National Exams Dec. 2016

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. Graphs, equations, and data are provided as attachments; however, not all of graphs and equations are necessarily need to be used for this exam. Graph papers are also provided in the attachments.

   Approved calculators are permitted.

4. This exam contains 11 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:

In the context of acoustic properties of the rocks, what are the applications of:

a. Compressional and shear wave velocities. **(3 pts)**

b. Compressional and shear wave attenuation. **(2 pts)**

c. Amplitude of reflected waves. **(3 pts)**

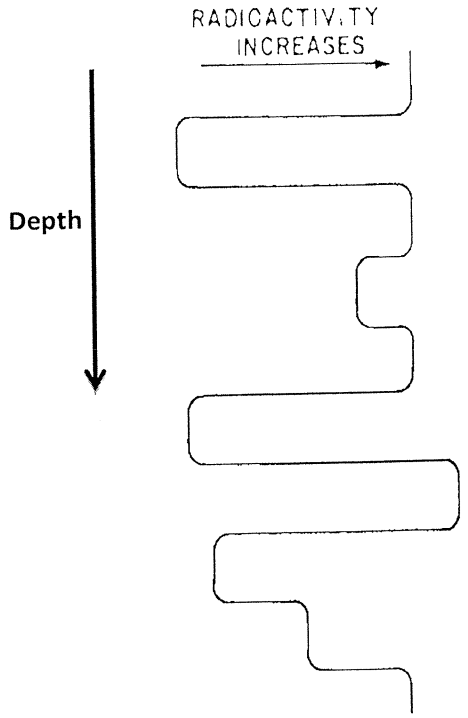
Question 2:

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. (**5 pts**)

Question 3:

Below is the output log for a gamma ray tool. Locate the following zones on the below figure: **(7 pts)**

1.Shale, 2. Sandstone, 3. Limestone, 4. Shaly sand, 5. Sandy shale, 6. Anhydrite, 7. Black marine shale



Question 4:

Calculate the *SSP* for a clean, predominantly NaCl water-bearing sand drilled with a fresh water-based mud (also predominantly NaCl). The formation temperature is 200 °F, and R_{mf} and R_w measured at 68 °F temperature are 0.31 and 0.054 Ω.m, respectively. **(4 pts)**

Question 5:

Provide a definition/clear explanation for the following terms.

a) Mud invasion? **(2 pts)**

b) Mud cake? **(2 pts)**

c) Mud filtrate? **(2 pts)**

d) Flushed zone? **(2 pts)**

Question 6:

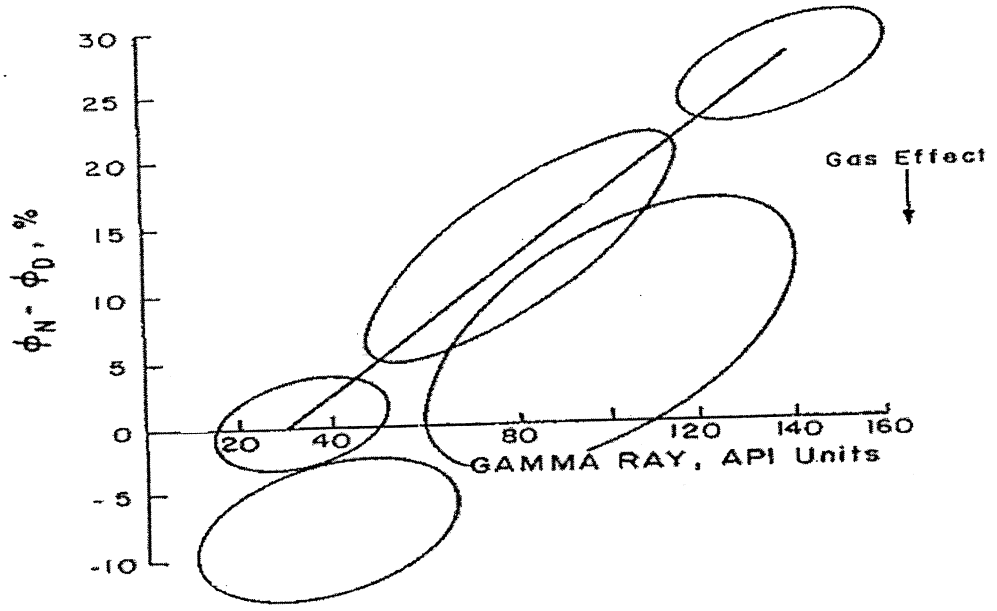
I. Reservoir rock contains minerals that give off Natural Gamma Radiation. Name three radioisotops that Spectral Gamma can detect? **(3 pts)**

II. What is the application (usage) of amplitude of reflected waves? **(3 pts)**

III. What is the application (usage) of compressional and shear wave attenuation? **(2 pts)**

Question 7:

Below figure shows a crossplot of (ϕ_N-ϕ_D) vs. gamma ray for a specific log interval, as it can be seen on the figure, 5 different zones were observed and each zone is shown by an ellipse. Assume that the detected zones are: 1. Shaly gas-bearing formation, 2. Clean-gas bearing formation, 3. Shaly-liquid bearing formation, 4. Shale and 5. Clean liquid-bearing formation. Show each zone on the corresponding ellipse in below figure. **(5 pts)**



Question 8:

A Neutron and density log reading in a clean, gas-bearing sandstone formation are 5% and 2.0 g/cm^3, respectively. Assuming the gas is low density and filtrate is fresh mud, determine ϕ and S_{xo} with and without inclusion of excavation effect. **(15 Pts)**

Question 9:

a. Assuming that the shale membrane is perfect and formation temperature is 200 F, estimate ESSP for a case where R_{mf} and R_w are 0.5 Ω.m and 0.1 Ω.m (at formation temperature), respectively. **(5pts)**

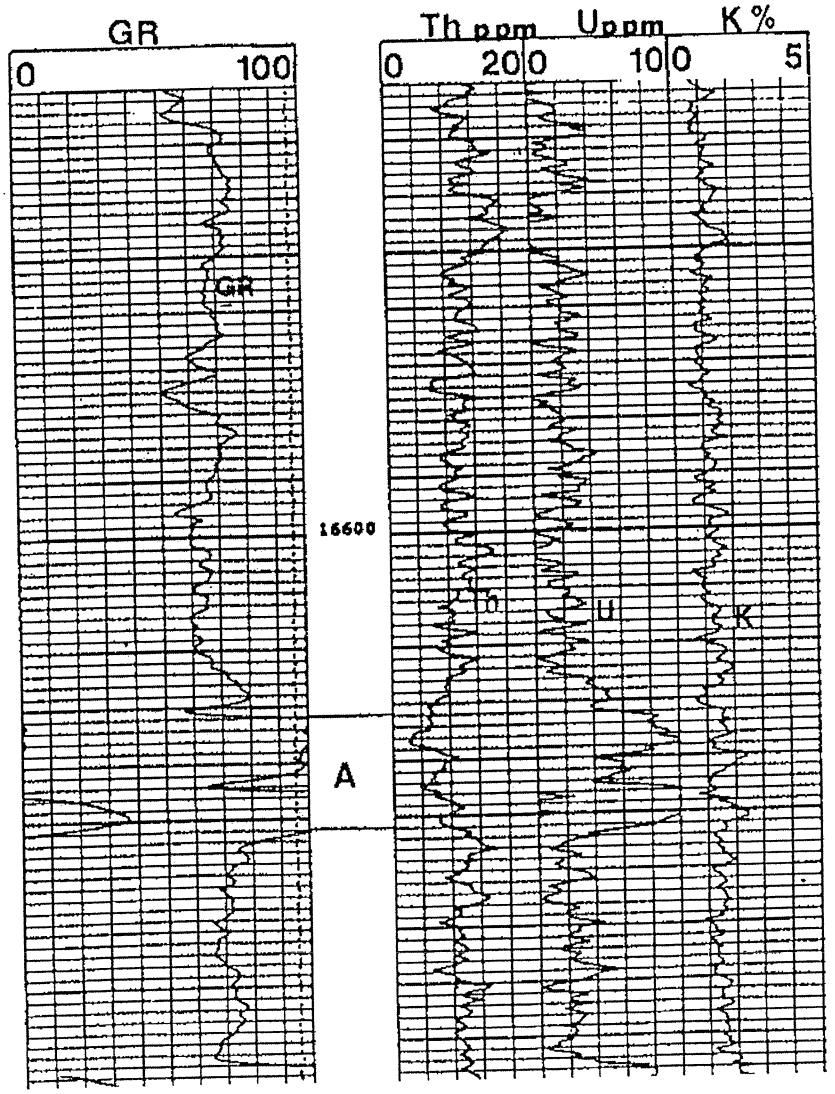
b. What will be the ESSP value if shale membrane is nonideal (R_{sh} is 2 Ω.m at 200F). **(5pts)**

Question 10:

Consider the following log which is obtained by Schlumburger device; calculate the shale index using the gamma ray and spectrometry log responses. *(Please write your answer in next page)*

a) Compare the results obtained and explain which value is more representative of the shale index. **(6 Pts)**

b) Assume that the zone is 0.7 g/cm^3 oil bearing limestone and drilled by an oil-based mud, if the residual oil saturation is 35%, calculate the apparent and true porosities for the zone of interest. **(4 Pts)**



This page is left blank (intentionally). Please use it for Q.10 if necessary.

Question 11:

The following figures show a section of IES and FDC logs obtained in a 9100 ft-deep well drilled offshore Louisiana. R_m at a bottomhole temperature (BHT) of $156°F$ was $0.34\ \Omega.m$. **(20 pts)**

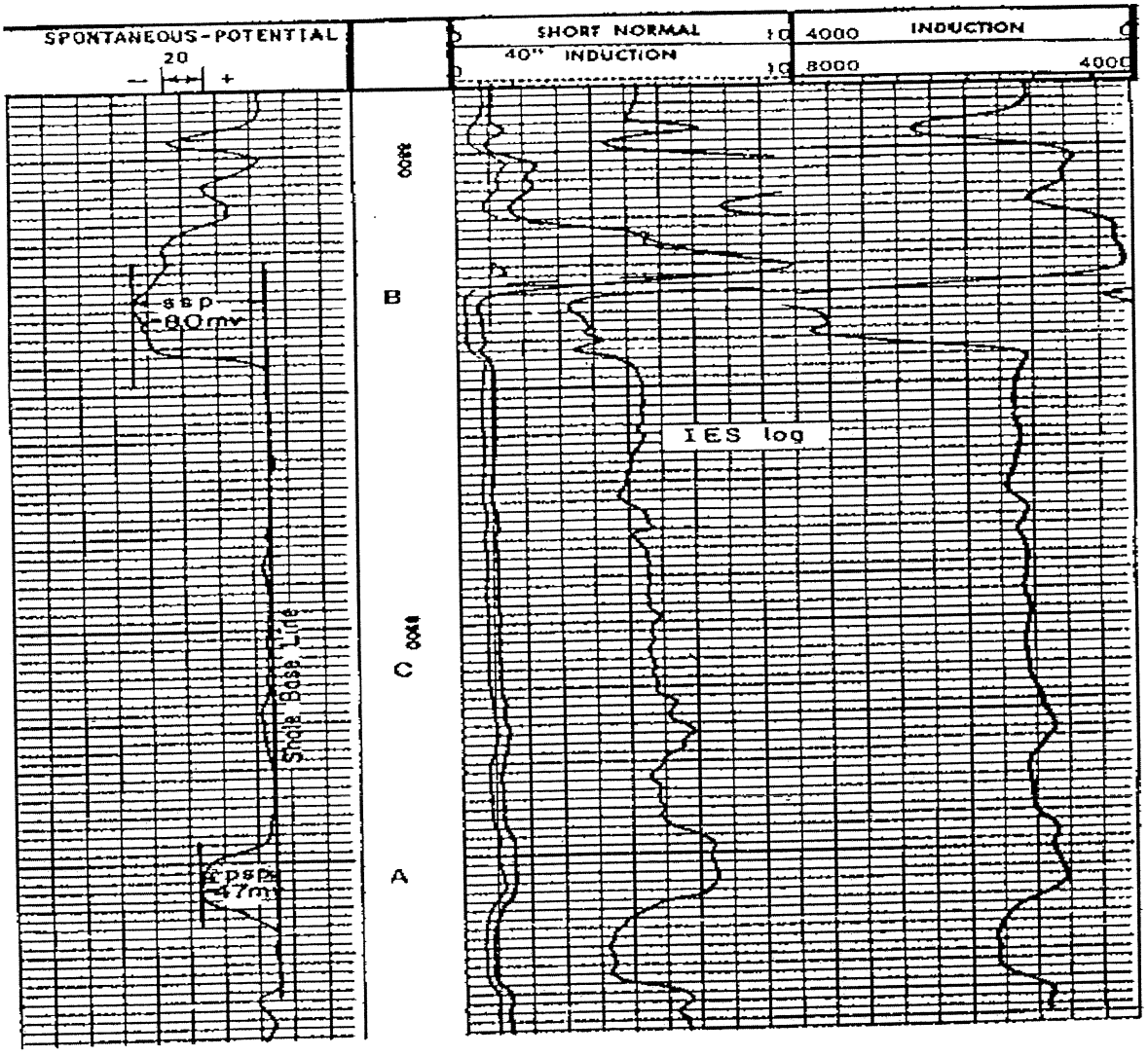
a) Using the SP curve, determine the shale content of zone A in the logs.

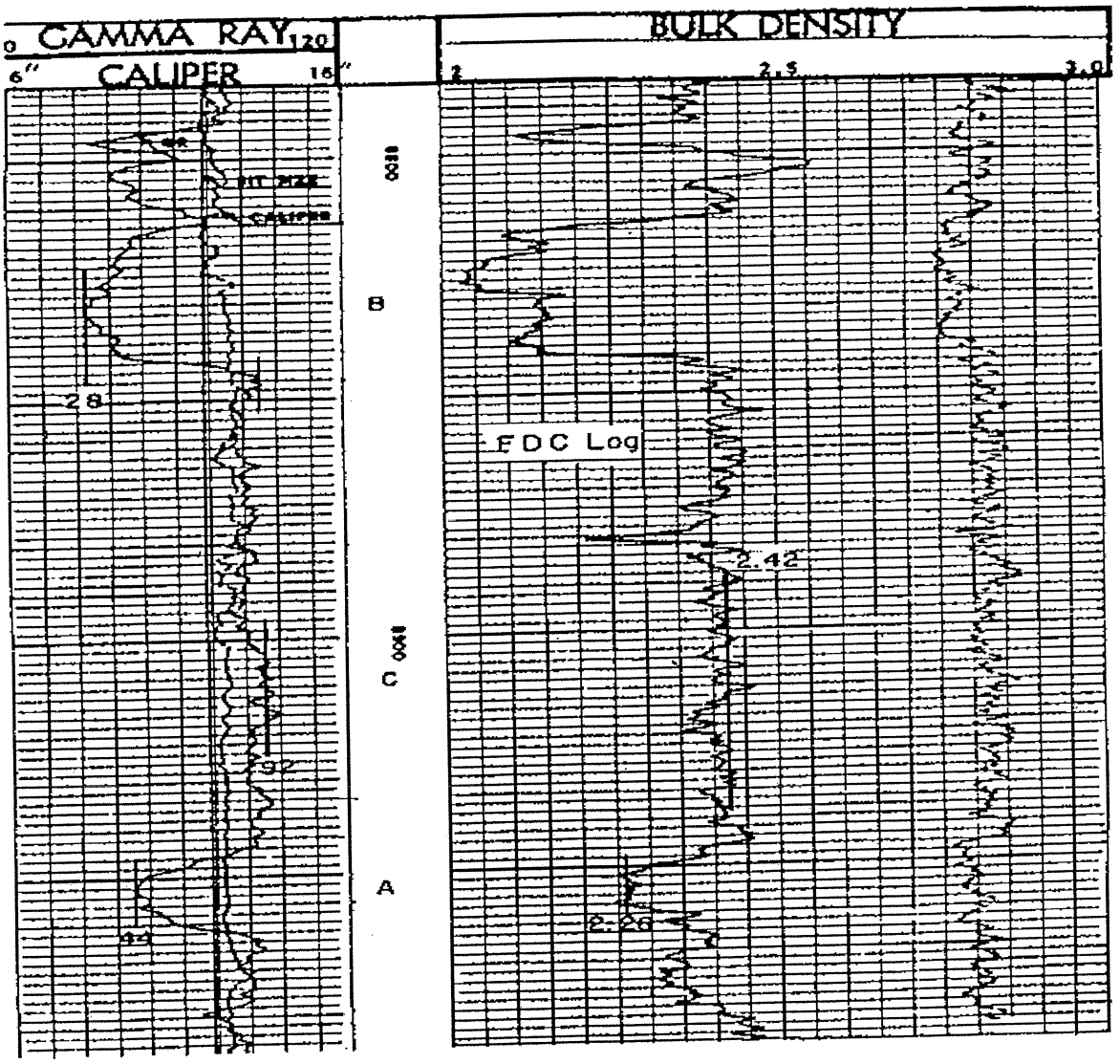
b) List the assumptions implied in the procedure used in Part (a).

c) Using the gamma ray curve, determine the shale content of Zone A.

d) List the assumptions implied in the procedure used in Part (c).

e) Compare the values in Part (a) and (c); and recommend a V_{sh} value.


SPONTANEOUS-POTENTIAL
20
SHORT NORMAL
40" INDUCTION
4000
INDUCTION
8000
4000
IES log
B
C
A
Shale Base Line


0 GAMMA RAY 120
6" CALIPER 16"
BIT SIZE
CALIPER
28
B
C
A
94
BULK DENSITY
2
2.5
3.0
EDC Log
2.42
2.20

This page is left blank (intentionally). Please use it for Q.11 if necessary.

Attachment: (Please note that NOT all the equations and graphs are necessarily needed)

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

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

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

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

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

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

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

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

$$K = 61.3 + 0.133T$$

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

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

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

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

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

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

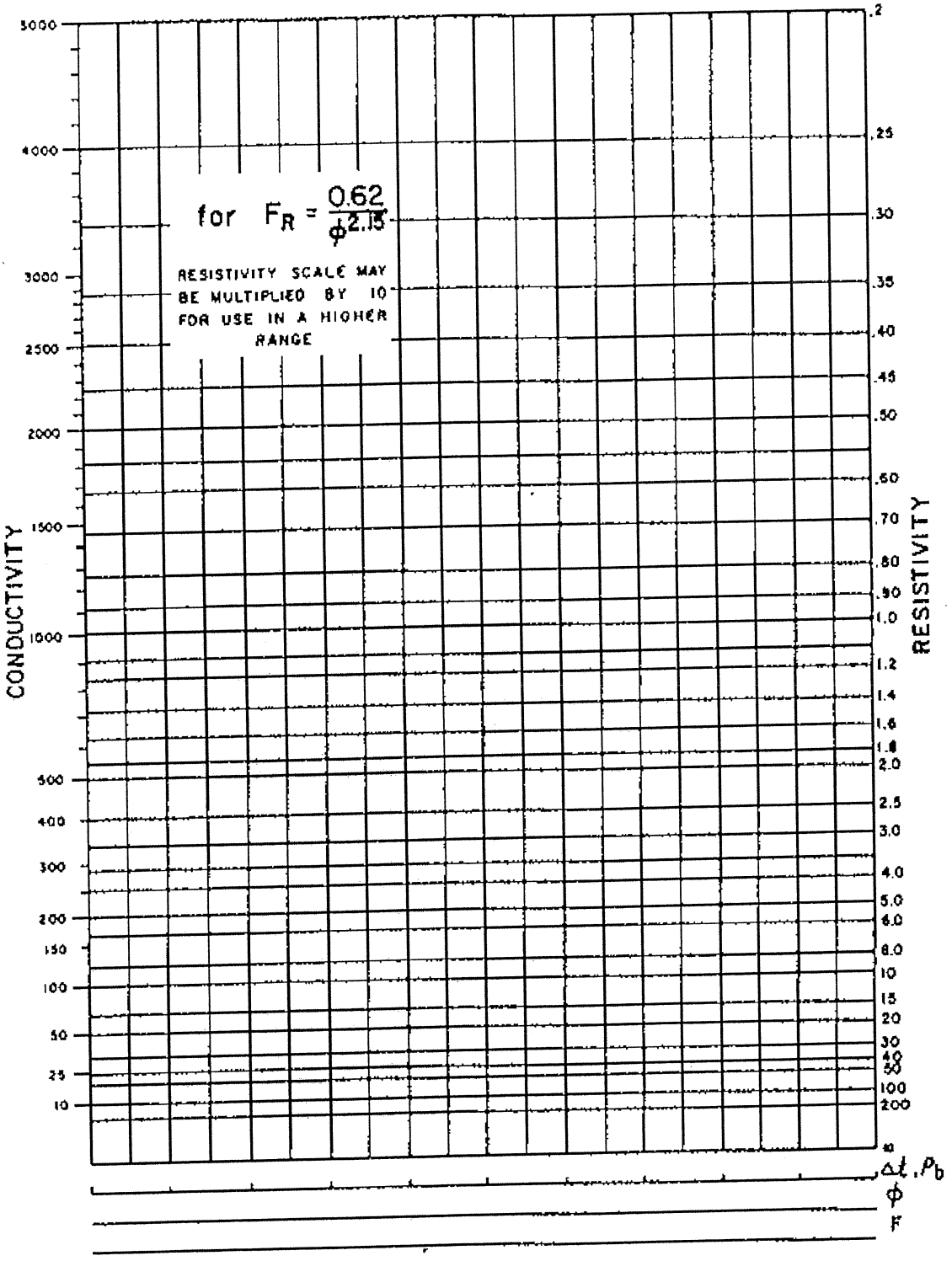
$$V_{sh} = \frac{I_{sh}}{3 - 2I_{sh}}$$

— ——

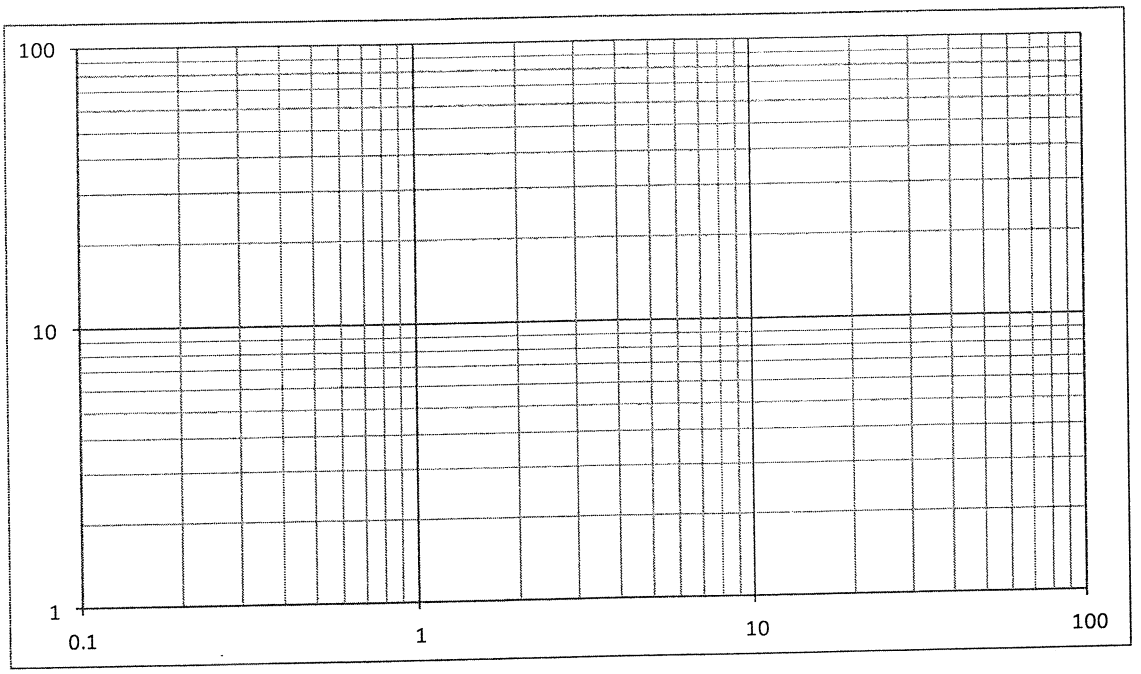
$$S_w = \left(\frac{R_o}{R_t}\right)^{1/2} \qquad S_o = 1 - S_w \qquad \square_N = \square S_{xo} \qquad N = N_0 e^{\square t/\square}$$

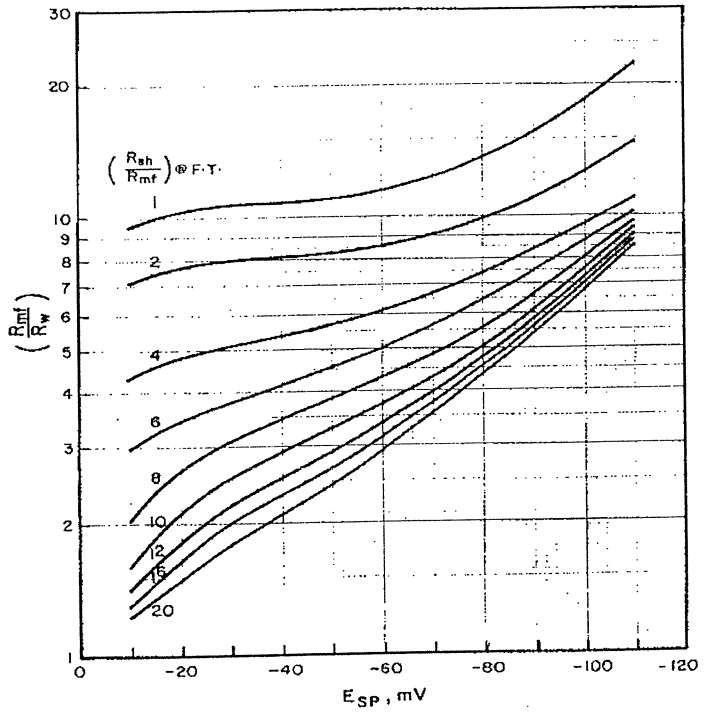
$$\square = \frac{\square_{ma}\,\square\,\square_b + \square_N}{\square_{ma}} \qquad S_w = \left(\frac{R_o}{R_t}\right)^{1/2} \qquad S_o = 1 - S_w$$

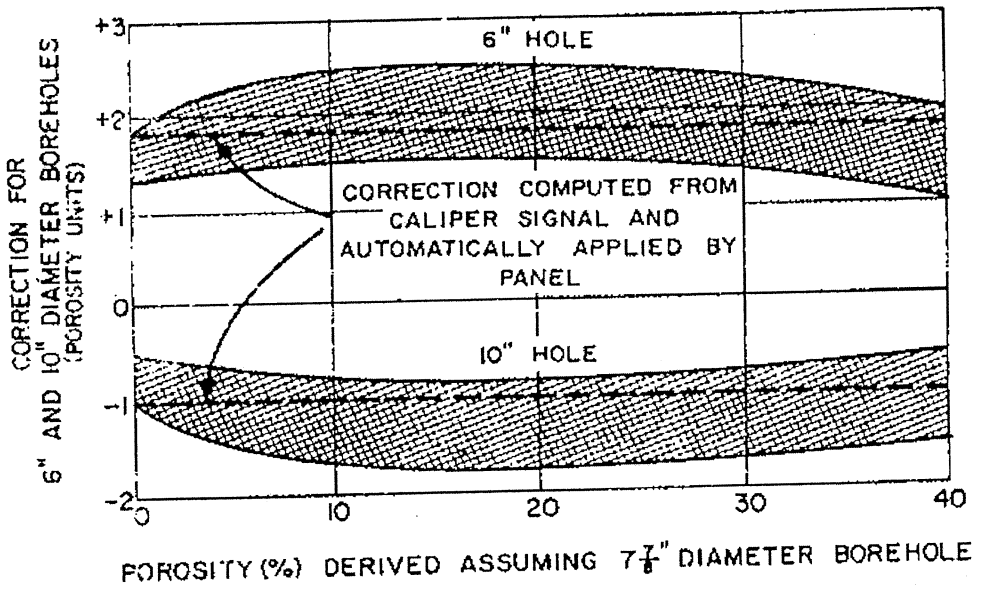
$$S_w = \left(\frac{R_o}{R_t}\right)^{1/2} \qquad S_o = 1 - S_w$$

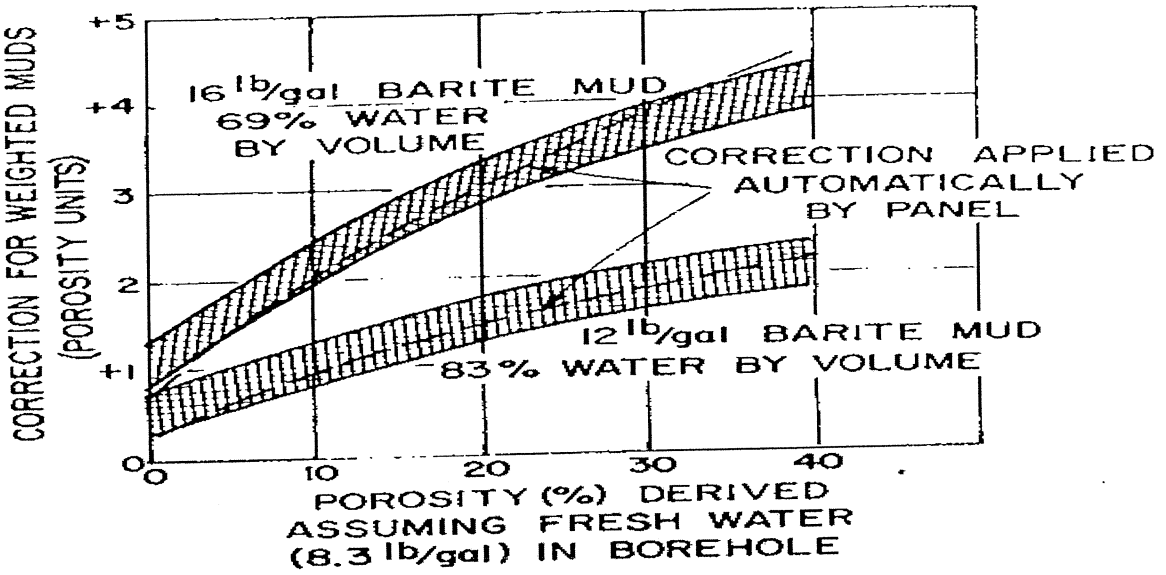

for $F_R = \frac{0.62}{\phi^{2.15}}$
RESISTIVITY SCALE MAY BE MULTIPLIED BY 10 FOR USE IN A HIGHER RANGE
CONDUCTIVITY
RESISTIVITY
5000
4000
3000
2500
2000
1500
1000
500
400
300
200
150
100
50
25
10
.2
.25
.30
.35
.40
.45
.50
.60
.70
.80
.90
1.0
1.2
1.4
1.6
1.8
2.0
2.5
3.0
4.0
5.0
6.0
8.0
10
15
20
30
40
50
100
200
Δt, Pb
ϕ
F

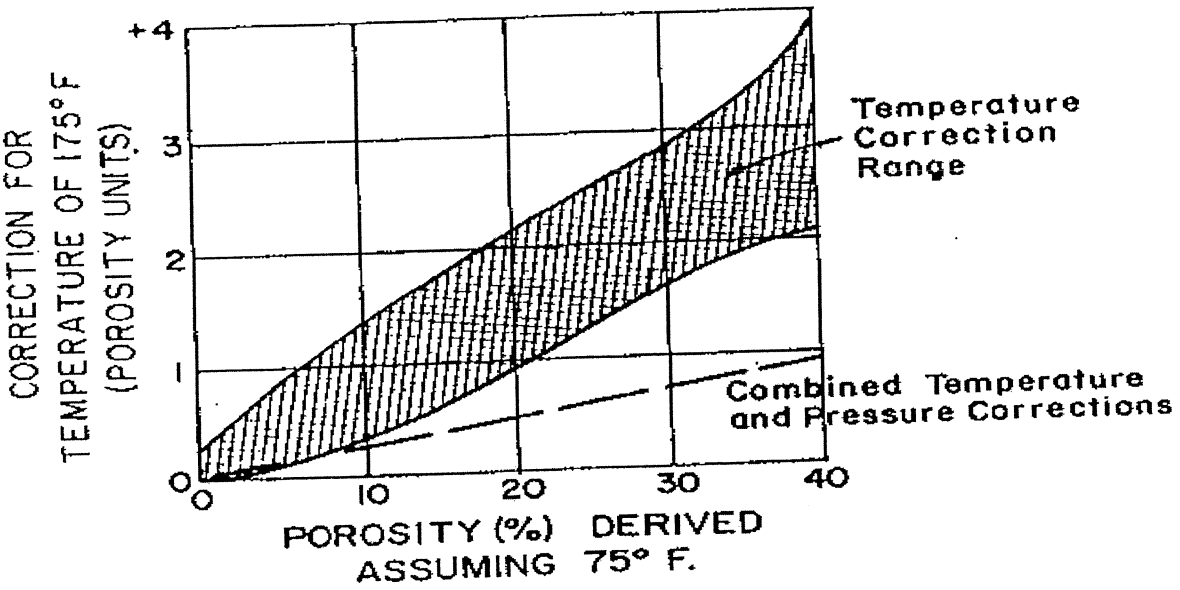
Use only if necessary

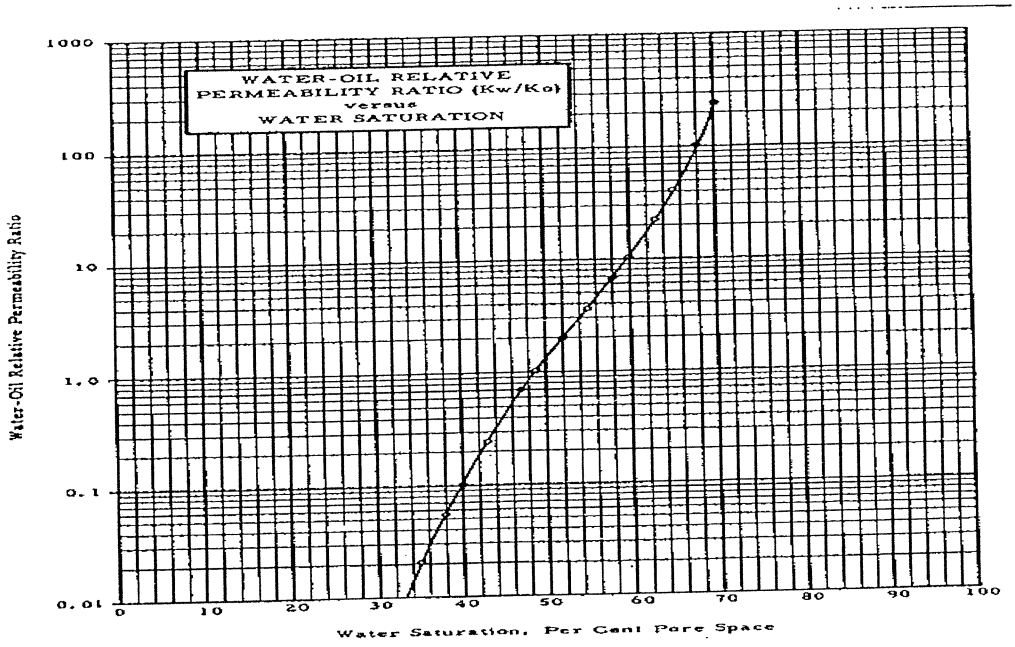


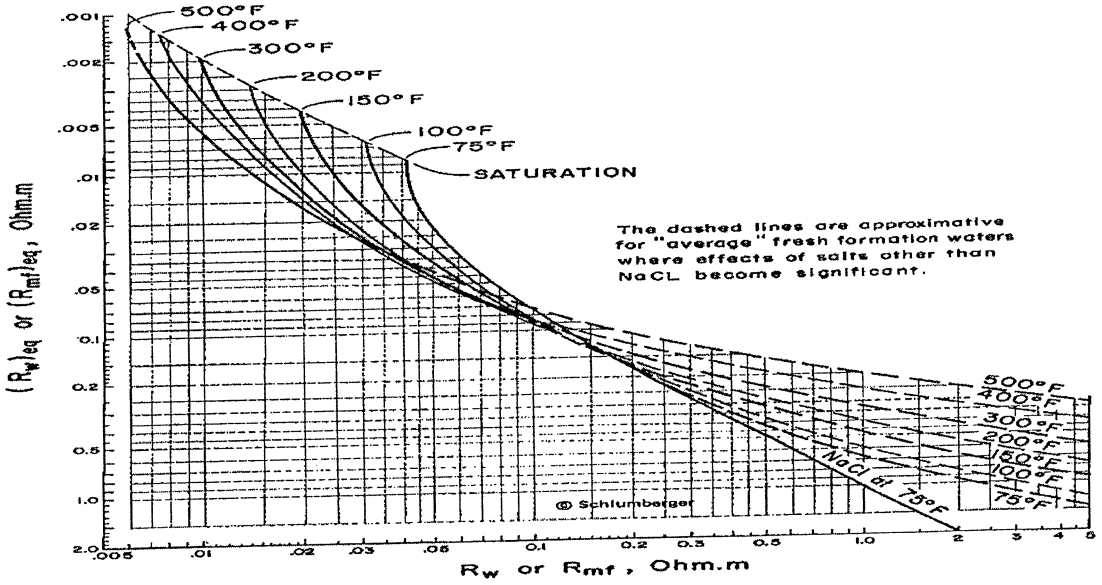

30
20
10
9
8
7
6
5
4
3
2
1
$\left(\frac{R_{sh}}{R_{mf}}\right)$ @ F.T.
1
2
4
6
8
10
12
15
20
$\frac{R_{mf}}{R_w}$
0
-20
-40
-60
-80
-100
-120
E_{SP}, mV

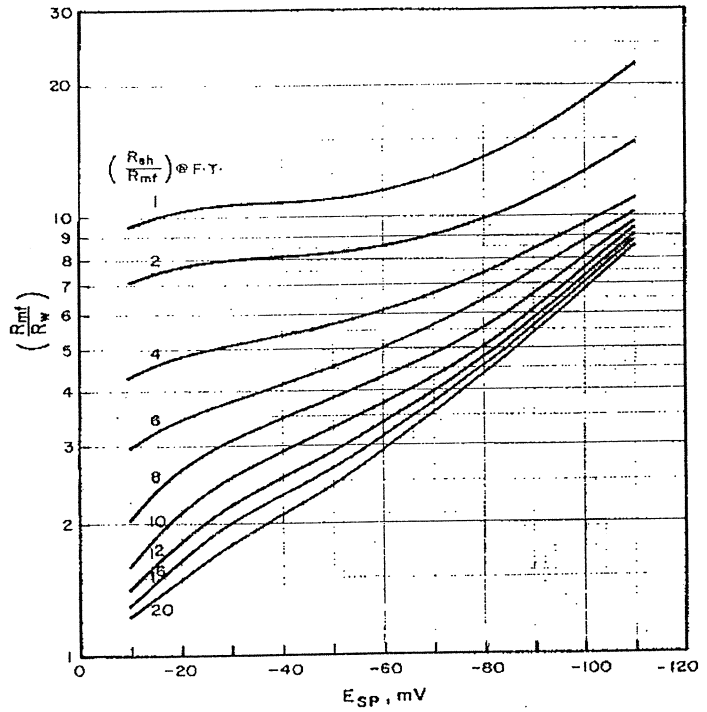

+3
+2
+1
0
-1
-2
6" HOLE
CORRECTION COMPUTED FROM CALIPER SIGNAL AND AUTOMATICALLY APPLIED BY PANEL
10" HOLE
CORRECTION FOR 6" AND 10" DIAMETER BOREHOLES (POROSITY UNITS)
0
10
20
30
40
POROSITY (%) DERIVED ASSUMING 7⅞" DIAMETER BOREHOLE

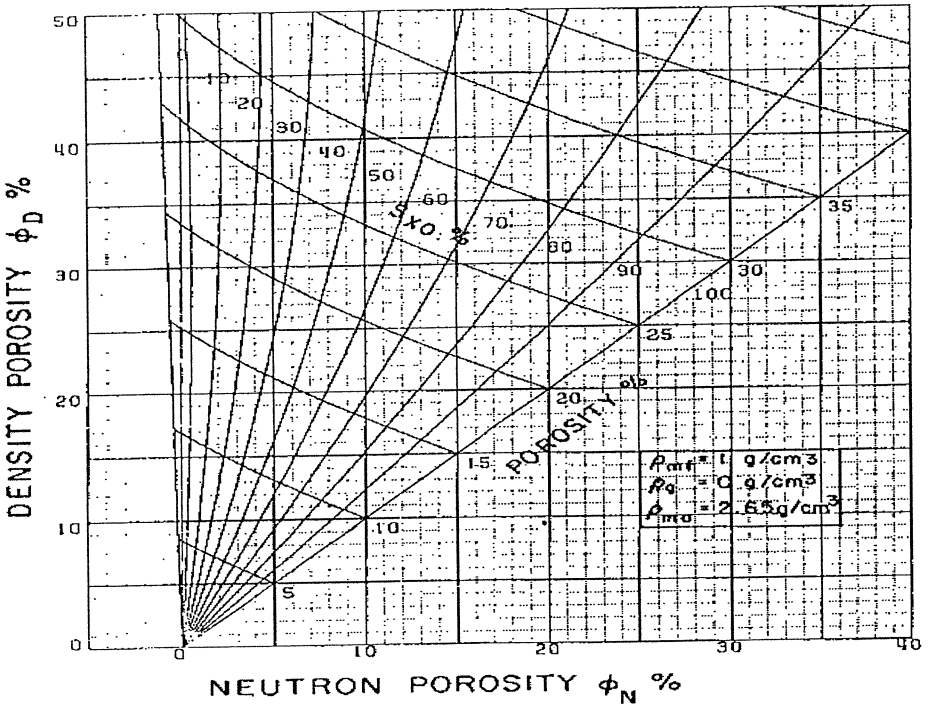

CORRECTION FOR WEIGHTED MUDS (POROSITY UNITS)
+5
+4
3
2
+1
0
16 lb/gal BARITE MUD
69% WATER
BY VOLUME
CORRECTION APPLIED
AUTOMATICALLY
BY PANEL
12 lb/gal BARITE MUD
83% WATER BY VOLUME
0
10
20
30
40
POROSITY (%) DERIVED
ASSUMING FRESH WATER
(8.3 lb/gal) IN BOREHOLE


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.
NaCl at 75°F
© Schlumberger
(Rw)eq or (Rmf)eq, Ohm.m
Rw or Rmf, Ohm.m
.001
.002
.005
.01
.02
.05
.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


$\left(\frac{R_{sh}}{R_{mf}}\right)$ @ F.T.
1
2
4
6
8
10
12
16
20
$\frac{R_{mf}}{R_w}$
E_{SP}, mV


DENSITY POROSITY ϕ_D %
NEUTRON POROSITY ϕ_N %
S_{xo}, %
POROSITY, %
ρ_{mf} = 1 g/cm3
ρ_f = 1 g/cm3
ρ_{ma} = 2.65 g/cm3

Use only if necessary