" seal = 214.85 sq in

Pressure wellhead = 8815 psi

Downwards force = 1893934 lb

Net Buoyancy, lbm = Displaced weight - casing weight+upwards force - downwards force

+Weight of fluid in ProductionCasing =

Net Buoyancy, lb -6.41E+05

Production Fluid densities,pressures and temperatures for annulus from HYSYS calculation for static column, File name "DensityCalc110Deg F"

Production Fluid densities,pressures and temperatures for production casing the same as annulus.

Production casing contents ignored since contents do not affect buoyancy.

Note: 11835 psi (sample pressure) used instead of 11844 psi (reservoir pressure) in HYSYS run.

5.26 bbl premium H at 16.74 ppg

Note: If Production Casing pressure is less than annulus pressure by 2084 psi (at Hanger), than buoyant force on hanger is positive and hanger and production casing will lift unless held by cement.

Table 3.6 – Condition 6

Comments	Start True Vertical Depth	End True Vertical Depth	Production Casing Description	Production Casing ID	Production Casing Fluid	Production Casing Ave Temp. DegF	Production Casing Fluid ppg	Production Casing Pressure at end of segment	Production Casing Fluid Capacity gal/ft	Production Casing Fluid Capacity wt/section, lb	Production Casing weight, lb/ft	Production Casing weight, lb per segment	Annulus Casing Description	Annulus ID for Displacement	Exterior Fluid	Annulus Fluid Ave Temp. DegF	Annulus Fluid ppg	Annulus Pressure at end	Production Casing Fluid Displacement gal/ft	Production Casing Fluid Displacement wt/section, lb	Production Casing Fluid Temp gradient, DegF/ft	Production Casing Material
	0	300	Conductor	19.5	NA				15.4188	0												
	300	600	Conductor	19.5					15.4188	0												
	600	900	Conductor	19.5					15.4188	0												
	900	1200	Conductor	19.5					15.4188	0												
	1200	1500	Conductor	19.5					15.4188	0												
	1500	1800	Conductor	19.5					15.4188	0												
	1800	2100	Conductor	19.5					15.4188	0												
	2100	2400	Conductor	19.5					15.4188	0												
	2400	2700	Conductor	19.5					15.4188	0												
	2700	3000	Conductor	19.5					15.4188	0												
	3000	3300	Conductor	19.5					15.4188	0												
	3300	3600	Conductor	19.5					15.4188	0												
	3600	3900	Conductor	19.5					15.4188	0												
	3900	4200	Conductor	19.5					15.4188	0												
	4200	4500	Conductor	19.5					15.4188	0												
	4500	4800	Conductor						15.4188	0												
	4800	5001	Conductor						15.4188	0												
TOBOP	5001	5053	BOP						13.7760	0												
	5053	5058	Lock down seal						13.7760	0												
TOProd. Casing	5058	5058			Prod. Fluid	145	4.463	8815					Casing	9-7/8	Mud	40	14		3.9787	0		
	5058	5059	Hanger		Prod. Fluid	145	4.463		3.0353	14	62.8	62.8	Casing	9-7/8	Mud	48	14		3.979	56		
	5059	5061	Prod. Casing		Prod. Fluid	145	4.463		3.0353	27	62.8	125.6	Casing	9-7/8	Mud	48	14		3.979	111		
TO 18" x 16" Annulus	5061	5061	Prod. Casing		Prod. Fluid	145	4.463						Casing	9-7/8	Mud	48	14	3679			0	
	5061	5561	Prod. Casing	8.626	Prod. Fluid	149	4.46		3.0353	6769	62.8	31400	Casing	9-7/8	Mud	55.07405178	14	4042	3.979	27851	0	Q-125
	5561	6061	Prod. Casing	8.626	Prod. Fluid	152	4.455		3.0353	6761	62.8	31400	Casing	9-7/8	Mud	62.14810355	14	4406	3.979	27851	0	
	6061	6561	Prod. Casing	8.626	Prod. Fluid	156	4.455		3.0353	6761	62.8	31400	Casing	9-7/8	Mud	69.22215533	14	4769	3.979	27851	0	
	6561	7061	Prod. Casing	8.626	Prod. Fluid	160	4.453		3.0353	6758	62.8	31400	Casing	9-7/8	Mud	76.2962071	14	5133	3.979	27851	0	
	7061	7561	Prod. Casing	8.626	Prod. Fluid	162	4.451		3.0353	6755	62.8	31400	Casing	9-7/8	Mud	83.37025888	14	5496	3.979	27851	0	
	7561	8061	Prod. Casing	8.626	Prod. Fluid	166	4.449		3.0353	6752	62.8	31400	Casing	9-7/8	Mud	90.44431066	14	5860	3.979	27851	0	
	8061	8367	Prod. Casing	8.626	Prod. Fluid	168	4.447		3.0353	4130	62.8	19216.8	Casing	9-7/8	Mud	94.77363034	14	6082	3.979	17045	0	
	8367	8867	Prod. Casing	8.626	Prod. Fluid	171	4.445		3.0353	6746	62.8	31400	Casing	9-7/8	Mud	101.8476821	14	6445	3.979	27851	0.0141481	
	8867	9367	Prod. Casing	8.626	Prod. Fluid	175	4.443		3.0353	6743	62.8	31400	Casing	9-7/8	Mud	109	14	6809	3.979	27851	0.0141481	
	9367	9867	Prod. Casing	8.626	Prod. Fluid	179	4.441		3.0353	6740	62.8	31400	Casing	9-7/8	Mud	116	14	7172	3.979	27851	0.0141481	
	9867	10367	Prod. Casing	8.626	Prod. Fluid	182	4.439		3.0353	6737	62.8	31400	Casing	9-7/8	Mud	123	14	7536	3.979	27851	0.0141481	
	10367	10867	Prod. Casing	8.626	Prod. Fluid	186	4.437		3.0353	6734	62.8	31400	Casing	9-7/8	Mud	130	14	7899	3.979	27851	0.0141481	
	10867	11153	Prod. Casing	8.626	Prod. Fluid	188	4.435		3.0353	3850	62.8	17960.8	Casing	9-7/8	Mud	134	14	8107	3.979	15931	0.0141481	
TO 13-5/8"	11153	11585	Prod. Casing	8.626	Prod. Fluid	188	4.434		3.0353	5814	62.8	27129.6	Casing	9-7/8	Mud	140	14	8421	3.979	24063	0.0141481	
BO 16"	11585	12085	Prod. Casing	8.626	Prod. Fluid	194	4.432		3.0353	6726	62.8	31400	Casing	9-7/8	Mud	147	14	8784	3.979	27851	0.0141481	
	12085	12486	Prod. Casing	8.626	Prod. Fluid	197	4.43		3.0353	5392	62.8	25182.8	Casing	9-7/8	Mud	153	14	9076	3.979	22336	0.0141481	
Mid of x-over	12486	12488	x-over		Prod. Fluid	197	4.43	10540	1.8674	17		470.6	Casing		Mud	153	14	9077	3.628	102	0.0141481	
	12488	12490	x-over		Prod. Fluid	197	4.43		1.8674	17			Casing		Mud	153	14	9079	3.628	102	0.0141481	
	12490	12585	Prod. Casing	6	Prod. Fluid	198	4.43		1.5150	638	32	3040	Casing	7	Mud	154	14	9148	1.999	2659	0.0141481	HCQ-125
	12585	12792	Prod. Casing	6	Prod. Fluid	199	4.429		1.5150	1389	32	6624	Casing	7	Mud	157	14	9298	1.999	5794	0.0141481	
TO 11-7/8	12792	13292	Prod. Casing	6	Prod. Fluid	203	4.427		1.5150	3353	32	16000	Casing	7	Mud	164	14	9662	1.999	13994	0.0141481	
	13292	13792	Prod. Casing	6	Prod. Fluid	206	4.425		1.5150	3352	32	16000	Casing	7	Mud	172	14	10025	1.999	13994	0.0141481	
	13792	14292	Prod. Casing	6	Prod. Fluid	209	4.423		1.5150	3350	32	16000	Casing	7	Mud	179	14	10389	1.999	13994	0.0141481	
	14292	14748	Prod. Casing	6	Prod. Fluid	213	4.422		1.5150	3055	32	14592	Casing	7	Mud	185	14	10720	1.999	12763	0.0141481	
TO 9-7/8"	14748	15092	Prod. Casing	6	Prod. Fluid	215	4.421		1.5150	2304	32	11008	Casing	7	Mud	190	14	10970	1.999	9628	0.0141481	
BO 11-7/8"	15092	15592	Prod. Casing	6	Prod. Fluid	219	4.419		1.5150	3347	32	16000	Casing	7	Mud	197	14	11334	1.999	13994	0.0141481	
	15592	16092	Prod. Casing	6	Prod. Fluid	222	4.417		1.5150	3346	32	16000	Casing	7	Mud	204	14	11697	1.999	13994	0.0141481	
	16092	16592	Prod. Casing	6	Prod. Fluid	226	4.415		1.5150	3344	32	16000	Casing	7	Mud	211	14	12060	1.999	13994	0.0141481	
	16592	17092	Prod. Casing	6	Prod. Fluid	229	4.413		1.5150	3343	32	16000	Casing	7	Mud	218	14	12424	1.999	13994	0.0141481	
BO 9-7/8"	17092	17157	Prod. Casing	6	Prod. Fluid	230	4.413		1.5150	435	32	2080	Casing	7	Mud	219	14	12471	1.999	1819	0.0141481	
Open Hole	17157	17289	Prod. Casing	6	Prod. Fluid	230	4.413		1.5150	883	32	4224	Open Hole	7	Mud	221	14	12567	1.999	3695	0.0141481	
TO Annulus Cement	17289	18072	Prod. Casing	6	Prod. Fluid	236	4.411		1.5150	5233	32	25056	Cement	7	Cement	232			1.999	0	0.0141481	
TO Formation	18072	18104	Prod. Casing	6	Prod. Fluid	236	4.41		1.5150	214	32	1024	Cement	7	Cement	233			1.999	0	0.0141481	
TO Float Collar	18104	18160	Prod. Casing	6	Prod. Fluid	236	4.41		1.5150	374	32	1792	Open Hole	7	Cement	233			1.999	0	0.0141481	
TO Inside Cement	18160	18195	Prod. Casing	6	Prod. Fluid	236	4.41	11835	1.5150	234	32	1120	Open Hole	7	Cement	233.8211921					0.0141481	
BO Formation	18195	18349	Prod. Casing	6	Prod. Fluid	236	4.411	11835	1.5150	1029	32	4928	Open Hole	7	Cement	236			1.999	0	0.0141481	
Shoe	18349	18349	Prod. Casing	6	Prod. Fluid	236	4.411	11835	1.5150	0	32	0	Open Hole	7		236			1.999	0	0.0141481	
Total weight										NA		654437								548270		

Notes:

Communication between reservoir and Production Casing.

Mud fills annulus, is trapped by seals at T O Annulus, no flow of production fluid

Pressure at T O annulus is set by reservoir pressure and density of mud.

Production fluid is in annulus, cement does not hold Production Casing.

Production Casing contains production fluid

Since hole is open, the contents of the Production Casing do not affect the buoyancy.

Area of Production Casing seal = 195.71 sq in

Pressure at top of Annulus = 3679 psi

Upwards force = 720026 lb

Area of 18" seal = 214.8 sq in

Pressure wellhead = 8815 psi

Downwards force = 1893869 lb

Net Buoyancy, lbm = Displaced weight - casing weight+upwards force - downwards force

+Weight of fluid in ProductionCasing =

Net Buoyancy, lb -1.28E+06

Production Fluid densities,pressures and temperatures for annulus from HYSYS calculation for Static column, File name "DensityCalc110Deg F"

Temperature criteria In wellbore, mud in equilibrium with formations

Production casing contents ignored since contents do not affect buoyancy.

Note: 11835 psi (sample pressure) used instead of 11844 psi (reservoir pressure) in HYSYS run.

Table 3.7 – Condition 7

Comments	Start True Vertical Depth	End True Vertical Depth	Production Casing Description	Production Casing ID	Production Casing Fluid	Production Casing Ave Temp. Deg F	Production Casing Fluid ppg	Production Casing Pressure at end of segment	Production Casing Fluid Capacity gal/ft	Production Casing Fluid Capacity wt/section, lb	Production Casing weight, lb/ft	Production Casing weight, lb per segment	Annulus Casing Description	Annulus ID for Displacement	Exterior Fluid	Annulus Fluid Ave Temp. Deg F	Annulus Fluid ppg	Annulus Pressure at end	Production Casing Fluid Displacement gal/ft	Production Casing Fluid Displacement wt/section, lb	Diff. Press. at end of segment	Production Casing Fluid Temp gradient, Deg F/ft	Annulus Fluid Temp gradient, Deg F/ft	Production Casing Material
	0	300	Conductor	19.5					15.4188															
	300	600	Conductor	19.5					15.4188															
	600	900	Conductor	19.5					15.4188															
	900	1200	Conductor	19.5					15.4188															
	1200	1500	Conductor	19.5					15.4188															
	1500	1800	Conductor	19.5					15.4188															
	1800	2100	Conductor	19.5					15.4188															
	2100	2400	Conductor	19.5					15.4188															
	2400	2700	Conductor	19.5					15.4188															
	2700	3000	Conductor	19.5					15.4188															
	3000	3300	Conductor	19.5					15.4188															
	3300	3600	Conductor	19.5					15.4188															
	3600	3900	Conductor	19.5					15.4188															
	3900	4200	Conductor	19.5					15.4188															
	4200	4500	Conductor	19.5					15.4188															
	4500	4800	Conductor						15.4188															
	4800	5001	Conductor						15.4188															
TO BOP	5001	5053	BOP						13.7760															
	5053	5058	Lock down seal						13.7760															
TO Prod. Casing	5058	5058			Prod. Fluid			2358	3.0353				Casing	9-7/8	Prod. Fluid	145	4		3.9787	0				
	5058	5059	Hanger		Prod. Fluid			2358	3.0353		62.8	62.8	Casing	9-7/8	Prod. Fluid	145	4		3.979	18				
	5059	5061	Prod. Casing		Prod. Fluid			2358	3.0353		62.8	125.6	Casing	9-7/8	Prod. Fluid	145	4		3.979	36				
TO 18" x 16" Annulus	5061	5061	Prod. Casing		Prod. Fluid			2358					Casing	9-7/8	Prod. Fluid	145	4	8816	3.9787	0.0000				
	5061	5561	Prod. Casing	8.626	Prod. Fluid				3.0353		62.8	31400	Casing	9-7/8	Prod. Fluid	149	4.46		3.979	8872				Q-125
	5561	6061	Prod. Casing	8.626	Prod. Fluid				3.0353		62.8	31400	Casing	9-7/8	Prod. Fluid	152	4.455		3.979	8862				
	6061	6561	Prod. Casing	8.626	Prod. Fluid				3.0353		62.8	31400	Casing	9-7/8	Prod. Fluid	156	4.455		3.979	8862				
	6561	7061	Prod. Casing	8.626	Prod. Fluid				3.0353		62.8	31400	Casing	9-7/8	Prod. Fluid	160	4.453		3.979	8858				
	7061	7561	Prod. Casing	8.626	Prod. Fluid				3.0353		62.8	31400	Casing	9-7/8	Prod. Fluid	162	4.451		3.979	8855				
	7561	8061	Prod. Casing	8.626	Prod. Fluid				3.0353		62.8	31400	Casing	9-7/8	Prod. Fluid	166	4.449		3.979	8851				
	8061	8367	Prod. Casing	8.626	Prod. Fluid				3.0353		62.8	19216.8	Casing	9-7/8	Prod. Fluid	168	4.447		3.979	5414				
	8367	8867	Prod. Casing	8.626	Prod. Fluid				3.0353		62.8	31400	Casing	9-7/8	Prod. Fluid	171	4.445		3.979	8843				
	8867	9367	Prod. Casing	8.626	Prod. Fluid				3.0353		62.8	31400	Casing	9-7/8	Prod. Fluid	175	4.443		3.979	8839				
	9367	9867	Prod. Casing	8.626	Prod. Fluid				3.0353		62.8	31400	Casing	9-7/8	Prod. Fluid	179	4.441		3.979	8835				
	9867	10367	Prod. Casing	8.626	Prod. Fluid				3.0353		62.8	31400	Casing	9-7/8	Prod. Fluid	182	4.439		3.979	8831				
	10367	10867	Prod. Casing	8.626	Prod. Fluid				3.0353		62.8	31400	Casing	9-7/8	Prod. Fluid	186	4.437		3.979	8827				
	10867	11153	Prod. Casing	8.626	Prod. Fluid				3.0353		62.8	17960.8	Casing	9-7/8	Prod. Fluid	188	4.435		3.979	5047				
TO 13-5/8"	11153	11585	Prod. Casing	8.626	Prod. Fluid				3.0353		62.8	27129.6	Casing	9-7/8	Prod. Fluid	188	4.434		3.979	7621				
BO 16"	11585	12085	Prod. Casing	8.626	Prod. Fluid				3.0353		62.8	31400	Casing	9-7/8	Prod. Fluid	194	4.432		3.979	8817				
	12085	12486	Prod. Casing	8.626	Prod. Fluid				3.0353		62.8	25182.8	Casing	9-7/8	Prod. Fluid	197	4.43		3.979	7068				
Mid of x-over	12486	12488	x-over		Prod. Fluid				1.8674			470.6	Casing		Prod. Fluid	197	4.43	10540	3.628	32				
	12488	12490	x-over		Prod. Fluid				1.8674				Casing		Prod. Fluid	197	4.43		3.628	32				
	12490	12585	Prod. Casing	6	Prod. Fluid				1.5150		32	3040	Casing	7	Prod. Fluid	198	4.43		1.999	841				HCQ-125
	12585	12792	Prod. Casing	6	Prod. Fluid				1.5150		32	6624	Casing	7	Prod. Fluid	199	4.429		1.999	1833				
TO 11-7/8	12792	13292	Prod. Casing	6	Prod. Fluid				1.5150		32	16000	Casing	7	Prod. Fluid	203	4.427		1.999	4425				
	13292	13792	Prod. Casing	6	Prod. Fluid				1.5150		32	16000	Casing	7	Prod. Fluid	206	4.425		1.999	4423				
	13792	14292	Prod. Casing	6	Prod. Fluid				1.5150		32	16000	Casing	7	Prod. Fluid	209	4.423		1.999	4421				
	14292	14748	Prod. Casing	6	Prod. Fluid				1.5150		32	14592	Casing	7	Prod. Fluid	213	4.422		1.999	4031				
TO 9-7/8"	14748	15092	Prod. Casing	6	Prod. Fluid				1.5150		32	11008	Casing	7	Prod. Fluid	215	4.421		1.999	3040				
BO 11-7/8"	15092	15592	Prod. Casing	6	Prod. Fluid				1.5150		32	16000	Casing	7	Prod. Fluid	219	4.419		1.999	4417				
	15592	16092	Prod. Casing	6	Prod. Fluid				1.5150		32	16000	Casing	7	Prod. Fluid	222	4.417		1.999	4415				
	16092	16592	Prod. Casing	6	Prod. Fluid				1.5150		32	16000	Casing	7	Prod. Fluid	226	4.415		1.999	4413				
	16592	17092	Prod. Casing	6	Prod. Fluid				1.5150		32	16000	Casing	7	Prod. Fluid	229	4.413		1.999	4411				
BO 9-7/8"	17092	17157	Prod. Casing	6	Prod. Fluid				1.5150		32	2080	Casing	7	Prod. Fluid	230	4.413		1.999	573				
Open Hole	17157	17289	Prod. Casing	6	Prod. Fluid				1.5150		32	4224	Open Hole	7	Prod. Fluid	230	4.413		1.999	1165				
TO Annulus Cement	17289	18072	Prod. Casing	6	Prod. Fluid				1.5150		32	25056	Cement	7	Prod. Fluid	236	4.411		1.999	6905				
TO Formation	18072	18104	Prod. Casing	6	Prod. Fluid				1.5150		32	1024	Cement	7	Prod. Fluid	236	4.41	11835	1.999	282				
TO Float Collar	18104	18160	Prod. Casing	6	Prod. Fluid				1.5150		32	1792	Open Hole	7	Prod. Fluid	236	4.41	11835	1.999	494				
TO Inside Cement	18160	18195	Prod. Casing	6	Prod. Fluid			11835	1.5150		32	1120	Open Hole	7	Prod. Fluid	236	4.41	11835						
BO Formation	18195	18349	Prod. Casing	6	Prod. Fluid			11835	1.5150		32	4928	Open Hole	7		236			1.999	0				
Shoe	18349	18349	Prod. Casing	6	Prod. Fluid			11835	1.5150		32	0	Open Hole	7		236			1.999	0				
Total weight										NA		654437								181509				

Notes:

Communication between reservoir and Production Casing.

Production fluid fills annulus, is trapped by seals at T O Annulus, no flow of production fluid

Pressure at T O annulus is set by reservoir pressure and density of production fluid.

Production fluid is in annulus, cement does not hold Production Casing.

Since hole is open, the contents of the Production Casing do not affect the buoyancy.

Area of Production Casing seal = 195.7 sq in

Pressure at top of Annulus = 8816 psi

Upwards force = 1725401 lb

Area of 18 " seal = 214.85 sq in

Pressure wellhead = 2358 psi

Downwards force = 506607 lb

Net Buoyancy, lbm = Displaced weight - casing weight+upwards force - downwards force

+Weight of fluid in ProductionCasing =

Net Buoyancy, lb 7.46E+05

Prodution Fluid densities,pressures and temperatures for annulus from HYSYS calculation for

Static column, File name "DensityCalc110Deg F"

Production casing pressure at TO casing set to 2358 psi.

Production casing contents ignored since contents do not affect buoyancy.

Note: 11835 psi (sample pressure) used instead of 11844 psi (reservoir pressure) in HYSYS run.

5.26 bbl premium H at 16.74 ppg

Note: If Production Casing pressure is less than annulus pressure by 2084 psi (at Hanger), than buoyant force on hanger is positive and hanger and production casing will lift unless held by cement.

Table 3.8 – Condition 8

Temperature Calculations

For temperature growth

delta L = L*alpha*delta T

Where:

L = characteristic length

alpha = thermal coefficient of material, in/in per Deg F

delta T = change in Temperature, Deg F

For 9-7/8" casing, close to the crossover:

I D, in, =	8.625			
b, in, =	4.3125			
t, in, =	0.625			
At 12486 feet depth,				
T, temperature at depth, Deg F =	178			
T0, temperature at floor, Deg F =	70			
delta T, Deg F =	108			
alpha =	6.26E-06			
b, inner id, in, =	4.3125			
a, outer id, in, =	4.9375			
Delta a, in, = a*alpha*delta T, in				
Delta a, in, =	3.34E-03	or	0.0676	percent, negligible
Delta b, in, = b*alpha*delta T, in				
Delta b, in, =	2.91E-03	or	0.0676	percent, negligible

The increase in steel volume is accompanied by a reduction in density.

For 7" casing, close to the shoe:

O D, in, =	7			
b, in, =	3.047			
t, in, =	0.453	R/t =	6.726269	
At 18349 TVD feet depth,				
T, temperature at depth, Deg F =	262			
T0, temperature at floor, Deg F =	70			
delta T, Deg F =	192			
alpha =	6.52E-06			
b, inner id, in, =	3.047			
a, outer id, in, =	3.5			
Delta a, in, = a*alpha*delta T, in				
Delta a, in, =	4.38E-03	or	0.1253	percent, negligible
Delta b, in, = b*alpha*delta T, in				
Delta b, in, =	3.82E-03	or	0.1253	percent, negligible

The increase in steel volume is accompanied by a reduction in density.

Pressure Calculations

per Roark & Young, "Formulas for Stress and Strain, Fifth Edition:
Table 29, "Formulas for membrane stresses and deformations in thin walled pressure vessels ", pp 448

for vessel with radius R, thickness t under uniform load q (psi)
applicable for R/t > 10
Delta R =q * R^2/(E *t)
E = modulus of elasticity, psi

For 9-7/8" casing, close to the crossover:

I D, in, =	8.625		
R, in, =	4.3125		
t, in, =	0.625	R/t =	6.90

For 7" casing, close to the shoe:

O D, in, =	7		
R, in, =	3.047		
t, in, =	0.453	R/t =	6.73

Do not use, R/t is too small.

Table 39, "Formulas for thick walled vessels under internal and external loading", pp 505

For 9-7/8" casing, the maximum differential is at the hanger in condition 4

I D, in, =	8.625		
R, in, =	4.3125		
t, in, =	0.625	R/t =	6.9

At 5061 foot depth, 48 Deg F

inner pressure, psi, =	2358	(Condition 4)		
Outer pressure , psi, =	8816			
net inner pressure, psi, =	-6458	Condition 2		
E, psi, =	2.99E+07		Temp =	at 70 Deg F
mu, Poisson's ratio =	0.3			
b, inner id, in, =	4.3125		L, length, in =	89160
a, outer id, in, =	4.9375			

Delta a, in, = q*/E*2*a*b^2*/(a^2-b^2)
Delta a, in, = -0.008986 or -0.182 percent, negligible
Delta b, in, = q*b/E*((a^2+b^2)/(a^2-b^2)+mu)
Delta b, in, = -0.007197 or -0.167 percent, negligible
Delta L, in, = -q*mu*L/E*2*b^2/(a^2-b^2)
37.134928 or 0.042 percent, negligible

Pressure Calculations (Cont'd)

For 7" casing, the maximum differential is at the bottom hole in condition 5

O D, in, =	7		
R, in, =	3.047		
t, in, =	0.453	R/t =	6.726269

At 17163 feet depth,

inner pressure, psi, =	11079				
Outer pressure , psi, =	12576				
net inner pressure, psi, =	-1497				
E, psi, =	2.92E+07		Temp =	at 262 Deg F	
mu, Poisson's ratio =	0.3				
b, inner id, in, =	3.047		L, length, in =		68064
a, outer id, in, =	3.50				

Delta a, in, = q*/E*2*a*b^2*/(a^2-b^2)

Delta a, in, =	-0.001483	or	-0.042	percent, negligible

Delta b, in, = q*b/E*((a^2+b^2)/(a^2-b^2)+mu)

Delta b, in, =	-0.001181	or	-0.039	percent, negligible

Delta L, in, = -q*mu*L/E*2*b^2/(a^2-b^2)

	27.59	or	0.041	percent, negligible

Differential Pressure

			Casing size, in		Differential, psi	
Condition 1			9-7/8"	7"		
	hanger	Pi, psig	3676			
		Po, psig	3676		0	
	xovr	Pi, psig	9077			
		Po, psig	9077		0	
	BH	Pi, psig		12567		
		Po, psig		13200	-633	
Condition 2			9-7/8"	7"		
	hanger	Pi, psig	3676			
		Po, psig	2956		-720	
	xovr	Pi, psig	9077			
		Po, psig	8358		719	
	BH	Pi, psig		13200		
		Po, psig		11844	1356	
Condition 3			9-7/8"	7"		
	hanger	Pi, psig	3676			
		Po, psig	8816		-5140	
	xovr	Pi, psig	9077			
		Po, psig	10540		-1463	
	BH	Pi, psig		13200		
		Po, psig		11844	1356	
Condition 4			9-7/8"	7"		
	hanger	Pi, psig	2358			
		Po, psig	8816		-6458	max
	xovr	Pi, psig	6818			
		Po, psig	10540		-3722	max
	BH	Pi, psig		10941		
		Po, psig		11835	-894	
Condition 5			9-7/8"	7"		
	hanger	Pi, psig	2358			
		Po, psig	3679		-1321	
	xovr	Pi, psig	6818			
		Po, psig	9078		-2260	
	BH	Pi, psig		11079		
		Po, psig		12567	-1488	max
Condition 6			9-7/8"	7"		
	hanger	Pi, psig	8815			
		Po, psig	8816		-1	
	xovr	Pi, psig	10540			
		Po, psig	10540		0	
	BH	Pi, psig		11835		
		Po, psig		11835	0	

Differential Pressure (Cont'd)

			Casing size, in		Differential, psi
Condition 7			9-7/8"	7"	
	hanger	Pi, psig	8815		
		Po, psig	3679		5136
	xovr	Pi, psig	10540		
		Po, psig	9077		-1463
	BH	Pi, psig		11835	
		Po, psig		11835	0
Condition 8			9-7/8"	7"	
	hanger	Pi, psig	2358		
		Po, psig	8816		-6458
	xovr	Pi, psig	NA		
		Po, psig	NA		
	BH	Pi, psig		11835	
		Po, psig		11835	0

Material Properties

Low Chrome Moly steels, Cr less than 3%

Modulus of elasticity from ANSI B31.3

Temp, Deg F	E, psi (multiply table by 10^6)		
-100	30.4		
70	29.9		
200	29.5	178	29.6
300	29.0	262	29.19
262	29.19		
162	29.6		

Mean Coefficient of thermal expansion between 70 Deg F and temperature, from ANSI B31.3

Temp, Deg F	A, in/in (multiply table by 10^-6)		
70	0		
125	6.19		
150	6.25		
175	6.31	178	6.26
200	6.43		
250	6.49		
275	6.54		
262	6.52		
162	6.28		

Volumes and weights of Displaced Fluids

19.5" ID conductor =	.3694 bbl/ft =	15.419 gal/ft
18.375 " ID casing =	.3280 bbl/ft =	13.776 gal/ft
14.92" ID casing =	.2162 bbl/ft =	9.080 gal/ft
9-7/8" OD casing =	.09473 bbl/ft displacement =	3.979 gal/ft
9-7/8" OD, 8.626 " ID casing =	.07227 bb//ft =	3.035 gal/ft
7" OD casing, displacement =	.0476 bbl/ft =	1.999 gal/ft
7" OD, 6" ID casing =	0.036071 bbl/ft =	1.515 gal/ft

9-7/8" OD, 62.8 #/ft casing is 8.626 "
7" OD, 32 #/ft casing is 6" ID
16", 97#/ft casing is 14.92" ID

"Prod. Casing Fluid ppg" used density of seawater at 80 Deg F

Fresh water =	8.318 lb/gal at 80 Deg F	(Ref. No. 9)
Seawater sp gr =	1.025	
Seawater =	8.526 lb/gal	

Production Fluid density is determined from HYSYS runs which give static gradient at each depth.

gradient (in/ft) / 12 = gradient (psi/ft) psi/ft * 8.337 / .433 = lb/gal.

7.38257 inH2O/ft= 0.26475 psi/ft = 5.098 lb/gal

Density of seawater at depths is read from the graph of density vs. sea depth, (Ref. No.2)
This data is generic, site specific data was not used.

Density of mud was fixed at 14 ppg. No data was given for the change in density with pressure or temperature.

"Prod Casing Pressure at end of segment" is determined from:

Fluid ppg / 8.37 (freshwater ppg) * .433 (gradient of freshwater) * length of segment plus previous pressure

"Prod Casing Fluid Capacity" is determined from:

Either id of casing or tables (Ref. No. 2)

Temperatures of fluid and casing were determined by:

For pumped seawater, temperature is 80 Deg F.
For mud in Production Casing, temperature is in equilibrium with the formations.
Temperatures of the formations were determined from Ref. No. 1
Temperatures of produced fluids were determined from Appendix B, Item 6.

Reservoir pressure was determined from Halliburton, Appendix B Item 5.

Annulus Casing Description is not applicable for the segments of the riser, BOP and the Production Casing hanger.

These items are supported by the well head and surface conductor and do not affect the loads on the Production Casing. The contents of the riser, BOP and Production Casing hanger would move if the Production Casing moves.

Therefore, the contents of the riser, BOP and Production Casing hanger are included in the Production Casing loads.

Crossover Dimensions

Crossover dimensions from K&B drawing, (See Apeendix B, Item.4)

1	Cross over is 10.078 " od, 8.626" id for 8.5"	
2	Cross over is 10.078 " od, 6.034" id at 48-32.161-8.5 =7.34"	7.339
1.5	Tapers from 1 to 2 over the 7.34"	
3	Cross over is 10.078 " od, 6.034" id for 32.382-48+32.151"=16.533"	16.533
4	Cross over is 7.016" od, 6.034" id at 6.9"	
3.5	Tapers from 3 to 4 over 48-32.392-6.9 = 8.708"	8.708

so:

10.087	" od by	8.626	" id for	8.5	", volume of OD =	679.26	cu in					
					", volume of ID =	496.74	cu in		0.2875	cu ft =	2.15	gal
Taper is												
10.087	" od by	7.33	" id for	7.34	", volume of OD =	586.56	cu in					
					", volume of ID =	309.74	cu in		0.9990	cu ft =	7.47	gal
10.087	" od by	6.034	" id for	16.533	", volume of OD =	1321.19	cu in					
					", volume of ID =	472.77	cu in					
Taper is												
8.5515	" od by	6.034	" id for	8.708	", volume of OD =	500.14	cu in					
					", volume of ID =	249.01	cu in					
7.016	" od by	6.034	" id for	6.9	", volume of OD =	266.76	cu in					
					", volume of ID =	197.31	cu in					

Displacement is total of OD volume =	3353.90	cu in =	1.94	cu ft =	14.51	gal
Contents is total of ID volume =	1725.57	cu in =	0.999	cu ft =	7.47	gal
Weight is difference of OD volume and ID volume =	1628.33	cu in =	470.59	lb		
Density is 8000 kg/cu m =	0.289 lb/cu in					

7700	0.287
8000	0.289
8030	0.29

Check totals

Add section 1-4 47.981 Overall length from drawing = 48 inches
Length is ok.

Seal Area Calculations

Pressure, force downward

Pressure = pressure in wellhead = pressure at top of Production casing = pressure at 5058 foot depth

Area = inside of 18.620" Seal = Area (18.62" dia) - Area (8.553" dia)

214.8461 sq in

Pressure, force upwards

Pressure = pressure in annulus at T O Annulus = pressure at 5061 foot depth

Area = inside of 18.620" Seal = Area (18.62" dia) - Area (9.875" dia)

195.7124

Forces at Crossover

Crossover dimensions from K&B drawing, (See Appendix B, Item.4)

1 Cross over is 10.078 " od, 8.626" id at upper end

4 Cross over is 7.016" od, 6.034" id at lower end

External area

The external vertical force on the crossover is the external pressure times the horizontal projection of the outside area

The internal vertical force on the crossover is the internal pressure times the horizontal projection of the inside area

Outside area, below reducer = 10.087 OD by 7.016" ID = Ao =	54.14	sq in
Outside area, above reducer = 10.087 OD by 9.875" ID = Ao =	16.21	sq in
Inside area = 8.625" OD by 6.034" ID = Ai =	29.83	sq in

Note the two outside area counteract each other.

Pressure forces

Pressure forces are due to the different pressures and areas at the crossover.

Radial forces.

The Horizontal forces are due to the difference in the external and internal pressures.

The pressures are listed below because the radial pressures are used to determine stress levels in the casing.

Condition	External Pressure, psi	Internal Pressure, psi
1	9077	9077
2	8354	9077
3	10540	9077
4	10540	6818
5	9078	6818
6	10540	10540
7	9077	10540

Forces at Crossover (Cont'd)

Vertical Forces

The external vertical force on the crossover is the external pressure times the horizontal projection of (the below outside area - the above outside area.)

The internal vertical force on the crossover is the internal pressure times the horizontal projection of the inside area

The forces oppose each other because the external vertical force is an upward force, and the internal force is an downrwards force.

For simplicity, the same external pressure is used for the above and below outside areas.

These areas a only 4 feet apart.

Condition	External Pressure, psi	Internal Pressure, psi	Net upwards vertical force, lbm
1	9077	9077	73500
2	8354	9077	46078
3	10540	9077	128988
4	10540	6818	196363
5	9078	6818	140896
6	10540	10540	85346
7	9077	10540	29872

These forces are included in the buoyancy calculations by Archimedes principle.

WELL SIMULATION USING ASPEN HYSYS (ver. 7.1)

The well bore sample report from Schlumberger (Appendix B) was reviewed for the best fit for the component input requirements for HYSYS. The sample chosen was sample 1.18. The component information supplied was entered into the computer for simulation. Components heavier than C30 were combined to form a C30+ component. Since the oil/gas composition is eighty-five mole percent gas, the C30+ component will not significantly change the simulation.

Once the input stream compositions were entered and a physical property database chosen, the process flow for the well simulation was modeled in HYSYS. The sample component results were entered for the gas and the oil phases at a set reservoir pressure of 11,856 psia and reservoir temperature of 243 degrees Fahrenheit. A mixer was used to combine the phases into one stream at a 11,856 psia and 243 degrees Fahrenheit, then sent through a heat exchanger to adjust temperature and pressure to the sample collection conditions of 236 degrees Fahrenheit and 11,835.3 psig. The output was connected to a pipe with a length and vertical elevation specified to match the bottom hole to RKB TVD. The exit temperature was also specified. The velocity in the pipe was minimized in order to approximate a static column of fluid. The chosen output numbers were density, temperature and pressure at various elevations. These outputs were inputs into the buoyancy calculation worksheets.

The specified output temperature was chosen to be 110 deg F at rig floor elevation. This approximates a normal wellhead temperature for this type of production.

In this simulation, the pipe length and elevation (well inlet is zero length at zero elevation) were set to 18,074 feet. The molar flow was set to 100 moles per hour to make checking of the component composition percentages easier and to minimize the flow through the pipe (i.e. Well) to approach static conditions.
The well profile output was extracted and loaded into an Excel spreadsheet. The density and pressure were used in the buoyancy spreadsheets.

To check sensitivity to temperature, the specified output temperature was changed to 160 Deg F at rig floor elevation. All other parameters were held constant. The output for the 110 Deg F outlet temperature case was compared to that for the 160 outlet temperature case. The pressure differences at the production casing hanger were different by only 0.36%. For the buoyancy calculations, this difference is negligible, so the pressures are insensitive to the chosen outlet temperature.

The temperature of the static column will drop with time due to lower temperatures in the formations eventually reaching the formation temperatures. This process will take an undetermined length of time. The densities of the fluid will be higher so the hydrostatic pressures will be lower at the top of the column. (The bottom pressure is controlled by the reservoir pressure.) The higher temperatures used in the model therefore result in higher pressures at the hanger. The results in the buoyancy calculations are an upper bound for pressures at the hanger.

The buoyant force that lifts the casing in Condition 4 will be lower as the production fluid cools.

Section 6 - List of References

1. "Density of Ocean Water", Pynocline graph Windows to the Universe website, accessed 8/24/2010
2. Schlumberger\i-Handbook
3. Crane "Flow of Fluids" Technical Paper No. 410 Physical Properties of Water, pg-A6
4. Roark & Young "Formulas for Stress & Strain", Fifth Edition, 1975 McGraw-Hill ppg 504, ppg 583

Appendix A – List of Abbreviations

KEI	Keystone Engineering Inc
BOEMRE	Bureau of Ocean Energy, Management, Regulation and Enforcement
RKB	Rig Kelly Bushing
ppg	pound per gallon
SOBM	Synthetic oil based mud
T O	Top Of
BH	Bottom Hole
BOP	Blow Out Preventer
TVD	True Vertical Depth
sq in	Square Inch
psi	Pounds per square inch
lb	Pounds
wt	Weight
x-over	crossover
Deg F	Degrees Fahrenheit
ID	inner diameter
OD	outer diameter
bbl	barrel (42 gallons)

Appendix B – Material Supplied by BOEMRE

1. Wellbore Schematic, File Name "BP-HZN-MBI000184559.xls" BP GoM Deepwater Exploration "Macondo" As-Drilled Schematic, Rev. 15, 4/22/2010

2. Halliburton "BP AMERICA PRODUCTION COMPANY PO Box 22024 Tulsa OK 74121-2024 Macondo #1" 9 7/8" x 7" Production Casing Design Report" for Brian Morel, April 18, 2010

3. Dril-Quip BP Proposal Drawing for Wellhead System, Part Number 2-PD-32424-02CP "Macando" , File name DQ-DHJI-000011

4. K & B Machine Works Drawing of Crossover – 9 7/8" 62.80# TSH 523 BOX x 7" 32.0# TSH 513 PIN x 48" LG, Drawing # KB-TOX-0978-0014, Rev. B, 3/30/10

5. Halliburton, Houston Technology Center, "GeoTap Pressure Transient Analysis, BP Exploration & Production Inc. Well: OCS-G 32306 001 ST00BP01…" by Steve Kizziar, 04/08/10

6. Schlumberger "Fluid Analysis on "Macondo" Samples, BP …Well: OCS-G 32306 #1, Reservoir Sample Analysis Report", Updated 6/09/10 . Prepared by S.George Mathews, Schlumberger OilPhase – DBR