National Exams May 2014

98-Pet-B1, Well Logging and Formation Evaluation

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. Candidates are also encouraged to make any reasonable assumption for the missing parameters (if any) and answer questions.
3. This is a CLOSED BOOK exam.

   Approved calculators are permitted.
4. This exam contains 12 questions. All questions will be marked.
5. Value of each question is shown.
6. Some questions require an answer in essay format. Clarity and organization of the answer are important.

Question 1:

a. List four factors which affect the resistivity of log. **(4 pts)**

b. With the help of two separate diagrams for the resistivity as a function of distance away from the wellbore, describe the invasion profile when i) transition and ii) annulus zones are observed. **(6 pts)**

Question 2:

Describe four characteristics which affect the log quality. **(8 pts)**

Question 3:

List the four sources of spontaneous potential. **(4 pts)**

Question 4:

List the three factors which determine the response of porosity logs in gas-bearing formations. **(3 pts)**

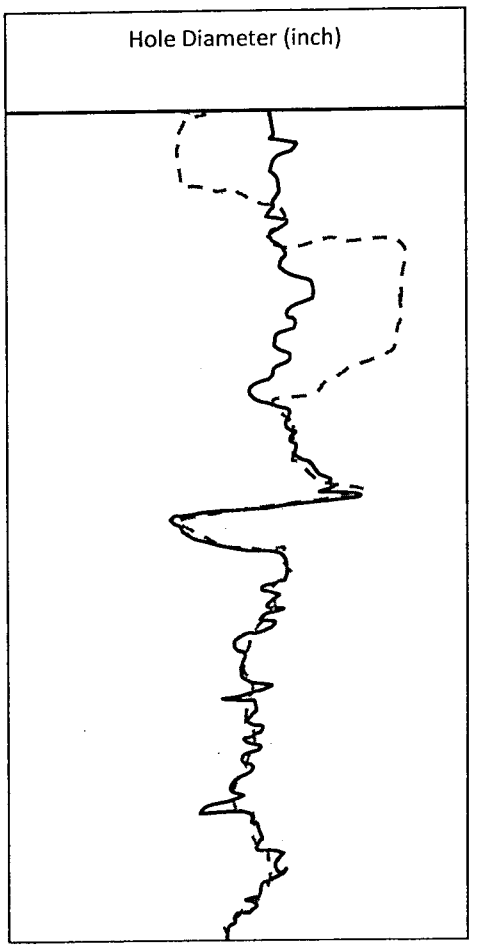
Question 5:

List four limitations of Hingle plot. **(4 points)**

Question 6:

a) The following log shows responses of two independent arms of a calliper tool.

Estimate shape of borehole (cross-sectional) in at least three depths where irregularity exists. **(4 pts)**



b) Reservoir rock contains minerals that give off Natural Gamma Radiation.

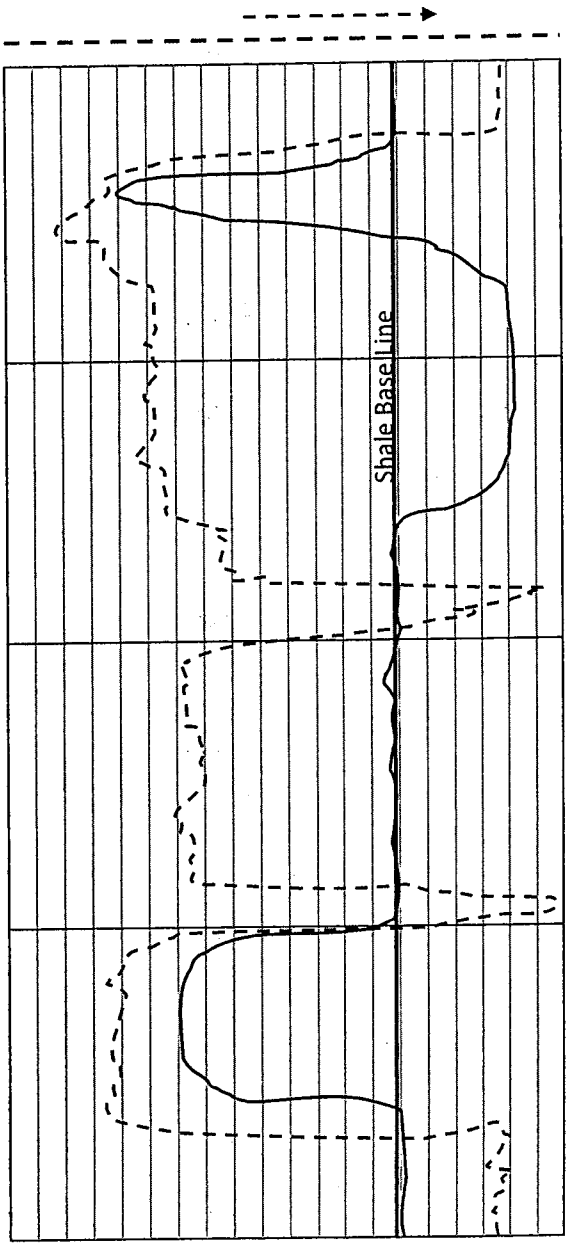
Name three radioisotops that Spectral Gamma can detect? **(3 pts)**

Question 7:

A 20% SNP porosity was determined from the calibration curves. The actual measurement conditions are as follows: borehole diameter is 6", drilling fluid is 12-lb/gal barite fresh water-based mud, formation temperature is 175°F, and formation pressure is 5200 psia. Estimate the order of magnitude of the correction applied by the SNP panel. **(7 Pts)**

Question 8:

Spontaneous Potential (SP, solid line) and Gamma Ray (dashed line) are shown. Comment on the reason for deflections (from lithology point of view) and compare the mud filtrate resistivity and water resistivity corresponding to deflections in each section. **(6 Pts)**



Question 9:

Determine the water saturation cutoff value, corresponding to 40% water cut from an oil formation whose relative permeability characteristics are shown in figure provided in **Attachment**. Assume that the oil viscosity is four times the water viscosity at formation temperature and pressure. Also calculate the minimum productive resistivity, R_{mp}, if the formation water resistivity and the average formation resistivity factor are 0.06 Ω.m and 18, respectively. (Assume that the saturation exponent is 2) **(6 pts)**

Question 10:

When a clean, consolidated sandstone rock sample is fully saturated with water (during drilling), the rock and water resistivity at the surface is measured in the lab to be 2.2 Ω.m and 0.2 Ω.m, respectively. The temperature at the surface is 68 °F, and geothermal gradient is 1.2 °F /100ft.

a. The formation of interest with the same rock and water properties is to be at 12000 ft, using the Humble's correlation find the porosity of that formation. **(7 Pts)**

b. Now, for the same rock in the zone of interest, assume that the resistivity of rock measured after sometime and is reported to be 7.5 Ω.m, explain what could be the reason for this change? **(4 Pts)**

c. Determine hydrocarbon saturation in the zone of interest for both cases "a" and "b". **(4 Pts)**

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Question 11:

A development well is drilled to evaluate the oil sand shown by the ISF/sonic and CNL/FDC logs of following figures. Interpretation experience with this formation type indicated that R_w= 0.05 Ω.m at formation temperature; that the formations are unconsolidated and hence high sonic log readings are expected; and that the sands are moderately shaly, so a good porosity value can be obtained by averaging the porosity readings of the density and neutron curves.

Additional date: A = 40 acres FR = 35% B_o = 1.25 RB/STB

a. Is there oil/water contact in the sands shown by the logs, if yes, at what depth, if not why? **(3 pts)**

b. Estimate the value of the summation $\Sigma\varphi_i h_i(S_o)_i$. **(15 pts)**

c. Estimate the recoverable oil from the sand situated in this interval. **(2 pts)**

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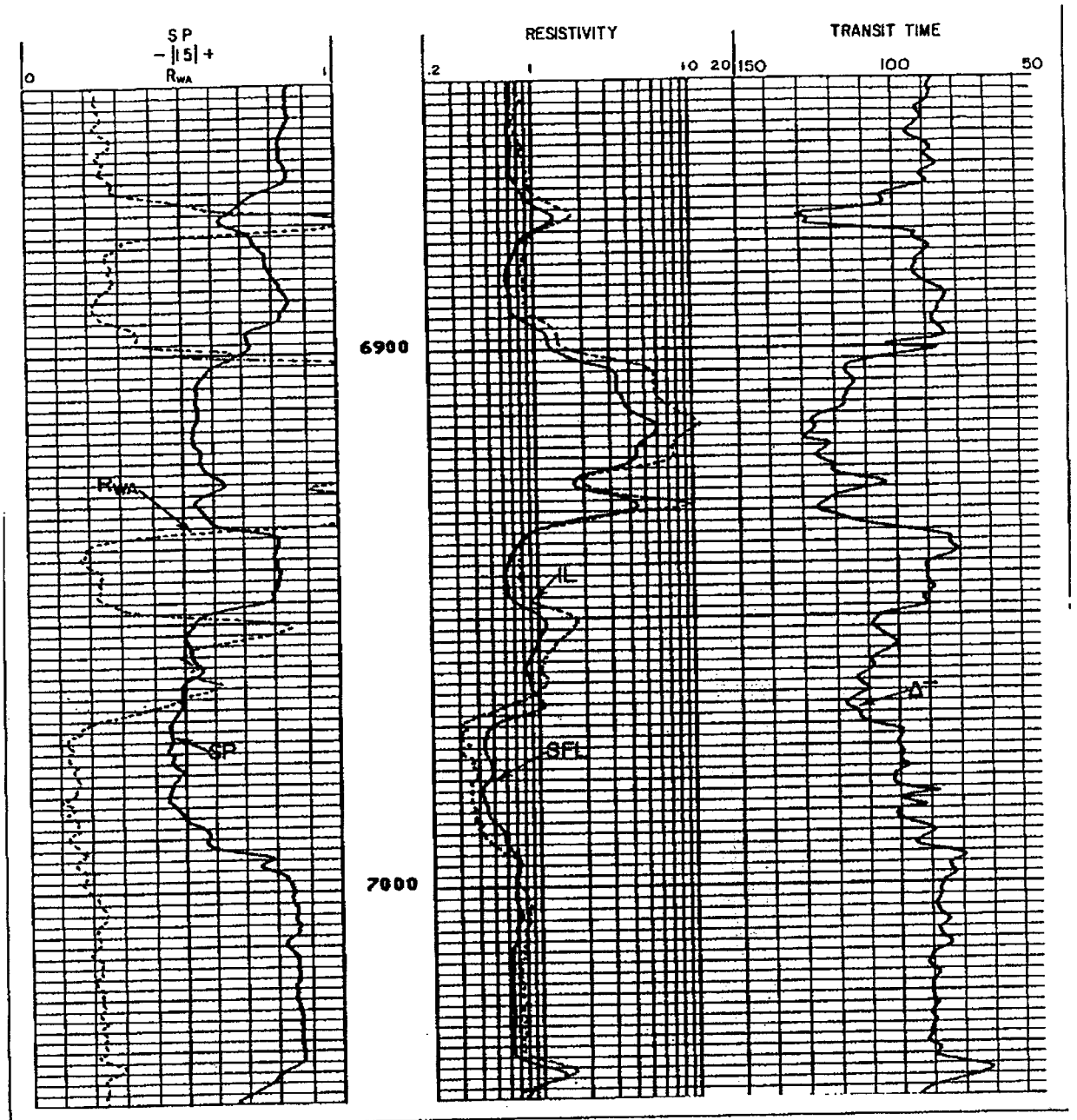


Fig. 11.26—ISF/sonic log of Problem 11.3 (courtesy Schlumberger).

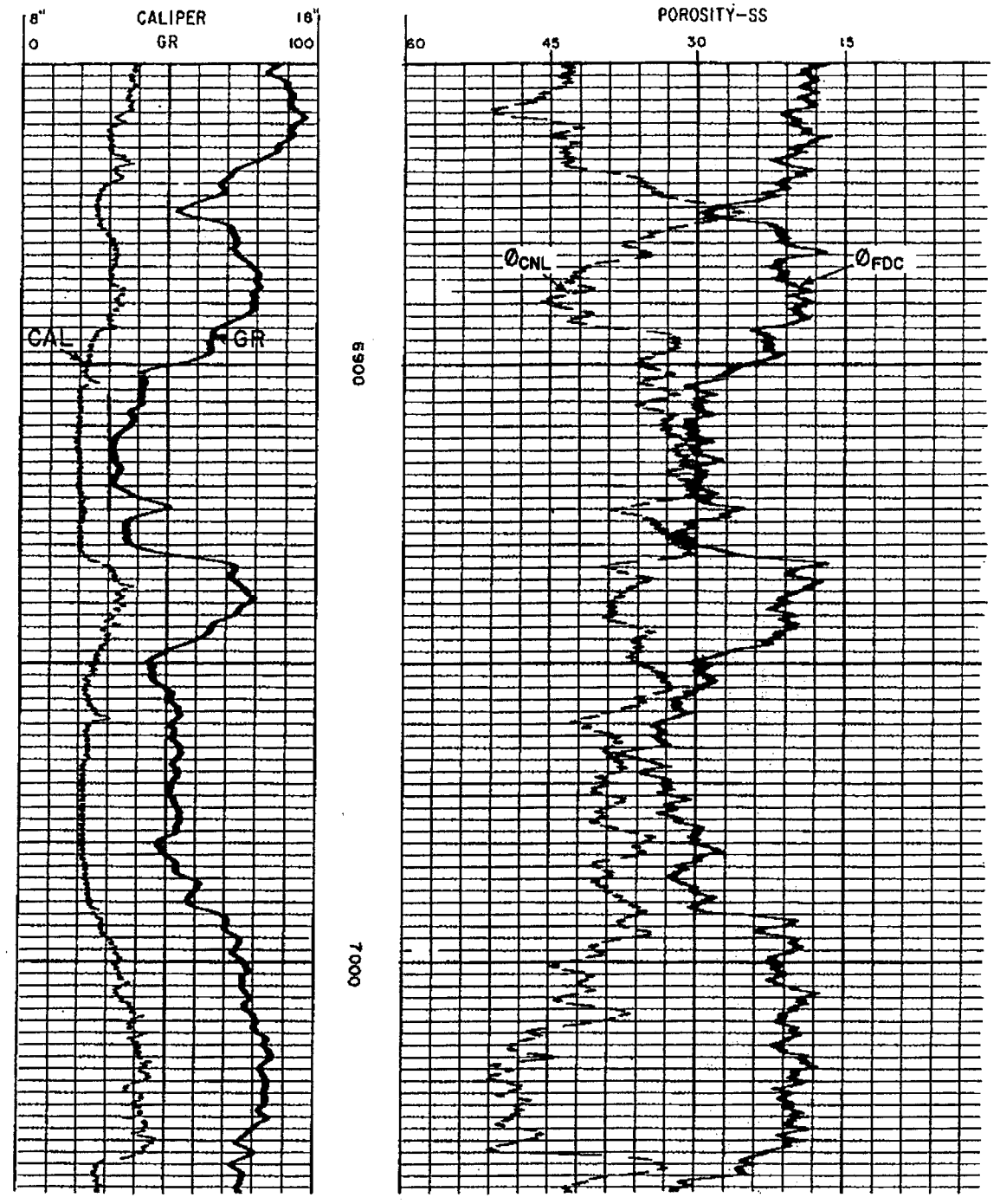


Fig. 11.27—CNL/FDC log of Problem 11.3 (courtesy Schlumberger).

Question 12:

In a formation with fresh water, the mud filtrate resistivity and water resistivity are measured to be 0.6 Ω.m and 0.12 Ω.m, respectively. If the formation temperature is 200 °F:

a. Calculate the ESSP assuming ideal shale membrane. **(5 Pts)**

b. Assume non-ideal shale membrane, with the same value obtained for resistivity of water and mud filtrate, what will be the resistivity of adjacent shale formation if the SP log reading is -60 mV. **(5 Pts)**

Attachment:

$$R_2 = R_1 \frac{T_1 + 6.77}{T_2 + 6.77}$$

$$f_w = \frac{1}{1 + \frac{k_{ro}\mu_w}{k_{rw}\mu_o}} \qquad R_{mp} = \frac{FR_w}{(S_{cw})^n}$$

$$S_w = \left(\frac{0.81R_w}{\phi^2 R_t}\right)^{1/2} - \left(\frac{V_{sh}R_w}{0.4\phi R_{sh}}\right)$$

$$\mathrm{F} = \frac{0.62}{\phi^{2.15}}$$

$$\mathrm{R_w} = \frac{\mathrm{R_o}}{F}$$

$$N_R = 7758\frac{AF_R}{B_o}\sum_{i=1}^{n} h_i\phi_i(S_o)_i$$

$$(\phi_D)_{sh} = \left[\frac{\rho_{ma} - \rho_{sh}}{\rho_{ma} - \rho_f}\right]$$

$$\phi = \left[\frac{(\Delta t - \Delta t_{ma})}{(\Delta t_f - \Delta t_{ma})}\right]$$

$$I_R = \frac{R_t}{R_o} = \frac{7.5}{0.752}$$

$$S_w = \left(\frac{R_o}{R_t}\right)^{1/2} \qquad S_o = 1 - S_w$$

$$K = 61.3 + 0.133T$$

$$E_{SSP} = -K\left[\log(R_{mf})_{eq}/(R_w)_{eq}\right]$$

$$\phi_D = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f}$$

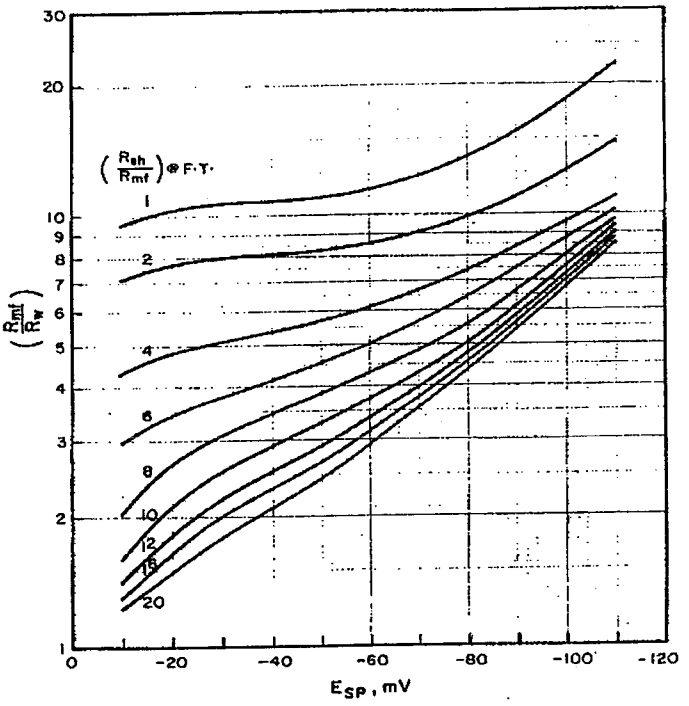
$$\phi = \phi_a - V_{sh}(\phi_a)_{sh}$$

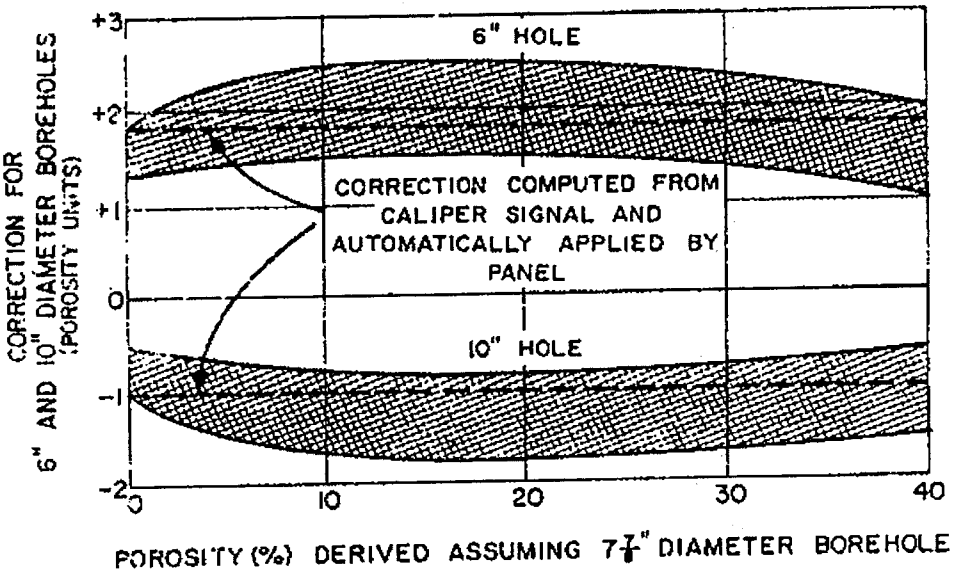
$$V_{sh} = 1.7 - \left[3.38 - (I_{sh} + 0.7)^2\right]^{1/2}$$

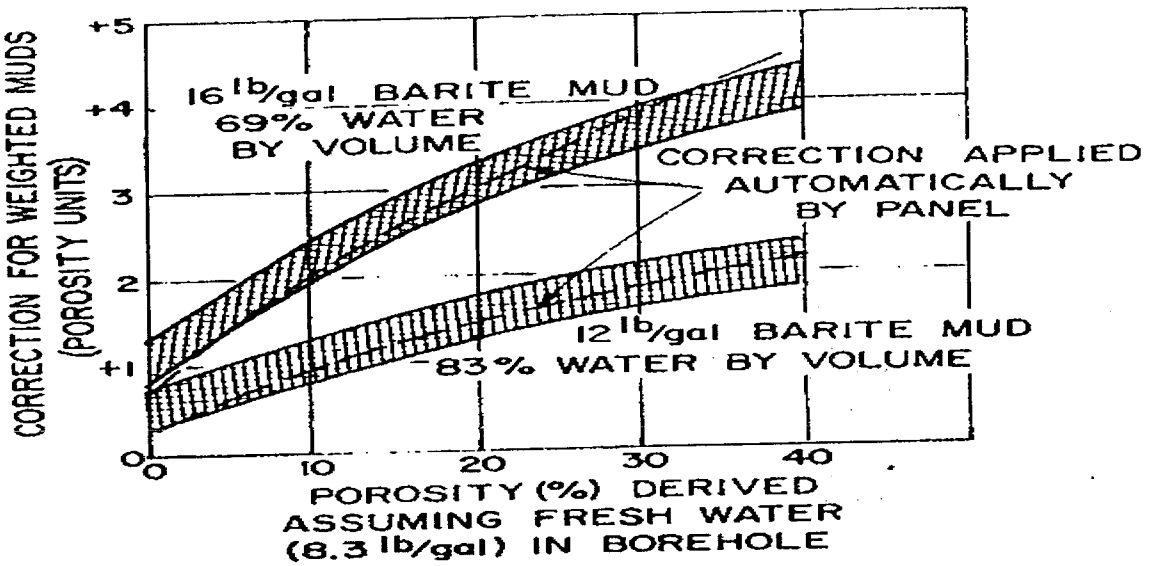
$$I_{sh} = \frac{\gamma_{\log} - \gamma_c}{\gamma_{sh} - \gamma_c}$$

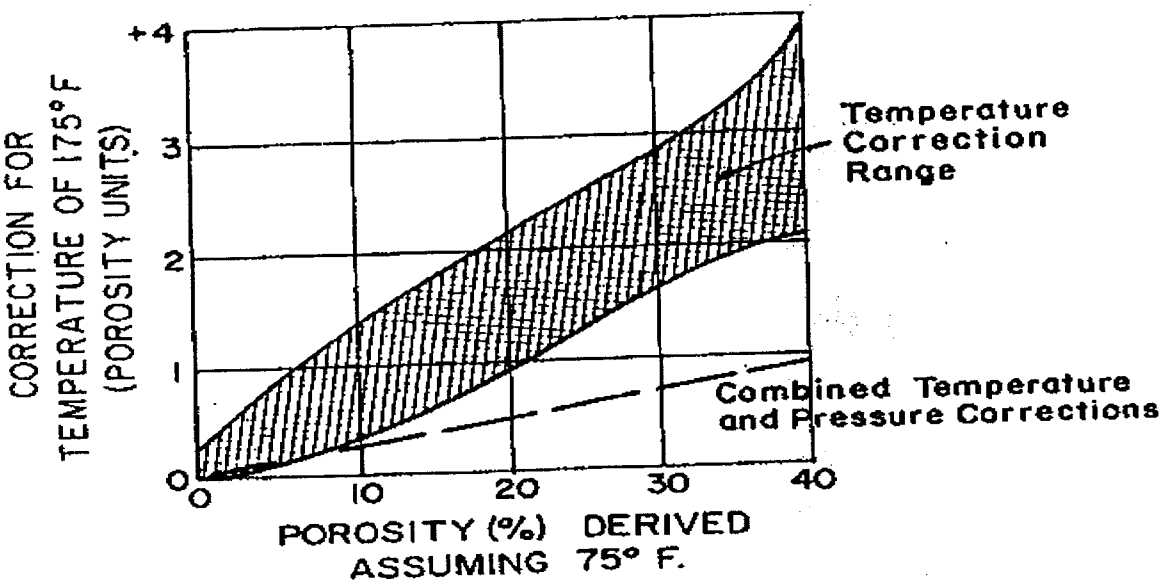
$$V_{sh} = 0.33\left(2^{2I_{sh}} - 1\right)$$

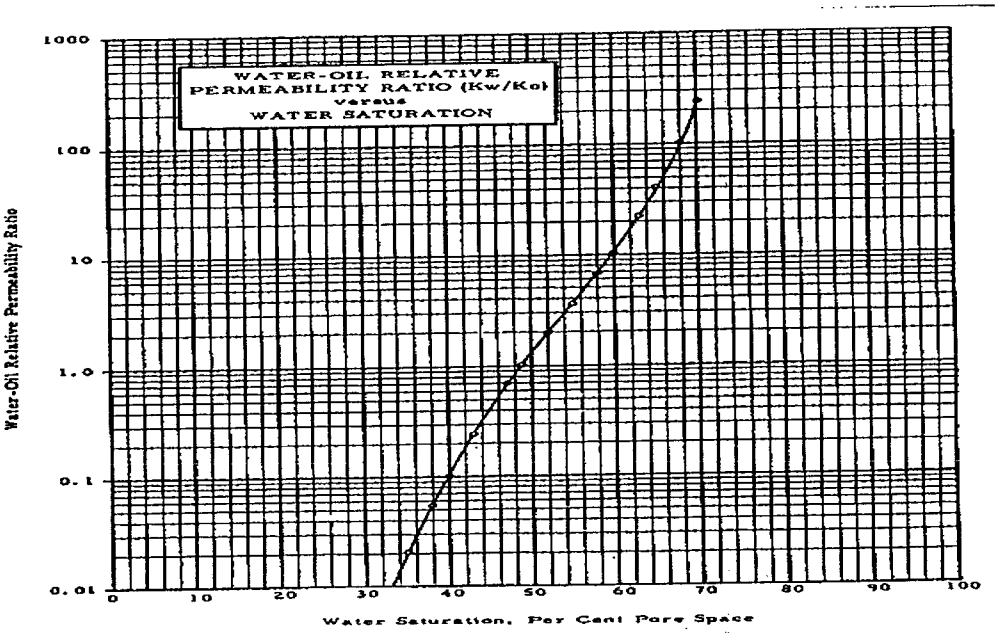
$$V_{sh} = \frac{I_{sh}}{3 - 2I_{sh}}$$

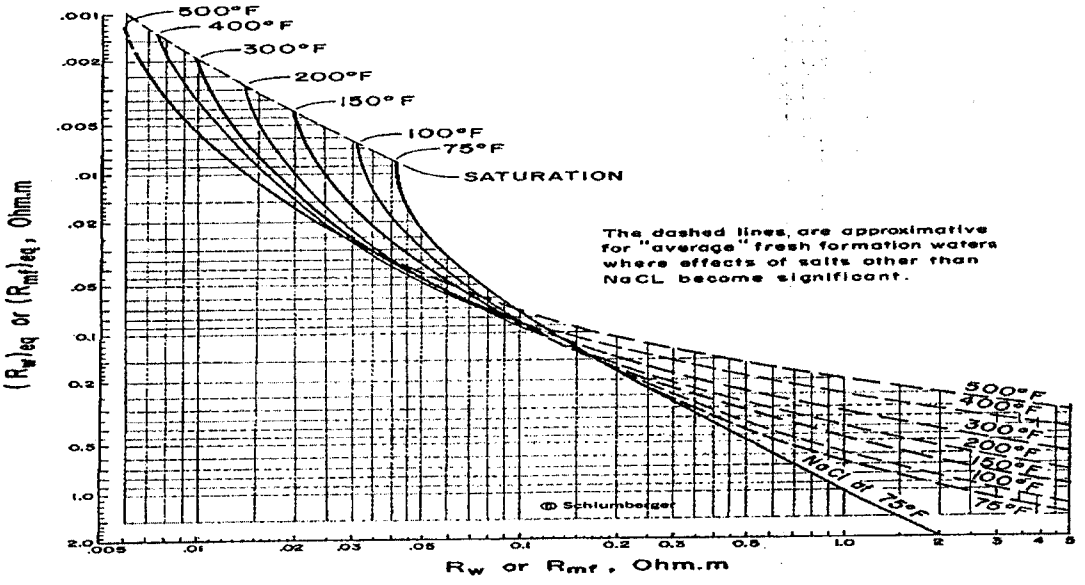

$\left(\frac{R_{sh}}{R_{mf}}\right)$ @ F·T·
1
2
4
6
8
10
12
15
20
$\frac{R_{mf}}{R_w}$
E_{SP}, mV


6" HOLE
CORRECTION COMPUTED FROM CALIPER SIGNAL AND AUTOMATICALLY APPLIED BY PANEL
10" HOLE
CORRECTION FOR 6" AND 10" DIAMETER BOREHOLES (POROSITY UNITS)
POROSITY (%) DERIVED ASSUMING 7⅞" DIAMETER BOREHOLE


CORRECTION FOR WEIGHTED MUDS (POROSITY UNITS)
+5
+4
3
2
+1
0
16 lb/gal BARITE MUD
69% WATER
BY VOLUME
CORRECTION APPLIED
AUTOMATICALLY
BY PANEL
12 lb/gal BARITE MUD
83% WATER BY VOLUME
0
10
20
30
40
POROSITY (%) DERIVED
ASSUMING FRESH WATER
(8.3 lb/gal) IN BOREHOLE


CORRECTION FOR
TEMPERATURE OF 175° F
(POROSITY UNITS)
+4
3
2
1
0
Temperature
Correction
Range
Combined Temperature
and Pressure Corrections
0
10
20
30
40
POROSITY (%) DERIVED
ASSUMING 75° F.


WATER-OIL RELATIVE PERMEABILITY RATIO (Kw/Ko) versus WATER SATURATION
Water-Oil Relative Permeability Ratio
1000
100
10
1.0
0.1
0.01
0
10
20
30
40
50
60
70
80
90
100
Water Saturation, Per Cent Pore Space


500°F
400°F
300°F
200°F
150°F
100°F
75°F
SATURATION
The dashed lines, are approximative for "average" fresh formation waters where effects of salts other than NaCL become significant.
(Rw)eq or (Rmf)eq, Ohm.m
Rw or Rmf, Ohm.m
.001
.002
.005
.01
.02
.05
0.1
0.2
0.5
1.0
2.0
.005
.01
.02
.03
.05
0.1
0.2
0.3
0.5
1.0
2
3
4
5
Schlumberger