## 4.1 Pore Pressure Evaluation

Baker Hughes INTEQ formation pressure evaluation services commenced at 337m. An average seawater density of 1.04sg was assumed as the normal saline pressure gradient for all calculations for Baleen - 4. Using real time data, such as the hydrocarbon gas trend, lithology, flowline temperature, corrected Drilling Exponent (Dxc) data for conventional roller bits, constant drilling fluid parameters, pore pressure estimates were made during the drilling of Baleen - 4. For more details, please refer to Appendix 3, "Pressure Evaluation Plot".

The following brief description of the Dxc is an extraction from Baker Hughes INTEQ manual; **Formation Pressure Evaluation Pore Pressure Evaluation Techniques**. Please refer to it for further clarification.

Bingham (1965) proposed a relationship between penetration rate, weight on bit, rotary speed, and bit diameter, Jorden and Shirley (1966) solved the equation and allowed a constant, “a”, to be unity, but made the d-exponent lithology specific. In a constant lithology, the d-exponent should increase as the depth, compaction and differential pressure across the bottom increase. Upon penetration of a geopressured zone, compaction and differential pressure will decrease and will be reflected by a decrease in the d-exponent

Since differential pressure is dependent upon the mud density as well as formation pore pressure, Rehm and McClendon (1971) proposed a correction for this, hence the Dxc (**Equation 4-12)**

$$\mathbf{Dxc = [\log (R/60N) / \log (12W/10^3B)] \times [N.FBG/ECD]}$$

Where Dxc = corrected d-exponent (dimensionless)

R = rate of penetration (ft/hr)

N = rotary speed (rpm)

B = hole diameter (inches)

N.FBG = normal formation balance gradient (ppg)

ECD = effective circulating density (ppg)

W = weight on bit (1000 lbs)

Factors not considered by the Dxc in its basic form are drilling hydraulics, tooth efficiency (tooth wear and change in bit type) and lithology variation (matrix strength). If differential pressure becomes too large, the simple ratio correction will not completely compensate for its effect on the drill rate. In addition, the relationships among force applied (W/B), rotary speed (N), differential pressure (N.FBG/ECD), and rate of penetration (R) are more complex than the Dxc formulation would imply. While working within “normal” working ranges, radical changes in any of these parameters (for example, change in hole size after setting casing) may result in a change in the Dxc. 80824 Rev B /January 1996 Confidential

Whilst sliding with a downhole motor, bit RPM values are calculated from the flowrates used, as specified by the manufacturer. And in high angle deviated holes, the translation of the weight onto the bit may not be very exact, thus affecting the Dxc.

## 12.25" Hole Section

A synthetic oil based mud system was used to drill this section. The mud density ranged from 9.3ppg to 9.85ppg with the effective circulation density calculated to be in the area of 9.58ppg to 9.89ppg.

This interval consisted of Calcareous Claystones, Calcilutites, Calcarenites, Argillaceous Calcilutite, Claystones, Siltstone, Silty Sandstone, Sandstones and minor Glauconitic Claystone.

The Dxc showed no major deflections that could be associated with abnormal pressure. Negative deflections in the Dxc trend line were thought to be related to lithology changes. Weight on bit relationships associated with mud motor and high angle deviated hole was another factor affecting Dxc values and therefore Dxc trends could not be relied upon with any certainty to ascertain pore pressure gradients.

The temperature gradient showed a gradual increase with depth ranging from 34.4degrees to 68.5degrees, with a gradient of approximately 2.27degrees /100m (thought to be due to rigs drilling parameters being pushed to the limit) and no notable deflections in the trend line.

No significant cavings were noted on the shakers and no connection gasses (gas peaks did not seem to coincide with connections) were observed while drilling Baleen - 4.

In the absence of any abnormal pressure indicators while drilling Baleen - 4 the whole 12.25" section was estimated to have a relatively normal pore pressure in the range of 1.04sg to 1.07sg EMW. Indications from the previous wells drilled in the extreme near vicinity likewise showed no signs of abnormal pressure.

## 8.5" Hole Section

A KCL brine based mud system was used throughout this section. The mud density varied from 1.09sg (9.1ppg) to 1.18sg with the effective circulating density calculated to be in the range of 1.26sg to 1.31sg.

The 8.5" hole (drilling for production liner) section consisted mainly of a Sandstone interval and was largely extreme angle to horizontal, with little increase in TVD.

The Dxc showed no major deflections that could be associated with abnormal pressure. Negative deflections in the Dxc trend line were thought to be related to changes of the mud system from SBOM to KCL brine. Weight on bit relationships associated with mud motor and high angle deviated hole was another factor affecting Dxc values and therefore Dxc trends could not be relied upon with any certainty to ascertain pore pressure gradients.

The temperature gradient showed a gradual increase with depth, and no notable deflections in the trend line.

No significant cavings were noted on the shakers and no connection gasses were observed while drilling Baleen-4. Although significant gas peaks were recorded from drilled volume.

In the absence of any abnormal pressure indicators while drilling Baleen-4 the whole 8.5" section was estimated to have a relatively normal pore pressure in the range of 1.02g to 1.06g EMW. This estimate is supported by the known reservoir pressure of 950psi, indicating that this section was in act under-pressured.