Formation Evaluation

Log Interpretation Charts

Date: October 1, 2012
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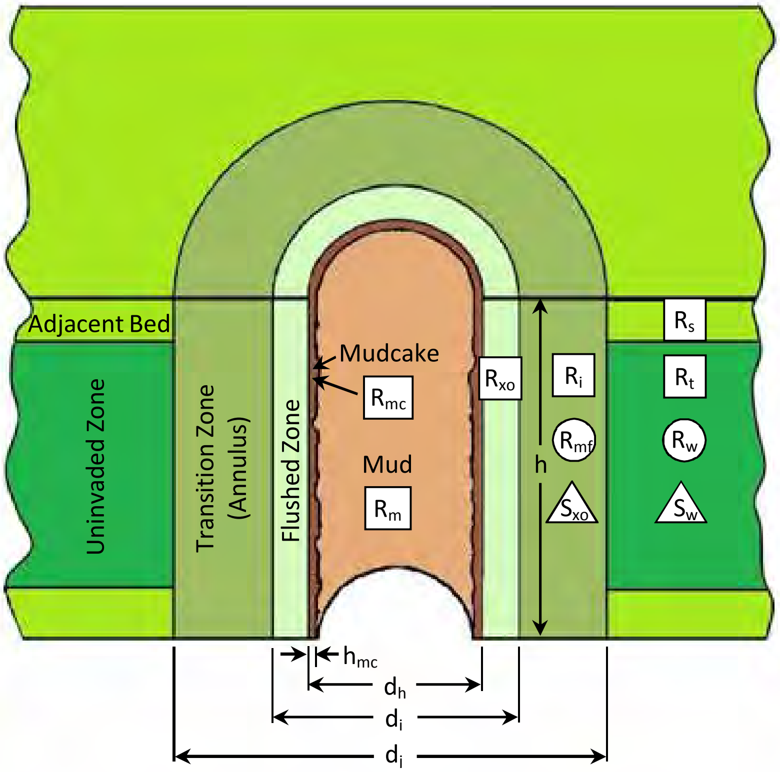
Log Interpretation Charts

1. General

2. Spontaneous Potential

3. Induction Array

Borehole and Formation Parameters



h	bed thickness	R_m	mud resistivity	S_{xo}	flushed zone water saturation
h_{mc}	mudcake thickness	R_{mc}	mudcake resistivity	S_w	water saturation
d_h	borehole diameter	R_{mf}	mud filtrate resistivity		
d_i	diameter of flushed zone	R_{xo}	flushed zone resistivity		
d_j	diameter of transition zone	R_t	true resistivity		
		R_s	adjacent bed resistivity		
		R_w	formation water resistivity		

Estimation of Formation Temperature with Depth

Purpose

This chart may be used to estimate the temperature gradient for a well by entering the depth and a known temperature at that depth. The chart may also be used to determine a temperature at a given depth if a temperature at another depth is known and the geothermal gradient is assumed.

Procedure

To estimate the geothermal gradient for a well, enter the chart at a known depth on the vertical axis and then project horizontally until intersecting the known temperature from the horizontal axis. The temperature on the horizontal axis should correspond to the row with the Annual Mean Surface Temperature for the area in which the well is located. The intersection of the vertical and horizontal lines can be interpolated to a geothermal gradient if it falls between the printed temperature gradient lines.

To determine the temperature at any depth from another depth with a known temperature enter the chart on the vertical axis point of the known depth and project horizontally until it intersects with the known temperature from the horizontal axis. From the intersecting point follow the gradient line until it intersects the desired depth projection on the vertical axis. Project the intersected point down to the horizontal axis and read the temperature from the appropriate row with the Annual Mean Surface Temperature.

Example

Given

TD of 14000 feet
Bottom hole temperature of 250 °F
Mean annual surface temperature of 60 °F

Find

Determine the temperature gradient for the well and the temperature at 9000 feet.

Answer

From the 14000 ft depth point on the vertical axis project horizontally across the chart. Since the mean annual surface temperature is 60 °F use the third temperature row at the bottom of the chart. From the 250 °F point project vertically into the chart until the two lines intersect. From this intersection point draw a line from to the upper left corner of the chart. This geothermal gradient line can be interpolated between the 1.2 °F/100 ft and 1.4 °F/100 ft gradient lines at approximately 1.37 °F/100 ft.

From the intersection of the 1.37 °F/100 ft gradient line and the 9000 ft depth line project down and read the temperature from the third line at the bottom of the chart (corresponding to the 60 °F mean surface temperature). The temperature at 9000 ft should be approximately 183 °F.

Equations

G = geothermal gradient

T_{AMST} = annual mean surface temperature

T_{d1} = Temperature at depth 1

T_{d2} = Temperature at depth 2

d = depth

d_1 = depth 1

d_2 = depth 2

Geothermal Gradient calculation

$$G = 100\left(\frac{T_{d2} - T_{d1}}{d_2 - d_1}\right)$$

Temperature at depth calculation

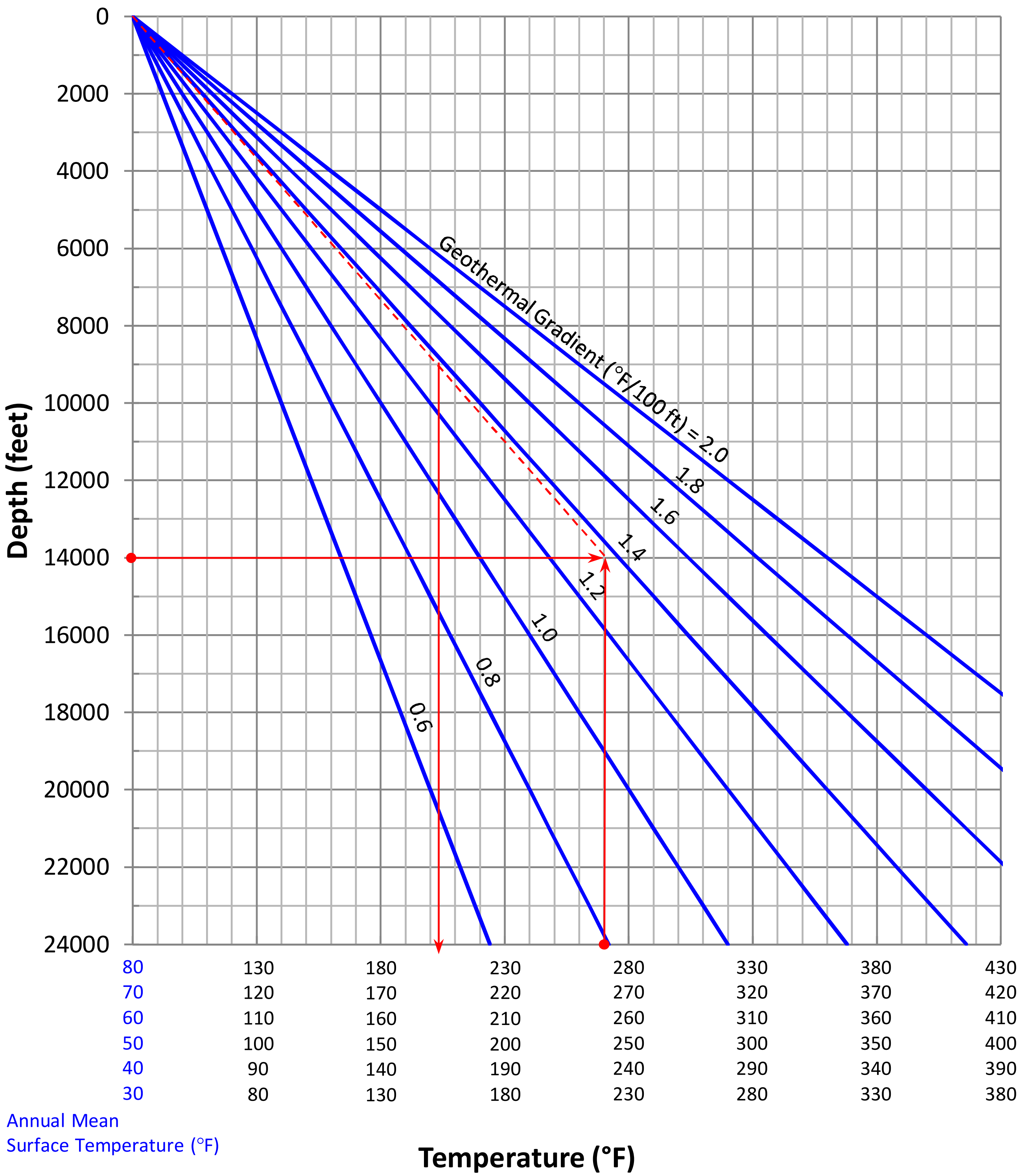
$$T_d = T_{AMST} + 0.01(G \cdot d)$$

Conversion factors

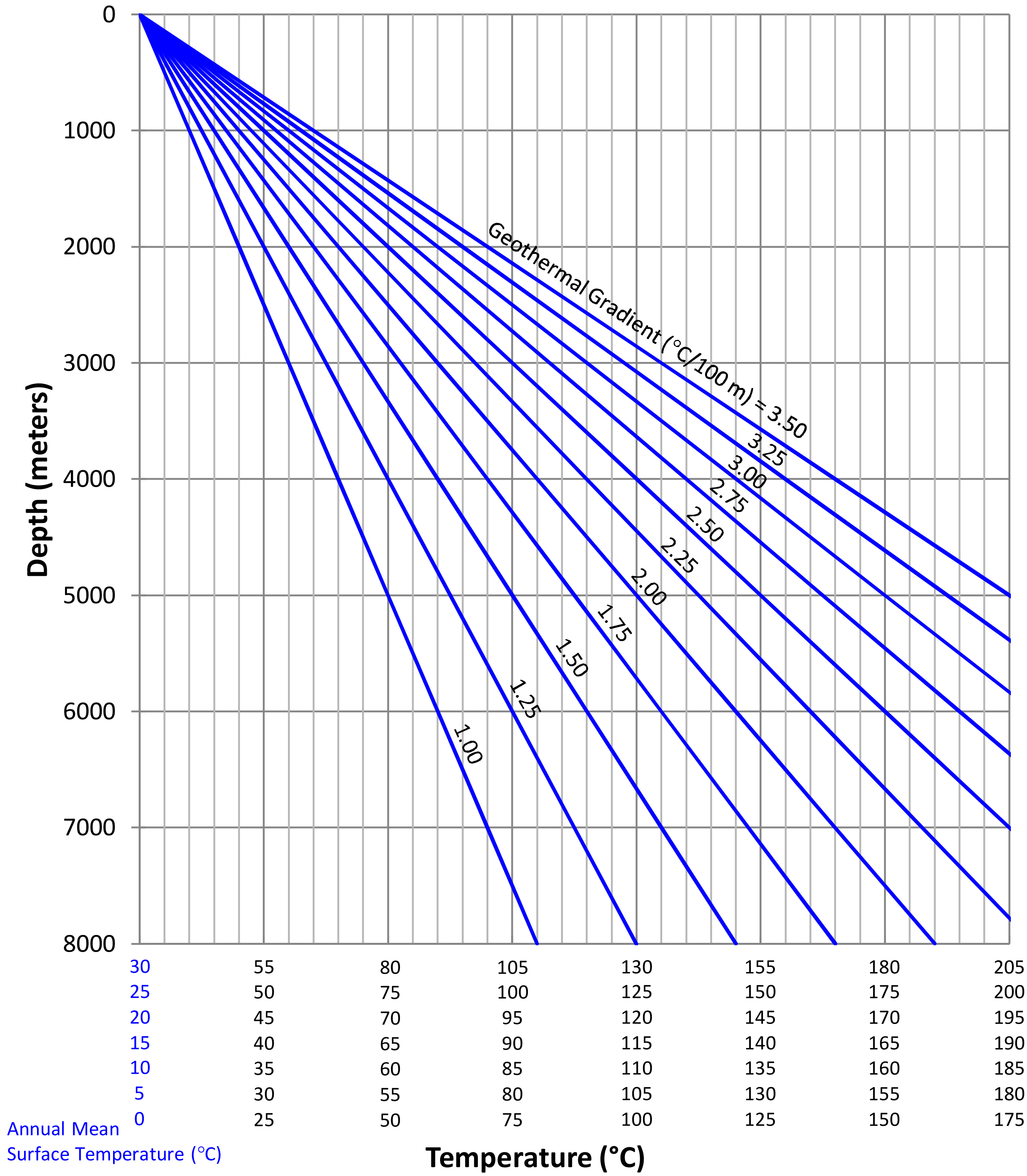
1 °F/100 ft = 1.823 °C/100 m

1 °C/100 m = 0.5486 °F/100 ft

Estimation of Formation Temperature with Depth using Geothermal Gradients



Estimation of Formation Temperature with Depth using Geothermal Gradients



Equivalent NaCl Concentrations of Salts

Purpose

This chart may be used on an ionic solution containing salts other than sodium chloride (NaCl) to estimate the equivalent NaCl concentration in parts per million.

Procedure

To estimate the resistivity of the solution enter the chart on the horizontal axis at the total ionic concentration in parts per million. Project this line vertically until intersection with each ion line. Project the intersection points horizontally to determine the weighting multiplication factor for each ion.

Multiply the concentration for the individual ions by the weighting factor and sum to obtain the equivalent NaCl concentration in parts per million.

Example

Given

A measured solution containing the following:
Calcium (Ca) = 8,100 ppm
Sodium (Na) = 32,500 ppm
Chlorine (Cl) = 54,000 ppm
Sulphate (SO_4) = 3,600 ppm

Find

Determine the equivalent NaCl concentration of the solution.

Answer

The weighting multiplier must be found for each ion component to determine the equivalent NaCl concentration. The individual equivalent ionic concentrations are then summed to obtain the total equivalent NaCl concentration of the solution.

Sum the individual ionic concentrations to obtain the total ionic concentration.

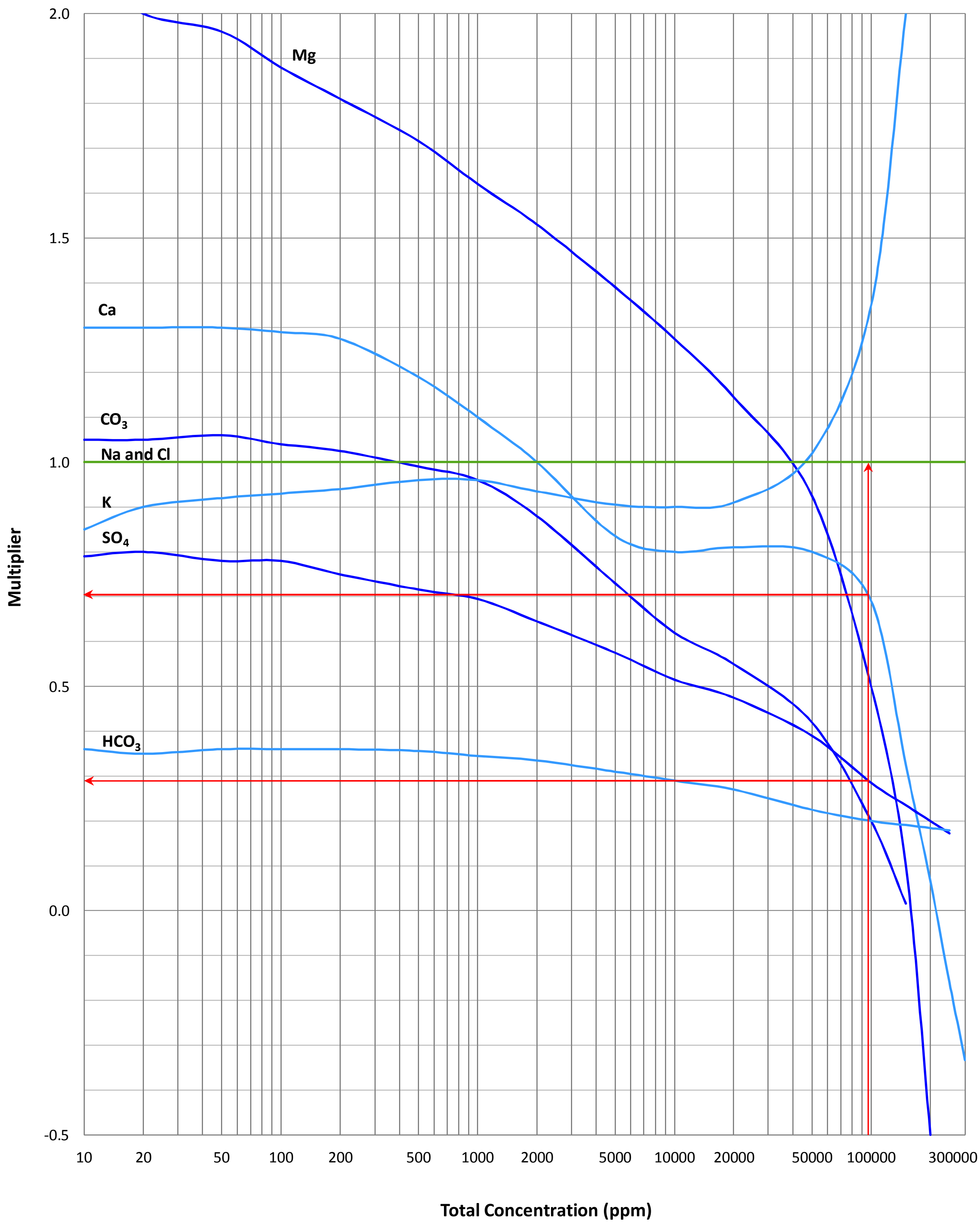
Total ions = 8,100 + 32,500 + 54,000 + 3,600 = 98,200 ppm

Enter the chart on the horizontal axis at 98,200 ppm. Project this line vertically to the Ca, Na and Cl, and the SO_4 curves. From the Ca curve intersection project horizontally to the Multiplier axis and estimate the multiplier to be 0.705. The multiplier for Na and Cl is 1. From the SO4 curve intersection project horizontally to the Multiplier axis and estimate the multiplier to be 0.29.

Multiply the ionic concentrations by the multipliers obtained and sum to obtain the total equivalent NaCl concentration.

$(8,100 \times 0.705) + (32,500 \times 1) + (54,000 \times 1) + (3,600 \times 0.29) = 93,254$ ppm

Equivalent NaCl Concentrations of Salts



Resistivity Salinity Temperature Conversions of NaCl Solutions

Purpose

This chart may be used to estimate the resistivity value of an equivalent NaCl solution at a given temperature or to determine the resistivity at one temperature given the resistivity at another temperature.

Procedure

To estimate the resistivity of the solution, enter the chart on the horizontal axis at the given temperature. Project this line vertically until intersection with the given equivalent concentration line. Project this intersection point horizontally to determine the resistivity.

For a solution with a known resistivity and temperature the resistivity at another temperature can be found. Enter the chart on the horizontal axis at the first temperature and on the vertical axis at the corresponding resistivity. Project both lines to find the intersection point. If the intersection point is between the ppm concentration lines interpolate between them to find a corresponding equivalent NaCl ppm concentration. Follow this line to the vertical projection of the temperature for the unknown resistivity. At the intersection of the ppm concentration and the temperature project horizontally to read the resistivity at that temperature.

Example

Given

Water with an equivalent NaCl concentration of 30,000 ppm
Temperature of 150 °F

Find

Determine the resistivity of the solution.

Answer

From the 150 °F temperature point on the horizontal axis project vertically into the chart until the line intersects the 30 000 ppm line. At the intersection point project horizontally to read the resistivity from the vertical axis scale of 0.105 ohm·m.

Given

Resistivity of a solution is 0.4 ohm·m
Temperature is 180 °F

Find

Determine the resistivity of the solution at 70 °F.

Answer

From the 180 °F temperature point on the horizontal axis project vertically into the chart until the line intersects the 0.4 ohm·m projected resistivity line. Follow the ppm concentration line to the projection of the 70 °F line. Interpolate the concentration line if necessary. Project the intersection point horizontally to read the new temperature of 0.99 at 70 °F.

Equations

R_1 = Resistivity of sample 1
R_1 = Resistivity of sample 2
T_1 = Temperature of sample 1
T_2 = Temperature of sample 2

Calculation with temperature in degrees Fahrenheit

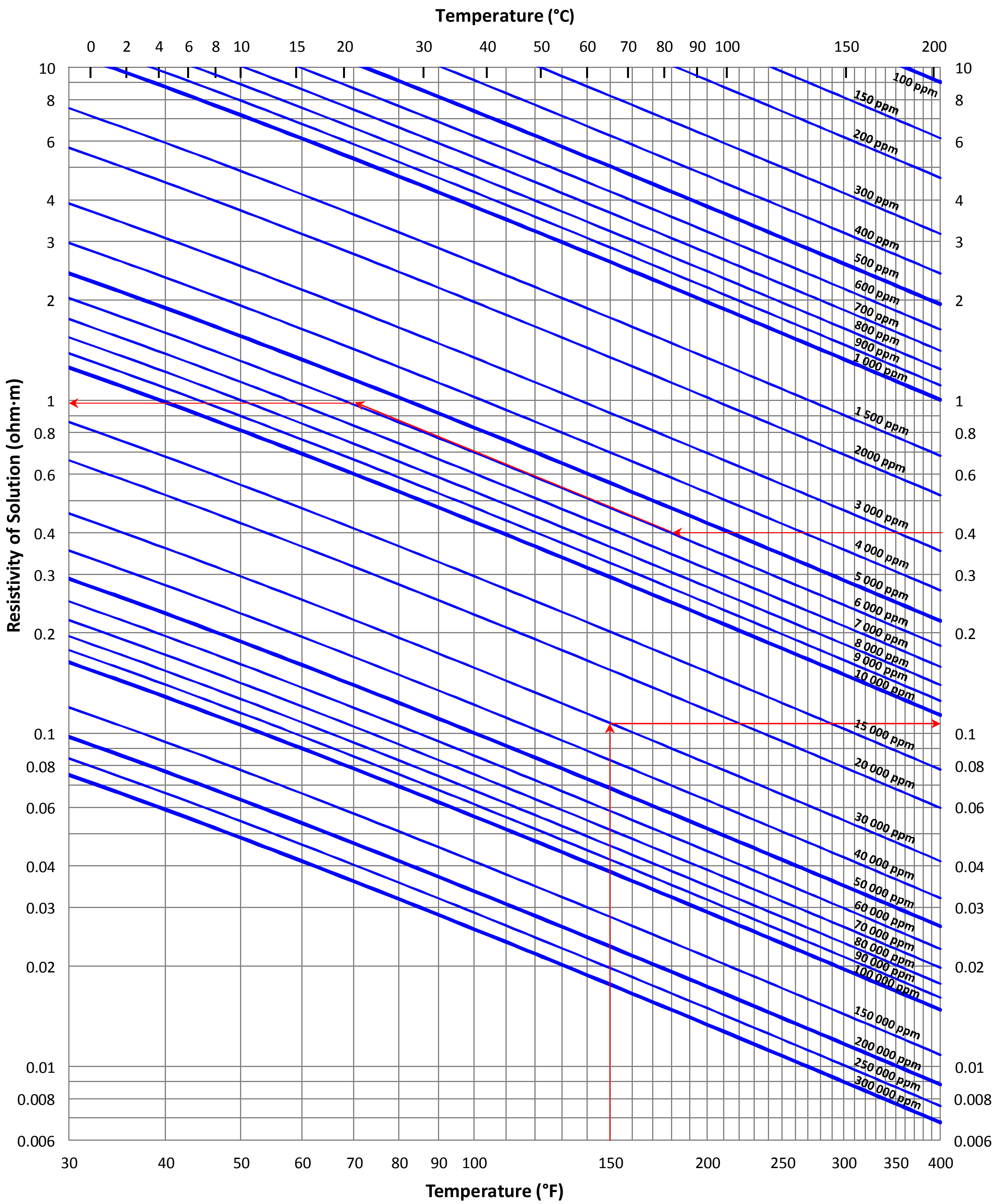
$$R_2 = R_1 \left(\frac{T_1 + 6.77}{T_2 + 6.77} \right)$$

Calculation with temperature in degrees Celcius

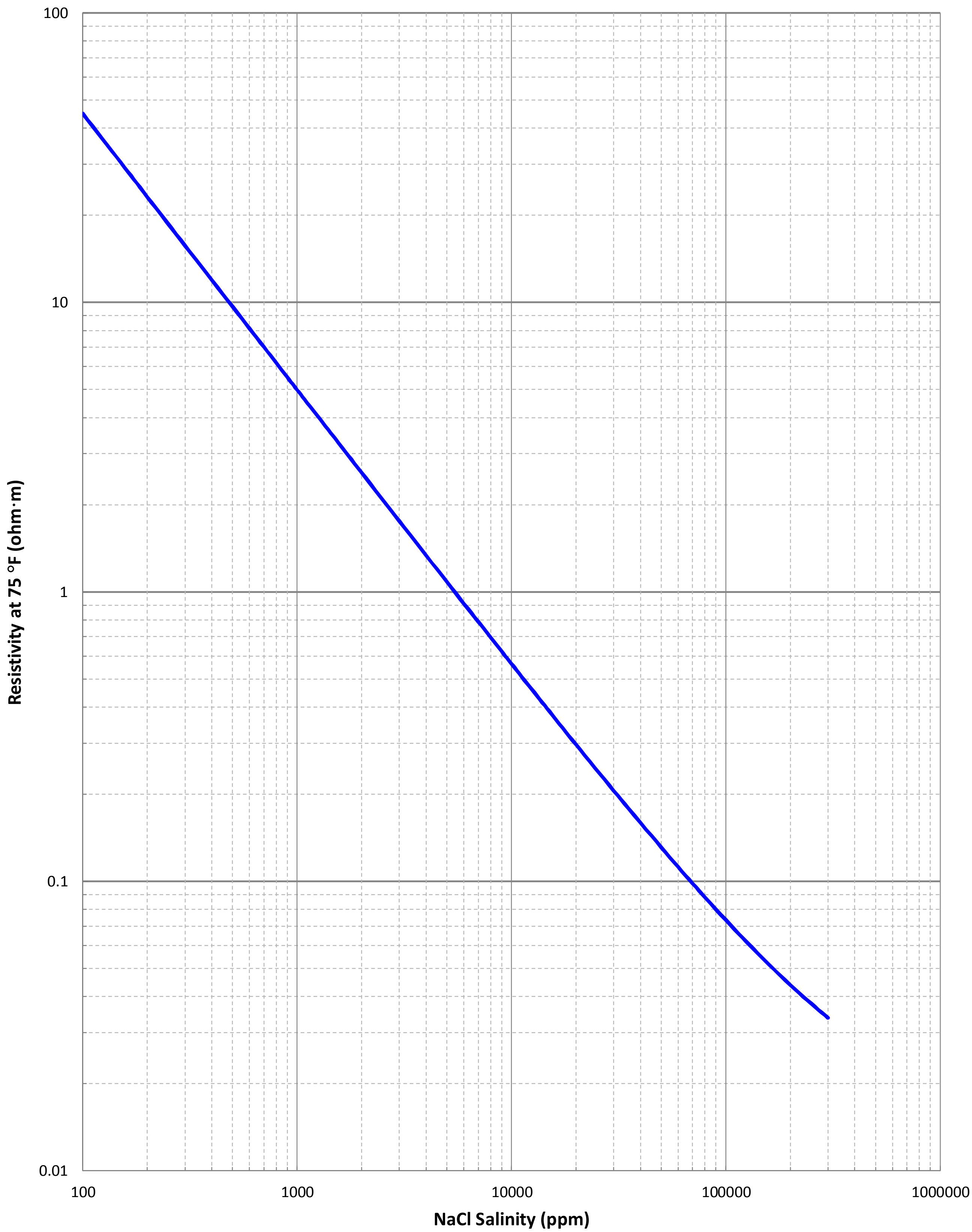
$$R_2 = R_1 \left(\frac{T_1 + 21.5}{T_2 + 21.5} \right)$$

Resistivity - Salinity - Temperature
Conversions of NaCl Solutions

For NaCl: Total salinity = Chlorides x 1.657



Resistivity of NaCl Solutions at 75 °F



Estimation of R_{mf} and R_{mc} from R_m

Purpose

This chart may be used to estimate the mud filtrate and mudcake resistivities given the mud resistivity and drilling mud density.

Procedure

To estimate the mud filtrate resistivity (R_{mf}) or mudcake resistivity (R_{mc}) enter the chart on the horizontal axis at the appropriate R_m value. Project this line vertically until it intersects the drilling fluid density curve for either R_{mf} or R_{mc}. Project the intersection point horizontally to determine the resistivity of either the mud filtrate or mudcake.

Example

Given

R_{mf} = 3.0 ohm·m
Drilling fluid density = 12 lb/gal

Find

Estimate the resistivity of the mud filtrate and mud cake.

Answer

From the 3.0 ohm·m point on the horizontal axis project vertically into the chart until the line intersects the solid 12 lb/gal curve and the dashed 12 lb/gal curve. At the intersection point from each of these curves project horizontally to read the resistivity for each of the mud filtrate, 1.1 ohm·m and mudcake 4.4 ohm·m.

Equations

R_m = mud resistivity
R_{mf} = mud filtrate resistivity
R_{mc} = mudcake resistivity
k_m = Coefficient of the mud

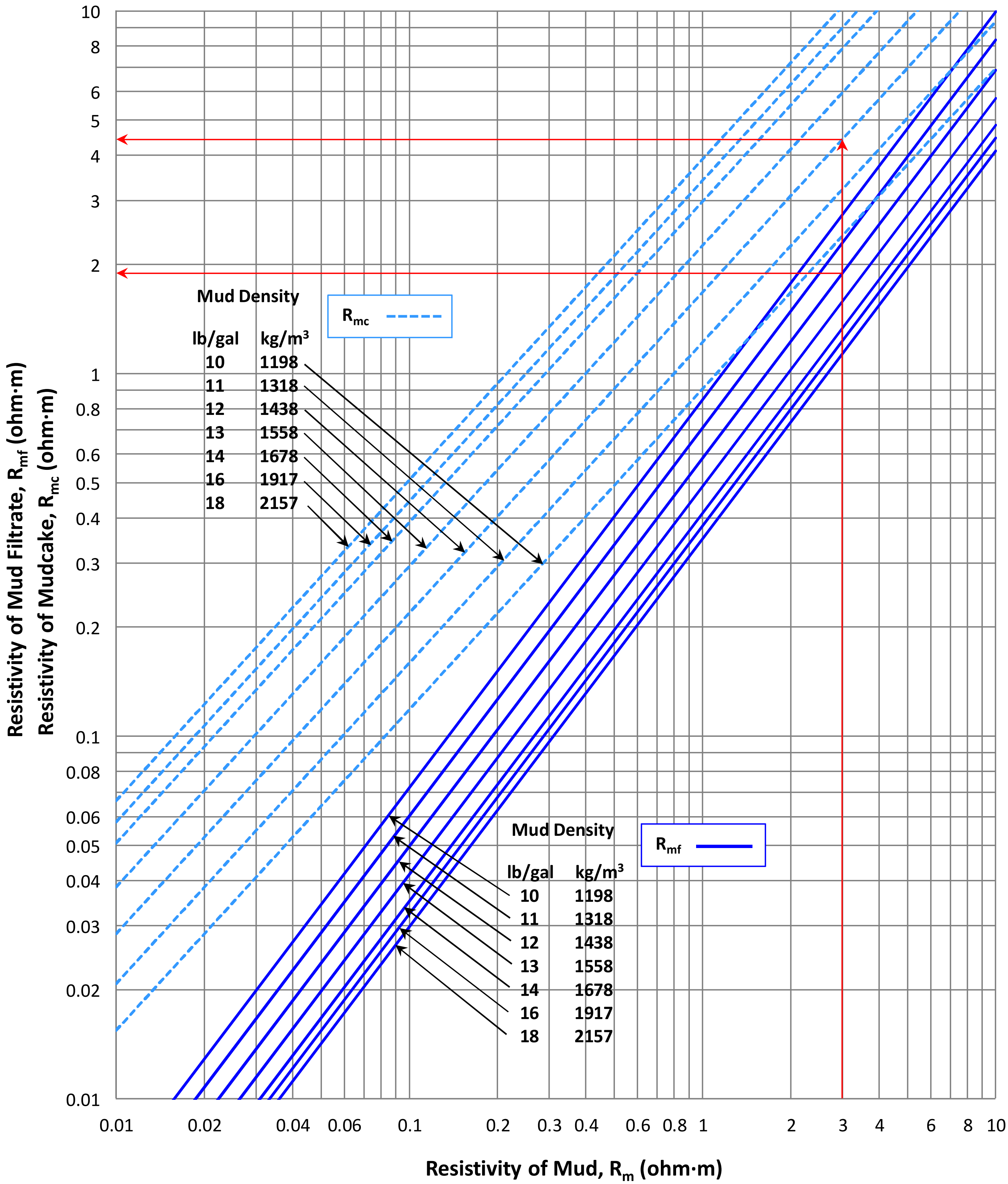
Mud Density		Coefficient of the mud
lb/gal	kg/m^3	k_m
10	1198	0.847
11	1318	0.708
12	1438	0.584
13	1558	0.488
14	1678	0.412
16	1917	0.380
18	2157	0.350

R_{mf} and R_{mc} can be calculated using the following equations and the values from the table above.

$$R_{mf} = k_m \times R_m^{\;1.07}$$

$$R_{mc} = 0.69 \times R_{mf} \times \left(\frac{R_m}{R_{mf}}\right)^{2.65}$$

Estimation of R_{mf} and R_{mc} from R_m



Formation Resistivity Factor versus Porosity

Purpose
This chart may be used to determine the formation resistivity factor for a given porosity.

Procedure
To estimate the formation resistivity factor (F) enter the chart on the vertical axis at the appropriate porosity value. Project this line horizontally until it intersects the desired cementation exponent curve (m) for the rock type. Project the intersection point vertically to determine the formation resistivity factor (F).

Example
Given

a = 1.0

m = 1.8

Φ = 10 %

Find

Estimate the formation resistivity factor (F).

Answer

From the 10 % point on the vertical axis project horizontally into the chart until the line intersects the m=1.8 curve. At the intersection point project vertically to read the formation resistivity factor of 62 from the horizontal axis.

Equations
F = formation resistivity factor

a = tortuosity factor

m = cementation exponent

Φ = porosity

General equation

$$F = \frac{a}{\Phi^m}$$

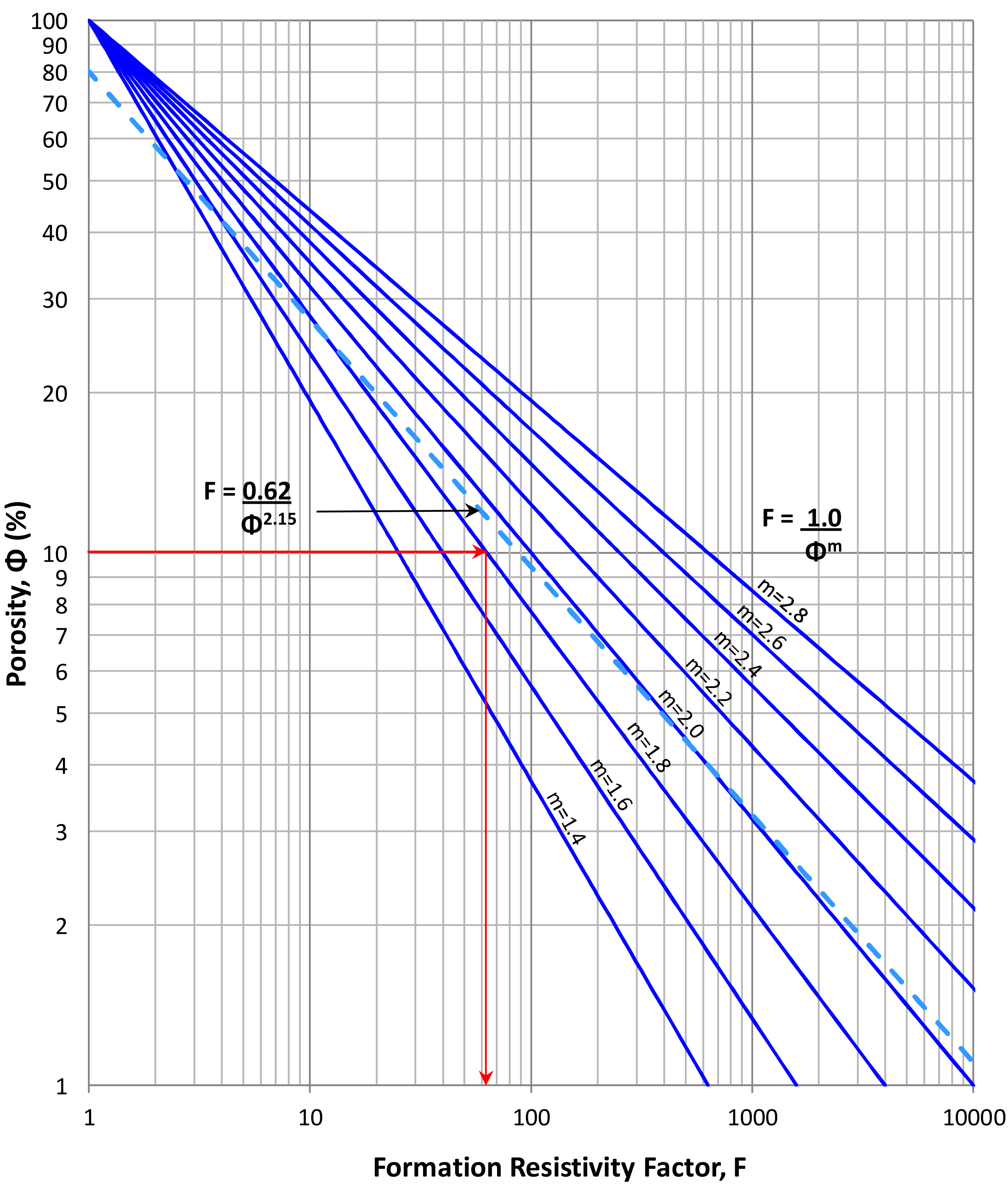
For sandstones

$$F = \frac{0.62}{\Phi^{2.15}} \quad \text{or} \quad F = \frac{0.81}{\Phi^2}$$

For carbonates

$$F = \frac{1.0}{\Phi^2}$$

Formation Resistivity Factor versus Porosity



SP Bed Thickness Correction

Purpose

This chart may be used to correct the spontaneous potential (SP) log for the effects of bed thickness.

Procedure

To estimate the SP correction factor first determine the ratio between the true formation resistivity and the mud resistivity at the formation temperature. Enter the chart on the vertical axis at the estimated bed thickness. Units of feet are on the left side of the chart and meters are on the right side of the chart. Project the line horizontally until it intersects the curve closest to the R_t/R_m value. Values between the curves can be interpolated. From the intersection point project vertically down to read the SP correction factor. Multiply the SP reading from the log by this correction factor to obtain a corrected SP log for bed thickness. Thicker beds should have less correction effects.

Example

Given

SP_{LOG} = -80 mV
h = 7 feet
R_t = 24 ohm·m
R_m = 1.2 ohm·m

Find

Estimate the SP corrected for bed thickness.

Answer

Determine the R_t/R_m ratio.

$$\frac{R_t}{R_m} = \frac{24 \text{ ohm} \cdot \text{m}}{1.2 \text{ ohm} \cdot \text{m}} = 20$$

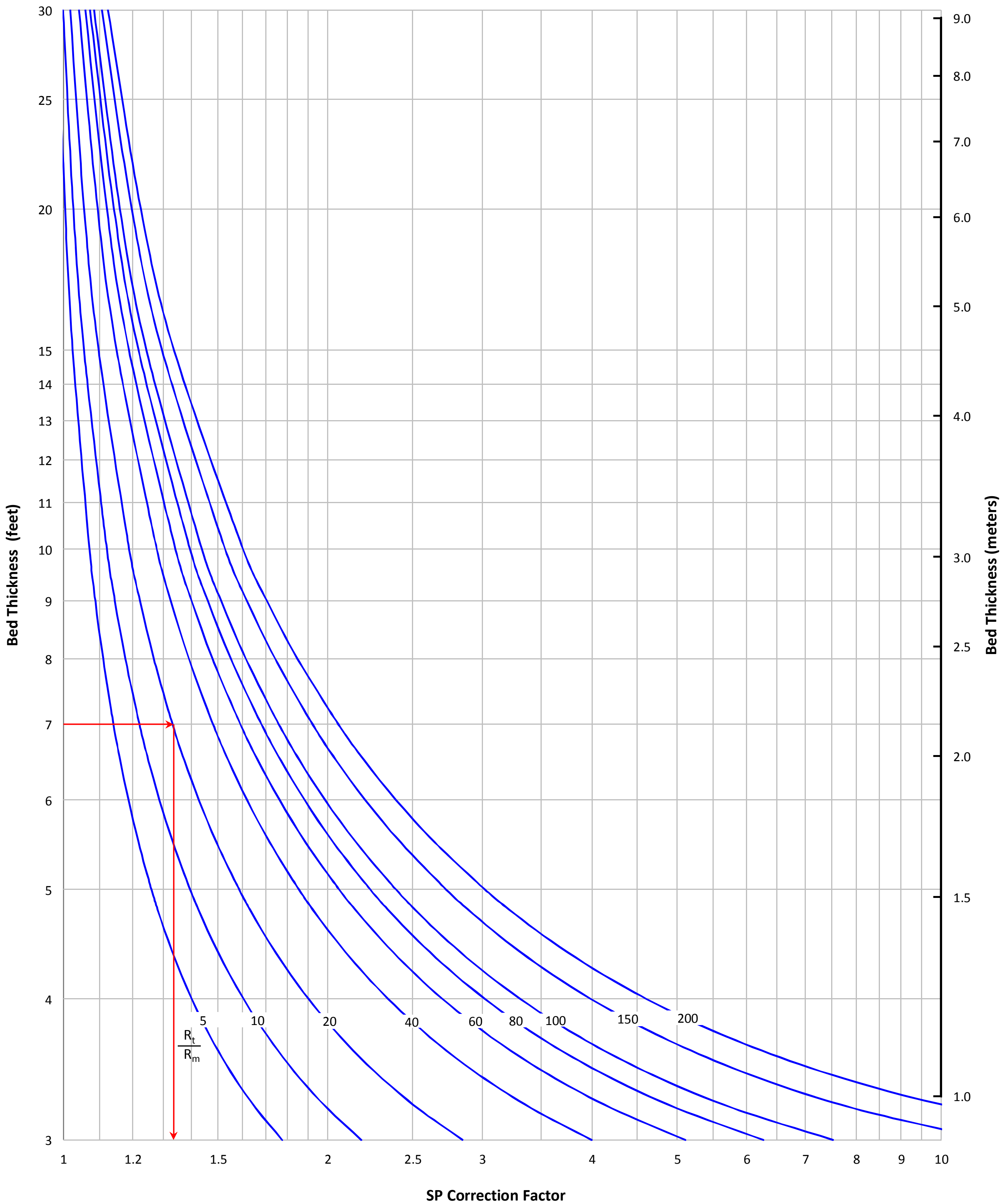
Enter the chart on the left vertical axis at 7 feet and project horizontally until the line intersects the R_t/R_m=20 curve. Project this intersection point vertically to the lower axis to obtain an SP correction factor of 1.34.

Multiply the SP reading from the log by the correction factor to obtain a corrected SP reading of -107.2 mV.

$SP_{CORR} = SP_{LOG} \times SP_{Correciton\ Factor}$

SP_{CORR} = -80 mV × 1.34 = -107.2 mV

SP Bed Thickness Correction



R_{we} Estimate from Static SP

Purpose

This chart may be used to determine the equivalent water resistivity from the static spontaneous potential (SSP).

Procedure

To estimate R_{we} first enter the chart on the lower axis with the SSP in millivolts. Project this line vertically until intersecting the appropriate temperature line. Project the intersection of the SSP and temperature line horizontally to determine the R_{mfe}/R_{we} ratio. R_{we} can be determined by dividing the R_{mfe} calculated from the log by the R_{mfe}/R_{we} ratio.

Example

Given

R_{mf} = 1.4 ohm·m @ 75 °F
SSP = -110 mV
Temperature = 150 °F

Find

Estimate the R_{we}.

Answer

Determine the equivalent mud resisitivity. Since R_{mf} > 0.1 at 75 °F we can use chart GEN 4b to determine the R_{mf} at the formation temperature of 150 °F. From the chart the R_{mf} at 150 °F is 0.7 ohm·m.

$R_{mfe} = 0.85R_{mf} = 0.85 \times 0.7 = 0.595$ ohm·m

Enter the chart on the horizontal axis at SSP = -110 mV. Project this line vertically until it intersects the 150 °F temperature line. Project this intersection point horizontally to the left to read the R_{mfe}/R_{we} ratio of 23.

$$\frac{R_{mfe}}{R_{we}} = 23$$

Input the value of 0.595 ohm·m for R_{mfe} into the equation and solve for R_{we} to get 0.0259 ohm·m.

$$R_{we} = \frac{0.595}{23} = 0.0259 \text{ ohm} \cdot \text{m}$$

Equations

- If R_{mf} at 75 °F is > 0.1 ohm·m then correct R_{mf} to formation temperature using chart **GEN 4b** and the equation: $R_{mfe} = 0.85R_{mf}$

- If R_{mf} at 75 °F is < 0.1 ohm·m then use chart **SP 3** to find R_{mfe} at the formation temperature.

SSP = static spontaneous potential
T_d = Temperature at formation depth
R_{mfe} = equivalent mud filtrate resistivity
R_{we} = equivalent water resistivity

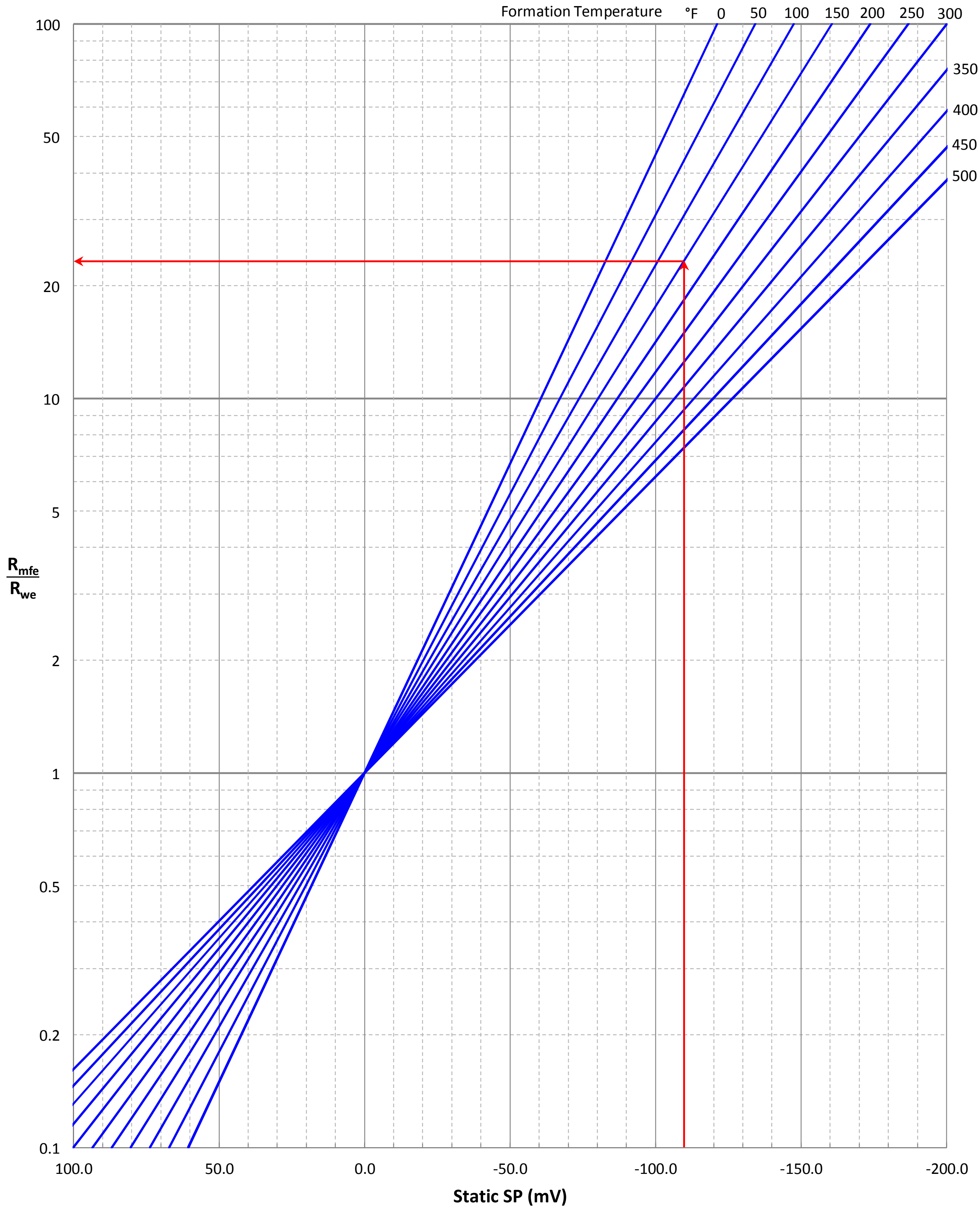
Static SP calculation with temperature in degrees Fahrenheit

$$SSP = -70.7 \times \left(\frac{460 + T_d}{537}\right) \times \log\left(\frac{R_{mfe}}{R_{we}}\right)$$

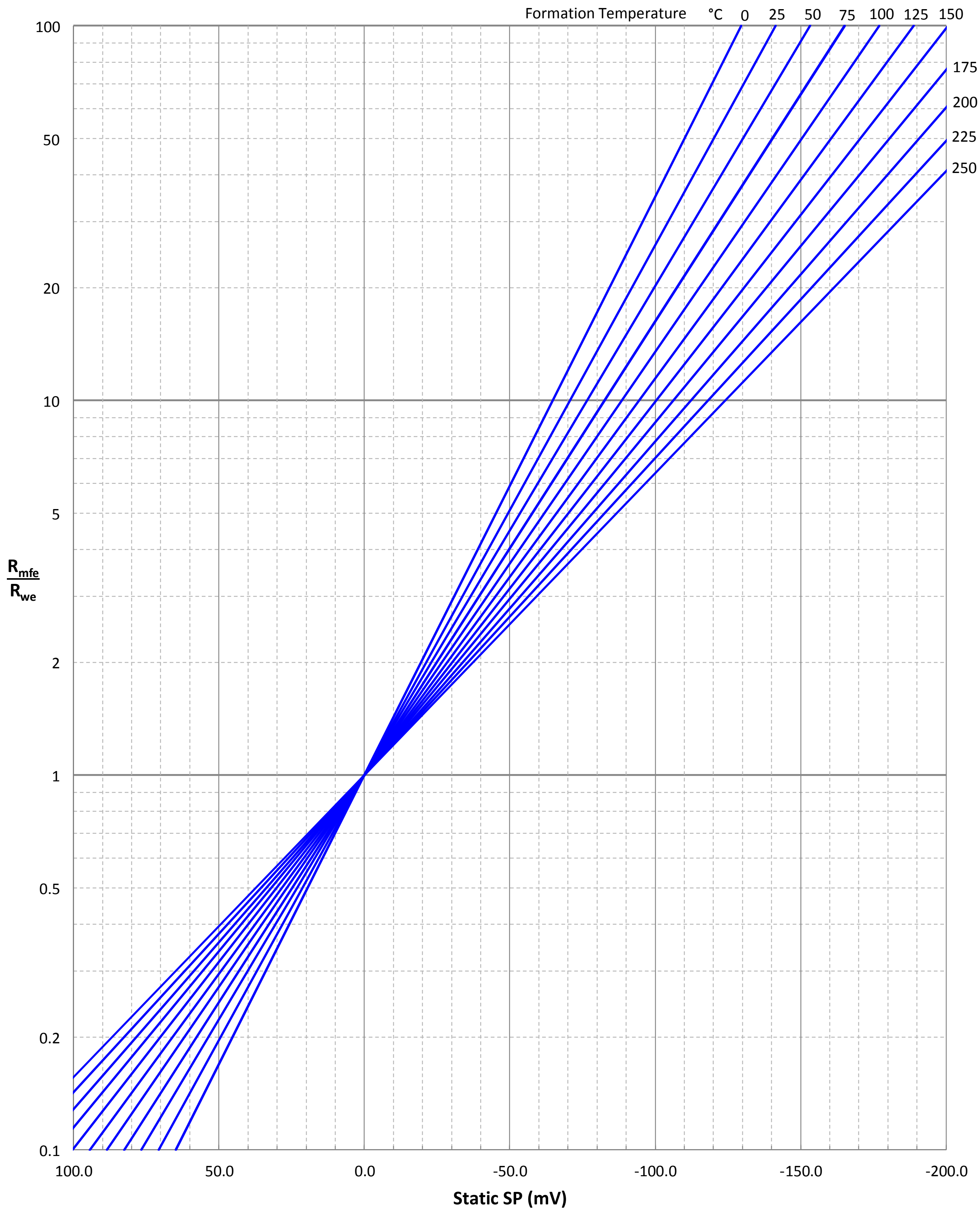
Static SP calculation with temperature in degrees Celcius

$$SSP = -70.7 \times \left(\frac{273 + T_d}{298}\right) \times \log\left(\frac{R_{mfe}}{R_{we}}\right)$$

R_{we} Estimate from Static SP



R_{we} Estimate from Static SP



Estimation of R_w from R_{we}

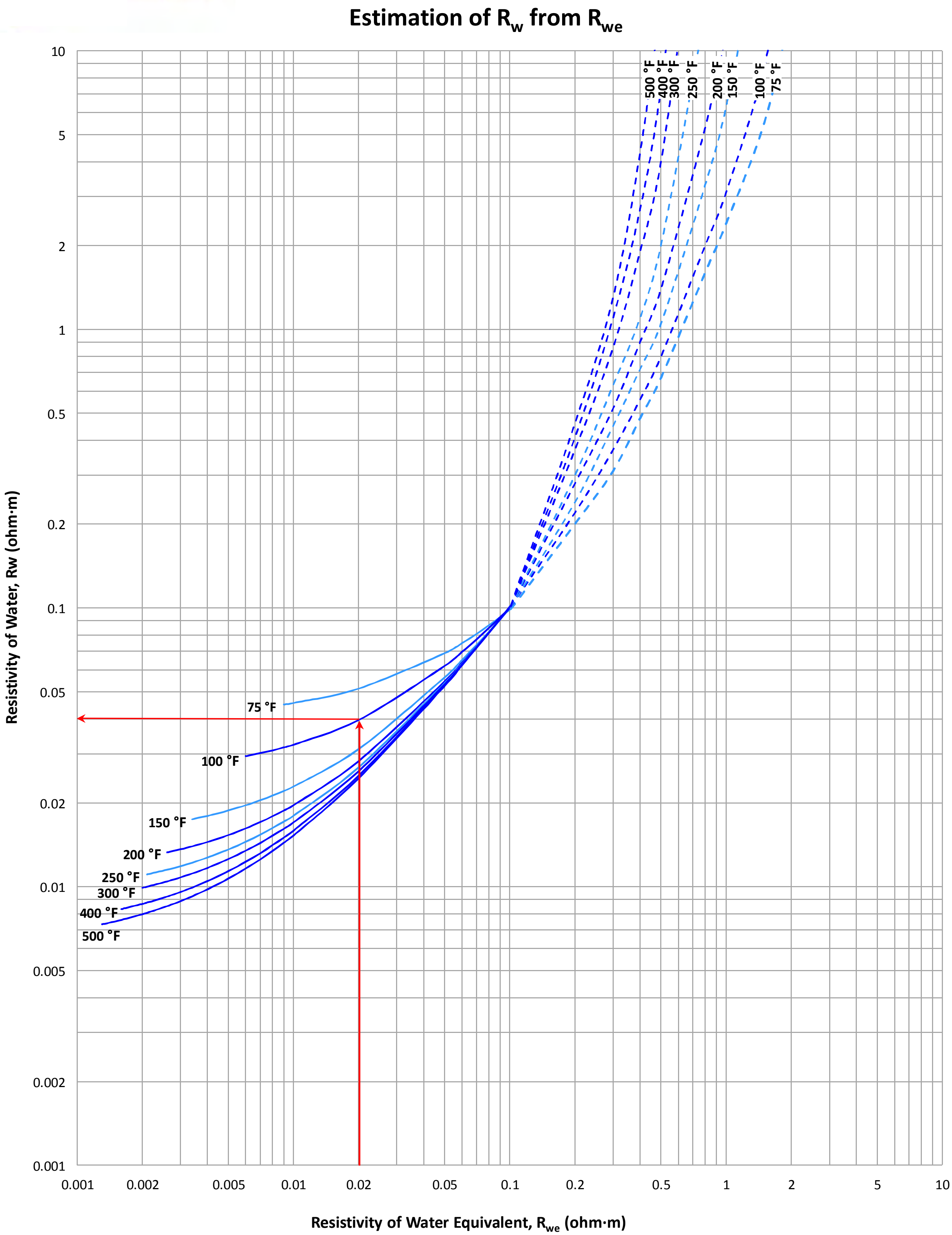
Purpose
This chart may be used to determine the actual water resistivity from the equivalent water resistivity.

Procedure
To estimate R_w first enter the chart on the lower R_{we} axis at the known resistivity. Project this line vertically until it intersects the temperature curve. From this intersection, project this point horizontally to read the R_w value from the vertical axis.

Example
Given
R_{we} = 0.2 ohm·m
Temperature = 100 °F

Find
Estimate actual water resistivity - R_w.

Answer
Enter the chart on the horizontal axis at R_{we} = 0.2 ohm·m. Project this line vertically to intersect the 100 °F temperature line. Project this intersection point horizontally to the left to read the R_w of 0.4 ohm·m.


Estimation of R_w from R_{we}
Resistivity of Water, Rw (ohm·m)
Resistivity of Water Equivalent, R_{we} (ohm·m)
10
5
2
1
0.5
0.2
0.1
0.05
0.02
0.01
0.005
0.002
0.001
0.001
0.002
0.005
0.01
0.02
0.05
0.1
0.2
0.5
1
2
5
10
75 °F
100 °F
150 °F
200 °F
250 °F
300 °F
400 °F
500 °F
500 °F
400 °F
300 °F
250 °F
200 °F
150 °F
100 °F
75 °F

Induction Array Tool - Invasion Correction Charts

Purpose

These charts may be used to determine the true resistivity, flushed zone resistivity and the diameter of invasion from the IAT logs. Separate charts are presented for different formation resistivity values and using different shallow array curves from the IAT tool. The existing charts are all for thick beds with a step profile invasion.

Procedure

Enter the chart with the ratio of the curves IA30/IA90 on the horizontal axis and the ratio of the IA20/IA90 curves on the vertical axis. The intersection of the two projections determines the diameter of invasion on the red dashed curves, R_{xo}/R_t on the blue curves and R_t/IA90 on the black curves. If the intersection does not lie on existing curves then the value may be obtained by interpolating between the two bounding curve values.

Example

Given

IA20 = 50 ohm·m
IA30 = 31 ohm·m
IA90 = 14 ohm·m
R_{xo} = ohm·m

Find

Determine R_t, R_{xo} and diameter of invasion (D_i).

Answer

Calculate the required ratios for the chart:

$$\frac{\mathrm{IA20}}{\mathrm{IA90}} = \frac{50\ \mathrm{ohm\cdot m}}{14\ \mathrm{ohm\cdot m}} = 3.6 \qquad \frac{\mathrm{IA30}}{\mathrm{IA90}} = \frac{31\ \mathrm{ohm\cdot m}}{14\ \mathrm{ohm\cdot m}} = 2.2$$

Using the chart IAT 2, as the estimated Rt will be close to 10, enter the chart at 3.6 on the vertical IA20/IA90 axis and project horizontally into the chart. Enter the chart at 2.2 on the horizontal IA30/IA90 axis and project vertically into the chart.

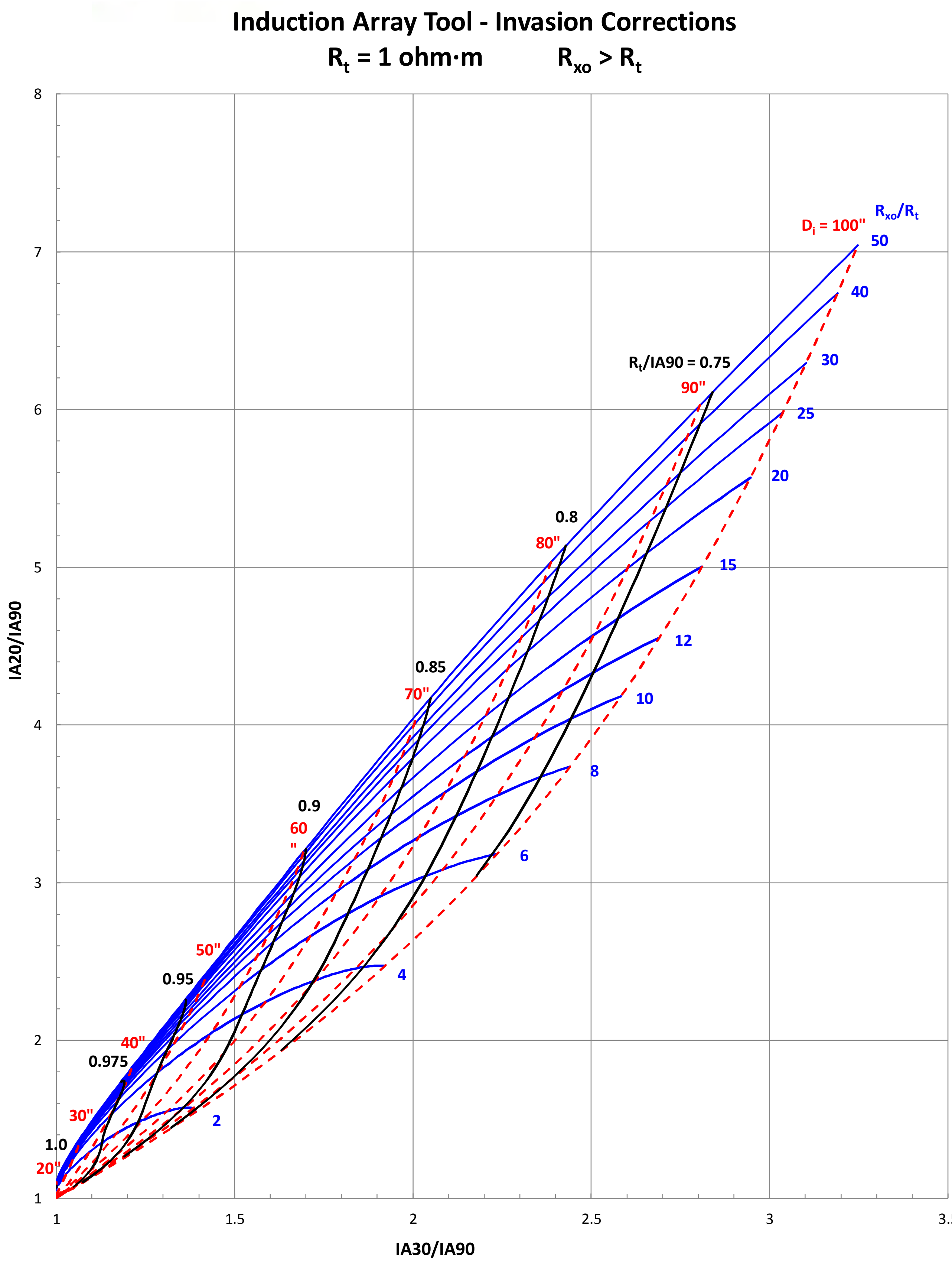
Using the intersection point, interpolate between the solid black lines to determine the ratio R_t/IA90 = 0.825. Calculate R_t to be 11.6 ohm·m.

$$\frac{\mathrm{R_t}}{\mathrm{IA90}} = \frac{\mathrm{R_t}}{14\ \mathrm{ohm\cdot m}} = 0.825 \qquad \mathrm{R_t} = 11.6\ \mathrm{ohm\cdot m}$$

Using the intersection point again, interpolate between the solid blue lines to determine the ratio R_{xo}/R_t = 9.0. Calculate R_{xo} to be 104.4 ohm·m.

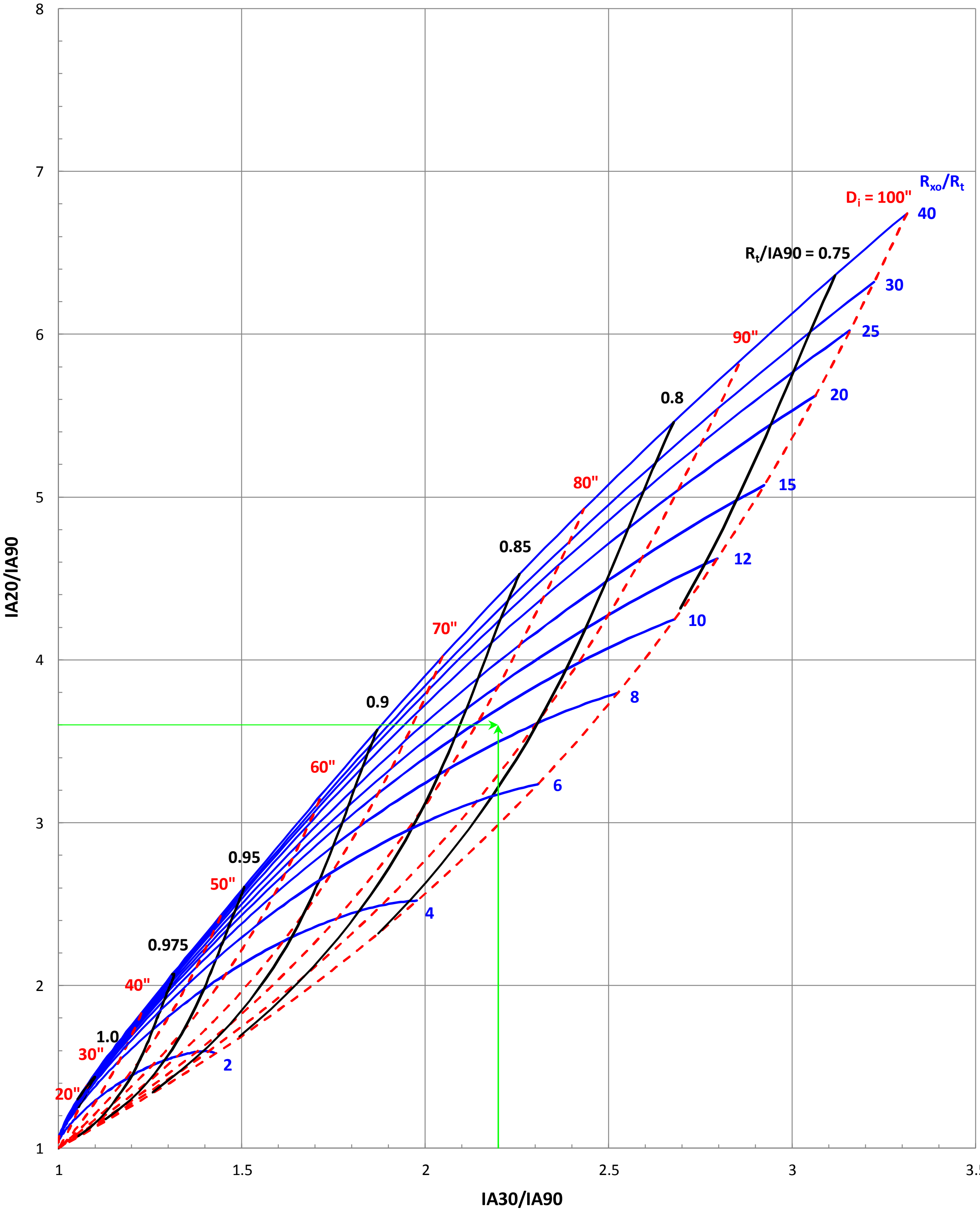
$$\frac{\mathrm{R_{xo}}}{\mathrm{R_t}} = \frac{\mathrm{R_{xo}}}{11.6\ \mathrm{ohm\cdot m}} = 9.0 \qquad \mathrm{R_{xo}} = 104.4\ \mathrm{ohm\cdot m}$$

Using the intersection point again, interpolate between the dashed red lines to determine the diameter of invasion to be 83 inches.

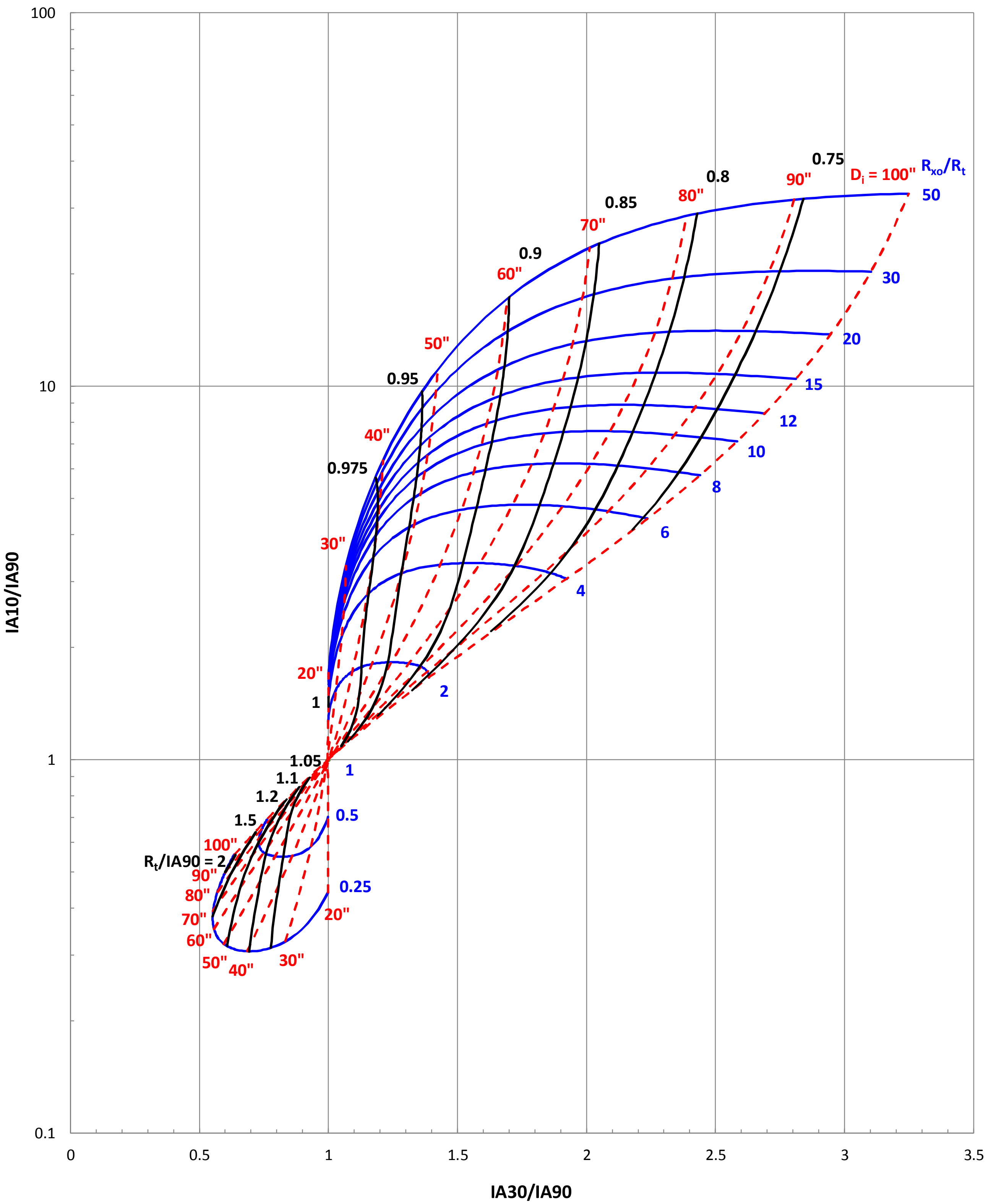

Induction Array Tool - Invasion Corrections
Rt = 1 ohm·m   Rxo > Rt
IA20/IA90
IA30/IA90
Rxo/Rt
Di = 100"
Rt/IA90 = 0.75
90"
0.8
80"
0.85
70"
0.9
60"
50"
0.95
40"
0.975
30"
1.0
20"
50
40
30
25
20
15
12
10
8
6
4
2

Induction Array Tool - Invasion Corrections

R_t = 10 ohm·m $R_{xo} > R_t$

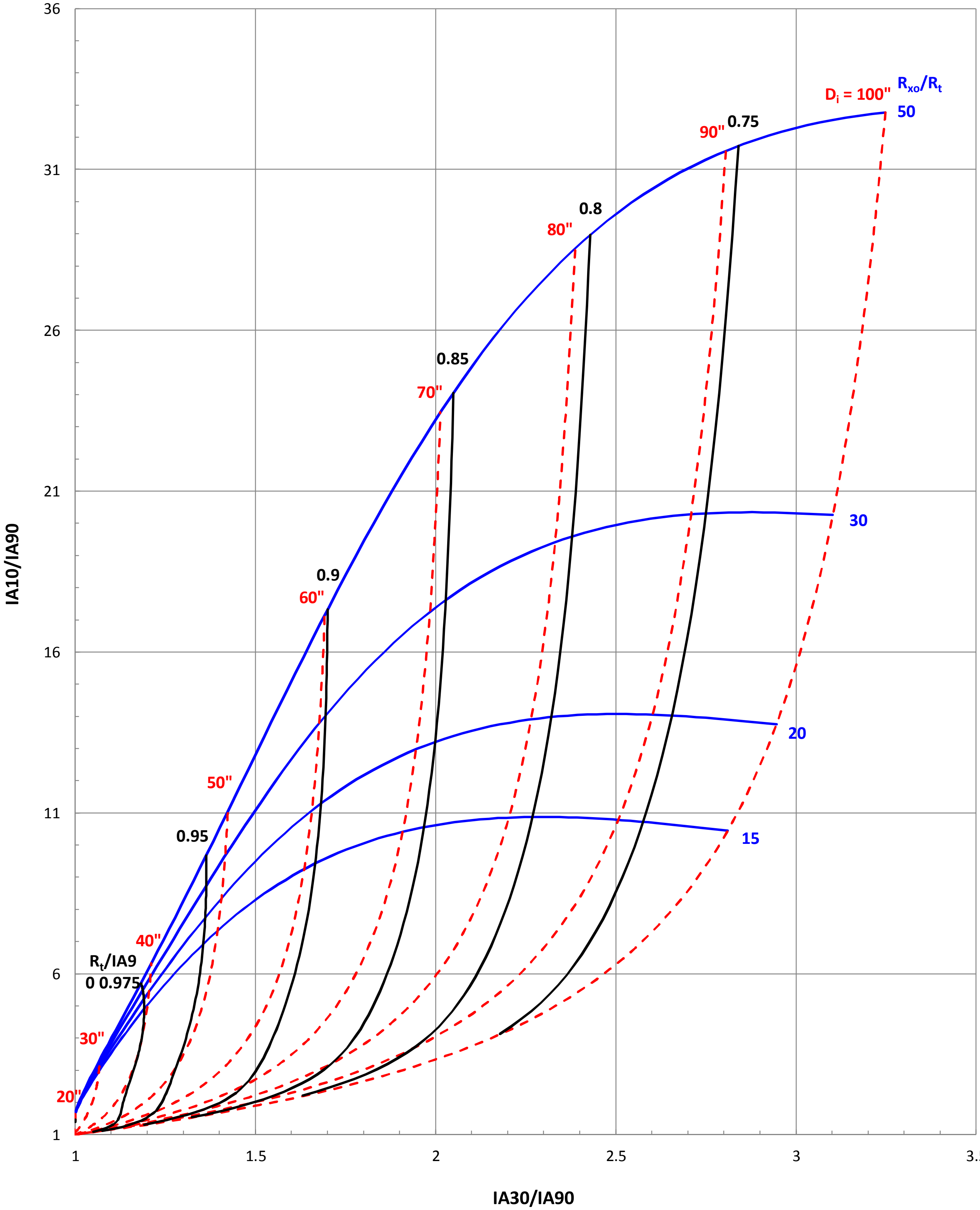


Induction Array Tool - Invasion Corrections
R_t = 1 ohm·m

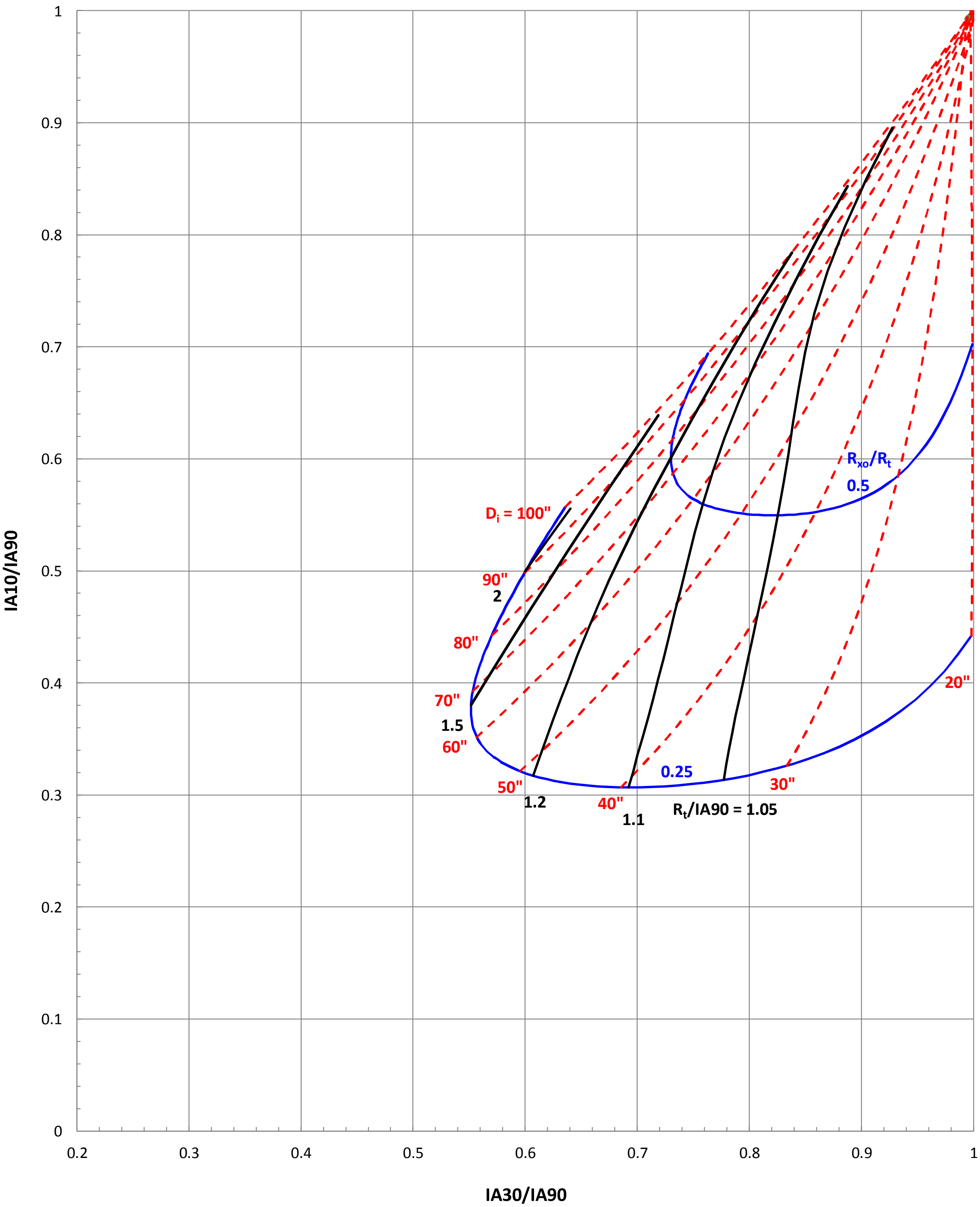


Induction Array Tool - Invasion Corrections

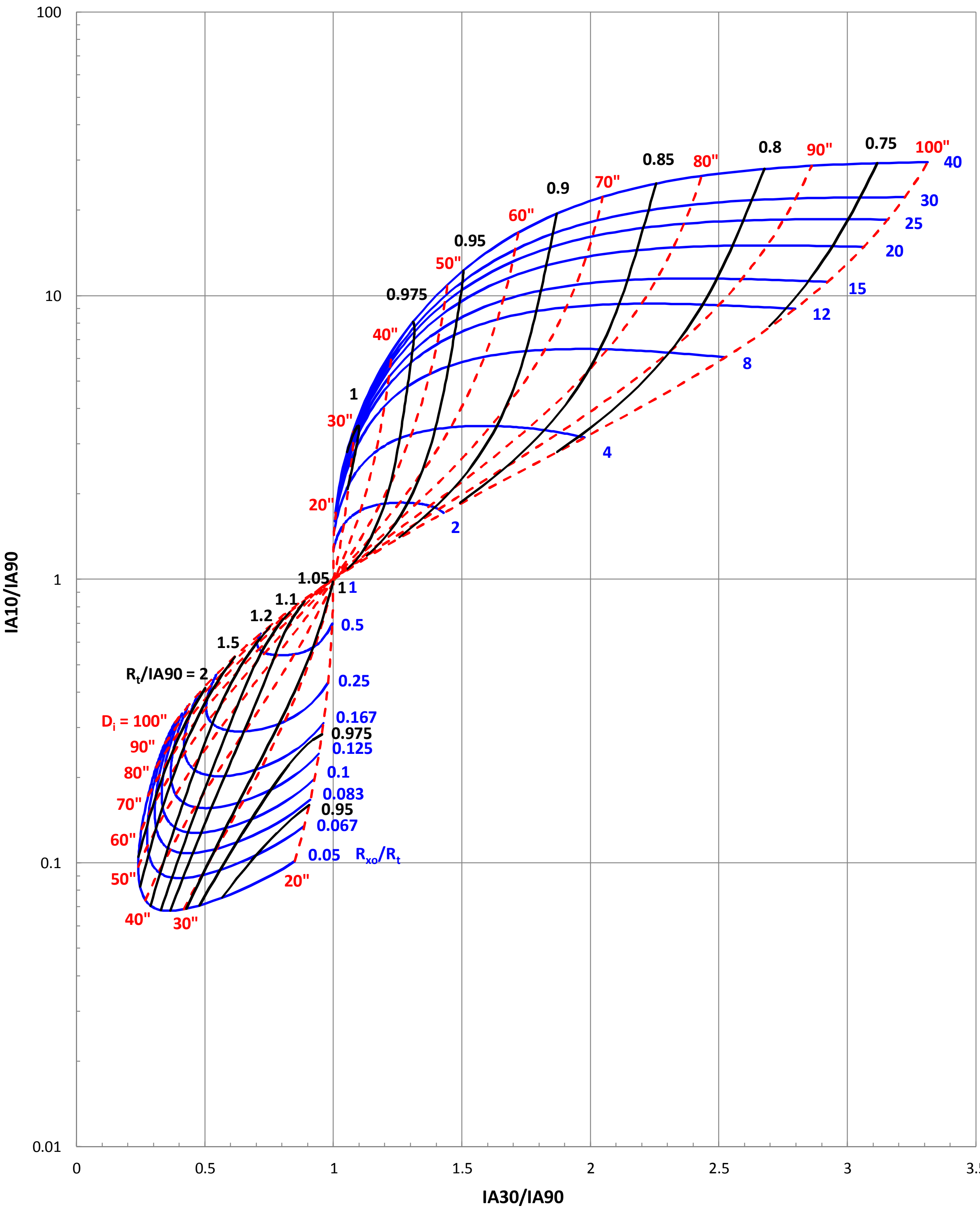
R_t = 1 ohm·m $R_{xo} > R_t$

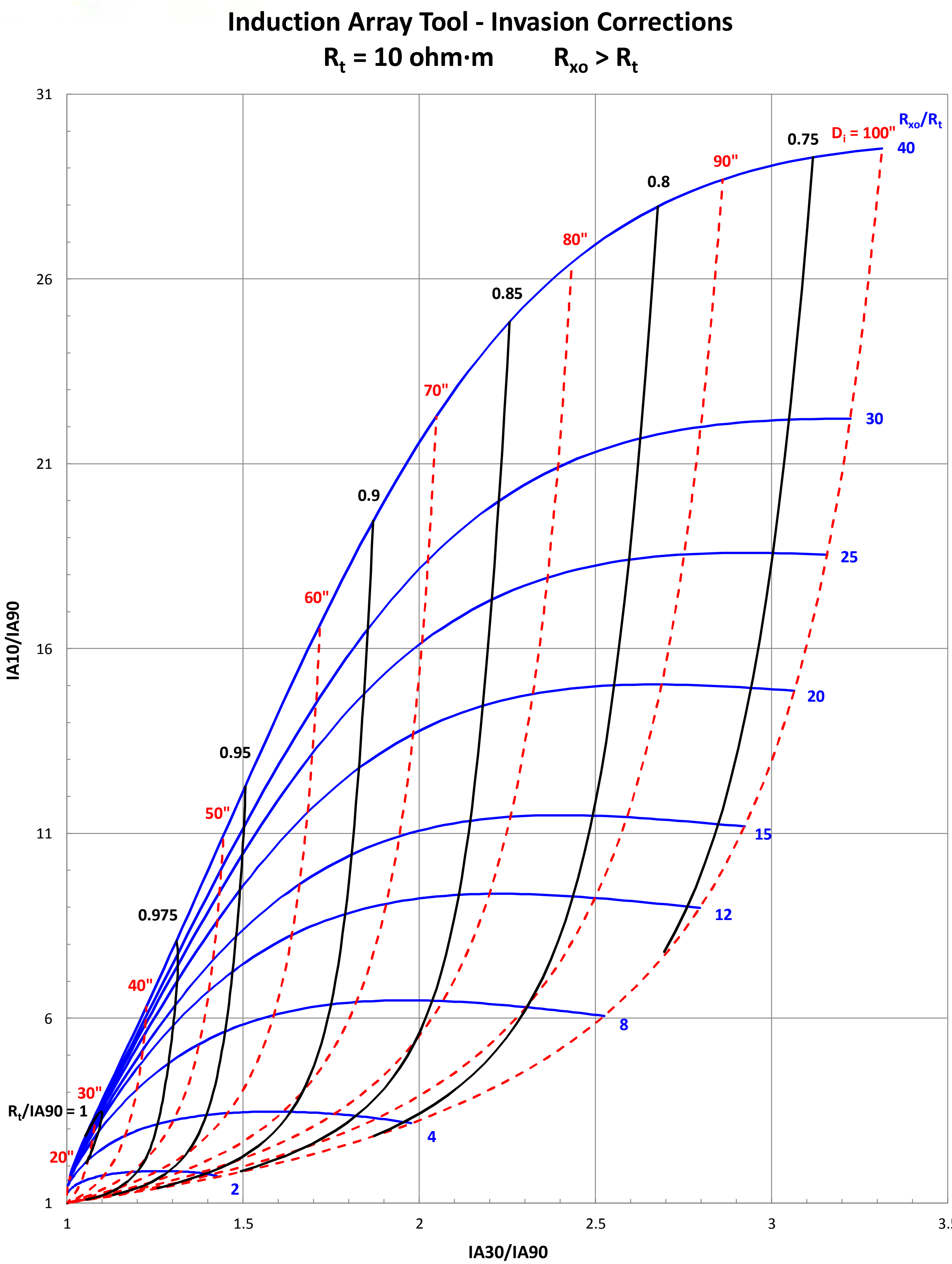


Induction Array Tool - Invasion Corrections
R_t = 1 ohm·m $R_{xo} < R_t$



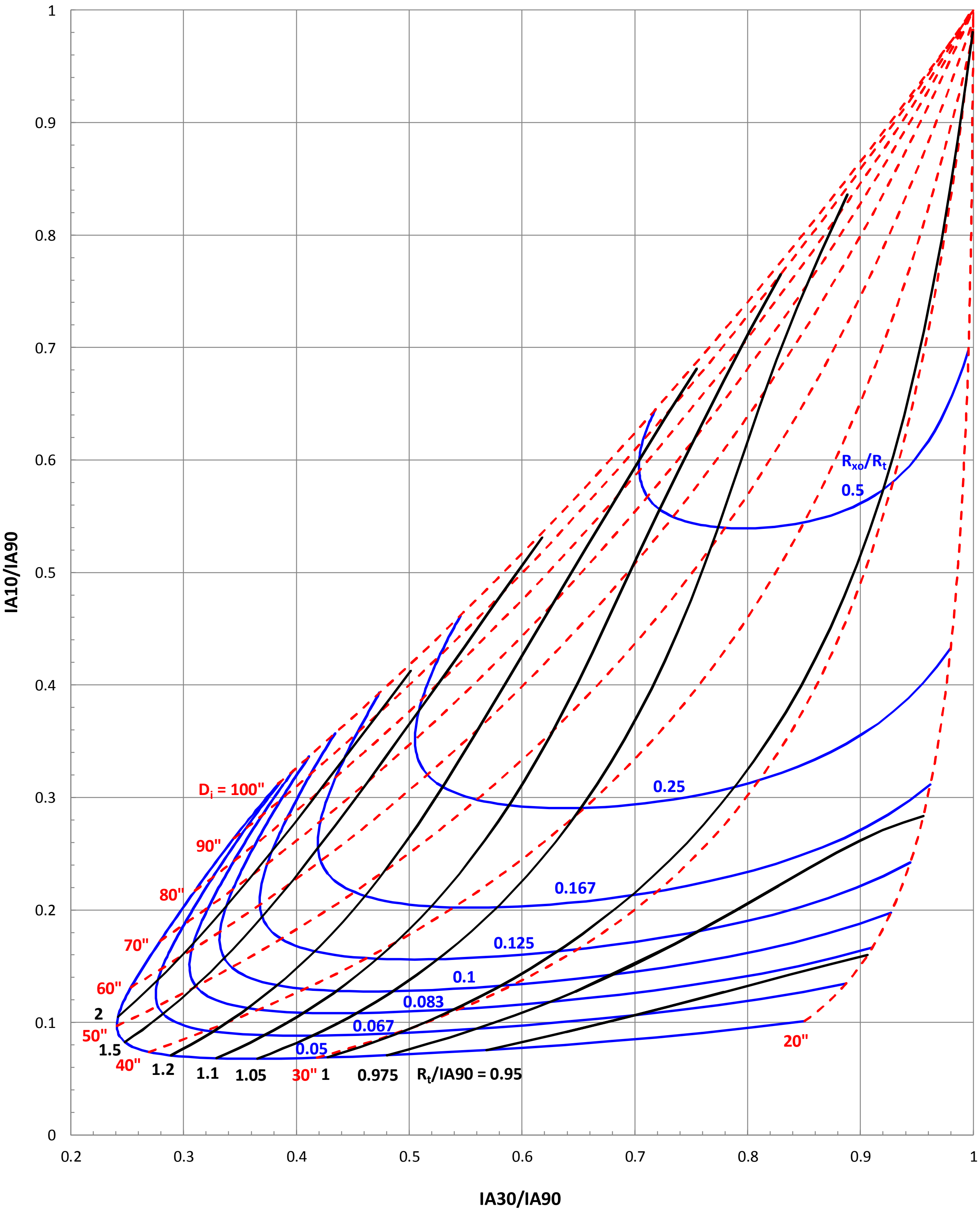
Induction Array Tool - Invasion Corrections
R_t = 10 ohm·m

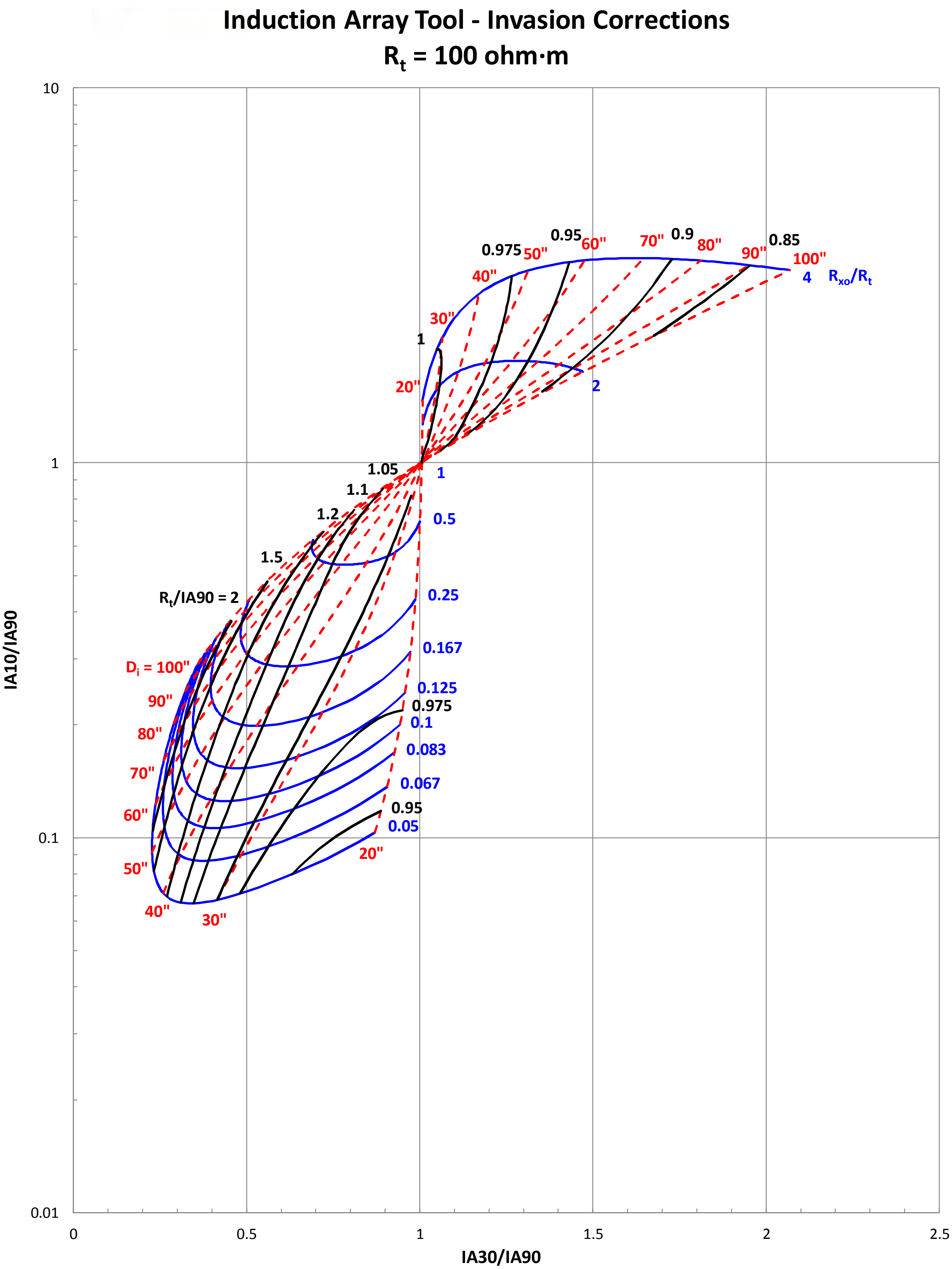



Induction Array Tool - Invasion Corrections
R_t = 10 ohm·m   R_xo > R_t
IA10/IA90
IA30/IA90
31
26
21
16
11
6
1
1
1.5
2
2.5
3
3.5
R_xo/R_t
D_i = 100"
90"
80"
70"
60"
50"
40"
30"
20"
0.75
0.8
0.85
0.9
0.95
0.975
R_t/IA90 = 1
40
30
25
20
15
12
8
4
2

Induction Array Tool - Invasion Corrections

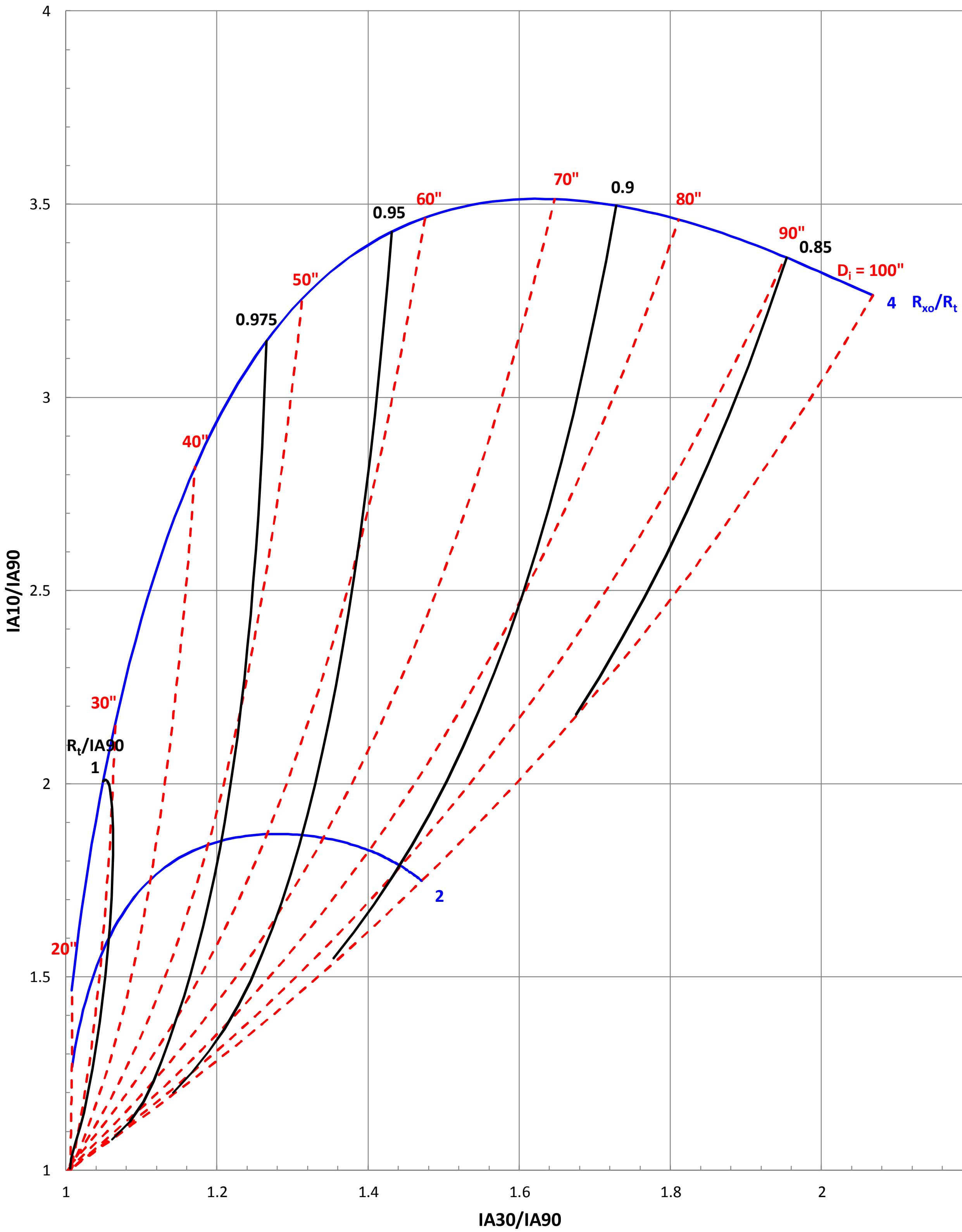
R_t = 10 ohm·m $R_{xo} < R_t$




Induction Array Tool - Invasion Corrections
R_t = 100 ohm·m
IA10/IA90
IA30/IA90
10
1
0.1
0.01
0
0.5
1
1.5
2
2.5
0.975
0.95
0.9
0.85
50"
60"
70"
80"
90"
100"
40"
30"
20"
4
R_{xo}/R_t
1
2
1.05
1.1
1.2
1.5
R_t/IA90 = 2
0.5
0.25
0.167
0.125
0.975
0.1
0.083
0.067
0.95
0.05
D_i = 100"
90"
80"
70"
60"
50"
40"
30"
20"

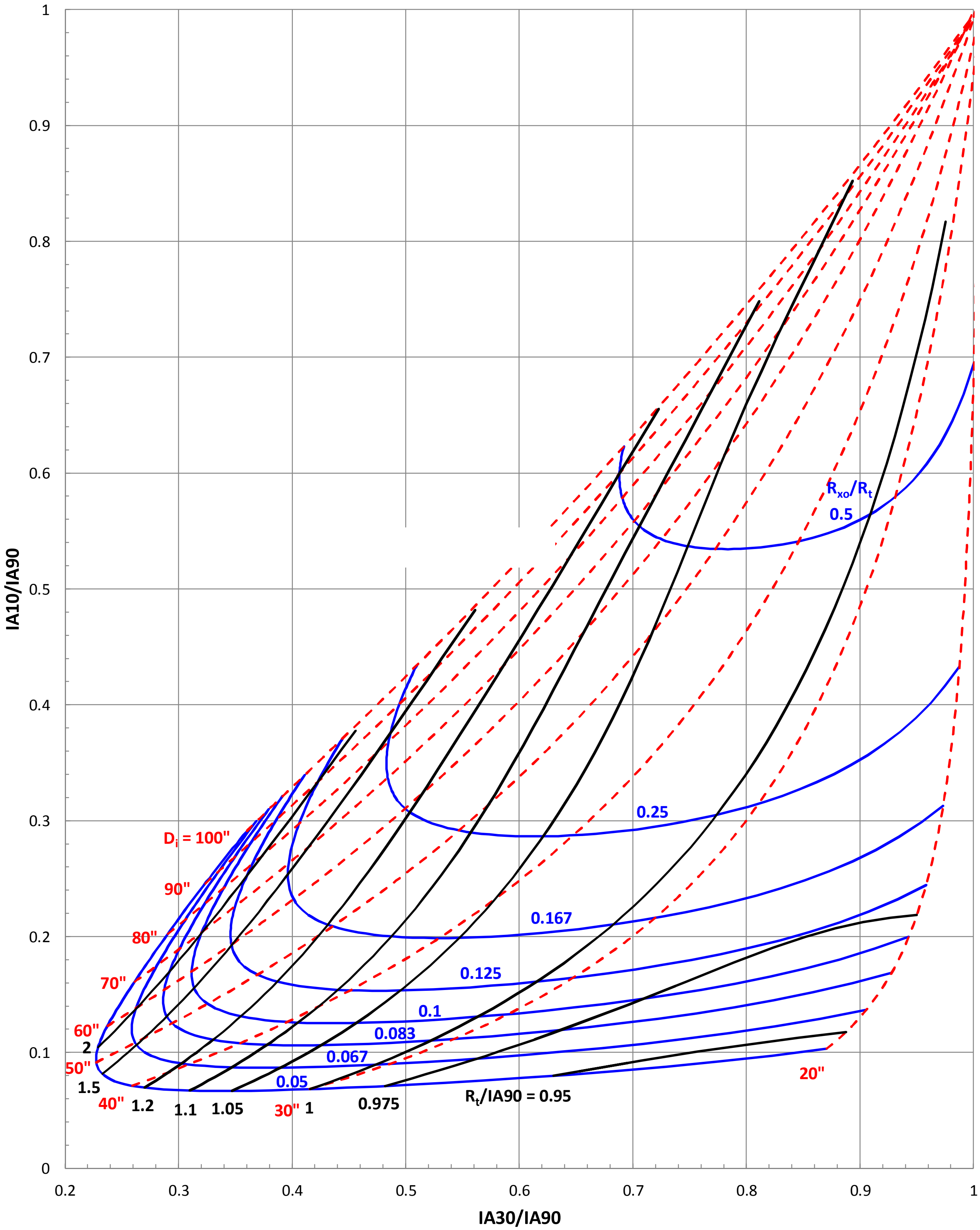
Induction Array Tool - Invastion Corrections

R_t = 100 ohm·m $R_{xo} > R_t$



Induction Array Tool - Invasion Corrections

R_t = 100 ohm·m $R_{xo} < R_t$



Dual Laterolog Borehole Corrections

Purpose

This chart may be used to correct the dual laterolog deep and shallow curves for the effect of borehole size.

Procedure

Choose the appropriate chart for the deep (LLD) or shallow (LLS) curve and whether the tool was centralized or decentralized with standoff. To estimate the correction for borehole size, calculate the ratio of the appropriate curve resistivity to the mud resistivity and enter the chart on the horizontal axis at this value.

Project vertically until the projection intersects the appropriate borehole diameter line. Interpolate between the borehole size lines if necessary. At the intersection point project horizontally to read the ratio of the true resistivity to the dual laterolog resistivity. Multiply the value of this ratio by the dual laterolog resistivity to determine the borehole size corrected resistivity.

Example

Given

LLD = 24 ohm·m
LLS = 22 ohm·m
R_m = 0.12 ohm·m
d_h = 10.0 inches
DLL tool was centralized

Find

Estimate the deep resistivity corrected for borehole size.

Answer

Determine the R_{LLD} to R_m ratio from the log parameters.

$$\frac{\mathrm{R_{LLD}}}{\mathrm{R_m}} = \frac{24}{0.12} = 200$$

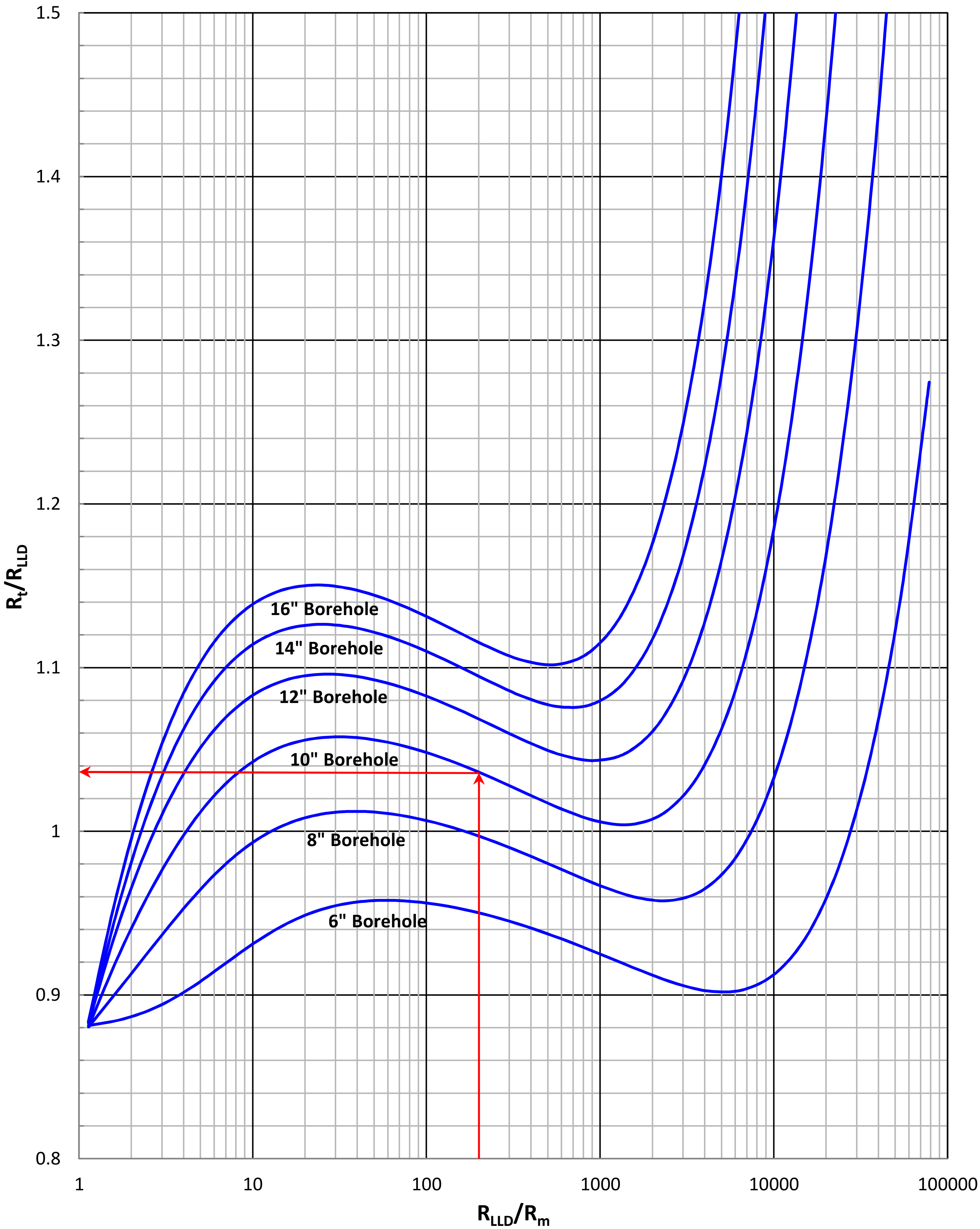
Using the chart for a centralized deep dual laterolog tool (DLL1) enter the horizontal axis at 200 and project vertically into the chart to the 10 inch borehole size line. Project the intersection point horizontally to the $\frac{\mathrm{R_t}}{\mathrm{R_{LLD}}}$ axis to read 1.037.

Multiply the LLD reading from the log by this correction factor to obtain the borehole corrected reading of

$$24\ \mathrm{ohm}\cdot\mathrm{m} \times 1.037 = 24.89\ \mathrm{ohm}\cdot\mathrm{m}$$

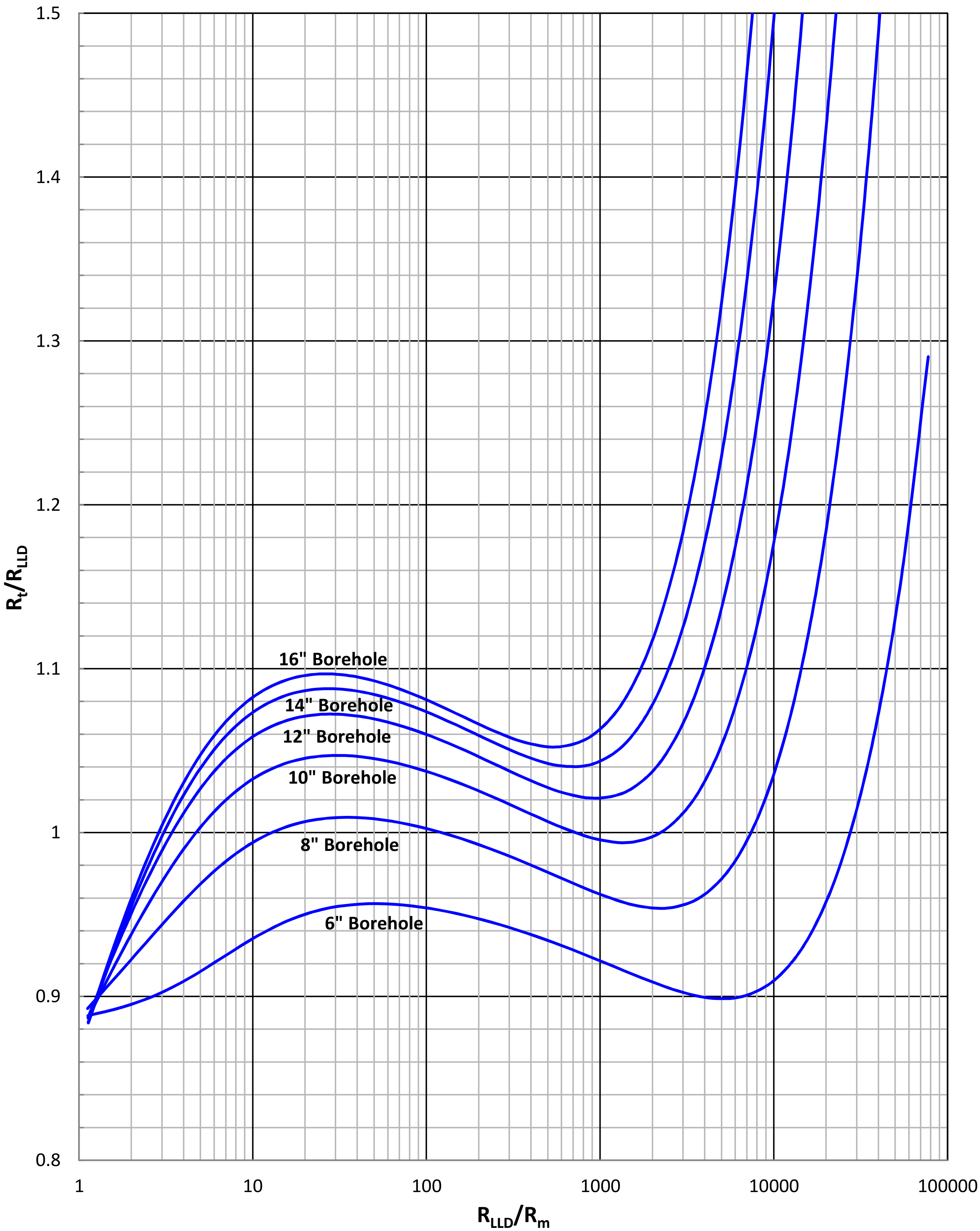
Dual Laterolog Borehole Corrections

LLD - Centralized



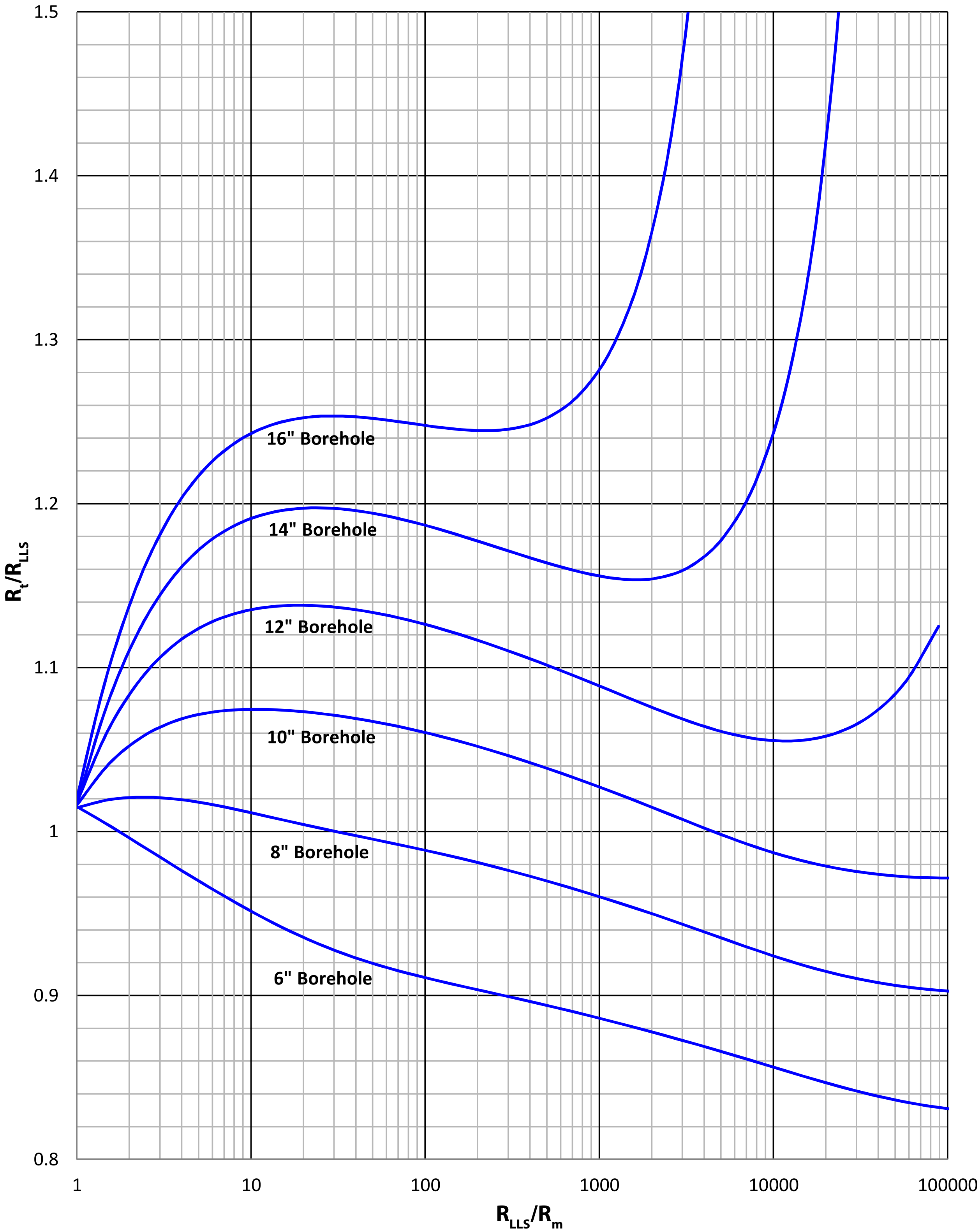
Dual Laterolog Borehole Corrections

LLD Eccentered at 1.5" Standoff



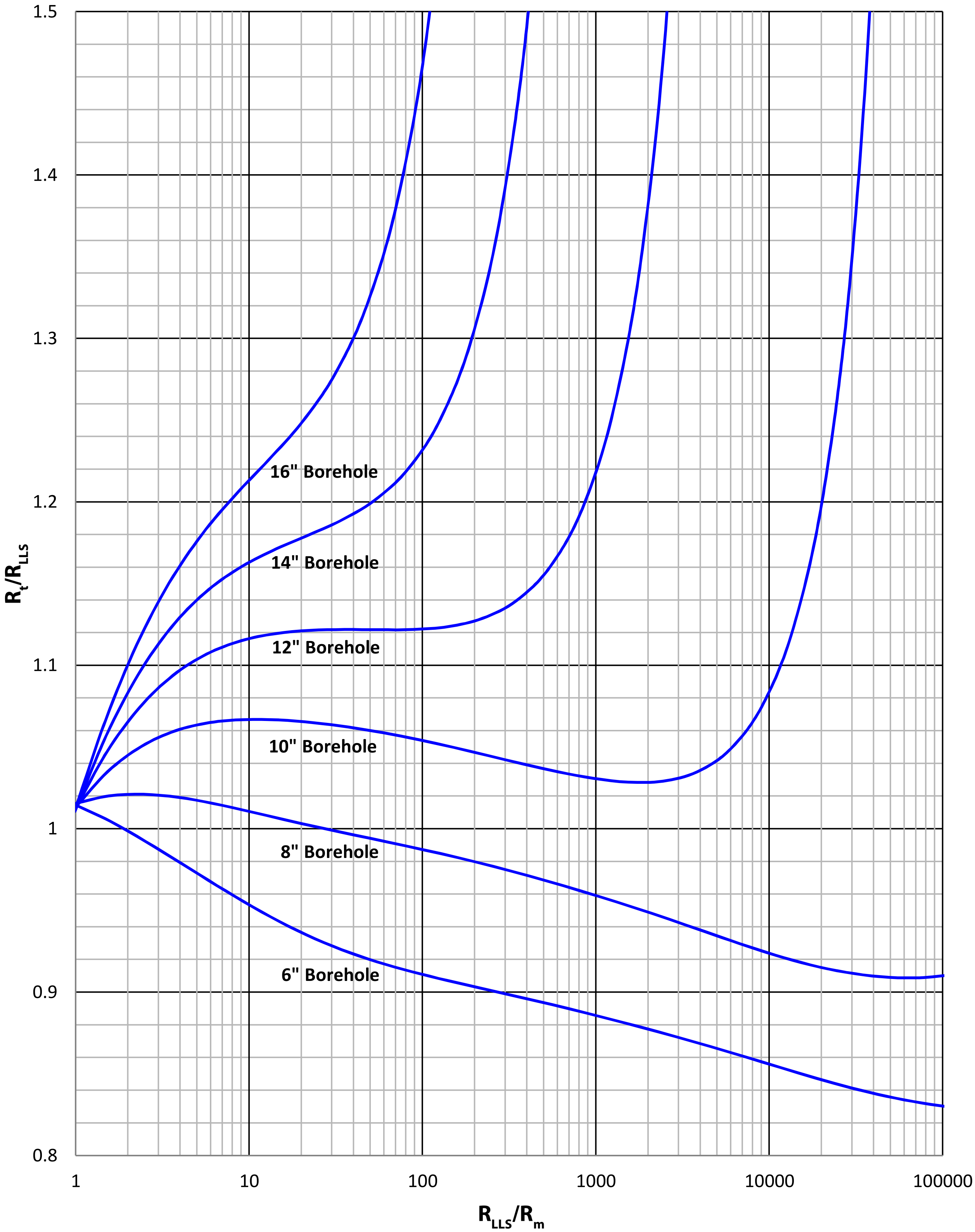
Dual Laterolog Borehole Corrections

LLS - Centralized

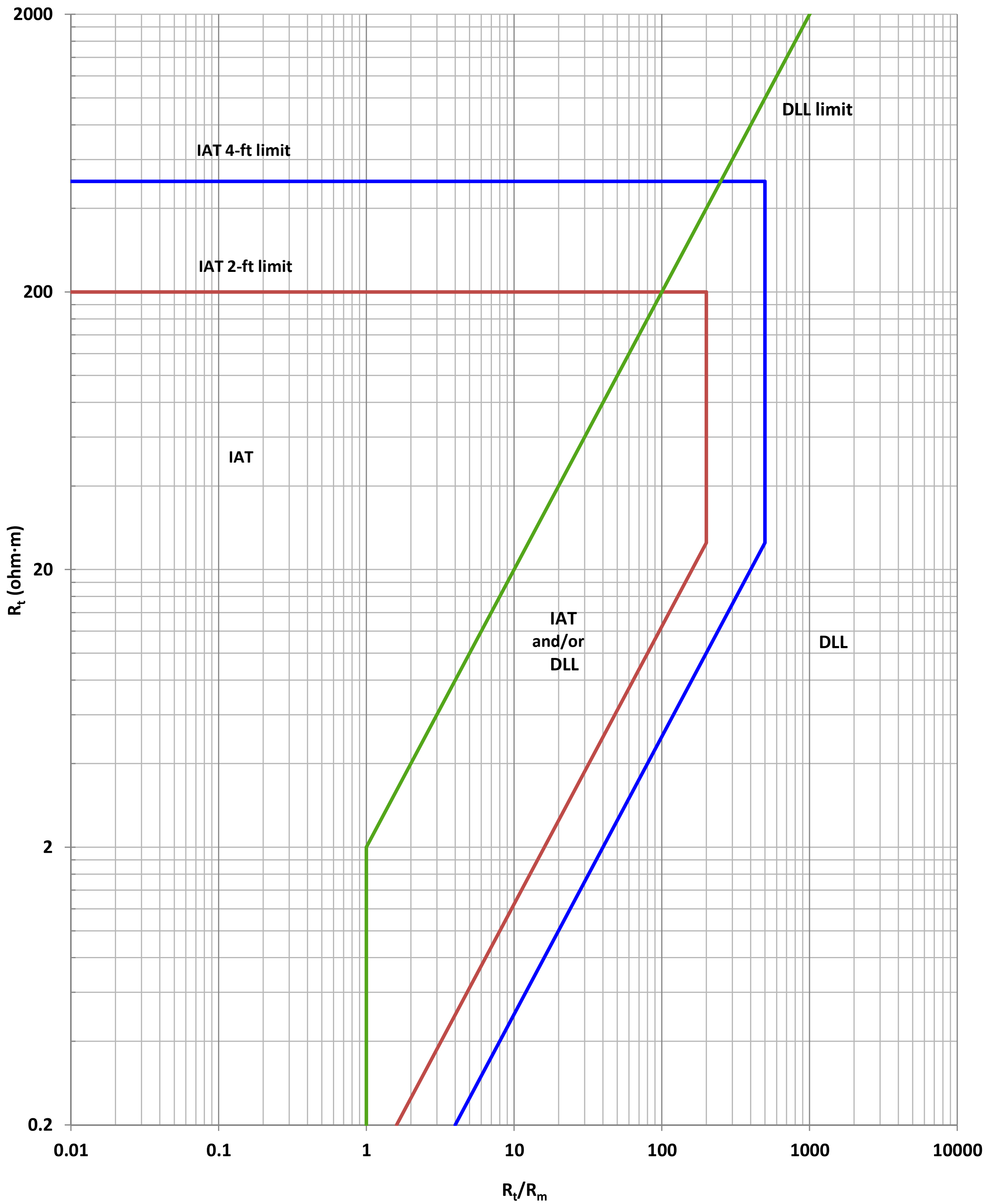


Dual Laterolog Borehole Corrections

LLS Eccentered at 1.5" Standoff



IAT verses DLL Selection



Micro-Spherically Focused Log Mudcake Thickness Corrections

Purpose

This chart may be used to correct the Micro-Spherically Focused Log (MSFL) curve for the effect of mudcake thickness on the measurement.

Procedure

Determine the ratio of the MSFL log reading (R_{MSFL}) to the resistivity of the mudcake (R_{mc}). Project vertically until the projection intersects the appropriate mudcake thickness line. Interpolate between the mudcake thickness lines if necessary. At the intersection point project horizontally to read the ratio of the corrected resistivity to the log reading resistivity. Multiply the value of this ratio by the MSFL reading from the log to determine the corrected resistivity.

Example

Given

R_{MSFL} = 20 ohm·m
R_{mc} = 0.8 ohm·m
Mudcake Thickness = ½ inch

Find

Estimate the MSFL reading corrected for mudcake.

Answer

Determine the R_{MSFL} to R_{mc} ratio from the log parameters.

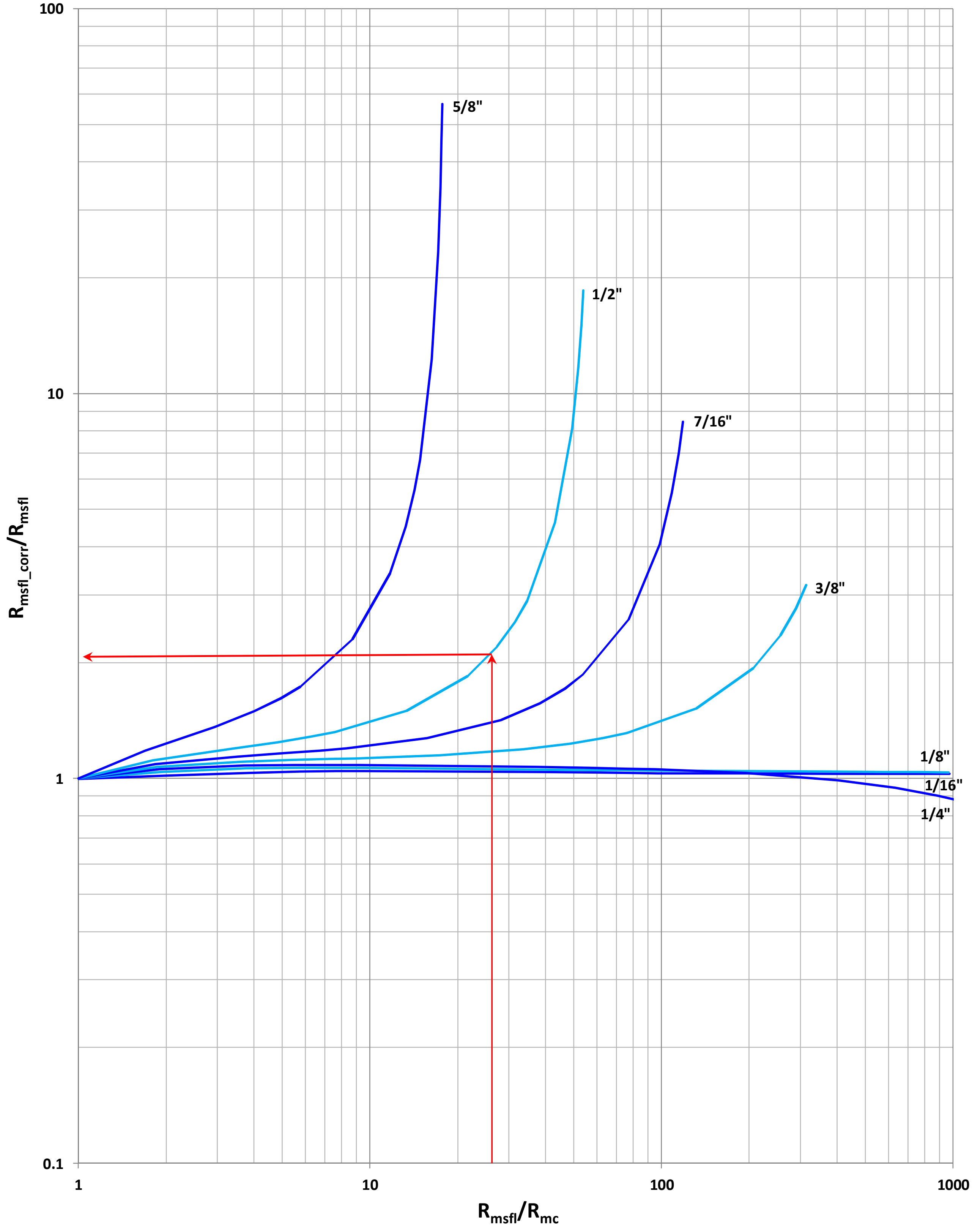
$$\frac{R_{MSFL}}{R_{mc}} = \frac{20}{0.8} = 25$$

Using the MSFL mudcake thickness correction chart enter the horizontal axis at 25 and project vertically into the chart to the 1/2 inch mudcake thickness line. Project the intersection point horizontally to the $\frac{R_{MSFL\_corr}}{R_{MSFL}}$ axis to read 2.05.

Multiply the MSFL reading from the log by this correction factor to obtain the mudcake thickness corrected reading of

$$20 \text{ ohm} \cdot \text{m} \times 2.05 = 41 \text{ ohm} \cdot \text{m}$$

MSFL Mudcake Thickness Correction



Spectral Gamma Ray Borehole Corrections

Purpose

These charts may be used to correct the Spectral Gamma Ray (SGR) outputs for the effect of mud weight and borehole diameter on the measurements.

Procedure

Use the gamma ray component (K, U, Th) chart for either a decentered or centralized tool. Using the borehole size on the horizontal axis, project vertically until the projection intersects the appropriate line for the mud weight in the borehole. Interpolate between the mud weight lines as necessary. At the intersection point, project horizontally to read the ratio of the corrected gamma ray component (K,U or Th) to the gamma ray component reading from the log. Multiply the value of this ratio by the SGR component reading from the log to determine the corrected component reading.

Example

Given

d_h = 12 ¼ inches
Mud Weight = 10 lb/gal
K_{log} = 3 %
Eccentered Tool

Find

Estimate the corrected Potassium (K) reading corrected for mudweight and borehole size.

Answer

Use chart **GR 1** for an eccentered Potassium component from the SGR.

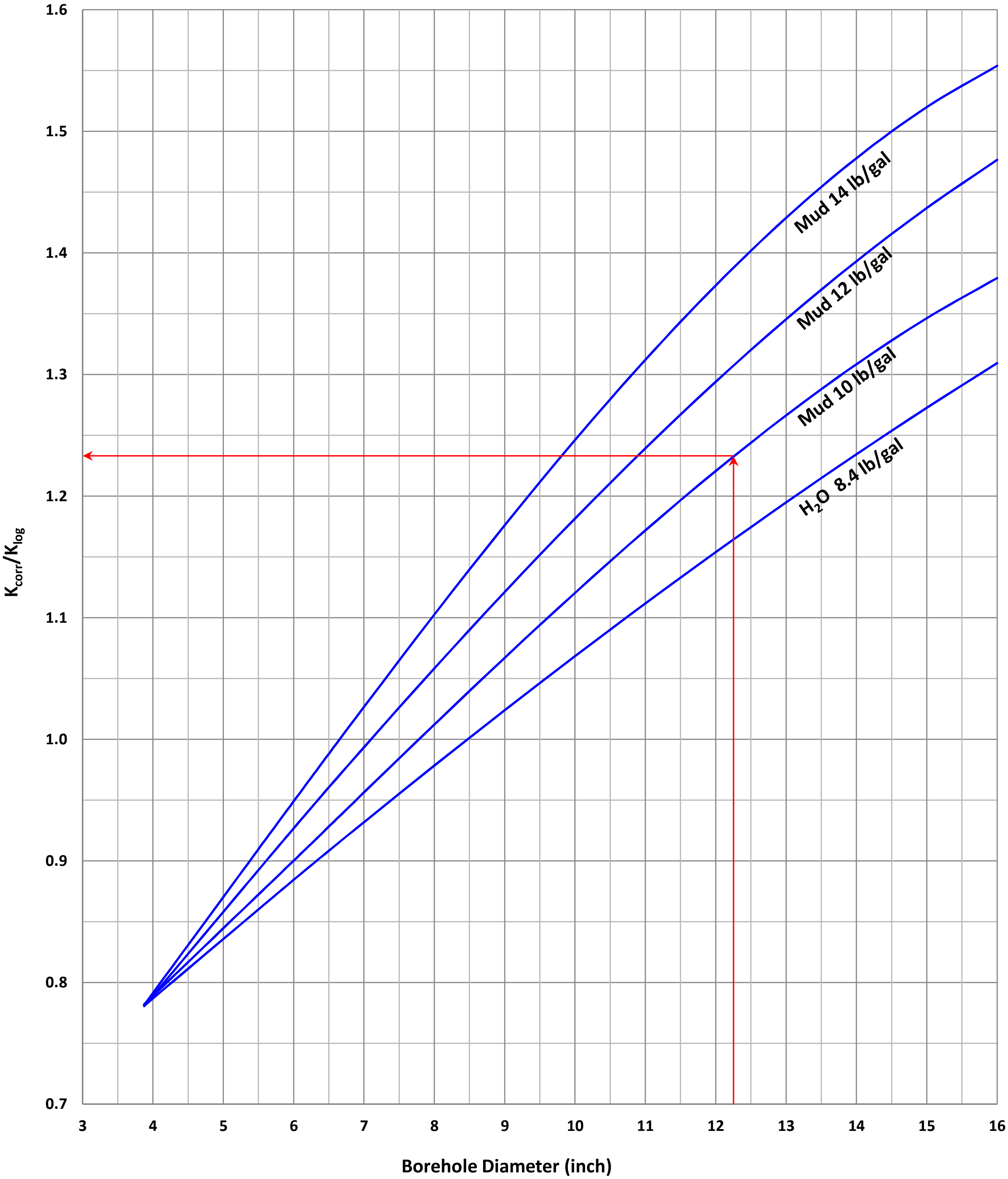
Enter the horizontal axis at 8.75 inches and project vertically into the chart to the 10 lb/gal mud weight line. Project the intersection point horizontally to the $\frac{K_{corr}}{K_{log}}$ axis to read 1.235.

Multiply the potassium (K) reading from the log by this correction factor to obtain the corrected potassium reading of 3.7 %.

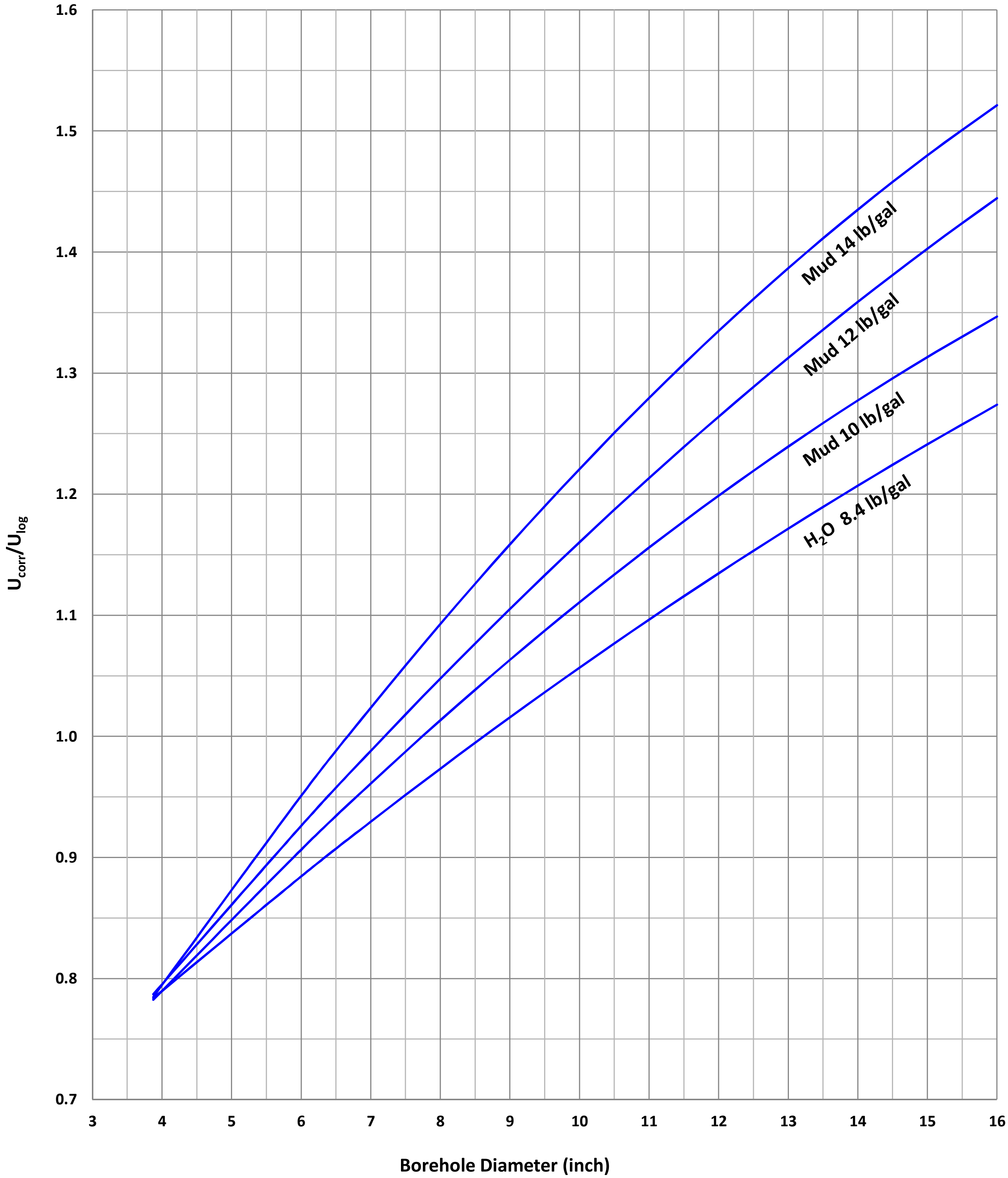
$$K_{corr} = 3\ \% \times 1.235 = 3.705\ \%$$

Spectral Gamma Ray Borehole Correction for Potassium

Eccentered Tool

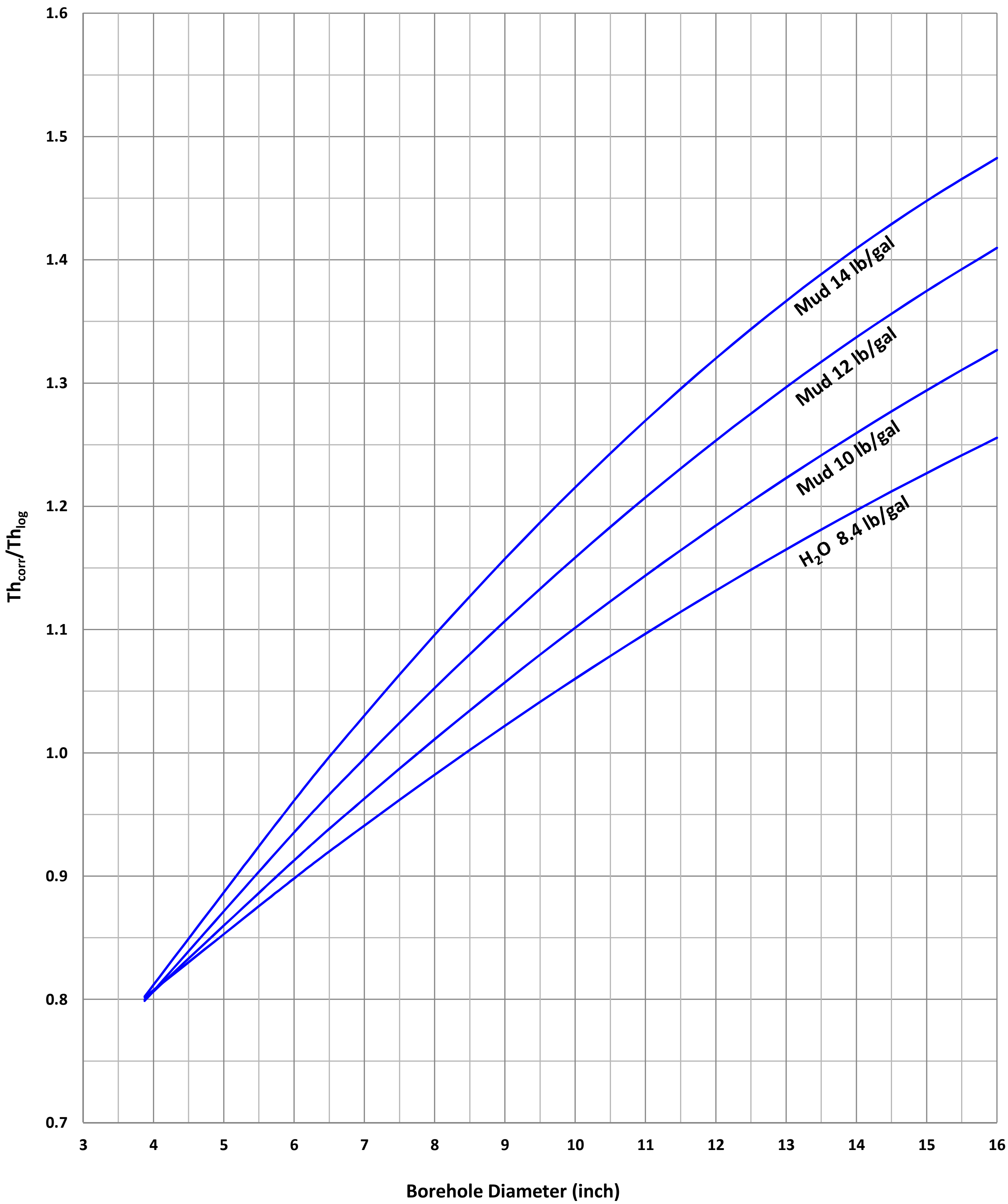


Spectral Gamma Ray Borehole Correction for Uranium
Eccentered Tool

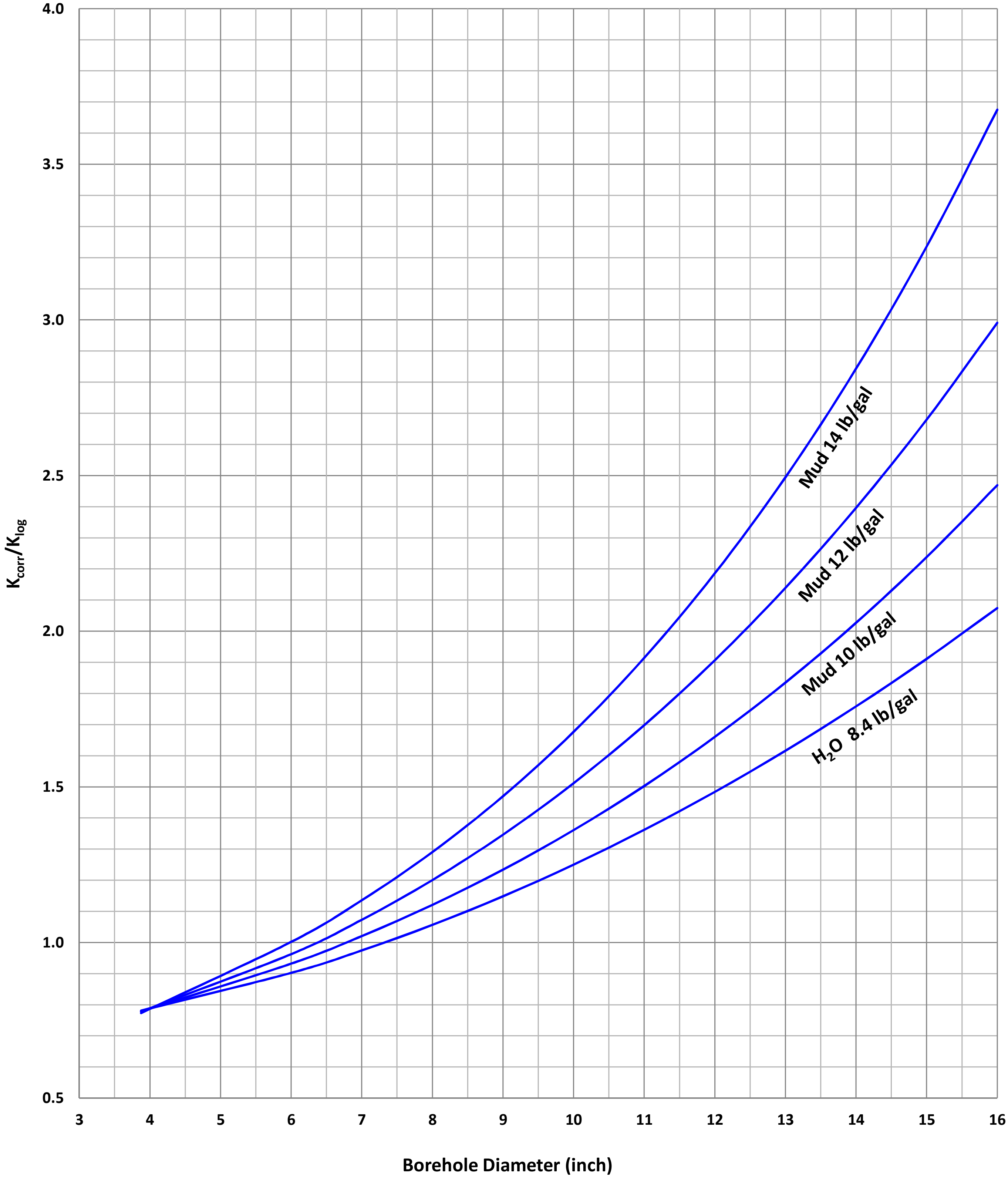


Spectral Gamma Ray Borehole Correction for Thorium

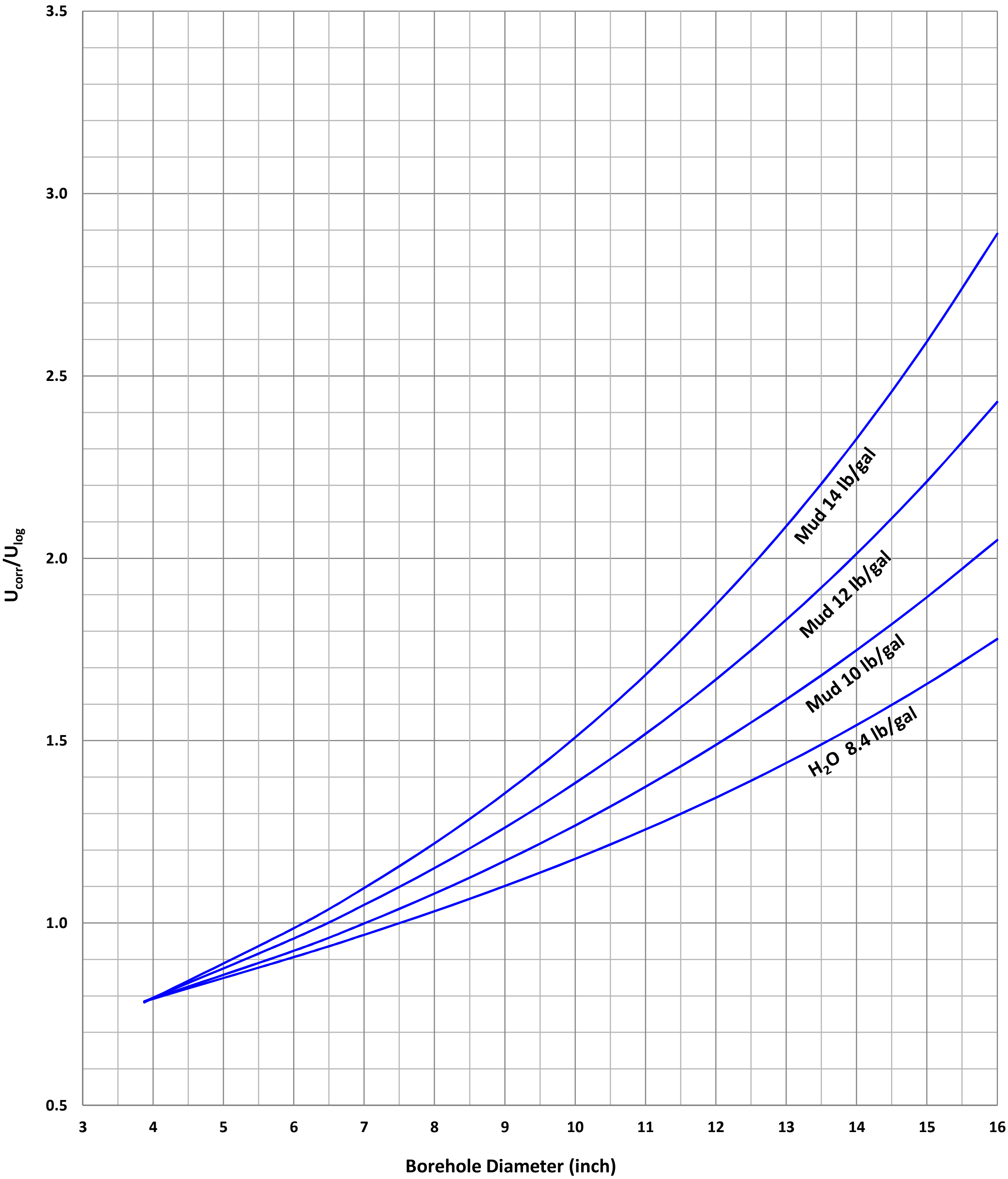
Eccentered Tool



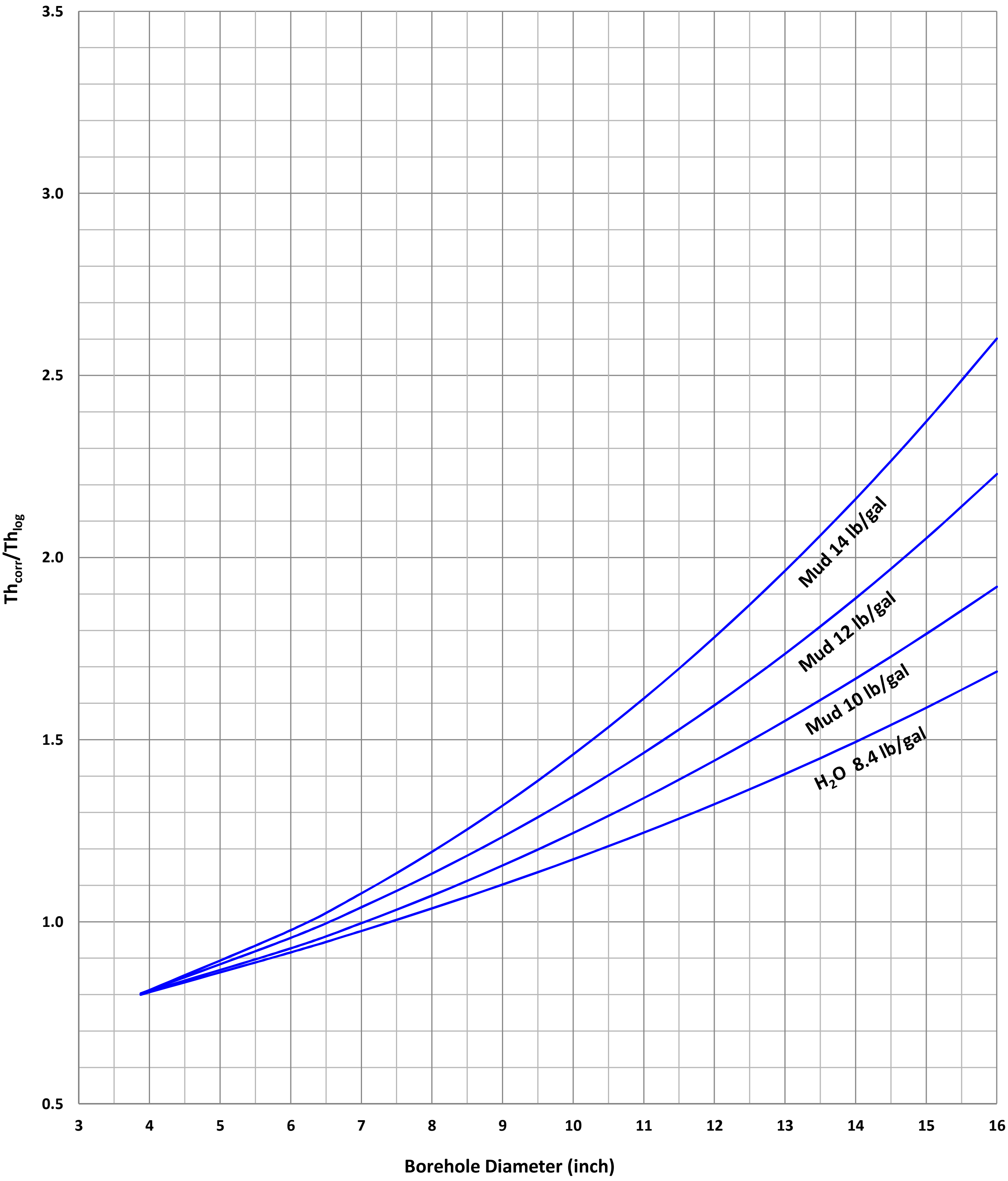
Spectral Gamma Ray Borehole Correction for Potassium
Centered Tool



Spectral Gamma Ray Borehole Correction for Uranium Centered Tool



Spectral Gamma Ray Borehole Correction for Thorium
Centered Tool



Compensated Neutron Log (CNL)

Purpose

The Compensated Neutron Log (CNL) response is affected by environmental parameters. These parameters are related to the tool string configuration, the borehole environment and the formation. The CNL tool records the raw short space and long space detector counts from which the ratio of these detector counts is used to calculate the apparent neutron porosity of the formation. Environmental correction factors are then applied to this uncorrected porosity to produce accurate corrected neutron porosity.

In the Warrior logging software the curve **NPHI** is the uncorrected neutron porosity. The curve **NPHC** is neutron porosity that is corrected for borehole size only.

The Warrior software also produces fully corrected curves for each of the three common formation matrices. The logging parameters/variables that are input into the Warrior software are the inputs to the corrections that are applied while logging. These corrected curves are:

NPHL	Neutron Porosity Limestone matrix
NPHS	Neutron Porosity Sandstone matrix
NPHD	Neutron Porosity Dolomite matrix

Using the correction charts the environmental corrections can be applied manually to the uncorrected porosity. The corrections can also be backed out of the corrected CNL porosity value using the same correction charts.

The correction charts are specific to the logging environment and the type of neutron source used for logging. Charts are available for both Americium-241/Beryllium and Californium-252 neutron sources as well as for Open Hole and Cased Hole wells.

Procedure

The neutron corrections are referenced to the standard conditions indicated by the solid red line on each chart. The standard conditions for Open Hole are:

Formation	Formation Fluid	Well Fluid	Temperature	Hole Diameter	Tool Position
Limestone	Pure Water	Pure Water	20 °C	8.0"	Eccentralized Source to Wall

The standard conditions for Cased Hole are:

Formation	Formation Fluid	Well Fluid	Temperature	Casing OD	Casing Thickness	Hole Diameter	Cement Thickness	Tool Position
Limestone	Pure Water	Pure Water	20 °C	5.5"	0.3"	7.875"	1.1875"	Eccentralized Source to Wall

To use the charts, select the correct chart for the parameter to correct. On each chart the neutron porosity is on the horizontal axis and the environmental parameter is on the vertical axis. At the top of the chart locate the uncorrected porosity reading and project a line vertically downward through the correction nomograph. Enter the environmental parameter on the vertical axis and project a line horizontally. At the intersection of the horizontal and vertical projected lines follow the general trend of the nomograph lines (blue line) back to the standard condition (red line). If the corrected value falls between the blue lines, interpolate a line at that point and follow the general trend. The porosity reading where the trend line intersects the standard condition is the corrected porosity for this environmental effect.

The corrections should be performed in a specific order:

Open Hole

1. Perform the borehole diameter correction and obtain the corrected porosity
2. Use the porosity from step 1 to enter each of the following charts and determine the change in porosity. This sum of the porosity changes is added to the porosity from 1.
    a. Standoff
    b. Borehole Fluid Density (charts included for barite weighted mud)
    c. Temperature
    d. Relative Water Density
    e. Mud Cake Thickness
    f. Borehole Fluid Salinity
3. Correct the porosity from step 2 for lithology
4. Correct the porosity from step 3 for formation salinity using the chart specific to that matrix

Cased Hole

1. Perform the correction for the Open Hole to Cased Hole correction.
2. Using the porosity from step 1 correct for casing diameter for centralized or eccentralized tool
3. Use the porosity from step 2 to enter each of the following charts and determine the change in porosity. The sum of the porosity changes is added to the porosity from step 2.
    a. Temperature
    b. Tool Position
    c. Casing Thickness
    d. Cement Thickness

   e. Borehole Water Relative Density
   f. Borehole Fluid Salinity
   g. Formation Fluid Salinity
4. Correct the porosity from step 3 for lithology depending on eccentralized or centralized tool.

Example

Given

Open hole well
Californium-252 neutron source
Uncorrected neutron porosity = 31.5%
8.5 inch borehole
100,000 ppm borehole salinity
100,000 ppm formation salinity
100 °C borehole temperature
¼" standoff between tool and borehole wall
Mud density of 1.17 g/cm^3
Mud cake thickness of 0.25 inches

Find

Determine the corrected neutron porosity in both limestone matrix and sandstone matrix from the parameters given.

Answer

Using chart CNL 1 enter the vertical axis on the Borehole Diameter Correction chart at 8.5 inches. Project the line horizontally until it intersects the 31.5 % porosity line. Interpolate between the blue curves on either side of the intersection and follow the general trend back to the red baseline at 31% porosity.

Using the porosity obtained in the step above (31%), enter each of the following charts and record the change in porosity. Sum the individual porosity changes.

a) Temperature Correction Chart (CNL 2)	+2.2 %
b) Stand Off Correction Chart – Eccentralized (CNL 3)	-0.4 %
c) Borehole Water Relative Density Correction (CNL 5)	0 %
d) Borehole Fluid Salinity Correction – Eccentralized (CNL 9)	-0.2 %
e) Mud Density Correction (CNL 13) – Eccentralized (CNL 13)	+0.3 %
f) Mud Cake Thickness Correction – Eccentralized (CNL 17)	+0.2 %
Sum of Corrections =	+2.1 %

Add the sum of the porosities to the Borehole diameter corrected porosity to obtain a porosity to enter into the next charts.

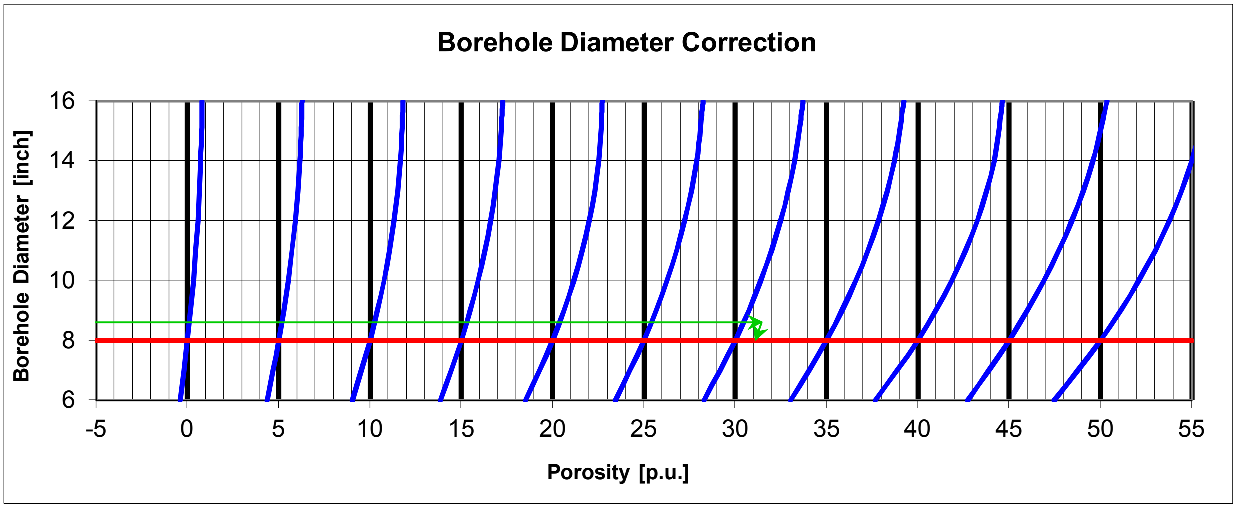
31 % + 2.1 % = 33.1 %

Using the corrected porosity of 33.1 % enter the Lithology Correction chart on CNL 19. For the Limestone matrix, follow the blue line straight down to obtain a porosity of 33.1 %. For the Sandstone matrix, follow the yellow line to obtain a matrix corrected porosity of 38 %.

Using the lithology matrix corrected porosities enter the Formation Fluid Salinity correction chart for the appropriate matrix on page CNL 20.
The corrected neutron porosity on a limestone matrix would be 29.2 % and on a sandstone matrix it would be 33.7 %.

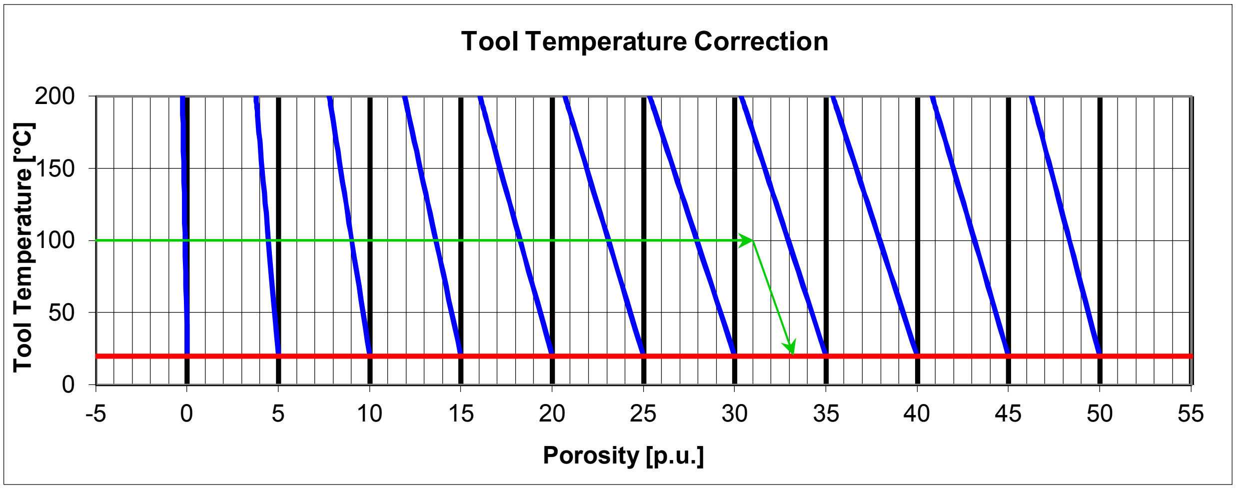
U-FLT CNL009 – Californium 252

Open Hole Borehole Diameter Correction



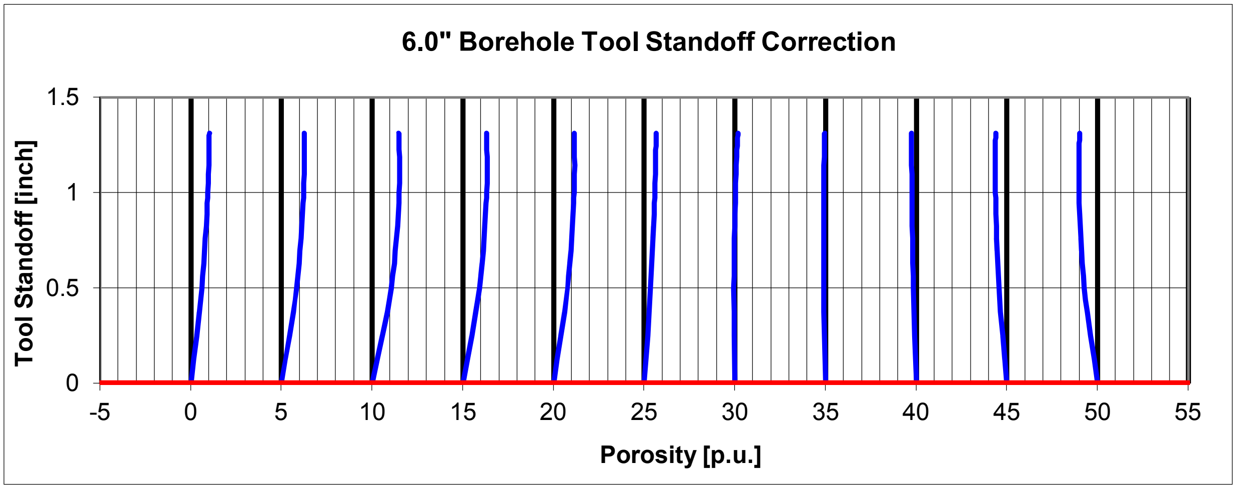
U-FLT CNL009 – Californium 252

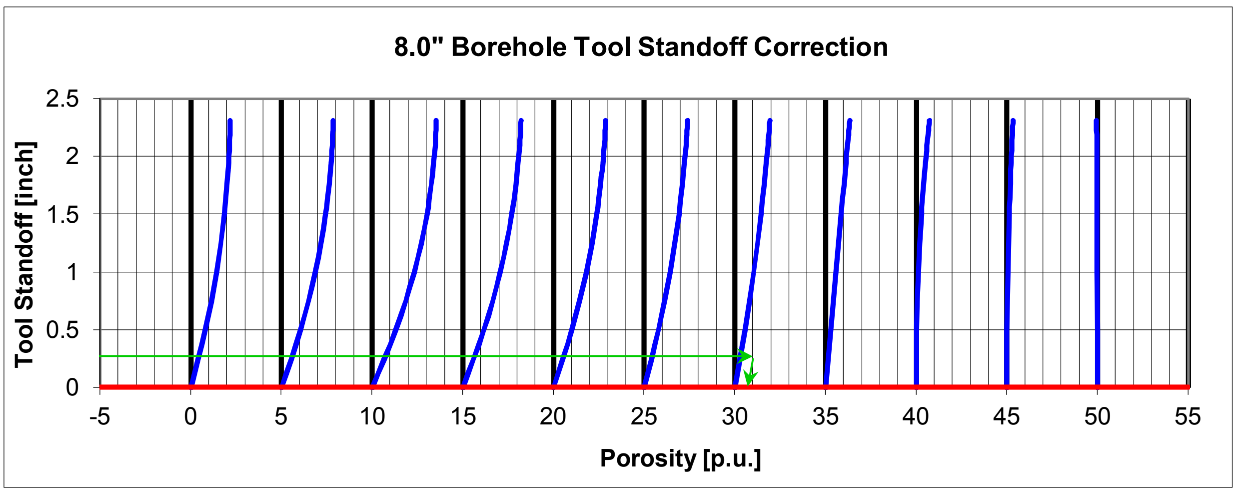
Open Hole Temperature Correction

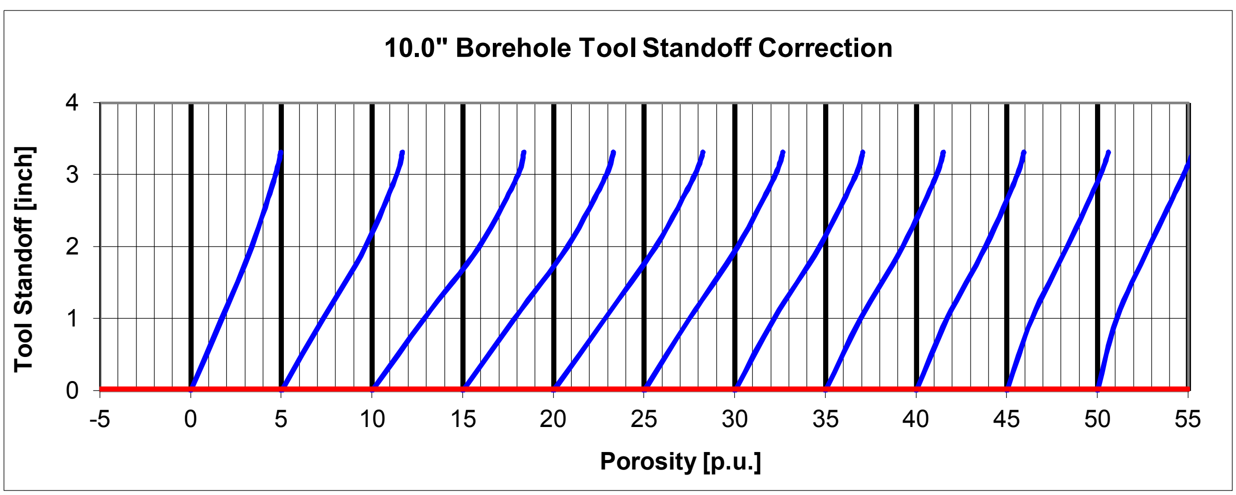


U-FLT CNL009 – Californium 252

Open Hole Standoff Corrections

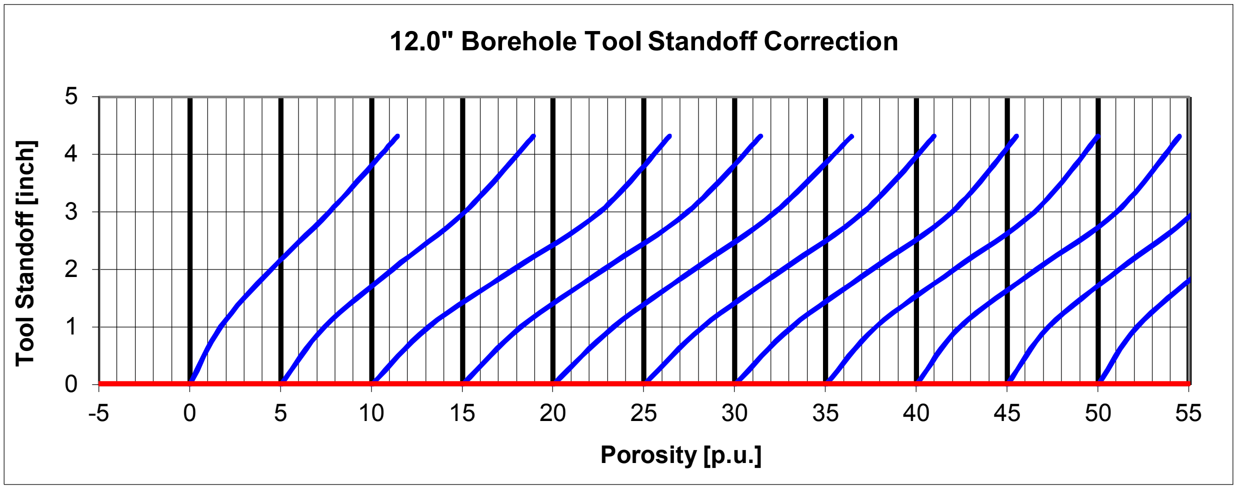


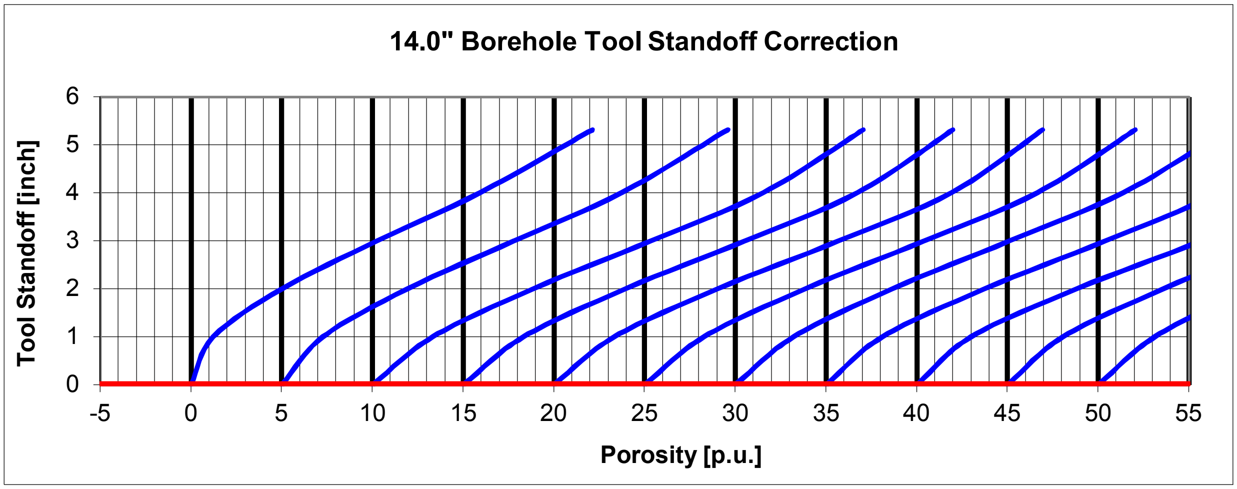


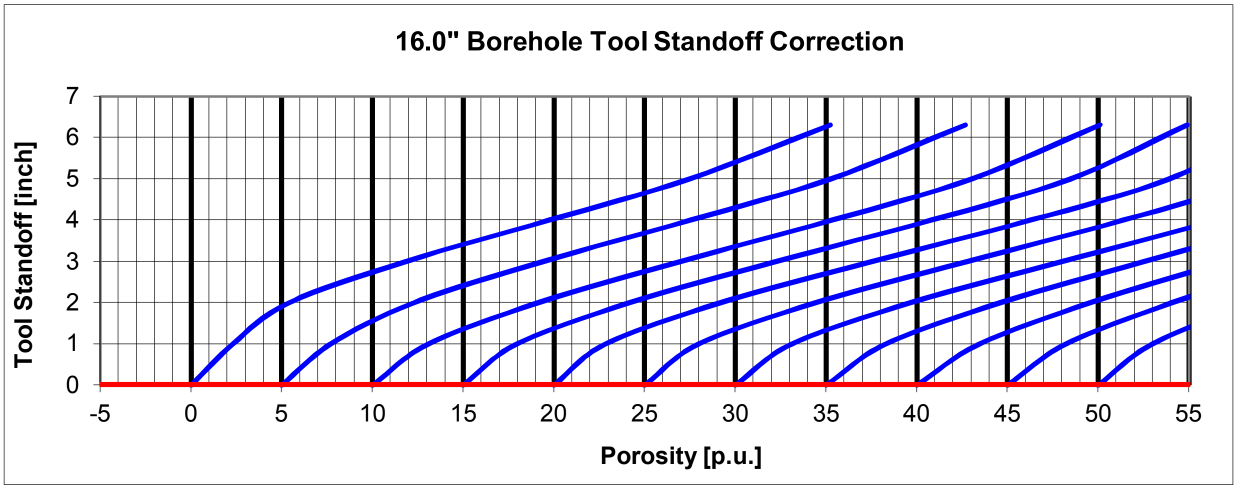


U-FLT CNL009 – Californium 252

Open Hole Standoff Corrections

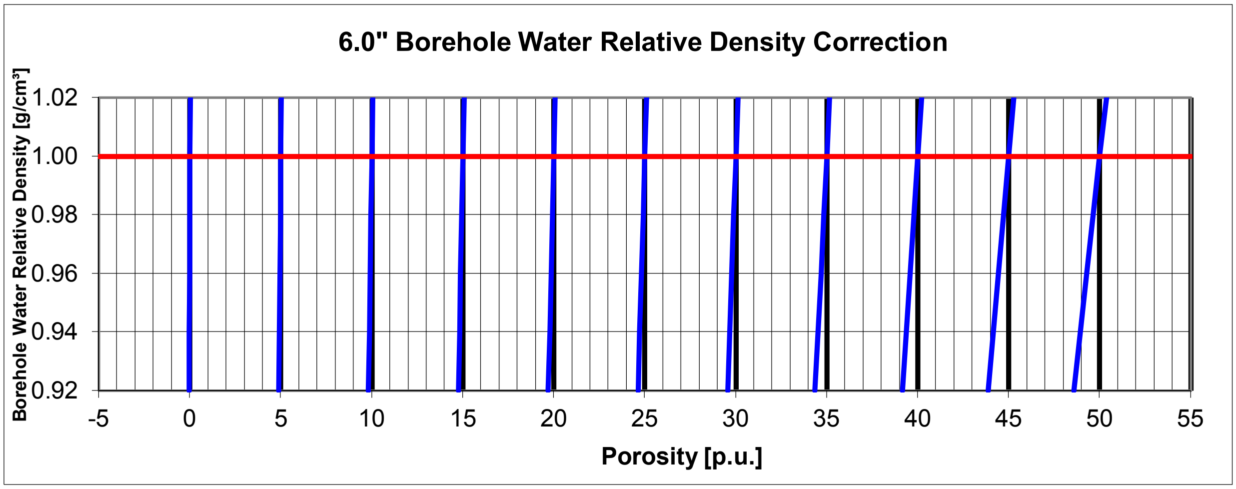


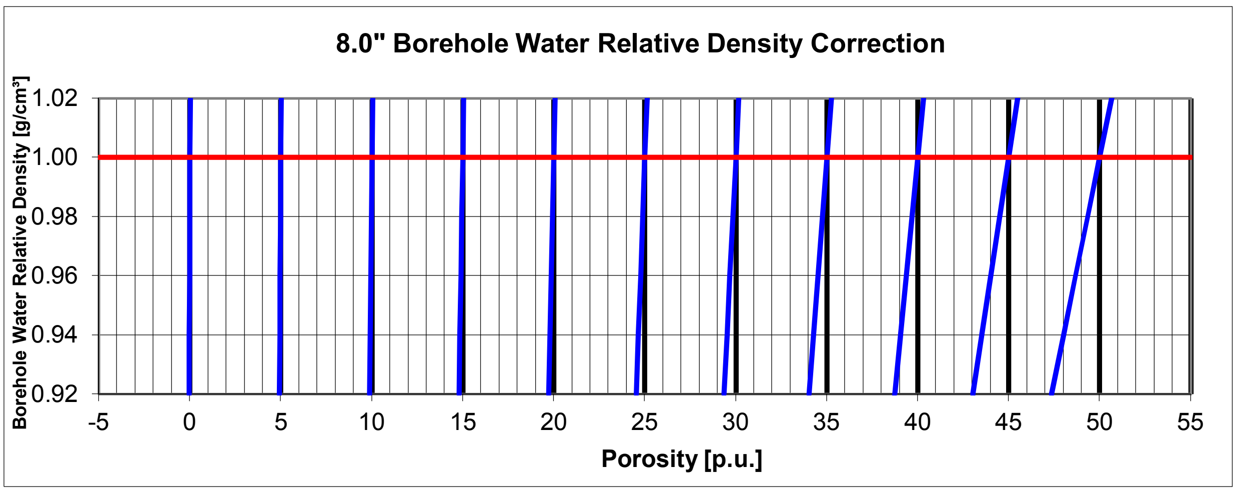


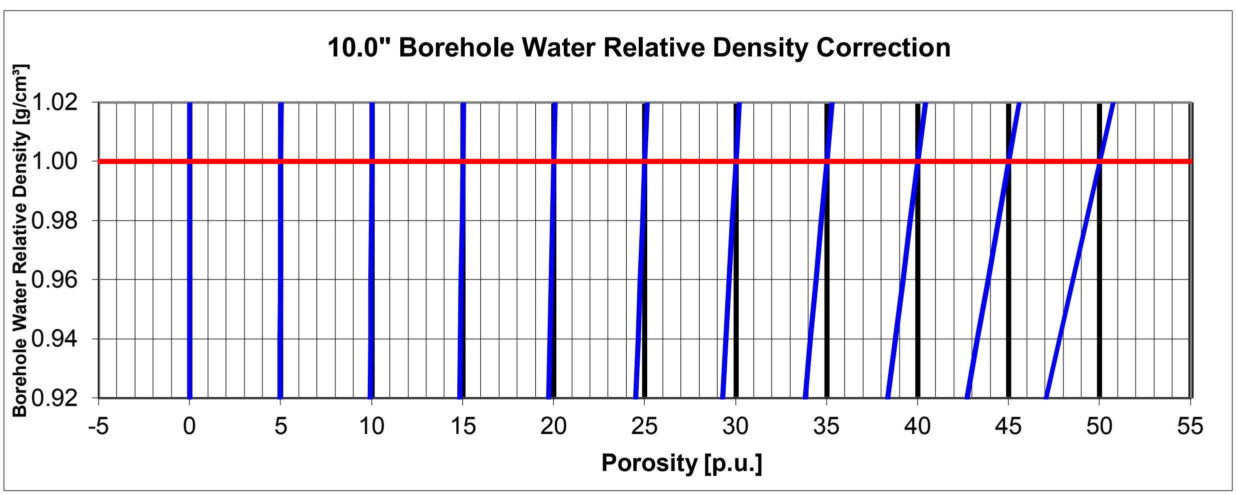


U-FLT CNL009 – Californium 252

Open Hole Borehole Water Relative Density Corrections – Eccentralized Tool

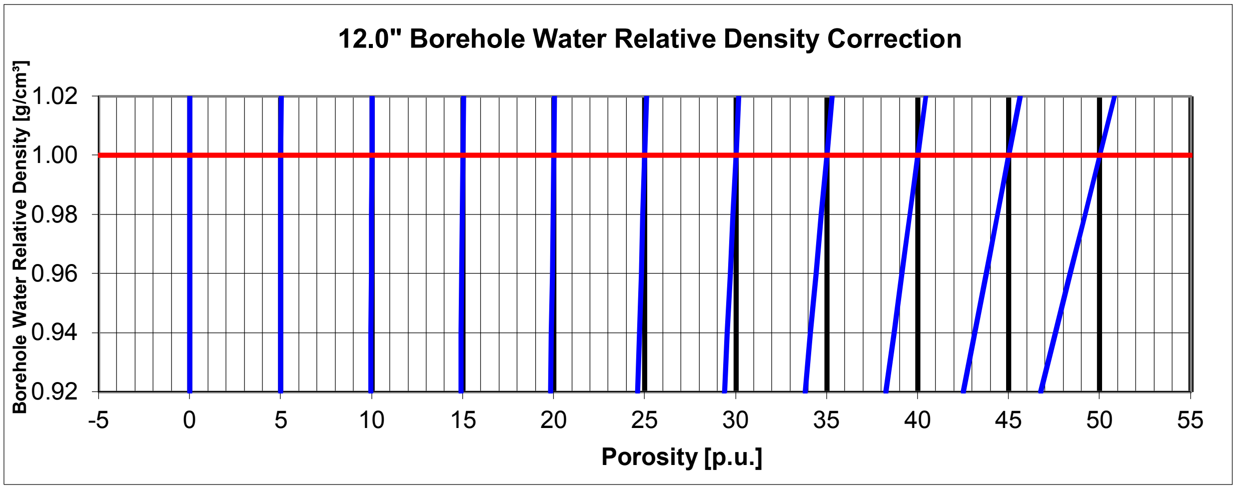


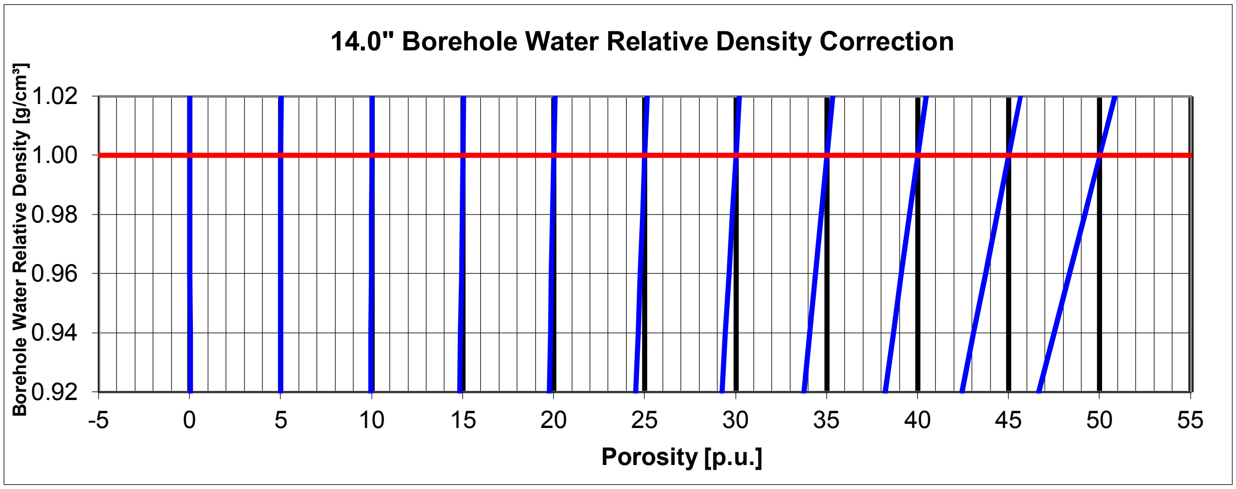


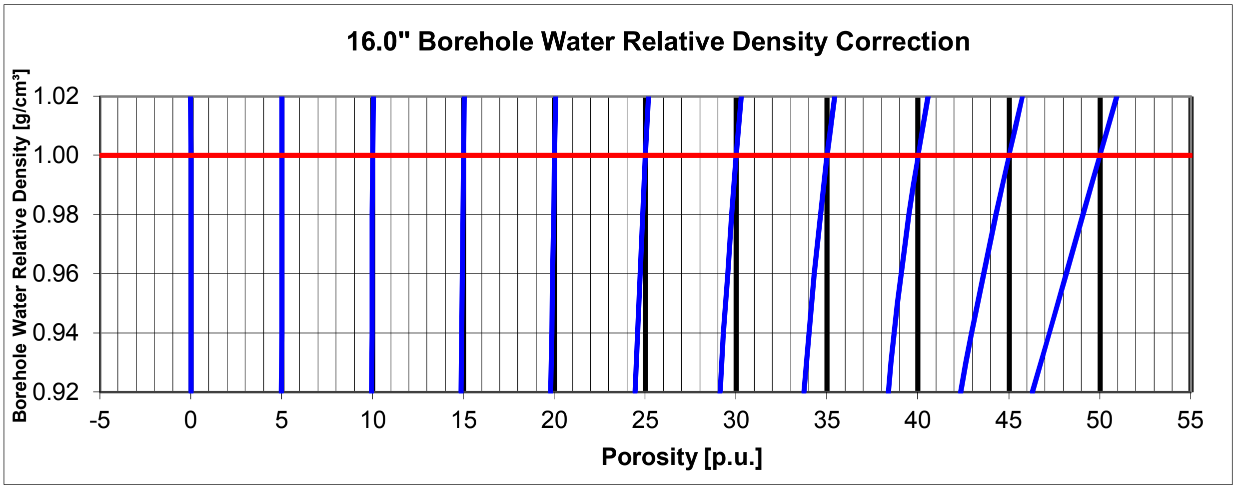


U-FLT CNL009 – Californium 252

Open Hole Borehole Water Relative Density Corrections – Eccentralized Tool

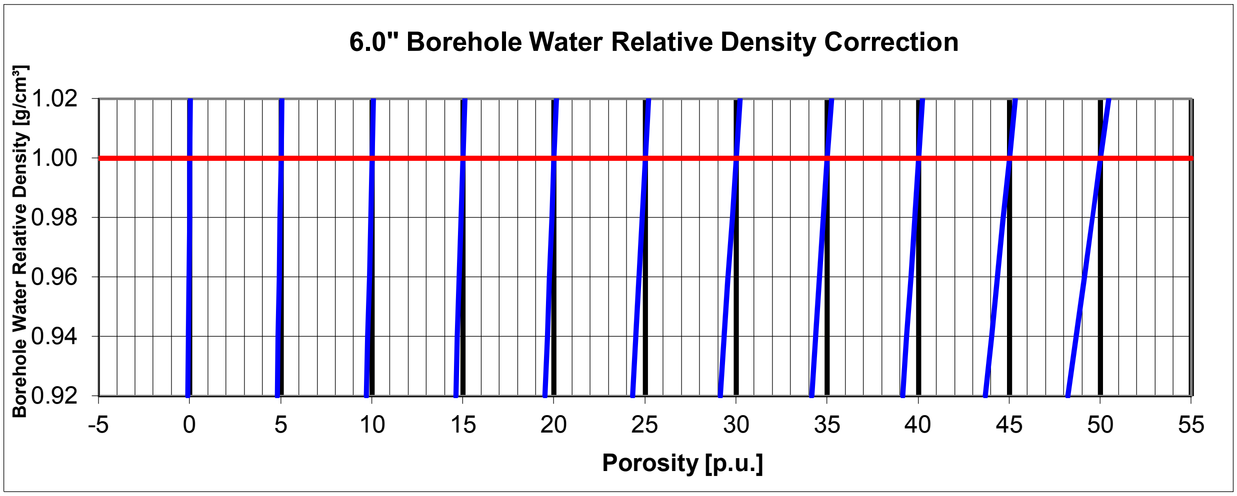


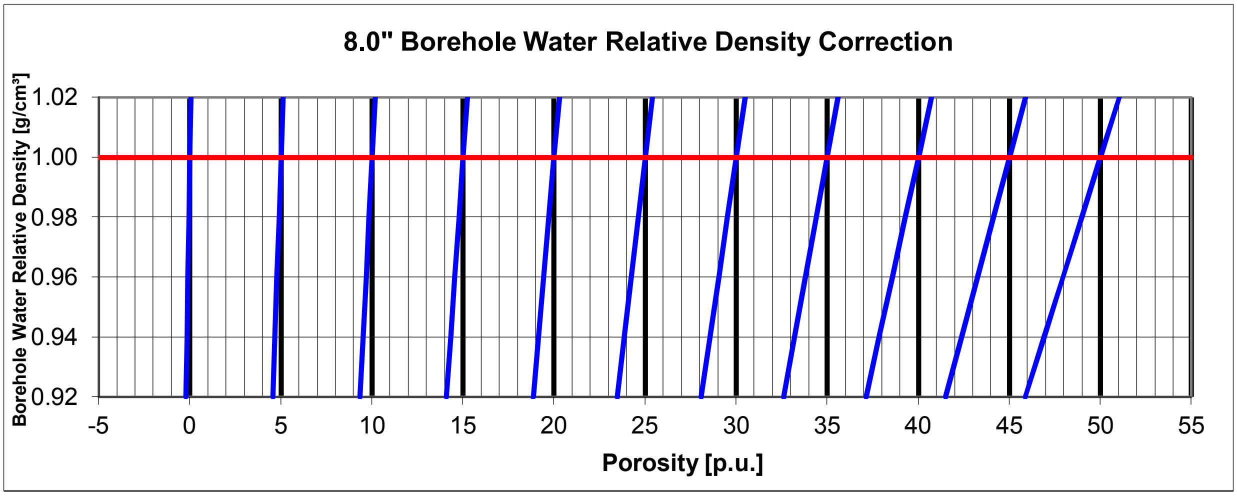


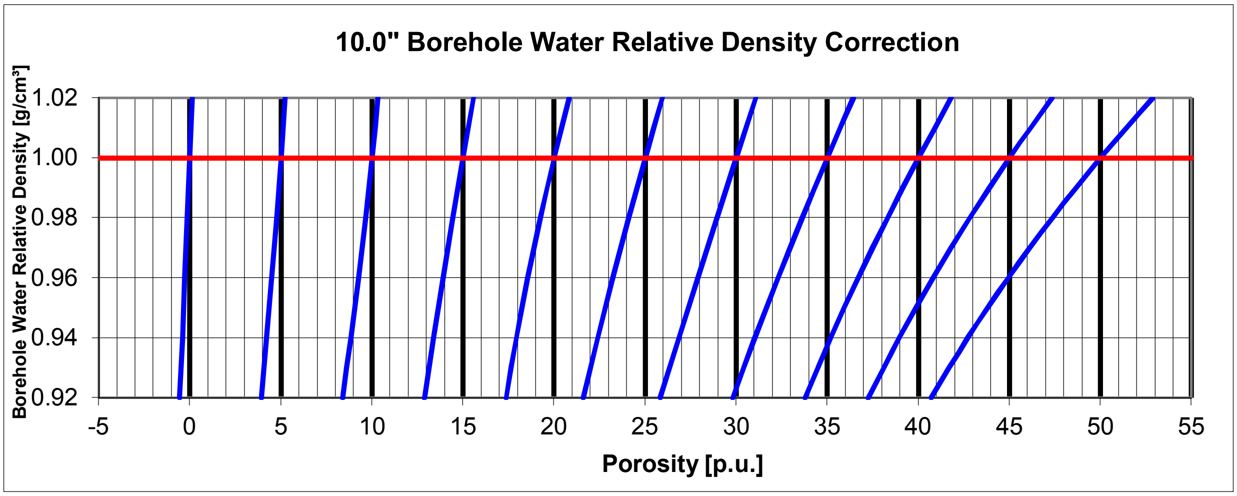


U-FLT CNL009 – Californium 252

Open Hole Borehole Water Relative Density Corrections –Centralized Tool

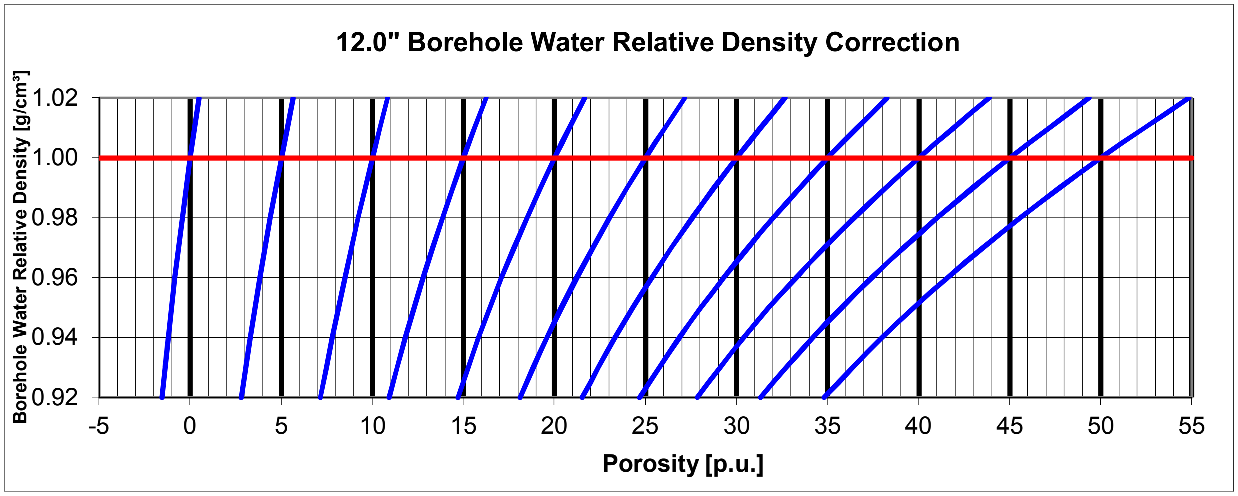


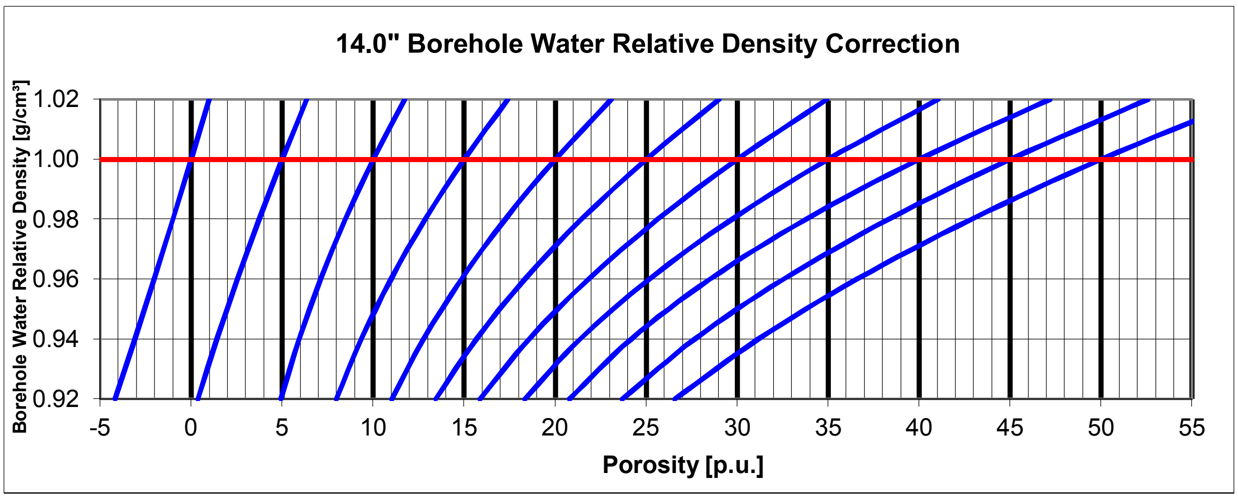


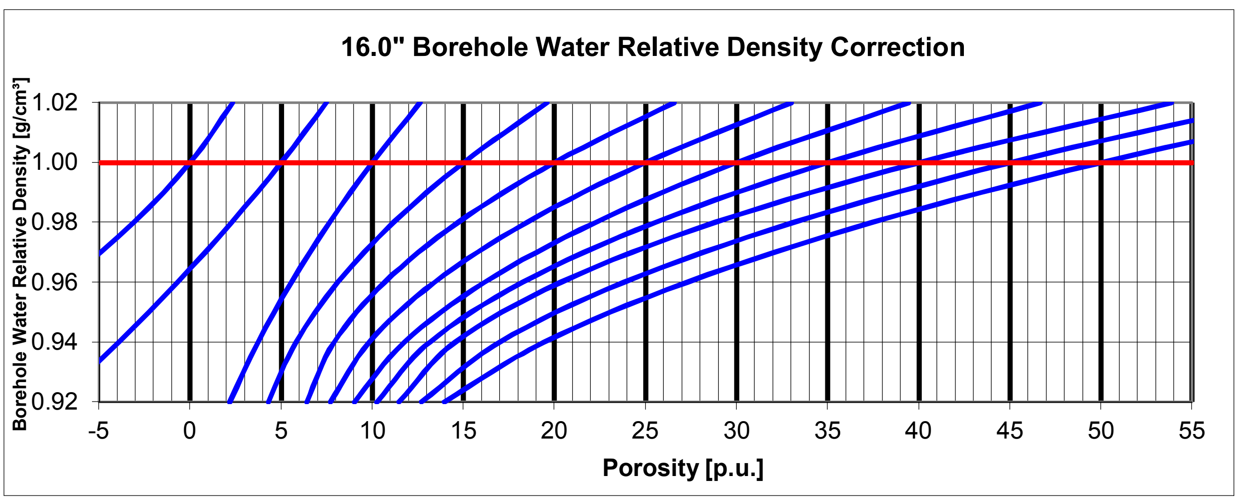


U-FLT CNL009 – Californium 252

Open Hole Borehole Water Relative Density Corrections –Centralized Tool

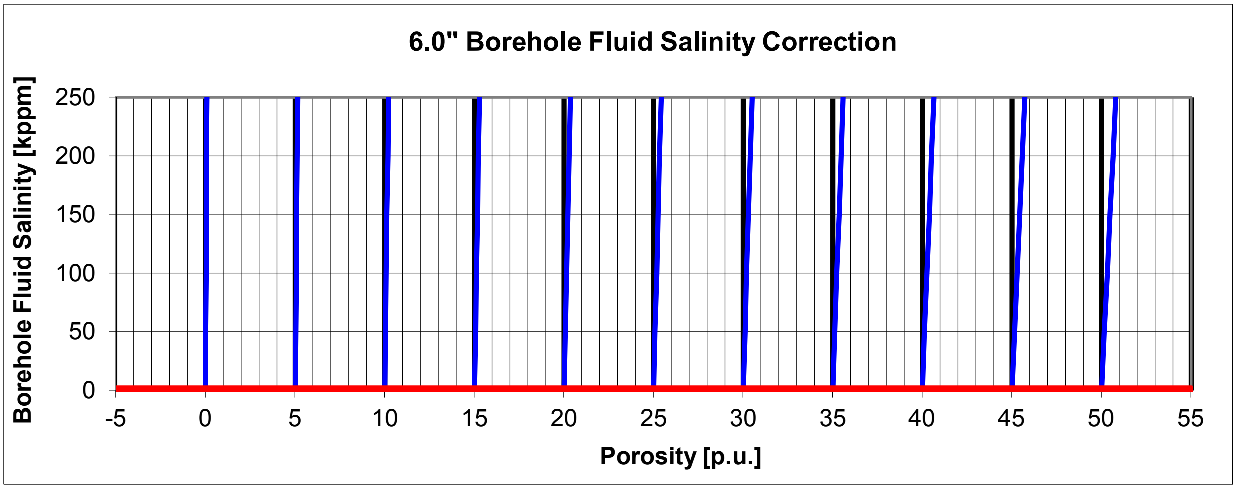


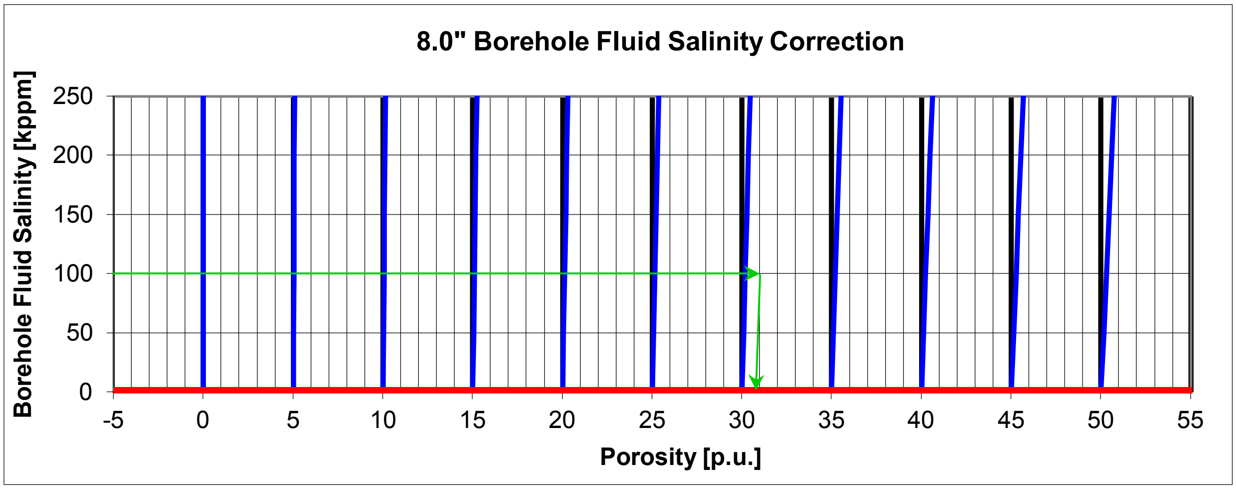


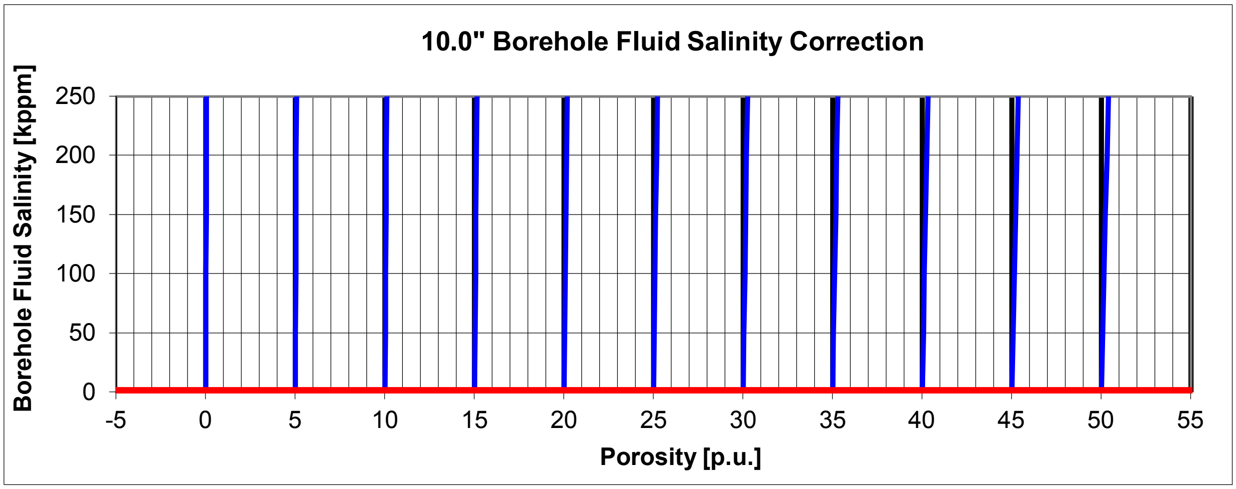


U-FLT CNL009 – Californium 252

Open Hole Borehole Fluid Salinity Corrections – Eccentralized Tool

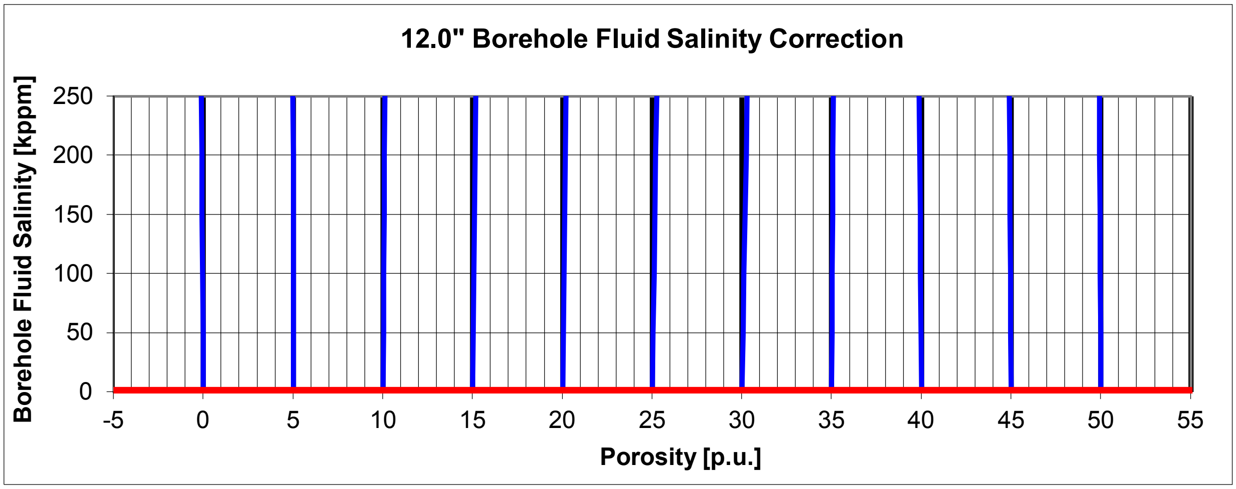


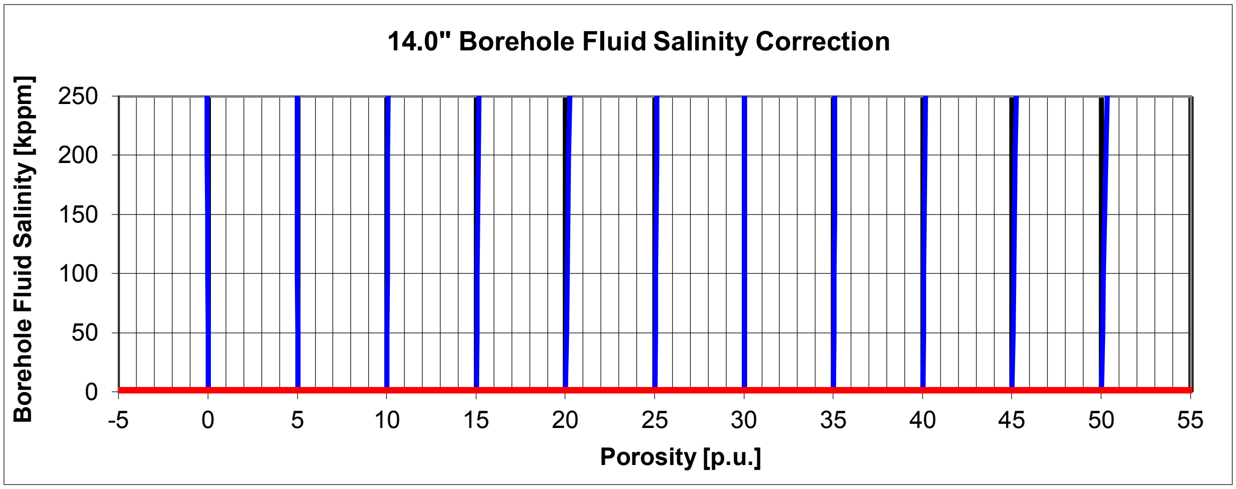


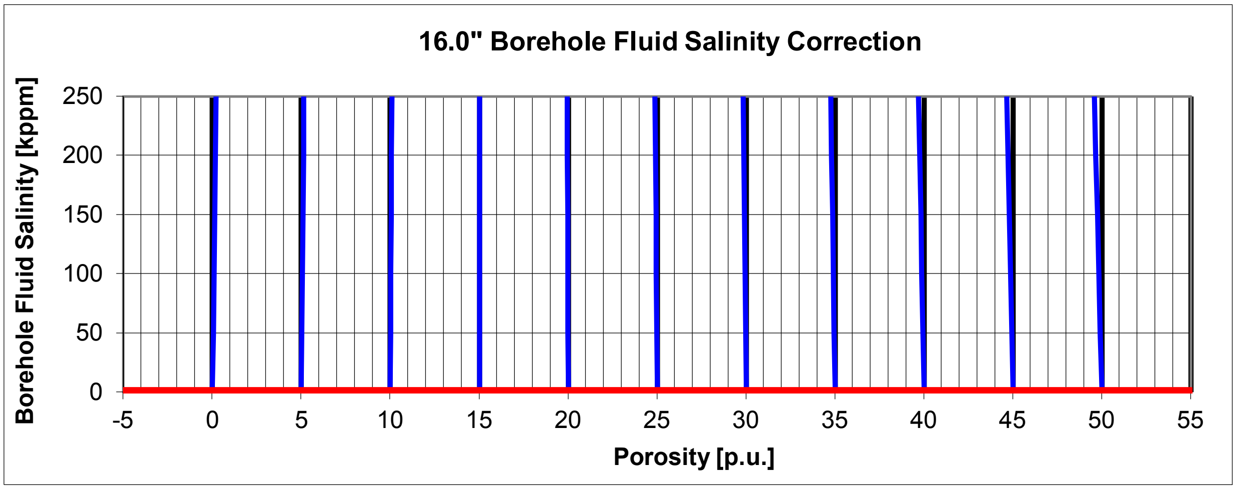


U-FLT CNL009 – Californium 252

Open Hole Borehole Fluid Salinity Corrections – Eccentralized Tool

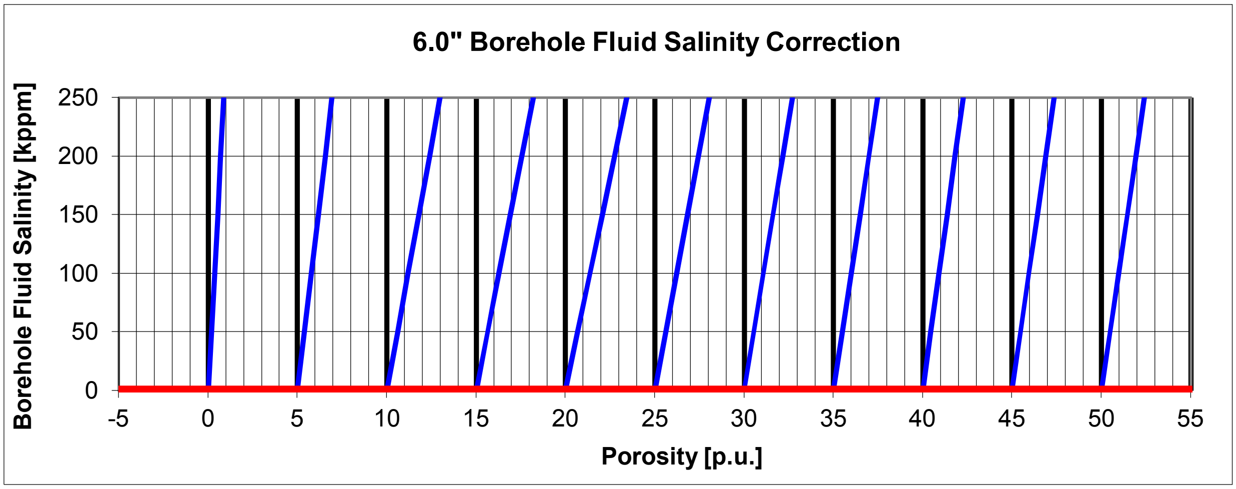


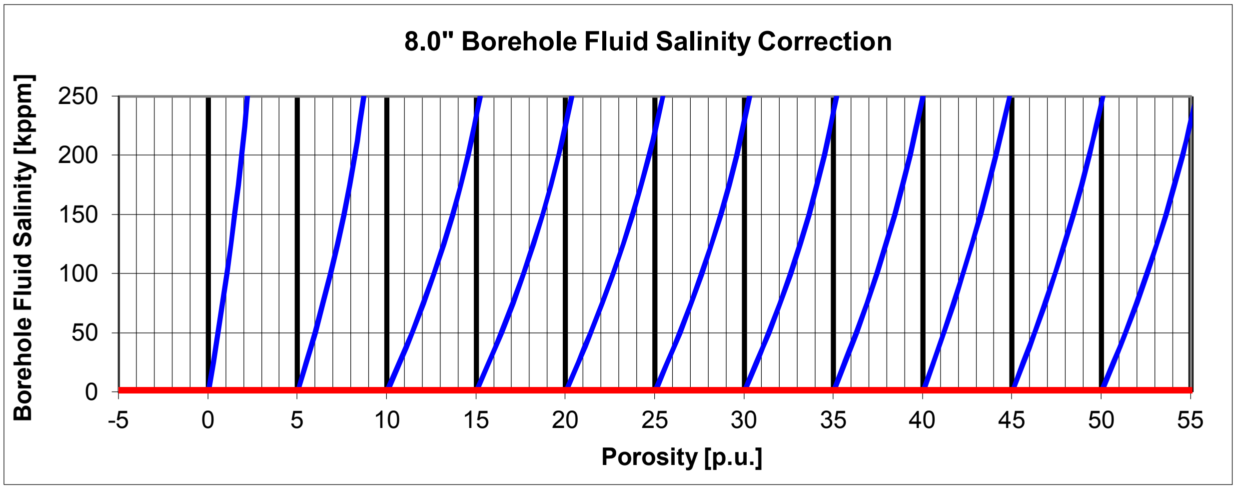


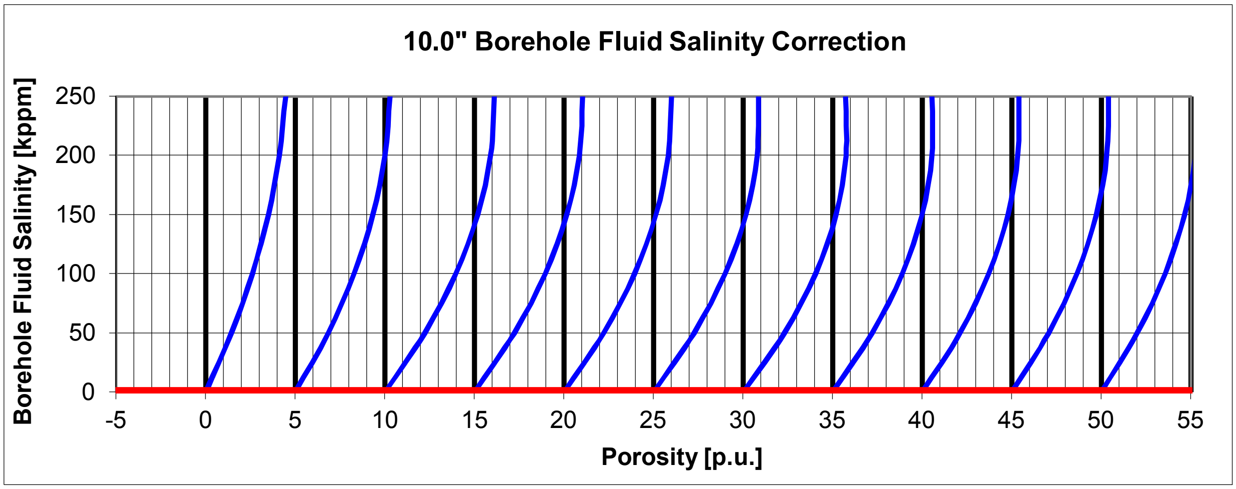


U-FLT CNL009 – Californium 252

Open Hole Borehole Fluid Salinity Corrections – Centralized Tool

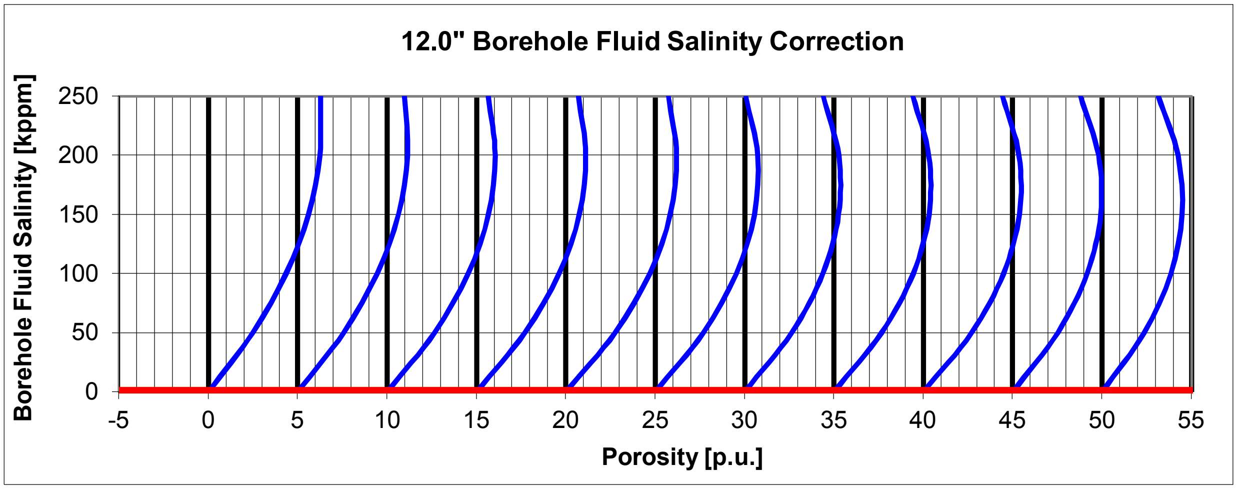


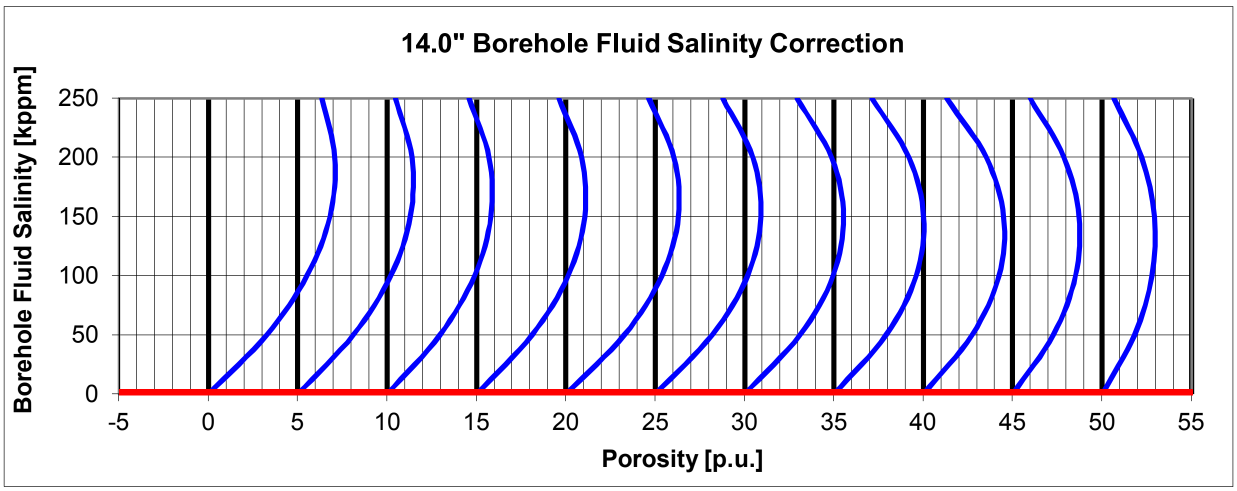


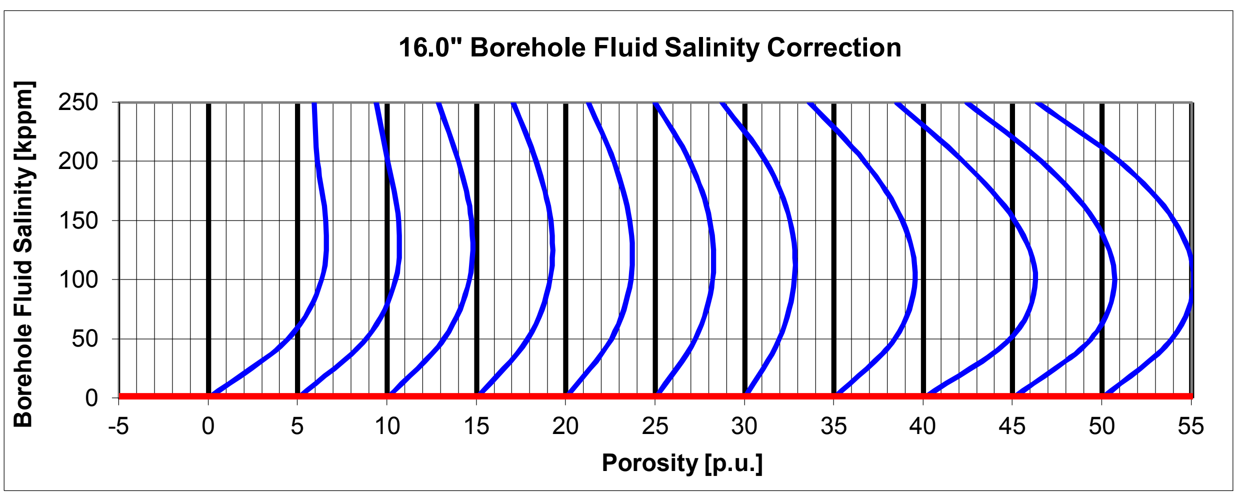


U-FLT CNL009 – Californium 252

Open Hole Borehole Fluid Salinity Corrections – Centralized Tool

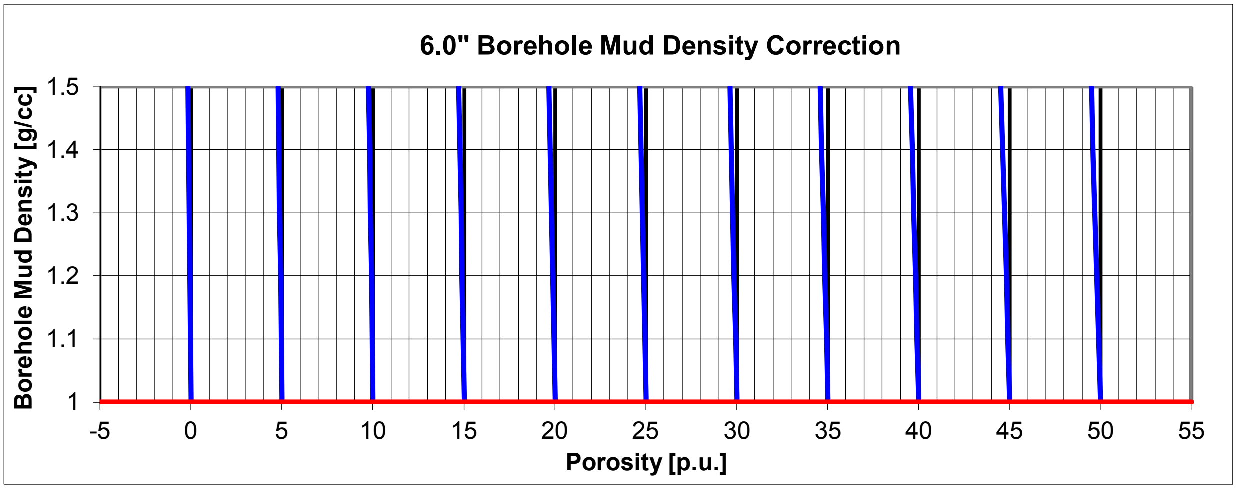


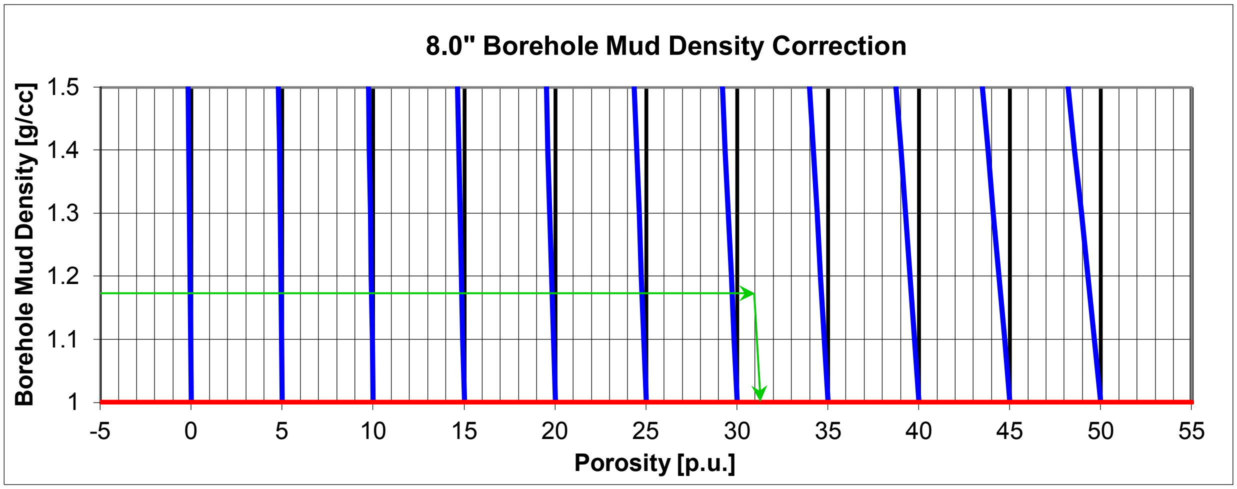


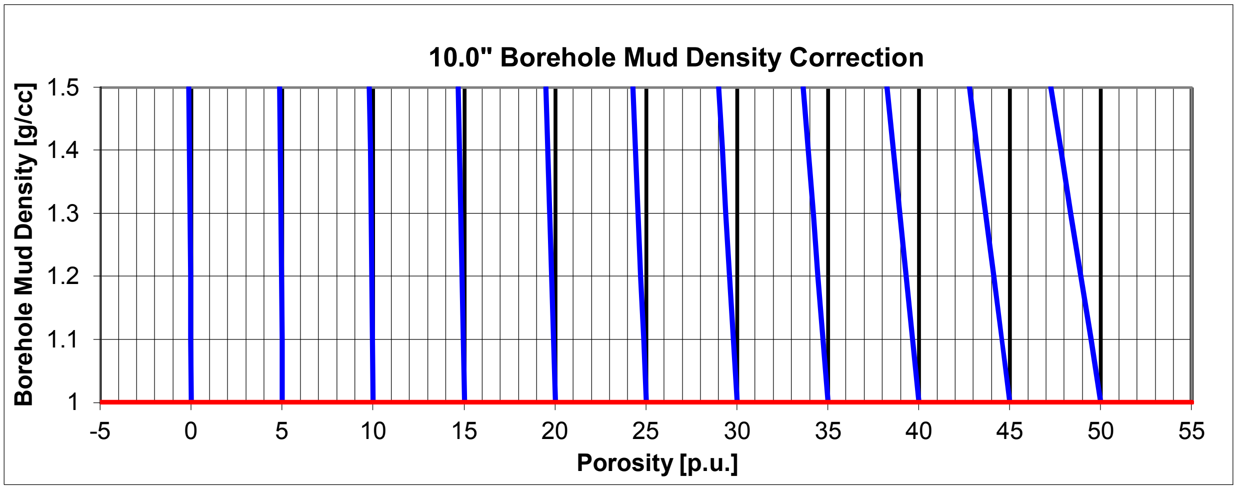


U-FLT CNL009 – Californium 252

Open Hole Borehole Mud Density Corrections – Eccentralized Tool

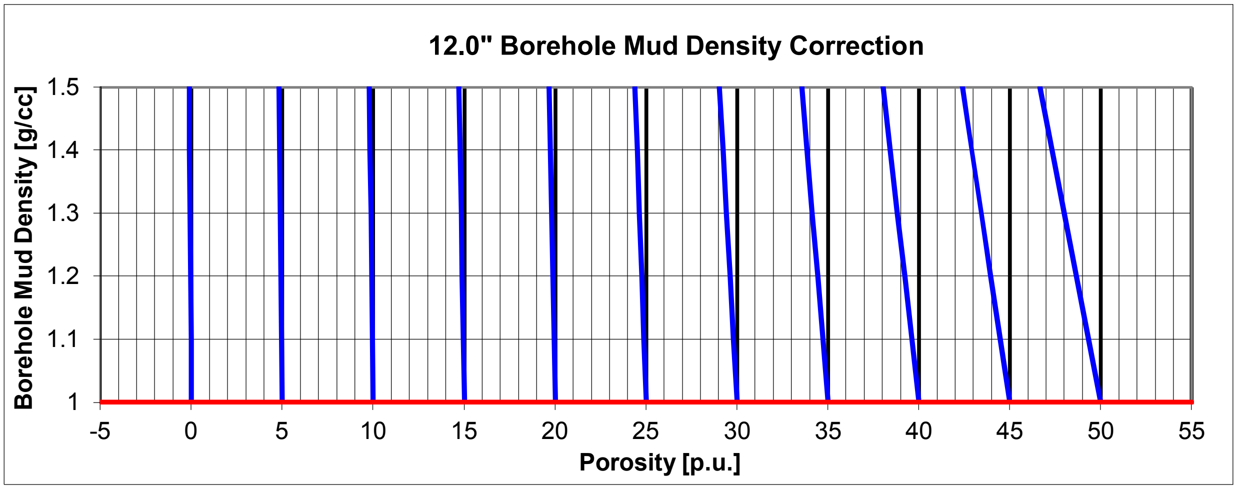


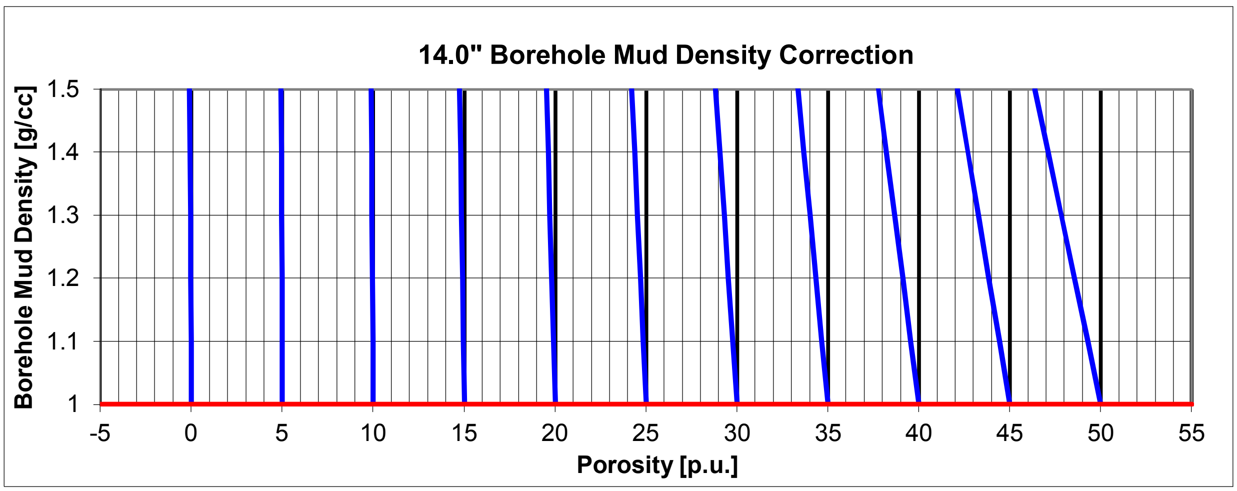


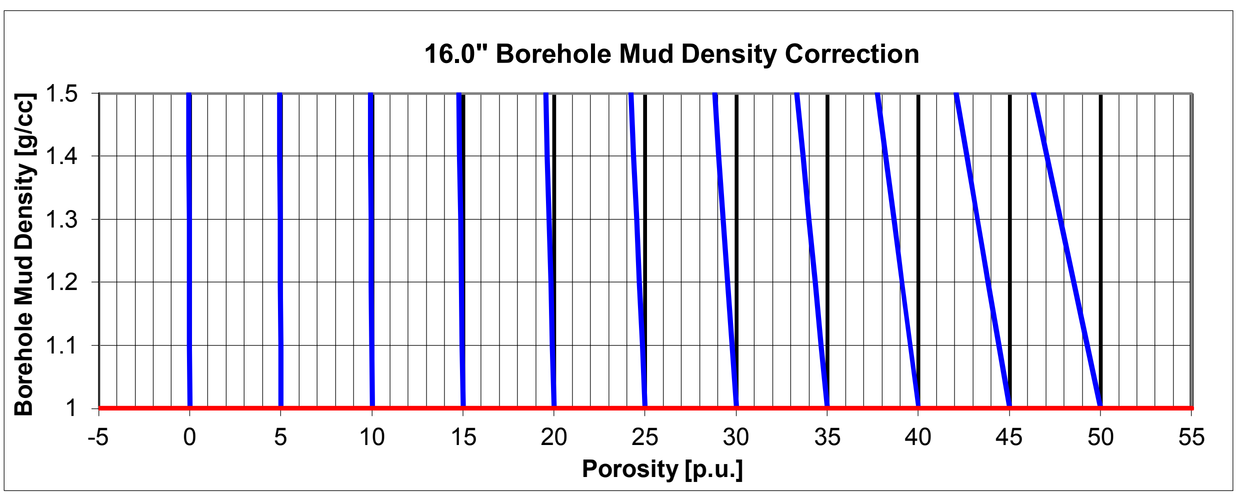


U-FLT CNL009 – Californium 252

Open Hole Borehole Mud Density Corrections – Eccentralized Tool

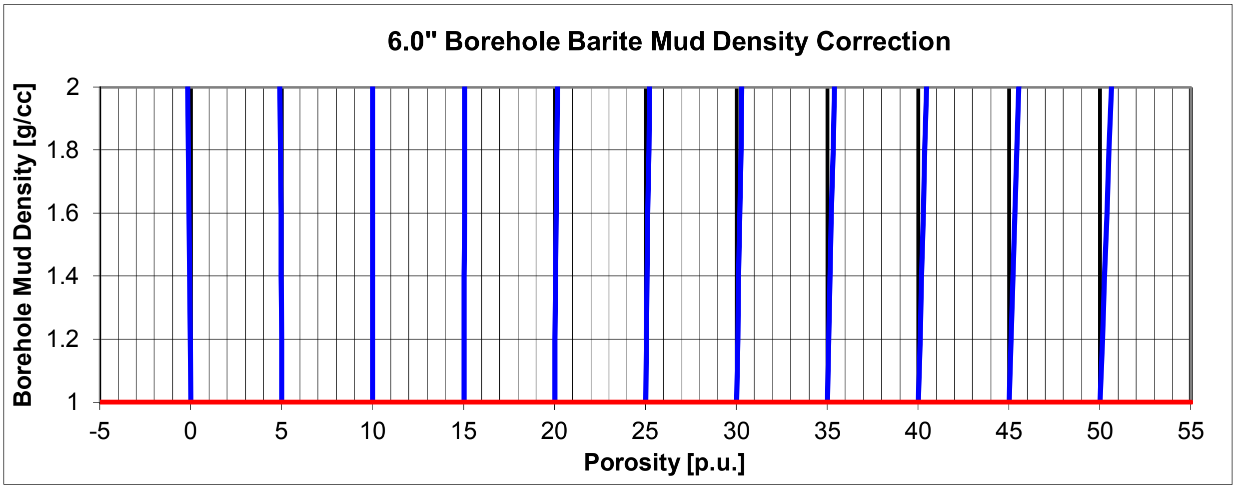


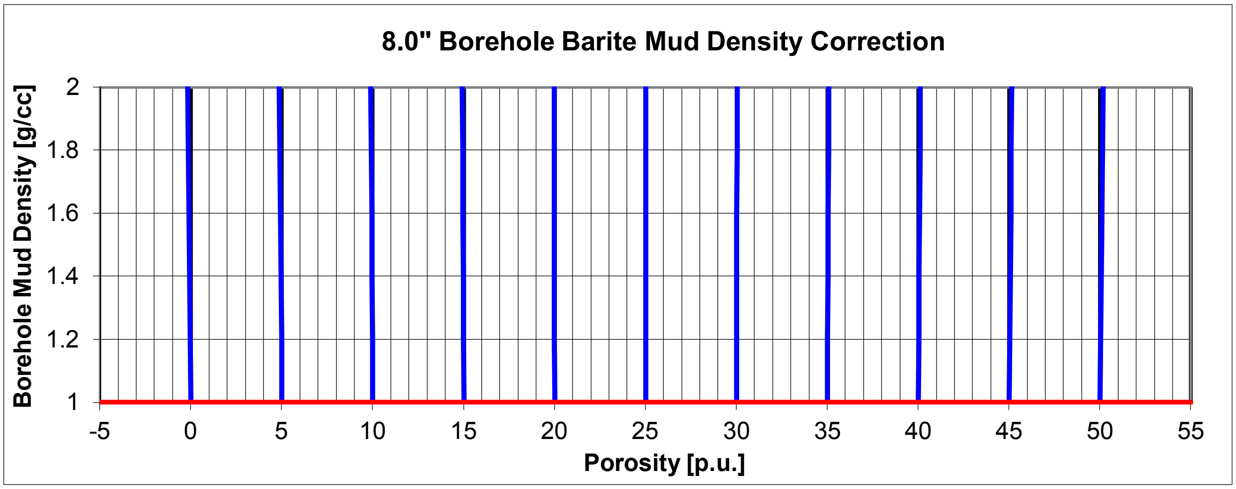


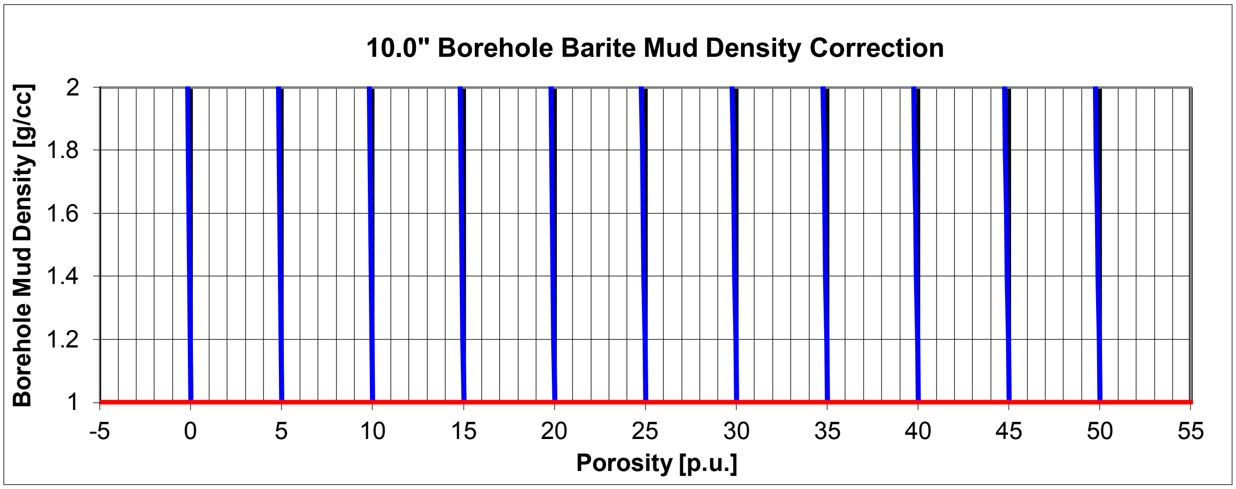


U-FLT CNL009 – Californium 252

Open Hole Borehole Barite Mud Density Corrections – Eccentralized Tool

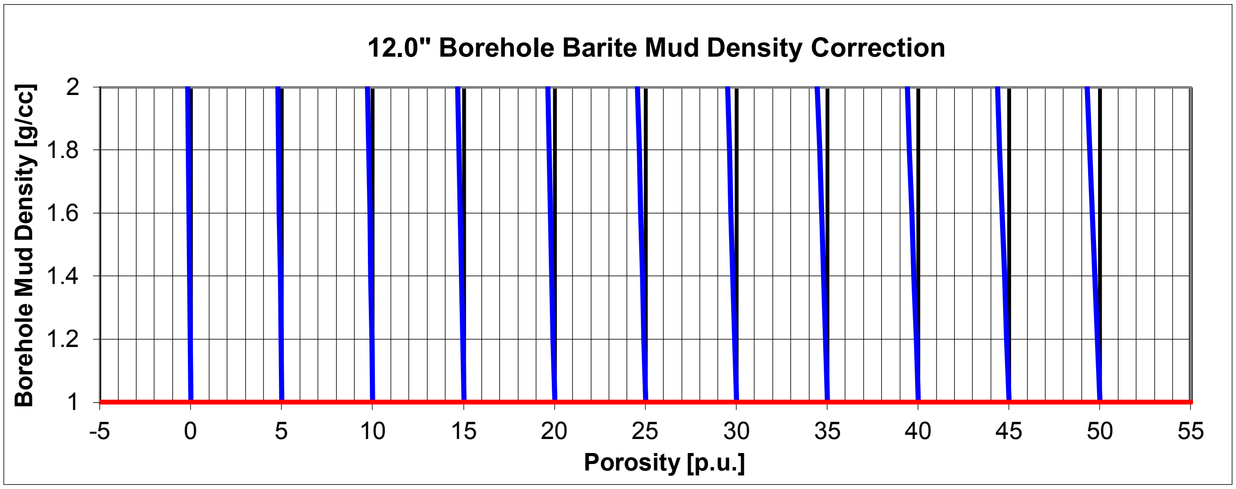


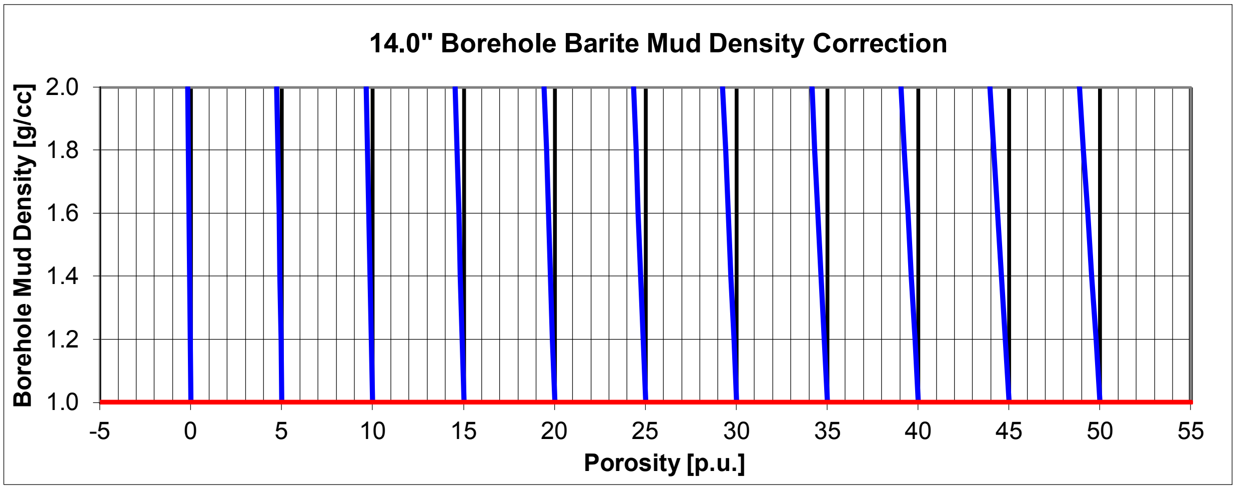


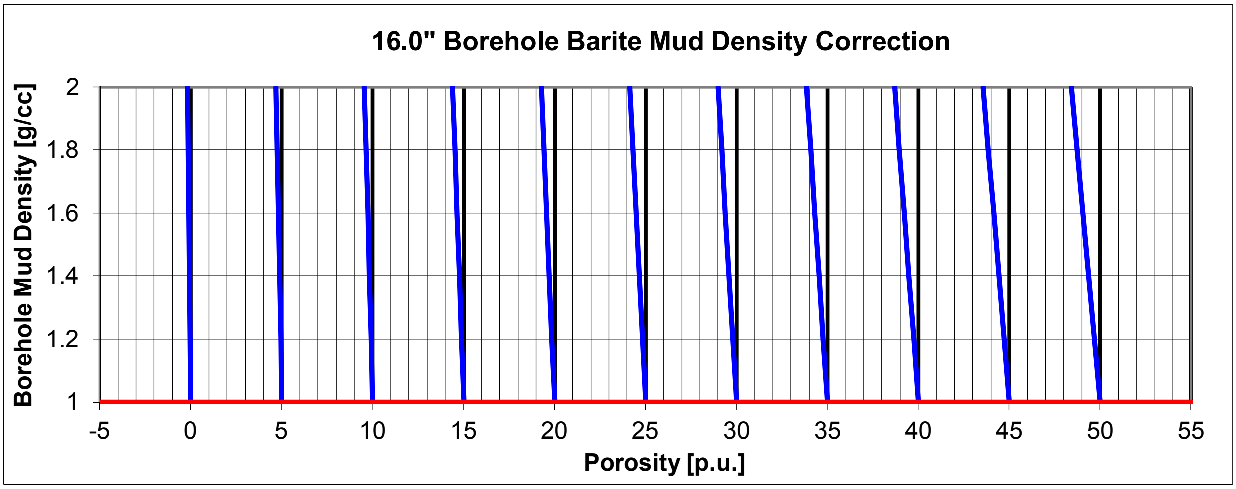


U-FLT CNL009 – Californium 252

Open Hole Borehole Barite Mud Density Corrections – Eccentralized Tool

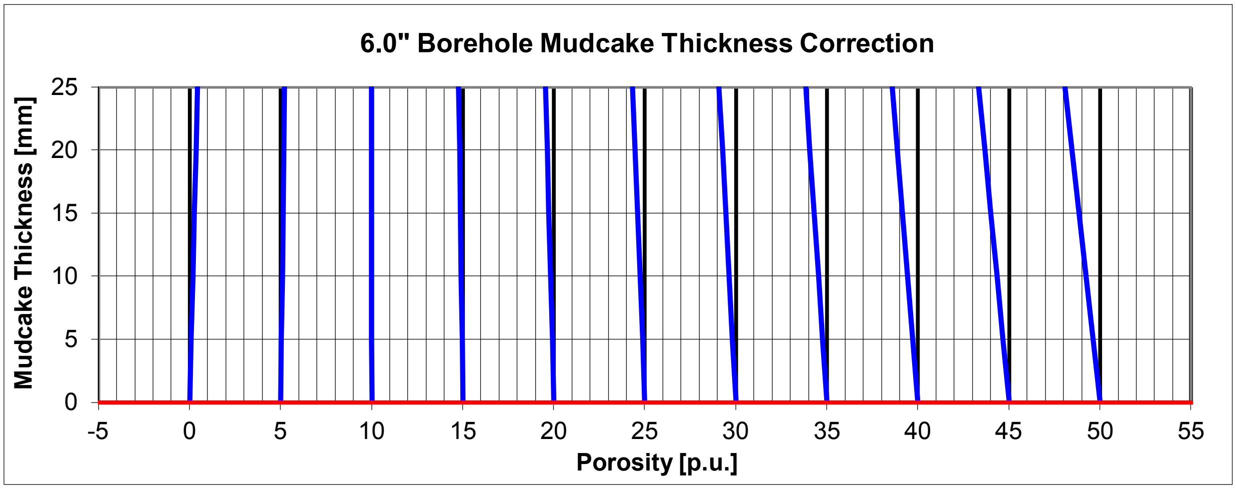


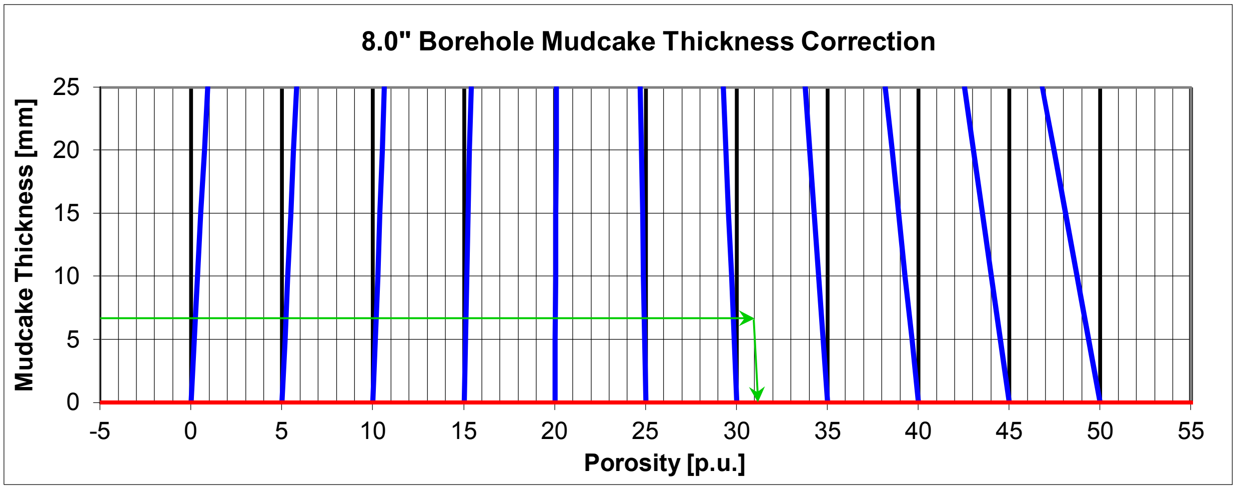


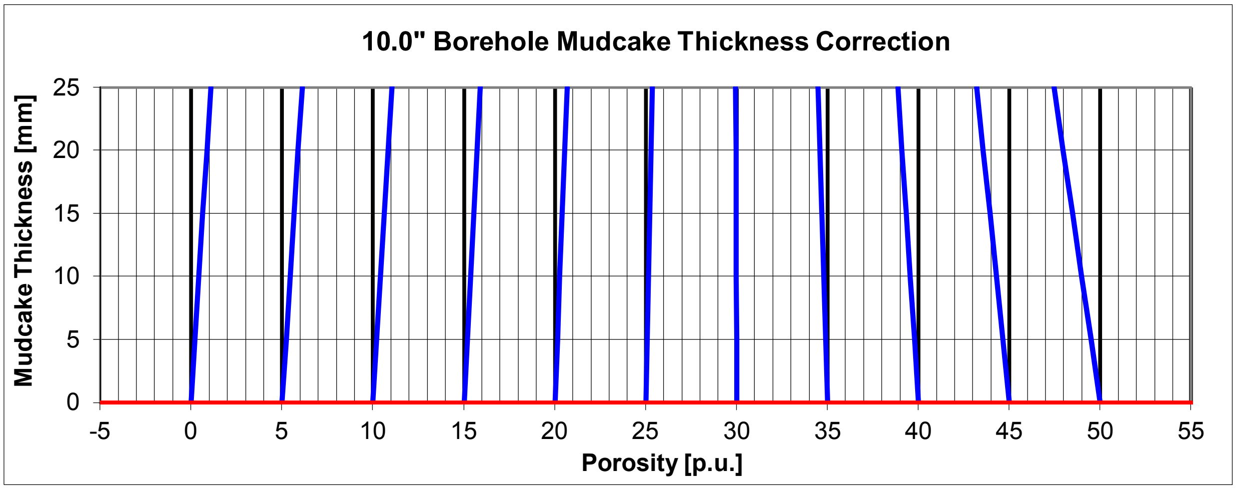


U-FLT CNL009 – Californium 252

Open Hole Borehole Mud Cake Thickness Corrections – Eccentralized Tool

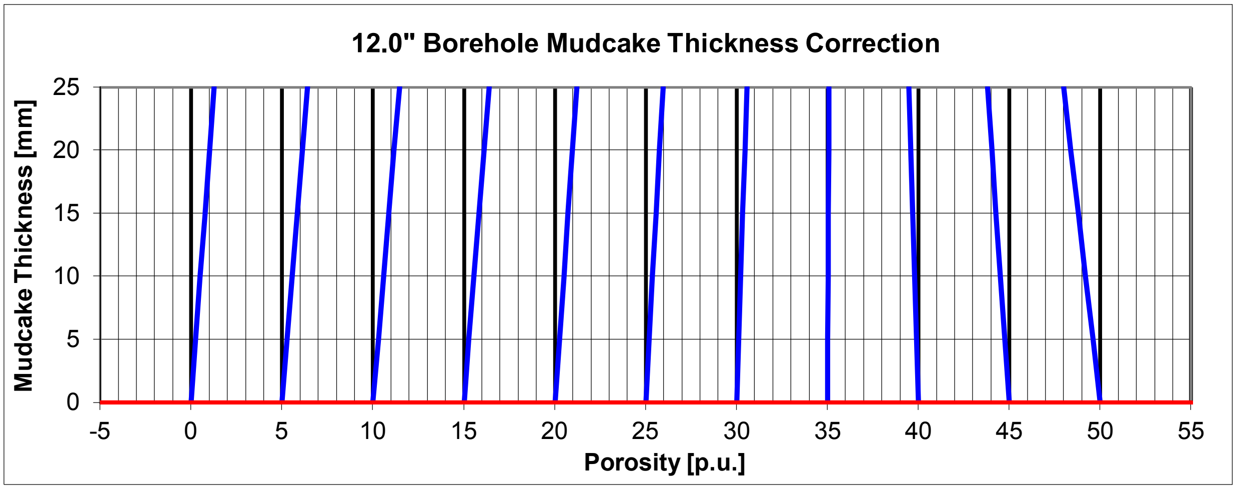


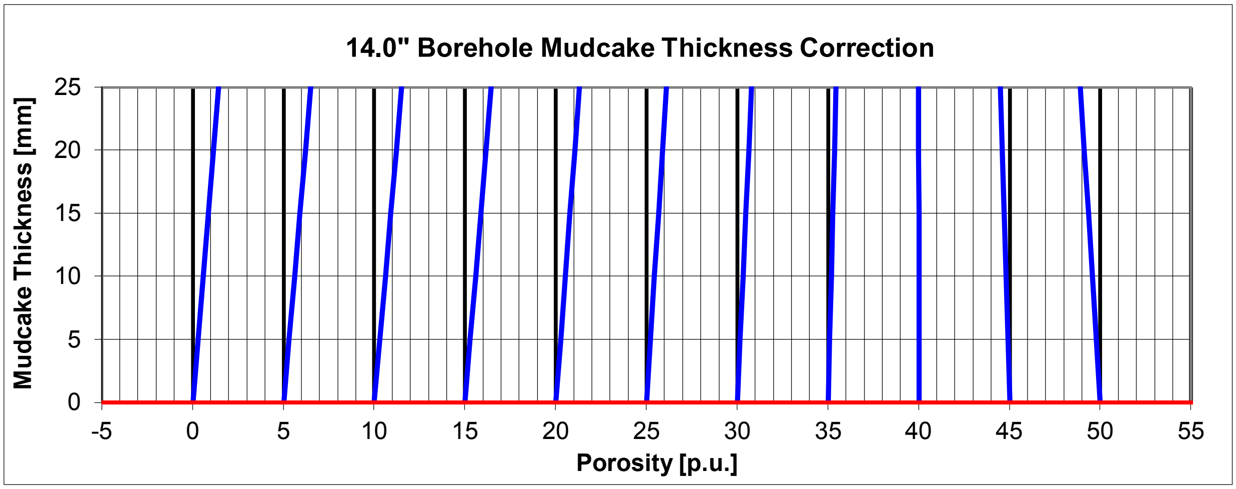


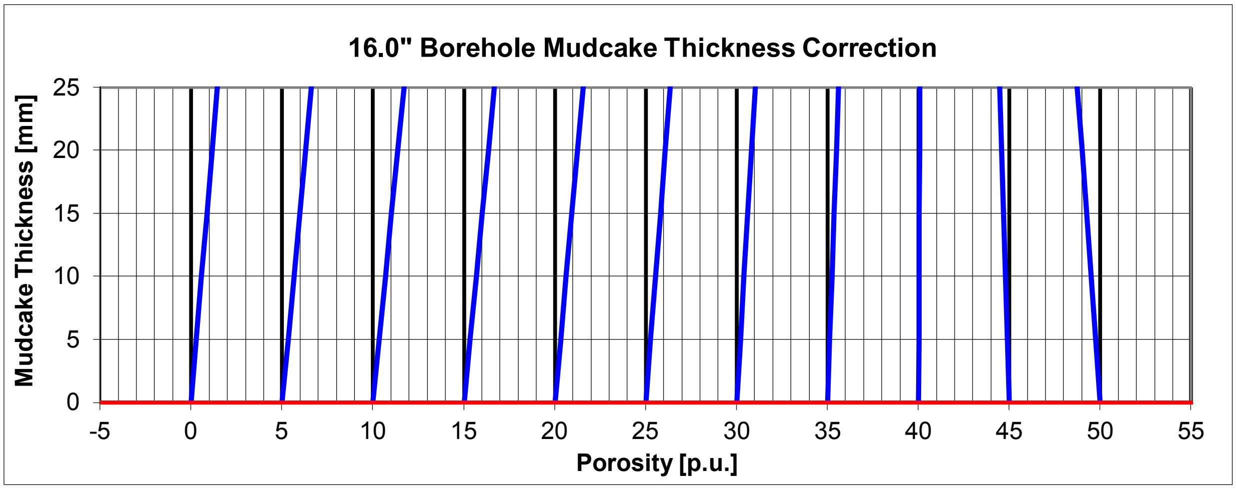


U-FLT CNL009 – Californium 252

Open Hole Borehole Mud Cake Thickness Corrections – Eccentralized Tool

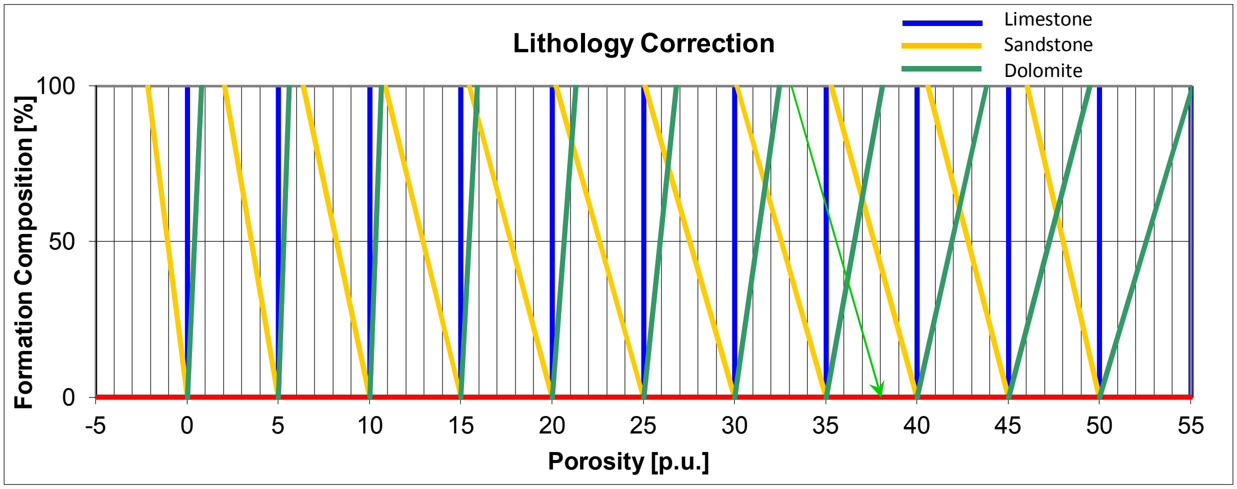






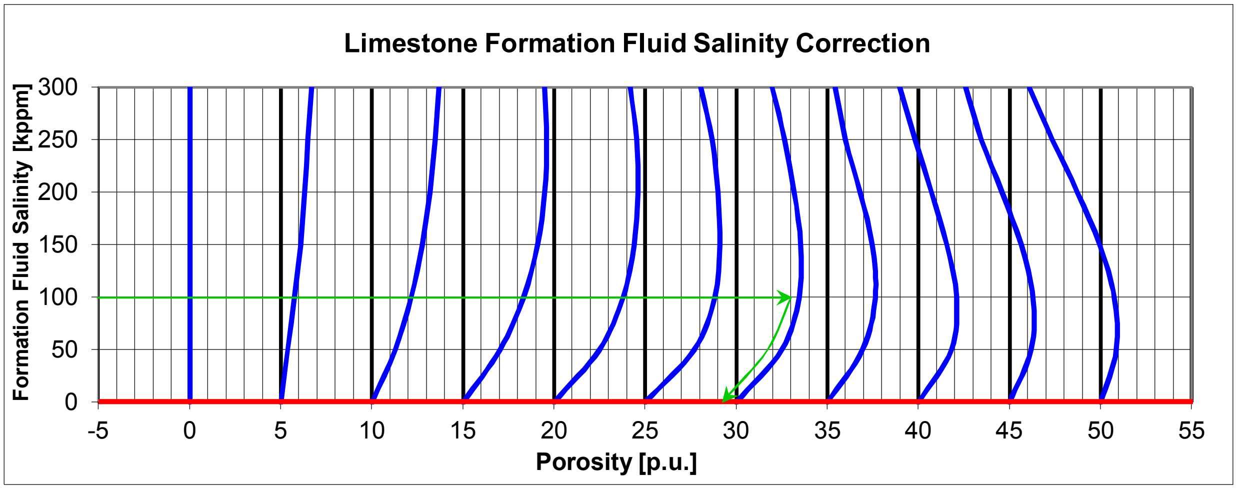
U-FLT CNL009 – Californium 252

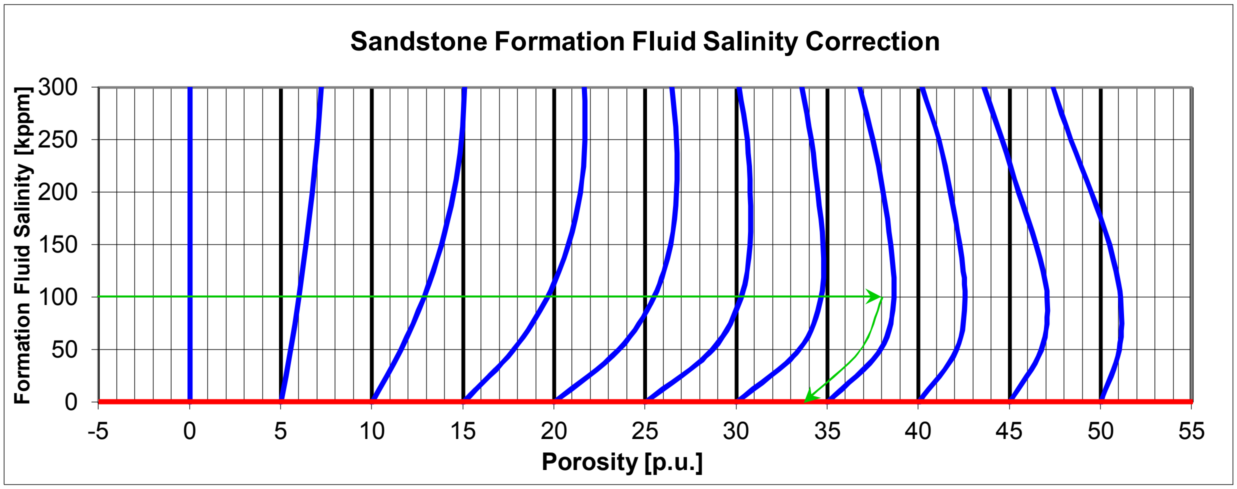
Open Hole Lithology Correction

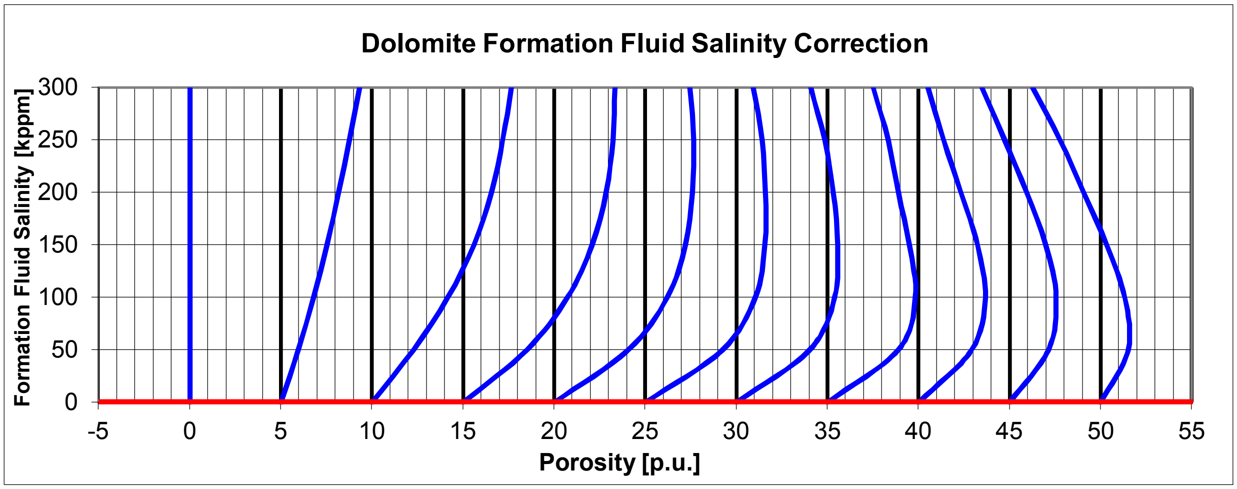


U-FLT CNL009 – Californium 252

Open Hole Formation Fluid Salinity Corrections

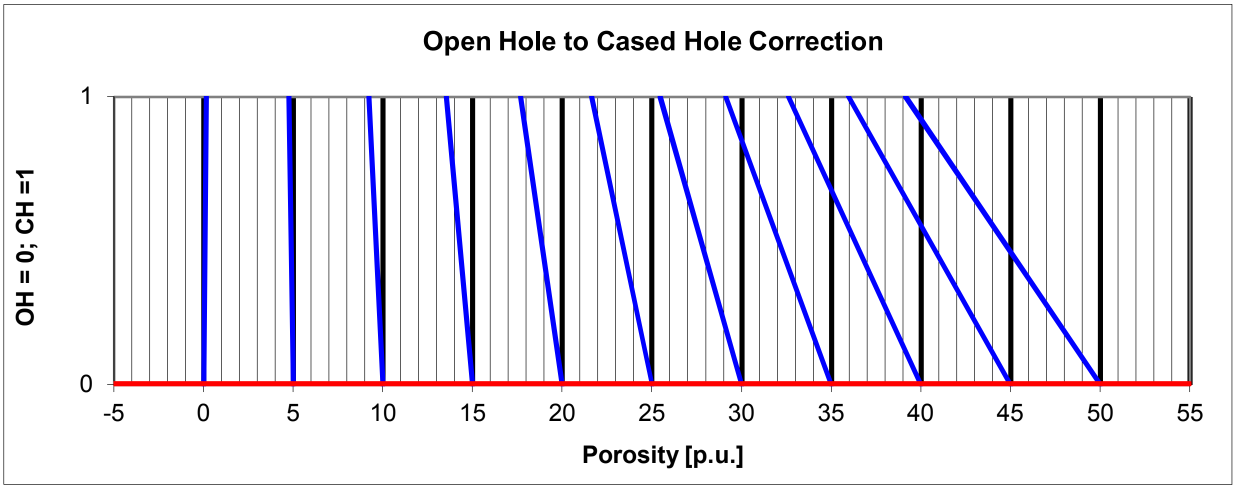


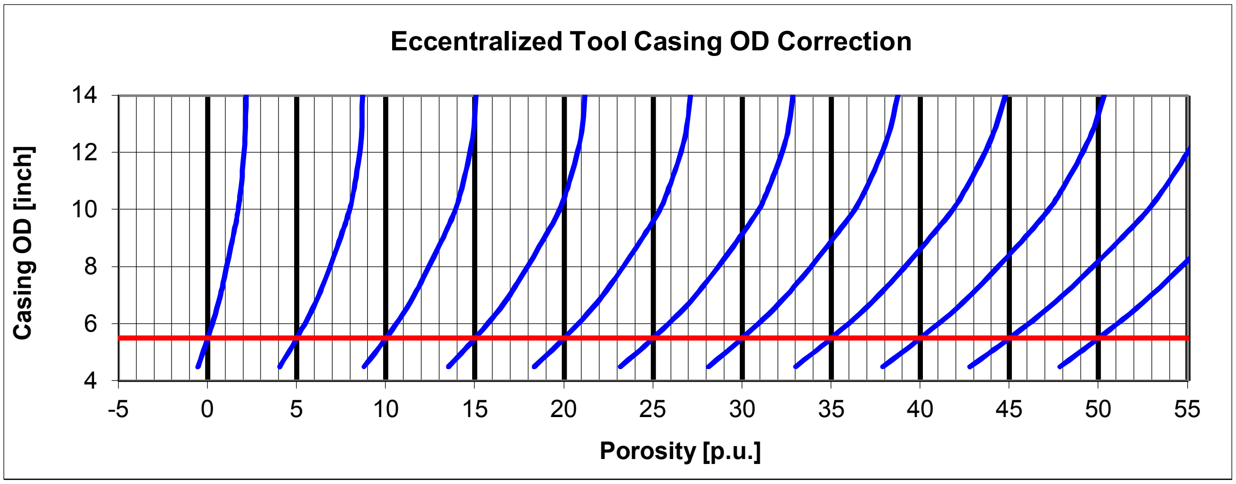


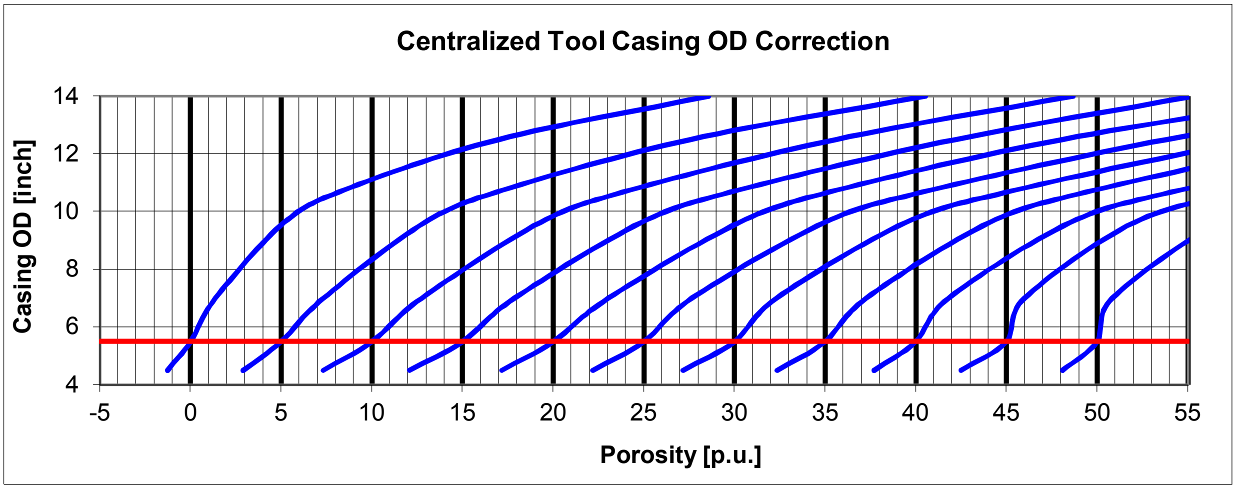


U-FLT CNL009 – Californium 252

Cased Hole Corrections - General

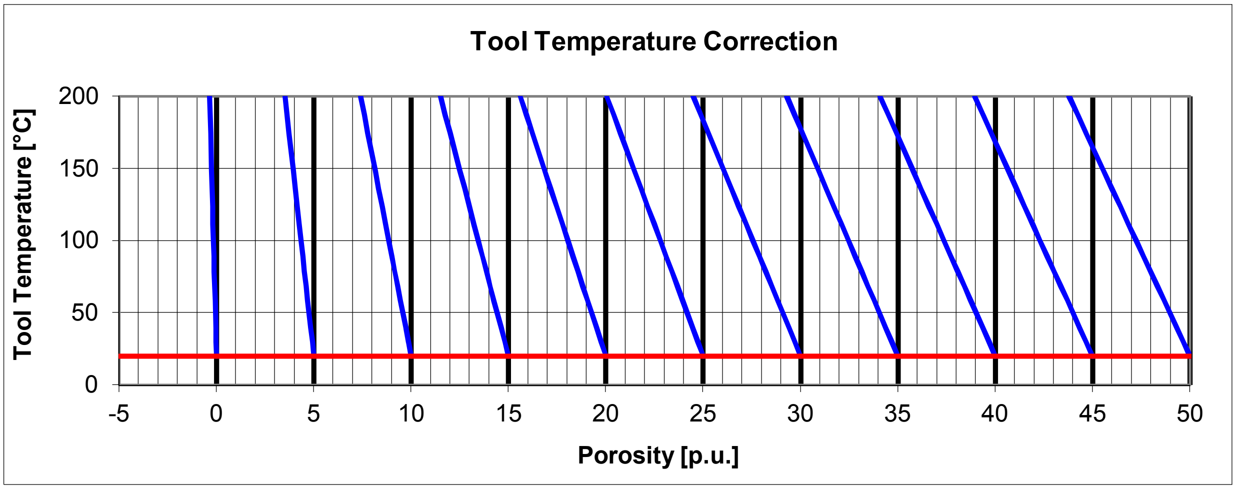


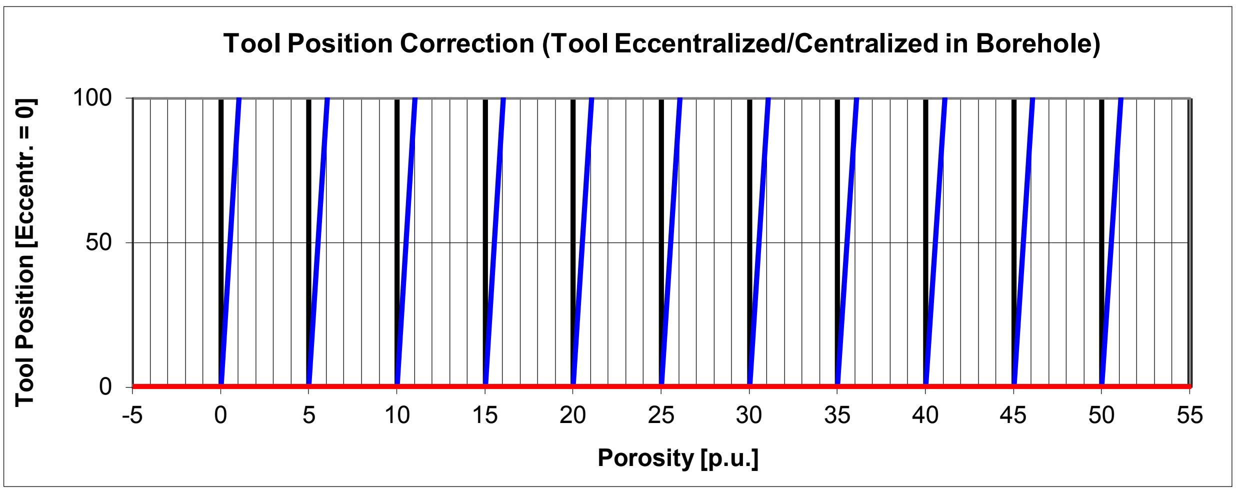




U-FLT CNL009 – Californium 252

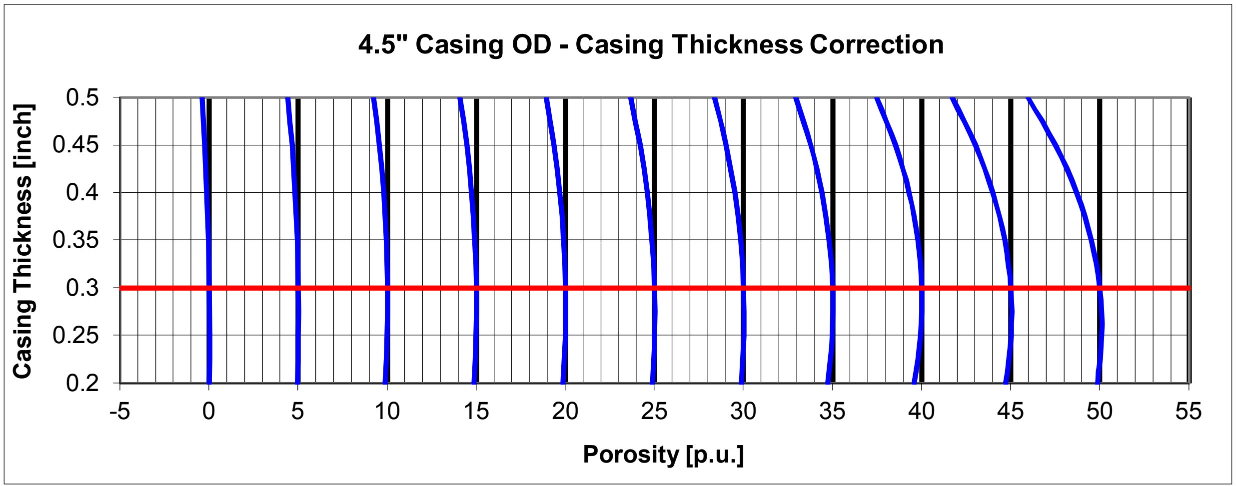
Cased Hole Corrections – General

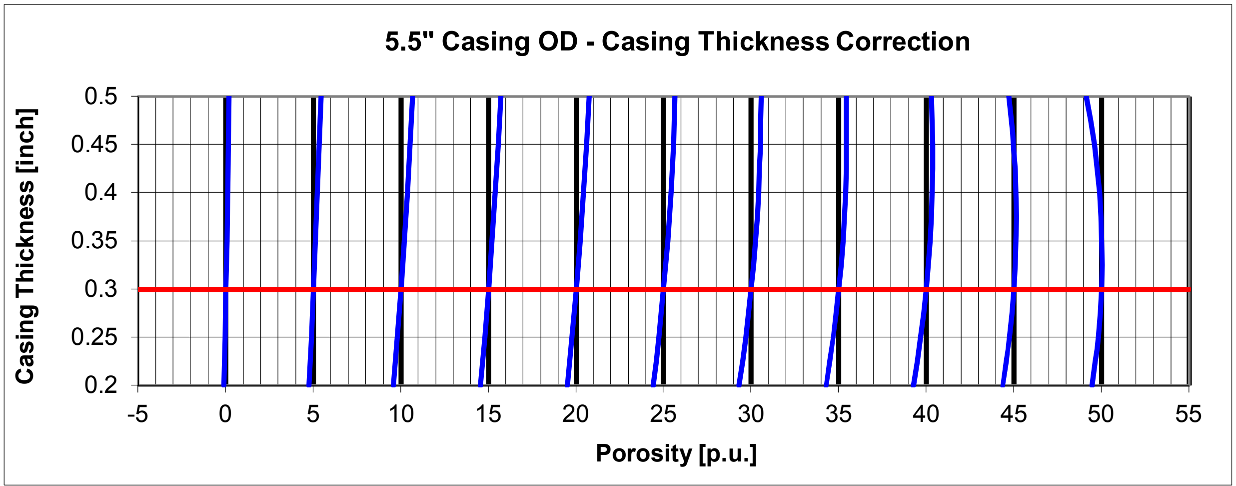


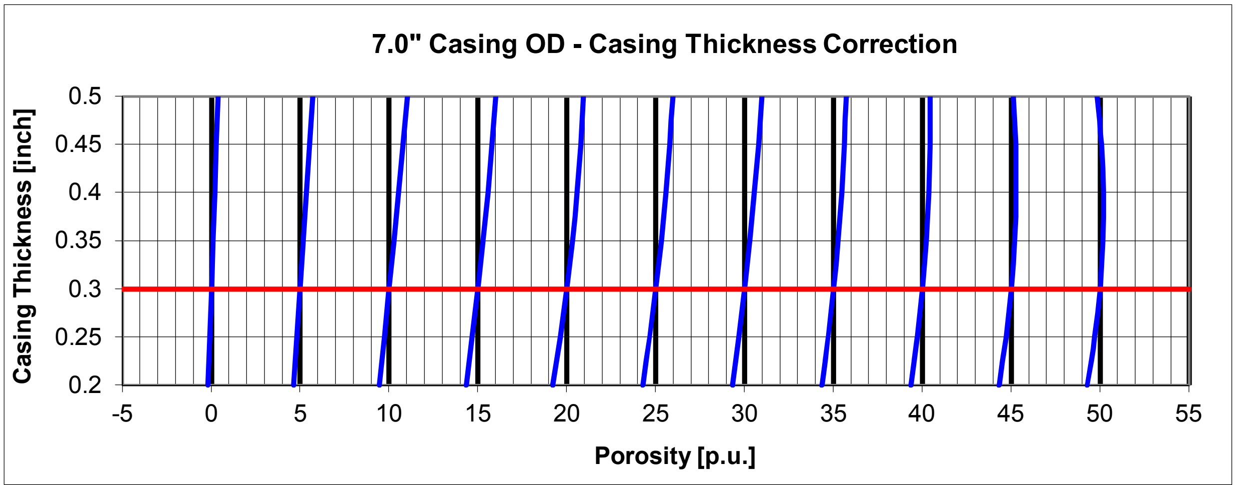


U-FLT CNL009 – Californium 252

Cased Hole Corrections – Casing Thickness – Eccentralized

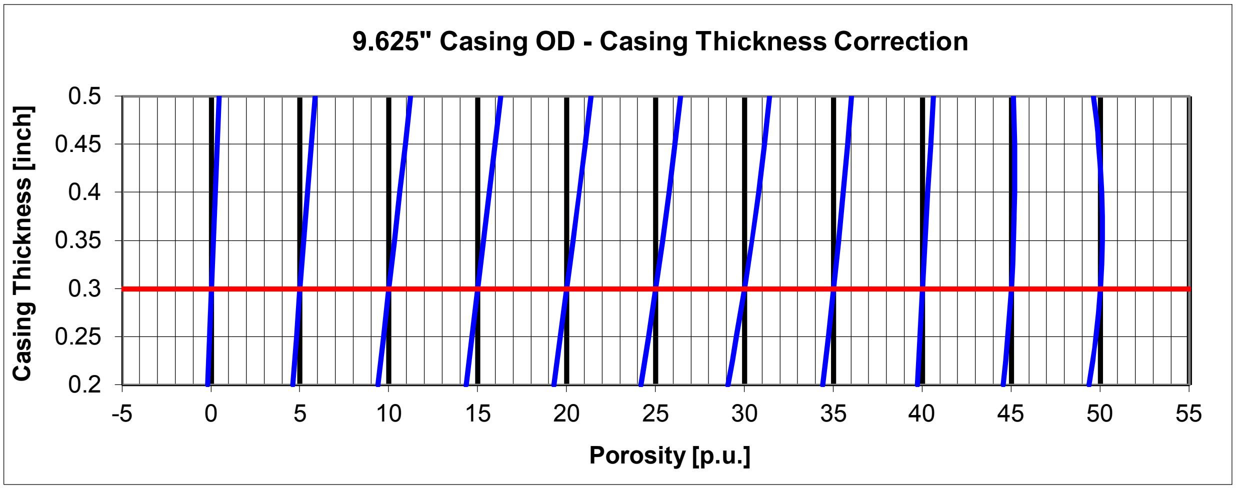


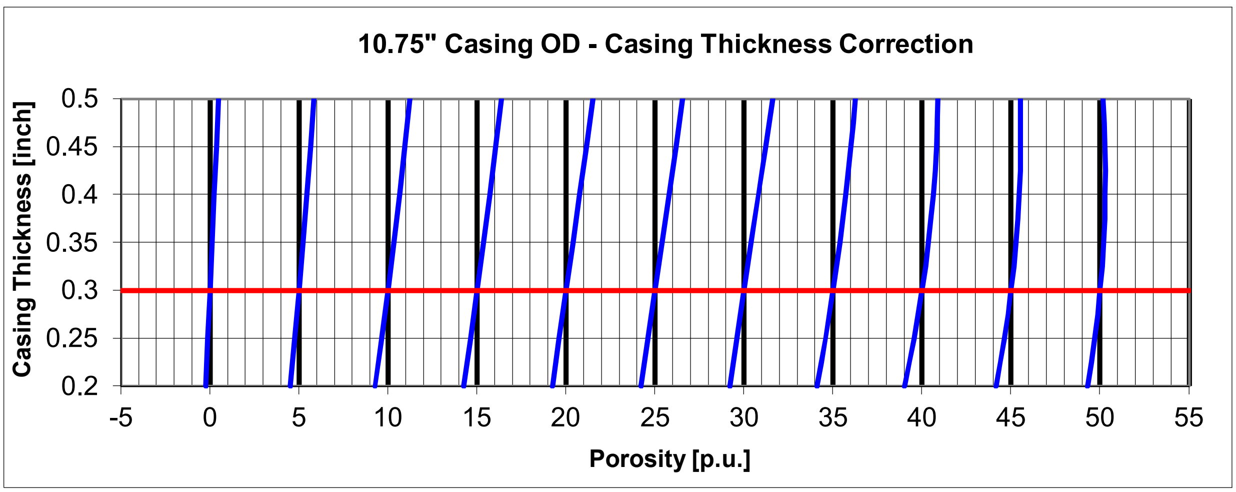




U-FLT CNL009 – Californium 252

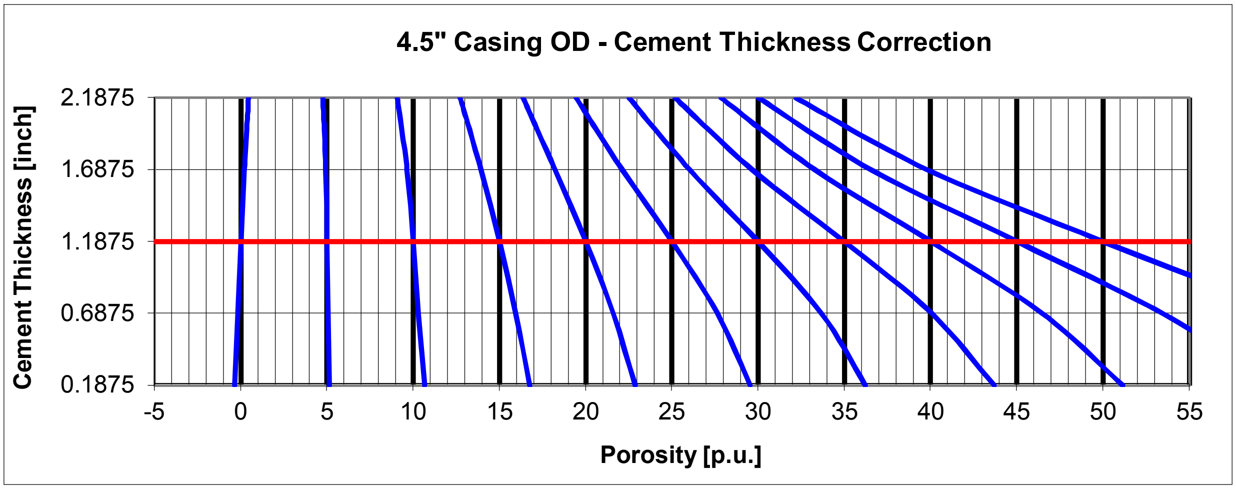
Cased Hole Corrections – Casing Thickness - Eccentralized

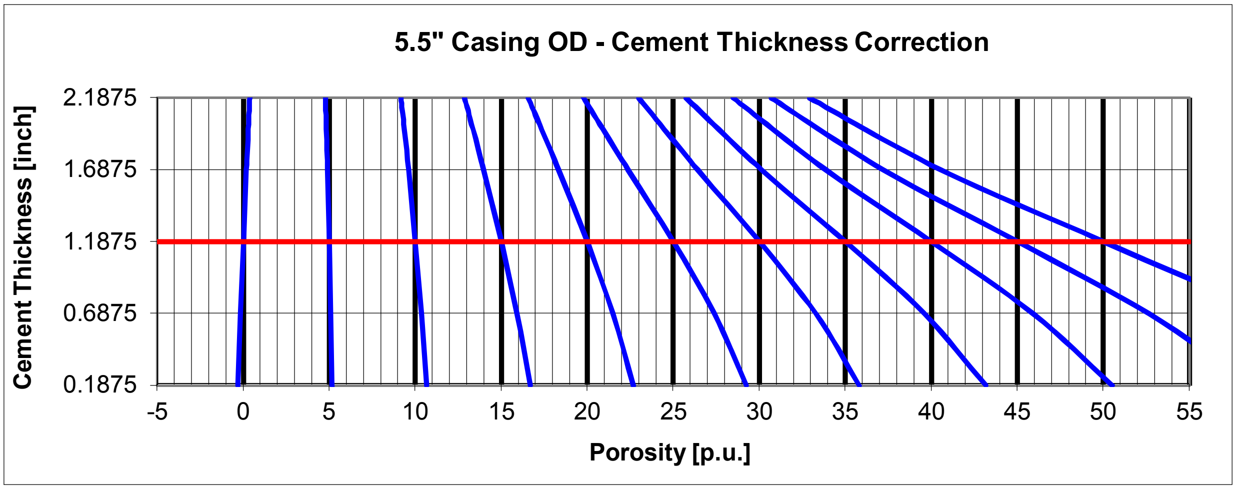


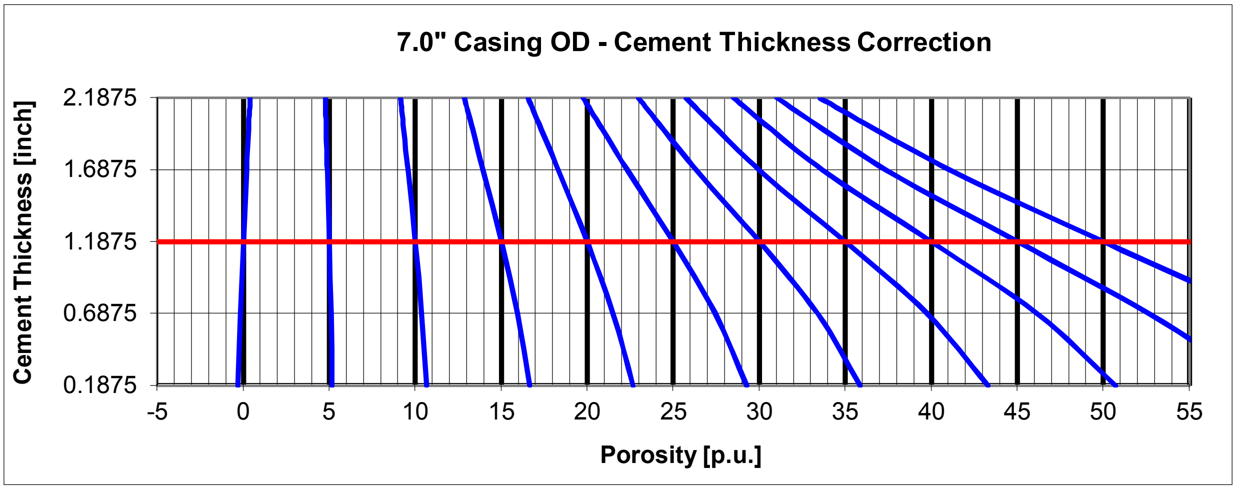


U-FLT CNL009 – Californium 252

Cased Hole Corrections – Cement Thickness - Eccentralized

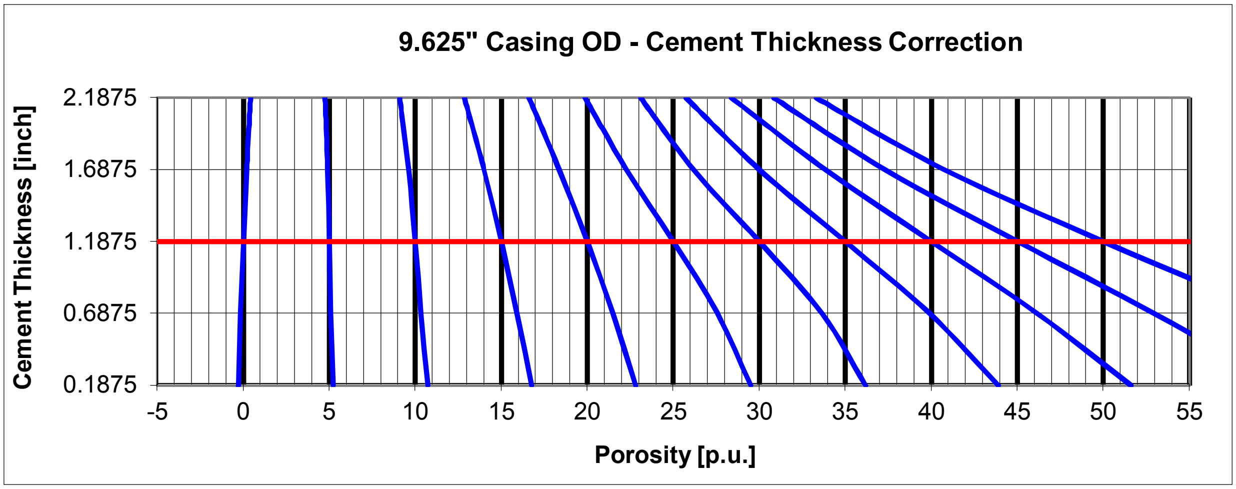


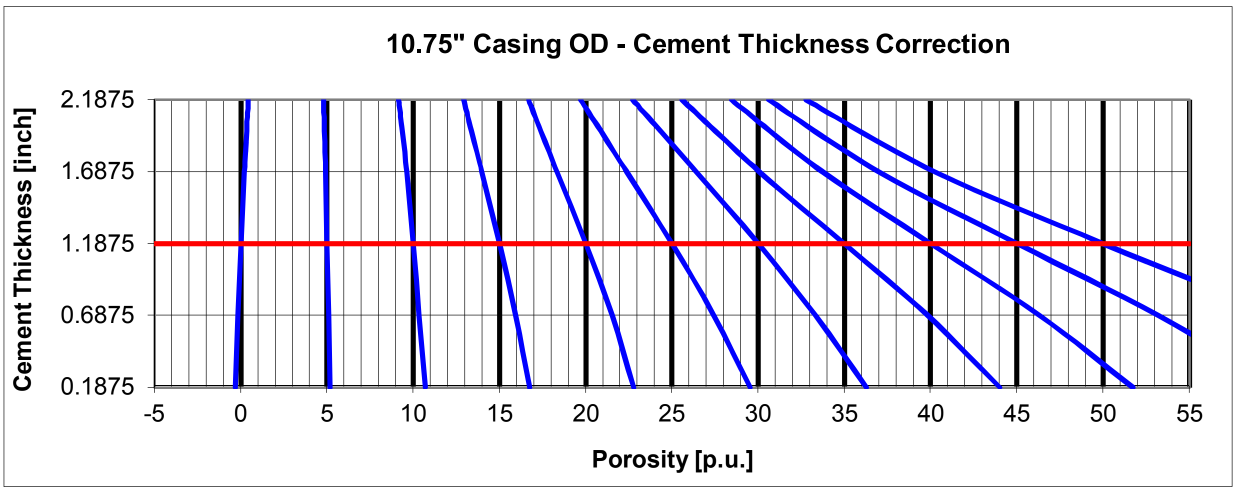




U-FLT CNL009 – Californium 252

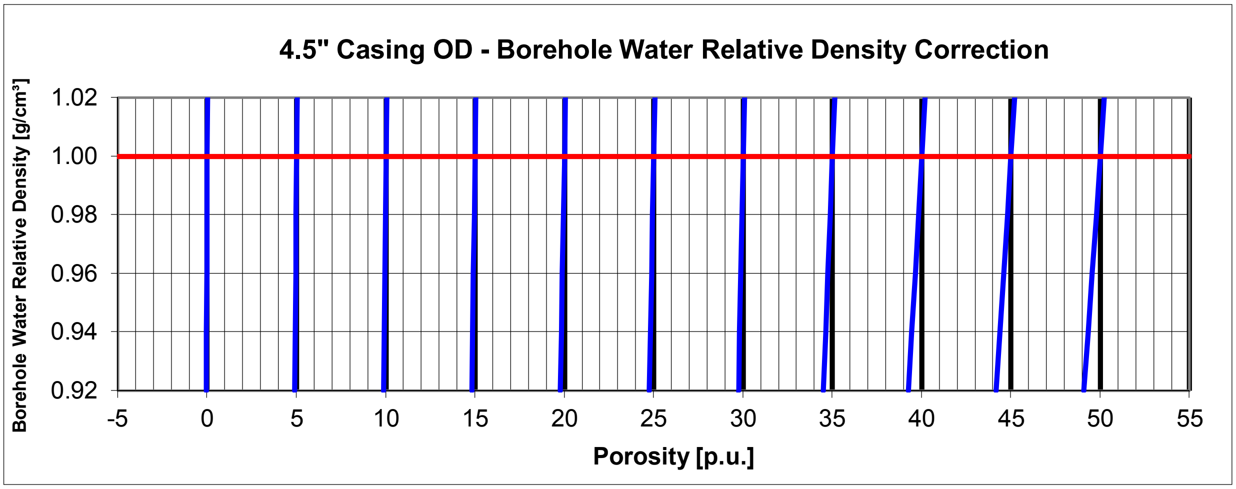
Cased Hole Corrections – Cement Thickness - Eccentralized

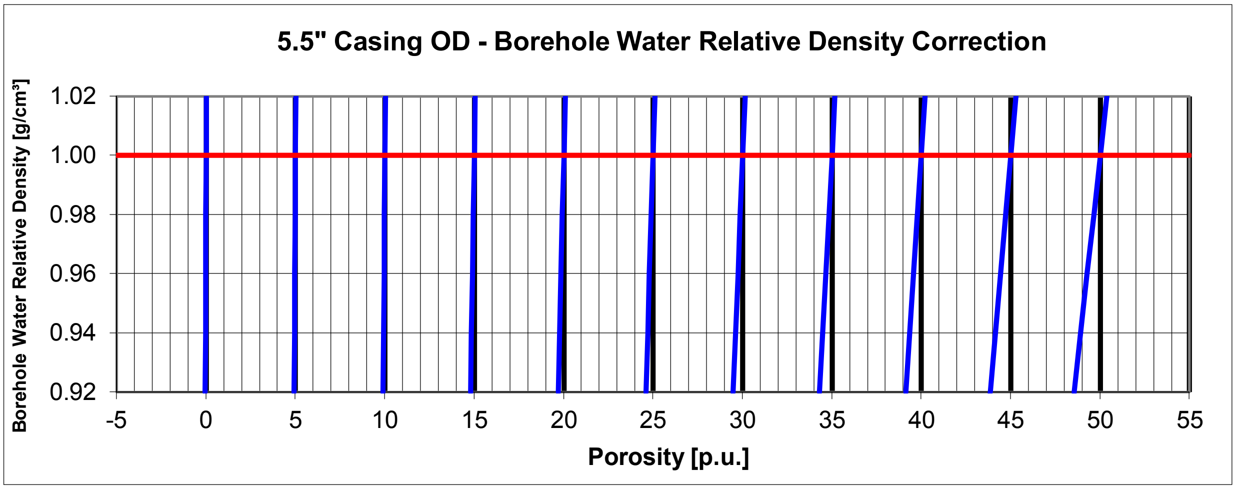


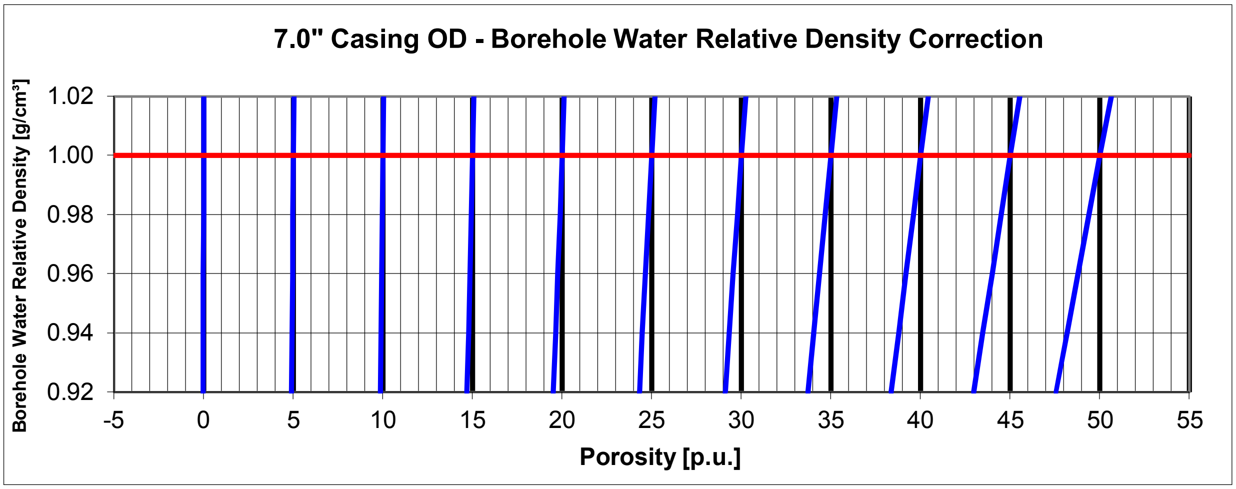


U-FLT CNL009 – Californium 252

Cased Hole Corrections – Borehole Water Relative Density - Eccentralized

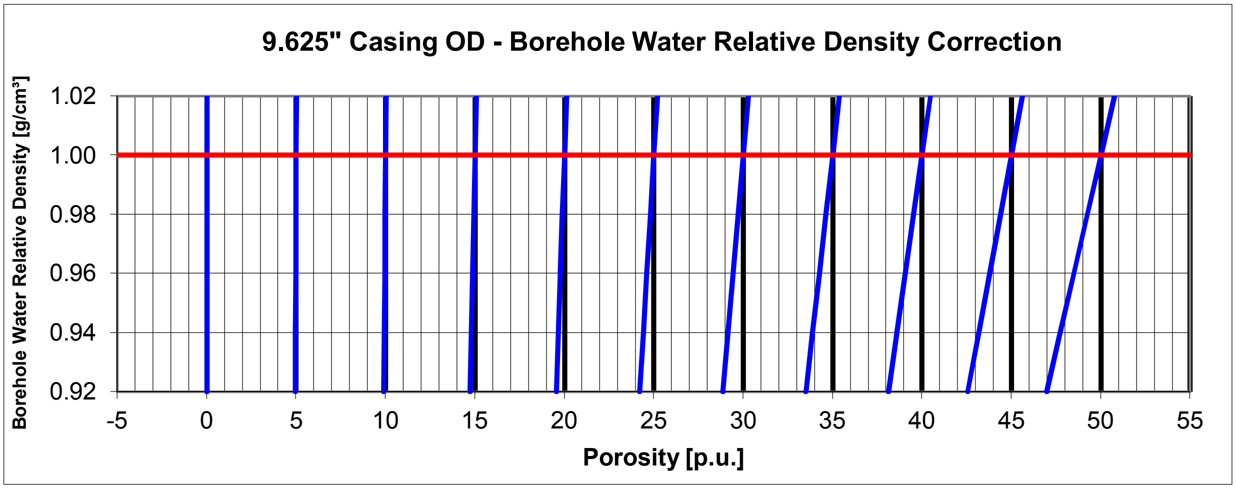


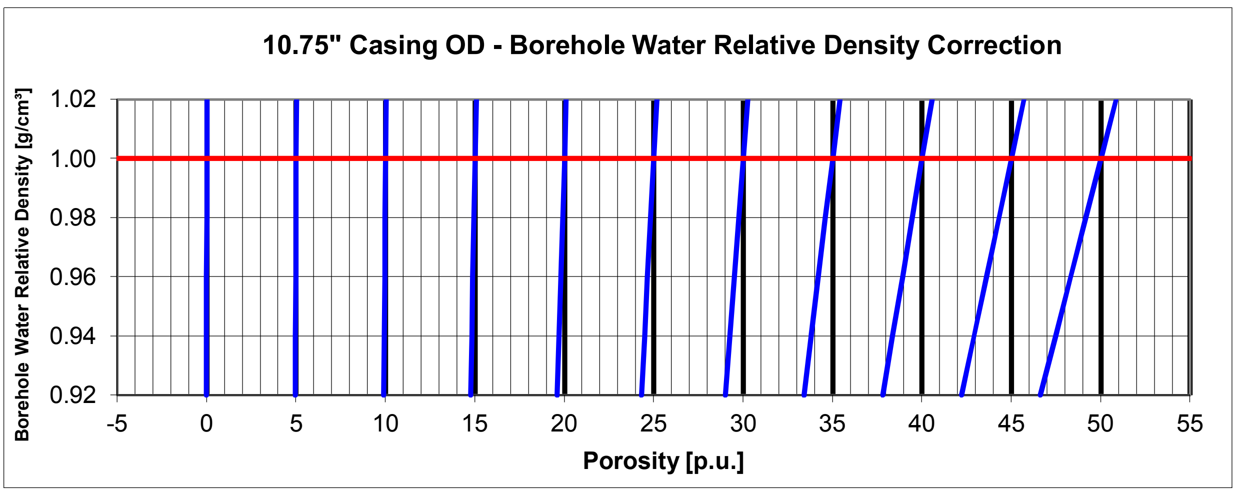




U-FLT CNL009 – Californium 252

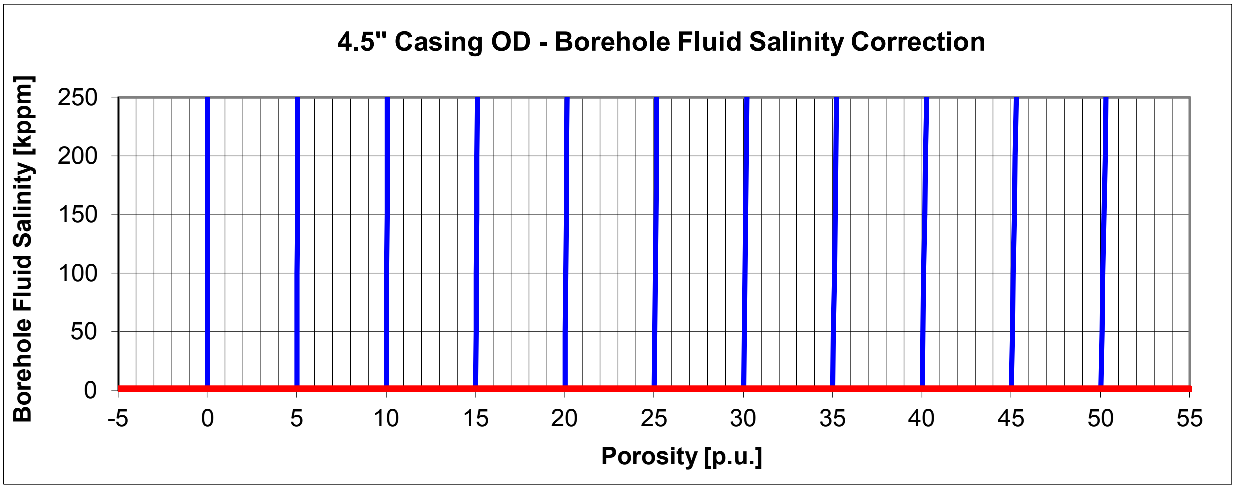
Cased Hole Corrections – Borehole Water Relative Density – Eccentralized

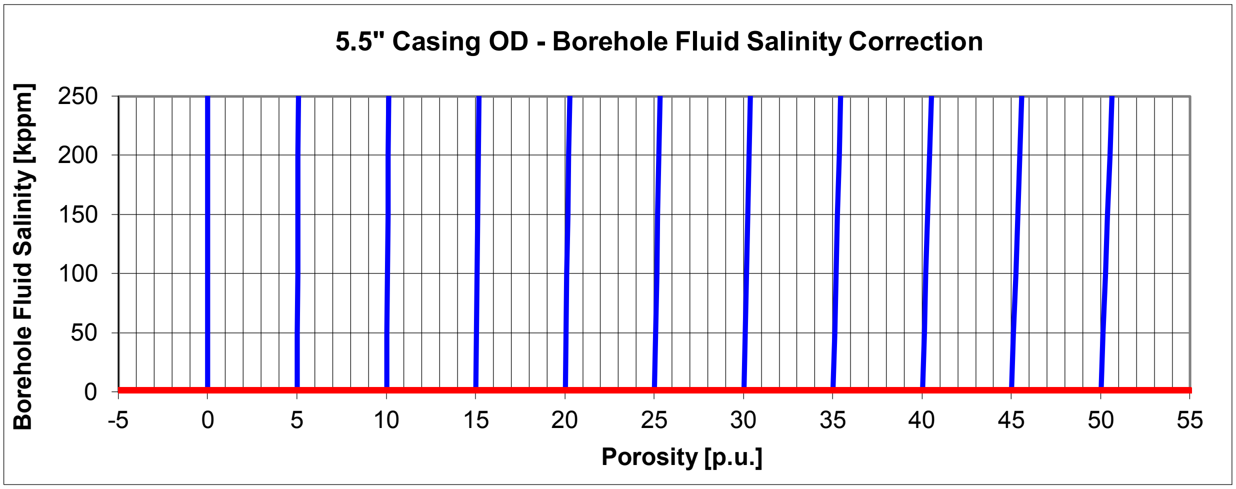


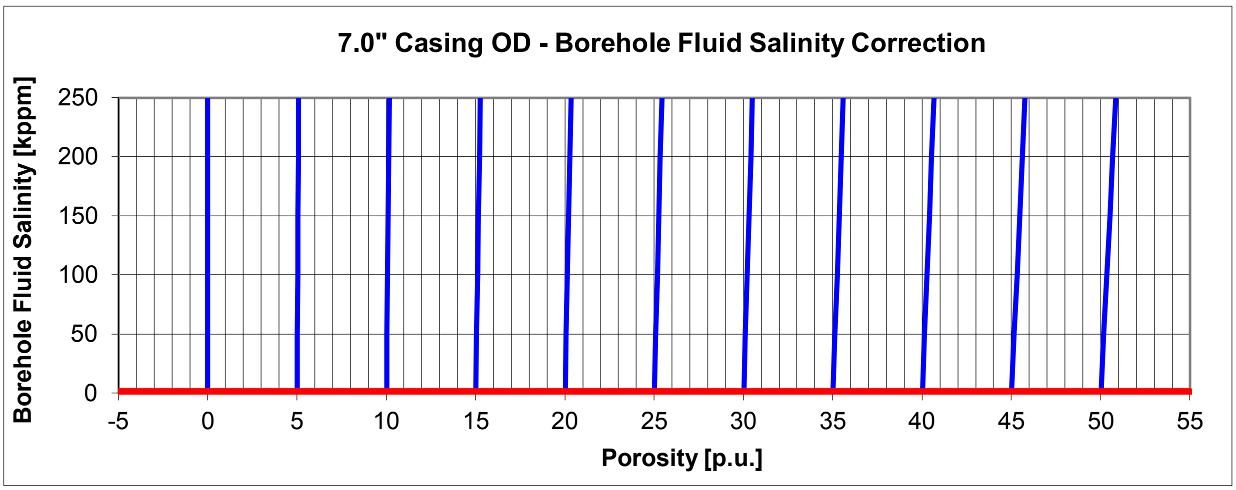


U-FLT CNL009 – Californium 252

Cased Hole Corrections – Borehole Fluid Salinity – Eccentralized

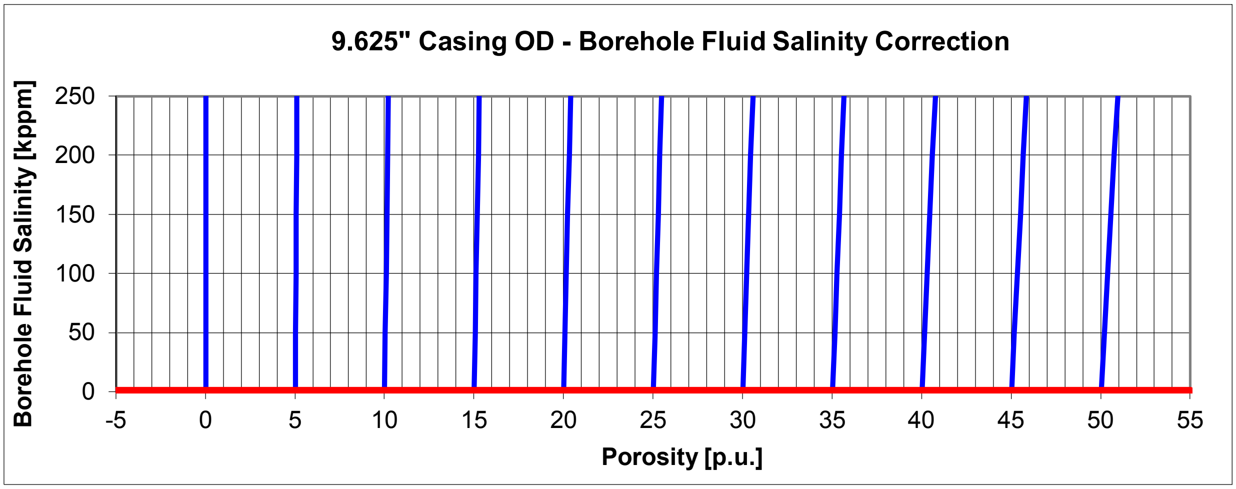


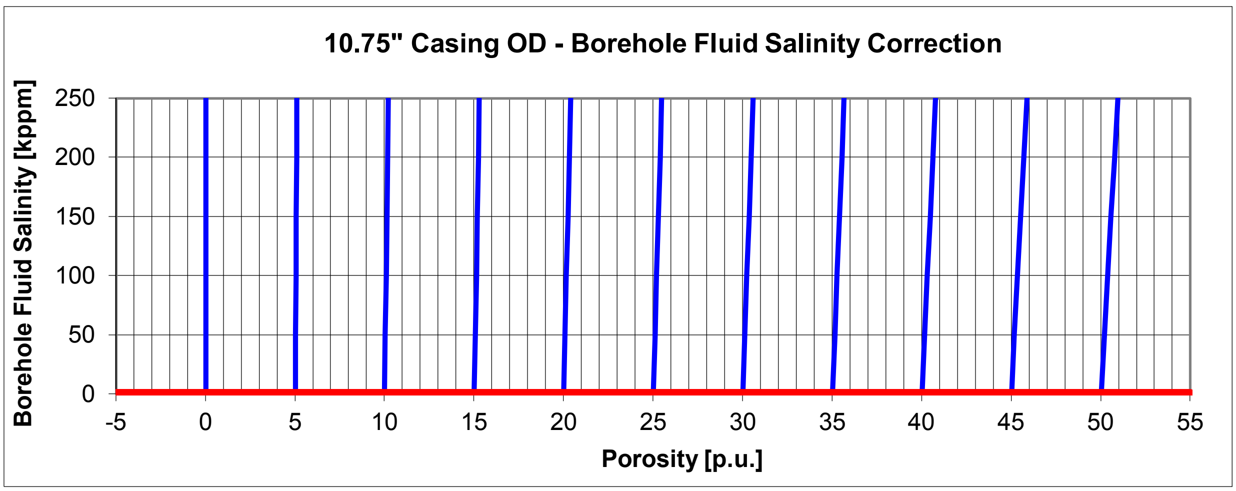




U-FLT CNL009 – Californium 252

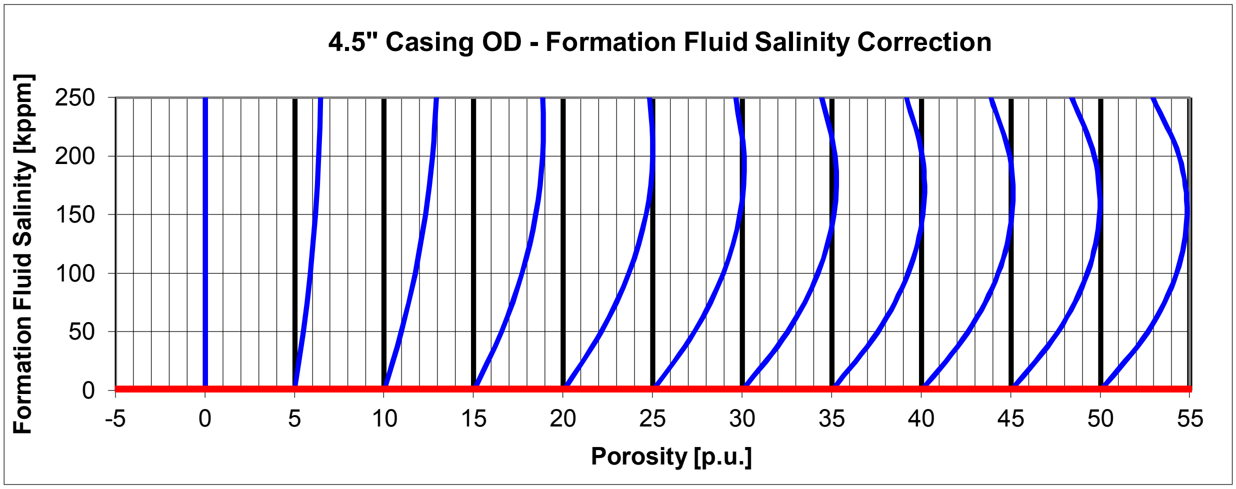
Cased Hole Corrections – Borehole Fluid Salinity – Eccentralized

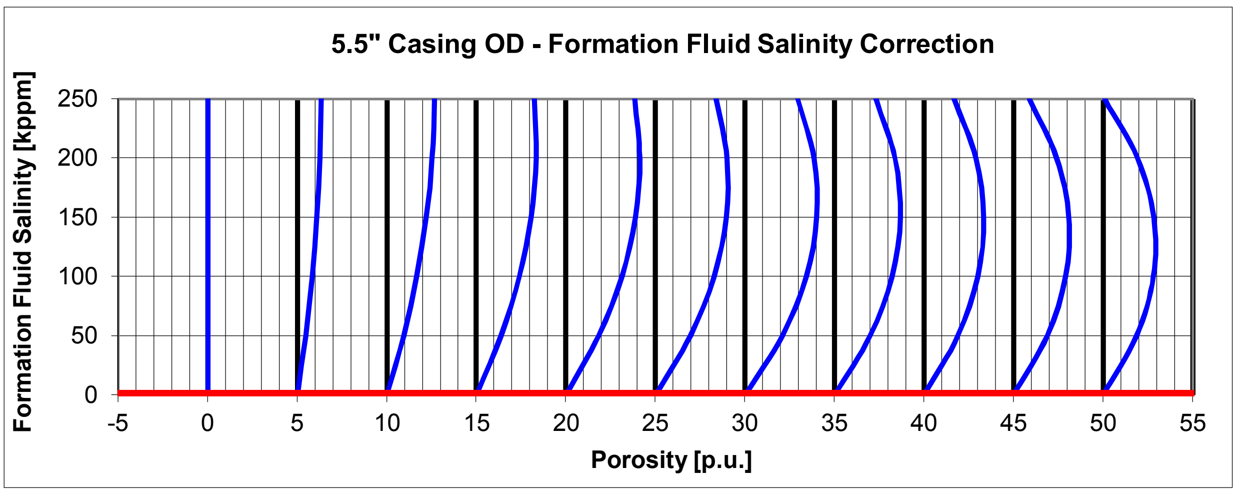


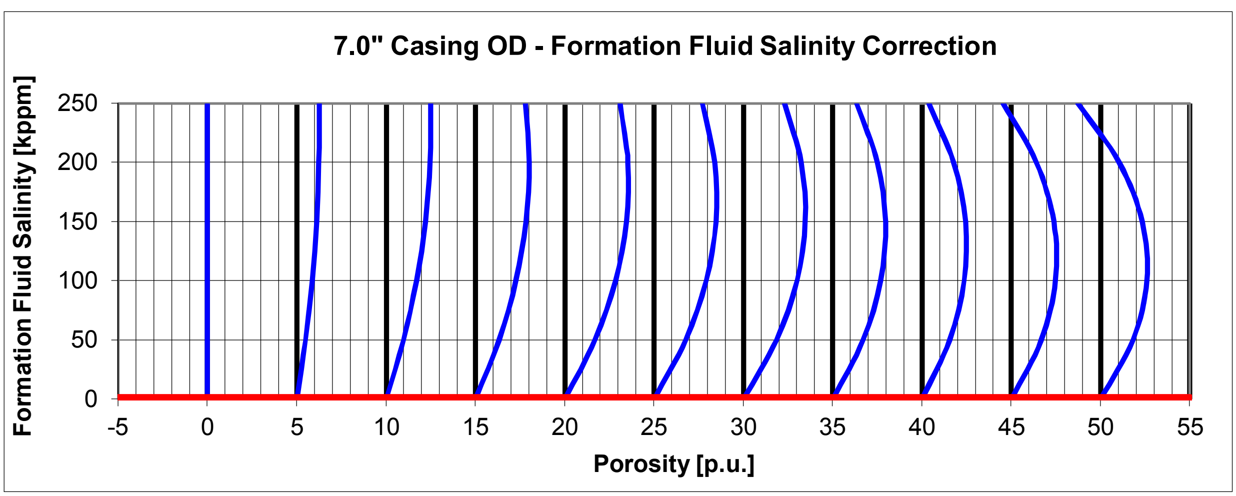


U-FLT CNL009 – Californium 252

Cased Hole Corrections – Formation Fluid Salinity – Eccentralized

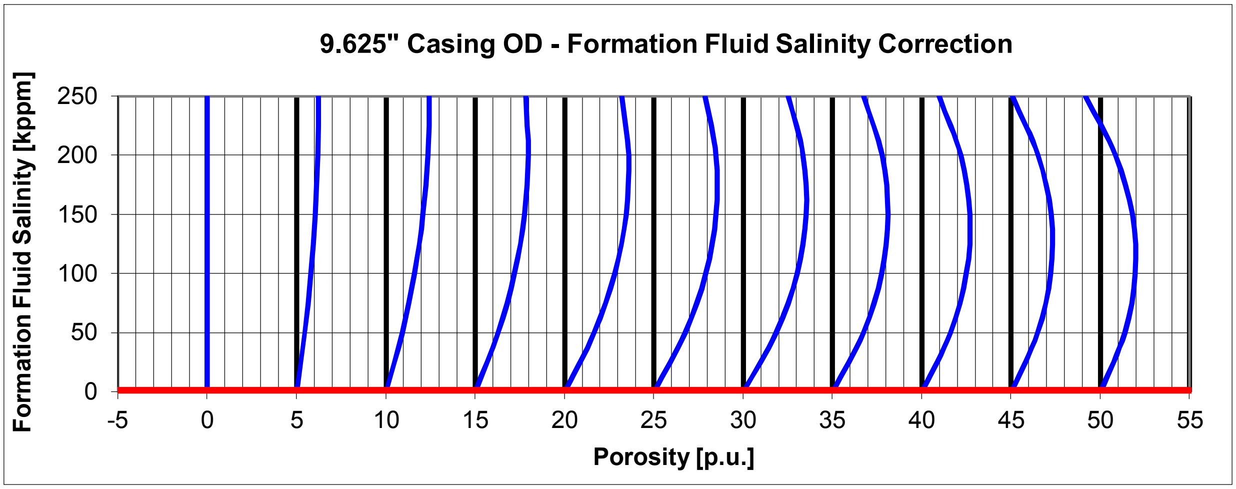


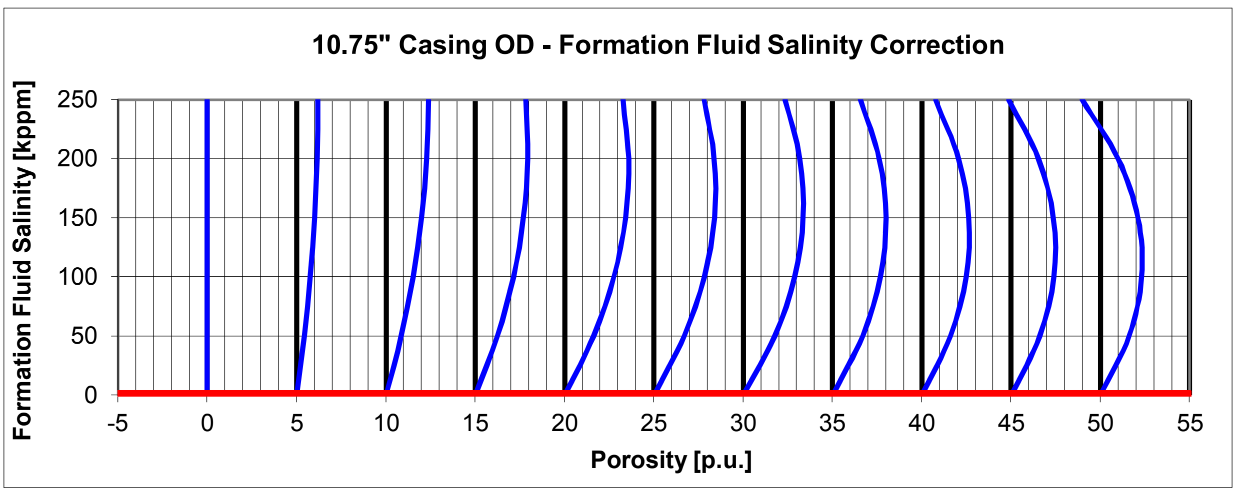




U-FLT CNL009 – Californium 252

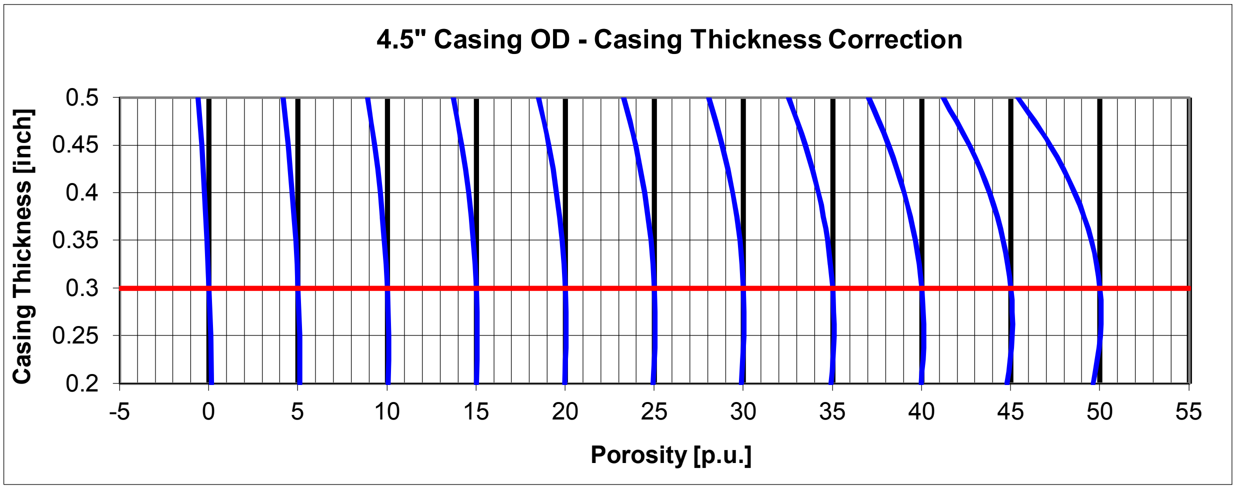
Cased Hole Corrections – Formation Fluid Salinity – Eccentralized

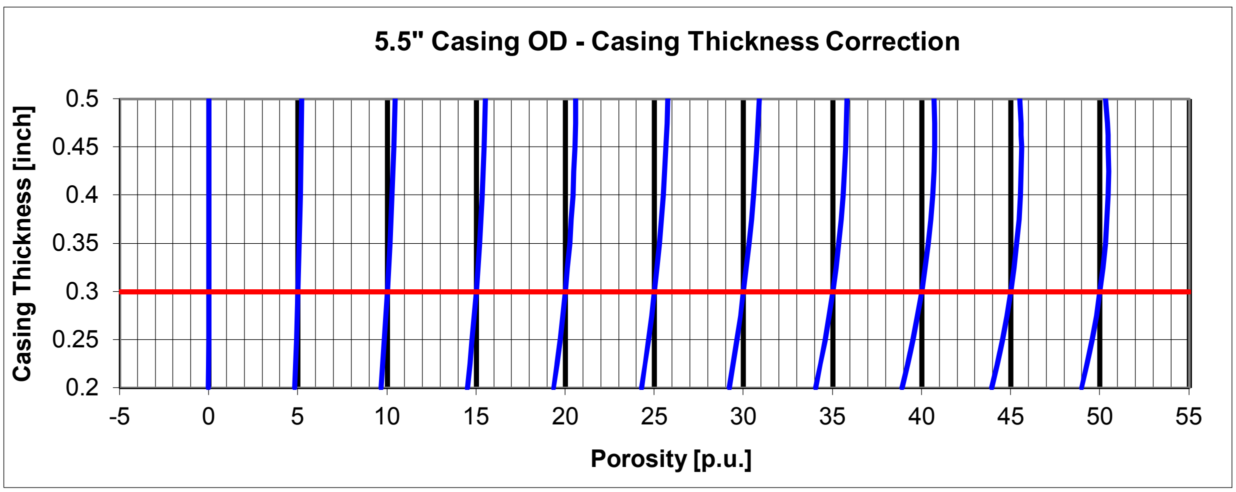


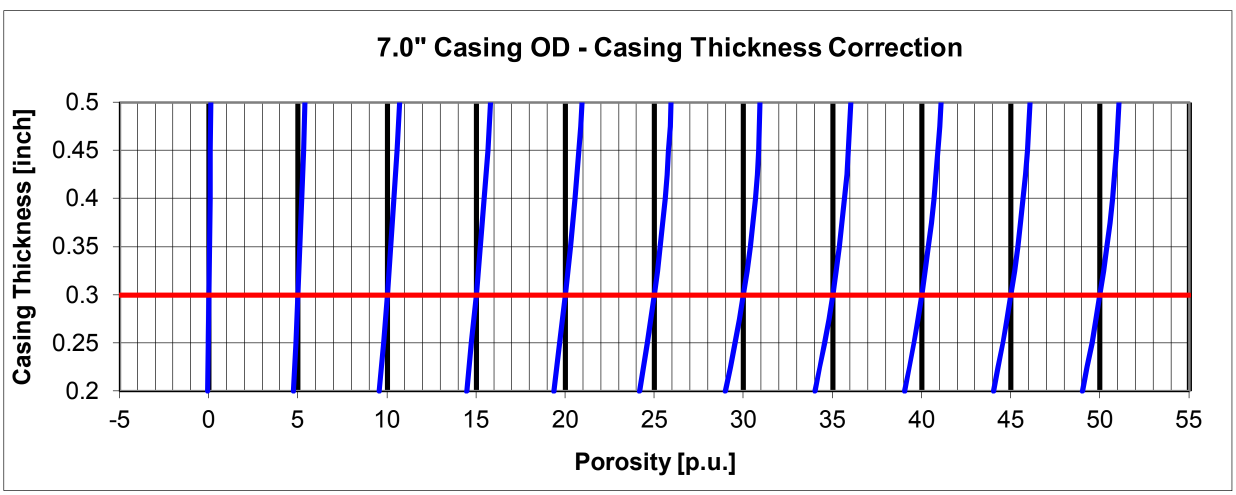


U-FLT CNL009 – Californium 252

Cased Hole Corrections – Casing Thickness - Centralized

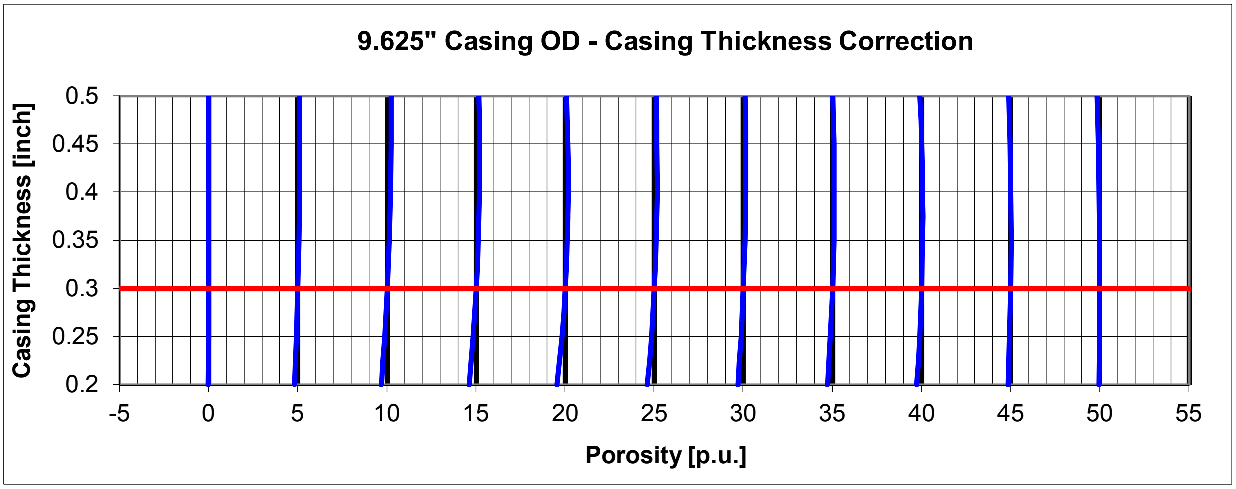


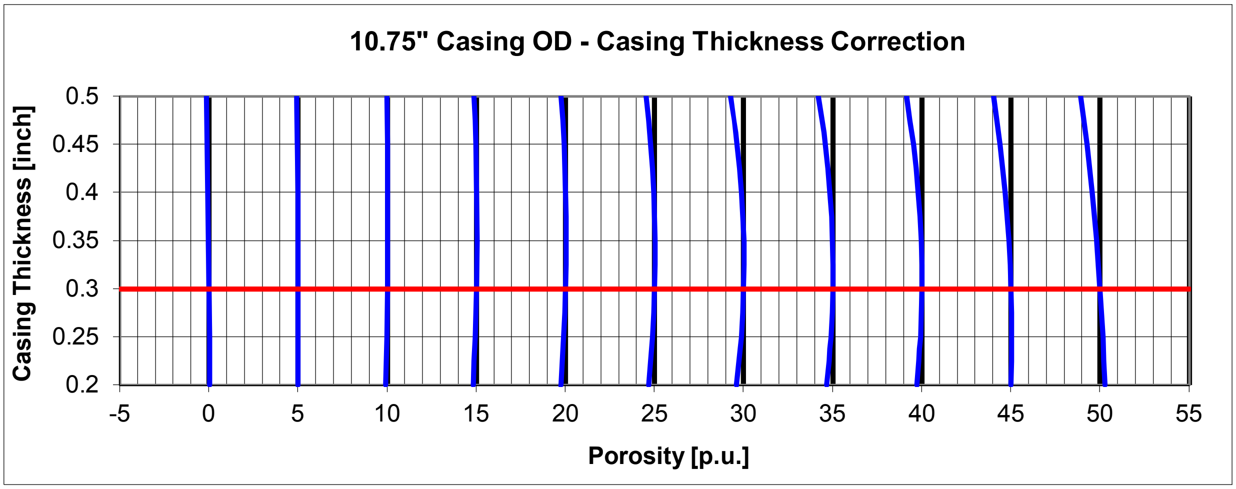




U-FLT CNL009 – Californium 252

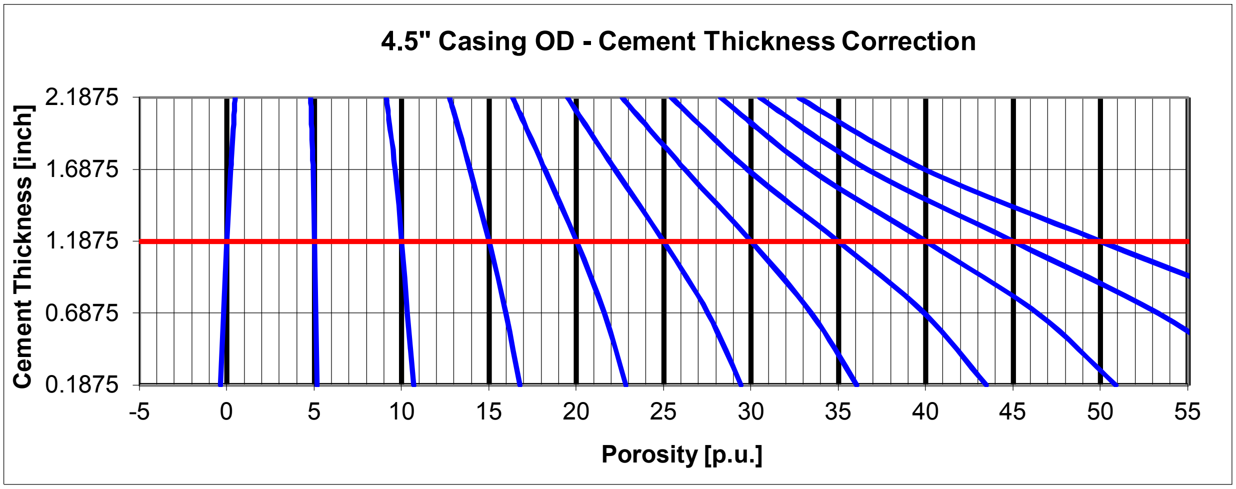
Cased Hole Corrections – Casing Thickness - Centralized

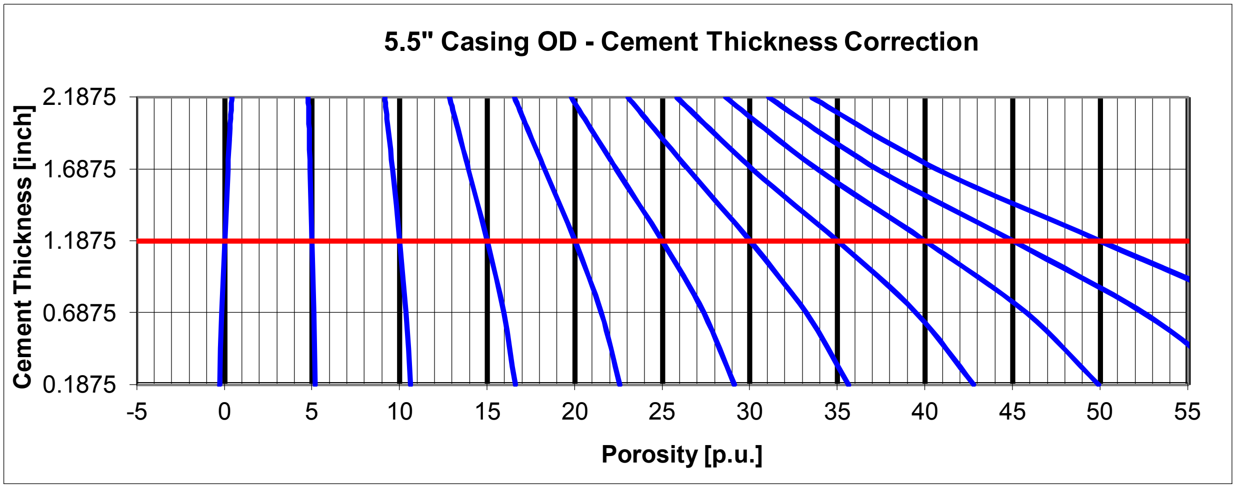


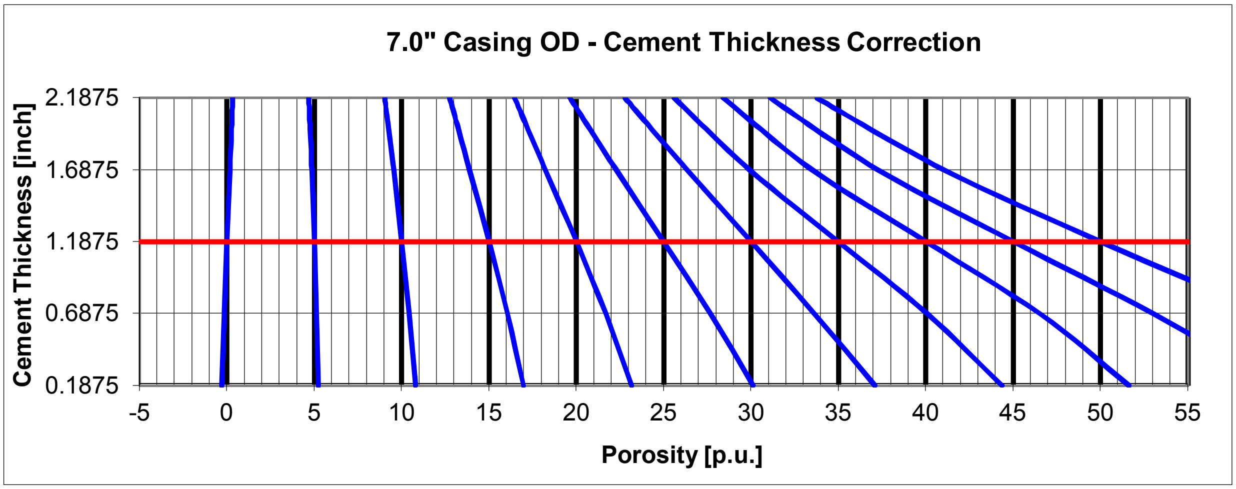


U-FLT CNL009 – Californium 252

Cased Hole Corrections – Cement Thickness - Centralized

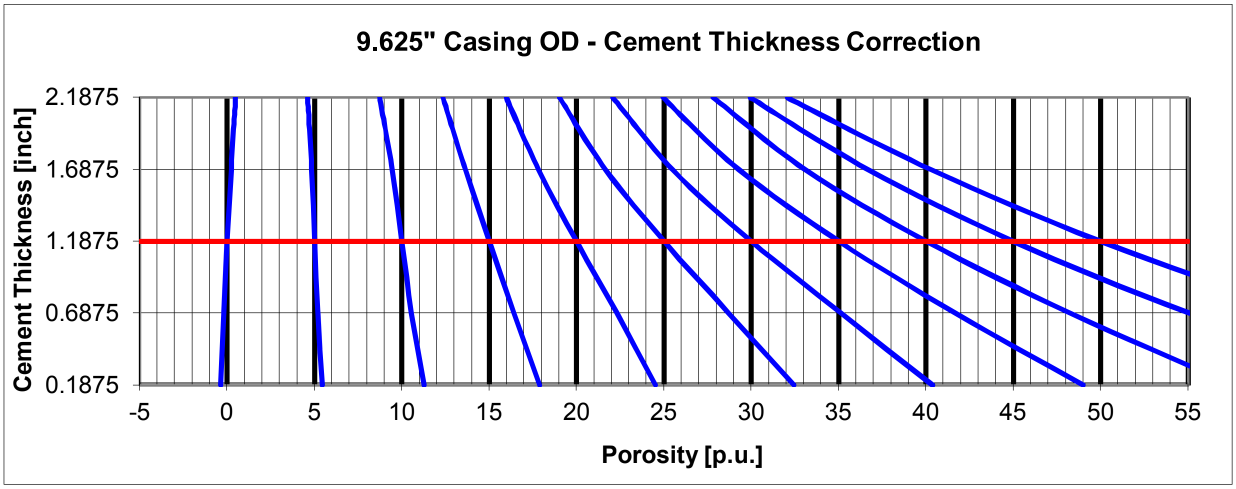


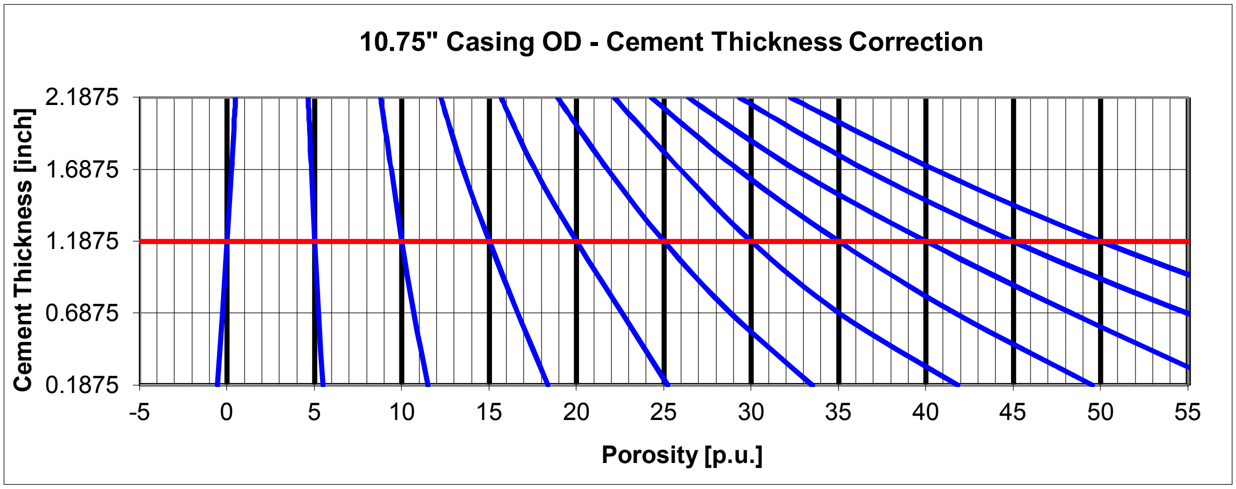




U-FLT CNL009 – Californium 252

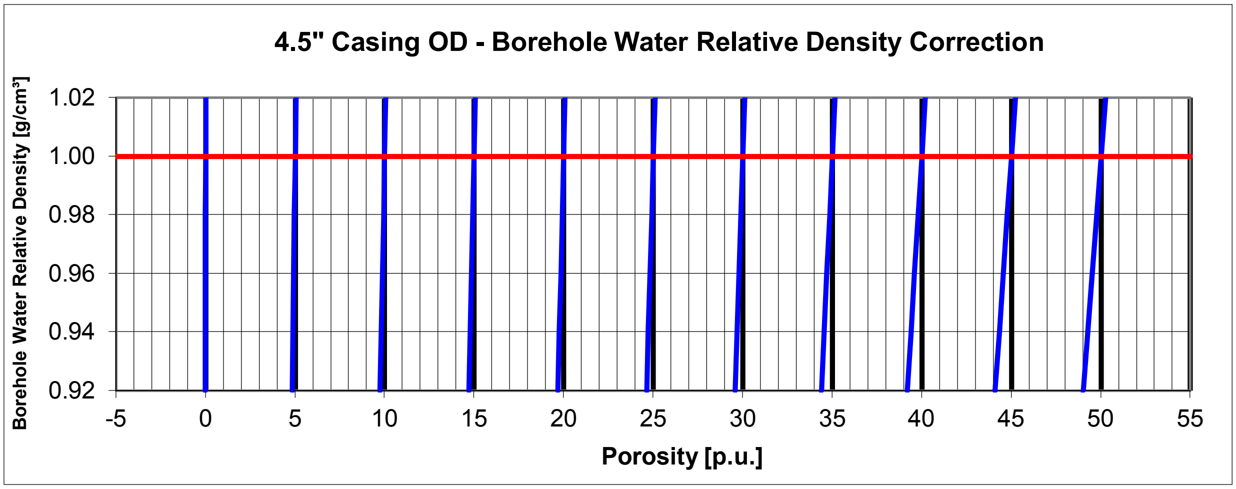
Cased Hole Corrections – Cement Thickness – Centralized

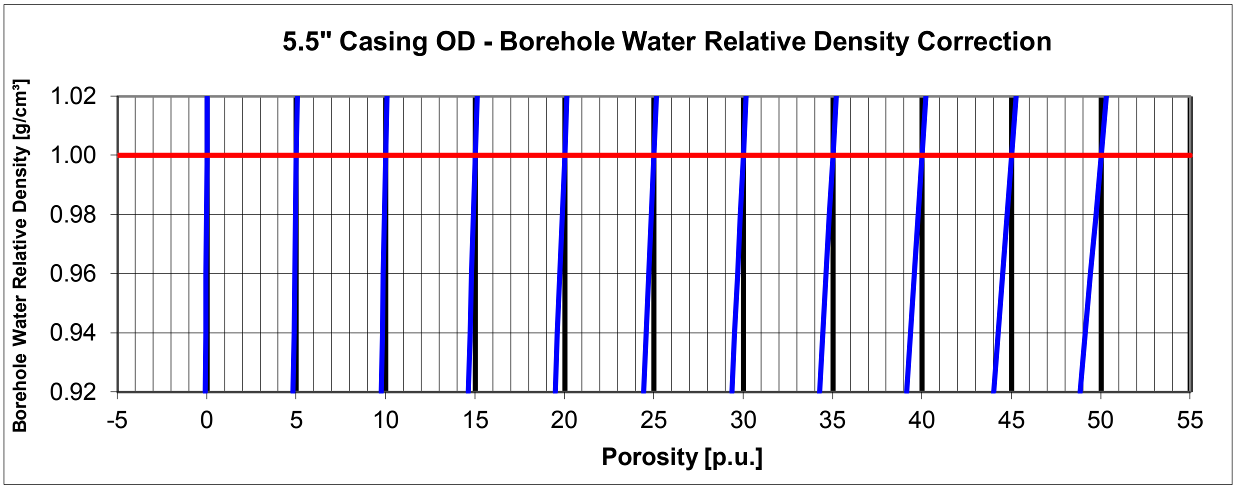


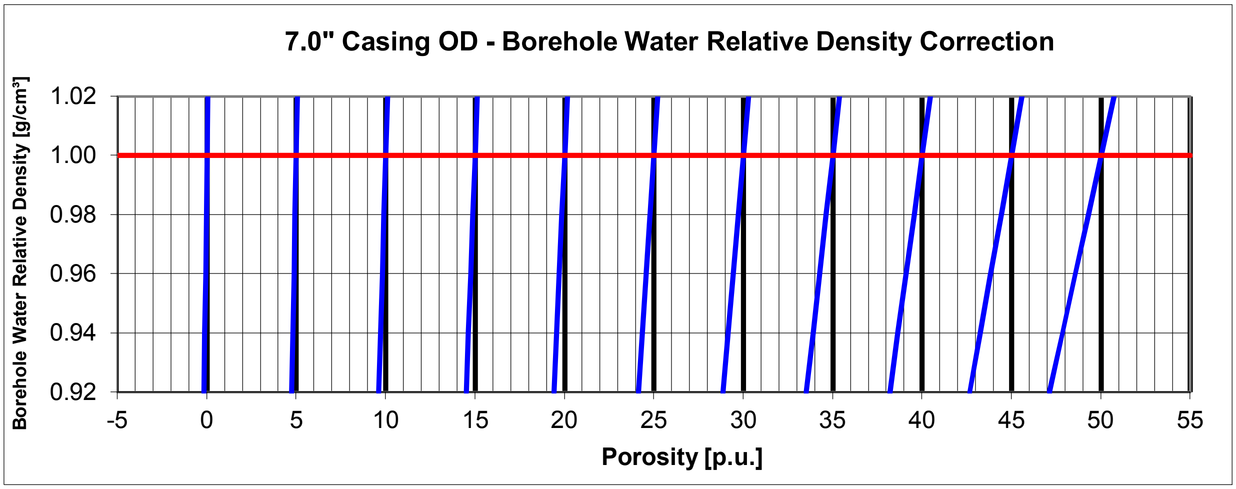


U-FLT CNL009 – Californium 252

Cased Hole Corrections – Borehole Water Relative Density - Centralized

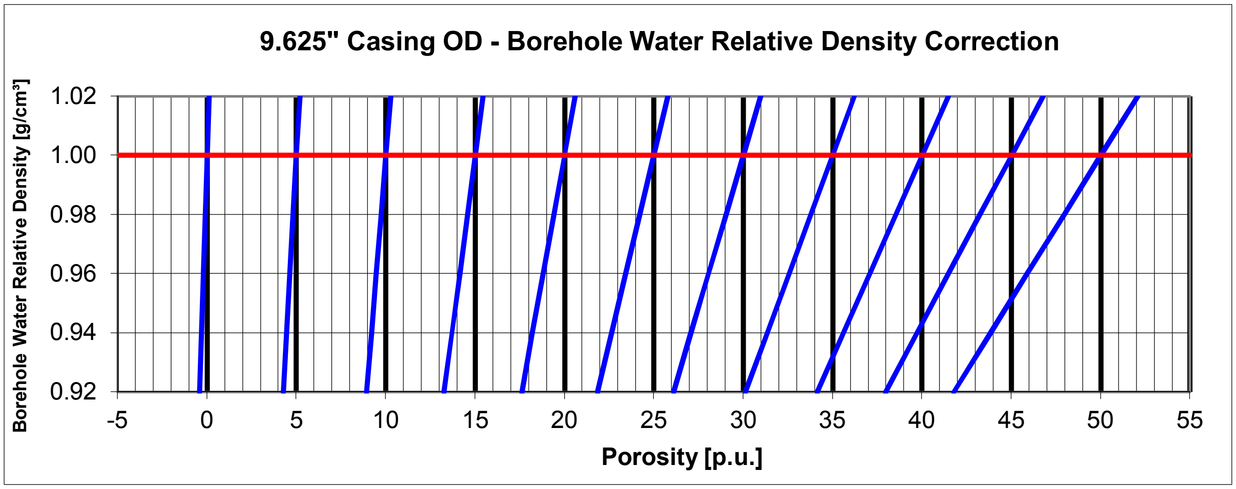


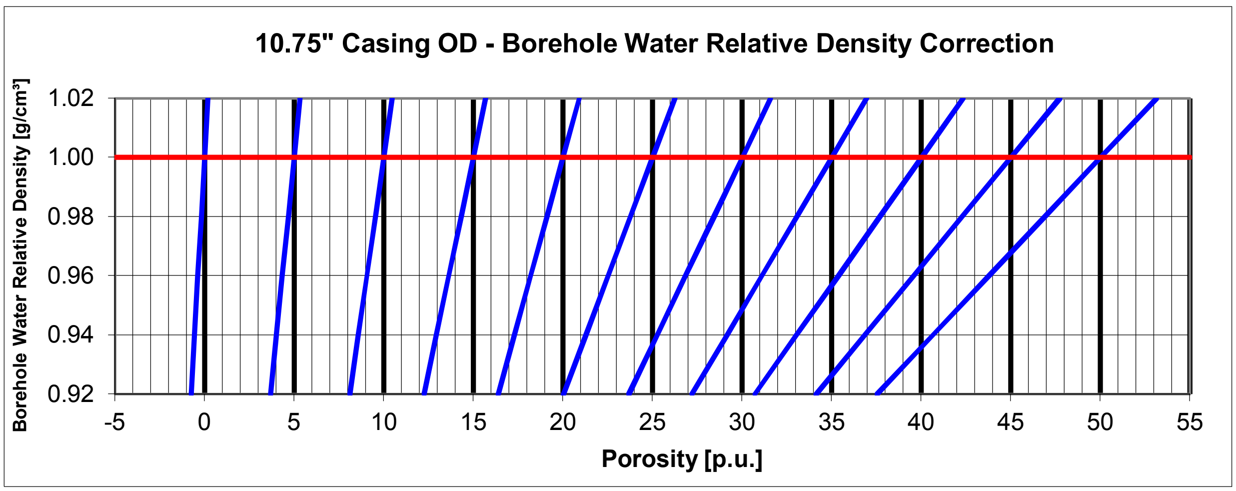




U-FLT CNL009 – Californium 252

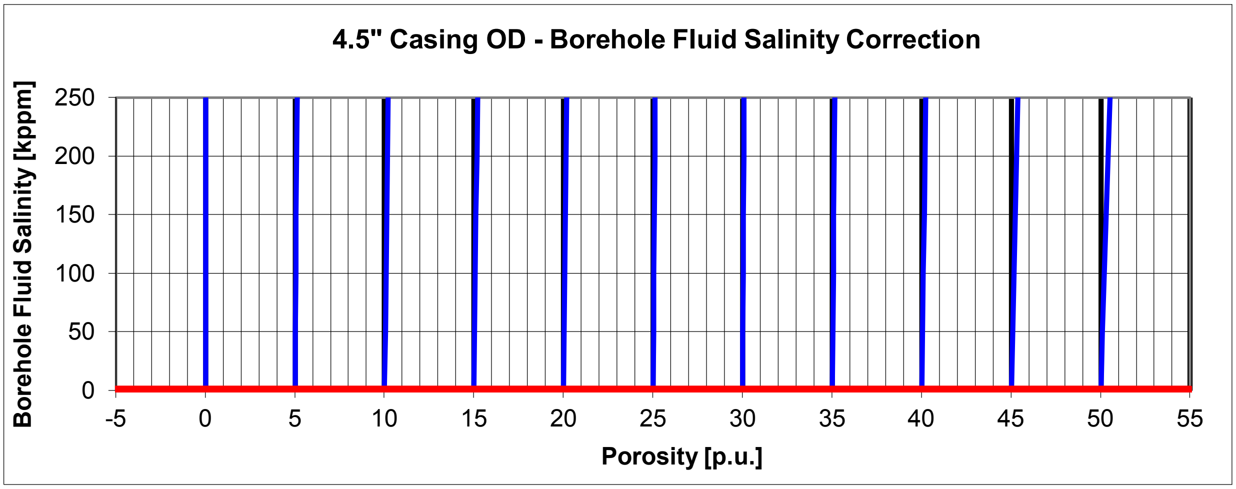
Cased Hole Corrections – Borehole Water Relative Density - Centralized

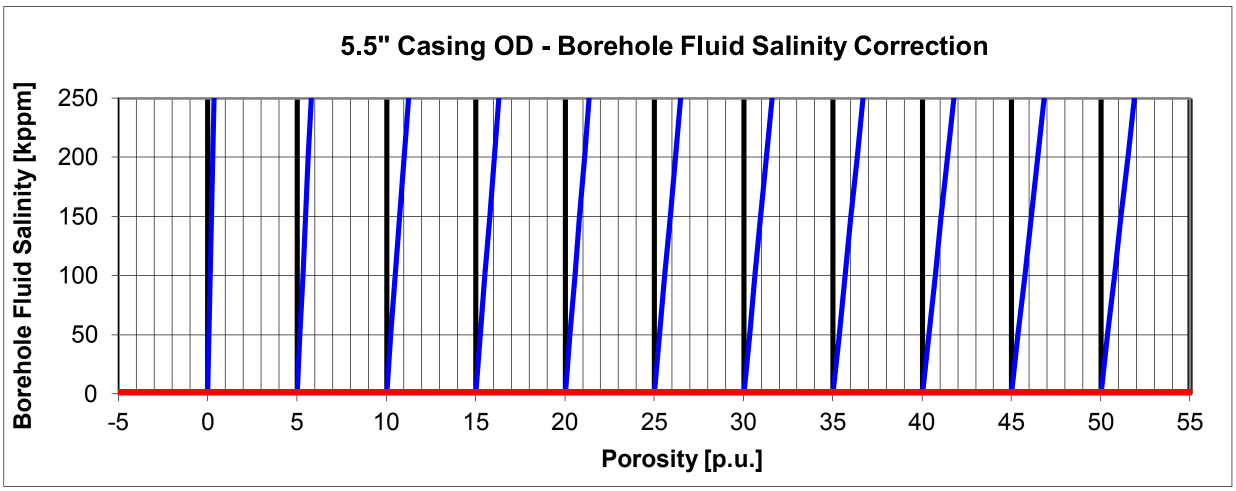


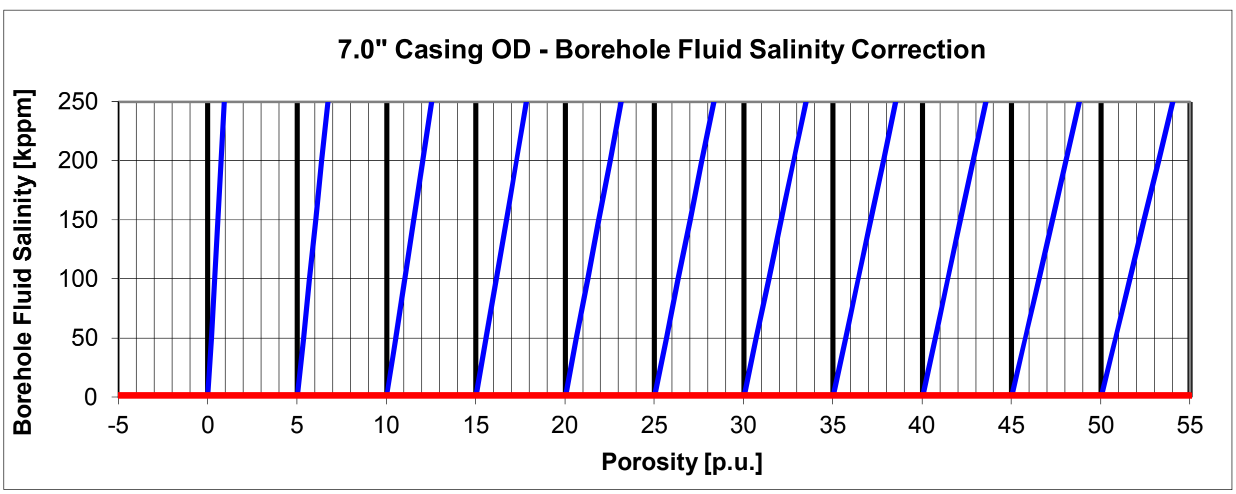


U-FLT CNL009 – Californium 252

Cased Hole Corrections – Borehole Fluid Salinity – Centralized

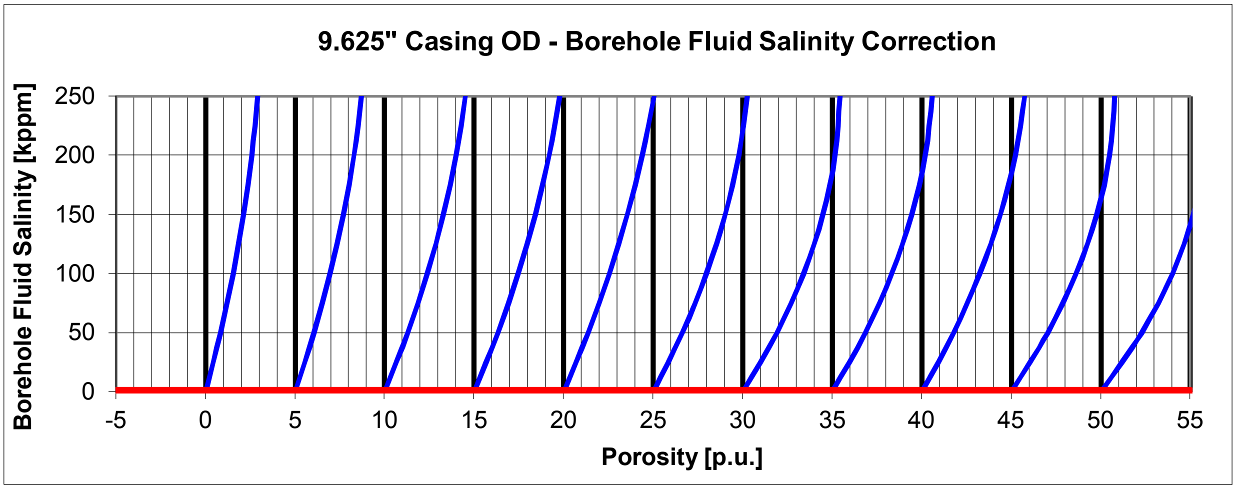


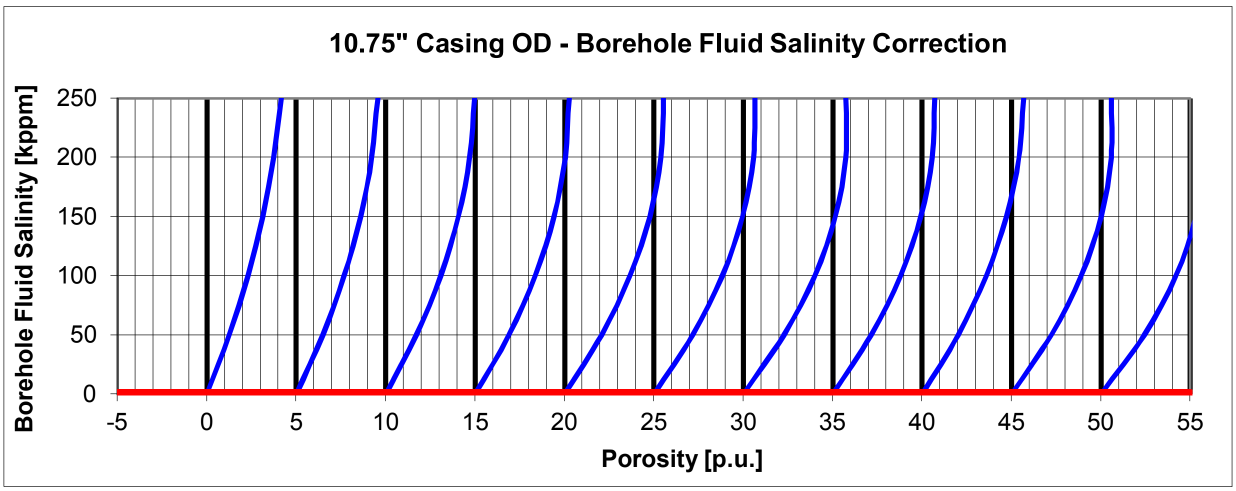




U-FLT CNL009 – Californium 252

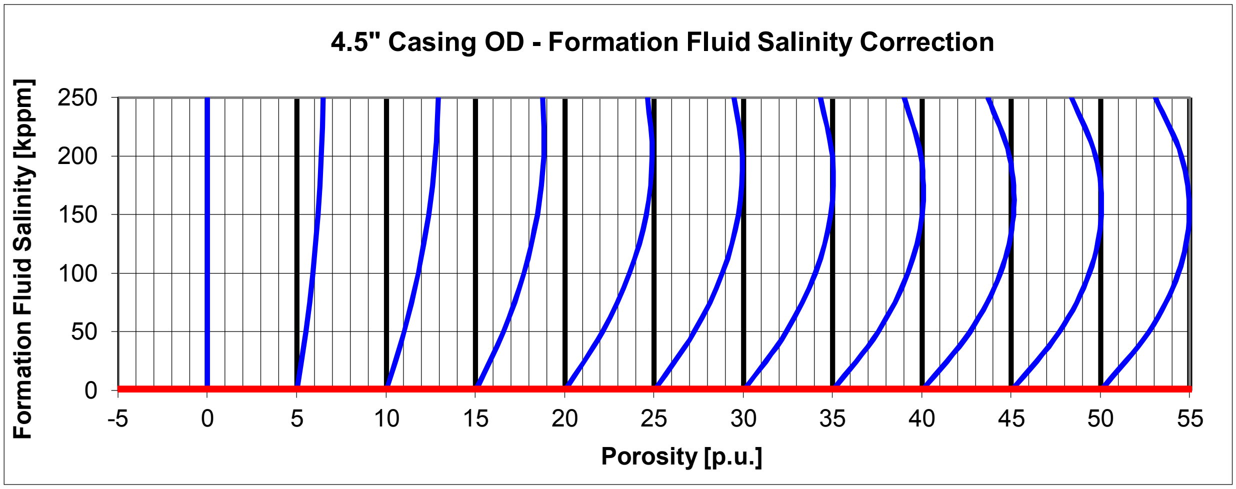
Cased Hole Corrections – Borehole Fluid Salinity – Centralized

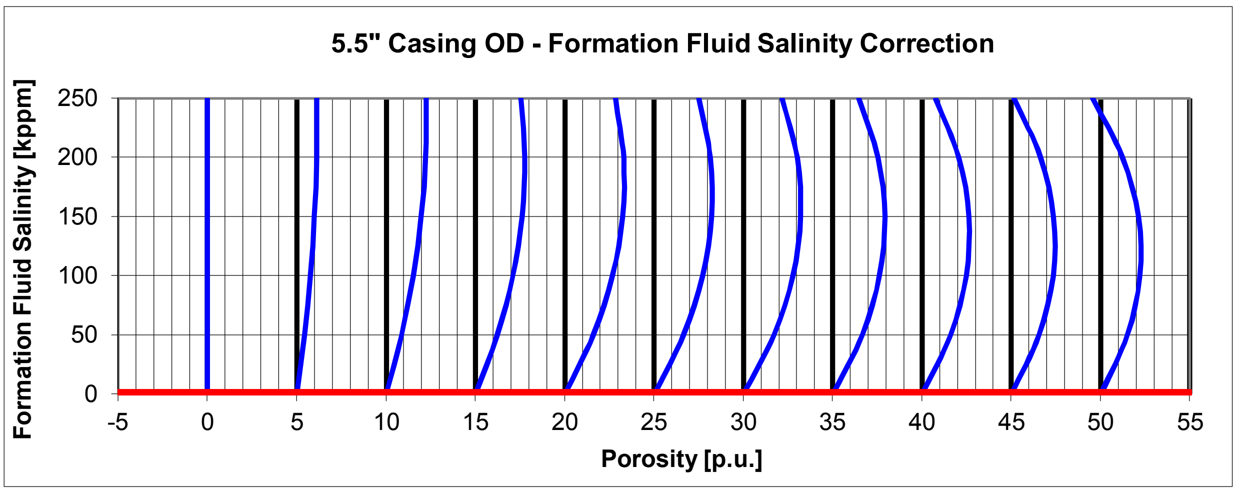


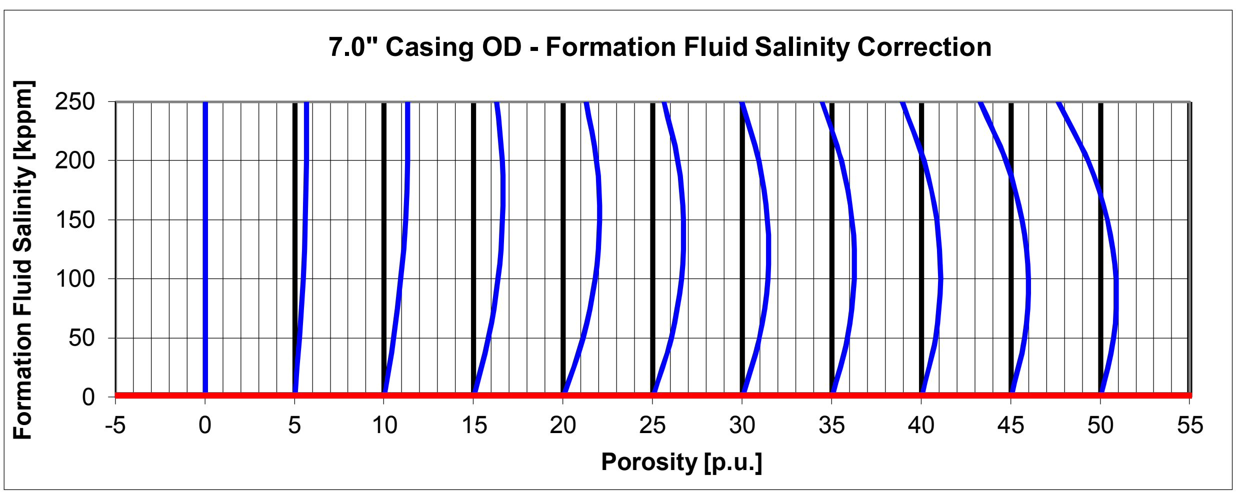


U-FLT CNL009 – Californium 252

Cased Hole Corrections – Formation Fluid Salinity – Centralized

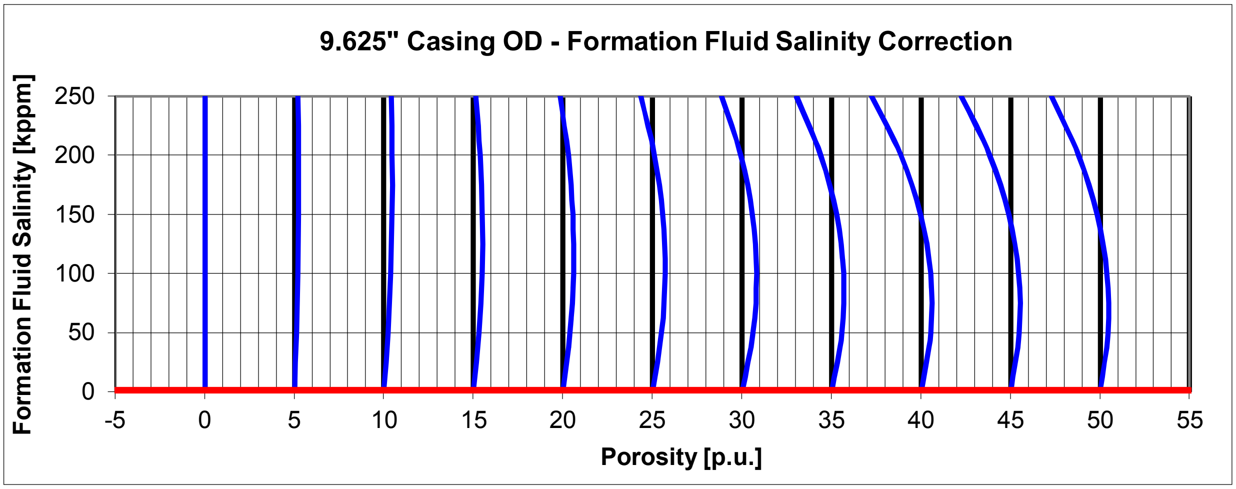


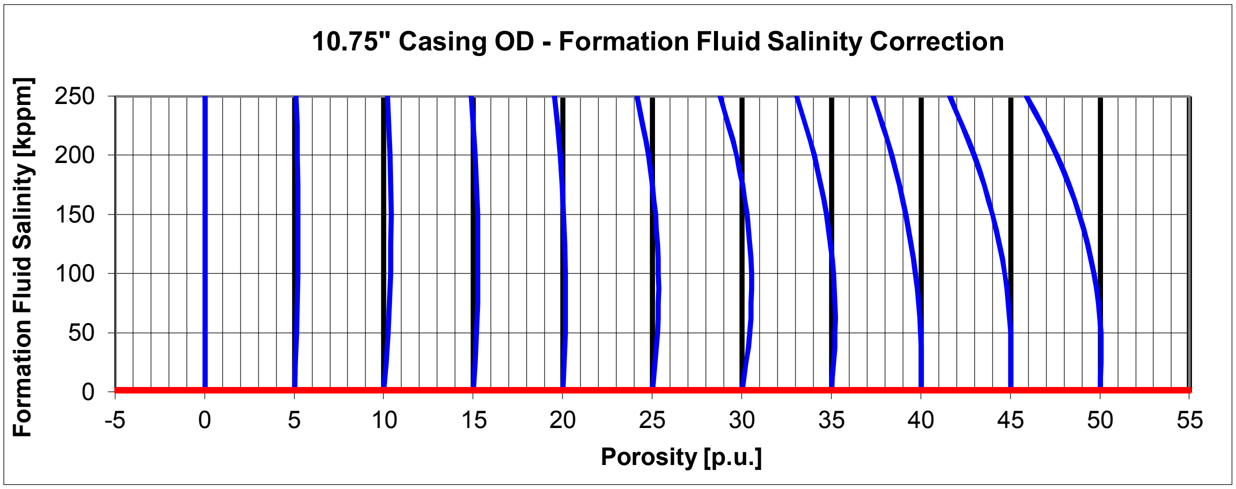




U-FLT CNL009 – Californium 252

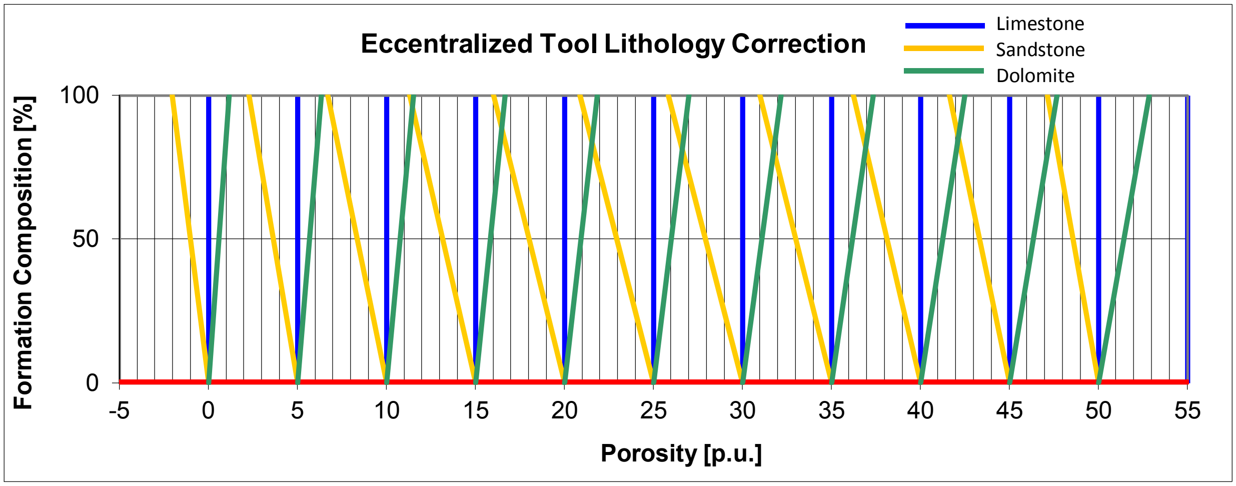
Cased Hole Corrections – Formation Fluid Salinity – Centralized

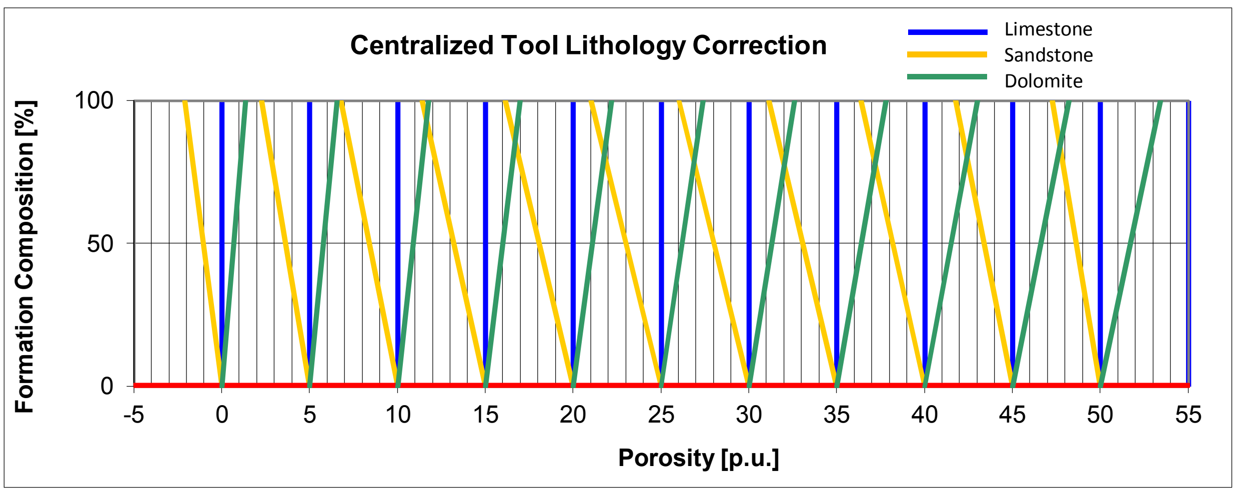




U-FLT CNL009 – Californium 252

Cased Hole Lithology Corrections





Determination of Density Porosity from Bulk Density

Purpose

This chart may be used to estimate the density porosity given the bulk log density, formation fluid density and the formation matrix.

Procedure

To estimate the density porosity (Φ_D) enter the chart on the horizontal axis at the appropriate bulk density (ρ_B) value as read from the log. Project this line vertically until it intersects the desired matrix curve. Project the intersection point horizontally to determine the density porosity from the vertical axis.

Example

Given

ρ_B = 6.2 g/cm^3
ρ_f = 1.0 g/cm^3

Find

Estimate the density porosity on a limestone matrix.

Answer

From the 6.2 g/cm^3 point on the horizontal axis project vertically into the chart until the line intersects the limestone matrix curve (2.710 g/cm^3). At the intersection point project horizontally to read the density porosity on a limestone matrix of 5 p.u.

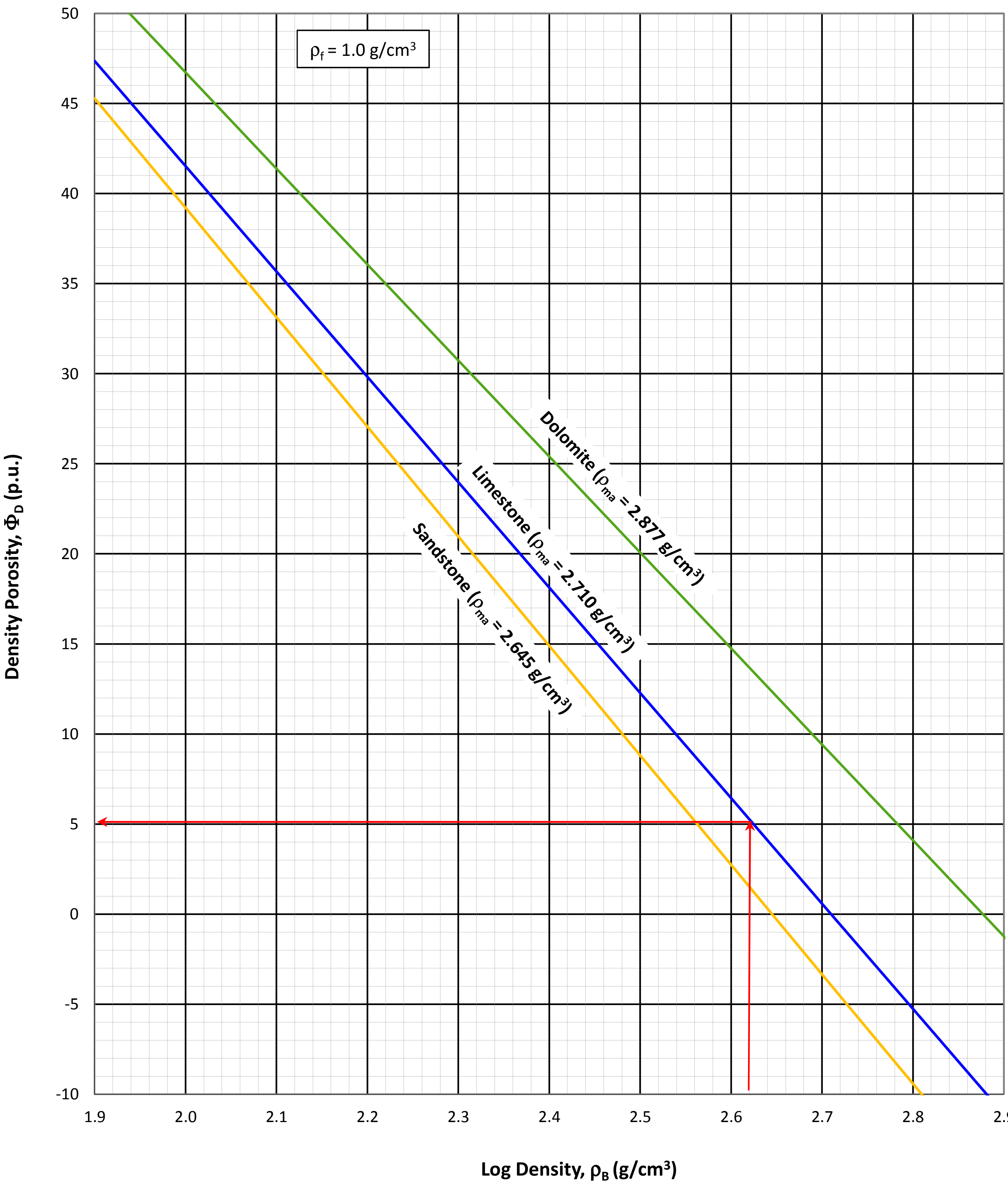
Equations

ρ_B = log bulk density
ρ_f = fluid density in formation
ρ_{ma} = matrix density
Φ_D = density porosity

The density porosity can be calculated using the following equation. The result will be in porosity units.

$$\Phi_D = \left(\frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f}\right) \times 100$$

Density Porosity from Bulk Density



Determination of Density Porosity and Lithology from LDT Log

Purpose

This chart may be used to estimate the density porosity and the lithology of a formation from the Litho-Density Tool (LDT). There are separate charts for both fresh water (ρ_f=1.0) and salt water (ρ_f=1.1)

Procedure

Choose the appropriate chart for either fresh (POR 2) or salt water (POR 3) formations. To estimate the density porosity (Φ_D) and lithology enter the chart on the vertical axis at the appropriate bulk density (ρ_B) value as read from the log. Enter the chart on the horizontal axis at the Pe value as read from the log and project vertically. At the intersection of the two projections read the porosity and lithology.

Example

Given

ρ_B = 2.72 g/cm^3
Pe = 3.05
ρ_f = 1.0 g/cm^3

Find

Estimate the density porosity and lithology.

Answer

From the Pe = 3.05 point on the horizontal axis project vertically into the chart until the line intersects the horizontal projection of the bulk density ρ_B = 2.72. At the intersection point read the density porosity and lithology in this instance to be a Dolomite with a porosity of 8.3 %.

Equations

ρ_B = log bulk density
ρ_f = fluid density in formation
ρ_{ma} = matrix density
Φ_D = density porosity
Pe = photoelectric factor
U_f = fluid volumetric photoelectric factor

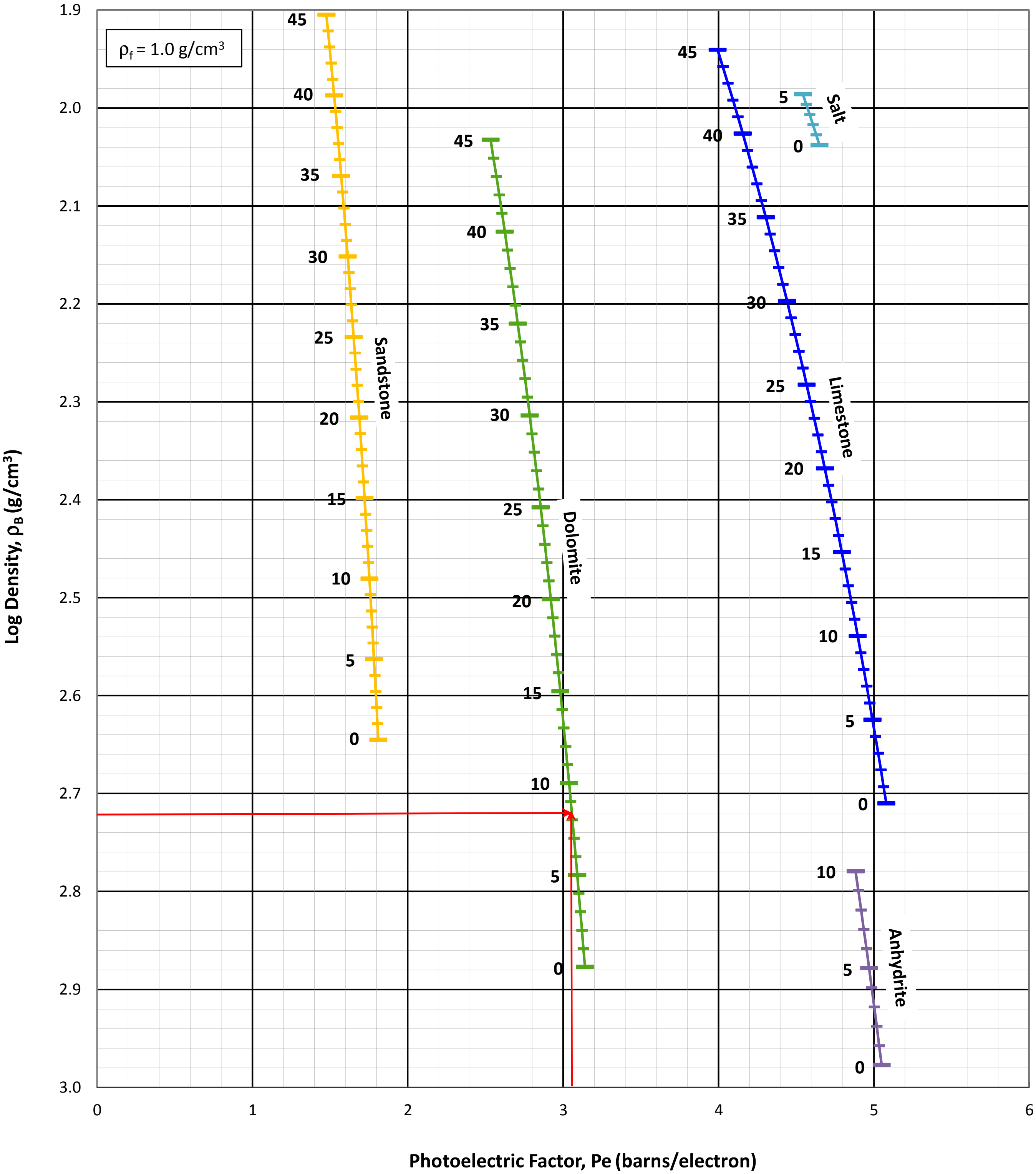
The bulk density can be calculated using the following equation.

$$\rho_b = \Phi \times \rho_f + (1 - \Phi) \times \rho_{ma}$$

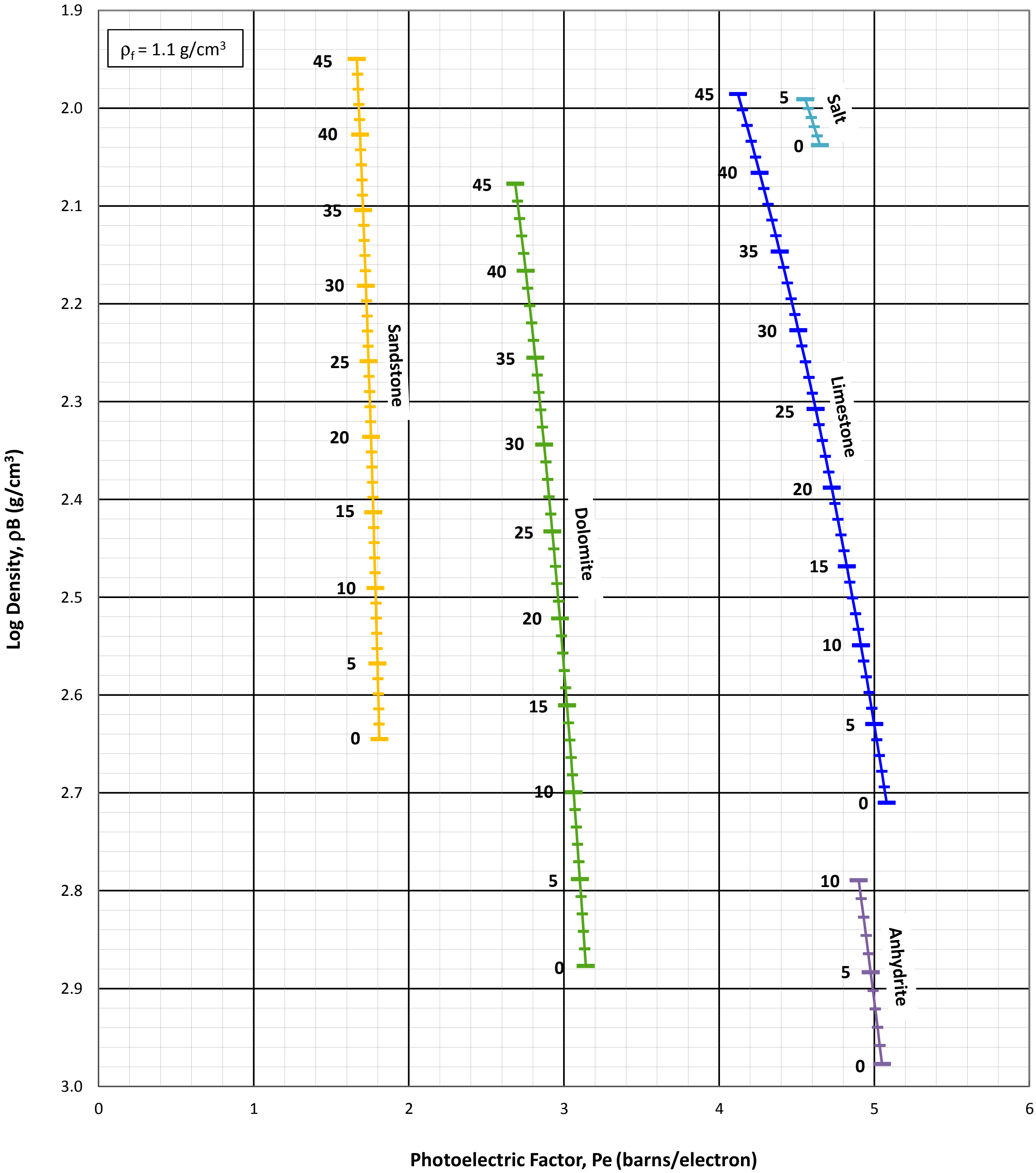
The Pe is calculated using the following equation.
Where:
U_f = 0.398 barns/cm^3 for fresh water
U_f = 1.36 barns/cm^3 for salt water

$$Pe = \left(\frac{(\Phi \times U_f) + (1 - \Phi)(Pe_{ma} \times \rho_{ma})}{\rho_b}\right)$$

Porosity and Lithology from LDT Log



Porosity and Lithology from LDT Log



Mineral Identification Plot (ρ_{maa} vs U_{maa})

Purpose

This chart may be used to identify formation mineralogy from the apparent matrix density and the apparent matrix volumetric photoelectric factor.

Procedure

To estimate the mineral type, enter the chart on the vertical axis at the apparent matrix density (ρ_{maa}) value. Enter the chart on the horizontal axis at the apparent matrix volumetric photoelectric factor (U_{maa}) and project vertically. At the intersection of the two projections determine the percentage of the component minerals.

Note

The effect of gas and barite is to shift the intersection point in the direction shown by the arrows.
A proportionality triangle may be constructed from any three minerals.

Example

Given

ρ_{maa} = 2.73 g/cm^3
U_{maa} = 7.4

Find

Estimate the mineral composition of the formation.

Answer

From the U_{maa} = 7.4 point on the horizontal axis project vertically into the chart until the line intersects the horizontal projection of the ρ_{maa} = 2.73. From the intersection point within the triangular area we can see that the formation is mainly a mixture of sandstone and dolomite.

To obtain more accurate values of the three mineral compositions we can project the intersection point parallel to the individual mineral component lines to intersect the outer boundaries of the mineral triangle. The percentage of the individual components is read from the scale on the outer lines. The formation is this example is approximately 53% sandstone, 33% dolomite and 14% limestone.

Equations

ρ_{log} = log bulk density
ρ_f = fluid density in formation
$\rho_f = 1.0\ g/cm^3$ for fresh water
$\rho_f = 1.1\ g/cm^3$ for salt water
ρ_{maa} = apparent matrix density
Φ = apparent formation porosity
Pe = photoelectric factor
U_f = fluid volumetric photoelectric factor
$U_f = 0.398\ barns/cm^3$ for fresh water
$U_f = 1.36\ barns/cm^3$ for salt water

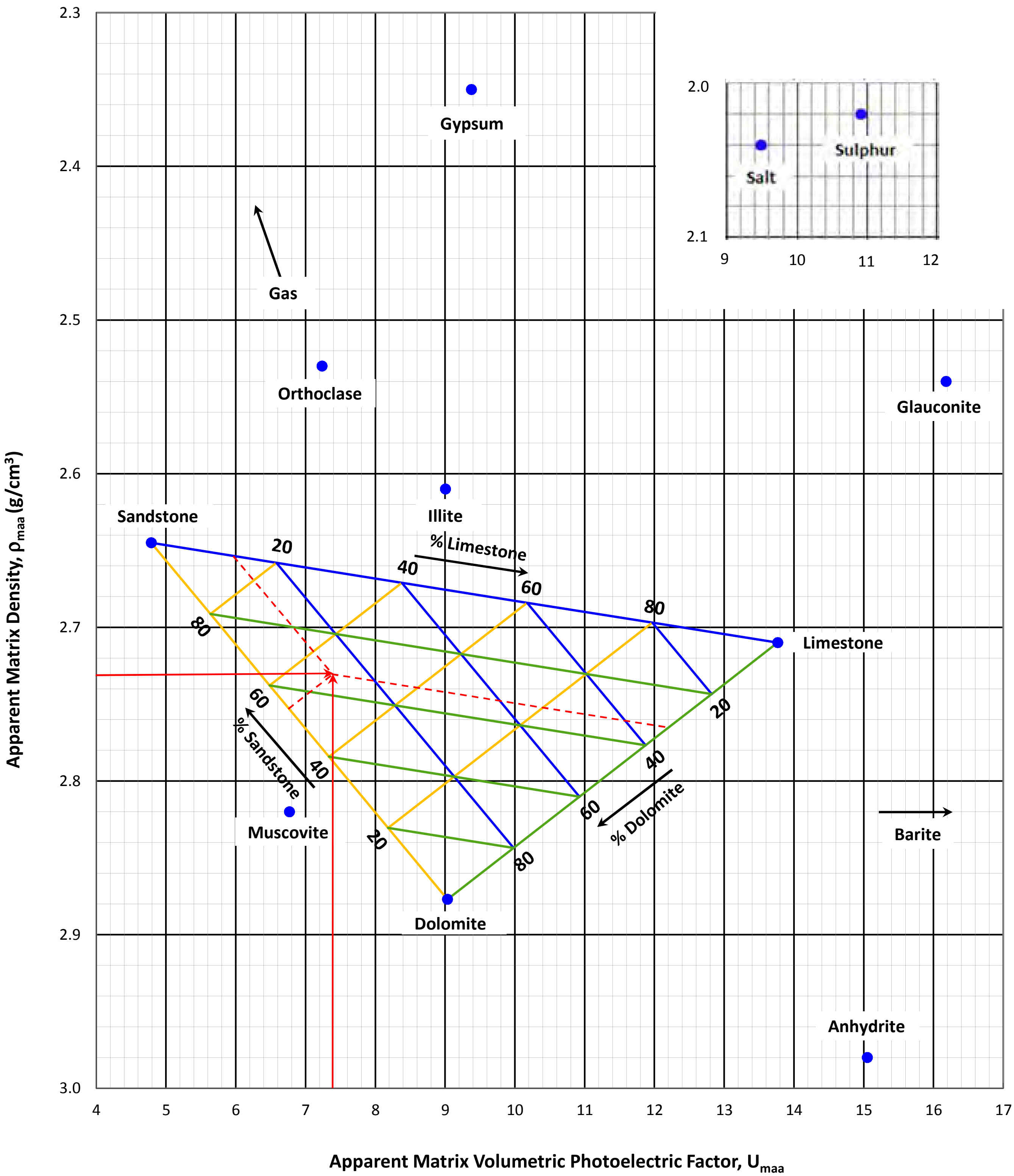
The apparent matrix density can be calculated using the equation:

$$\rho_{maa} = \left(\frac{(\rho_{log} - (\Phi \times \rho_f))}{(1 - \Phi)}\right)$$

The apparent volumetric photoelectric factor can be calculated using the equation:

$$U_{maa} = \left(\frac{(Pe_{log} \times \rho_{log}) - (\Phi \times U_f)}{(1 - \Phi)}\right)$$

Mineral Identification Plot (ρ_{ma_a} vs U_{ma_a})



Mineral Identification Plot (ρ_{maa} vs Δt_{maa})

Purpose

This chart may be used to identify formation mineralogy from the apparent matrix density and the apparent sonic interval transit time of the formation matrix.

Procedure

To estimate the mineral type, enter the chart on the vertical axis at the apparent matrix density (ρ_{maa}) value. Enter the chart on the horizontal axis at the sonic interval transit time (Δt_{maa}) and project vertically. At the intersection of the two projections determine the percentage of the component minerals by following each of the component lines back to the baseline and reading the percentage.

Example

Given

ρ_{maa} = 2.69 g/cm^3

Δt_{maa} = 51 μsec/ft

Find

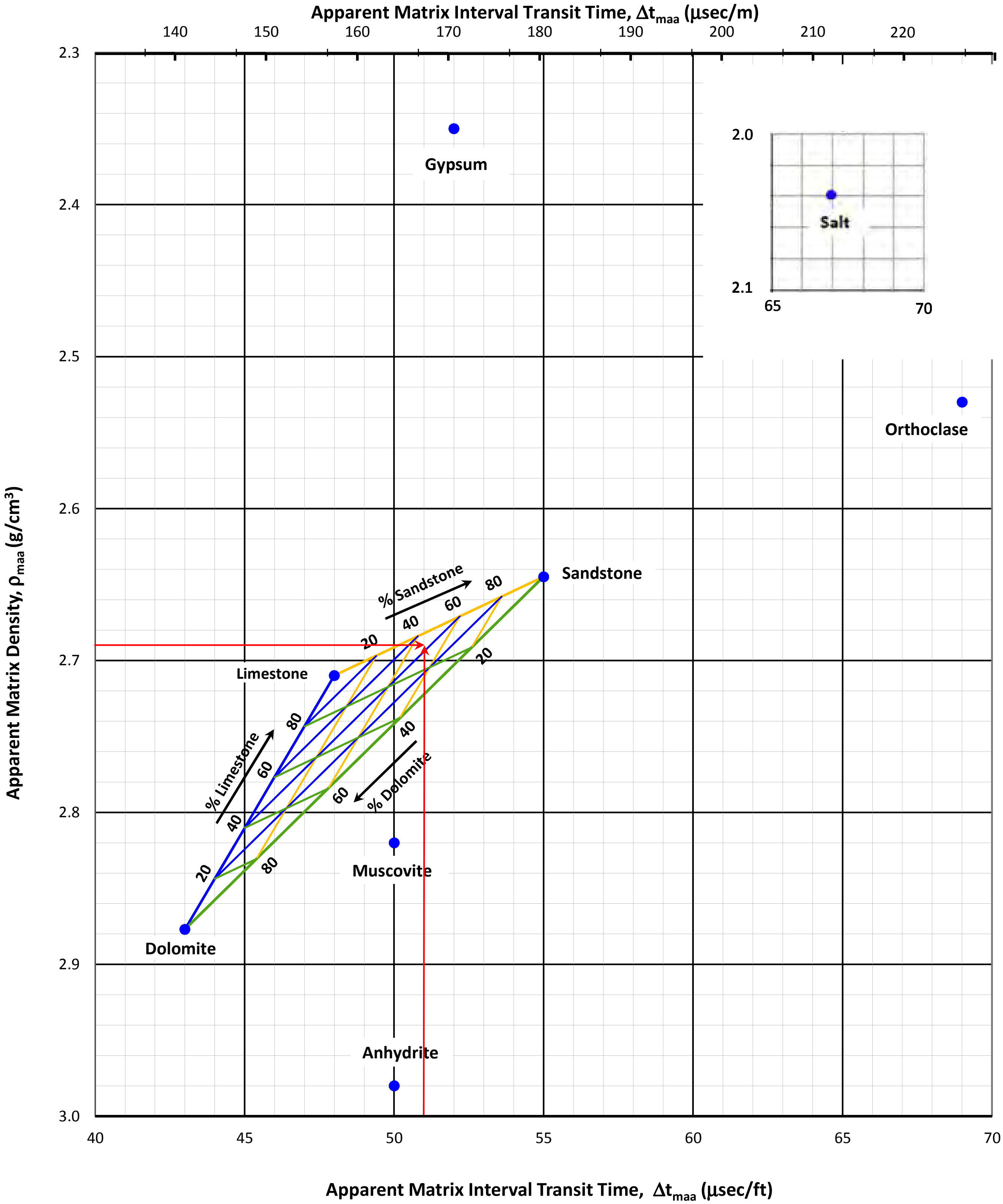
Estimate the mineral composition of the formation.

Answer

From the Δt_{maa} = 51 position on the horizontal axis project vertically into the chart until the line intersects the horizontal projection of the ρ_{maa} = 2.69 g/cm^3. From the intersection point within the triangular area we can see that the formation is mainly a mixture of sandstone and limestone.

To obtain more accurate values of the three mineral compositions we can project the intersection point parallel to the individual mineral component lines to intersect the outer boundaries of the mineral triangle. The percentage of the individual components is read from the scale on the outer lines. The formation is this example is approximately 53% sandstone, 42% limestone and 5% dolomite.

Mineral Identification Plot (ρ_{ma_a} vs Δt_{ma_a})



MAS Tool 3 Foot Receiver				Travel Time				
Casing Size (in)	Casing Weight (lb/ft)	Casing ID (in)	Amplitude (mV)	6 kHz (µsec)	8 kHz (µsec)	10 kHz (µsec)	12 kHz (µsec)	18 kHz (µsec)
4	**11.6**	**3.428**	87	310	279	260	247	227
4-1/2	**9.5**	**4.090**	81	320	289	270	257	237
	11.6	**4.000**	81	319	287	269	256	235
	13.5	**3.920**	81	317	286	267	255	234
5	**15.0**	**4.408**	76	325	293	275	262	241
	18.0	**4.276**	76	323	291	273	260	239
	21.0	**4.154**	76	321	290	271	258	238
5-1/2	**13.0**	**5.044**	72	344	303	284	272	251
	15.5	**4.950**	72	333	302	283	270	249
	17.0	**4.892**	72	332	301	282	269	249
	20.0	**4.778**	72	330	299	280	268	247
	23.0	**4.670**	72	329	297	279	266	245
7	**23.0**	**6.366**	62	354	323	304	292	271
	26.0	**6.276**	62	353	321	303	290	269
	29.0	**6.184**	62	351	320	301	289	268
	32.0	**6.094**	62	350	319	300	287	267
	35.0	**6.004**	62	349	317	299	286	265
	38.0	**5.920**	62	347	316	297	285	264
8-5/8	**28.0**	**8.017**	55	379	348	329	316	296
	32.0	**7.921**	55	377	346	327	315	294
	36.0	**7.825**	55	376	345	326	313	293
	40.0	**7.725**	55	374	343	324	312	291
	44.0	**7.625**	55	373	342	323	310	290
9-5/8	**40.0**	**8.835**	51	391	360	341	329	308
	43.5	**8.755**	51	390	359	340	327	307
	47.0	**8.681**	51	389	358	339	326	305
	53.5	**8.535**	51	387	355	337	324	303
10-3/4	**40.5**	**10.050**	48	409	378	359	347	326
	45.5	**9.950**	48	408	377	358	345	325
	51.0	**9.850**	48	406	375	356	344	323
	55.5	**9.760**	48	405	374	355	343	322
11-3/4	**47.0**	**11.000**	45	424	392	374	361	340
	54.0	**10.880**	45	422	391	372	359	339
	60.0	**10.772**	45	420	389	370	358	337
12	**40.0**	**11.384**	45	429	398	379	367	346
13	**40.0**	**12.438**	43	445	414	395	383	362
13-3/8	**48.0**	**12.715**	42	449	418	399	387	366
16	**55.0**	**15.375**	38	489	458	439	427	406

Porosity and Lithology Determination
Compensated Neutron and Litho-Density Tool

Purpose

These charts may be used to determine the crossplot porosity and lithology mixture of a formation using the compensated neutron and litho-density logs. Separate charts are presented for both the bulk density and the density porosity verses the neutron porosity.

Charts for fresh water (ρ_f=0, C_f = 0 ppm) and saline fluids (ρ_f=1.19, C_f=250 kppm) are available.

Procedure

Enter the chart on the horizontal axis at the apparent limestone neutron porosity and project vertically to intersect the projection of the bulk density from the vertical axis. The intersection of the two projections determines the crossplot porosity and lithology mix.

The crossplot porosity is read by drawing a line between matching porosity scales on each of the two lithology curves.

If the intersection point is between two of the lithology curves then the formation is a mixture of those two lithologies. The position of the point between the two mineral curves relates the composition percentage of each mineral by proportioning the composition based on how close the plotted point is to each line. If the line is closer to one mineral line then there is a greater percentage of that mineral in the composition.

This chart works for formations with up to two mineral compositions. Possible mineral compositions may be:

- quartz – calcite
- quartz – dolomite
- dolomite – calcite

Example

Given

ρ_f = 1.0 g/cm^3

C_f= 0 ppm

Φ_N = 16 % on a limestone matrix

ρ_B = 2.36 g/cm^3

Find

Determine the crossplot porosity and the lithology mix.

Answer

On the XPL 1 chart project vertically from 16 % porosity on the horizontal axis to intersect the 2.38 g/cm3 projection from the vertical bulk density axis.

The intersection point lies between the sandstone and limestone curves on the chart as well as between the sandstone and dolostone curves. The lithology could then be either sandstone and limestone or sandstone and dolomite.

To determine the crossplot porosity and lithology mix requires that a line be drawn between the same porosity on the sandstone and limestone curves if the minerals are quartz and calcite (shown by a dashed line) or between the sandstone and dolostone curves if the minerals are quartz and dolomite (shown by a dotted line).

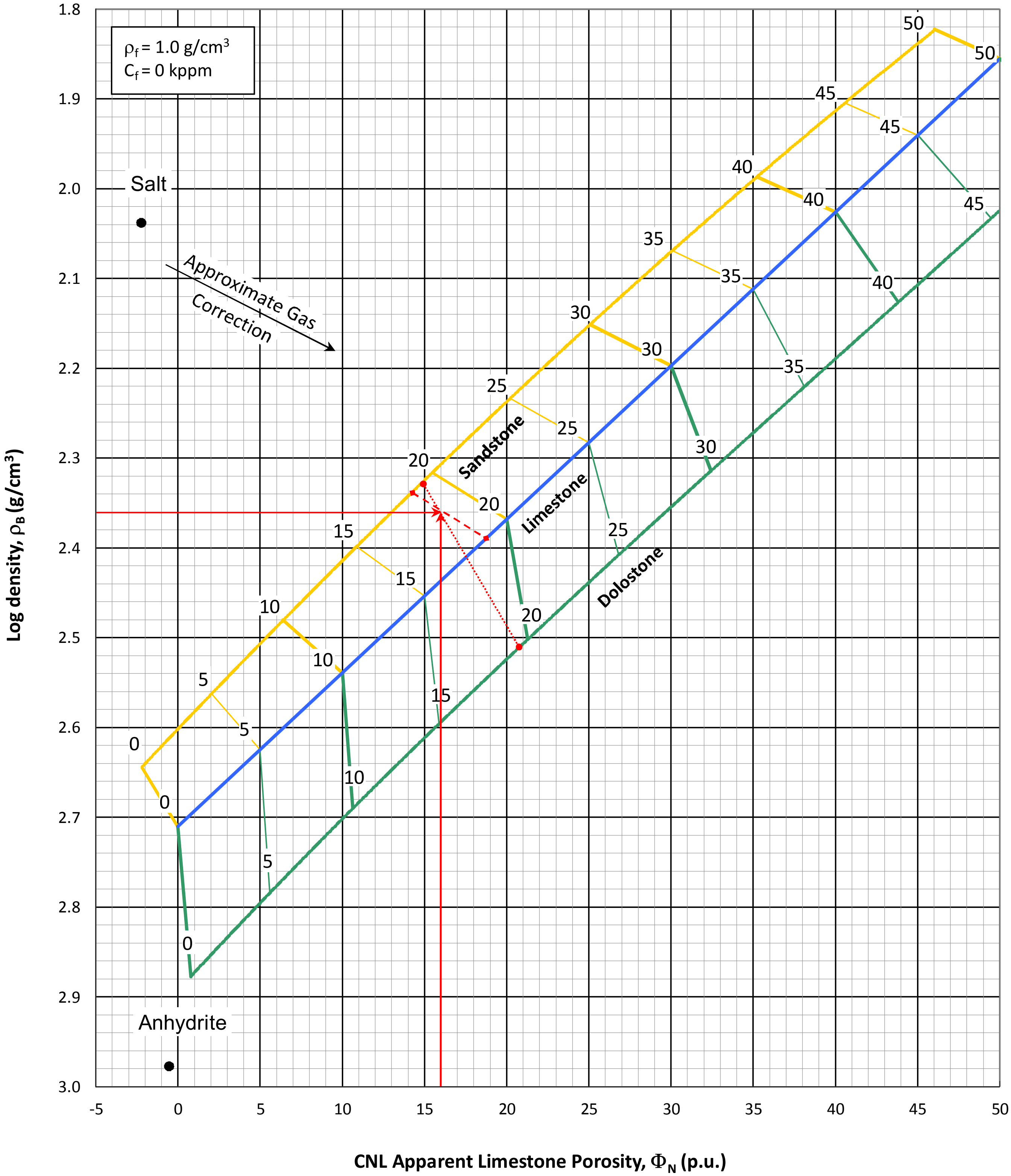
If the mineral composition is sandstone and limestone then the crossplot porosity for this example would be 18.5 % with a lithology mix of approximately 63 percent quartz and 37 percent calcite.

If the mineral composition is sandstone and dolostone then the crossplot porosity would be 19 % with a lithology mix of approximately 84 percent quartz and 16 percent dolomite.

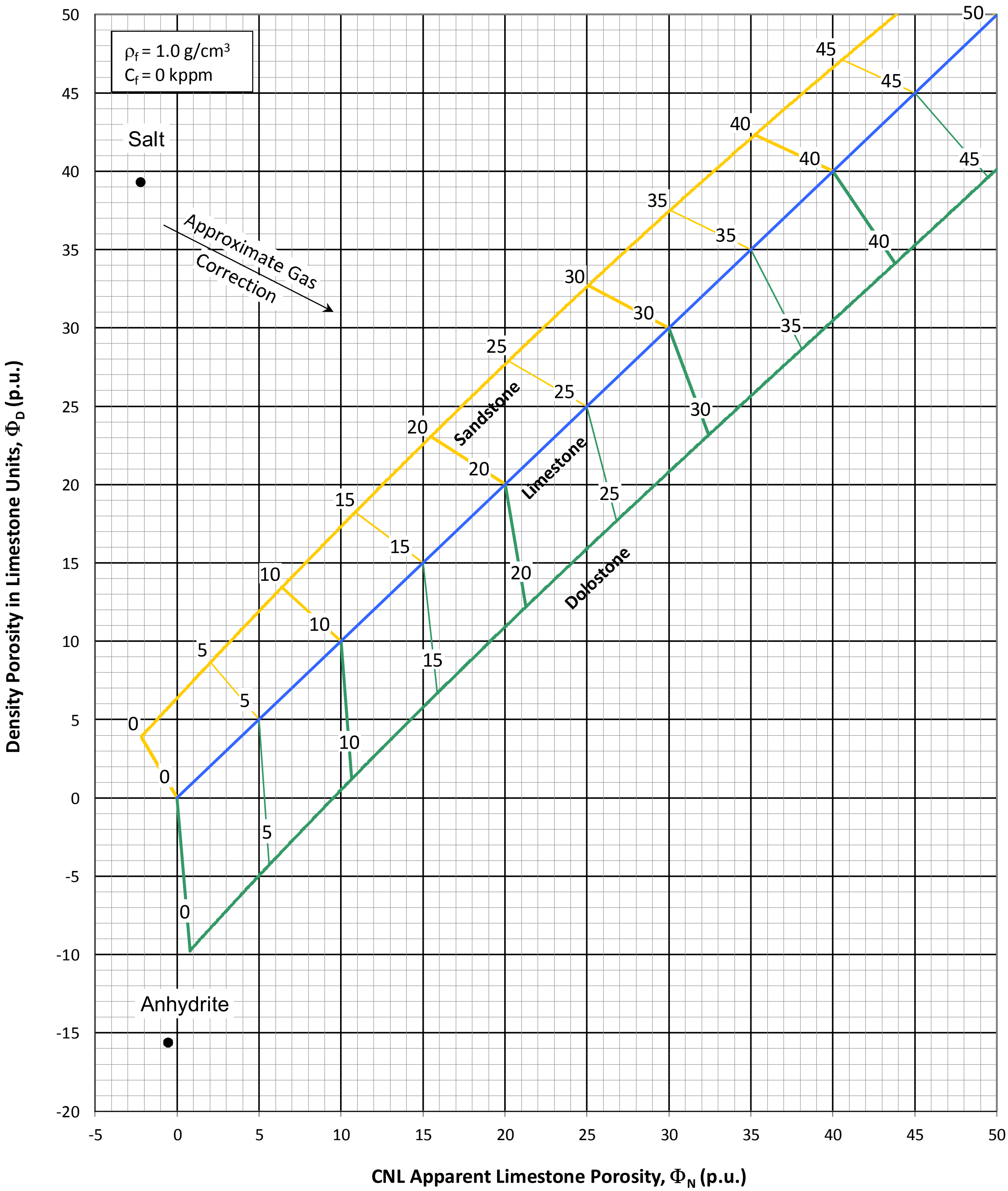
Note

Formation salinity is the total salinity – not only the chlorides (typically entered on a mud report).

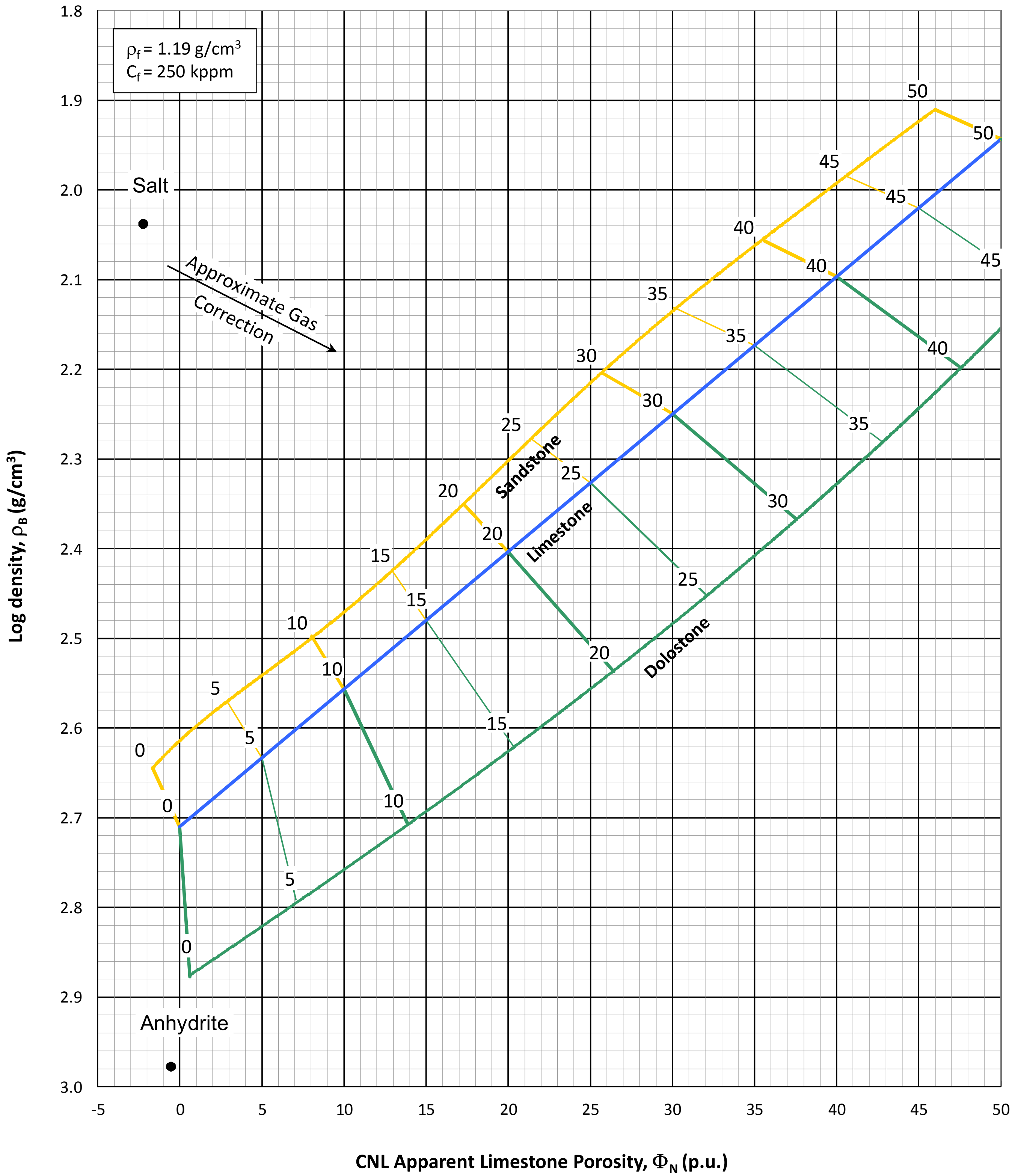
Bulk Density Log and Compensated Neutron Porosity



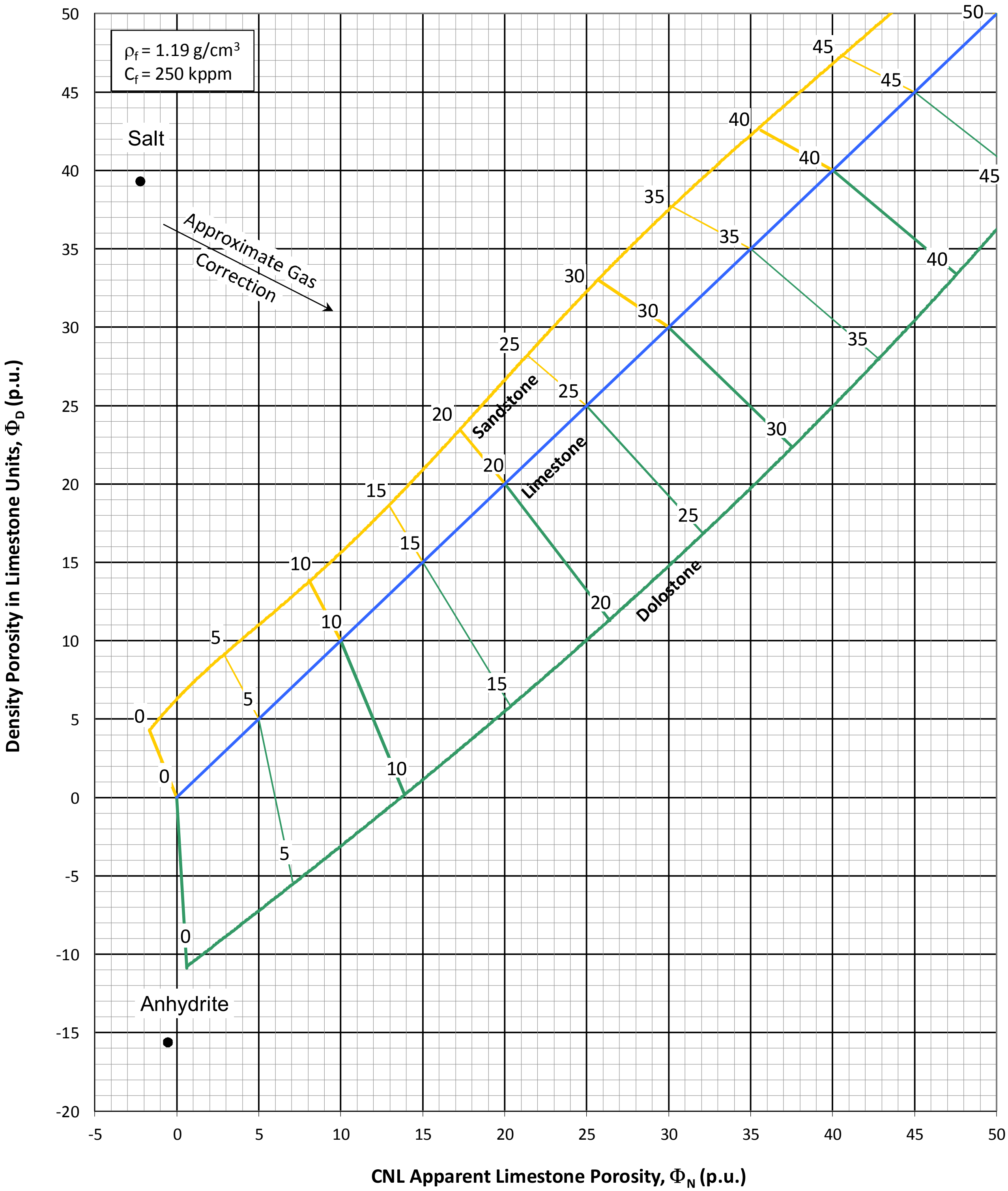
Litho-Density Porosity and Compensated Neutron Porosity



Bulk Density Log and Compensated Neutron Porosity



Litho-Density Porosity and Compensated Neutron Porosity



Logging Tool Response in Sedimentary Minerals

Name	Formula	ρ_b g/cm^3	Pe barns/electron	ϕ_N p.u.	Δt_c µs/ft	U barns/cm^3
Silicates						
Quartz	SiO_2	2.65	1.81		55	4.79
Cristobalite	SiO_2	2.30	1.81			4.16
Opal (3.5% H_2O)	SiO_2 $(H_2O)_{0.1209}$	2.12	1.75		58	3.71
Garnet	Fe_3 Al_2 $(SiO_4)_3$	4.31	11.09		36	47.80
Hornblende	Ca_2 $NaMg_2$ Fe_2 $AlSi_8$ O_{22} $(O,OH)_2$	3.15	5.99		44	18.87
Tourmaline	$NaMg_3Al_6B_3Si_6O_2(OH)_4$	2.98	2.14			6.38
Carbonates						
Calcite	$CaCO_3$	2.71	5.08	0	48	13.77
Dolomite	$CaCO_3$ $MgCO_3$	2.88	3.14		43	9.03
Ankerite	$Ca(Mg,Fe)(CO_3)_2$	2.9	9.32		53	27.03
Siderite	$FeCO_3$	3.89	14.69		45	57.14
Evaporites						
Halite	NaCl	2.04	4.65	-2.2	67	9.49
Anhydrite	$CaSO_4$	2.98	5.05	-0.6	50	15.05
Gypsum	$CaSO_4(H_2O)_2$	2.35	3.99		53	9.38
Trona	$Na_2CO_3NaHCO_3H_2O$	2.09	0.71		65	1.48
Tachydrite	$CaCl_2(MgCl_2)_2(H_2O)_{12}$	1.66	3.84		92	6.37
Sylvite	KCl	1.87	8.51		74	15.91
Carnalite	$KClMgCl_2(H_2O)_6$	1.57	4.09		79	6.42
Langbenite	$K_2SO_4(MgSO_4)_2$	2.82	3.56		52	10.04
Polyhalite	$K_2SO_4(MgSO_4)_2(CaSO_4)_2(H_2O)_2$	2.79	4.32		58	12.05
Kainite	$MgSO_4KCl(H_2O)_3$	2.13	3.5			7.46
Kieserite	$MgSO_4H_2O$	2.59	1.83			4.74
Epsomite	$MgSO_4(H_2O)_7$	1.71	1.15			1.97
Bischofite	$MgCl_2(H_2O)_6$	1.54	2.59		100	3.99
Barite	$BaSO_4$	4.09	267		69	1092.03
Celestite	$SrSO_4$	3.79	55.2		60	209.21
Oxidates						
Hematite	Fe_2O_3	5.18	21.48		45	111.27
Magnetite	Fe_3O_4	5.09	22.24		73	113.20
Geothite	FeO(OH)	4.28	19.02			81.41
Limonite	$FeO(OH)(H_2O)_{2.05}$	3.6	13		57	46.80
Gibbsite	$Al(OH)_3$	2.49	1.1			2.74

Logging Tool Response in Sedimentary Minerals

Name	Formula	ρ_b g/cm^3	Pe barns/electron	ϕ_N p.u.	Δt_c µs/ft	U barns/cm^3
Sulphides						
Pyrite	FeS_2	5	16.96		38	84.80
Marcasite	FeS_2	4.87	16.97			82.64
Pyrrhotite	Fe_7S_8	4.54	20.55		65	93.30
Sphalerite	ZnS	3.93	35.93		57	141.20
Chalopyrite	$CuFeS_2$	4.07	26.72			108.75
Galena	PbS	6.39	1631			10422.09
Sulphur	S	2.02	5.04		122	10.18
Felspars						
Orthoclase	$KAlSi_3O_8$	2.53	2.86		69	7.24
Anorthoclase	$KAlSi_3O_8$	2.56	2.86		69	7.32
Microcline	$KAlSi_3O_8$	2.56	2.86		45	7.32
Albite	$NaAlSi_3O_8$	2.6	1.68		49	4.37
Anorthite	$CaAl_2Si_2O_8$	2.75	3.13		45	8.61
Micas						
Muscovite	$KAl_2\ (Si_3AlO_{10})(OH)_2$	2.82	2.4		50	6.77
Biotite	$K_2(Mg,Fe)_2Al_6(Si_4OH_{10})_3(OH)_2$	2.99	6.27		49	18.75
Glauconite	$K(Mg,Fe)_3(AlSi_3O_{10}(OH)_2$	2.54	6.37		51	16.18
Phlogopite	$KMg_3(AlSi_3O_{10}(OH)_2$				50	0.00
Clays						
Kaolinite	$Al_4Si_4O_{10}(OH)_8$	2.6	1.83		212	4.76
Chlorite	$(Mg,FeAl)_6(Si,Al)_4O_{10}(OH)_8$	2.76	6.3			17.39
Illite	$K_{1-15}\ Al_4(Si_{7-6.5},Al_{1-1.5}O_{20}(OH)_4$	2.61	3.45			9.00
Smectite	$(Ca,Na)_7(Al,Mg,Fe)_4(Si,Al)_8O_{20}(OH)_4(H_2O)_n$	2.12	2.04			4.32
Coals						
Anthracite	$CH_{0.358}N_{0.009}O_{0.022}$	1.55	0.16		105	0.25
Bituminous	$CH_{0.793}N_{0.015}O_{0.078}$	1.3	0.17		120	0.22
Lignite	$CH_{0.849}N_{0.015}O_{0.211}$	1.05	0.2		160	0.21

Conversions

Length

1 inch (in)	2.540 centimeters (cm)
1 foot (ft)	30.48 centimeters (cm)
1 meter (m)	39.37 inches (in)
	3.281 feet (ft)

Area

1 square centimeter (cm^2)	0.1550 square inches (in^2)
1 square inch (in^2)	6.452 square centimeters (cm^2)

Volume

1 U.S. gallon (gal)	0.83267 imperial gallons (imp gal)
	231 cubic inches (in^3)
	0.13368 cubic feet (ft^3)
	3.785 liters (l)
1 Imperial gallon (imp gal)	1.20095 U.S. gallons (imp gal)
	4.54596 liters (l)
1 barrel (bbl)	42 U.S. gallons (gal)
	5.61458 cubic feet (ft^3)
	158.98284 liters (l)
1 cubic foot (ft^3)	7.48052 U.S. gallons (gal)
	28.316847 liter (l)
1 liter (l)	0.26417 U.S. gallons (gal)
	0.03531 cubic feet (ft^3)
	0.001 cubic meters (m^3)
1 cubic meter(m^3)	1000 liters (l)
	264.172 05 U.S. gallons (gal)
	219.969 25 Imperial gallons (imp gal)
	6.28981 barrels (bbl)
	35.31467 cubic feet (ft^3)

Mass

1 pound (lb)	0.45359 kilograms (kg)
1 long ton	2240 pounds (lbs)
1 tonne	1000 kilograms
	2205 pounds (lbs)

Conversions

Density

1 gram/cubic centimeter (g/cm^3) .... 62.42796 lb/ft^3
0.036127 lb/in^3
8.34540 lb/ U.S. gal
10.02241 lb/imp gal
1000 kg/m^3

Pressure

1 pound per square inch (psi) .... 0.06805 atmosphere (atm)
6.895 kiloPascal (kPa)
0.06895 bar

1 atmosphere (atm) .... 14.69594 pounds per square inch (psi)
101.32501 kiloPascals (kPa)
1.01325 bar
1.03323 kilograms/square centimeter (kg/cm^2)

Pressure Gradient

psi/ft .... 0.433 × density (g/cc)
density (lb/gal) / 19.25

kPa/ft .... psi/ft × 0.231

Temperature

degree Fahrenheit (°F) .... (1.8 × °C) + 32
degree Centigrade (°C) .... (°F - 32) / 1.8
degree Kelvin (°K) .... °C + 273.16
degree Rankin (°R) .... °F + 459.69

Concentration

1 grain/U.S. gal .... 17.11854 ppm/density (g/cc)
1 g/liter .... 58.41620 grains/gal

Tool Mnemonic Outputs

Name.Units	Description
DEPT.FT	Depth
LTEN.LB	Surface Line Tension
LSPD.FT/MIN	Line Speed
Head Tension Unit	
HTEN.LB	Head Tension
BFR	
MUDTEMP.DEGF	Mud Temperature
MUDRES.OHM-M	Mud Resistivity
Induction Array	
SP.MV	Spontaneous Potential
ILM.OHM-M	Induction Log Medium (60" Depth of Investigation)
ILD.OHM-M	Induction Log Medium (90" Depth of Investigation)
CILM.MMHO/M	Induction Medium Conductivity
CILD.MMHO/M	Induction Deep Conductivity
IA10_2.OHM-M	Induction Array 10in Radial 2ft Vertical Resistivity
IA20_2.OHM-M	Induction Array 20in Radial 2ft Vertical Resistivity
IA30_2.OHM-M	Induction Array 30in Radial 2ft Vertical Resistivity
IA60_2.OHM-M	Induction Array 60in Radial 2ft Vertical Resistivity
IA90_2.OHM-M	Induction Array 90in Radial 2ft Vertical Resistivity
CIA10_2.MMHO/M	Induction Array 10in Radial 2ft Vertical Conductivity
CIA20_2.MMHO/M	Induction Array 20in Radial 2ft Vertical Conductivity
CIA30_2.MMHO/M	Induction Array 30in Radial 2ft Vertical Conductivity
CIA60_2.MMHO/M	Induction Array 60in Radial 2ft Vertical Conductivity
CIA90_2.MMHO/M	Induction Array 90in Radial 2ft Vertical Conductivity
IA10_4.OHM-M	Induction Array 10in Radial 4ft Vertical Resistivity
IA20_4.OHM-M	Induction Array 20in Radial 4ft Vertical Resistivity
IA30_4.OHM-M	Induction Array 30in Radial 4ft Vertical Resistivity
IA60_4.OHM-M	Induction Array 60in Radial 4ft Vertical Resistivity
IA90_4.OHM-M	Induction Array 90in Radial 4ft Vertical Resistivity
CIA10_4.MMHO/M	Induction Array 10in Radial 4ft Vertical Conductivity
CIA20_4.MMHO/M	Induction Array 20in Radial 4ft Vertical Conductivity
CIA30_4.MMHO/M	Induction Array 30in Radial 4ft Vertical Conductivity
CIA60_4.MMHO/M	Induction Array 60in Radial 4ft Vertical Conductivity
CIA90_4.MMHO/M	Induction Array 90in Radial 4ft Vertical Conductivity
RXO_4.OHM-M	Resistivity of Invaded Zone 4ft Vertical Resolution
RT_4.OHM-M	True Resistivity of Formation 4ft Vertical Resolution

Tool Mnemonic Outputs

Name.Units	Description
DI_4.IN	Diameter of Invasion 4ft Vertical Resolution
RXO_2.OHM-M	Resistivity of Invaded Zone 2ft Vertical Resolution
RT_2.OHM-M	True Resistivity of Formation 2ft Vertical Resolution
DI_2.IN	Diameter of Invasion 2ft Vertical Resolution
RWA.OHM-M	Formation Water Resisitivity
Dual Laterolog	
LLD.OHM-M	Laterolog Deep Resisitivity
LLM.OHM-M	Laterolog Medium Resisitivity
Micro Spherically Focussed Log	
MFSLCAL.IN	MSFL Caliper
MSFLCAL1.IN	MSFL Caliper 1 Radius
MSFLCAL2.IN	MSFL Caliper 2 Radius
MSFL.OHM-M	Micro Spherically Focused Log Resisitivity
Litho Density	
CALI.IN	Density Caliper
RHOB.G/CC	Bulk Density
DRHO.G/CC	Bulk Density Correction
DPHL.POROSITY DECIMAL FRACTION	Density Limestone Porosity
DPHI.POROSITY DECIMAL FRACTION	Density Porosity
DPHS.POROSITY DECIMAL FRACTION	Density Sandstone Porosity
DPHD.POROSITY DECIMAL FRACTION	Density Dolomite Porosity
PEF.	Photoelectric Factor
ABHV.FT3	Annular Borehole Volume
AVTX.FT3	Annular Borehole Volume Ticks
TBHV.FT3	Total Borehole Volume
BVTX.FT3	Borehole Volume Ticks
QSS.	LDT Short Spacing Log Quality
QLS.	LDT Long Spacing Log Quality
QLDT.	LDT Log Quality
Compensated Neutron	
NPHL.POROSITY DECIMAL FRACTION	Compensated Neutron Corrected Limestone Porosity
NPHI.POROSITY DECIMAL FRACTION	Compensated Neutron Uncorrected Limestone Porosity
NPHC.POROSITY DECIMAL FRACTION	Compensated Neutron Hole Size Corrected Limestone Porosity
NPHS.POROSITY DECIMAL FRACTION	Compensated Neutron Corrected Sandstone Porosity
NPHD.POROSITY DECIMAL FRACTION	Compensated Neutron Corrected Dolomite Porosity
NPHM.POROSITY DECIMAL FRACTION	Compensated Neutron Corrected Matrix Porosity

Tool Mnemonic Outputs

Name.Units	Description
PXND.POROSITY DECIMAL FRACTION	Neutron-Density Crossplot Porosity
Compensated Sonic	
DT57.USEC/FT	Depth Derived Delta T 5FT - 7FT
DT35.USEC/FT	Depth Derived Delta T 3FT - 5FT
ATT3.DB/FT	Attenuation from 3FT
AMP3FT.MV	Amplitude 3FT
AMP5FT.MV	Amplitude 5FT
TT3FT.USEC	Travel Time 3FT
TT5FT.USEC	Travel Time 5FT
BONDIX.	Bond Index
Array Sonic	
DT100120.USEC/FT	Depth Derived Delta T 10FT - 12FT
DT105125.USEC/FT	Depth Derived Delta T 10.5FT - 12.5FT
DT110130.USEC/FT	Depth Derived Delta T 11FT - 13FT
DT115135.USEC/FT	Depth Derived Delta T 11.5FT - 13.5FT
DTCO.USEC/FT	Delta T Compressional (Processed)
Compensated Sonic and Array Sonic	
SPHL.POROSITY DECIMAL FRACTION	Sonic Limestone Porosity
SPHI.POROSITY DECIMAL FRACTION	Sonic Porosity
SPHS.POROSITY DECIMAL FRACTION	Sonic Sandstone Porosity
SPHD.POROSITY DECIMAL FRACTION	Sonic Dolomite Porosity
ITT.MSEC	Integrated Travel Time
Microlog	
MINV.OHM-M	Micro Inverse Resistivity
MNOR.OHM-M	Micro Normal Resistivity
MCAL.IN	MEL Caliper Diameter
MCAL1.IN	MEL Caliper 1 Radius
MCAL2.IN	MEL Caliper 2 Radius
Gamma Ray	
GR.GAPI	Gamma Ray
Spectral Gamma Ray	
SGR.GAPI	Spectral Gamma Ray
CSGR.GAPI	Computed Spectral Gamma Ray
KGR.%	Potassium
UGR.PPM	Uranium
TGR.PPM	Thorium
UKRA.	Uranium/Potassium Ratio

Tool Mnemonic Outputs

Name.Units	Description
TKRA.	Thorium/Potassium Ratio
TURA.	Thorium/Uranium Ratio
CKGR.GAPI	Computed Potassium
CUGR.GAPI	Computed Uranium
CTGR.GAPI	Computed Thorium
Resistivity Micro Imager	
DEVI.DEG	Deviation
HAZI.DEG	Hole Azimuth
RB.DEG	Relative Bearing
P1NO.DEG	Pad 1 Rotation Relative to North Azimuth
P1AZ.DEG	Pad 1 Azimuth
RAD1.IN	Radius 1
RAD2.IN	Radius 2
RAD3.IN	Radius 3
RAD4.IN	Radius 4
RAD5.IN	Radius 5
RAD6.IN	Radius 6
PP.LB	Pad Pressure
TEMP.DEGF	Temperature
MAGX.GAUSS	Magnetometer X
MAGY.GAUSS	Magnetometer Y
MAGZ.GAUSS	Magnetometer Z
MAGF.GAUSS	Magnetic Field Magnitude
MDIP.DEG	Magnetic Dip
ACCX.GEE	Accelerometer X
ACCY.GEE	Accelerometer Y
ACCZ.GEE	Accelerometer Z
FACC.GEE	Fast Accelerometer
GRAV.GEE	Gravity Magnitude
STIM.SEC	Sample Time
K001-K144.MMHO/M	Conductivity Button 1 to Button 144
DIA1.IN	Diameter 1
DIA2.IN	Diameter 2
DIA3.IN	Diameter 3

Header Nmemonics

Name.Units	Description
STRT.FT	START DEPTH
STOP.FT	STOP DEPTH
STEP.FT	STEP
NULL. -999.2500	NULL VALUE
COMP.	COMPANY
WELL.	WELL
FLD.	FIELD
LOC.	LOCATION
SRVC.	SERVICE COMPANY
DATE.	LOG DATE
UWI.	UNIQUE WELL ID
SECT.	SECTION
TOWN.	TOWNSHIP
RANG.	RANGE
API.	API#
OS.	OTHER SERVICES
PDAT.FT	PERMANENT DATUM
EEL.FT	ELEVATION
LMF.FT	LOG MEASURED FROM
DMF.FT	DRILLING MEASURED FROM
EKB.FT	KB
EDF.FT	DF
EGL.FT	GK
DATE1.	DATE1
RUN1.	RUN NUMBER
TDD1.FT	DEPTH DRILLER
TDL1.FT	DEPTH LOGGER
BLI1.FT	BOTTOM LOGGED INTERVAL
TLI1.FT	TOP LOG INTERVAL
CDD1.IN_FT	CASING DRILLER
CDL1.FT	CASING LOGGER
BS1.IN	BIT SIZE
DFT1.	TYPE FLUID IN HOLE
DFDV1.GM/C3_CP	DENSITY/VISCOSITY
DFPL1.C3	PH/FLUID LOSS
MSS1.	SOURCE OF SAMPLE
RMT1.OHHM_DEGF	RM@MEASURED TEMP
RMFT1.OHMM_DEGF	RMF@MEASURED TEMP
RMCT1.OHMM_DEGF	RMC@MEASURED TEMP
RMFS1.	SOURCE OF RMF/RMC
RMBT1.OHMM_DEGF	RM@BHT
TCS1.	TIME CIRCULATION STOPPED
TLOB1.	TIME LOGGER ON BOTTOM
BHT1.DEGF	MAXIMUM RECORDED TEMPERATURE
LUN1.	EQUIPMENT NUMBER
LUL1.	LOCATION
ENGI1.	RECORDED BY
WITN1.	WITNESSED BY

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