Schlumberger

Historical Charts

Contents

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(continued)

Log Interpretation

SCHLUMBERGER WELL SURVEYING CORP.

LOG INTERPRETATION CHARTS

REFERENCE SHEET

SYMBOLS

AM — Normal Curve Spacing
AO — Lateral Curve Spacing
BHT — Bottom Hole Temperature in °F
d — Diameter of the Hole
Di — Average Diameter of Invaded Zone
e — Bed Thickness in Feet
t_{mc} — Mud Cake Thickness

R_m — Resistivity of the Mud
R_{mf} — Resistivity of the Mud Filtrate
R_{mc} — Resistivity of the Mud Cake
R_w — Resistivity of the Formation Water
R_{wa} — Apparent Resistivity of the Formation Water in Shaly Sands
R_z — Resistivity of the Mixture of the Electrolytes (It can be defined for a given zone — invaded or noninvaded)

R_t — Resistivity of the Formation — Uncontaminated Zone
R_o — Resistivity of the Formation when 100% Water
R_i — Resistivity of the Invaded Zone
R_{xo} — Resistivity of the Flushed Zone (Close to Bore Hole)
R_s — Resistivity of the Surrounding Beds
$R_{16''}$, $R_{64''}$, $R_{18'8''}$, $R_{1''x1''}$, and $R_{2''}$ — Apparent Resistivity of 16″ Normal, 64″ Normal, 18′8″ Lateral, 1″x1″ Microinverse, and 2″ Micronormal, respectively

F — Formation Resistivity Factor
F_a — Apparent Formation Resistivity Factor
ϕ — Effective Porosity in Per Cent
S_w — Water Saturation, Per Cent of Pore Space in Uncontaminated Zone
S_i — Water Saturation, as above, in Invaded Zone
S_{xo} — Water Saturation, as above, in Flushed Zone
ROS — Residual Oil Saturation as Per Cent of Pore Space; $= (1 - S_{xo})$

K — Coefficient in the SP Formula
E_c — SP Electrochemical Component
E_k — SP Electrofiltration Component
SSP — Static Spontaneous Potential — The Maximum Possible for a particular R_{mf}/R_w
PSP — Pseudostatic Spontaneous Potential — The SP Found in a Thick Shaly Sand
α — SP Reduction Factor — PSP/SSP
k — Permeability in millidarcies

FORMULAS

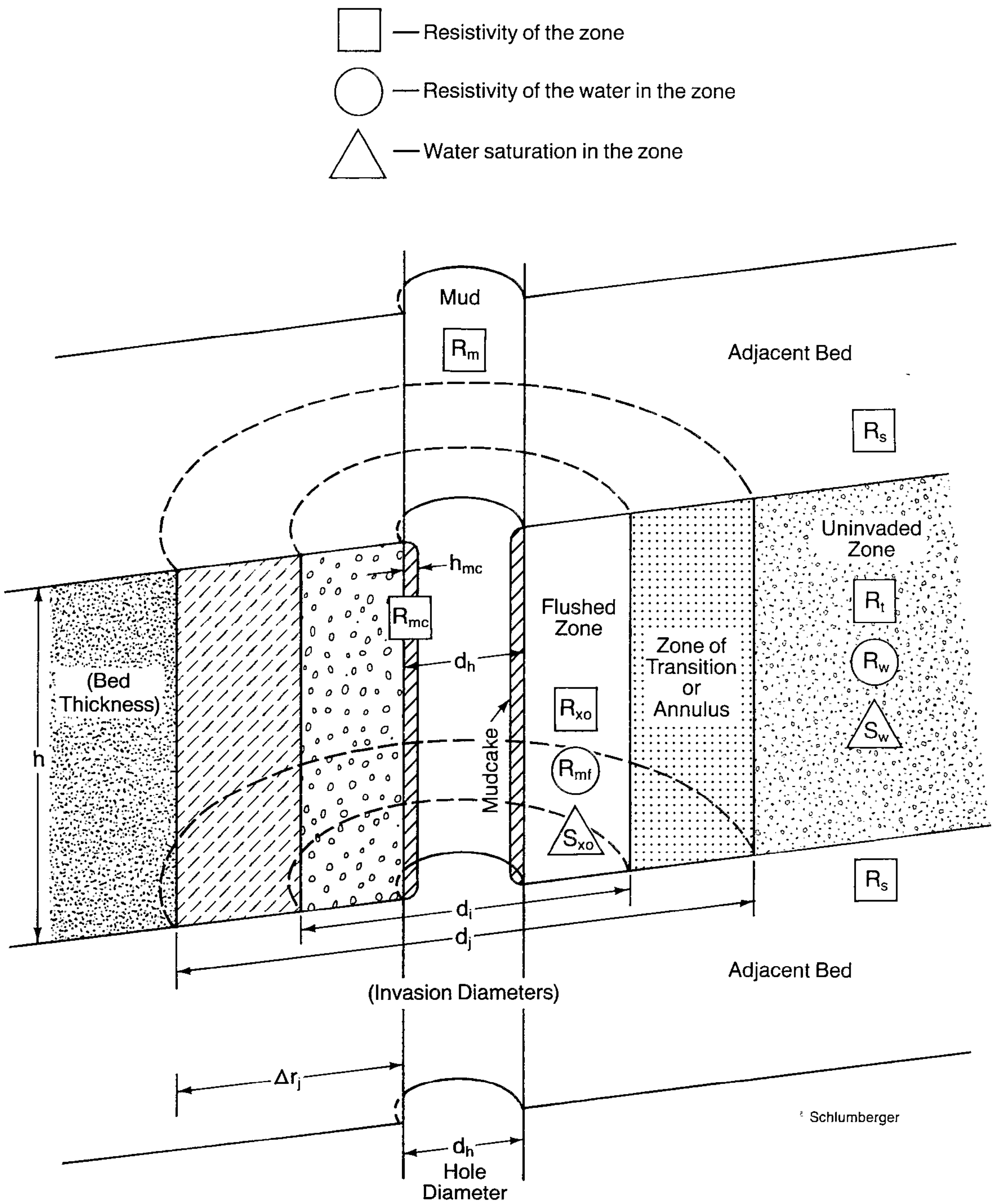
Archie's Formula: $S_w^n = F R_w/R_t$; $S_w = \sqrt[n]{R_o/R_t}$. (n usually taken as 2)

Formation Resistivity Factor: $F = R_o/R_w$; $F_a = R_{xo}/R_{mf}$.

Humble Formula: $F = 0.62/\phi^{2.15}$.

SP Formulas: $SSP = -K \log_{10} R_{mf}/R_w$; $PSP = -K \log_{10} R_{mf}/R_{wa}$.

R_i Method: $S_w = \dfrac{F}{a\ R_i/R_m}$; $S_w \simeq \dfrac{R_{xo}}{a\ R_i}$.



— Resistivity of the zone
— Resistivity of the water in the zone
— Water saturation in the zone
Mud
R_m
Adjacent Bed
R_s
Uninvaded Zone
R_t
R_w
S_w
h_{mc}
R_{mc}
Flushed Zone
d_h
Zone of Transition or Annulus
(Bed Thickness)
h
R_{xo}
Mudcake
R_{mf}
S_{xo}
R_s
d_i
d_j
Adjacent Bed
(Invasion Diameters)
Δr_j
© Schlumberger
d_h
Hole Diameter

SCHLUMBERGER WELL SURVEYING CORP.

LOG INTERPRETATION CHARTS

DETERMINATION OF FORMATION TEMPERATURE

USE AND DESCRIPTION

This chart is used:

1. To find the formation temperature at a given depth when it is known at some other depth — usually bottom hole.
2. To estimate temperature at any depth when no temperature has been measured.

The range of normal temperature gradients is shown by diagonal lines. The formation temperatures are scaled according to the mean surface temperature, A. Two values are provided.

INFORMATION REQUIRED

First Use

Depth of Formation
Total Depth
Bottom Hole Temperature (BHT)

Second Use

Depth of Formation
A — Mean Surface Temperature
G — Geothermal Gradient

PROCEDURE

First Use

BHT is known, being 200°F at 11000′. We need to find the temperature at 8000′. Use the upper temperature scale (A = 80). Proceed vertically to intersect the line corresponding to 11000′. Move this point diagonally upward, guided by the gradient line, until it intersects the horizontal line corresponding to 8000′. Read 166°, the temperature corresponding to this point.

Second Use

If no bottom hole temperature (BHT) is available, the temperature any place in the hole can be estimated from this chart providing the mean surface temperature, A, and the gradient, G, are known. The relation is of the form: $T^\circ = A + (G \times \text{Depth}/100')$. Usually A is about 80° and G is between 0.8 and 1.2 degrees/100′.

EXAMPLE: Formation Depth = 8000′; A = 80°; G = 1.2. Proceed from the depth to the diagonal line of 1.2, go to bottom, and read 176°F on scale starting with 80°.

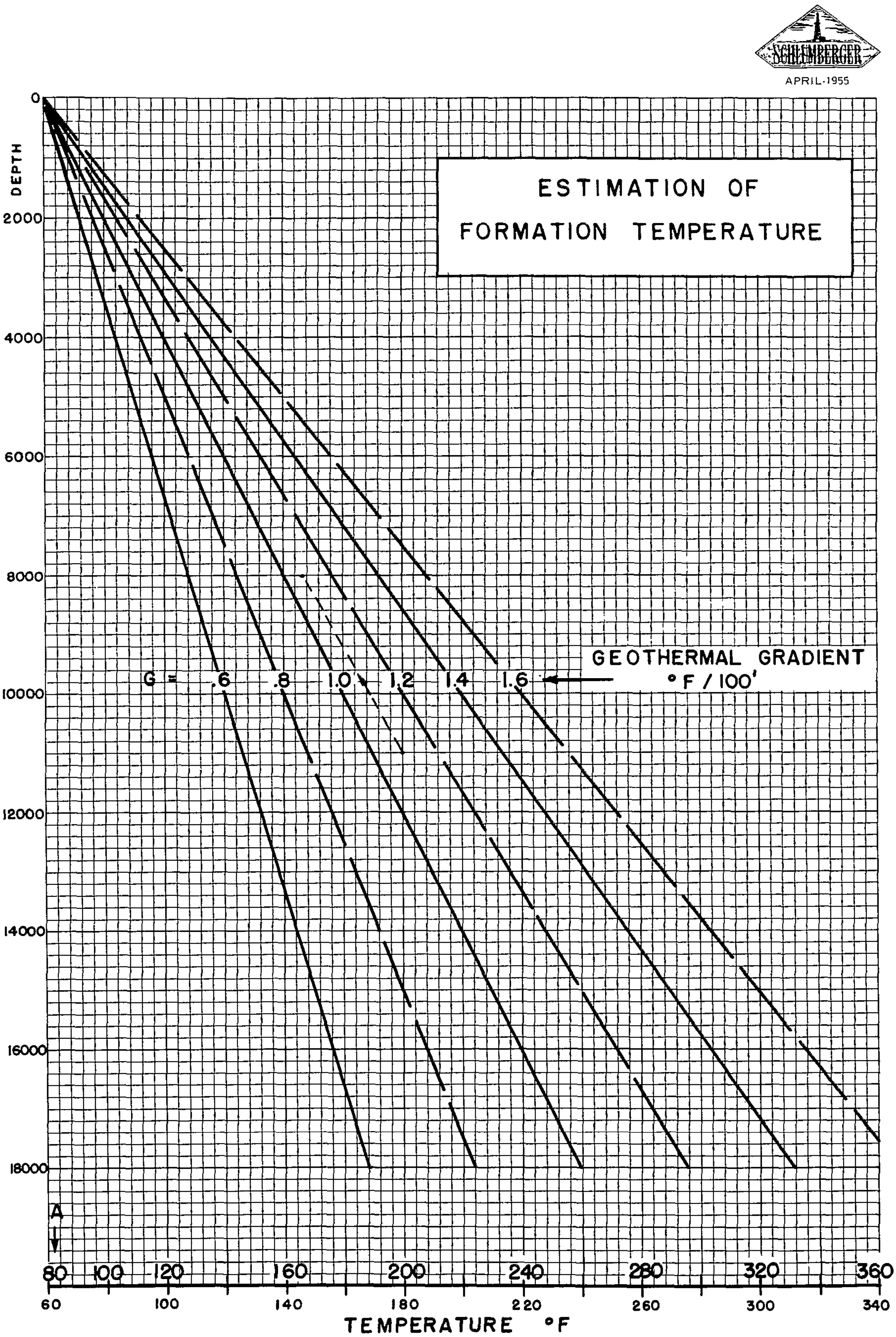

SCHLUMBERGER
APRIL-1955
ESTIMATION OF
FORMATION TEMPERATURE
DEPTH
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
G = .6 .8 1.0 1.2 1.4 1.6
GEOTHERMAL GRADIENT
°F / 100'
A
80 100 120 160 200 240 280 320 360
60 100 140 180 220 260 300 340
TEMPERATURE °F

Chart A-2

SCHLUMBERGER WELL SURVEYING CORP.

LOG INTERPRETATION CHARTS

RESISTIVITY — SALINITY CHART

USE AND DESCRIPTION

This chart is used:

1. To convert the resistivity of a fluid at one temperature to its resistivity at another temperature.
2. To convert the resistivity of a water sample to the NaCl concentration in parts per million or grains per gallon.
3. To convert concentration of a water sample of a solution to resistivity at a given temperature.

Data on salinity of NaCl solutions related to temperature and to resistivity are plotted, being derived from the International Critical Tables.

INFORMATION REQUIRED

R_m, R_{mf}, and R_w at a Known Temperature and Formation Temperature

or

Equivalent NaCl Salinity and Temperature

or

Chemical Analysis of the Solution and Temperature

PROCEDURE

If used to adjust resistivity due to a change in temperature: Plot a point corresponding to a measured resistivity and temperature. Enter a point for the measured fluid resistivity (read resistivity on lower horizontal scale) and its temperature (read temperature on left vertical scale). Move this point parallel to the diagonal lines (which represent constant salinity values) to the new temperature and then read on the bottom scale the new resistivity value.

If used to find R_w from a chemical analysis of a solution: Convert the solution to terms of equivalent NaCl by applying appropriate multipliers* for the separate ions, then finding the sum. Enter this value at the top and follow the diagonal line to the appropriate temperature and then read the resistivity at the bottom. If water analysis is in terms of chloride only, multiply this concentration by the factor 1.65 to find NaCl concentration. Note that the NaCl concentration is in terms of p.p.m., parts per million or micrograms/gram of solution, or in terms of G/G, grains per gallon of solution. Number of G/G $\times$ 17.1 = number of p.p.m.

* MULTIPLIERS:	Na = 1.0	Cl = 1.0
	Ca = 0.95	SO_4 = 0.5
	Mg = 2.0	CO_3 = 1.26
		HCO_3 = 0.27

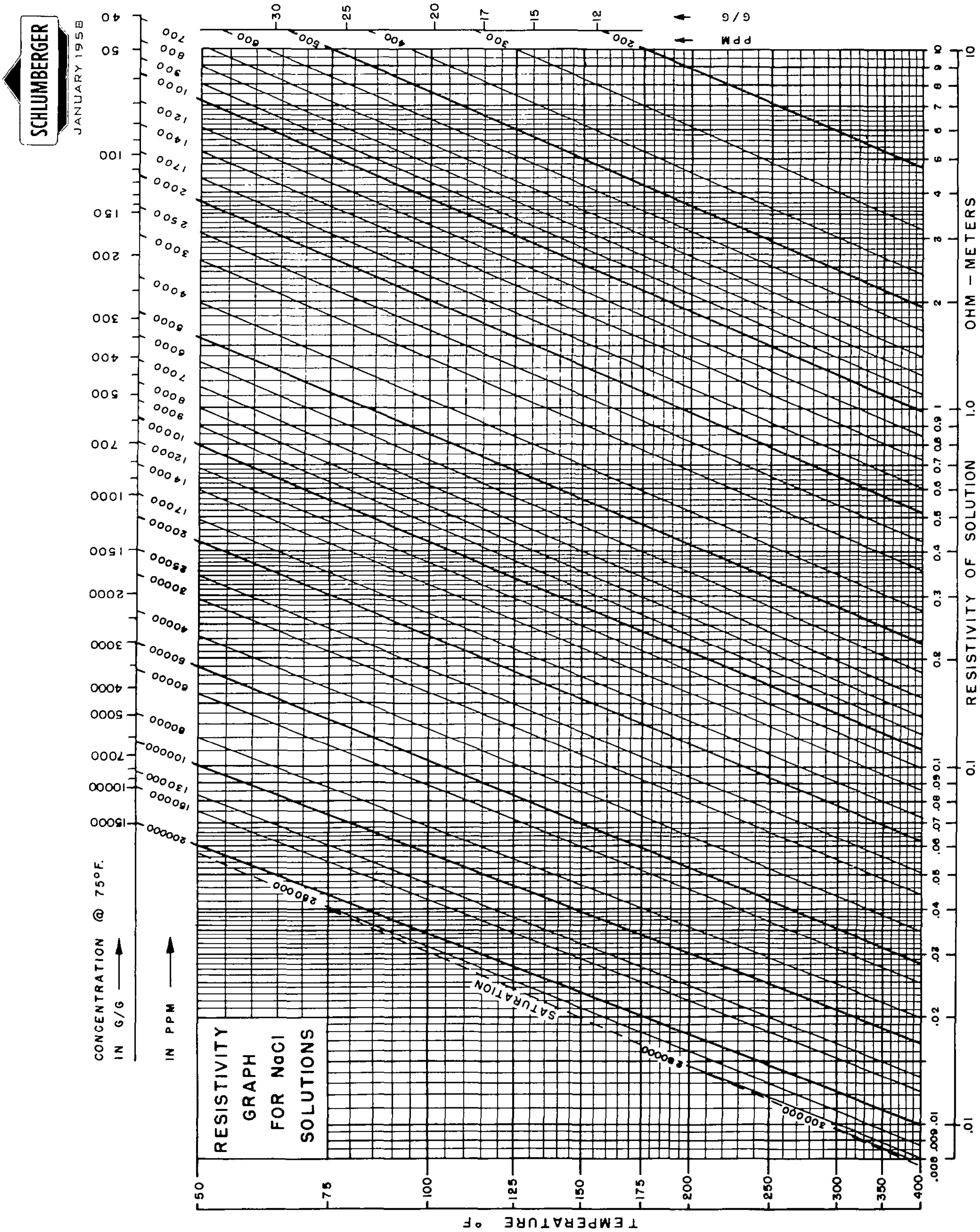

SCHLUMBERGER
JANUARY 1958
RESISTIVITY GRAPH FOR NaCl SOLUTIONS
CONCENTRATION @ 75°F.
IN G/G
IN PPM
G/G
PPM
SATURATION
RESISTIVITY OF SOLUTION OHM - METERS
TEMPERATURE °F

Chart A-6

SCHLUMBERGER WELL SURVEYING CORP.

LOG INTERPRETATION CHARTS

R_{mc} AND R_{mf} DETERMINATION*

USE AND DESCRIPTION

This chart is used to find the mud cake and mud filtrate resistivities at formation temperature.

The average values of resistivity of mud cake and filtrate as determined in the laboratory have been plotted versus R_m at formation temperature. R_{mf} is needed to estimate R_w (Charts A-10, D-2). R_{mf} and R_{mc} are both needed to determine F and ϕ from MicroLog or MicroLaterolog curves.

INFORMATION REQUIRED

R_m at Formation Temperature

Formation Temperature

PROCEDURE

From a log heading read R_m at BHT. If several hundred feet above bottom, estimate correct formation temperature, using Chart A-2. Then, R_m at formation temperature = (BHT/Formation Temperature) $\times$ R_m at BHT. (Chart A-6 can be used instead.) Enter this on the vertical axis on the left.

Proceed to the right to intersect the dashed curve and read R_{mf} on the horizontal axis. To find R_{mc}, go right to intersect the solid curve for the appropriate formation temperature; then read the value on the horizontal axis. For salty muds of resistivity less than 0.1 ohm use the insert chart at right and enter the R_m on the right vertical axis. Find the R_{mf} by going to the dashed line and then down. Find the R_{mc} by going to the solid line and then down.

EXAMPLE:

GIVEN: R_m at BHT = 0.4 ohm-m. at 200°F (11000′ depth).

TO FIND: R_{mf} and R_{mc} at 8000′ depth.

SOLUTION: From Chart A-2, temperature at 8000′=166°F.

R_m at 8000′=(200/166) $\times$ 0.4 ohm-m.=0.48 ohm-m. at 166°F.

R_{mf}=0.30.

R_{mc}=0.83.

** IMPORTANT REMARKS:*

R_{mc} and R_{mf} should preferably be measured from mud samples. When these measurements are not available, values can be estimated rather closely by the relations R_{mc}=1.5 R_m and R_{mf}=0.75 R_m, particularly in muds where NaCl is the major dissolved solid. For other cases, Chart A-4 may be used as a first approximation.

A method of measuring R_{mc} in the hole is described on Charts C-4 and C-6.

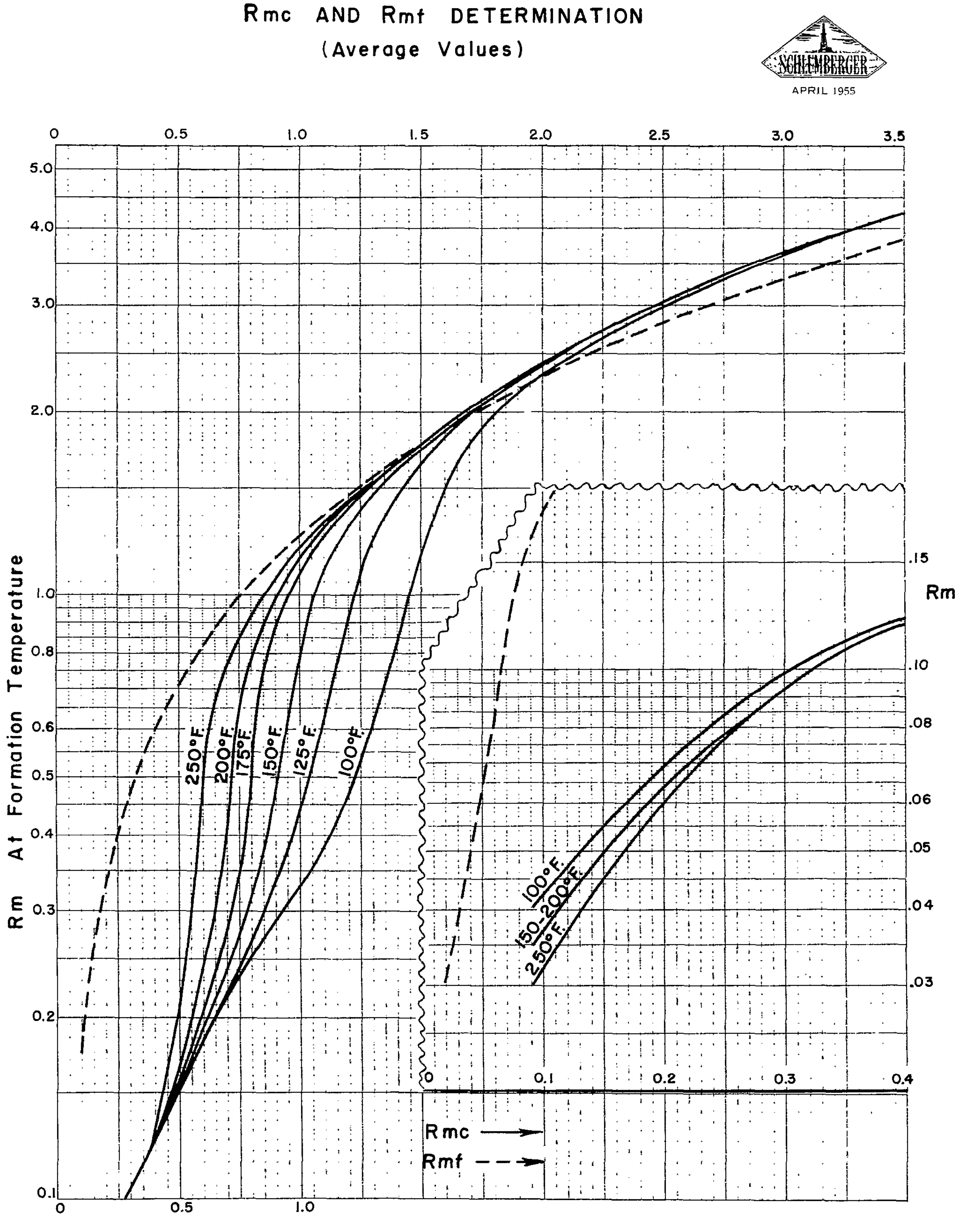

Rmc AND Rmf DETERMINATION
(Average Values)
SCHLUMBERGER
APRIL 1955
0 0.5 1.0 1.5 2.0 2.5 3.0 3.5
5.0 4.0 3.0 2.0 1.0 0.8 0.6 0.5 0.4 0.3 0.2 0.1
Rm At Formation Temperature
250°F. 200°F. 175°F. 150°F. 125°F. 100°F.
.15 .10 .08 .06 .05 .04 .03
Rm
100°F. 150-200°F. 250°F.
0 0.1 0.2 0.3 0.4
Rmc
Rmf
0 0.5 1.0

Chart A-4

SCHLUMBERGER WELL SURVEYING CORP.

LOG INTERPRETATION CHARTS

SP CORRECTION CHART

USE AND DESCRIPTION

This provisional chart is used to correct the observed SP when it is too low because of bed thickness. The effect of invasion is also accounted for. The data used to construct this chart are largely empirical, and inaccuracies may be present when R_i/R_m is high. This applies to average hole sizes of about 8″ or 9″.

INFORMATION REQUIRED

Bed Thickness with help of SP Inflection Point or MicroLog

R_i/R_m from 16″ Normal—See Chart B-10.

PROCEDURE

Enter the bed thickness at the bottom; proceed up to an appropriate curve of R_i/R_m; then move to the left where a correction factor (multiplier) is given.

EXAMPLE

GIVEN: $R_i/R_m = 50$.

Bed Thickness = 10′.

Observed SP = –60 MV.

SOLUTION: Correction Factor is 1.33.

Corrected SP = –80 MV.

SPECIAL CASE: The curve of $R_i/R_m = 5$ is used for low resistivity formations.

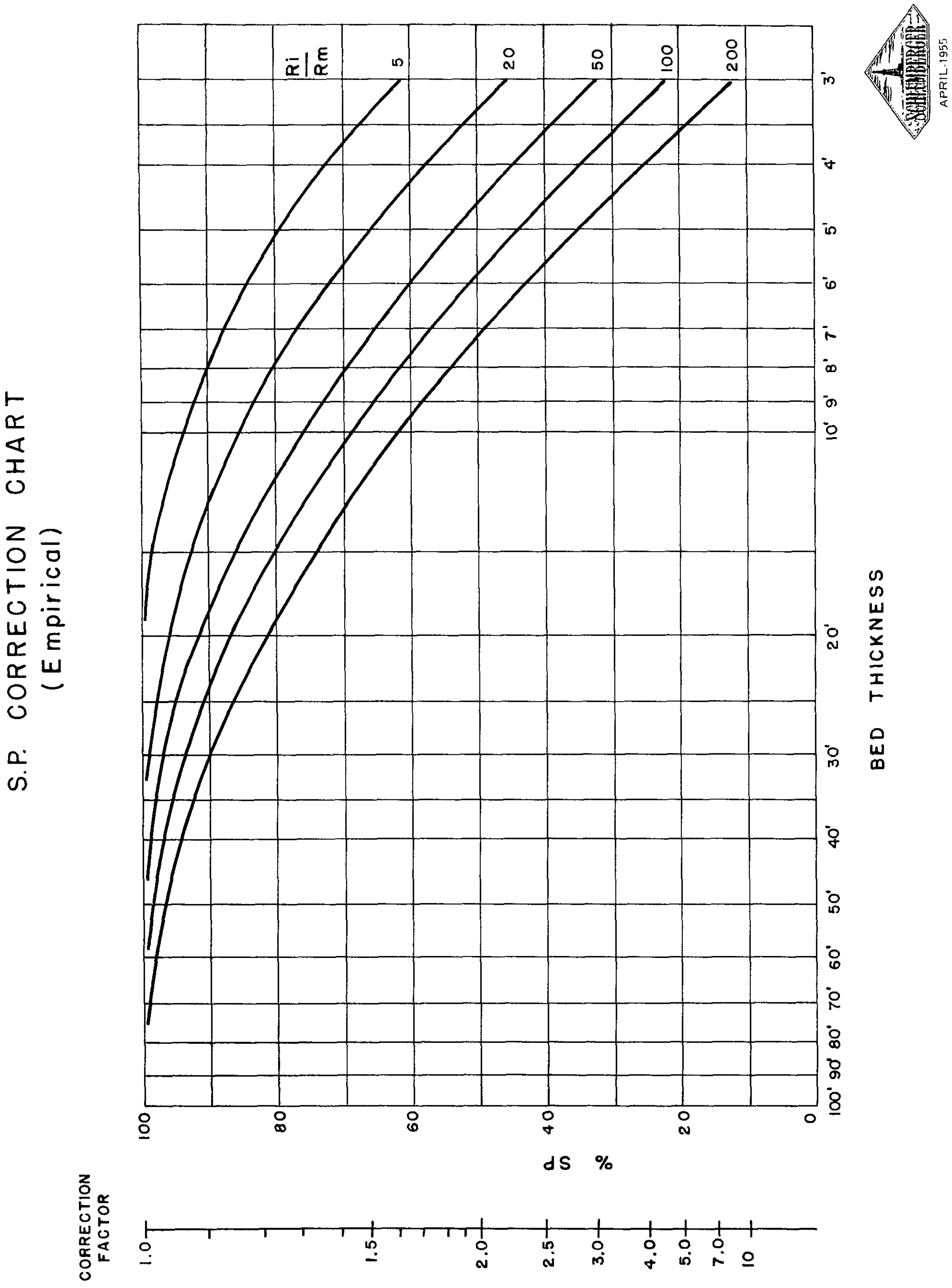

S.P. CORRECTION CHART
(Empirical)
Ri/Rm
5
20
50
100
200
3' 4' 5' 6' 7' 8' 9' 10' 20' 30' 40' 50' 60' 70' 80' 90' 100'
BED THICKNESS
100 80 60 40 20 0
% SP
CORRECTION FACTOR
1.0 1.5 2.0 2.5 3.0 4.0 5.0 7.0 10
SCHLUMBERGER
APRIL-1955

Chart A-8

SCHLUMBERGER WELL SURVEYING CORP.

LOG INTERPRETATION CHARTS

R_w DETERMINATION FROM THE SP

PART I. FINDING $(R_w)_e$

USE AND DESCRIPTION

The electrochemical component of the SP, E_c, is correctly related to the activity of the formation water and of the mud filtrate, such that $E_c = -K \log a_w/a_{mf}$, where K varies with temperature.

Also a relation such as $E_c = -K \log R_{mf}/(R_w)_e$ can be used. The term $(R_w)_e$, the equivalent water resistivity, is often nearly equal to the true R_w; but, when the formation waters are either very saline or quite fresh, important deviations occur.*

Therefore, the first step is to find $(R_w)_e$ from the static SP reading. The second step is to convert $(R_w)_e$ to R_w by using Chart A-12.

SPECIAL CASES: SALINE MUDS

If the mud filtrate, R_{mf}, is less than 0.1 ohm-m at 75°F, the effect of its increased activity must also be considered. The relation now becomes $E_c = -K \log (R_{mf})_e/(R_w)_e$. An extra step is required to convert R_{mf} to $(R_{mf})_e$ by Chart A-12.

MUDS CONTAINING GYPSUM OR $CaCl_2$

For muds containing Ca or Mg in solution, special procedures must be used (see reference below). Lime base muds usually have a negligible amount of Ca in solution and may be treated as regular mud types.

INFORMATION REQUIRED

SP, Corrected for bed thickness if necessary (Chart A-8)
R_{mf} at a known temperature
Formation Temperature (Chart A-2) *or* Knowledge of K

PROCEDURE

The SP is entered; proceed up to either a line equivalent to the formation temperature or to a line representing K. On left margin read $R_{mf}/(R_w)_e$. This is then divided into the R_{mf} at formation temperature, giving $(R_w)_e$.

EXAMPLE

Fresh Mud

GIVEN: SP = −100 MV at 190°F.
R_{mf} = 0.45 ohm-m at 190°F.

SOLUTION: $R_{mf}/(R_w)_e = 15.$ (K = − 85.)

$$(R_w)_e = \frac{R_{mf}}{R_{mf}/(R_w)_e} = 0.45/15.$$

$(R_w)_e = .03.$

Saline Mud

SP = +40 MV at 150°F.
R_{mf} = .025 ohm-m at 150°F.

R_{mf} corresponds to $(R_{mf})_e = .013.$ (A-12)

$$(R_w)_e = \frac{(R_{mf})_e}{(R_{mf})_e/(R_w)_e} = .013/.32 = .04.$$

$(R_{mf})_e/(R_w)_e = 0.32.$

*Gondouin, M., Tixier, M. P., and Simard, G. L. "An Experimental Study on the Influence of the Chemical Composition of Electrolytes on the SP Curve." Preprint, American Institute of Mining, Metallurgical and Petroleum Engineers Meetings: Casper, Wyoming, May, 1956 and Los Angeles, California, October, 1956.

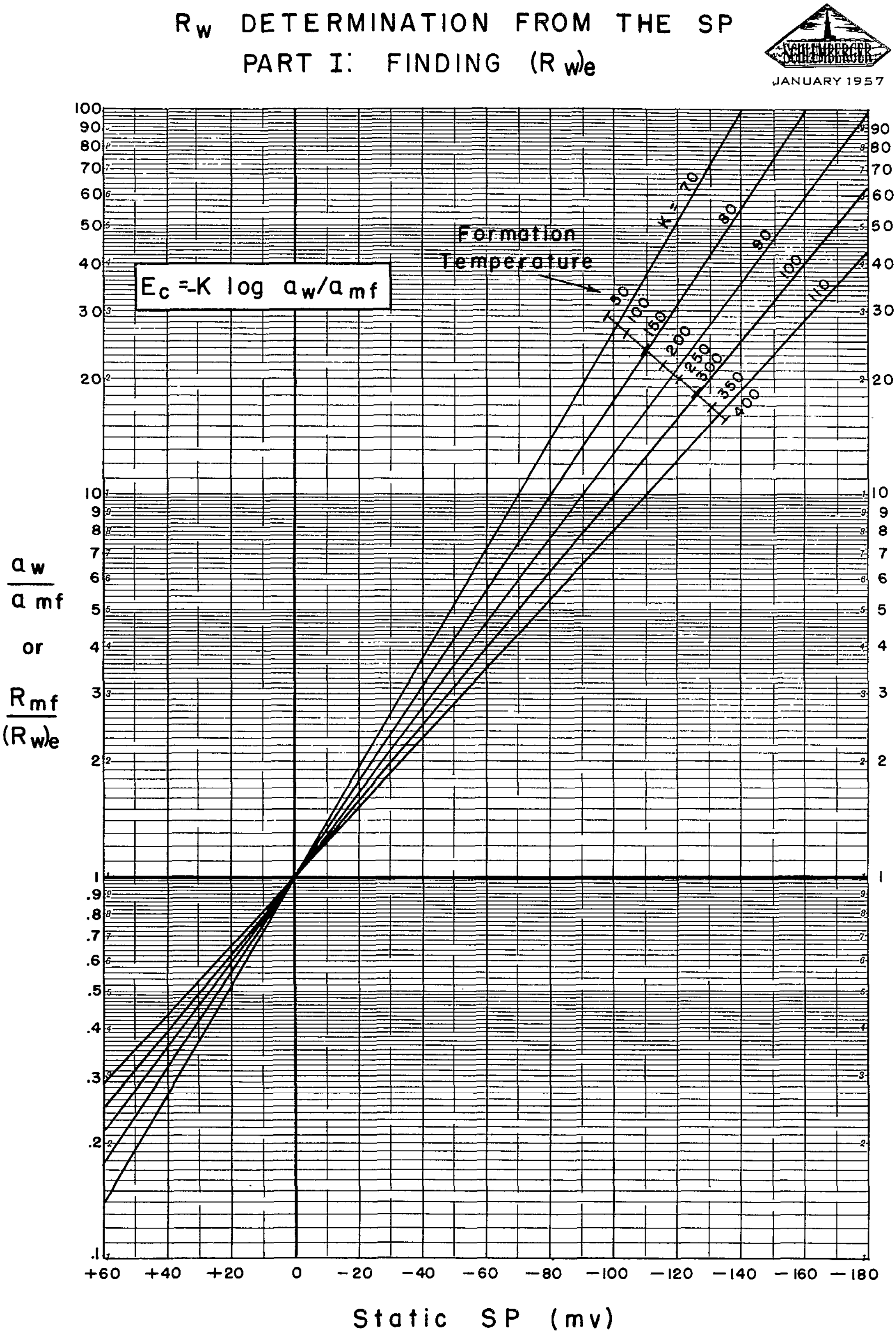

R_W DETERMINATION FROM THE SP
PART I: FINDING (R_w)_e
SCHLUMBERGER
JANUARY 1957
E_c = -K log a_w/a_mf
Formation Temperature
K = 70
80
90
100
110
50
100
150
200
250
300
350
400
a_w / a_mf or R_mf / (R_w)_e
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
+60 +40 +20 0 -20 -40 -60 -80 -100 -120 -140 -160 -180
Static SP (mv)

Chart A-10

SCHLUMBERGER WELL SURVEYING CORP.

LOG INTERPRETATION CHARTS

R_w DETERMINATION FROM THE SP
PART II. TRUE R_w VS. EQUIVALENT $(R_w)_e$

USE AND DESCRIPTION

This chart provides a means of correcting the equivalent $(R_w)_e$ to the true R_w (at BHT). It can be separated into two parts:

A. Where $R_w > 0.1$ at BHT

These curves are plotted for average fresh formation waters (Where Ca and Mg become important) as reported in the Gondouin, Tixier, and Simard paper.* Local experience and chemical analysis of the waters may show these curves somewhat in error in special cases.

B. Where $R_w < 0.1$ at BHT.

These curves are constructed from activity considerations and are theoretically correct.

INFORMATION REQUIRED

$(R_w)_e$ at a specified temperature (from Chart A-10).

PROCEDURE

Enter $(R_w)_e$ at the bottom, go up to the curve for the correct temperature, and then to the left to read R_w at that temperature.

EXAMPLE:

Fresh Mud

From Page A-9, we found:
$(R_w)_e = .03$ at 190°F.
$R_w = .037$ ohm-m at 190°F.

Saline Mud

$(R_w)_e = .04$ at 150°F.
$R_w = .05$ ohm-m at 150°F.

*Gondouin, M., Tixier, M. P., and Simard, G. L. "An Experimental Study on the Influence of the Chemical Composition of Electrolytes on the SP Curve." Preprint, American Institute of Mining, Metallurgical and Petroleum Engineers Meetings: Casper, Wyoming, May, 1956 and Los Angeles, California, October, 1956.

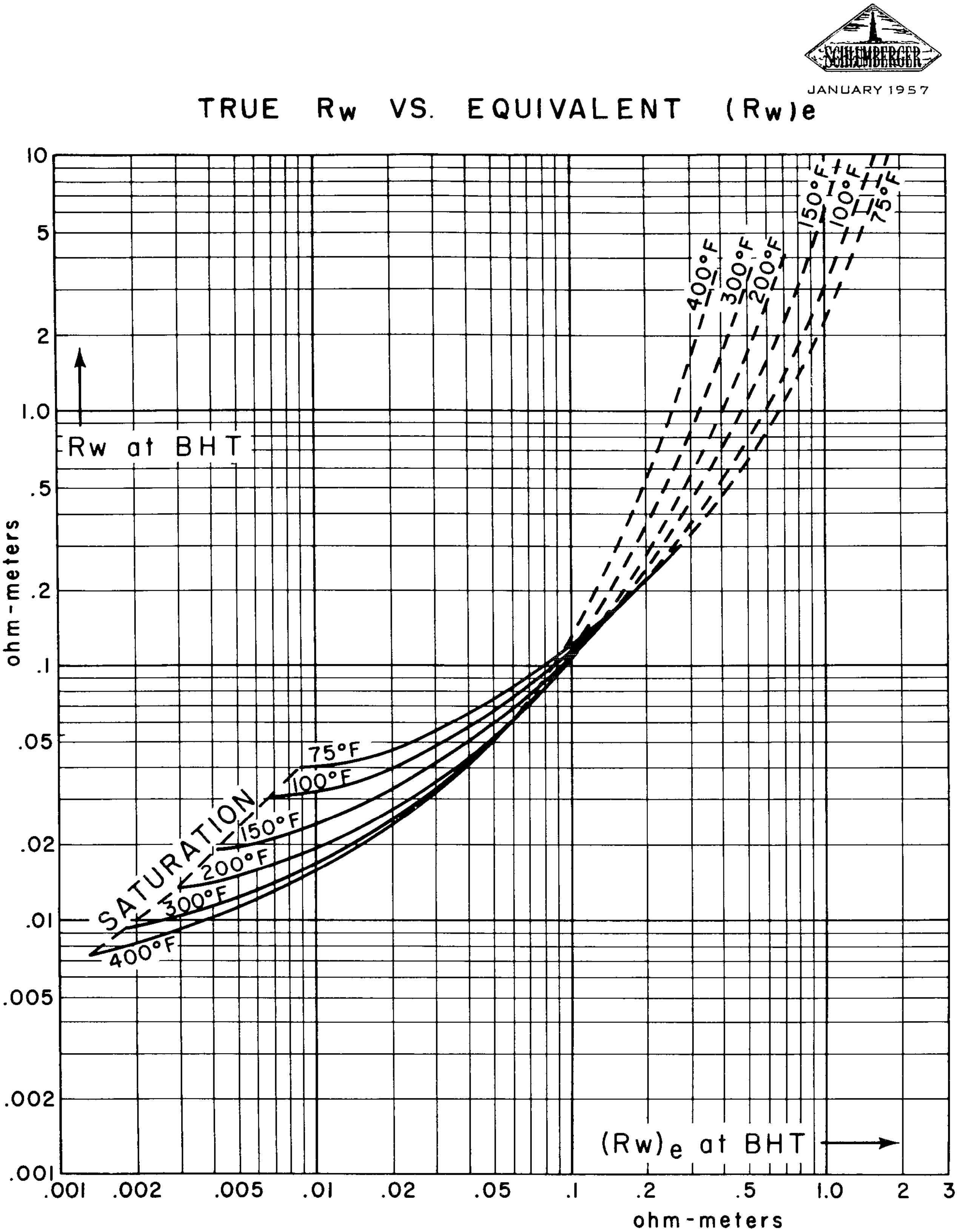

SCHLUMBERGER
JANUARY 1957
TRUE Rw VS. EQUIVALENT (Rw)e
Rw at BHT
ohm-meters
(Rw)e at BHT
ohm-meters
SATURATION
75°F
100°F
150°F
200°F
300°F
400°F
10
5
2
1.0
.5
.2
.1
.05
.02
.01
.005
.002
.001
.002
.005
.01
.02
.05
.1
.2
.5
1.0
2
3

Chart A-12

SCHLUMBERGER WELL SURVEYING CORP.

LOG INTERPRETATION CHARTS

SIMPLIFIED RESISTIVITY DEPARTURE CURVES

USE AND DESCRIPTION

This chart corrects for the influence of the bore hole on the 16″ normal and for the hole and average invasion on the 18′8″ lateral. The sonde diameter and the effect of the reference electrodes are taken into account.

It is used in relatively thick formations of moderate and high resistivity where the 16″ normal is influenced by the invaded zone.

INFORMATION REQUIRED

R_m at Formation Temperature

Actual Hole Diameter

Apparent 16″ and 18′8″ Resistivities

PROCEDURE

For the 16″ normal: Find the ratio $R_{16''}/R_m$. Enter at the left margin and proceed to the solid curve for appropriate hole size. Read R_i/R_m at the bottom.

For the 18′8″ lateral: Find the ratio $R_{18'8''}/R_m$. Enter at the left margin and proceed to the dashed line for appropriate hole size and read R_t/R_m at the bottom.

EXAMPLE

GIVEN: $R_m = .5$ ohm at formation temperature.
Hole Size = 9″.
$R_{16''} = 50.$
$R_{18'8''} = 250.$

SOLUTION: $R_{16''}/R_m = 100.$
$R_{18'8''}/R_m = 500.$
$R_i/R_m = 150.$
$R_t/R_m = 300.$

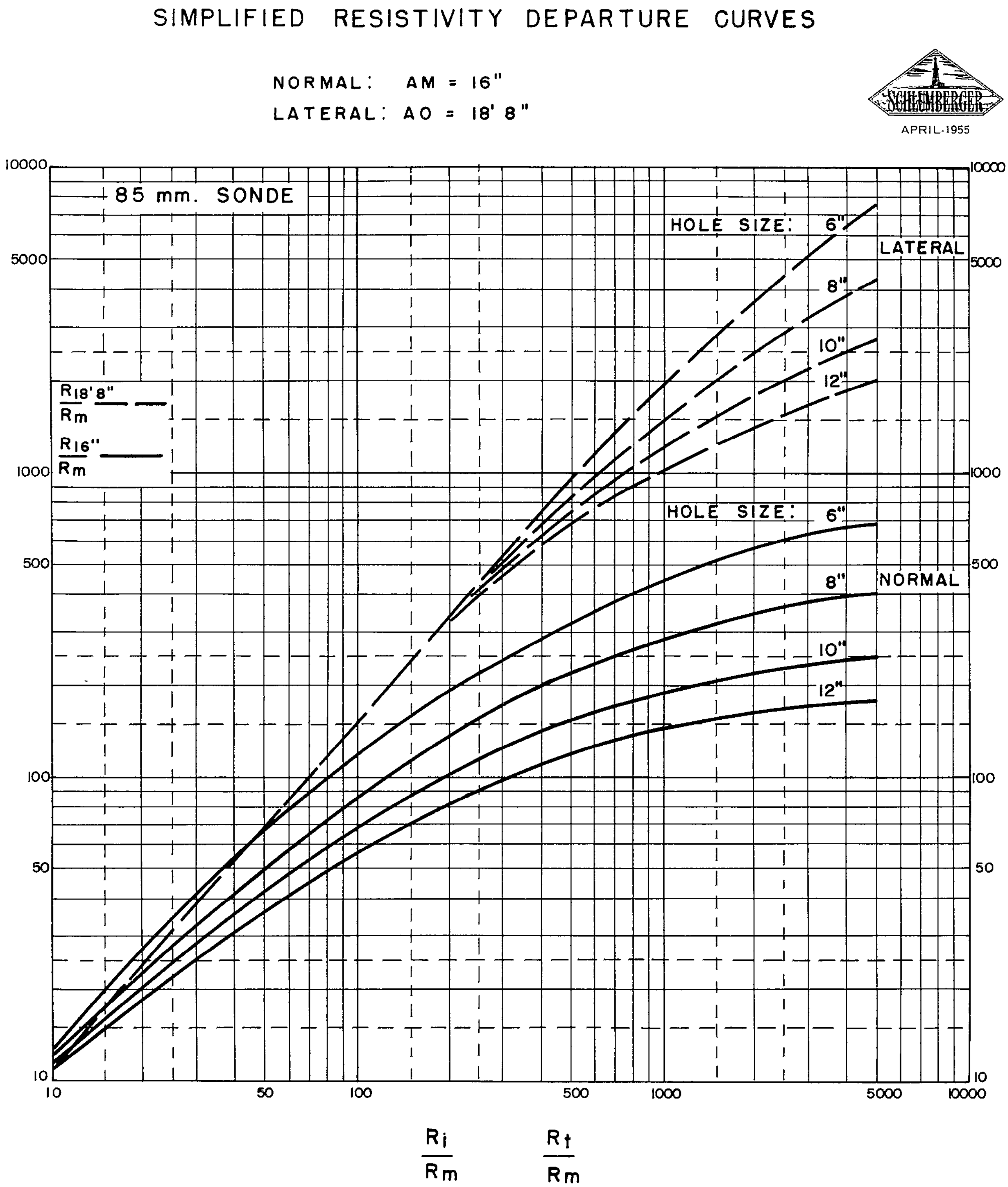

SIMPLIFIED RESISTIVITY DEPARTURE CURVES
NORMAL: AM = 16"
LATERAL: AO = 18' 8"
SCHLUMBERGER
APRIL-1955
85 mm. SONDE
HOLE SIZE: 6"
8"
10"
12"
LATERAL
HOLE SIZE: 6"
8"
10"
12"
NORMAL
R18'8" / Rm
R16" / Rm
10000
5000
1000
500
100
50
10
10
50
100
500
1000
5000
10000
Ri / Rm
Rt / Rm

Chart B-2

SCHLUMBERGER WELL SURVEYING CORP.

LOG INTERPRETATION CHARTS

SIMPLIFIED RESISTIVITY DEPARTURE CURVES — PERMIAN BASIN

USE AND DESCRIPTION

This chart corrects for the influence of the bore hole on the 10″ normal and for the hole and average invasion on the 18′8″ lateral. The sonde diameter and the effect of the reference electrodes are taken into account.

It is used in relativly thick formations of moderate and high resistivity where the 10″ normal is influenced by the invaded zone.

INFORMATION REQUIRED

R_m at Formation Temperature

Actual Hole Diameter

Apparent 10″ and 18′8″ Resistivities

PROCEDURE

For the 10″ normal: Find the ratio $R_{10''}/R_m$. Enter at the left margin and proceed to the solid curve for appropriate hole size. Read R_i/R_m at the bottom.

For the 18′8″ lateral: Find the ratio $R_{18'8''}/R_m$. Enter at the left margin and proceed to the dashed line for appropriate hole size and read R_t/R_m at the bottom.

EXAMPLE

GIVEN: $R_m = .5$ ohm at formation temperature.
Hole Size = 9″.
$R_{10''} = 50$.
$R_{18'8''} = 250$.

SOLUTION: $R_{10''}/R_m = 100$.
$R_{18'8''}/R_m = 500$.
$R_i/R_m = 250$.
$R_t/R_m = 300$.

SCHLUMBERGER
APRIL 1955

SIMPLIFIED RESISTIVITY DEPARTURE CURVES – PERMIAN BASIN

NORMAL: M 10" A 71' 3" N
LATERAL: AO = 18' 8"

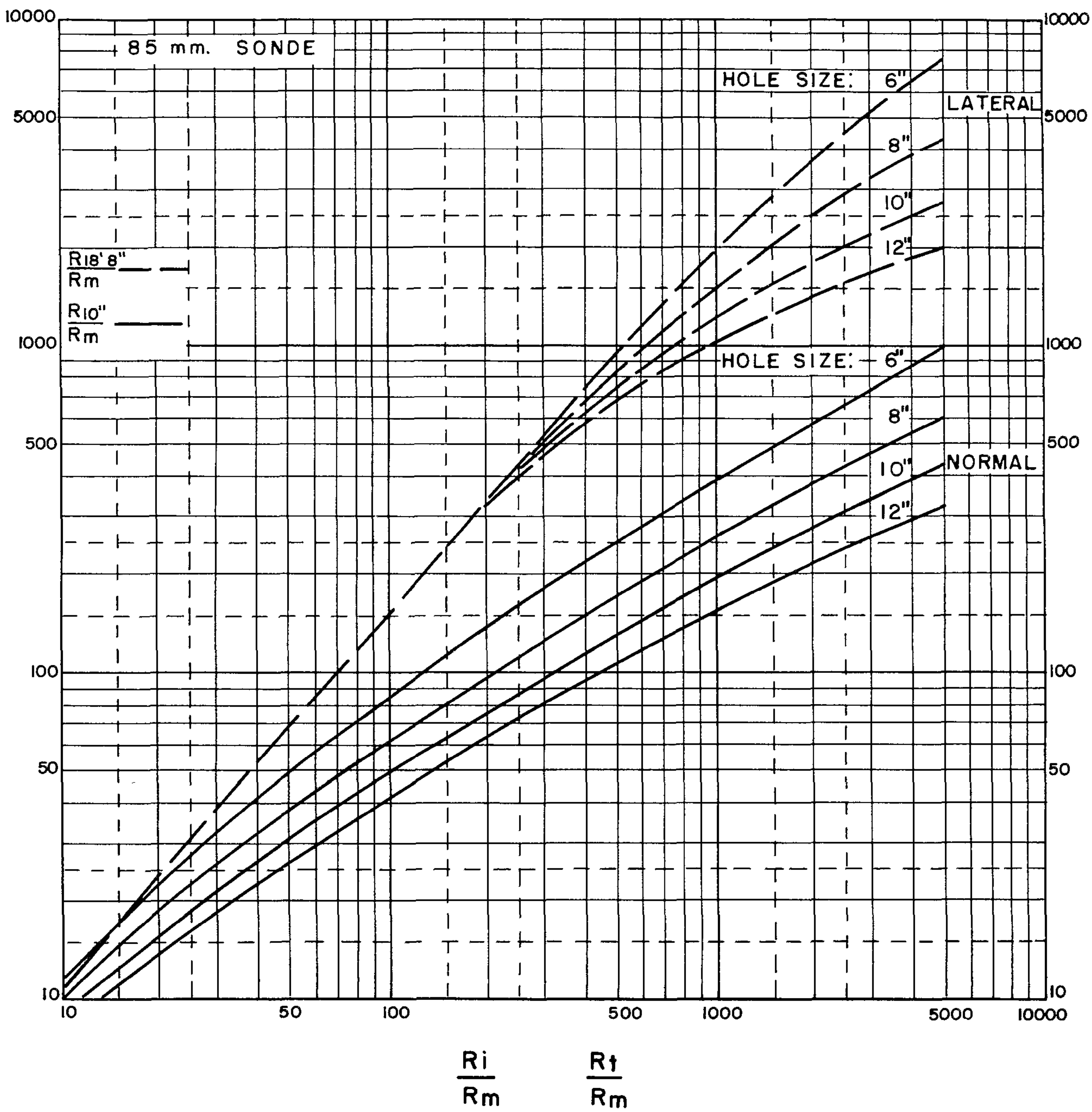


Chart B-4

R_t ESTIMATION FROM ELECTRICAL LOGS

Selection of the proper logging method is very important. Recommended programs, based upon formation and mud type, are given on page 2 of this chartbook.

The Electrical Log is at its best when used in fresh muds, formations of low to moderate resistivity, and fairly thick beds. Departure from these conditions complicates determination of R_t.

Rules for obtaining R_t from Electrical Logs are based on the relative resistivities of the beds compared to the resistivities of the mud and surrounding formations. Therefore, formations are subdivided into three classes, depending on the ratio $R_{16''}/R_m$. These simplifying rules are derived from a study of resistivity departure curves.

1) Low Resistivity — when $R_{16''}/R_m < 10$.

The shorter spacings, such as 16″ and 64″ normals are most useful in finding R_t. Often $R_m \simeq R_s$, in which case the apparent value of the 64″ normal can be easily adjusted to R_t, depending on the ratio $R_{64''}/R_s$ and the bed thickness. The upper part of page B-8 gives this information.

Correction of the 16″ normal for thin beds is shown on Charts B-12 and B-13.

2) Medium Resistivity — when $10 < R_{16''}/R_m < 50$.

In this case the 64″ normal is very useful in the lower portion of this resistivity range, but when $R_{16''}/R_m >$ 20, use of the 18′8″ lateral becomes important, either to find R_t, or to confirm the apparent 64″ normal value. The lateral, being an unsymmetrical curve, requires picking of R_t as is shown on page B-8, *Rules for using Lateral.*

3) High Resistivity — When $R_{16''}/R_m > 50$.

The 64″ normal is greatly affected by invasion, so that the 18′8″ lateral is the best choice for estimating R_t. Choice of the values to use are as shown on page B-8, but these must be further corrected by Chart B-2 (or B-4). In some very tight formations invasion may be such that R_t cannot be found by any device, in which case R_i and R_t as found from Chart B-2 (or B-4) tend to approach the same value. Also, at this time the ratio of this apparent R_t compared to a reconstructed R_o tends to approach the ratio R_{mf}/R_w in nonproductive, slightly permeable formations.

Application of the Porosity Balance is desirable if an independent porosity is available. This method will help to confirm the R_t value (Refer to page D-13).

Laterolog: The Laterolog is particularly useful in this type of resistivity, mainly because of the detailed response obtained and the elimination of a borehole effect. As the equations at the bottom of page B-8 show, invasion affects the Laterolog considerably; but the corrections are simple. Required are a measurement of R_{xo} and a selection of D_i, which must be determined by experience. Invasion effects are minimized when R_{xo} is equal to or less than R_t, a condition met with salt muds.

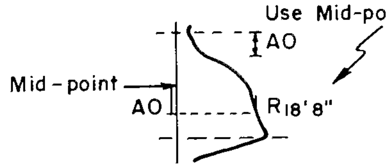
SCHLUMBERGER
OCTOBER 1958

R_t ESTIMATION FROM ELECTRICAL LOGS

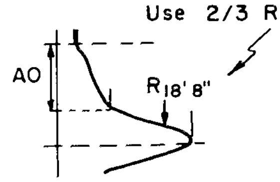
BED THICKNESS (e)	QUALIFICATIONS		DEVICE	RESPONSE
A. IN LOW RESISTIVITY, WHEN $R_{16''}/R_m < 10$ (INVASION UP TO 2d)				
$e > 20'$ (>4 AM')			Long Normal	$R_{64''} = R_t$
$e \simeq 15'$ (3AM')	$R_m \simeq R_s$	$R_{64''}/R_s \geq 2.5$	Long Normal	$R_{64''} = 2/3\ R_t$
$e \simeq 15'$ (3AM')	$R_m \simeq R_s$	$R_{64''}/R_s \leq 1.5$	Long Normal	$R_{64''} = R_t$
$e \simeq 10'$ (2 AM')	$R_m \simeq R_s$	$R_{64''}/R_s \geq 2.5$	Long Normal	$R_{64''} = 1/2\ R_t$
$e \simeq 10'$ (2 AM')	$R_m \simeq R_s$	$R_{64''}/R_s = 1.5$	Long Normal	$R_{64''} = 2/3\ R_t$
$5' < e < 10'$	When oil bearing and SP is -50 – 80 MV		Short Normal	$R_{16''} \simeq R_t$
$5' < e < 10'$	Surrounding beds homogenous		Lateral in resistive bed	$R_t \gtrsim R_{Max} \times R_s/R_{Min}$
Thin beds (in general)	Surrounding beds homogenous		Lateral in conductive bed	$R_{19''} \simeq R_t$

B. RULES FOR USING LATERAL (AO = 18'8")

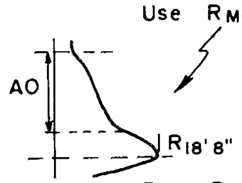
$e > 40'$ (> 2.0 AO) — Use Mid-point Method



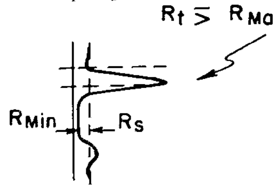
$e \simeq 28'$ (= 1.5 AO) — Use 2/3 Rule



$e \simeq 24'$ (= 1.3 AO) — Use R_{Max}



$5' < e < 10'$ — Resistive bed and surrounding beds homogeneous — $R_t \gtrsim R_{Max} \times R_s/R_{Min}$



(When $R_{16''}/R_m > 50$, these values must then be corrected for the bore hole.) (Chart B-2)

C. RESPONSE OF LATEROLOG – 7 AND LATEROLOG – 3

For Di = 20" $R_{LL7} \simeq 0.2\ R_{xo} + 0.8\ R_t$ $R_{LL3} \simeq 0.25\ R_{xo} + 0.75\ R_t$

Di = 40" $R_{LL7} \simeq 0.4\ R_{xo} + 0.6\ R_t$ $R_{LL3} \simeq 0.5\ R_{xo} + 0.5\ R_t$

Di = 80" $R_{LL7} \simeq 0.6\ R_{xo} + 0.4\ R_t$ $R_{LL3} \simeq 0.75\ R_{xo} + 0.25\ R_t$

Thus, the best results occur when $R_{xo} < R_t$ and $R_{mf}/R_w < 4$

SCHLUMBERGER WELL SURVEYING CORPORATION

16" NORMAL CORRECTION CHART

USE AND DESCRIPTION

This chart will correct the 16" Normal resistivity for thin beds. The corrected value is the value which a 16" Normal would read in a very thick bed with the same invasion.

INFORMATION REQUIRED

e - bed thickness
$R_{16"}$ - reading at the center of the bed
R_s - surrounding bed resistivity
R_m - mud resistivity at formation temperature

PROCEDURE

Determine $R_{16"}/R_m$

Enter this value at the appropriate hole size chart on the left margin; go to the proper bed thickness curve and then to the bottom to find the $R_{16"}/R_m$ corrected. Multiply by R_m to get $R_{16"}$corrected.

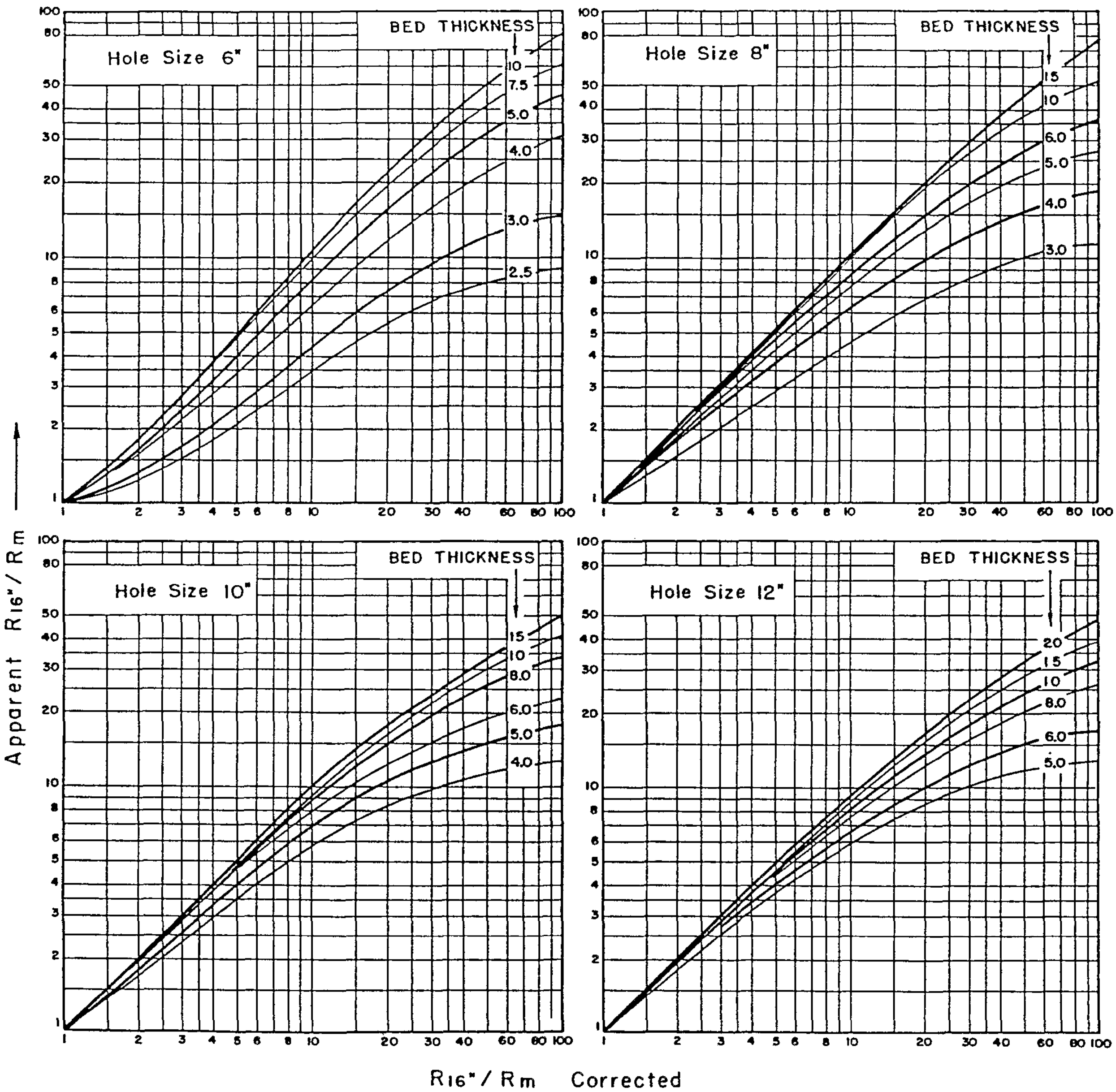
EXAMPLE

Given: $R_{16"} = 5$
$R_s = 1$
$R_m = 1.25$
$e = 3'$
$d = 8'$

Solution: $R_{16"}/R_m = 4$

Therefore, $R_{16"}/R_m$ corrected = 8
$R_{16"}$ corrected = 8 x 1.25 = 10

16" NORMAL CORRECTION CHART – THIN BEDS



Conditions for use : When $R_m \simeq R_s$, or when $R_t > 7 R_s$ (for $e > 6'$)

or when $R_t > 10 R_s$ (for $e < 6'$)

Chart B-10

SCHLUMBERGER WELL SURVEYING CORP.

LOG INTERPRETATION CHARTS

POROSITY INDEX FROM LIMESTONE LATERAL

USE AND DESCRIPTION

The response of the limestone lateral permits a graphical method for estimating porosity, since the curve levels out at 1±% porosity; the porosity index at any other point is a function of the deflection from zero compared to the maximum deflection for 1±%, providing the hole size is constant and known. This porosity index is then corrected to actual porosity according to the multiplier "C" shown at the bottom right of the chart.

At the bottom left is a table giving maximum R_a/R_m for several bit sizes. This is used to check the R_m value when a zone of 1±% is available. Also, if no such zone is available, the equivalent deflection can be found for 1±% porosity to use for "maximum deflection" at upper left.

INFORMATION REQUIRED

R_{Max} — in ohms or in divisions deflection

R_a — the same as above for the zone in question.

Hole Size and AO Spacing

SP

PROCEDURE

At the upper left a line is passed through points representing values on the curve for maximum deflection (from a dense zone) and observed deflection to get per cent deflection. This value is entered into the main chart, and intersection with the known hole size gives the porosity index. This value has to be corrected by consideration of the SP, as shown at the bottom right: Porosity = C × Porosity Index.

If no R_{Max} is seen on the log, it is computed by knowing the hole size and multiplying the appropriate maximum R_a/R_m by R_m which is known. See table, lower left.

EXAMPLE

GIVEN: R_a = 50 ohms; R_m = .5; SP = —25; Hole Size = 7⅞"; AO = 32".

SOLUTION: (1). Find maximum deflection. Maximum R_a/R_m for 7⅞" hole and AO = 32" = 128 ohms. Then maximum deflection = maximum $R_a/R_m \times R_m$ = 128 × .5 = 64 ohms.

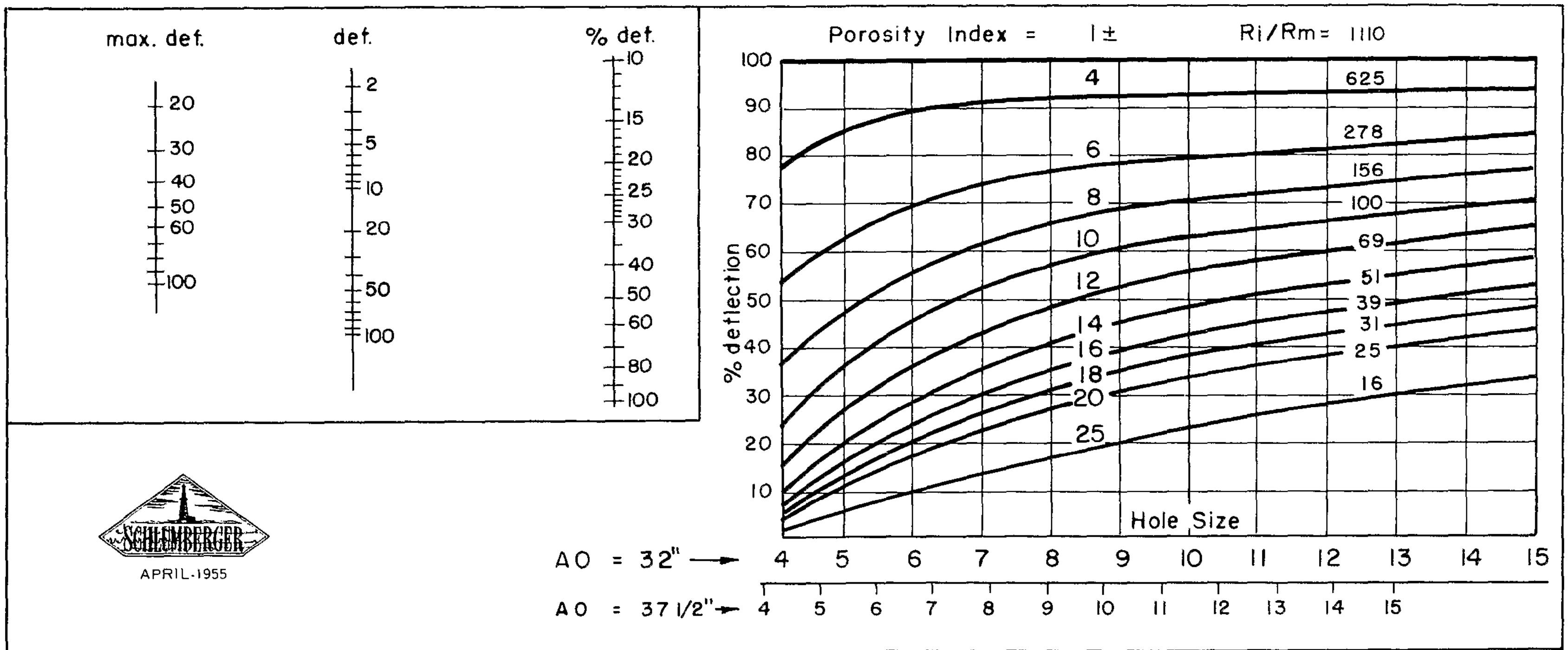
(2). Find per cent deflection. Use 64 on first scale and 50 on second scale; read 80 on third scale.

(3). Find porosity index for 7⅞" hole. Equals 5.5.

(4). Find porosity — see bottom right for value of "C".
If oil bearing, C = 1.3, since SP = —25.
Porosity = C × PI = 1.3 × 5.5 = 7%.

NOTE: Step (1) would be unnecessary if the maximum deflection in a dense zone was available for the same hole size.

POROSITY INDEX FROM LIMESTONE LATERAL



Max. Ra/Rm

HOLE SIZE	AO = 32"	AO = 37 1/2"
4 3/4"	445	605
6 3/4"	177	232
7 7/8"	128	171
8 3/4"	102	141

WATER – BEARING FORMATIONS

WHEN	THEN
" SP = 0	" C = 1
" SP = –50 MV	" C = 0.86
" SP = –100MV	" C = 0.7

OIL – BEARING FORMATIONS

WHEN	THEN
" SP = 0	" C = 1.4
" SP = –50 MV	" C = 1.22
" SP = –100MV	" C = 1

Chart C-16

SCHLUMBERGER WELL SURVEYING CORP.

LOG INTERPRETATION CHARTS

EMPIRICAL MICROLOG CHART

USE AND DESCRIPTION

This chart is used to find porosity and formation factor by use of the MicroLog. It is an empirical chart statistically built from comparisons between core analysis and the micronormal (2″) as read from Type D pad MicroLogs. Therefore, average mud cake thickness and residual oil are assumed. Thicker mud cakes make the porosity indicated as too large, and thinner mud cakes the porosity too small.

Use with the hydraulic type pad will give porosities which tend to be too low.

At the bottom of the sheet is attached an alignment graph giving the relation between porosity and formation factor, using the Humble Formula.

INFORMATION REQUIRED

R_m at Formation Temperature

$R_{2''}$ read from the Dotted Curve of the MicroLog

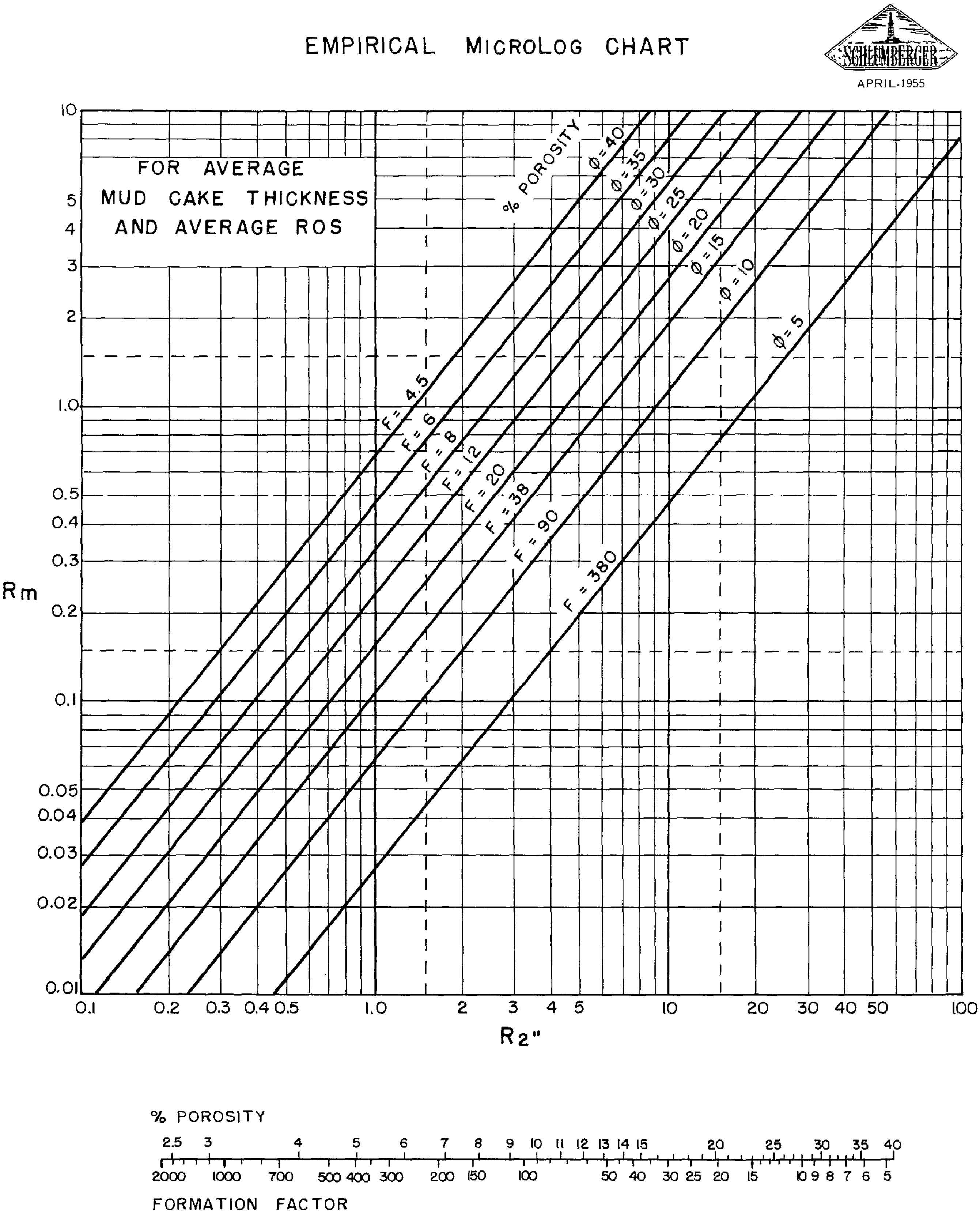
PROCEDURE

Enter R_m at the left and $R_{2''}$ at the bottom. Intersection of lines from these points permits estimation of porosity. Formation factor can also be noted, but for best interpolation the estimated porosity should be referred to the alignment graph at the bottom.

EXAMPLE

GIVEN: $R_m = 0.7$ at Formation Temperature.
$R_{2''} = 6$.

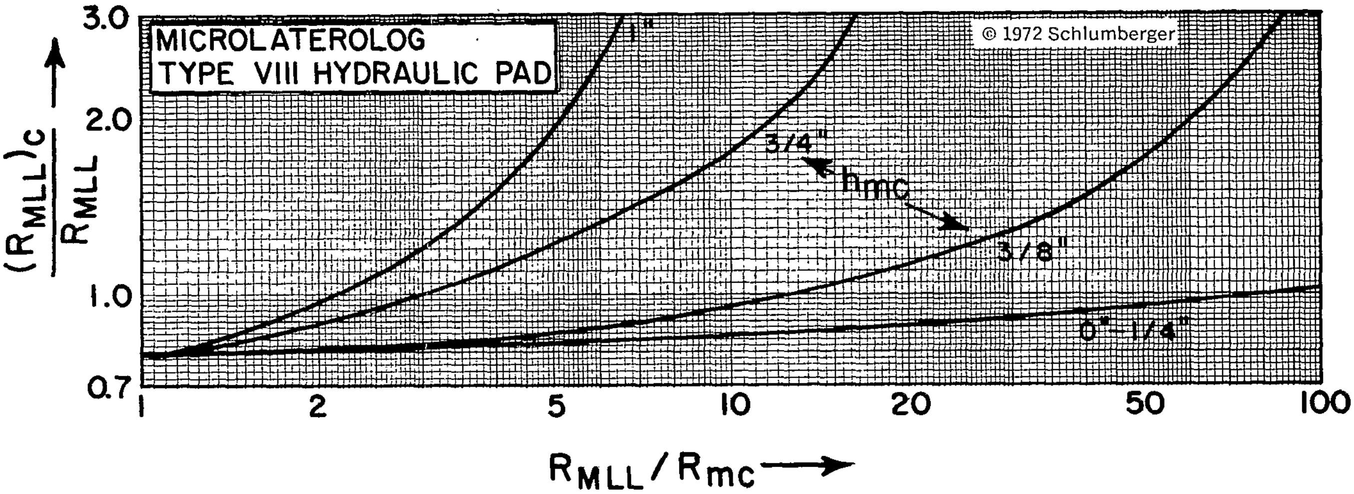
SOLUTION: Porosity = 12%.
Formation Factor = 62.

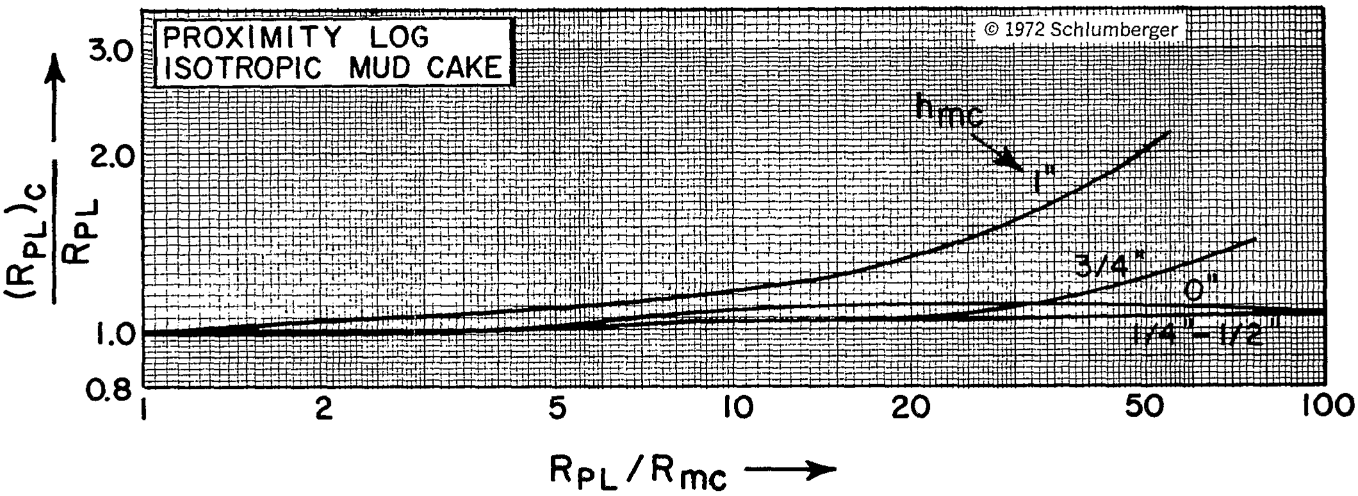

EMPIRICAL MICROLOG CHART
SCHLUMBERGER
APRIL-1955
FOR AVERAGE MUD CAKE THICKNESS AND AVERAGE ROS
% POROSITY
φ = 40
φ = 35
φ = 30
φ = 25
φ = 20
φ = 15
φ = 10
φ = 5
F = 4.5
F = 6
F = 8
F = 12
F = 20
F = 38
F = 90
F = 380
Rm
R2"
10
5
4
3
2
1.0
0.5
0.4
0.3
0.2
0.1
0.05
0.04
0.03
0.02
0.01
0.1
0.2
0.3
0.4
0.5
1.0
2
3
4
5
10
20
30
40
50
100
% POROSITY
2.5 3 4 5 6 7 8 9 10 11 12 13 14 15 20 25 30 35 40
2000 1000 700 500 400 300 200 150 100 50 40 30 25 20 15 10 9 8 7 6 5
FORMATION FACTOR

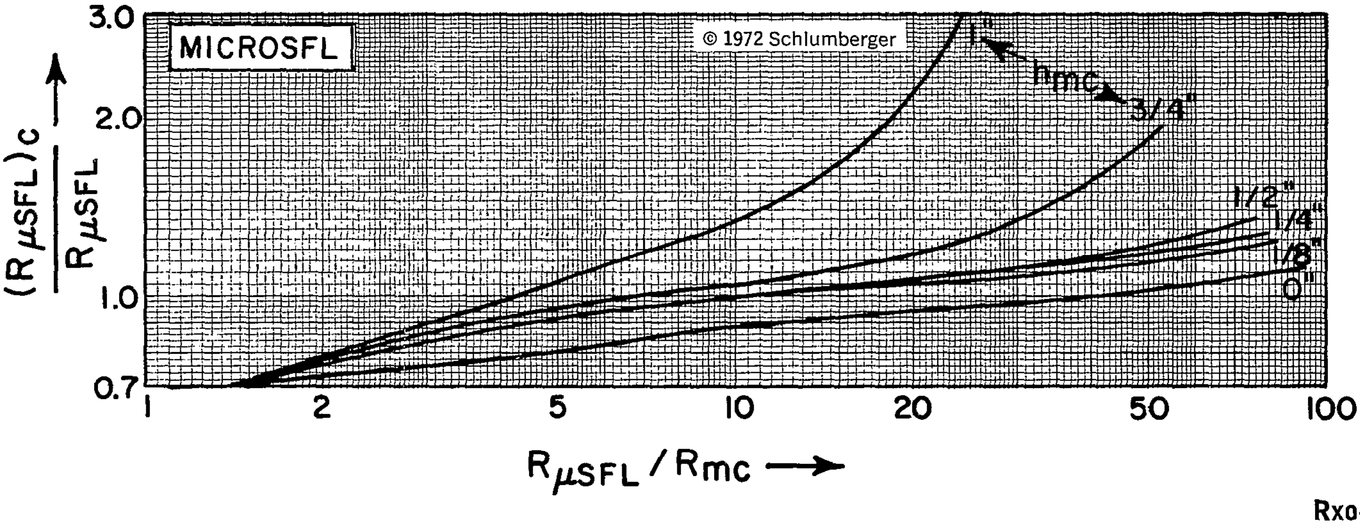
MICROLATEROLOG, PROXIMITY LOG, AND MICROSFL

MUD CAKE CORRECTION

8" HOLE







Density Log Interpretation

CHRONOLOGY

1961

FDL (PGT-A and -B tools). Departure curves for air- and water-filled holes.

Rodermund CG, Alger RP and Tittman J: "Empty Hole Logging Programs for Reservoir Evaluation," *Transactions of the SPWLA 2nd Annual Logging Symposium*, Dallas, May 18-19, 1961, paper 2.

1962

FDL (PGT-B tools). Departure curves for water-filled holes. Correction curves for normal and barite muds.

Alger RP, Raymer LL, Hoyle WR and Tixier MP: "Formation Density Log Applications in Liquid-Filled Holes," paper SPE 435, presented at the 37th SPE Annual Meeting, Los Angeles, October 7-10, 1962.

1962

FDL (PGT-C tools). Bulk density/porosity chart with borehole size corrections for gas- and liquid-filled holes. Mudcake corrections for normal and weighted muds.

Log Interpretation Charts. Houston: Schlumberger Well Surveying Corporation, 1962.

1968

FDC (PGT-K tools). Bulk density/porosity charts for fresh and salt water-filled boreholes (no borehole size corrections).

Wahl JS, Tittman J, Johnstone CW and Alger RP: "The Dual Spacing Formation Density Log," *Journal of Petroleum Technology* 16 (December 1964): 1411-1416.

1972

FDC (PGT-K tools). Bulk density/porosity charts for fresh and salt water-filled boreholes (different format). Hole size correction charts for gas- and water-filled boreholes.

1978

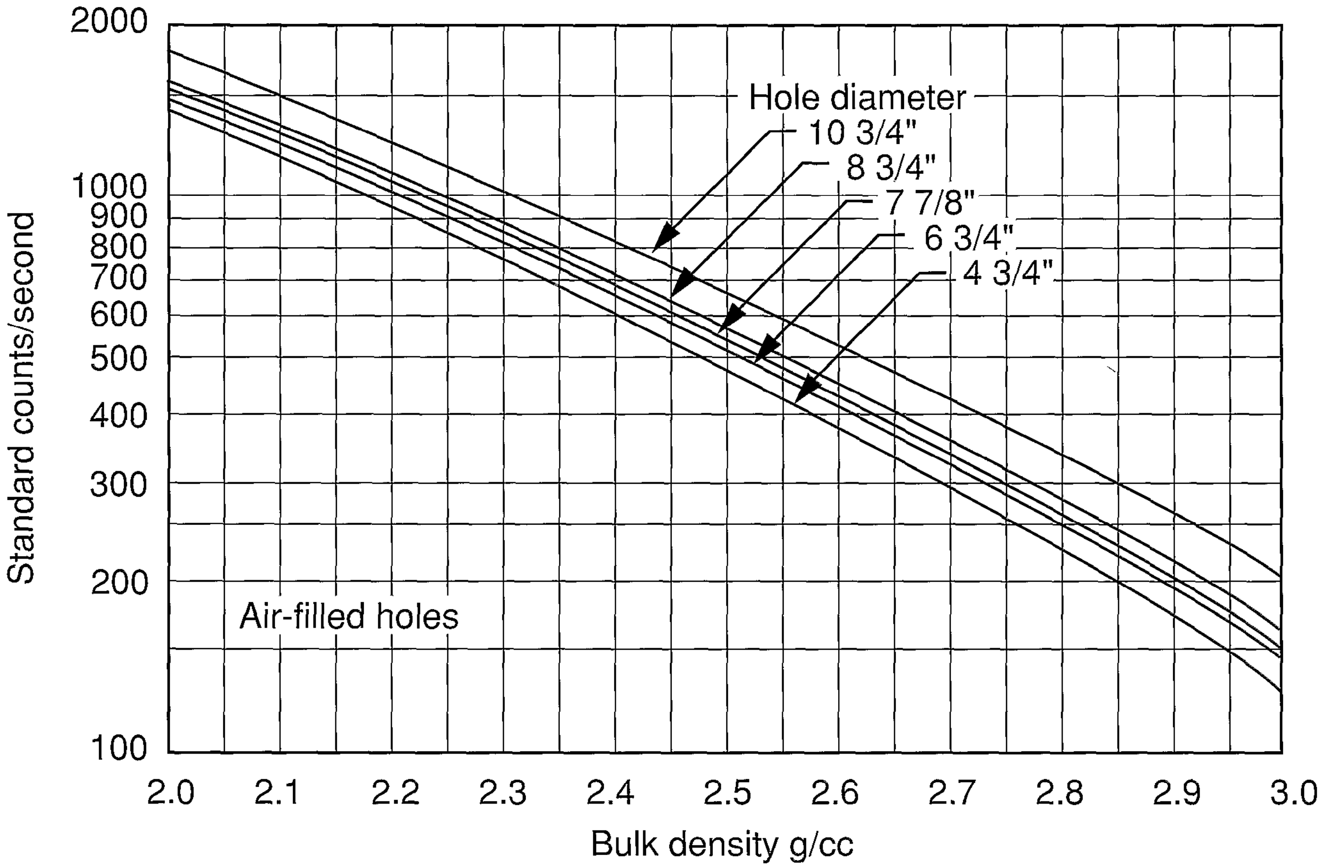
FDC (PGT-K tools). Bulk density/porosity charts with correction for borehole fluid density (no hole size correction chart — probably an oversight).

1984

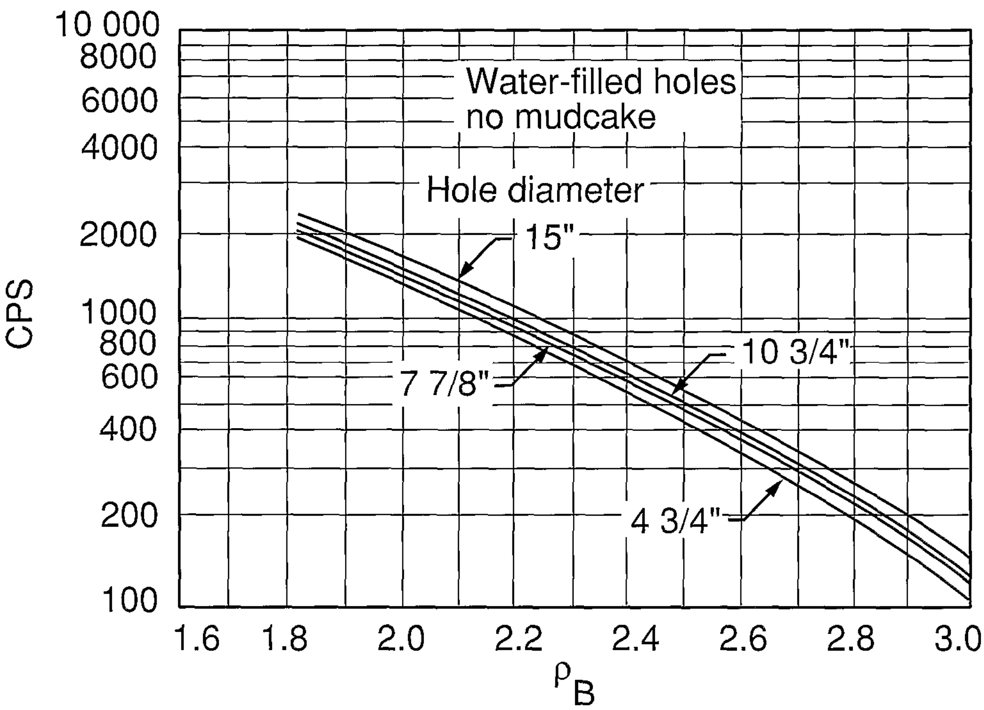
FDC and Litho-Density tools. Bulk density/porosity charts with correction for borehole fluid density (same as 1978 chart). FDC borehole correction chart for gas- and mud-filled holes (same as 1972). Litho-Density borehole correction chart. FGT environmental correction chart.

Gardner JS and Dumanoir JL: "Litho-Density* Log Interpretation," *Transactions of the SPWLA 21st Logging Symposium*, Lafayette, Louisiana, July 8-11, 1980, paper N.

Bulk Density from Formation Density Log
(PGT-A,B Tools)

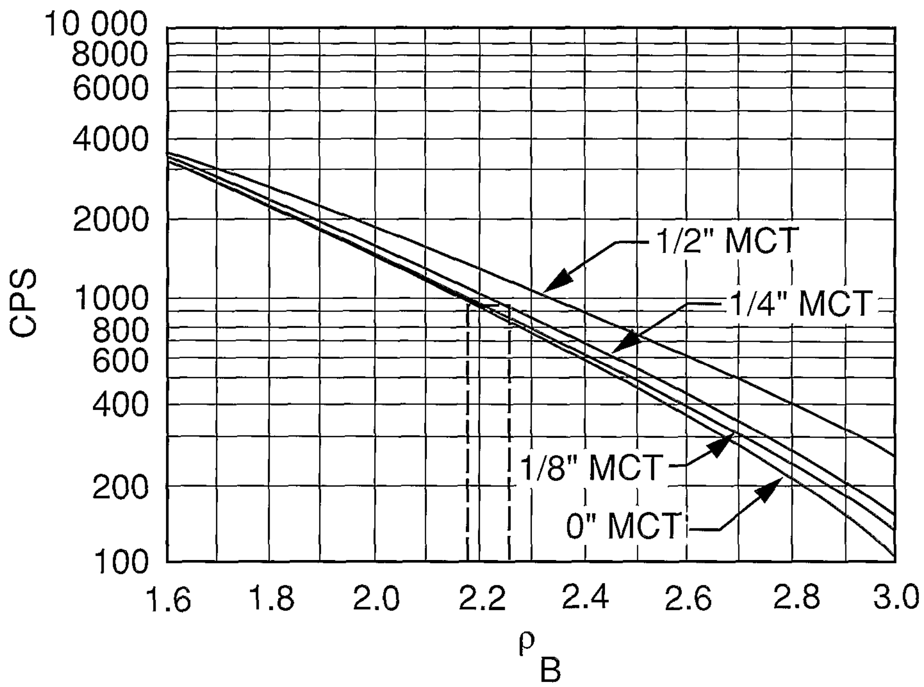


Bulk Density from Formation Density Log
(PGT-A,B Tools)

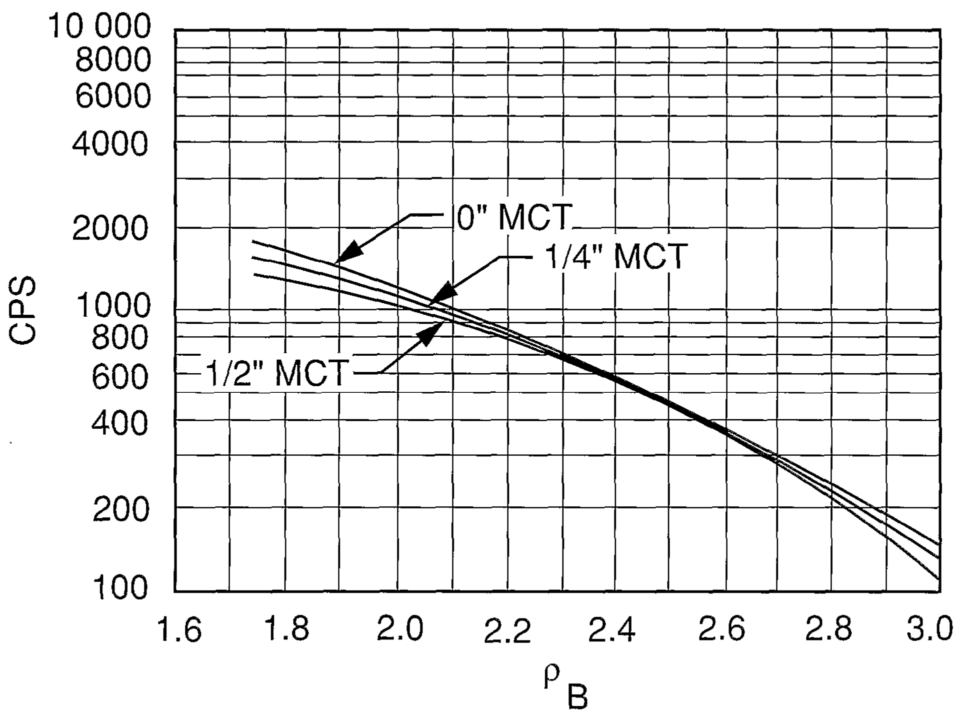


1961

Density Log Response Curves for Mudcakes
with Density of 1.5 gm/cc
(PGT-A,B Tools)



Density Log Response Curves for Mudcakes
with Density of 2.0 gm/cc
(PGT-A,B Tools)



SCHLUMBERGER WELL SURVEYING CORP.

POROSITY FROM FORMATION DENSITY LOG

USE AND DESCRIPTION

This chart is used to find porosity from bulk density or counts per second recorded by the Formation Density Log. It is the graphical solution of the equation $\emptyset = (\rho_G - \rho_B)/(\rho_G - \rho_F)$ in which fluid density is taken to be 1.0 gm/cc.

The chart may be entered with either bulk density or counts per second. Two counts per second scales are provided. One, at the top of the chart, is for empty or gas-filled holes. The other, at the bottom of the chart, is for liquid-filled holes.

In liquid-filled holes the Formation Density Log may require correction for the presence of mud cake. The scales below are used to make this correction.

INFORMATION REQUIRED

ρ_B — from Formation Density Log, *or*
cps — from Formation Density Log
d — hole diameter.
Knowledge of lithology.
In liquid-filled holes additional information is required
ρ_{mc} — approximate mud cake density.
t_{mc} — mud cake thickness.

PROCEDURE

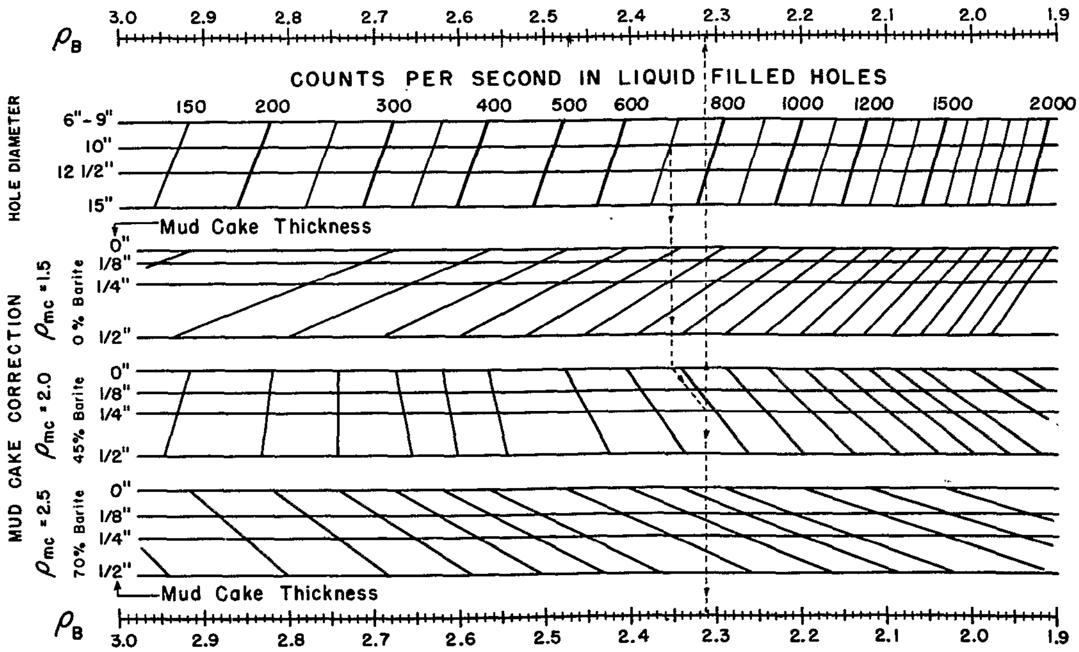
When little or no mud cake exists: Enter the appropriate hole-fluid grid with counts per second and hole diameter. From their intercept, go vertically to the proper value of grain density (ρ_G). From this latter intercept, go horizontally to the edge of the chart to read porosity.

When mud cake exists: Enter the grid below with counts per second and hole diameter. From their intercept, go vertically to the 0″ mud cake line of the appropriate ρ_{mc} (mud cake density) grid. From this point parallel the nearest diagonal line to the proper mud cake thickness. From this intercept, go vertically to the corrected ρ_B value. This value of ρ_B is then entered directly into chart C-16 for porosity determination.

EXAMPLE:

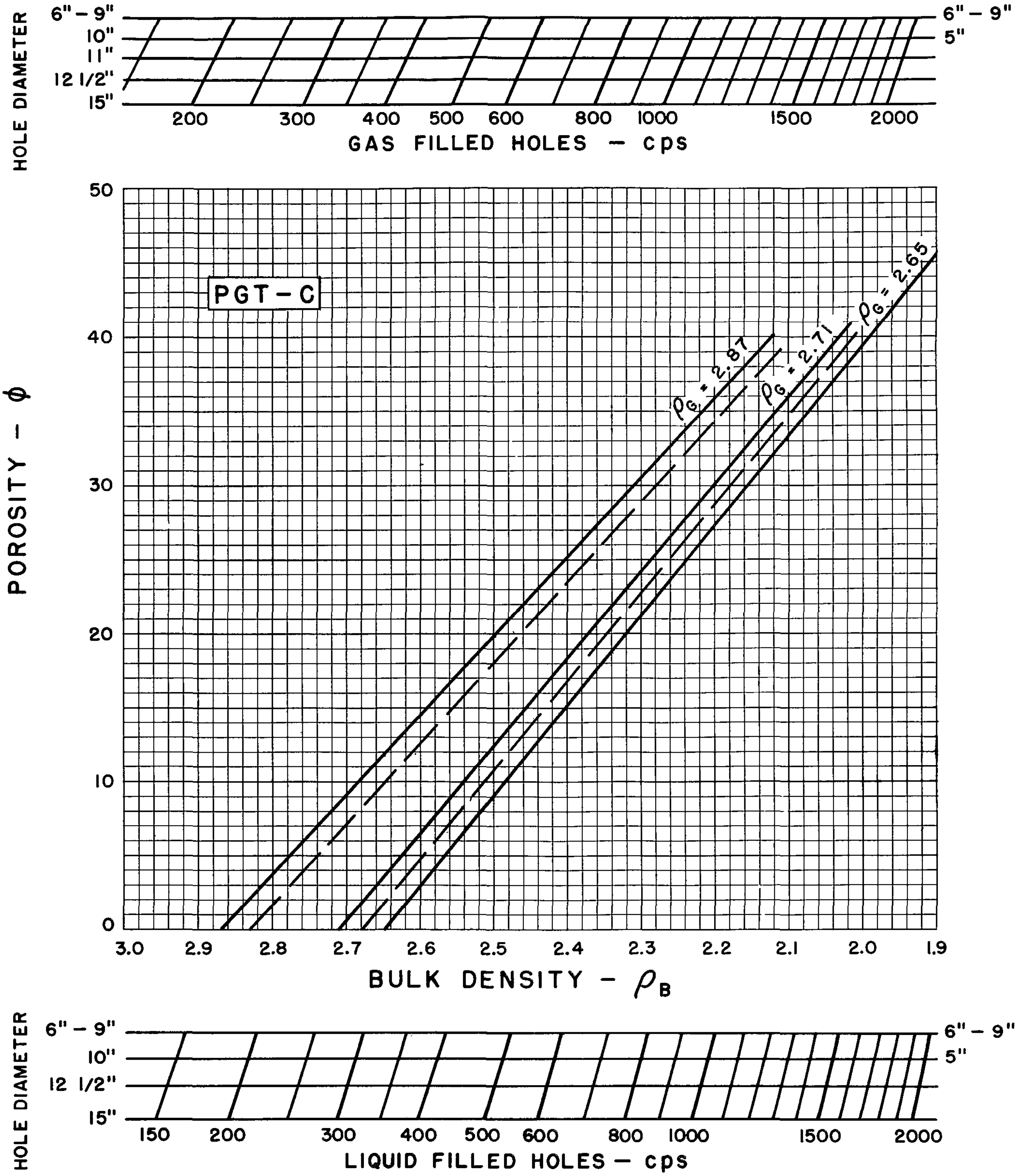
GIVEN: Liquid-filled hole
cps = 700
d = 10″
$t_{mc} = 1/4''$
$\rho_{mc} \approx 2.0$
Formation is sandstone

SOLUTION: ρ_B (corrected for mud cake) = 2.31
$\emptyset = 20.5\%$



SCHLUMBERGER
OCTOBER 1962

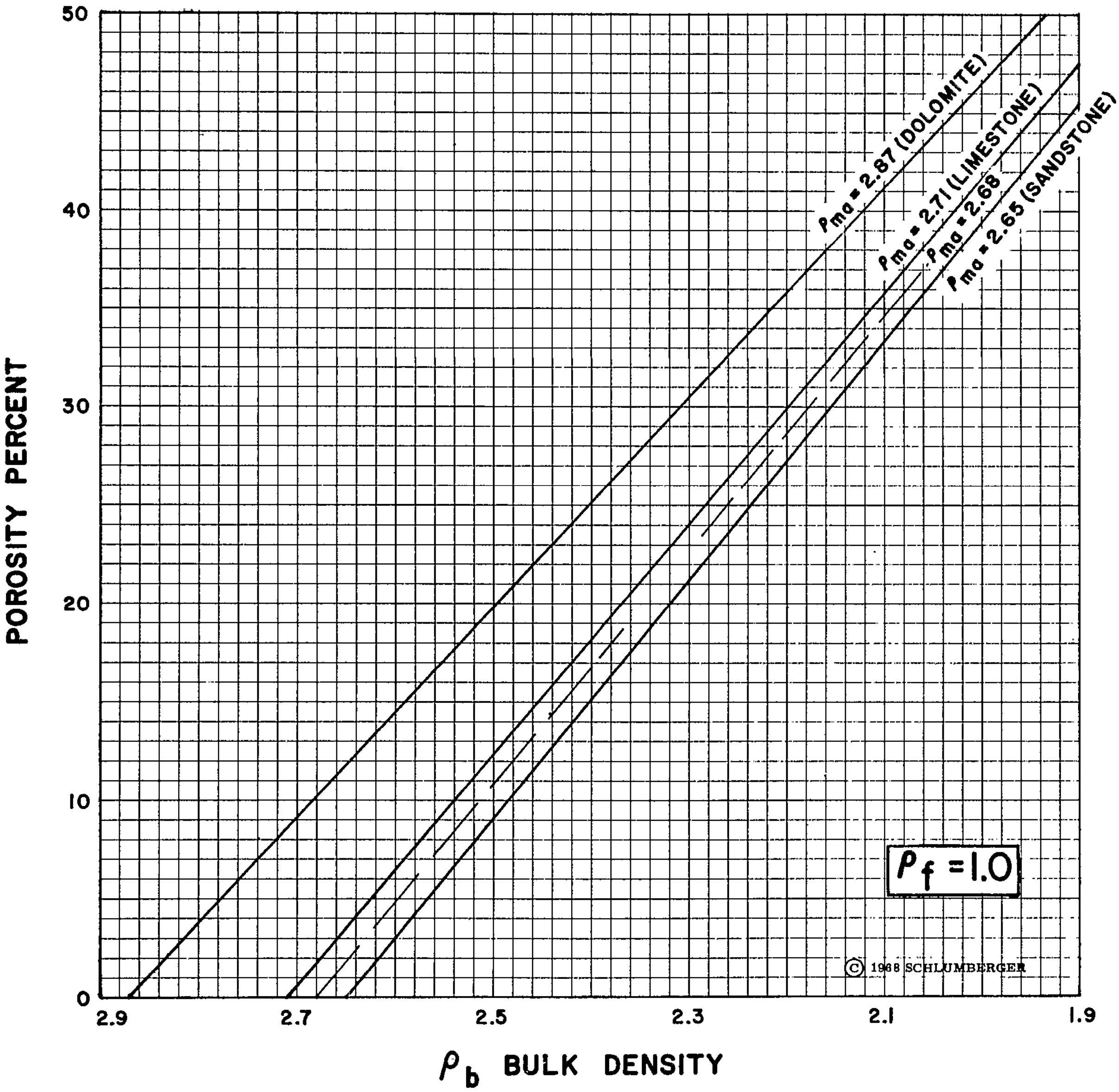
POROSITY FROM FORMATION DENSITY LOG



Note: Departure curves for PGT – A & B equipment are available upon request.

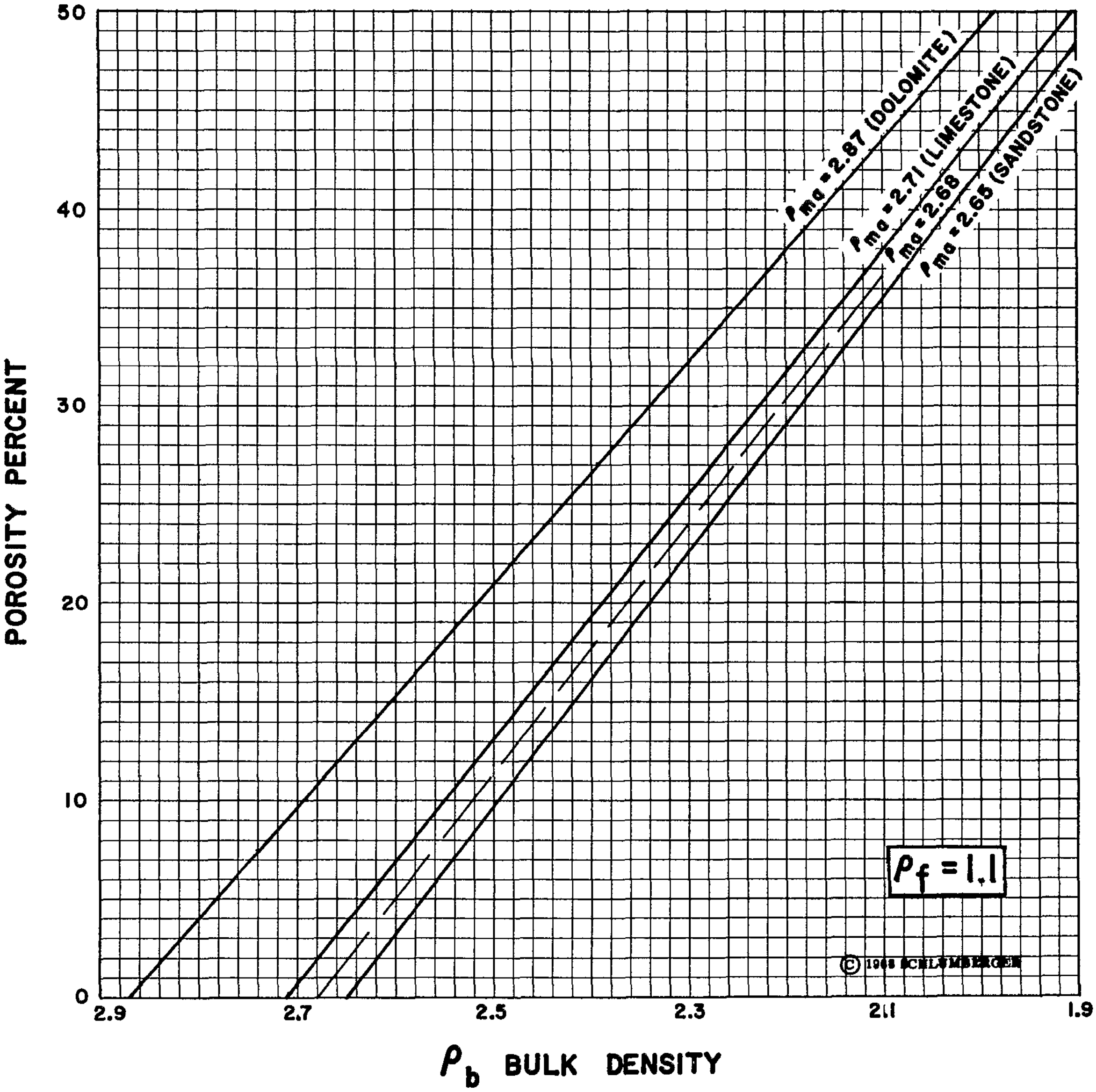
FORMATION DENSITY COMPENSATED DETERMINATION OF POROSITY

FRESH WATER

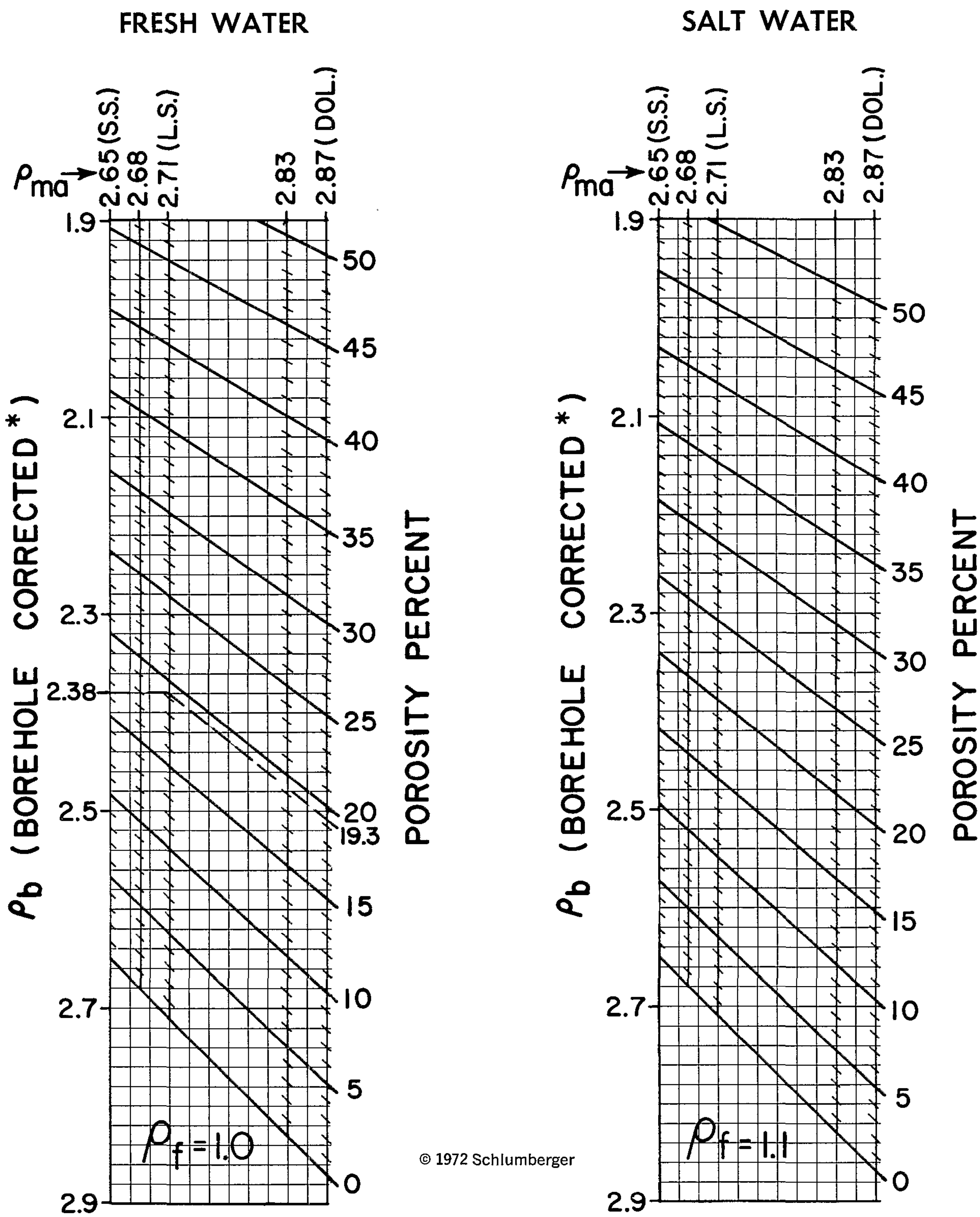


FORMATION DENSITY COMPENSATED DETERMINATION OF POROSITY

SALT WATER



FORMATION DENSITY COMPENSATED DETERMINATION OF POROSITY



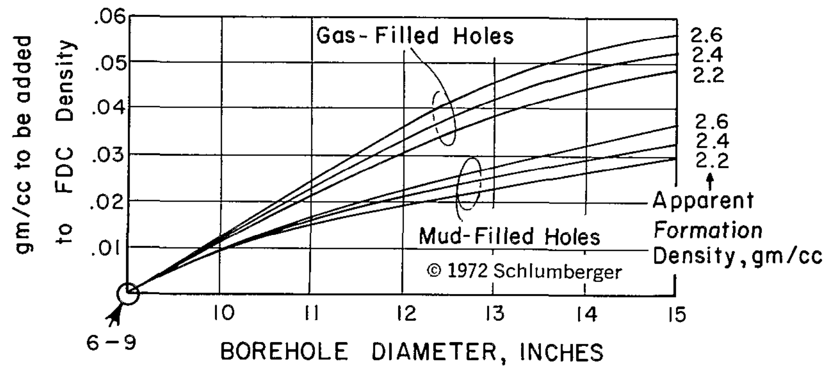
* See Por-5b, page 18.

Example: $\rho_b = 2.38$ in limestone lithology ($\rho_{ma} = 2.71$), fresh mud ($\rho_f = 1.0$).

Solution: $\phi_D = 19.3$.

FDC BOREHOLE CORRECTIONS

(For small mud-cake thicknesses)

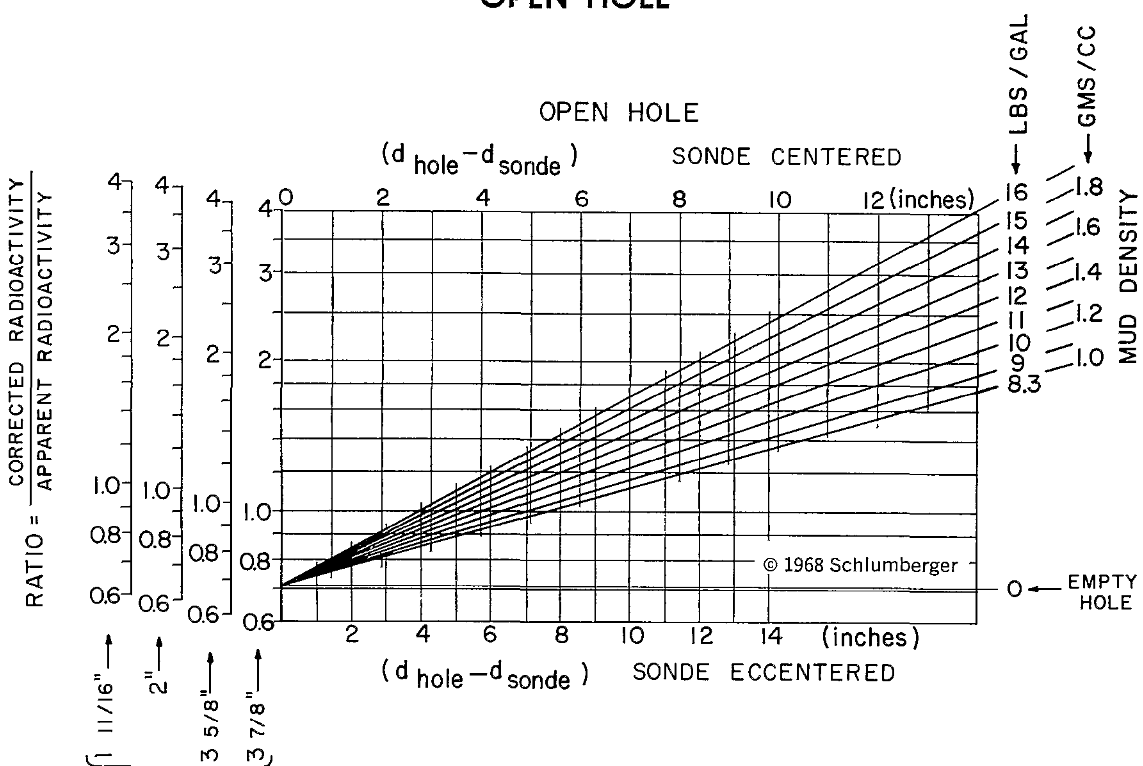


For cylindrical holes use bit size rather than caliper.

Por-5b

GAMMA RAY BOREHOLE CORRECTION

OPEN HOLE



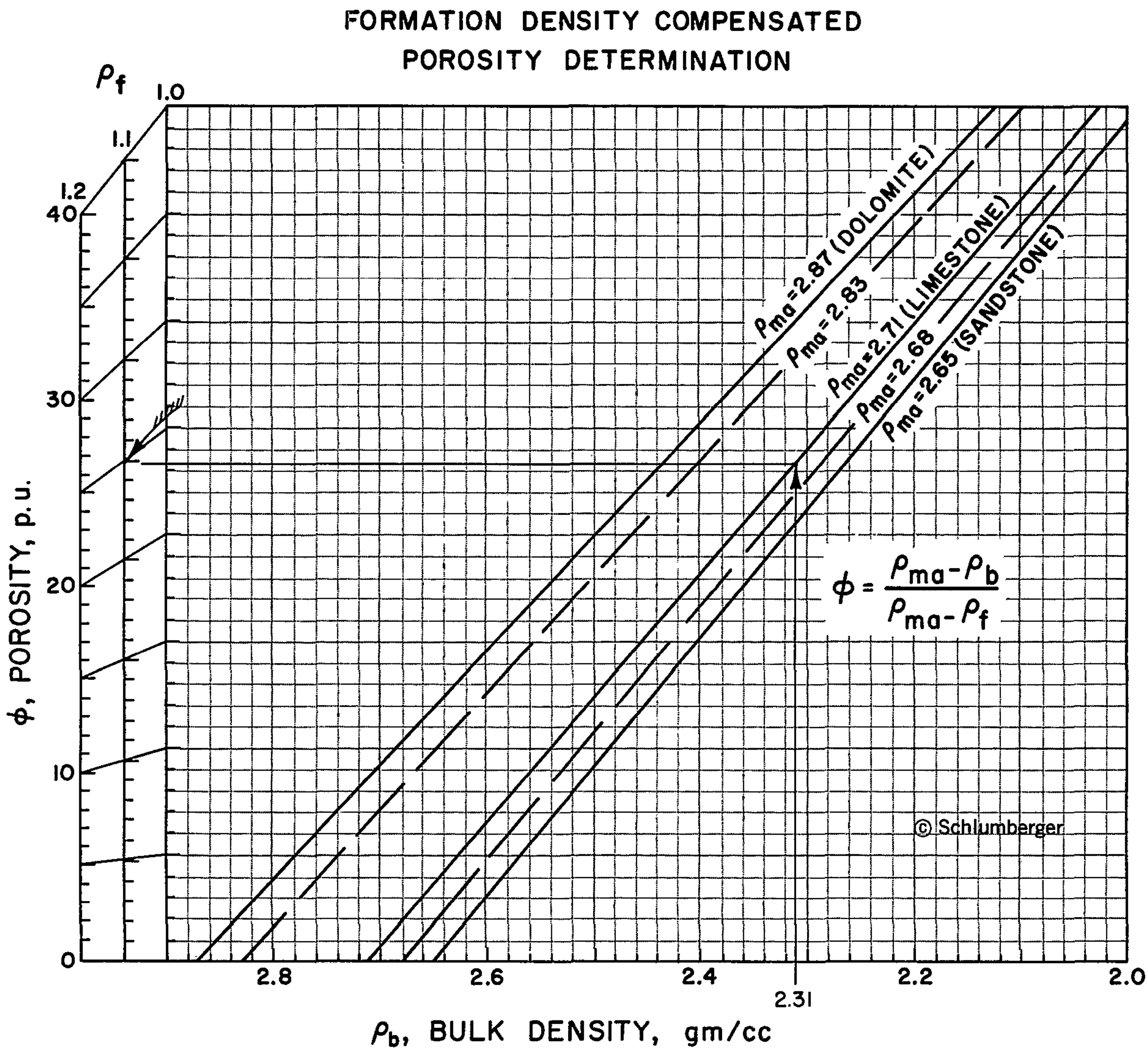
For centered sondes use scale of d_{hole}-d_{sonde} at top of chart. For eccentered sondes use scale at bottom. Find intercept with line for appropriate mud density. Read correction factor at left, on scale for appropriate sonde diameter.

These corrections are for sonde calibration corresponding to API test pit. (Belknap et al; "API Calibration Facility for Nuclear Logs," API Drilling and Production Practice, 1959.) They can also be used with little error for standard 3⅞-inch or 3⅝-inch sondes calibrated by the method of Blanchard and Dewan (Pet. Eng., Aug., 1953); i.e., calibrated with sonde eccentered in 10-inch hole filled with 10 lb/gal mud.

Por-7

Schlumberger

FORMATION DENSITY LOG DETERMINATION OF POROSITY



EXAMPLE: ρ_b = 2.31 gm/cc in limestone lithology
ρ_{ma} = 2.71 (limestone)
ρ_f = 1.1 (salt mud)

SOLUTION: ϕ_D = 25 p.u.

Por-5

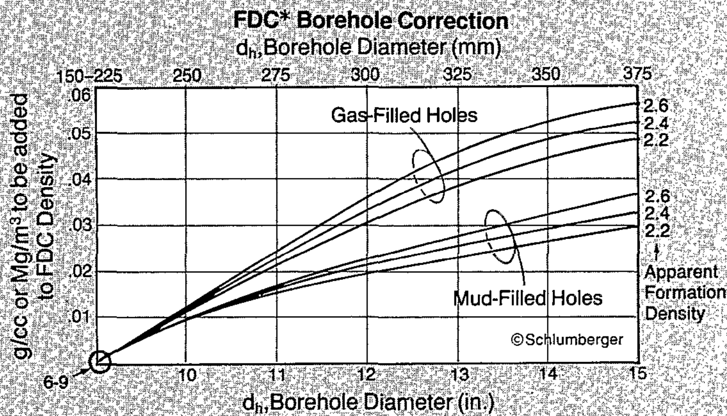
Environmental Corrections to Formation Density Log, Litho-Density* Log, and Sidewall Neutron Porosity Log

Under some circumstances, the FDC* Formation Density log and LDT Litho-Density log need to be corrected for borehole size, and the SNP Sidewall Neutron log needs to be corrected for mudcake thickness. These charts provide those corrections.

For the FDC log, enter the chart with borehole diameter, d_h. Go to the Apparent Formation Density, ρ_b (FDC log density reading); and read, in ordinate, the correction to be added to the FDC log density reading.

EXAMPLE:
d_h = 12 in.
ρ_b = 2.20 g/cc
Mud-filled borehole

Thus, Correction = + 0.02 g/cc
ρ_{bcor} = 2.20 + 0.02 = 2.22 g/cc



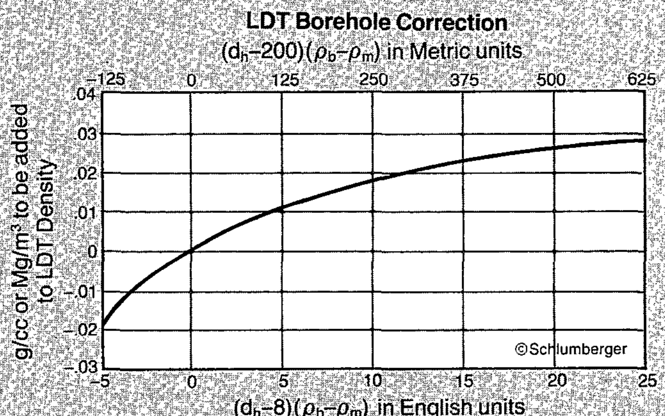
For the LDT log, enter the chart abscissa with the product of the borehole diameter, d_h, less 8 in. (or 200 mm) and the LDT density reading, ρ_b, less mud density ρ_m. Read, in ordinate, the correction to be added to the LDT bulk density reading.

EXAMPLE:
d_h = 325 mm
ρ_b = 2.45 Mg/m³
ρ_m = 1.05 Mg/m³

Giving, $(d_h - 200)(\rho_b - \rho_m)$ =
(325 – 200)(2.45 – 1.05) = 175

Thus, Correction = + 0.014 Mg/m³
ρ_{bcor} = 2.45 + 0.014 = 2.464 Mg/m³

Note: If the borehole diameter from the FDC or LDT caliper is less than bit size, use the bit size in the above charts.



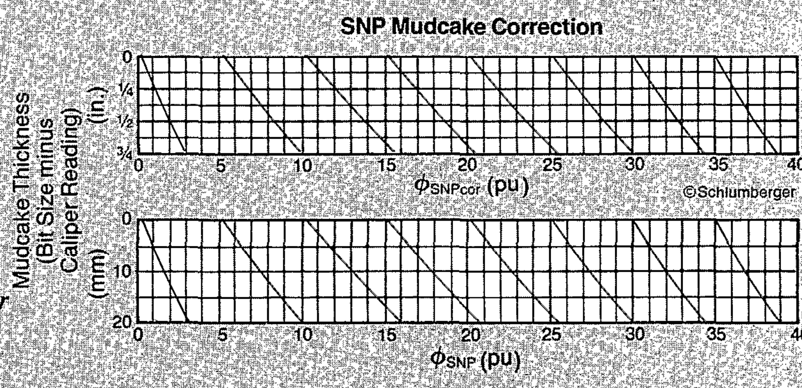
For the SNP log, enter the bottom of the chart with the SNP apparent porosity, ϕ_{SNP}; go vertically to the Bit Size minus Caliper Reading value; then follow the diagonal curves to the top edge of the chart to obtain the corrected SNP apparent porosity.

EXAMPLE:
ϕ_{SNP} = 13 pu
Caliper = 7⅝ in.
Bit Size = 7⅞ in.

Giving, Bit Size – Caliper =
7⅞ – 7⅝ = ¼ in.

Thus, ϕ_{SNPcor} = 11 pu

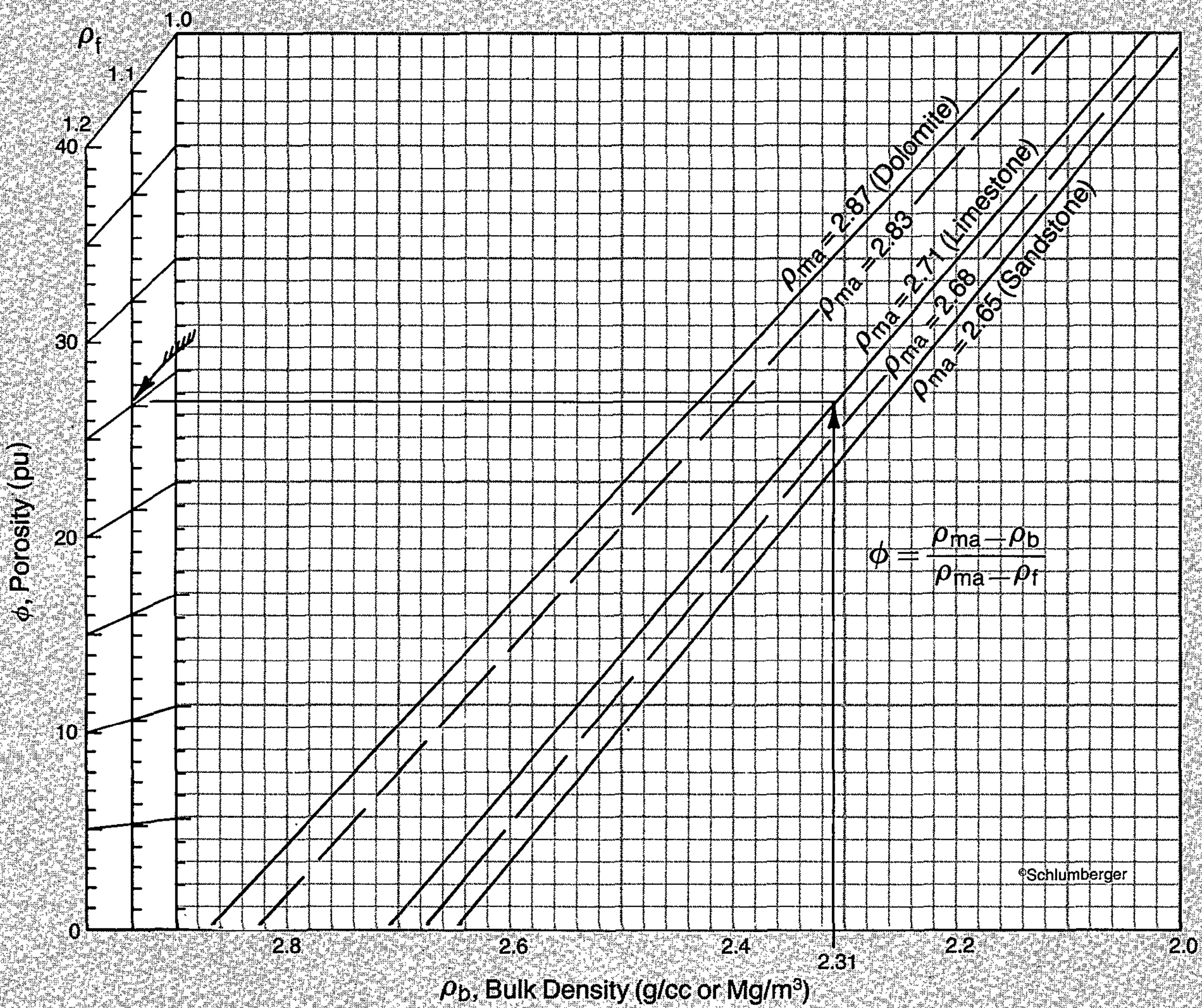
Note: The full borehole diameter reduction shown on the SNP caliper is used as mudcake thickness since the SNP backup shoe usually cuts through the mudcake.



*Mark of Schlumberger

Por-15a

Formation Density Log Determination of Porosity



Bulk density, ρ_b, as recorded with the FDC* or LDT density logs, is converted to porosity with this chart. To use, bulk density, corrected for borehole size, is entered in abscissa; go to the appropriate reservoir rock type and read porosity on the appropriate fluid density, ρ_f, scale in ordinate. (ρ_f is the density of the fluid saturating the rock immediately surrounding the borehole—usually mud filtrate.)

EXAMPLE: $\rho_b = 2.31$ Mg/m^3 in limestone lithology
$\rho_{ma} = 2.71$ (limestone)
$\rho_f = 1.1$ (salt mud)

Therefore $\phi_D = 25$ pu

*Mark of Schlumberger

Neutron Log Interpretation

CHRONOLOGY

1957

GNAM 1-5 neutron tools. Porosity index chart from neutron count rates for various borehole sizes.

Log Interpretation Charts. Houston: Schlumberger Well Surveying Corporation, 1957.

Blanchard A and Dewan JT: "The Calibration of Gamma Ray Logs and Experimental Basis for Neutron Logging Interpretation," *The Petroleum Engineer* 25, no. 8 (August 1953): B76, B78-80.

1962

GNAM 1-5 and GNT-F or - G tools with 19.5-in. spacing, RaBe or PuBe sources. Porosity index chart from neutron count rates.

Dewan JT: "Neutron Log Correction Charts for Borehole Conditions and Bed Thickness," *Journal of Petroleum Technology* 8 (February 1956): 50-58.

1968

GNT-F, -G or -H tools with 19.5- or 15.5-in. spacings. Neutron departure curves (API units) for limestone matrix, fresh mud and salt mud. Temperature, mudcake, hole diameter and mud weight corrections. Neutron equivalence curves for SNP and GNT-F, G, or H tools.

Recommended Practice for Standard Calibration and Form for Nuclear Logs, API RP 33. New York: American Petroleum Institute, 1959.

Tittman J, Sherman H, Nagel WA and Alger RP: "The Sidewall Epithermal Neutron Porosity Log," paper SPE 1180, presented at the 40th SPE Annual Meeting, Denver, October 3-6, 1965.

1972

GNT-J, - K (1-11/16-in. tools). Departure curves for limestone matrix, openhole, with fresh mud. Temperature corrections. GNT-N (2-5/8-in. tools). Departure curves for fresh mud, openhole, and limestone and sandstone matrix. SNP mudcake correction chart. CNL neutron porosity equivalence curves. Environmental correction charts for CNL logs for cased hole and openhole.

Alger RP, Locke S, Nagel WA and Sherman H: "The Dual Spacing Neutron Log — CNL," paper SPE 3565, presented at the 46th SPE Annual Meeting, New Orleans, October 3-6, 1971.

1978

SNP and CNL neutron porosity equivalence curves with mudcake corrections for the SNP. No GNT charts. Environmental correction charts for CNL logs with porosity scales for logs recorded prior to and after 1976.

Neutron Log Interpretation

(continued)

CHRONOLOGY

1984

Same neutron log charts as 1978 except slight changes to the CNL openhole correction nomograph based on additional lab measurements and computer studies.

1988

Porosity equivalence curves for CNL curves labeled "TNPH" and "NPHI". Environmental correction nomographs for TNPH and NPHI curves. NPHI-TNPH conversion nomograph for openhole logs. These charts do not appear in this document.

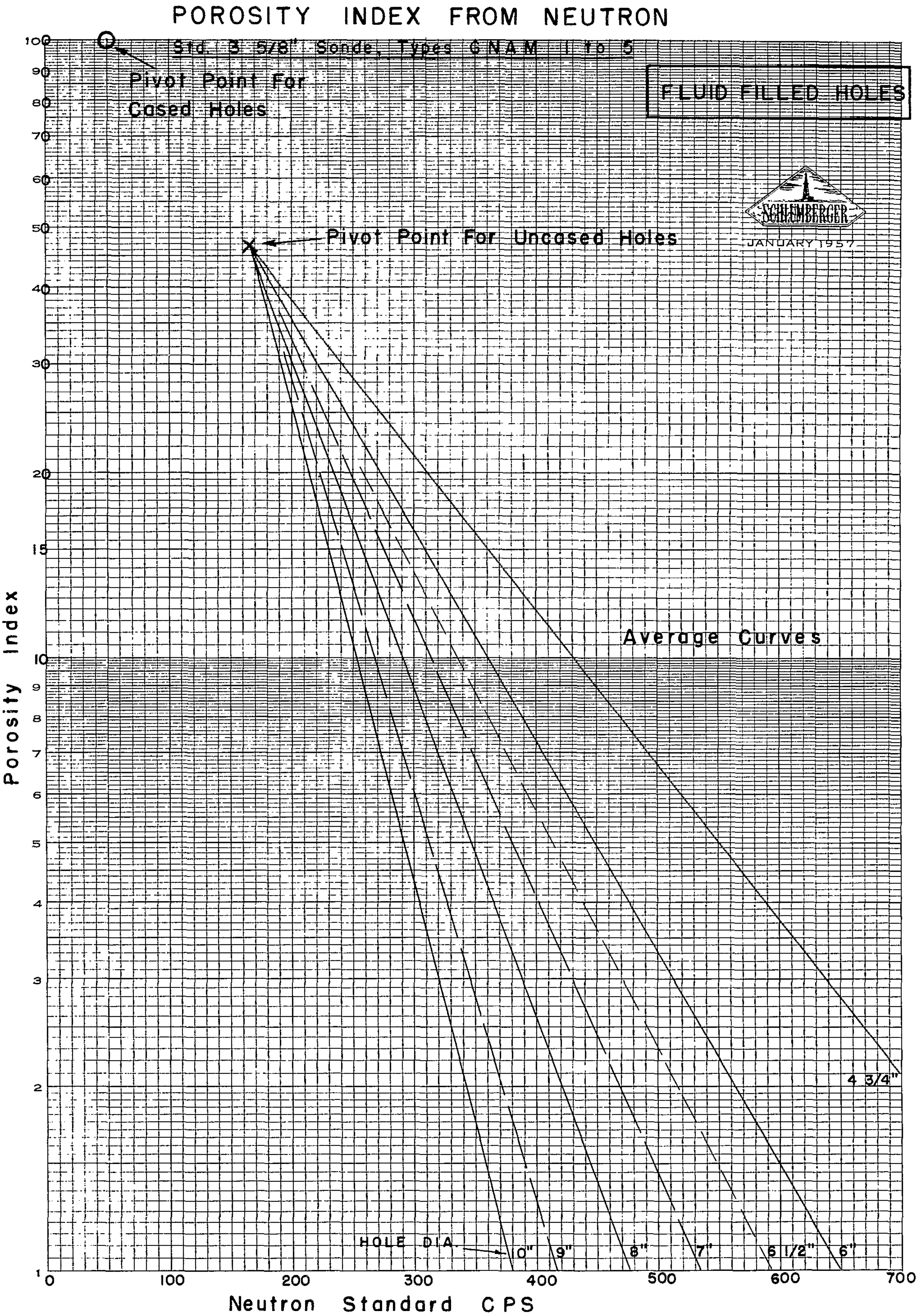
Gilchrist WA Jr, Galford JE, Flaum C and Soran PD: "Improved Environmental Corrections for Compensated Neutron Logs," paper SPE 15540, presented at the 61st SPE Annual Technical Conference and Exhibition, New Orleans, October 5-8, 1986.

1989

Charts for CNL "NPHI" curves dropped. Only the TNPH charts are presented. These charts can be found in the *Log Interpretation Charts - 1989.*

Conversion from CPS to API Units

Tool Type Source: PuBe or AmBe	Spacing in.	API Units per Std. CPS
GNT-F, G, H	15.5	1.55
GNT-F, H	19.5	5.50
GNT-G	19.5	5.70
GNT-J, K	16.0	2.70


POROSITY INDEX FROM NEUTRON
Std. 3 5/8" Sonde, Types GNAM 1 to 5
FLUID FILLED HOLES
Pivot Point For Cased Holes
Pivot Point For Uncased Holes
SCHLUMBERGER
JANUARY 1957
Average Curves
Porosity Index
Neutron Standard CPS
HOLE DIA.
10"
9"
8"
7"
6 1/2"
6"
4 3/4"
100
90
80
70
60
50
40
30
20
15
10
9
8
7
6
5
4
3
2
1
0
100
200
300
400
500
600
700

C-18

SCHLUMBERGER WELL SURVEYING CORP.

POROSITY INDEX FROM NEUTRON

USE AND DESCRIPTION

Porosity-neutron relations in carbonate rocks have been well established, both through empirical studies and in the laboratory. However, because of the sensitivity of the neutron log to small environmental changes in and around the borehole, the use of laboratory curves for determining porosity has been only partially successful.

This chart presents a technique in which an empirical response line is determined by a maximum deflection minimum porosity point and a pivot point. Using this empirical line, intermediate log readings may be converted to porosity index. Conditions such as hole size, borehole fluid type, mud weight, formation fluid, temperature effects, et cetera are at least partially normalized.

This method may be used on logs made with the standard 3⅝″ sonde — Types GNAM 1 to 5 equipment, and Types GNT-F or G equipment with 19.5″ spacing Ra Be or Pu Be sources. The technique is not valid for logs made with *15.5″ spacing GNT-F or G* tools.

Pivot points for GNAM tools in cased and uncased holes are denoted by squares. Pivot points for GNT tools in uncased holes are denoted by circles. Slightly different pivot points are required depending on the type of neutron source used and the rock matrix.

INFORMATION REQUIRED

Tool type and neutron source type.
Control point of maximum counting rate for a known minimum porosity.
Neutron deflection in cps or API units.
Hole conditions essentially uniform.
Knowledge of lithology.

PROCEDURE

For GNAM equipment: Determine a carbonate control point by finding maximum neutron deflection and assuming that it represents 1% or 2% porosity (based on experience). Draw a straight line from this point through the appropriate GNAM pivot point or through a shale porosity-neutron point. This line gives the neutron-porosity responses for any deflection if hole conditions are unchanged.

For GNT-F or G 19.5″ spacing equipment: Determine a control point by finding maximum neutron deflection and assuming that it represents 1% or 2% porosity in carbonates. Draw a straight line from this point through the appropriate GNT-F or G pivot point. This line gives the neutron-porosity response for any deflection if hole conditions remain unchanged.

EXAMPLE

GIVEN: GNAM tool
Neutron = 300 cps
Maximum Neutron = 500 cps
(Minimum Ø = 1%)
Uncased hole

SOLUTION: Porosity Index = 10%

GIVEN: GNT-F 19.5″ spacing Pu Be source.
Limestone
Neutron = 1500 API units
Maximum Neutron = 3000 API units
(Minimum Ø = 1%)

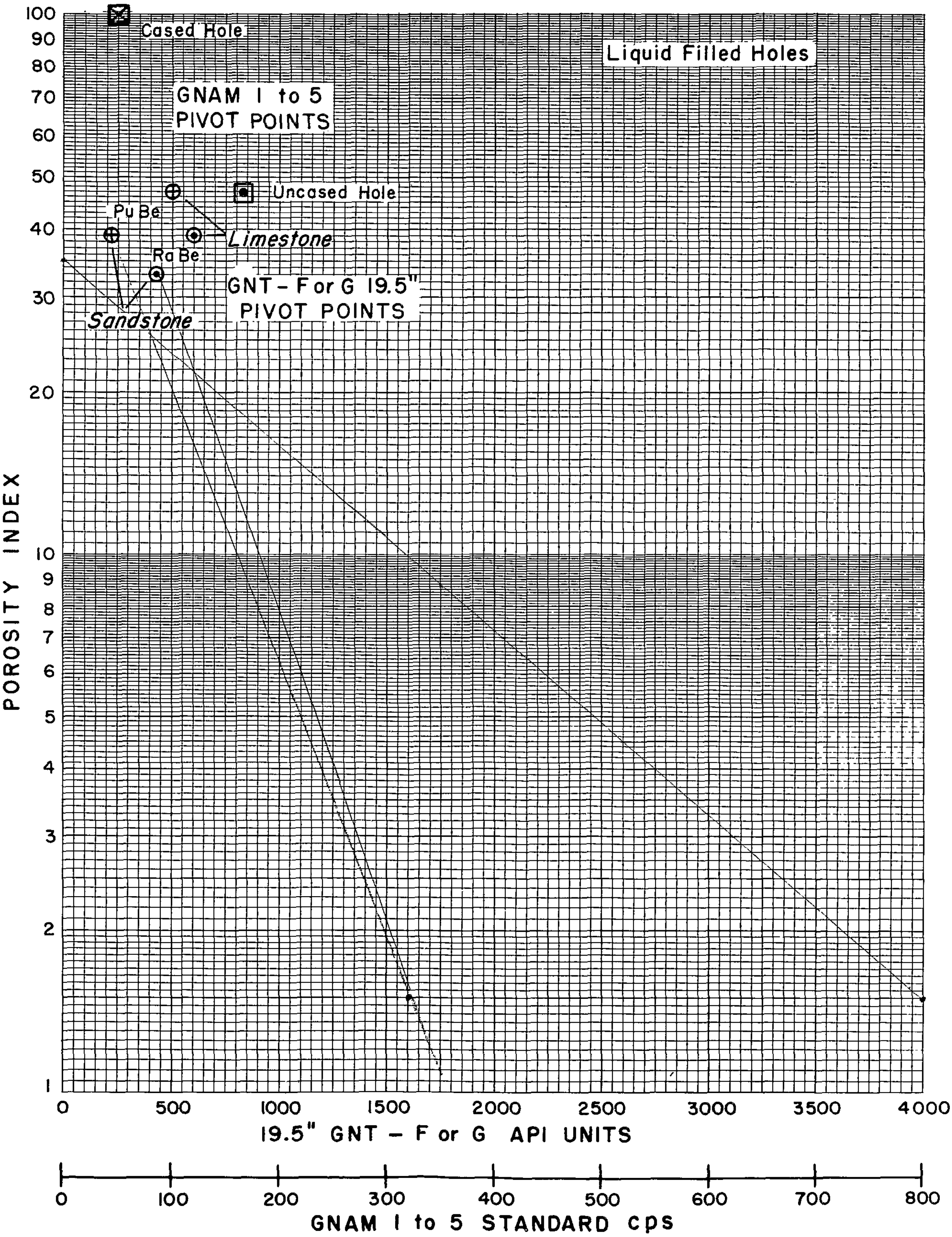
SOLUTION: Porosity Index = 10%

NOTE

Complete laboratory departure curves are available for GNT-F or G 15.5″ spacing Ra Be or Pu Be source equipment as well as for GNT-F or G 19.5″ spacing Ra Be or Pu Be source equipment.

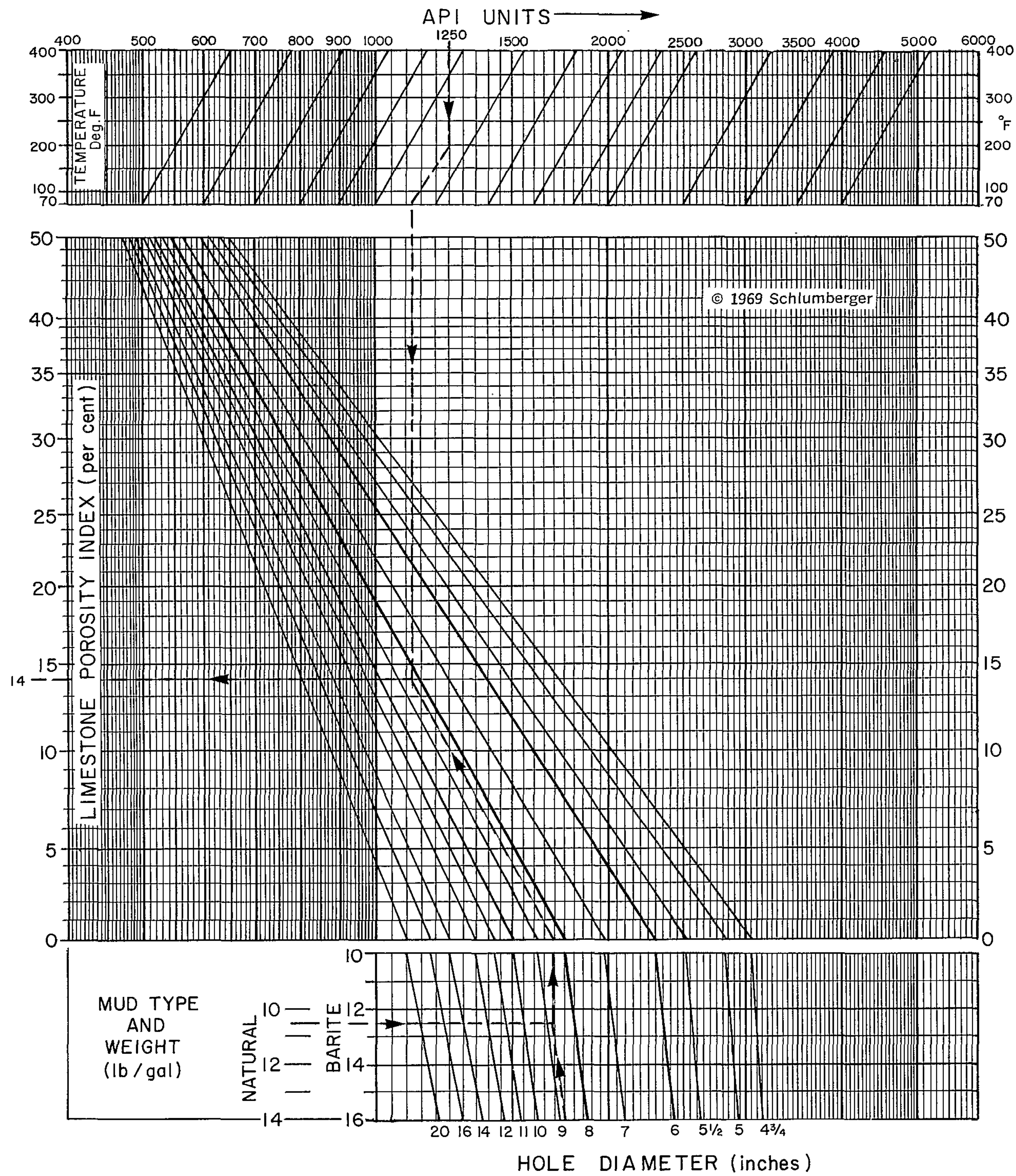
POROSITY INDEX FROM NEUTRON

SCHLUMBERGER
OCTOBER 1962



Neutron

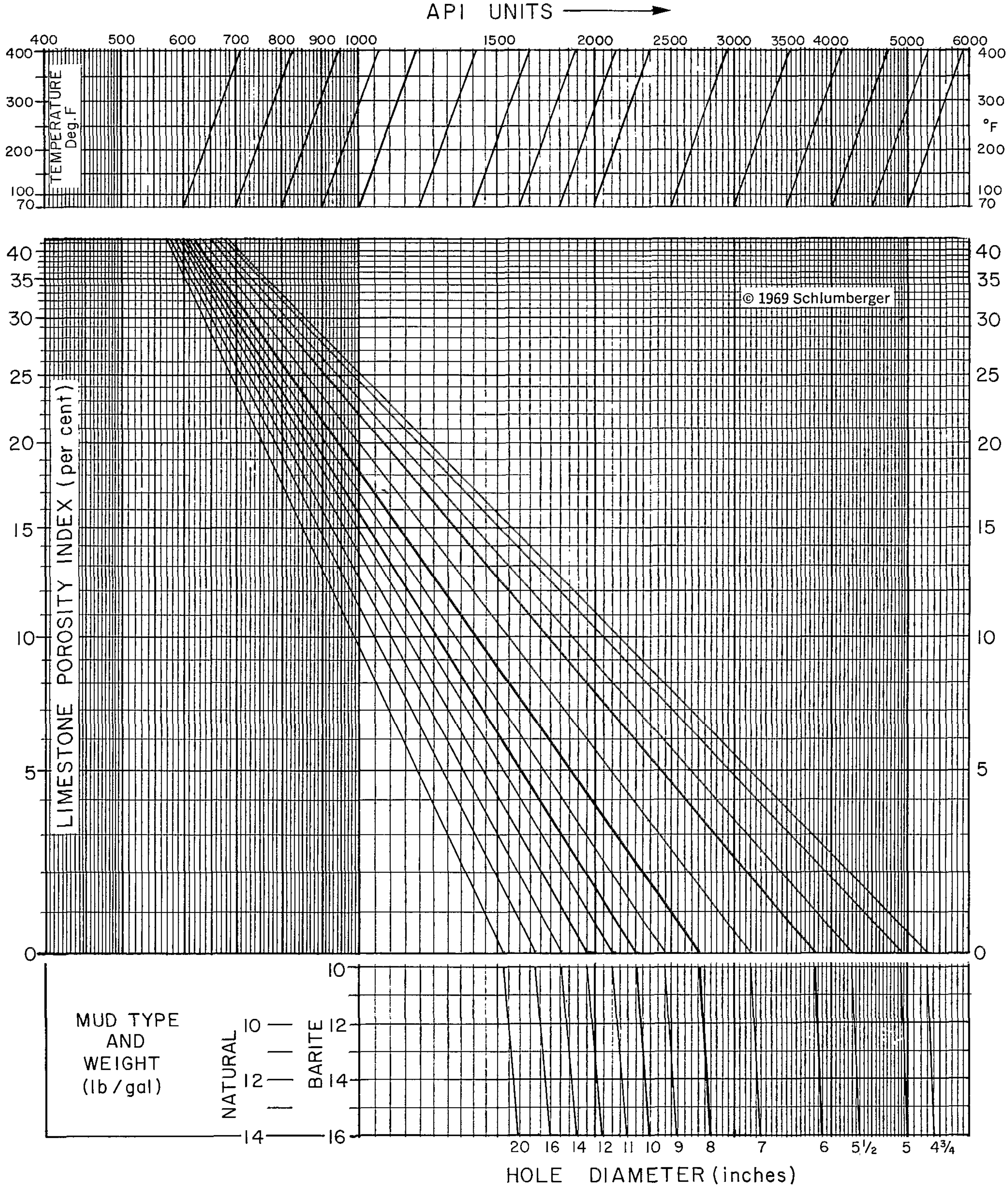
NEUTRON DEPARTURE CURVES
GNT F, G, or H
Pu-Be or Am-Be Source, 15½" Spacing
FRESH MUD, UNCASED HOLES, LIMESTONE



NEUTRON DEPARTURE CURVES
GNT F, G, or H

Pu-Be or Am-Be Source, 15½″ Spacing

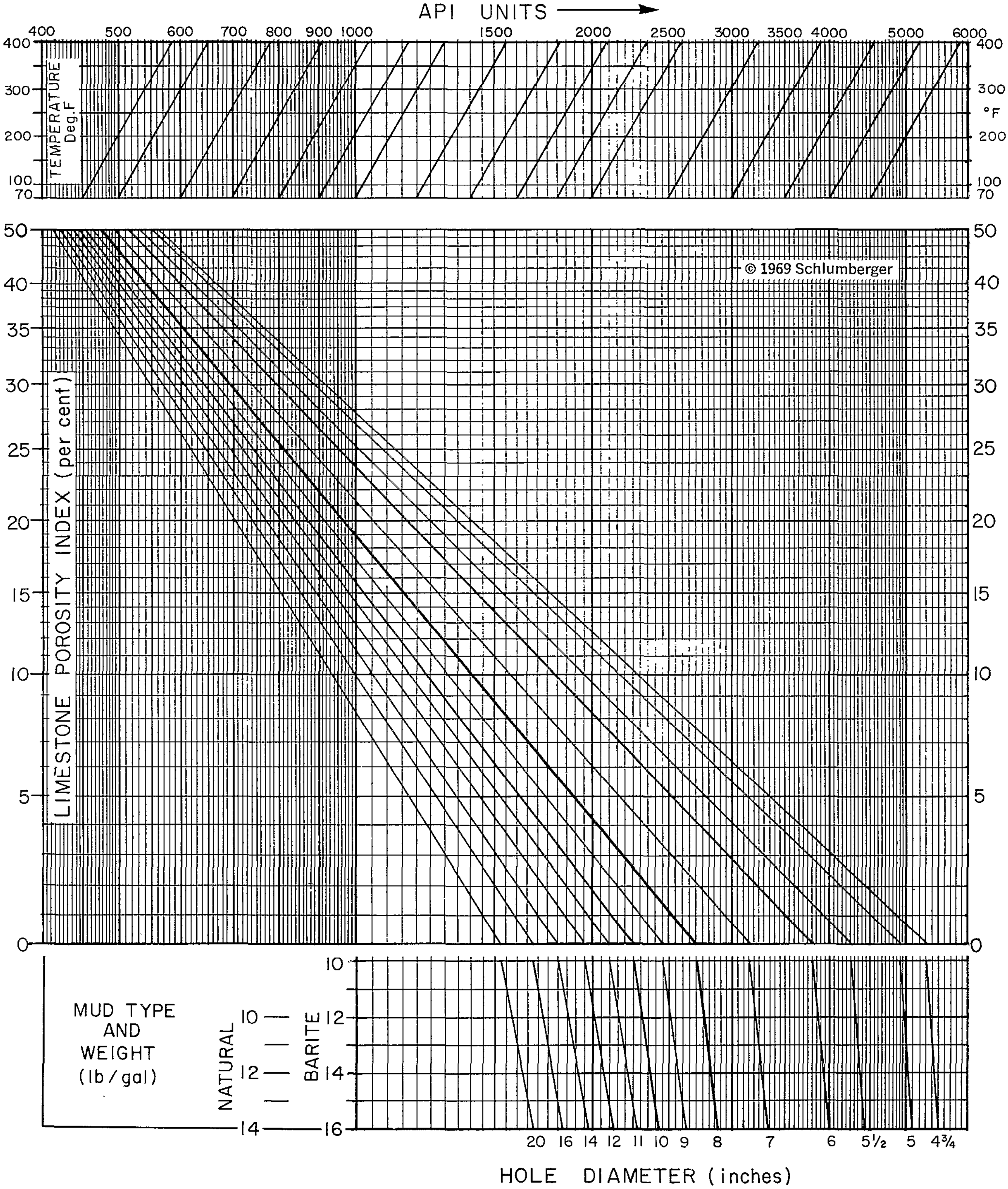
SALTY MUD, UNCASED HOLES, LIMESTONE



NEUTRON DEPARTURE CURVES
GNT F, G, or H

Pu-Be or Am-Be Source, 19½" Spacing

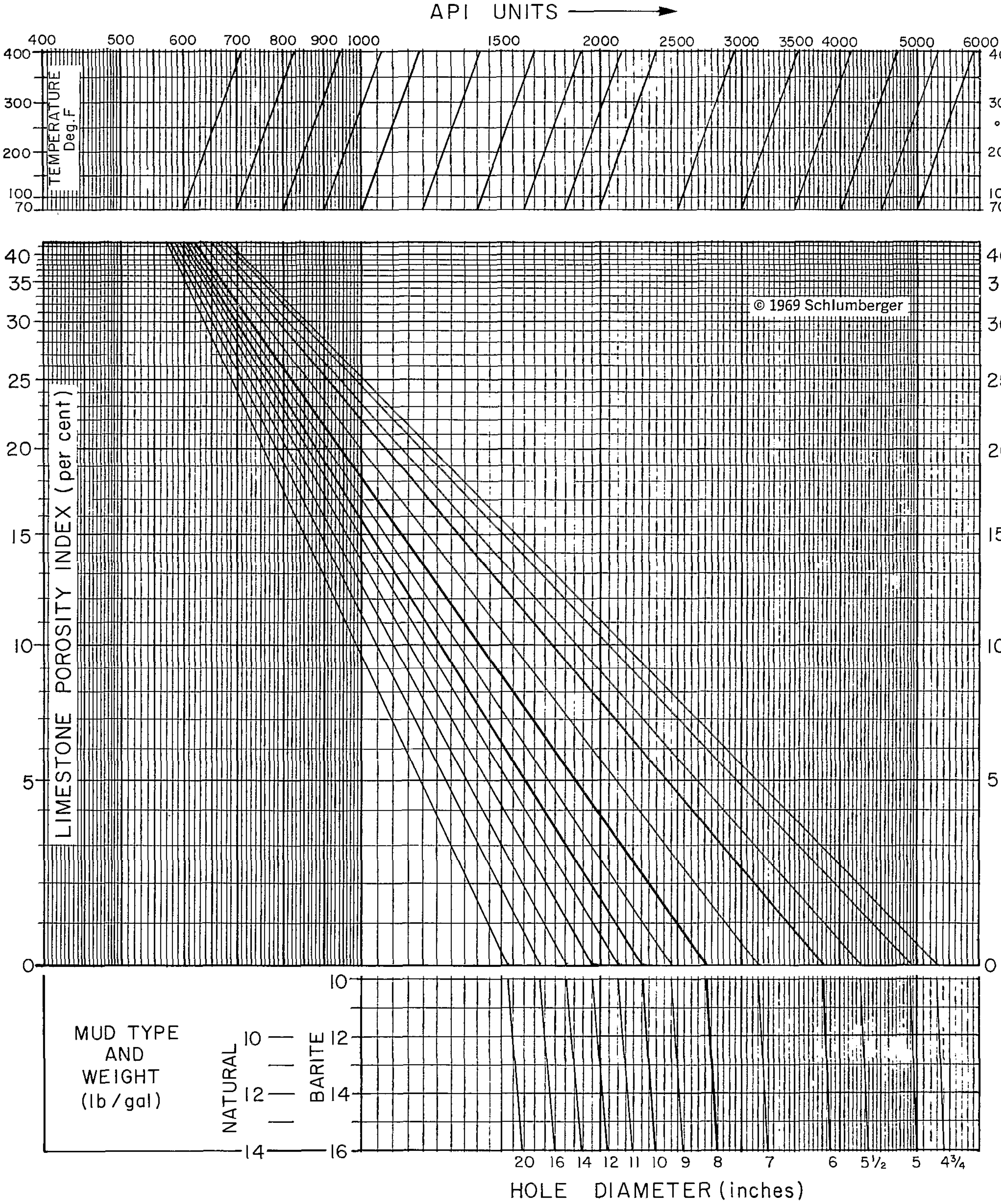
FRESH MUD, UNCASED HOLES, LIMESTONE



NEUTRON DEPARTURE CURVES
GNT F, G, or H

Pu-Be or Am-Be Source, 19½″ Spacing

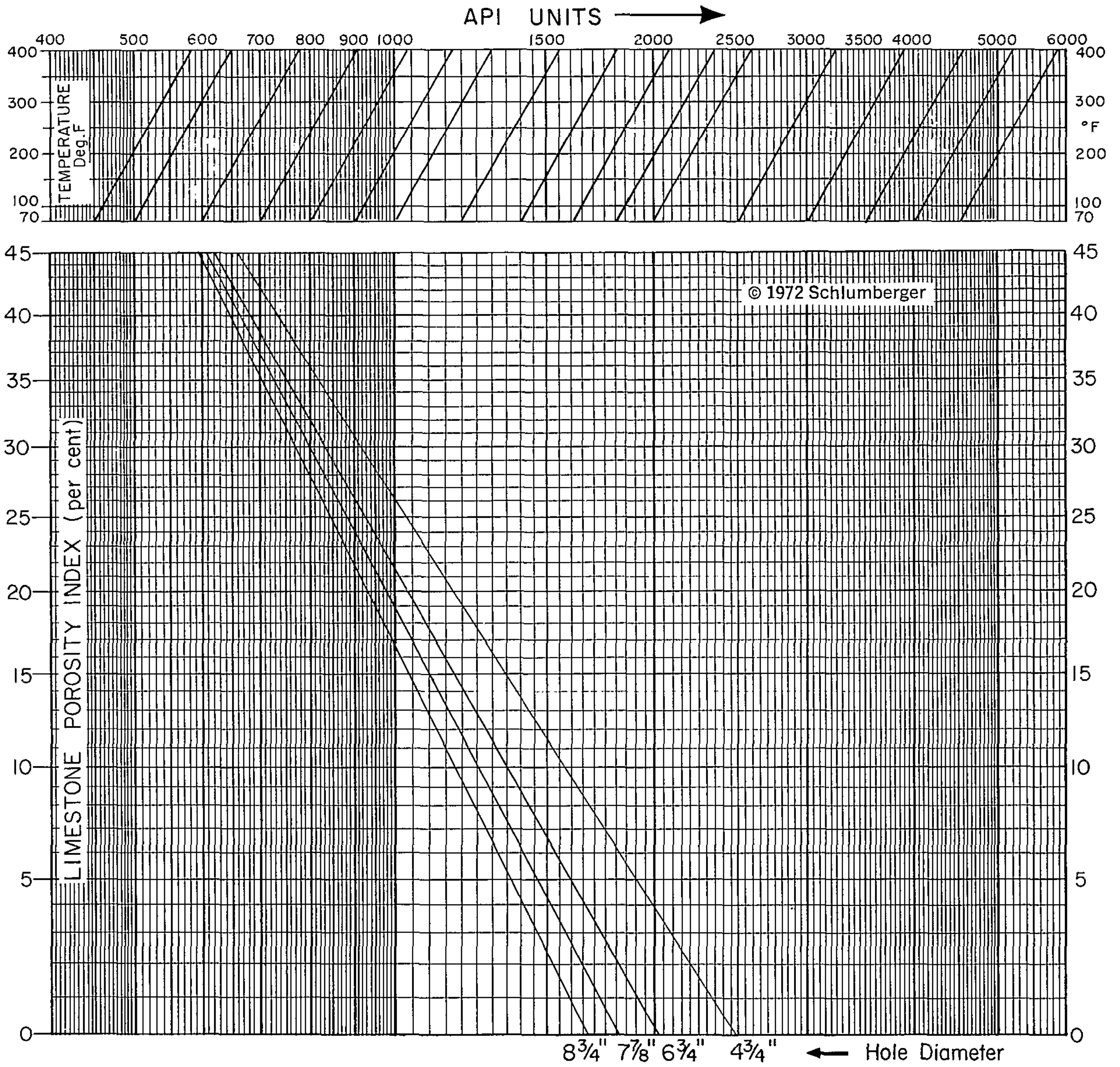
SALTY MUD, UNCASED HOLES, LIMESTONE



NEUTRON DEPARTURE CURVES
GNT J, K – 1 11/16″ SONDE

Pu-Be or Am-Be Source, 16″ Spacing

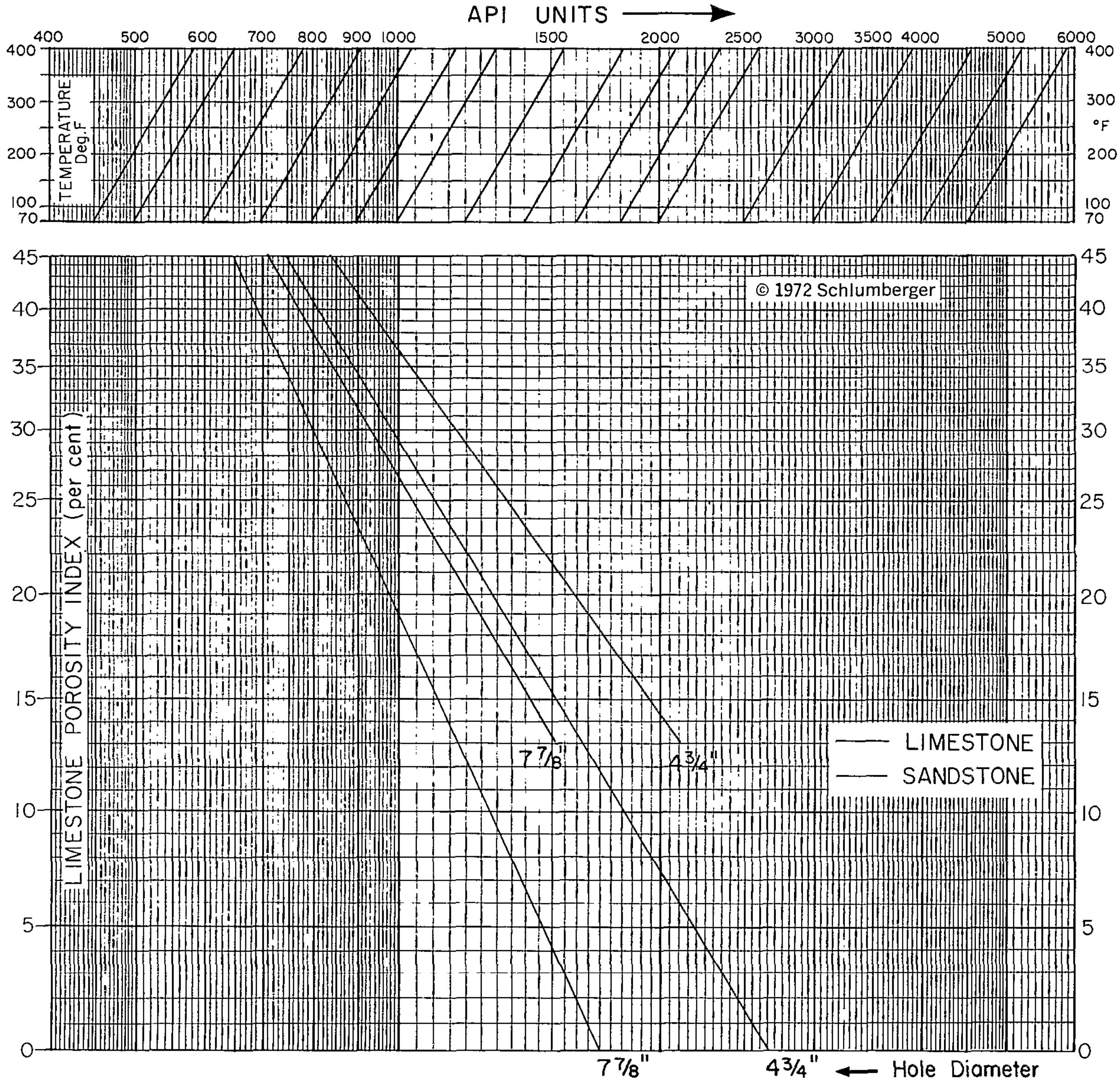
FRESH MUD, UNCASED HOLES, LIMESTONE



NEUTRON DEPARTURE CURVES
GNT N – 2⅝″ SONDE

Pu-Be or Am-Be Source

FRESH MUD, UNCASED HOLES, LIMESTONE AND SANDSTONE



Schlumberger

NEUTRON POROSITY EQUIVALENCE CURVES

SIDEWALL NEUTRON POROSITY LOG (SNP*)

COMPENSATED NEUTRON LOG (CNL*)

When the SNP is recorded in limestone porosity units, the large chart is used to find true porosities in sandstones or dolomites. First, correct the SNP for mud-cake thickness using the small chart. For mud-cake-thickness value use the full hole-diameter reduction shown on SNP caliper (since the backup shoe usually cuts through the mud cake). Then the corrected porosity value is entered on the abscissa of the chart and carried to the appropriate matrix line. Read ordinate for true porosity. The chart can also be used to find limestone porosity (needed for entering Charts CP-1 and CP-2) if recording is in sandstone or dolomite porosity units. Always correct for mud cake *before* entering equivalence chart.

EXAMPLE:

SANDSTONE BED: The SNP reads 13 p.u. (limestone). Bit size 7⅞″. Caliper reads 7⅝″, so h_{mc} = ¼ inch. Corrected limestone porosity is 11 p.u. Sandstone porosity is 14 p.u.

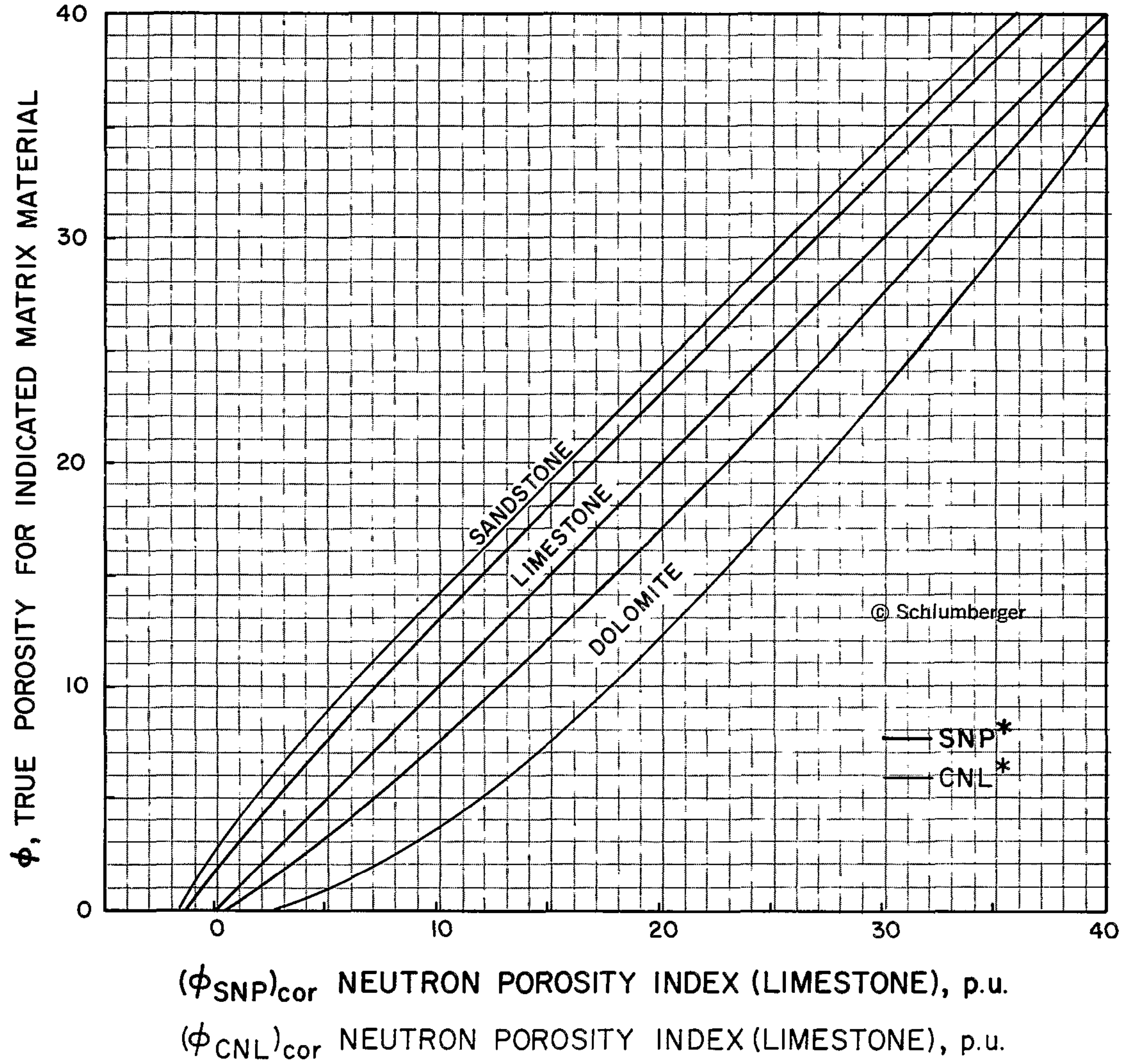
No mud-cake correction is needed for CNL conversions. Simply enter the chart in abscissa with CNL limestone porosity, go to appropriate matrix line, and read true porosity on the ordinate.

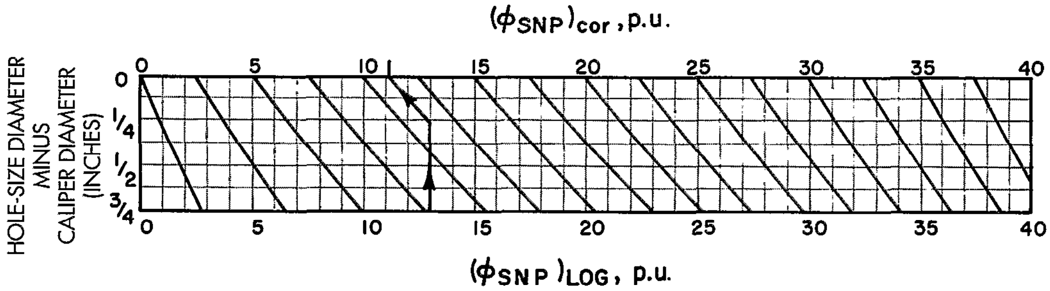
*Mark of Schlumberger.

Schlumberger

NEUTRON POROSITY EQUIVALENCE CURVES

SIDEWALL NEUTRON POROSITY LOG (SNP*)
COMPENSATED NEUTRON LOG (CNL*)

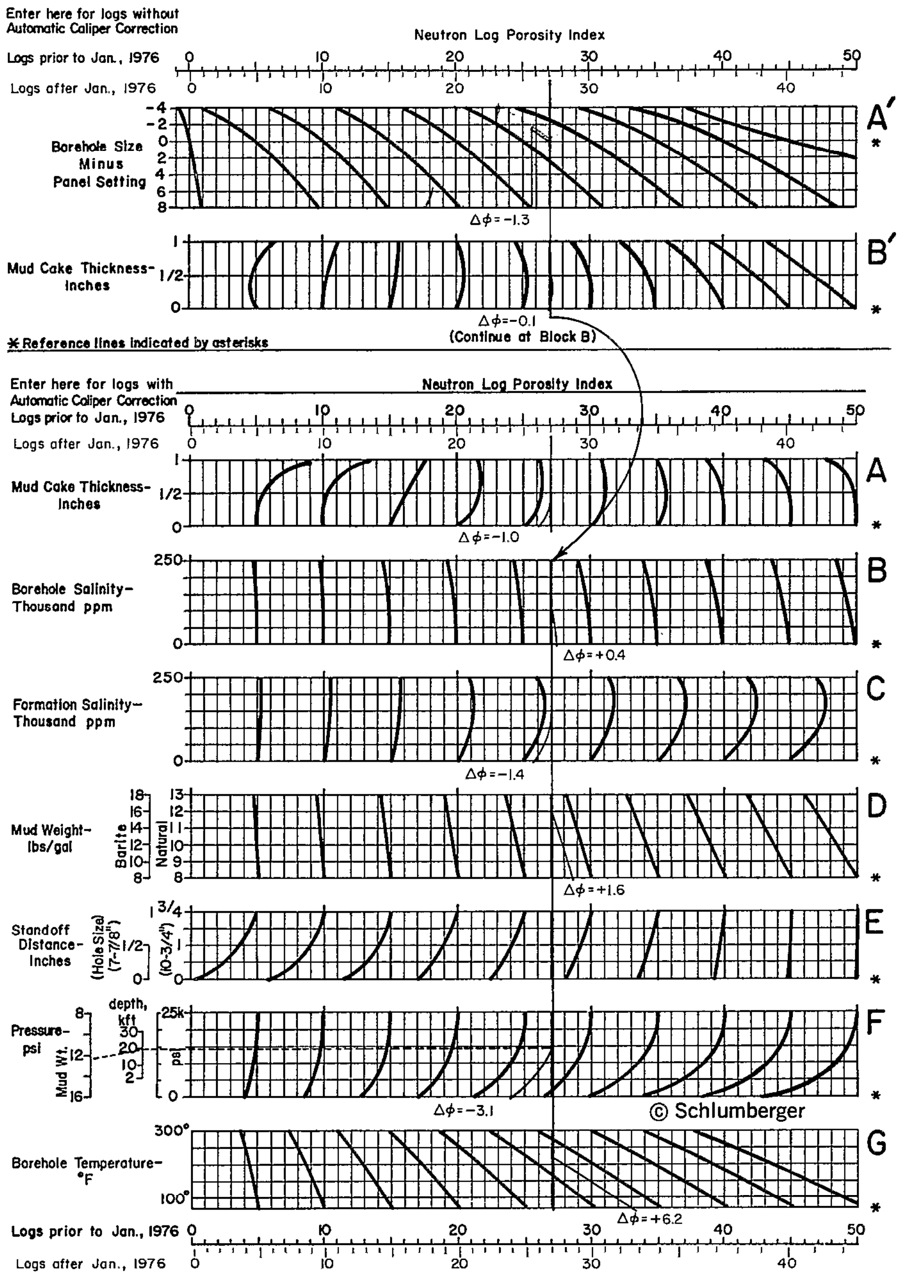




*Mark of Schlumberger.

Schlumberger

DUAL SPACING NEUTRON LOG (CNL*) CORRECTION NOMOGRAPH FOR OPEN HOLE[5]



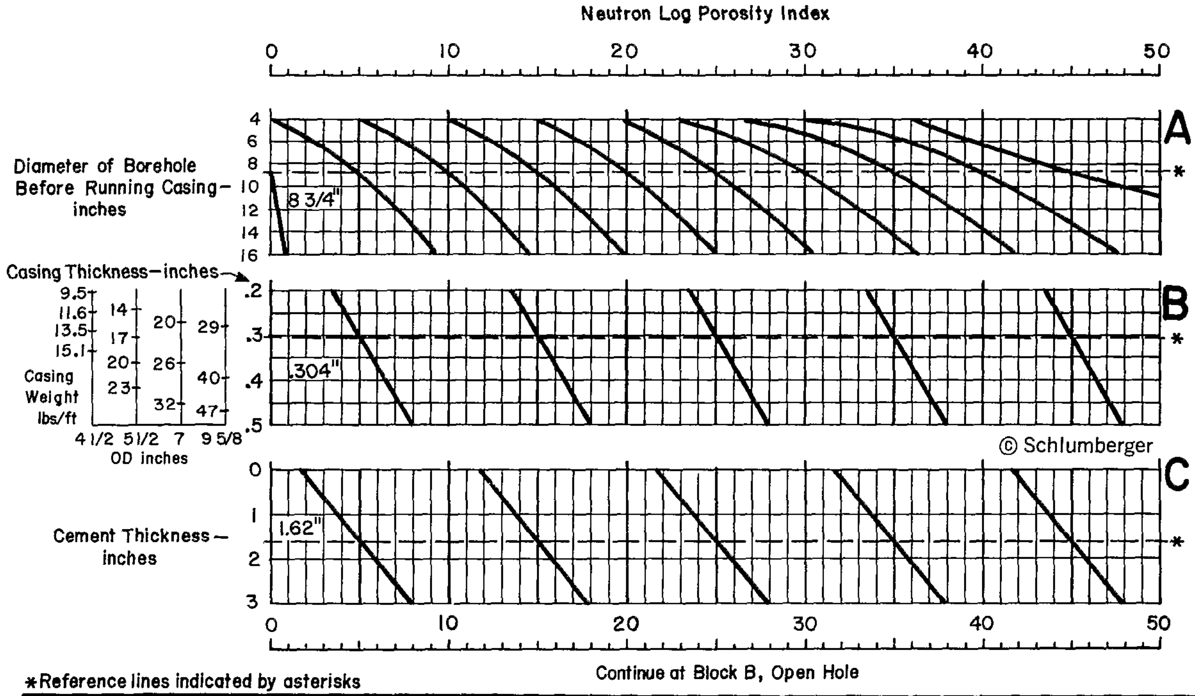
GIVEN:		SOLUTION 1	SOLUTION 2
		EXAMPLE	
CNL Reading	.... 27 p.u.	(w/ auto. caliper corr.)	(w/separate caliper)
Mud Weight (nat.)	.... 12 lb/gal	Start at Block **A**	Start at Block **A′**
h_{mc}	.... ½ in.	$\Sigma\Delta\phi = -1.0 + 0.4$	$\Sigma\Delta\phi = -1.3 - 0.1 + 0.4$
T_{bh}	.... 225°F	$-1.4 + 1.6 - 3.1 + 6.2$	$-1.4 + 1.6 - 3.1 + 6.2$
Salinity (borehole)	.... 100,000 ppm	$= +2.7$ p.u.	$= +2.3$ p.u.
Salinity (formation)	.... 150,000 ppm	$\phi_{cor} = 27 + 2.7$	(Note that only **one** h_{mc} correction is applied)
Standoff	 0	$=$ <u>29.7 p.u.</u>	$\phi = 27 + 2.3$
Depth	.... 21,000 ft		$=$ <u>29.3 p.u.</u>

Por-14a

*Mark of Schlumberger.

Schlumberger

DUAL SPACING NEUTRON LOG (CNL*) CORRECTION NOMOGRAPH FOR CASED HOLE



CNL ENVIRONMENTAL CORRECTIONS
(Open and Cased Hole)

Before using these nomographs, log values must be corrected for any matrix effect (Chart **Por 13**). For open-hole logs, a vertical line is drawn or overlaid on Chart **Por 14a** so as to pass through the corrected Neutron Log Porosity Index* above Block A (if automatic caliper correction was used) or Block A′ (if not). Then the corrections called for by each bar of the nomograph are tabulated and algebraically totalled to give the net correction to be applied to the log reading (example shown in blue). Note that when no automatic caliper correction was made, the mud-cake corrections from Block A are not used; Block B′ provides the needed mud-cake correction.

For cased-hole logs, the same procedure is followed on Chart **Por 14a,** except that Bars A′, B′, and A are bypassed. In addition, the corrections called for by Chart **Por 14b** are tabulated and totalled with those of **Por 14a.**

*Most logs run after the end of 1975 have a somewhat different response above 32 p.u. on "Limestone-Open-Hole" function. For these logs, use the blue scale divisions on the porosity bars.

*Mark of Schlumberger.

Dual-Spacing Neutron Log (CNL*) Environmental Corrections

(Cased and Open Hole)

The nomographs of Charts Por-14 provide environmental corrections for the CNL Compensated Neutron log when run in cased hole or open hole. Before using the nomographs, CNL log values must be corrected for matrix effect (Chart Por-13).

Cased Hole (Chart Por-14a)
For cased hole logs, enter the appropriate Chart Por-14a with the matrix-corrected CNL reading; draw a vertical line through the chart blocks. Find the corrections, relative to the Reference Lines (dashed lines indicated with asterisks), for each block. Then go to Chart Por-14b and, starting with the Borehole Salinity block, continue through the remaining blocks. Algebraically sum all the corrections to obtain the correction to the CNL reading.

EXAMPLE: $\phi_{CNL} = 27$ pu (matrix corrected)
Borehole size = 10 in.
Casing thickness = 0.255 in.
Cement thickness = 1.4 in.

Giving, $\Sigma\Delta\phi = -1.0 + 0.3 + 0.5 + \ldots$

This provides casing, cement, and borehole corrections for the cased hole CNL log; continue to Chart Por-14 for salinity, borehole fluid, pressure and temperature corrections.

Open Hole (Chart Por-14b)
Refer to CNL log heading to determine whether the log was run with or without automatic caliper correction.

For logs run with automatic caliper correction.

First, "back-out" the automatic caliper correction to find the "chart-base" porosity. To do this, enter the Actual Borehole Size block (top block) with the matrix-corrected CNL porosity; go to the 8-in. Borehole Reference Line (indicated by the asterisk), follow the trend lines to actual borehole size. This value is the chart-base porosity.

Draw a vertical line through all the chart blocks at the chart-base porosity value. Find the correction for each block, relative to the Reference Lines (indicated by the asterisks). Add their algebraic total to the chart-base porosity. This is the environmentally-corrected CNL porosity.

EXAMPLE: $\phi_{CNL} = 28$ pu (matrix corrected)
Caliper = 7.0 in.
Mud Weight = 12 lb/gal natural
$h_{mc} = \frac{1}{2}$ in.
Temperature = 225°F
Borehole Salinity = 100 Kppm
Formation Salinity = 150 Kppm
Standoff = 0
Depth = 21,000 ft

Giving, Chart-base porosity = 27 pu
And, $\Sigma\Delta\phi = +1.0 + 0.2 + 0.6 - 1.5 + 1.7 + 0 - 3.4 + 4.3 = 2.9$
$\phi = 27 + 2.9 = 29.9$ pu

For logs run without automatic caliper correction.

Enter the Actual Borehole Size block (top block) with the matrix-corrected CNL porosity; go to the 8-in. Borehole Reference Line (indicated by the asterisk), follow the trend lines to the Panel Setting value (see log heading for Panel Setting used). This value is the chart-base porosity.

Draw a vertical line through all the chart blocks at the chart-base porosity value. Find the correction for each block as described above.

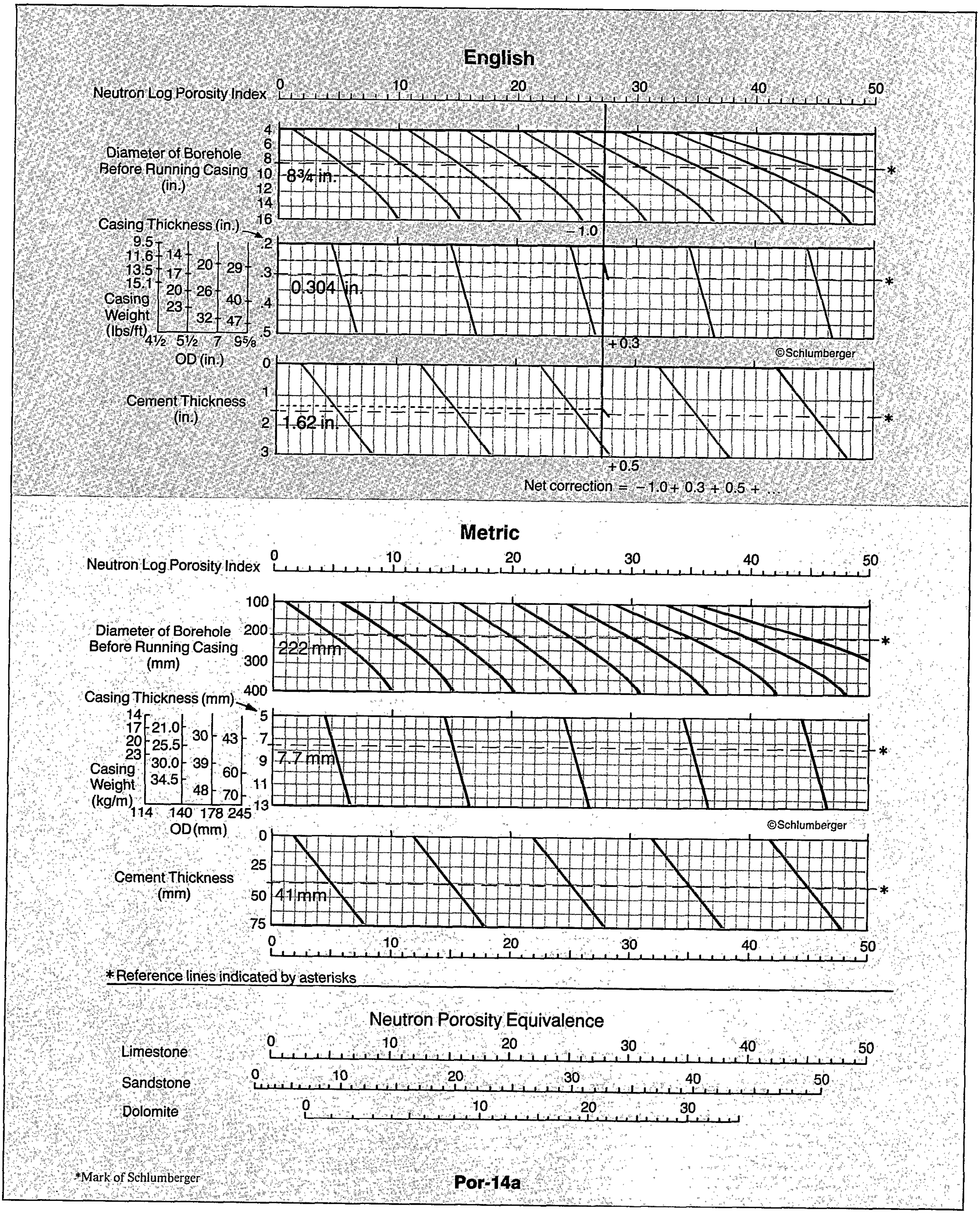
EXAMPLE: $\phi_{CNL} = 30$ pu (matrix corrected)
Panel Setting = 222 mm
Caliper = 305 mm
Mud Weight = 1.1 Mg/m^3 natural
Temperature = 80°C
Borehole Salinity = 50 mg/kg
Formation Salinity = 150 mg/kg
Standoff = 0
Depth = 3800 m

Giving, Chart-base porosity = 31 pu
And, $\Sigma\Delta\phi = -4.0 + 0 + 0.2 - 1.7 + 0.7 + 0 - 2.5 + 3.3 = -4.0$
$\phi = 31 - 4.0 = 27$ pu

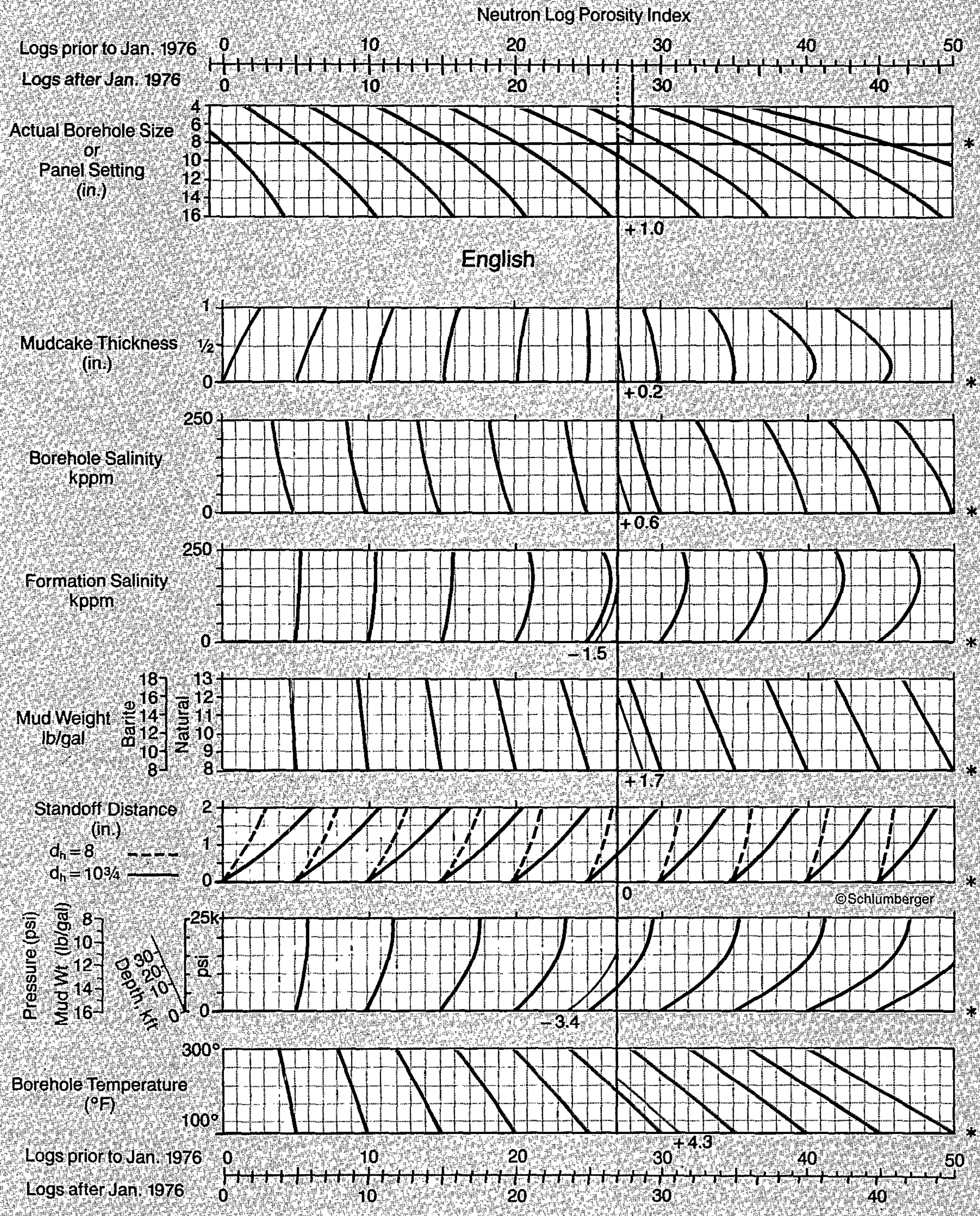
For more information, see Reference 5.

*Mark of Schlumberger

Dual-Spacing Neutron Log (CNL*) Correction Nomograph for Cased Hole



Dual-Spacing Neutron Log (CNL*) Correction Nomograph for Open Hole

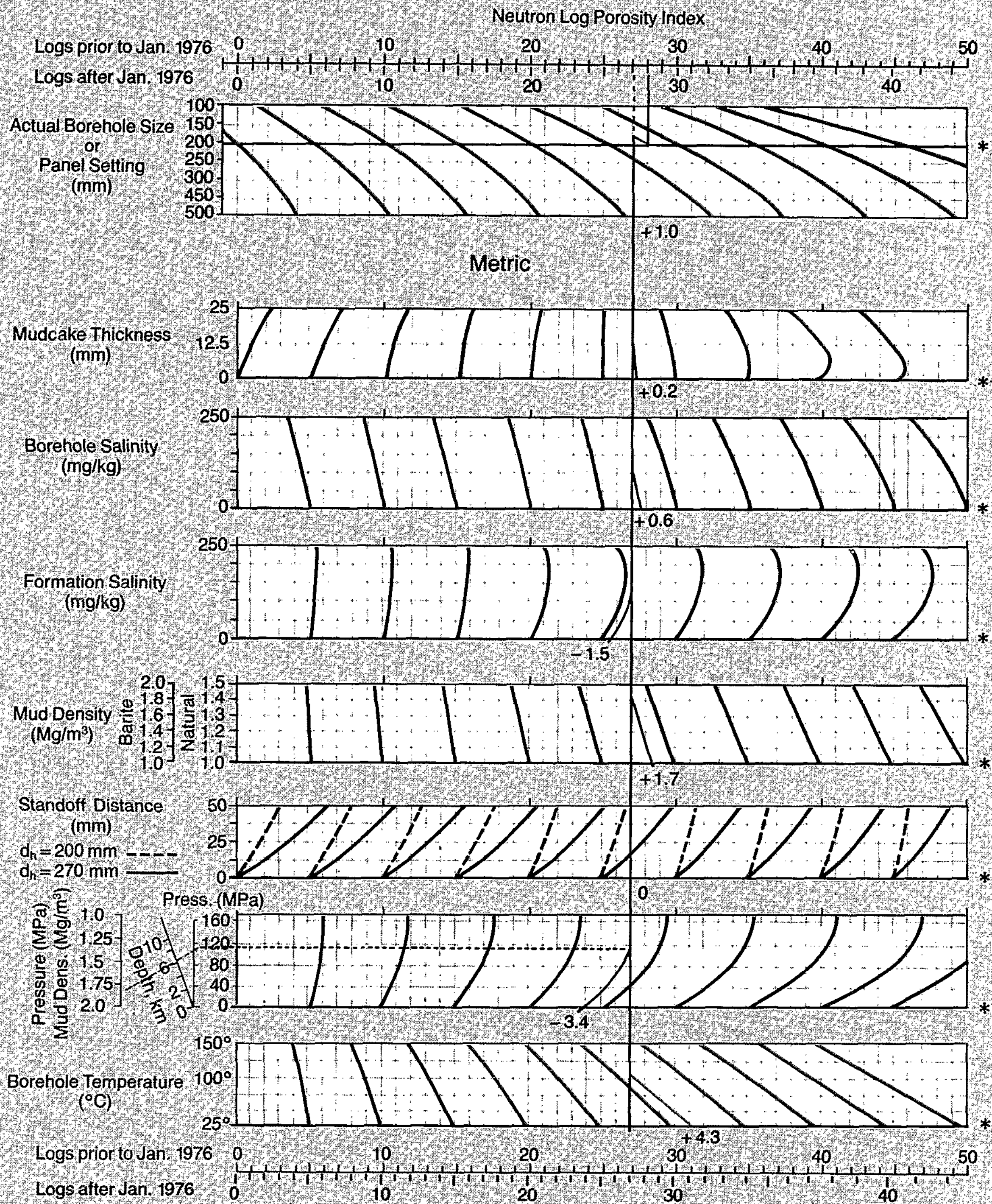


See Reference 5 for more information.

*Mark of Schlumberger

Por-14b

Dual-Spacing Neutron Log (CNL*) Correction Nomograph for Open Hole



See Reference 5 for more information.

*Mark of Schlumberger

Por-14bm

Resistivity Logging

CHRONOLOGY

Laterolog Tools

1968

LL-7 and LL-3 borehole correction charts.

Doll HG: "The Laterolog: A New Resistivity Logging Method With Electrodes Using an Automatic Focusing System," *Journal of Petroleum Technology* 3 (November 1951): 305-316.

Moran JH and Chemali RE: "More on the Laterolog Device," *Geophysical Prospecting* 27 (December 1979): 902-930.

1972

DLL borehole correction charts for 20-ft sequential and 28-ft continuous logs.

The Dual Laterolog (Technical Report). Houston: Schlumberger Limited, 1970.

Induction Tools

1955

5FF27 induction–16-in. normal. Chart to determine R_t and relative depth of invasion, d_i.

1957

5FF40 induction–16 in. normal. Chart to determine R_t and d_i.

Dumanoir JL, Tixier MP and Martin M: "Interpretation of the Induction-Electrical Log in Fresh Mud," *Journal of Petroleum Technology* 9 (July 1957): 202-217.

1962

5FF40 induction. Hole correction chart and bed thickness correction chart.

Moran JH and Kunz KS: "Basic Theory of Induction Logging and Application to Study of Two-Coil Sondes," *Geophysics* 27 (December 1962): 829-858.

1962

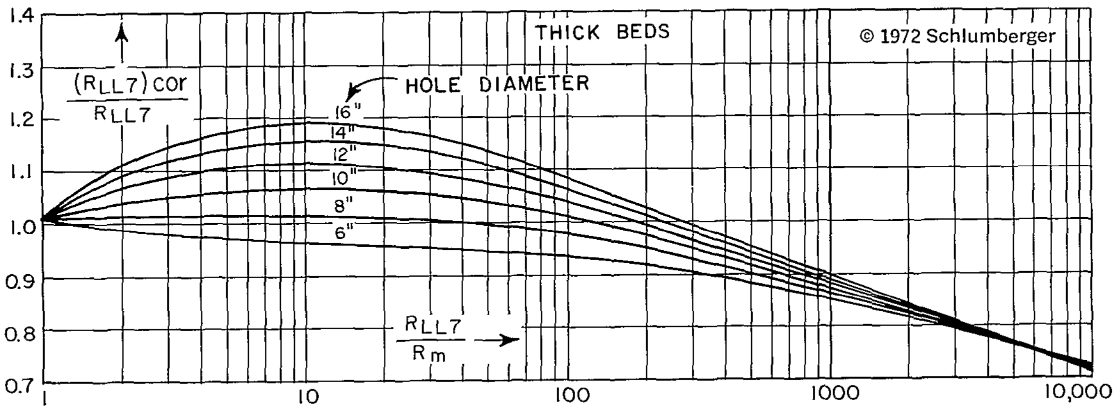
6FF40 induction. Hole correction chart and bed thickness correction chart.

1968

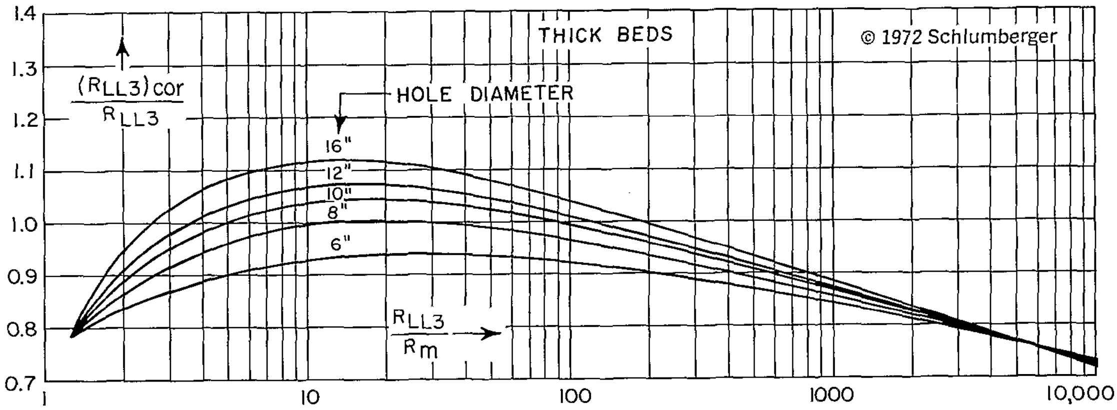
Dual Induction (DIT-A). Hole correction chart and bed thickness chart.

Tixier MP, Alger RP, Biggs WP and Carpenter BN: "Dual Induction-Laterolog: A New Tool for Resistivity Analysis," paper SPE 713, presented at the 38th SPE Annual Meeting, New Orleans, October 6-9, 1963.

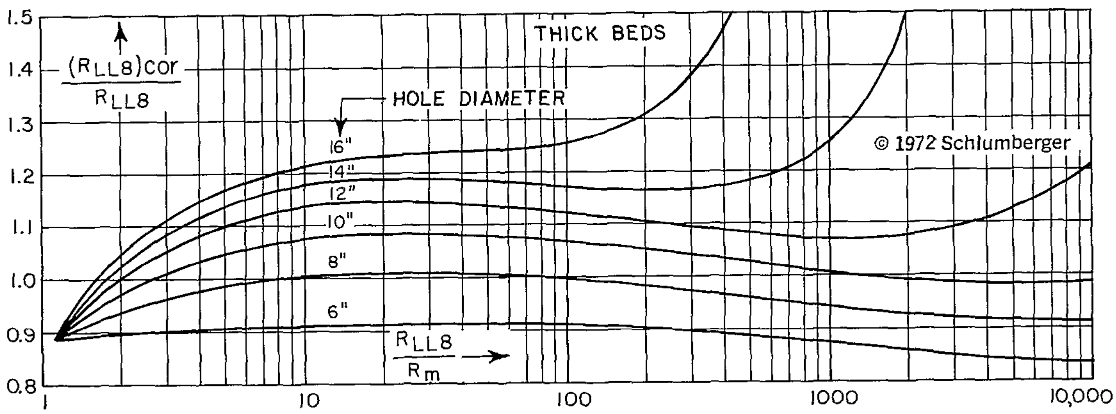
LATEROLOG 7 BOREHOLE CORRECTION



LATEROLOG 3 BOREHOLE CORRECTION

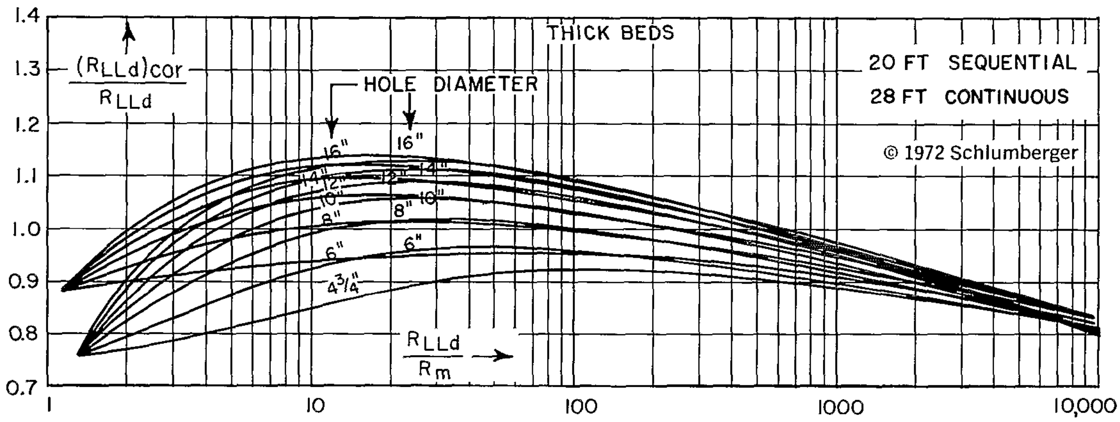


LATEROLOG 8 BOREHOLE CORRECTION

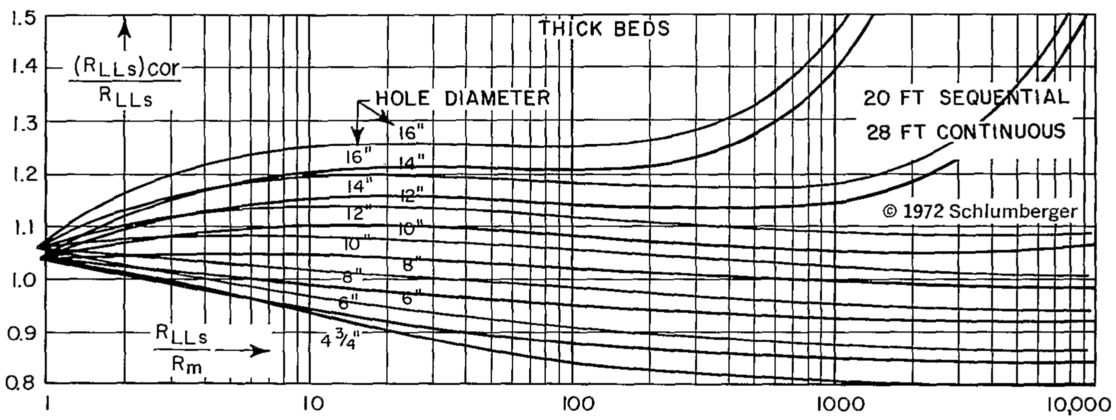


DUAL LATEROLOG CORRECTION CHARTS
SONDE CENTERED

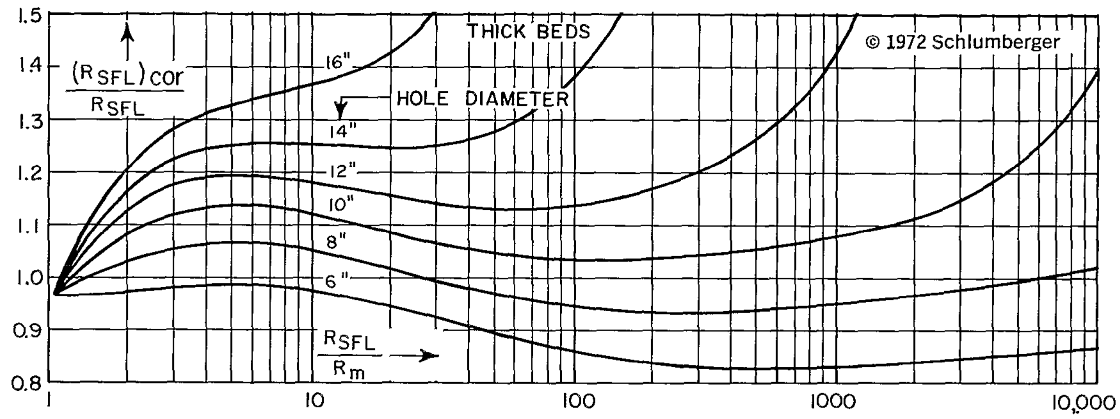
LATEROLOG D BOREHOLE CORRECTION



LATEROLOG S BOREHOLE CORRECTION



SPHERICALLY FOCUSED LOG BOREHOLE CORRECTION



SCHLUMBERGER WELL SURVEYING CORP.

LOG INTERPRETATION CHARTS

INDUCTION LOGGING
5FF27″ - 16″ NORMAL

USE AND DESCRIPTION

This chart is used to estimate R_t and the relative depth of invasion in low and medium resistivity types of formation and when $R_{xo} > R_t$.

The determinations are obtained by consideration of the relative effects of invasion on the 16″ normal and the 27″ induction. The chart shows that no correction of R_{IND} is required when $D_i < 2d$ or when $R_{16''}/R_{xo}$ is less than 0.3.

INFORMATION REQUIRED

R_{IND} — Apparent resistivity from induction log — bed > 5′ to 6′

$R_{16''}$ — Apparent 16″ normal — bed > 5′ to 6′

R_{xo} — Usually determined from the MicroLog

PROCEDURE

The ratios R_{IND}/R_{xo} and $R_{16''}/R_{xo}$ are determined and then entered at the vertical and horizontal axes respectively. The location of this point is used to interpolate a value of D_i and of R_t/R_{xo}. R_t is found by multiplying R_t/R_{xo} by R_{xo}.

EXAMPLE

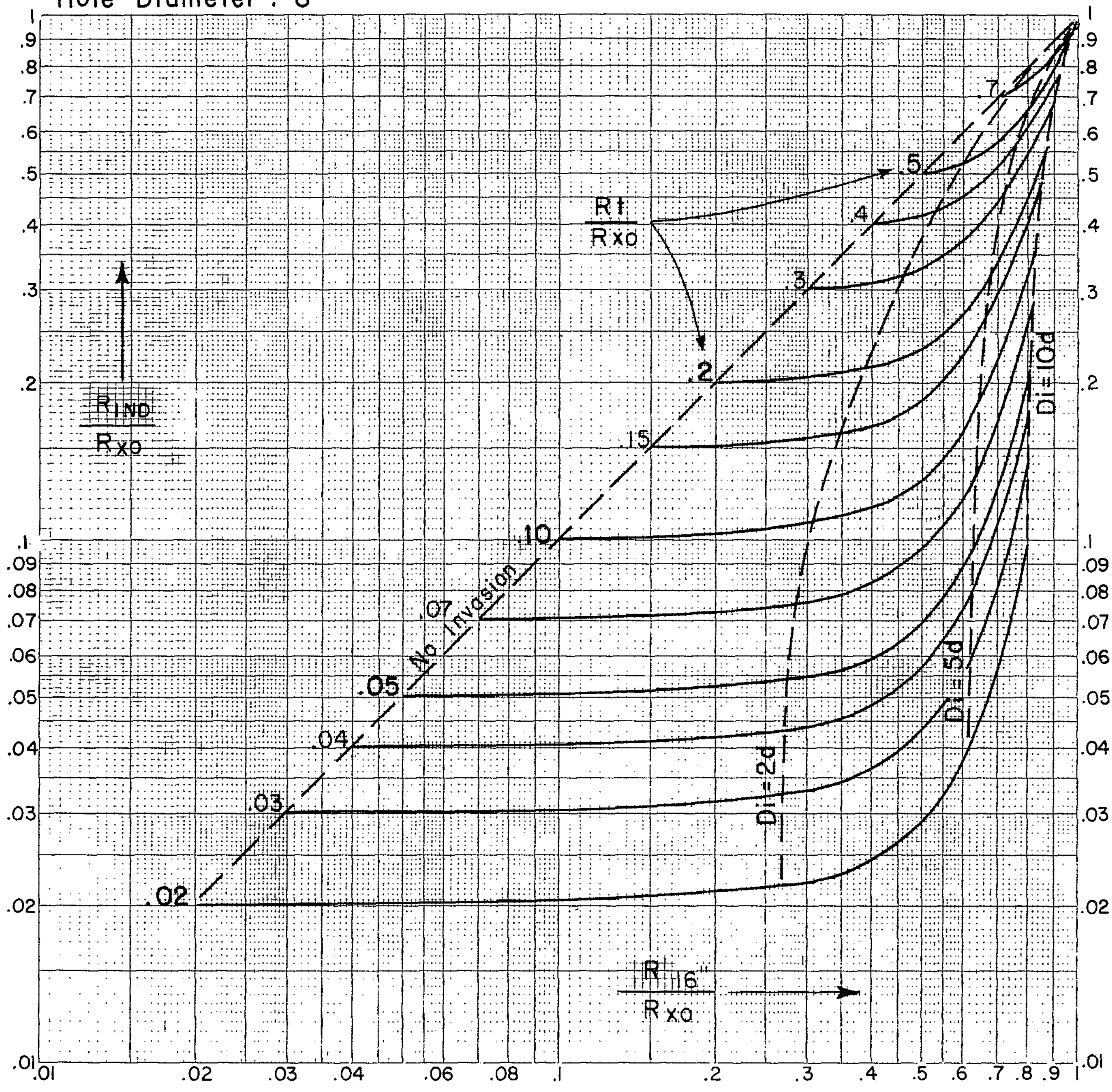
GIVEN: $R_{IND} = 3$ ohm-m.
$R_{16''} = 6$ ohm-m.
$R_{xo} = 10$ ohm-m.

SOLUTION: $R_{IND}/R_{xo} = .3$.
$R_{16''}/R_{xo} = .6$.
$D_i = 4d$.
$R_t/R_{xo} = .23$.
$R_t = .23 \times 10 = 2.3$ ohm-m.

SCHLUMBERGER
APRIL-1955

Induction Logging 5-FF-27
Normal 16"
Case of Sand and Shale Formations

Hole Diameter : 8"



For moderate $\frac{R_t}{R_m}$ ratios and for bed thicknesses greater than about 5' or 6' the readings of the Normal 16" and of the 5-FF-27 need no correction for the influence of the bore hole and surrounding formations.

SCHLUMBERGER WELL SURVEYING CORP.

LOG INTERPRETATION CHARTS

INDUCTION LOGGING 5FF40" WITH 16" NORMAL

USE & DESCRIPTION

This chart shows the relative response of the 40" induction and the 16" normal for changing values of R_{xo} and D_i.

The chart can be used for finding D_i and R_t if R_{xo} can be accurately measured. This procedure is similar to that discussed on Page B-5. However, an accurate R_{xo} may not be available; the following procedure shows how to find R_{xo}, D_i, and R_t in water-bearing sands (or in sands where no movable hydrocarbon exists) when the range of porosity value is known. This procedure is based on the fact that in these cases $R_{xo}/R_t = R_{mf}/R_w$ in clean sands and R_{mf}/R_{wa} in shaly sands.

INFORMATION REQUIRED

R_{IL} and R_{16}'' (corrected for borehole and/or bed effects, if necessary)

SSP in clean sands — PSP in shaly sands

PROCEDURE

Enter the ratio R_{16}''/R_{IL} on the ordinate (vertical) axis and then draw a 45° line from this point.

Enter the SSP or PSP, according to the temperature, using scales on the right-hand side. Draw a horizontal line. The ordinate of this line gives R_{xo}/R_t. Go left, following the trend of the solid curved lines. Usually, the 45° line (R_{16}''/R_{IL}) intersects the curved line (R_{xo}/R_t) at two points. Each point corresponds to a value of D_i, a value of R_{xo}/R_{IL}, and a value of R_{xo}/R_{16}''. Since both R_{IL} and R_{16}'' are known, this procedure gives two values of R_{xo}. The range of porosity known indicates which of the two R_{xo} (and D_i) values is correct. A MicroLog analysis may assist in this selection.

Generally, for $D_i = 5d$ the 45° line (R_{16}''/R_{IL}) is tangent to the curved line (R_{xo}/R_t); and there is only one solution.

R_t can be derived from the knowledge of R_{xo}, since R_{xo}/R_t is already known.

EXAMPLE

Invaded Water Sand: To Find D_i, R_{xo}, and R_t

Given: $R_{IL} = 5.$, $R_{16}'' = 35.$ $\Big\} \frac{R_{16}}{R_{IL}} = \frac{35}{5} = 7.$

SP $= -112$ MV. giving $\frac{R_{mf}}{R_w} = 25 = \frac{R_{xo}}{R_t}$

$R_{mf} = 1.0$ at 150°F, formation temperature.

Solutions: Trace 45° line starting from 7 on ordinate axis and find its intersection with $\frac{R_{xo}}{R_t} = 25.$

1) When $D_i/d = 2.5$, $R_{xo}/R_{IL} = 24.5$, $R_{xo} = 122$, and $\phi = 9\%$.

2) When $D_i/d = 9$, $R_{xo}/R_{IL} = 10.5$, $R_{xo} = 52$, and $\phi = 13\%$.

Since the last solution is the more logical (from experience) and since $R_{xo}/R_t = 25$,

R_t is $52/25 = 2.1$.

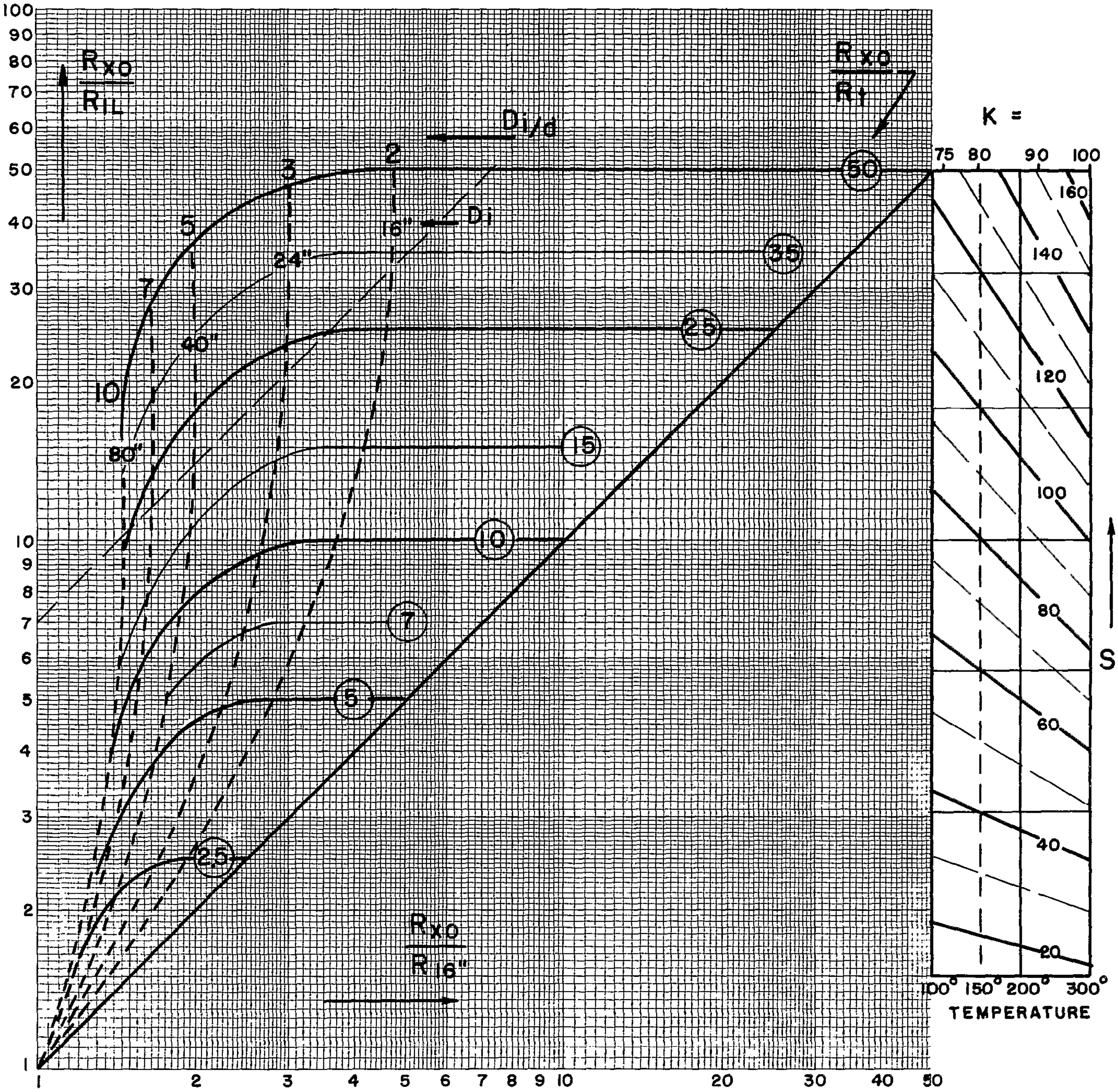
D_i/d is thus about 9.

40" INDUCTION – 16" NORMAL

HOLE: 8" THICK BEDS

CHART COMPUTED SUPPOSING NO ANNULUS OF FORMATION WATER IS PRESENT: CASE OF $S_w > 60\%$

AUGUST, 1957



R_{IL} and $R_{16"}$ are Induction Log and Short Normal readings corrected for borehole effect.

Chart values averaged for $\frac{R_{xo}}{R_{mf}}$ ranging from 6 to 101.

SCHLUMBERGER WELL SURVEYING CORP.

CORRECTIONS FOR 5FF40 INDUCTION LOG

USE AND DESCRIPTION

Chart A is used to obtain the amount of borehole conductivity signal for various hole sizes and positions of the sonde in the hole. This chart is based upon controlled measurements in the appropriate sizes of nonconductive pipe.

Charts B, C, D, and E are used to correct the induction log reading in thin beds for the effects of the surrounding formations. These charts were computed from geometric factors and include skin effects*.

INFORMATION REQUIRED

Chart A

Hole Diameter

Sonde Standoff

R_m at Formation Temperature

Charts B, C, D, and E

R_a — from induction log (corrected for hole signal, if necessary)

R_s — resistivity of surrounding beds

e — bed thickness.

PROCEDURE

Chart A: Enter hole size and proceed vertically to standoff (see Log Heading REMARKS). From this intercept, go horizontally to the vertical line corresponding to a 12″ hole diameter. From this intersection, draw a straight line through the value of R_m (at formation temperature) to the conductivity correction. Scale A is for fresh muds; Scale B is for salty muds. The hole conductivity signal is to be deducted from the conductivity value before other corrections are made. This correction will apply to all zones with the same hole size.

Charts B, C, D, and E: Select the chart appropriate for R_s. Enter the bed thickness and proceed upward to the curve for the proper value of R_a/R_s. Read R_{corr}/R_a at the left; this value is multiplied by R_a to give R_{IL}.

EXAMPLE

Given: $R_m = .46$. Ind. = 35 ohm-m ($C_{ind} = 29$ mmhos.)

$d = 10\frac{3}{4}''$. $R_s = 12$ ohm-m.

Standoff $= 1\frac{1}{2}''$. $e = 5'$.

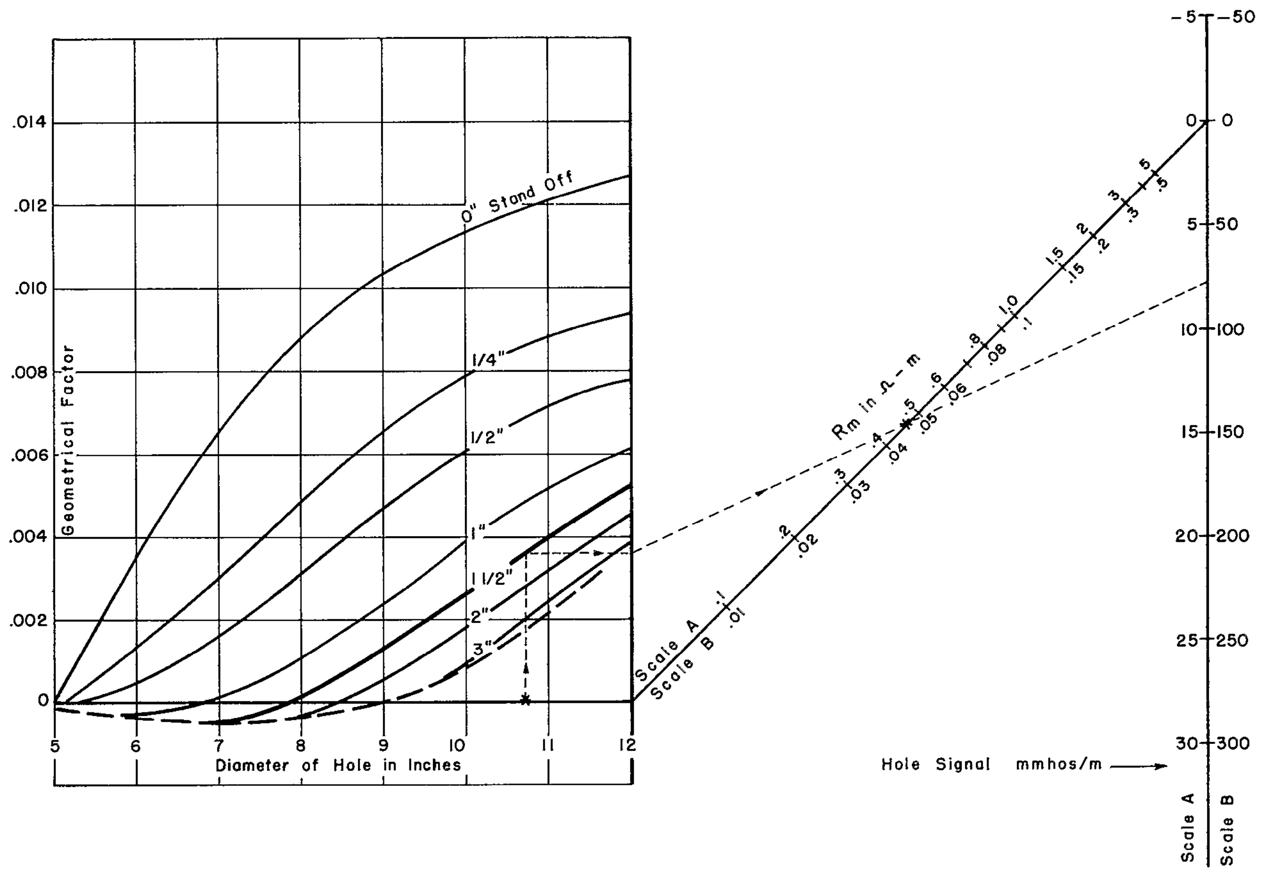
Solution: Chart A gives hole signal = 8. Corrected conductivity is 29 − 8 = 21 mmhos. This corresponds to $R_a = 48$ ohms. Chart E is next used since R_s is close to 16.

$R_a/R_s = 4$. For $e = 5'$, $R_{corr}/R_a = 1.2$. Therefore,

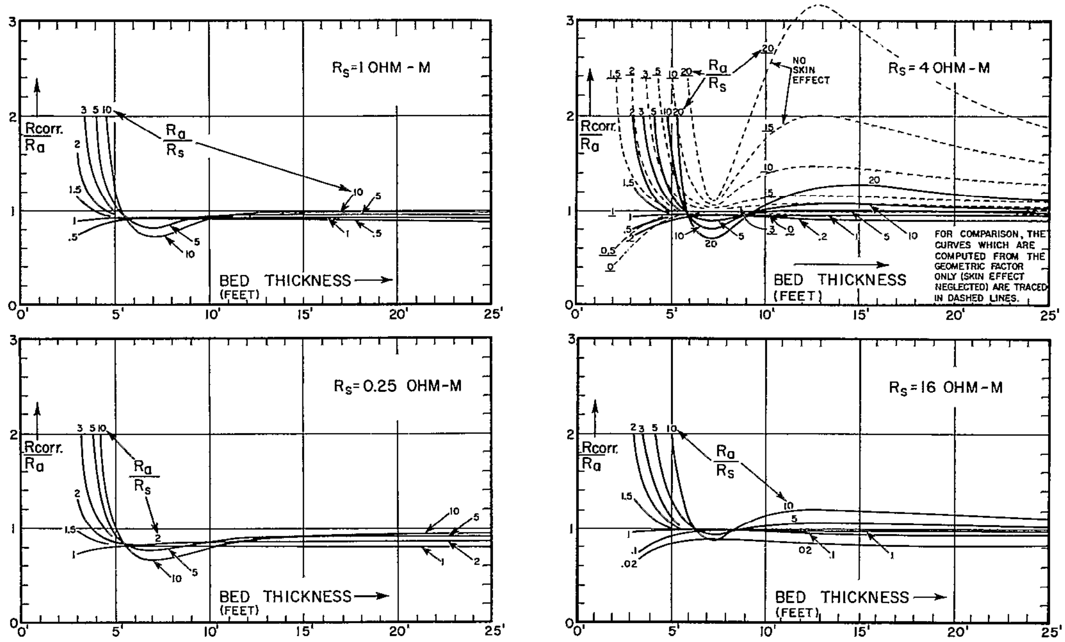
$R_{IL} = 1.2 \times 48 = 57$ ohm-m.

*Dumanoir, J. L., Tixier, M. P., and Martin, M. "Interpretation of the Induction-Electrical Log in Fresh Mud." T. P. 4610, *Petroleum Transactions of the AIME,* Vol. 210, July, 1957.

HOLE CORRECTIONS — 5FF40" INDUCTION



BED THICKNESS CORRECTION — 5FF40" INDUCTION



SCHLUMBERGER WELL SURVEYING CORP.

INDUCTION LOG CORRECTIONS

USE AND DESCRIPTION

The charts on pages B-14 and B-16 are used to correct the readings obtained with the various Induction Log sondes for borehole signal and bed thickness.

The chart at the top of B-16 is used to obtain the borehole conductivity signal for standoffs of zero and 1½″ in various hole sizes. Curves are shown for the 5FF40, Medium, and 6FF40 Induction devices. The chart is based upon controlled measurements in appropriate sizes of non-conductive pipe.

The charts at the bottom of B-16 are used to correct the 5FF40 Induction reading for the effects of surrounding formations in thin beds.

INFORMATION REQUIRED

Borehole Correction
- Type of Induction Log
- Hole diameter
- Sonde standoff
- R_m at formation temperature

Bed Thickness Correction
- Type of Induction Log
- R_a — form Induction Log (corrected for borehole signal, if necessary).
- R_s — resistivity of surrounding beds.
- e — bed thickness.

PROCEDURE

Borehole Correction: Enter hole size and proceed vertically to appropriate standoff (see Log Heading REMARKS). From this intercept, go horizontally to the vertical line corresponding to a 12″ hole diameter.

From this intersection, draw a straight line through the value of R_m (at formation temperature) to the conductivity correction. Scale A is for fresh muds; Scale B is for salty muds. The hole conductivity signal is to be deducted from the log conductivity value before other corrections are made. This correction will apply to all zones with the same hole size.

5FF40 Bed Thickness Correction: Select the chart appropriate for R_s. Enter the bed thickness and proceed upward to the curve for the proper value of R_a/R_s. Read R_{corr}/R_a at the left; this value is multiplied by R_a to give R_{IL}-corrected.

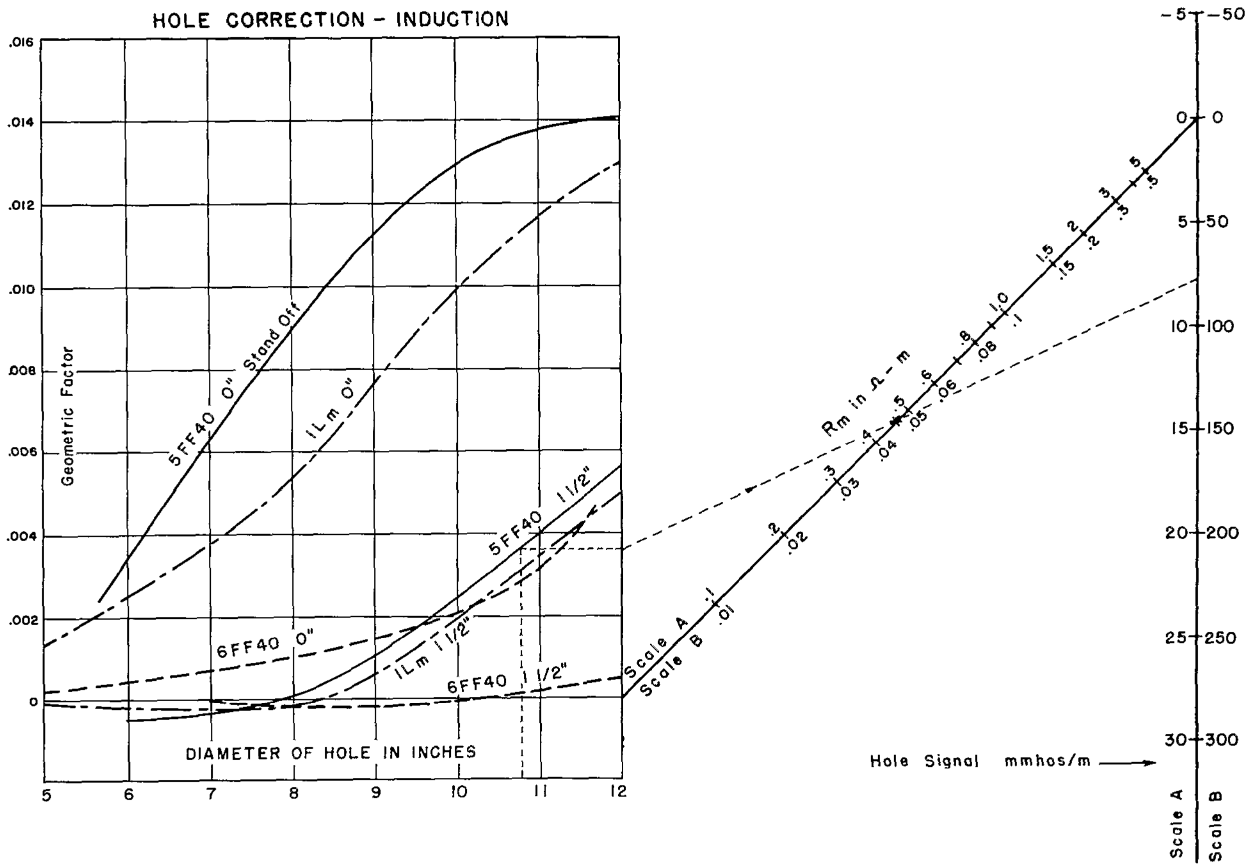
6FF40 Bed Thickness Correction: Select the appropriate R_s chart. Enter the bed thickness and proceed upward to the proper R_a curve. Read R_{IL}-corrected at the left.

EXAMPLE

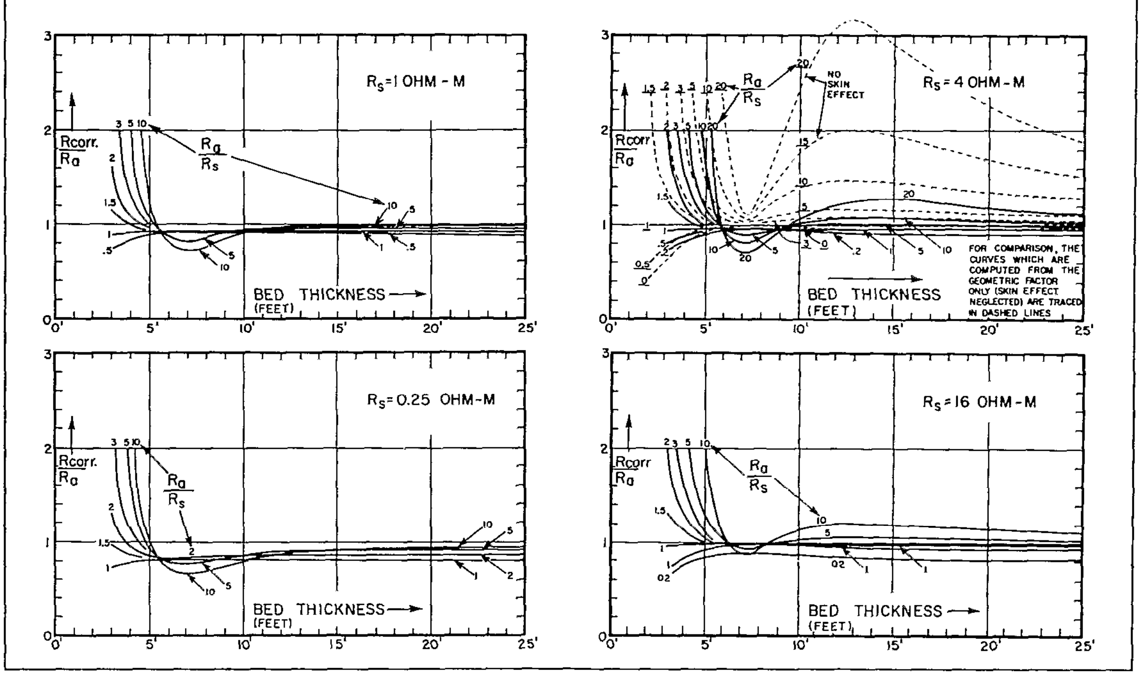
GIVEN: 5FF40 Induction
$R_m = 0.46$
d = 10¾″
Standoff = 1½″
$R_{ind} = 35$ ohm-m ($C_{ind} = 29$ mmhos/m)
$R_s = 12$ ohm-m
e = 5′

SOLUTION: Borehole correction chart gives hole signal = 8.
Corrected conductivity is 29-8 = 21 mmhos/m.
This corresponds to $R_a = 48$ ohm-m. Closest R_s chart is $R_s = 16$ ohm-m. $R_a/R_s = 4$.
For e = 5′, $R_{corr}/R_a = 1.2$.
Therefore, $R_{IL} = 1.2 \times 48 = 57$ ohm-m.

HOLE CORRECTIONS — 5FF40" INDUCTION



BED THICKNESS CORRECTION — 5FF40" INDUCTION



INDUCTION LOG CORRECTIONS

Charts on the following pages are used to correct Induction Log readings for borehole signal and bed thickness effects. For more detailed information on Induction Log corrections see "Schlumberger Induction Log Correction Charts," 1962.

1. *Borehole corrections.* The hole conductivity signal is to be subtracted, where necessary, from the Induction Log conductivity reading before other corrections are made.* This correction applies to all zones (including shoulder beds) having the same hole size and mud resistivity.

   The chart at top of Rcor-4 gives corrections for 6FF40 or ILd (solid curves) and ILm (dashed curves) and 6FF28 for various wall stand-offs. Dashed working lines illustrate use of the chart for the case of a 6FF40 sonde with a 1.5 inch standoff in a 14.6-inch borehole, and $R_m = 0.35$ ohm-m. The hole signal is found to be 5.5 mmhos/m. If the log reads $R_{IL} = 20$ ohm-m, C_{IL} (conductivity) = 50 mmhos/m. The corrected C_{IL} is then (50-5.5) = 44.5 mmhos/m. $R_{IL} = 1000/44.5 = 22.4$ ohm-m.

2. *Bed thickness corrections.* Charts are given on Rcor-5 and top of Rcor-6 for 6FF40, ILd, and 6FF28 in beds thicker than 4 feet. Rcor-7 is for the ILm. A skin effect correction is included in these charts. Select appropriate chart for value of adjacent bed resistivity (R_s) and SBR. Enter the bed thickness and proceed upward to the proper R_{IL} curve. Read ordinate values of $(R_{IL})_{corrected}$.

   An approximate chart for 6FF40, ILd, and 6FF28 is given on bottom of Rcor-6 for conductive beds thinner than 4 feet. Do not use the results from this chart when $(R_{IL})_{corr}$ is less than 1 ohm-m.

6FF28 INDUCTION LOG CORRECTIONS

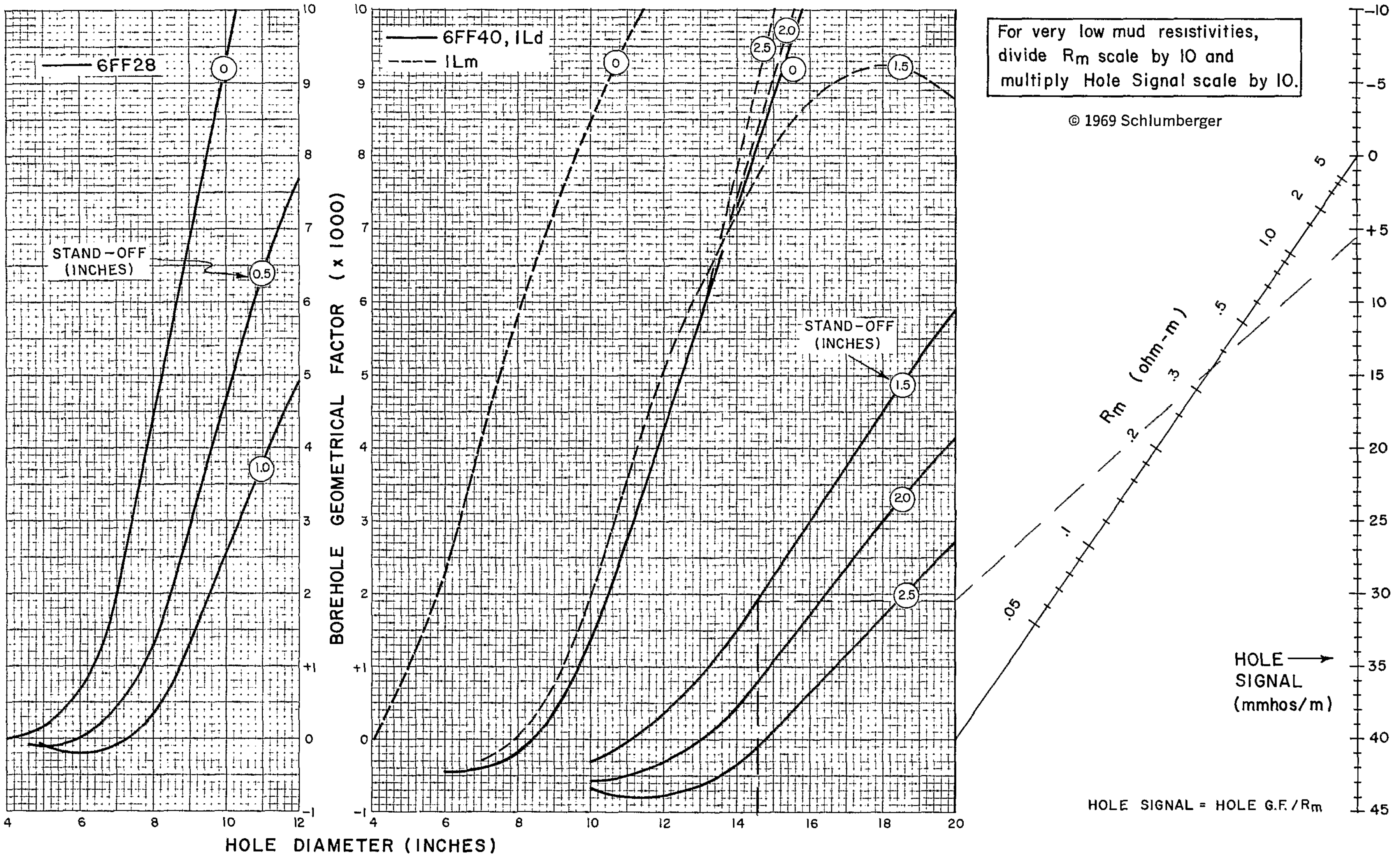
The 6FF28, designed for use in small holes, is a scaled-down version of the 6FF40. Bed thickness correction charts Rcor-5 and Rcor-6 have been adapted for the correction of 6FF28 Induction Log readings by adding scales that are adjusted by the scaling factor. The 6FF28 borehole corrections and integrated radial geometrical factor curve have been added to Rcor-4.

---

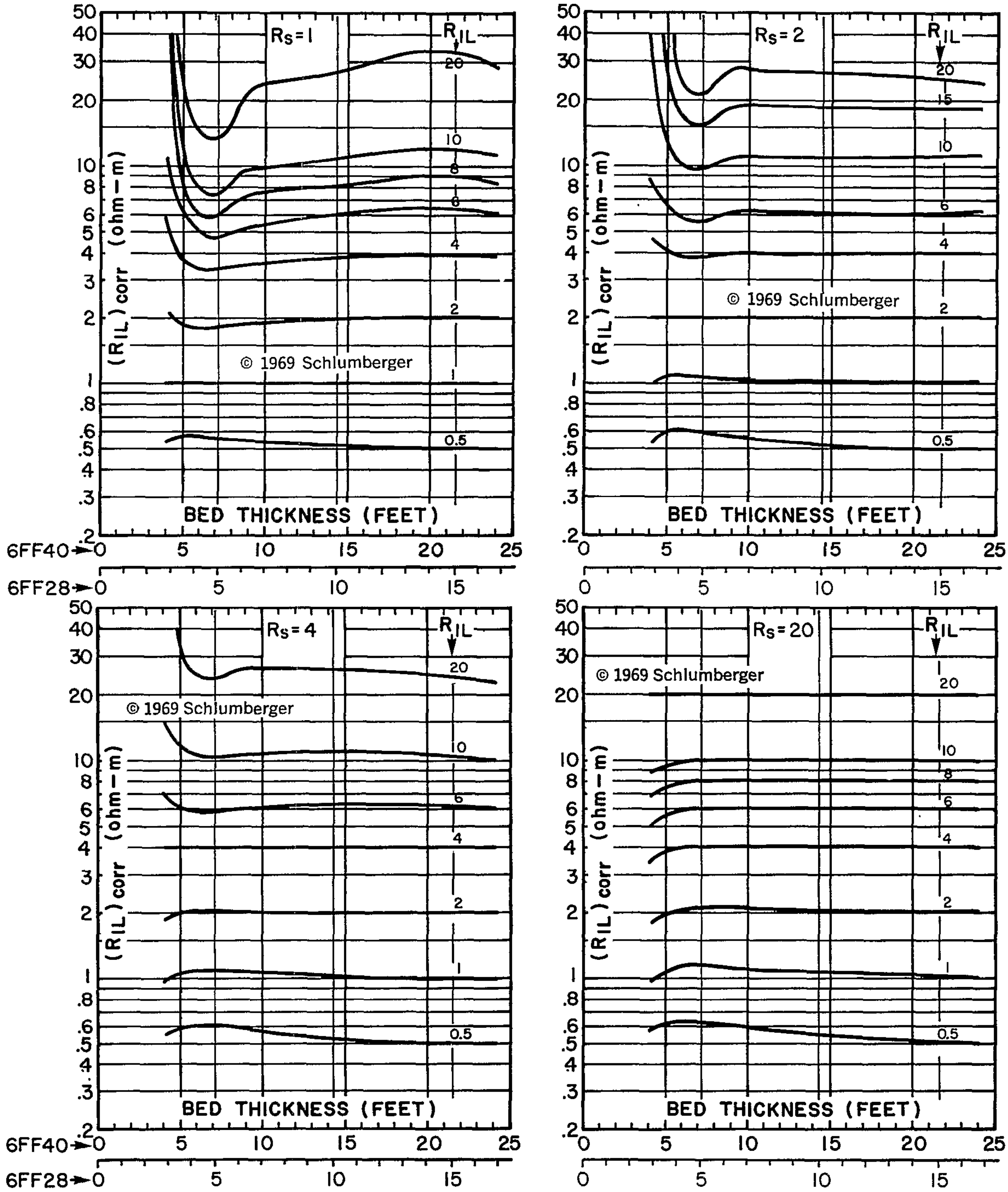
*Caution: Some Induction Logs, especially in salty muds, are adjusted so that the hole signal for the nominal hole size is already subtracted out of the recorded curve. Refer to log heading.

INDUCTION LOG BOREHOLE CORRECTION

DIS-A

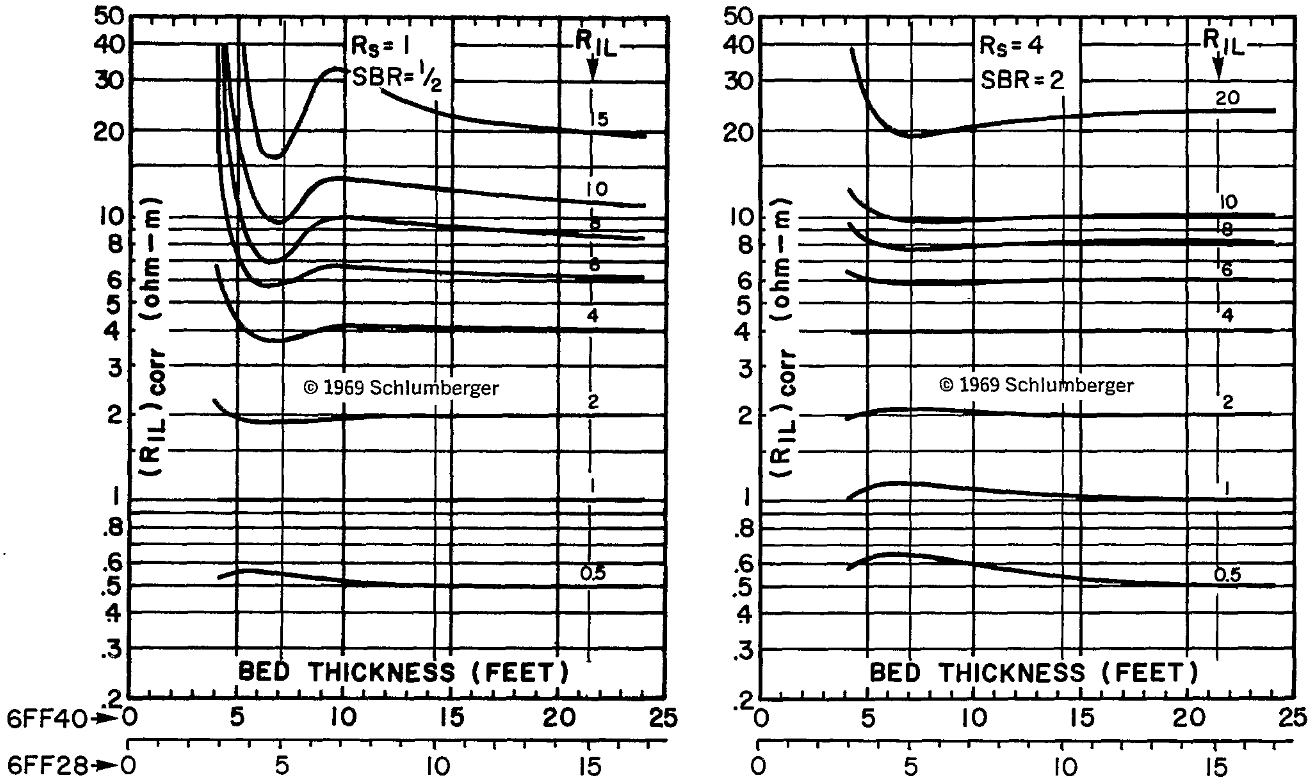


INDUCTION LOG BED THICKNESS CORRECTION
6FF40 or ILd and 6FF28
(SBR-1)

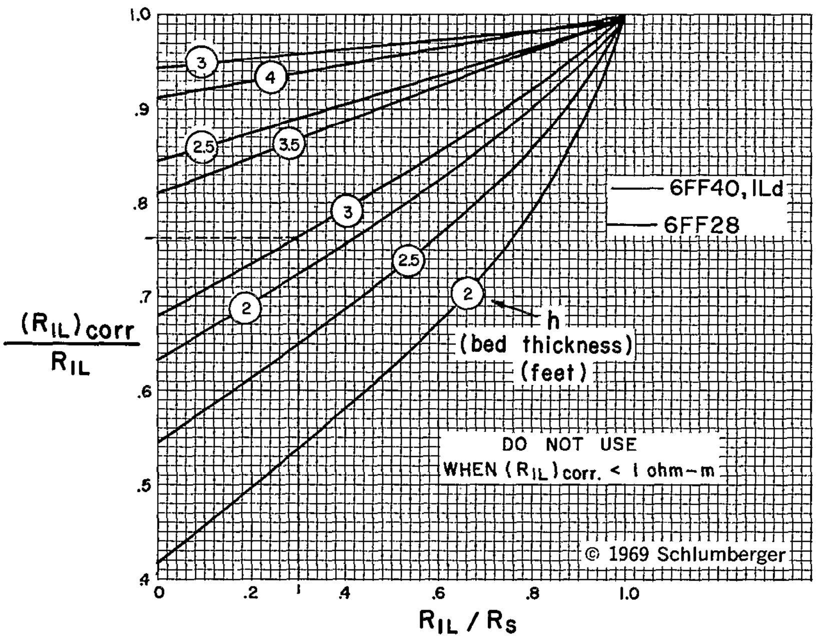


See Rcor-3 for discussion of Induction Log corrections.

INDUCTION LOG BED THICKNESS CORRECTION 6FF40 or ILd and 6FF28

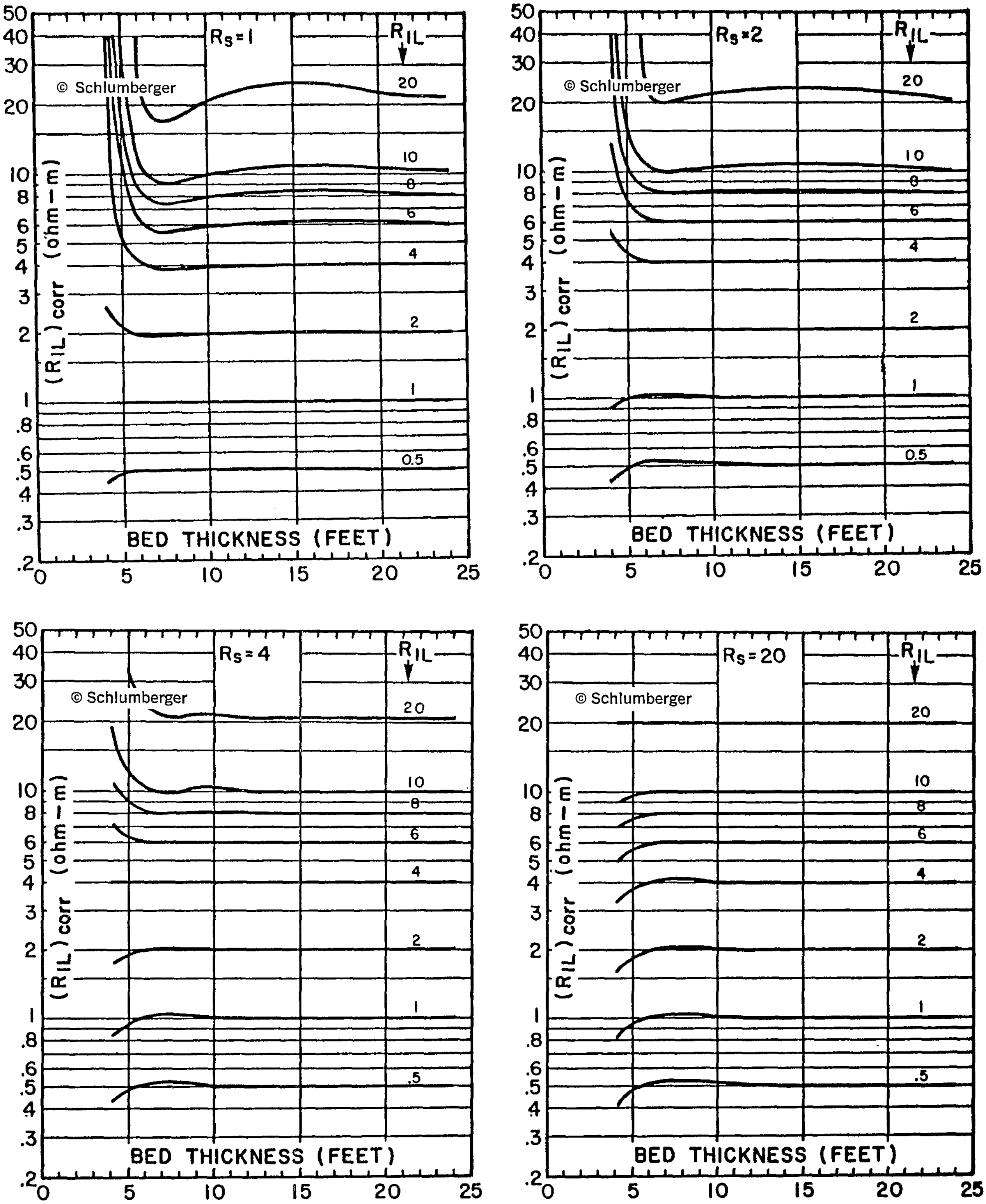


CORRECTION FOR THIN CONDUCTIVE BEDS: 6FF40, ILd, 6FF28



See Rcor-3 for discussion of Induction Log corrections.

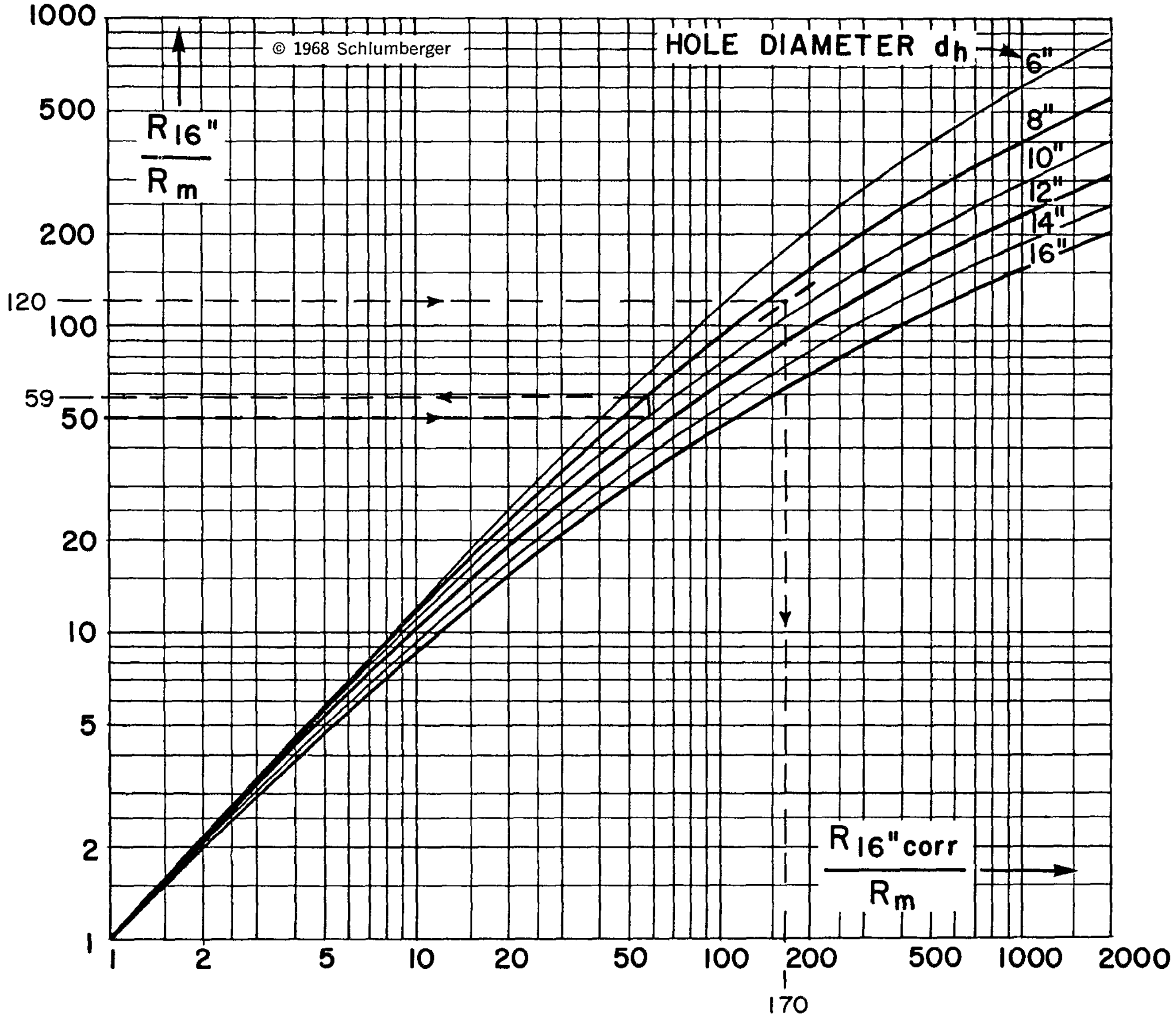
INDUCTION LOG BED THICKNESS CORRECTION
ILm



See Rcor-3 for discussion of Induction Log corrections.

BOREHOLE CORRECTION FOR 16-INCH NORMAL

RECORDED WITH INDUCTION-ELECTRICAL LOG (6FF40-16"N)



1. *Thick Beds*

   Example: $R_{16''}$ = 60 ohm-m, R_m (at formation temperature) = 0.5, d = 9″.

   Solution: $R_{16''corr}/R_m$ = 170, and $R_{16''corr}$ = 170 × 0.5 = 85.0.

2. *Correction to 8-inch Hole Size*

   Before using the log readings in charts Rcor-11 and Rcor-12 correct to 8″-hole-size reading. Enter with $R_{16''}/R_m$. Proceed horizontally to solid curve for actual hole size. Proceed vertically to 8″-hole-diameter line. Read $R_{16''}/R_m$ for 8″ hole on scale at left.

   Example: $R_{16''}/R_m$ = 50 in 10″ hole. Find $R_{16''}/R_m$ = 59 in 8″ hole.

DUAL INDUCTION-LATEROLOG 8

The ILd (Deep Induction Log), ILm (Medium Induction Log), and the LL8 (Laterolog 8) are recorded with the Dual Induction-Laterolog device. The improved chart on the facing page is used to determine values of R_t, R_{xo}/R_t, and d_i (assuming a step-contact profile of invasion). Skin-effect corrections have been included in the construction of this new chart.

The induction logs are corrected, where necessary, for hole effect and bed thickness using Charts Rcor-4 to Rcor-7. Correct the Laterolog 8 for hole effect using Rcor-2.

EXAMPLE OF USE: GIVEN: $R_{LL8} = 9.5$, $R_{ILm} = 1.9$, $R_{ILd} = 1.2$, all values previously corrected as noted above.

Enter with	R_{LL8}/R_{ILd}	$= 9.5/1.2 = 7.9$
	R_{ILm}/R_{ILd}	$= 1.9/1.2 = 1.58$
Read from the solid black curves	R_{xo}/R_t	$= 13.0$
Read from the dashed curves	d_i	$= 52''$
Read from the red curves	R_t/R_{ILd}	$= 0.83$

$$R_t = R_{ILd} \times (R_t/R_{ILd}) = 1.2 \times 0.83 = 1.0$$

SATURATION DETERMINATION (CLEAN FORMATIONS):

The chart-derived values of R_t and R_{xo}/R_t each can be used to find values for S_w. One value, which is designated as S_{wA} (S_w-Archie), is found using the Archie saturation formula (or Chart Sw-1) with the R_t value and otherwise known values of F and R_w. The alternate S_w value, designated as S_{wR} (S_w-ratio), is found using R_{xo}/R_t with R_{mf}/R_w as in Chart Sw-2.

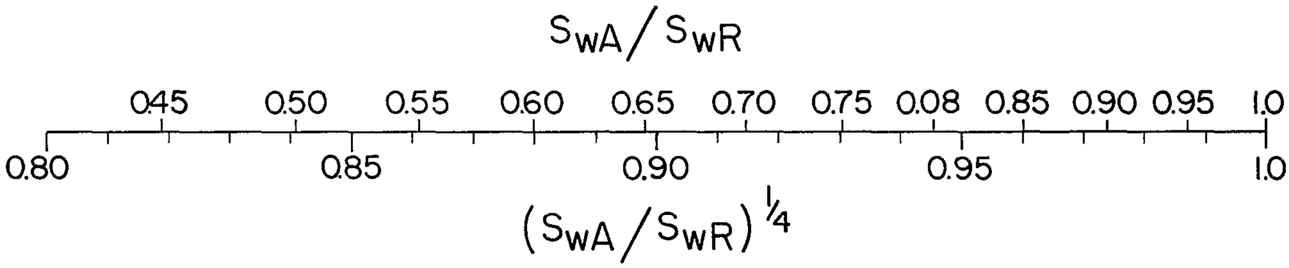
If S_{wA} and S_{wR} are equal, the assumption of a step-contact invasion profile is indicated to be correct, and all values found (S_w, R_t, R_{xo}, d_i) are considered good.

If $S_{wA} > S_{wR}$, either invasion is very shallow or a transition type of invasion profile is indicated; and S_{wA} is considered a good value for S_w.

If $S_{wA} < S_{wR}$, an annulus type of invasion profile may be indicated. In this case a more accurate value of water saturation may be estimated using the relation:

$$(S_w)_{corr} = S_{wA}\left(\frac{S_{wA}}{S_{wR}}\right)^{1/4}$$

The correction factor $(S_{wA}/S_{wR})^{1/4}$ can be found from the scale shown below:

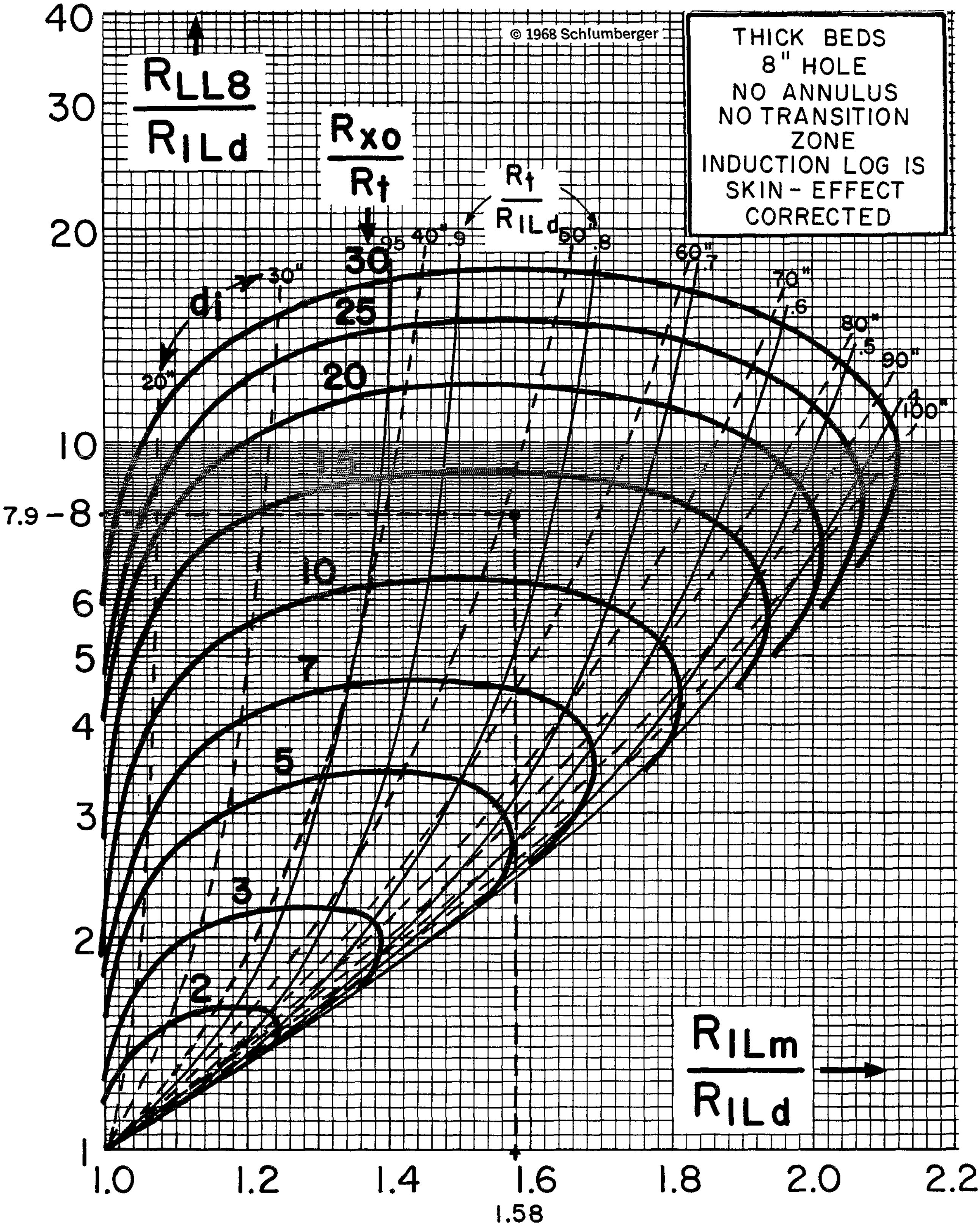


NOTE: The above procedure is correct for clean formations. For the shaly-sand procedures refer to the Appendix of "Dual Induction-Laterolog: A New Tool for Resistivity Analysis," by Tixier, M. P., Alger, R. P., Biggs, W. P., and Carpenter, B. N., Paper SPE-173, SPE of AIME Meeting, New Orleans, 1963.

DUAL INDUCTION–LATEROLOG

ILd – ILm – LL8

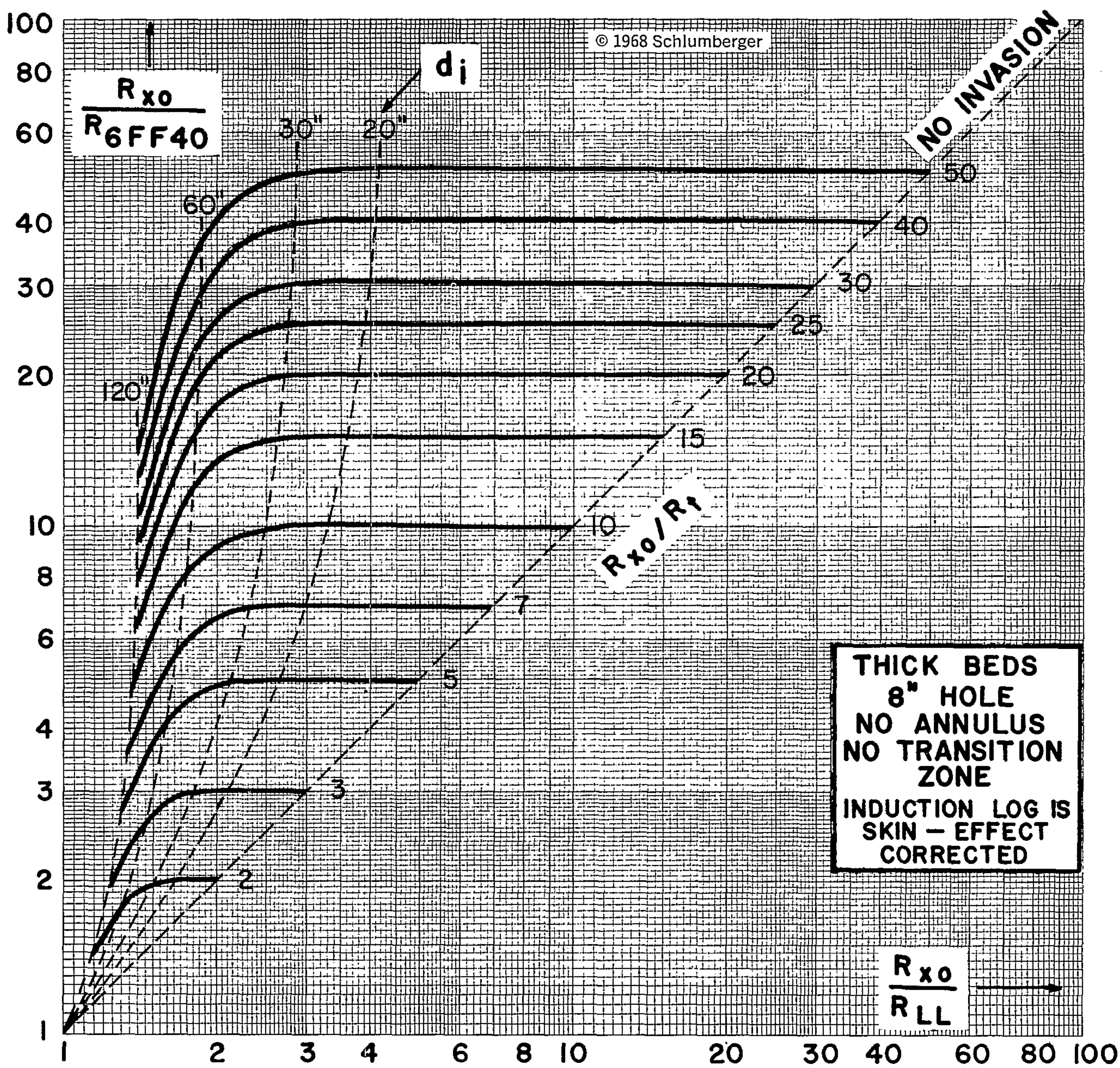
DIS-A



6FF40 – LATEROLOG – R_{xo}

LATEROLOG 7 or LATEROLOG 3 (5 FT GUARDS)

$R_{xo} > R_t$



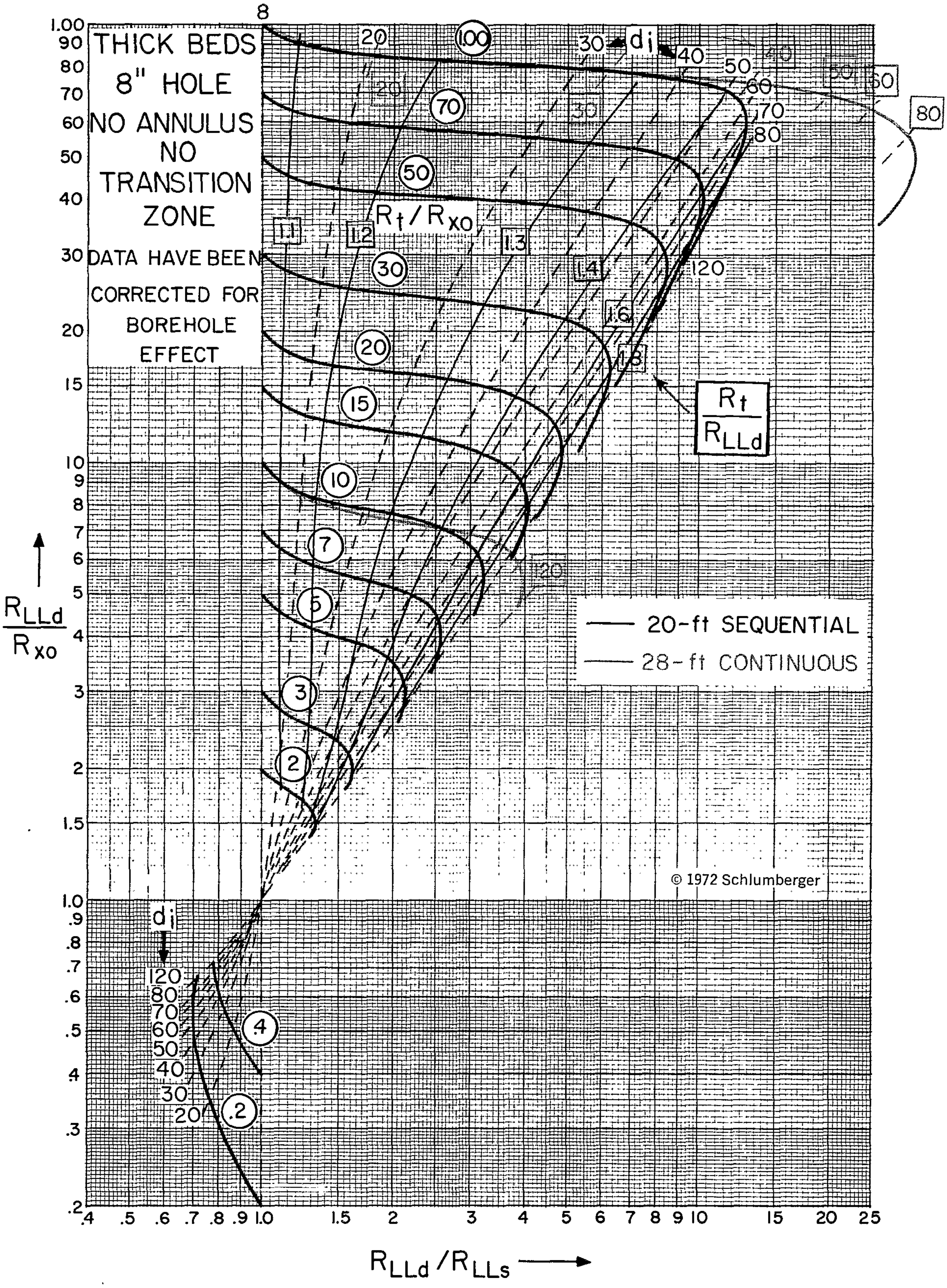
See facing page for discussion of Charts Rint-3 and Rint-4.

Example: $R_{6FF40c} = 5$, $R_{xo} = 20$, $R_{LL7c} = 10$

Solution: $R_{xo}/R_t = 4$, $d_i = 30''$

DUAL LATEROLOG – R_{xo}

LLd – LLs – R_{xo}



SCHLUMBERGER WELL SURVEYING CORPORATION

NOMOGRAM FOR SATURATION DETERMINATION—CLEAN FORMATION

USE AND DESCRIPTION

This nomogram provides solutions of the equation SP = K log R_{mf}/R_w to find R_w and of the Archie relations to find saturation. F or porosity must be known and related through the equation $F = 0.62\phi^{-2.15}$.

INFORMATION REQUIRED

R_w at Formation Temperature

If this is not known, it is found by the use of:

a. Static SP (Deduct electrofiltration if E_k is important.)

b. Formation Temperature or K

c. R_{mf} at Formation Temperature

F—Formation Factor

or

ϕ—Porosity

R_t—True Formation Resistivity

PROCEDURE

Case Where R_w Is Unknown: From the static SP and the formation temperature (or K) find $R_{mf}/(R_w)_e$. Then by passing through R_{mf}, $(R_w)_e$ is determined. This value may be lower than the true R_w (see pages A-9 through A-12). If greatly different, a true R_w from Chart A-12 should be found before saturation determination. In some regions experience will show that a choice of K, greater than that for the equivalent temperature, will be a more convenient way of obtaining R_w directly, without the need for Chart A-12.

Build R_o by passing on through the known value of F or per cent porosity.
Find per cent S_w by passing on through the known R_t.

Case Where R_w Is Known: Use of the SP is not required. Enter R_w at formation temperature in Column 4 and proceed as above.

EXAMPLE

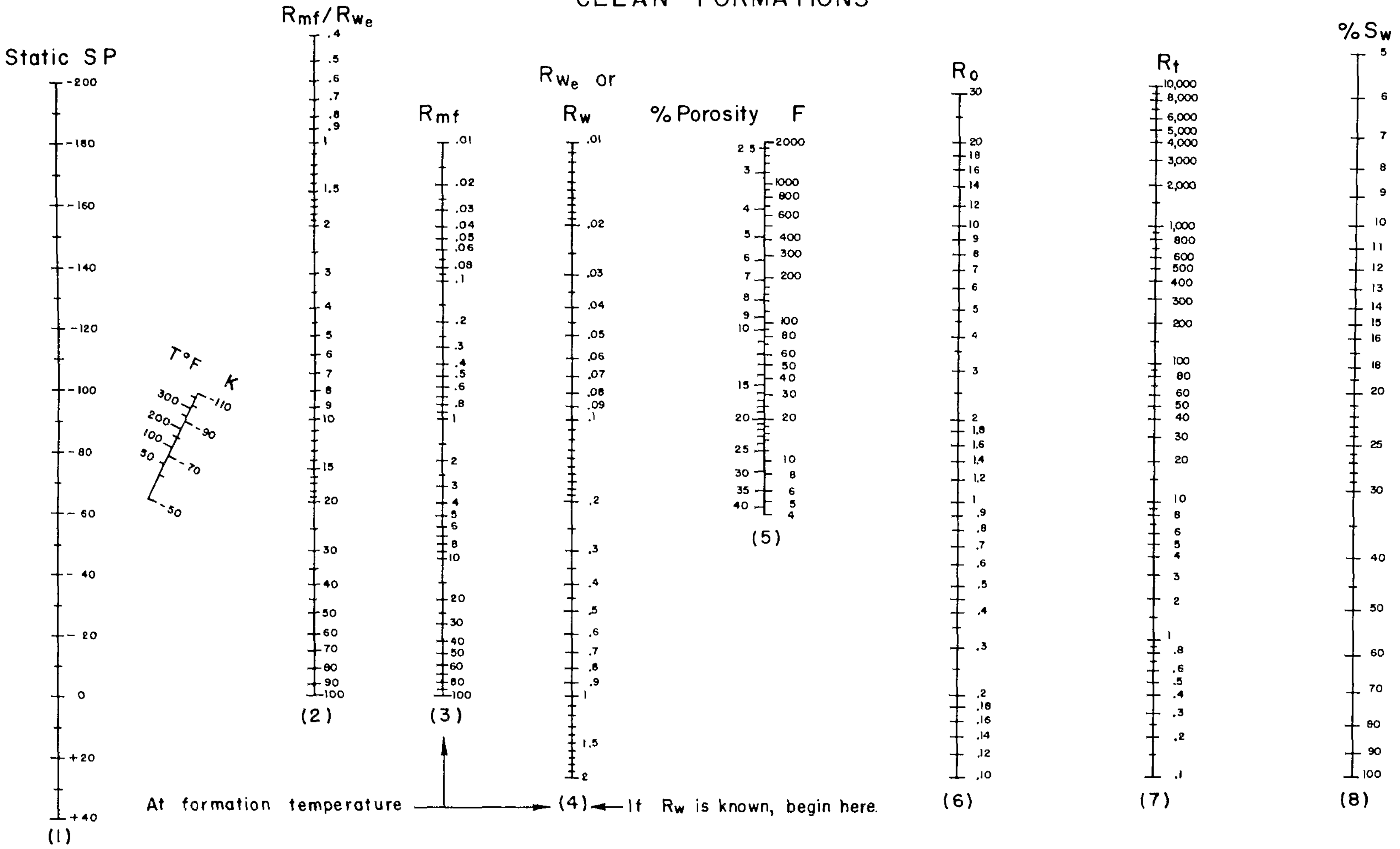
GIVEN: R_t = 15.
F = 20.
SP = −100.
R_{mf} = 0.75 at 200°F.

SOLUTION: S_w = 26% (R_w = .05; R_o = 1.0).

SCHLUMBERGER

OCTOBER 1958

SCHLUMBERGER WELL SURVEYING CORPORATION
NOMOGRAM FOR SATURATION DETERMINATION
CLEAN FORMATIONS



Column 4: from solution of $SP = -K \log_{10} R_{mf}/R_{we}$ (Correct R_{we} to R_w with Chart A-12.)

Column 5: $F = .62\ \phi^{-2.15}$ (Data from MicroLog, Microlaterolog, Neutron, Sonic, etc.)

Column 6: from solution of $R_w \times F = R_o$

Column 8: from solution of $\sqrt[2]{R_o / R_t} = S_w$

Chart D-2

SCHLUMBERGER WELL SURVEYING CORP.

LOG INTERPRETATION CHARTS

SATURATION DETERMINATION
CLEAN OR SHALY FORMATION

USE AND DESCRIPTION

This chart provides solutions of Equation (6) in the paper by Poupon, Loy, and Tixier, "A Contribution to Electrical Log Interpretation in Shaly Sands", so that S_w in the effective porosity of laminated sands can be found. The error is negligible if the sands also contain disseminated shale. An average Residual Oil (ROS) correction is built in based on the relation:

$$(1 - ROS) = S_{xo} = \sqrt[5]{S_w}.$$

The chart applies equally well to clean sands or limes. In such a case, PSP = SSP; and the apparent S_w is equal to the true S_w.

INFORMATION REQUIRED

R_{xo} — from the MicroLog
R_t — from the Electrical Log or Induction Log
PSP — read from the SP curve
SSP — read from the SP curve on nearby clean sand
or
R_{mf}/R_w — determined by knowledge of R_w and R_{mf}
K — by consideration of formation temperature
ROS — either assumed or known

PROCEDURE

Plot the ratio R_{xo}/R_t against PSP. (Make corrections for bed thickness by curve of $R_i/R_m = 5$, Chart A-8, for beds less than 10′ thick.) This point gives an apparent water saturation. Through this point and the circle on the chart where SP = 0 draw a line and extend it until intersection with the appropriate value of SSP or R_{mf}/R_w (scale at top of chart). If you use the ROS assumed, S_w is read by the position between the diagonal lines. If ROS is known, proceed parallel with the diagonal lines to the edge of the chart. Go horizontally to the ROS value and read S_w by the position between the diagonal curved lines.

EXAMPLE

I. *Clean Sand*

GIVEN: $R_{xo} = 10.$
$R_t = 5.$
$SSP = -100.$
$K = 80.$

SOLUTION: $S_w = 26\%.$
If ROS known to be 20%, $S_w = 28\%.$

II. *Shaly Sand*

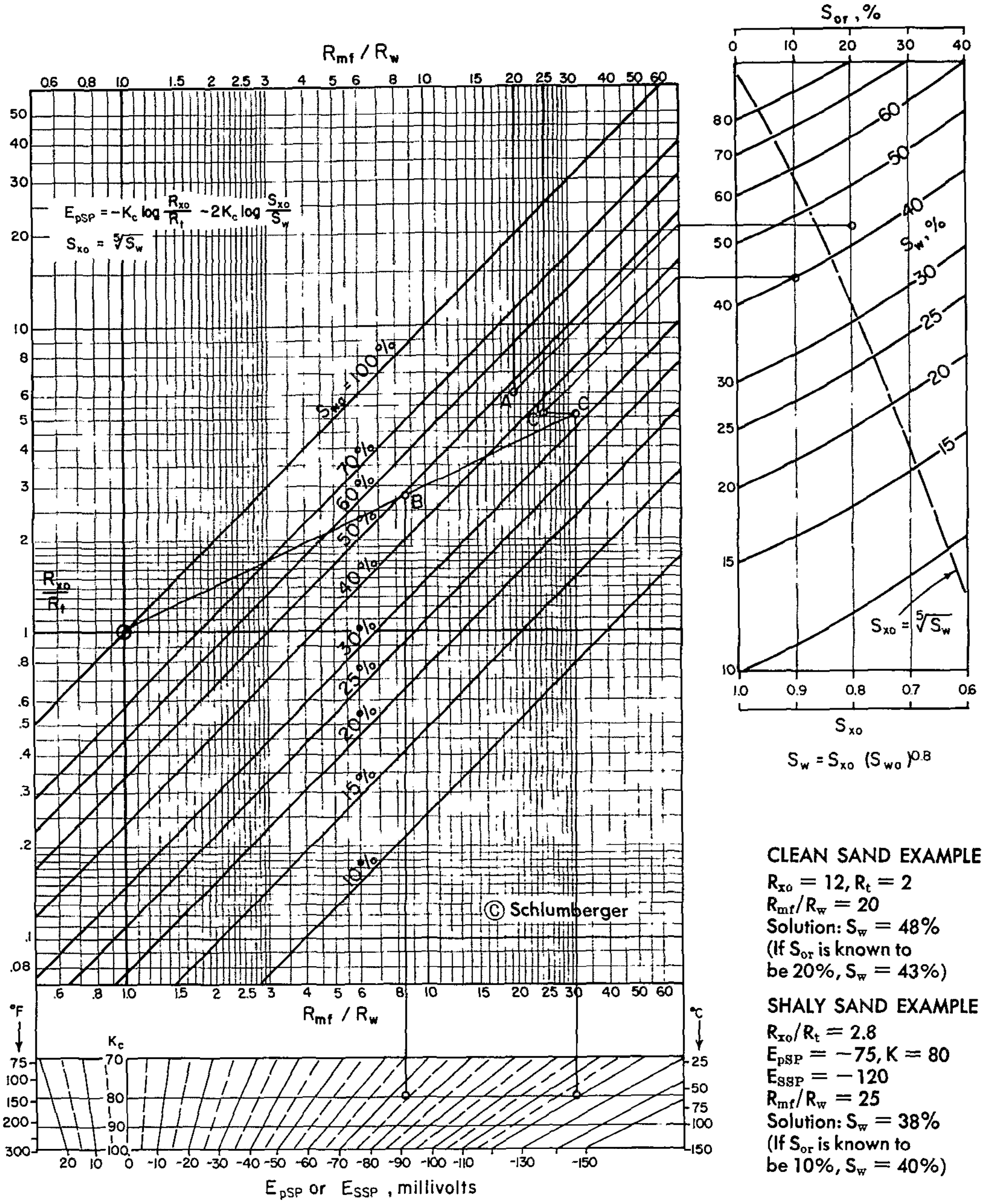
GIVEN: $R_{xo}/R_t = 2.5.$
$PSP = -65.$
$SSP = -112.$
$K = 80.$

SOLUTION: Apparent $S_w = 55\%.$
True $S_w = 35\%.$
If SSP not known, $R_{mf}/R_w = 25$ would have been used instead.

NOTE: If extraneous potentials exist, the SP terms have to be reduced accordingly before use in the chart.

Schlumberger

SATURATION DETERMINATION
(RATIO METHOD)[12]



CLEAN SAND EXAMPLE
$R_{xo} = 12, R_t = 2$
$R_{mf}/R_w = 20$
Solution: $S_w = 48\%$
(If S_{or} is known to be 20%, $S_w = 43\%$)

SHALY SAND EXAMPLE
$R_{xo}/R_t = 2.8$
$E_{pSP} = -75, K = 80$
$E_{SSP} = -120$
$R_{mf}/R_w = 25$
Solution: $S_w = 38\%$
(If S_{or} is known to be 10%, $S_w = 40\%$)

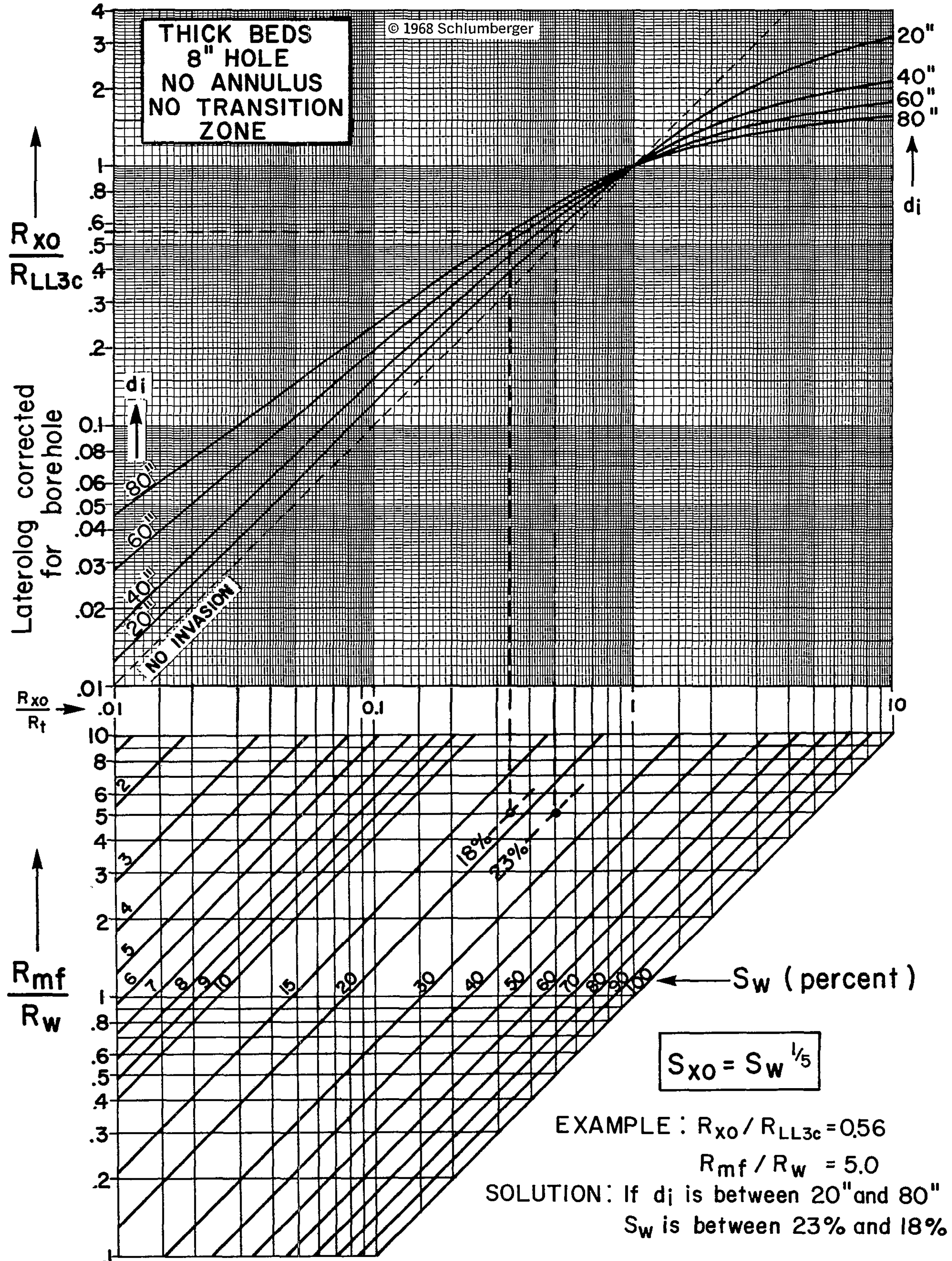
Procedure: For clean sands plot the ratio R_{xo}/R_t against R_{mf}/R_w (Point A) to find water saturation at "average" residual oil saturation ($S_{xo} = S_w^{1/5}$). If R_{mf}/R_w is unknown the SP can be used, assuming $E_{pSP} = -K \log R_{xo}/R_t$; enter chart from SP scale at bottom. (The chart includes no activity correction.)

For shaly sands plot R_{xo}/R_t against E_{pSP} (Point B). Draw a line through this point and the circle where $R_{mf}/R_w = R_{xo}/R_t = 1$. Extend line to intersect the value of E_{SSP} (Point C) to find a value of R_{xo}/R_t approximately corrected for shaliness. Plot this corrected value of R_{xo}/R_t versus R_{mf}/R_w (Point C') to find S_w assuming "average" S_{or}. If R_{mf}/R_w is unknown, use S_w value given by Point C.

Use diagram at right to correct S_w if S_{or} is known.

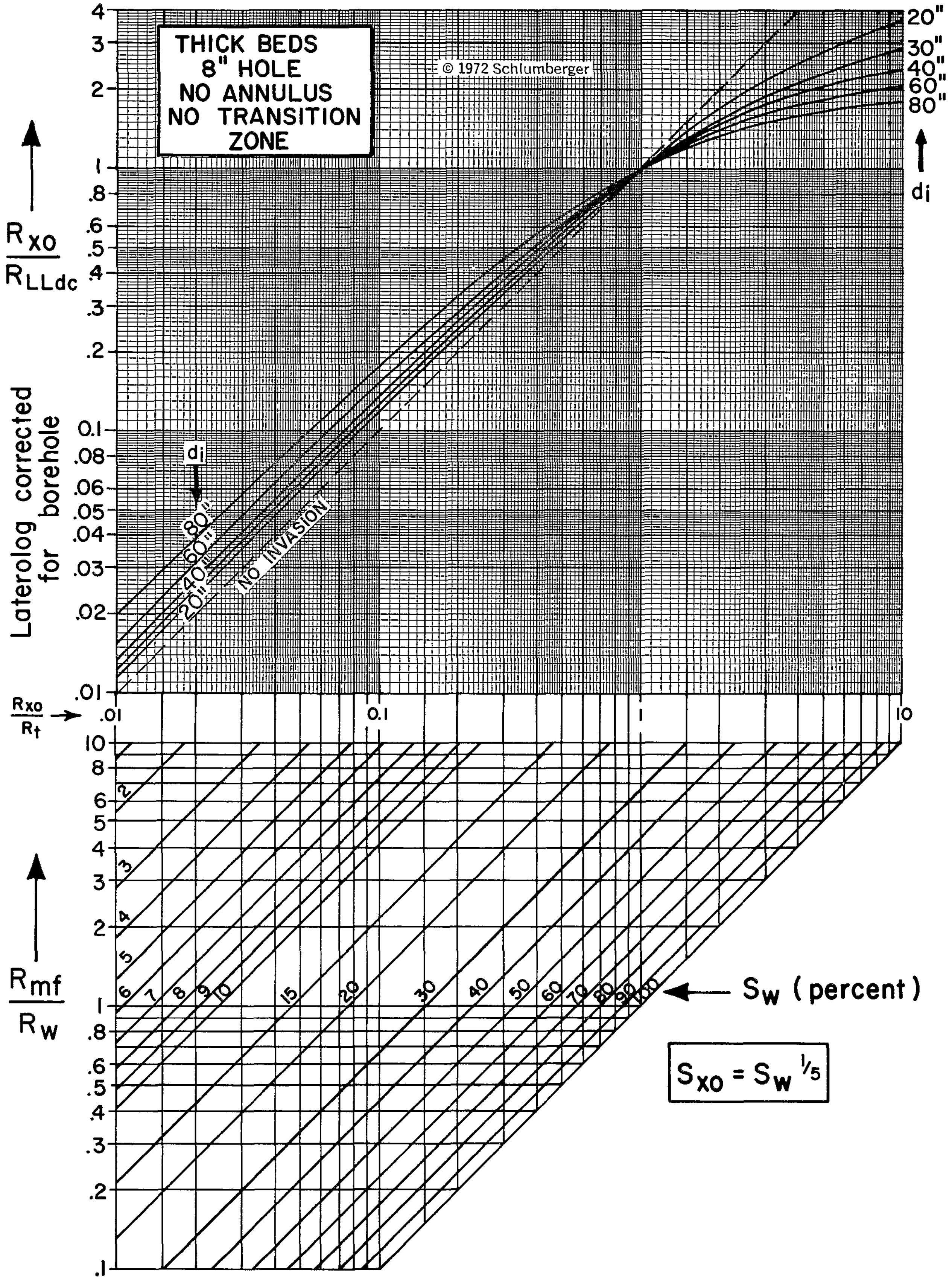
Sw-2

DETERMINATION OF S_w
LATEROLOG 3 (5 FT. GUARDS) or LL7 – R_{xo}



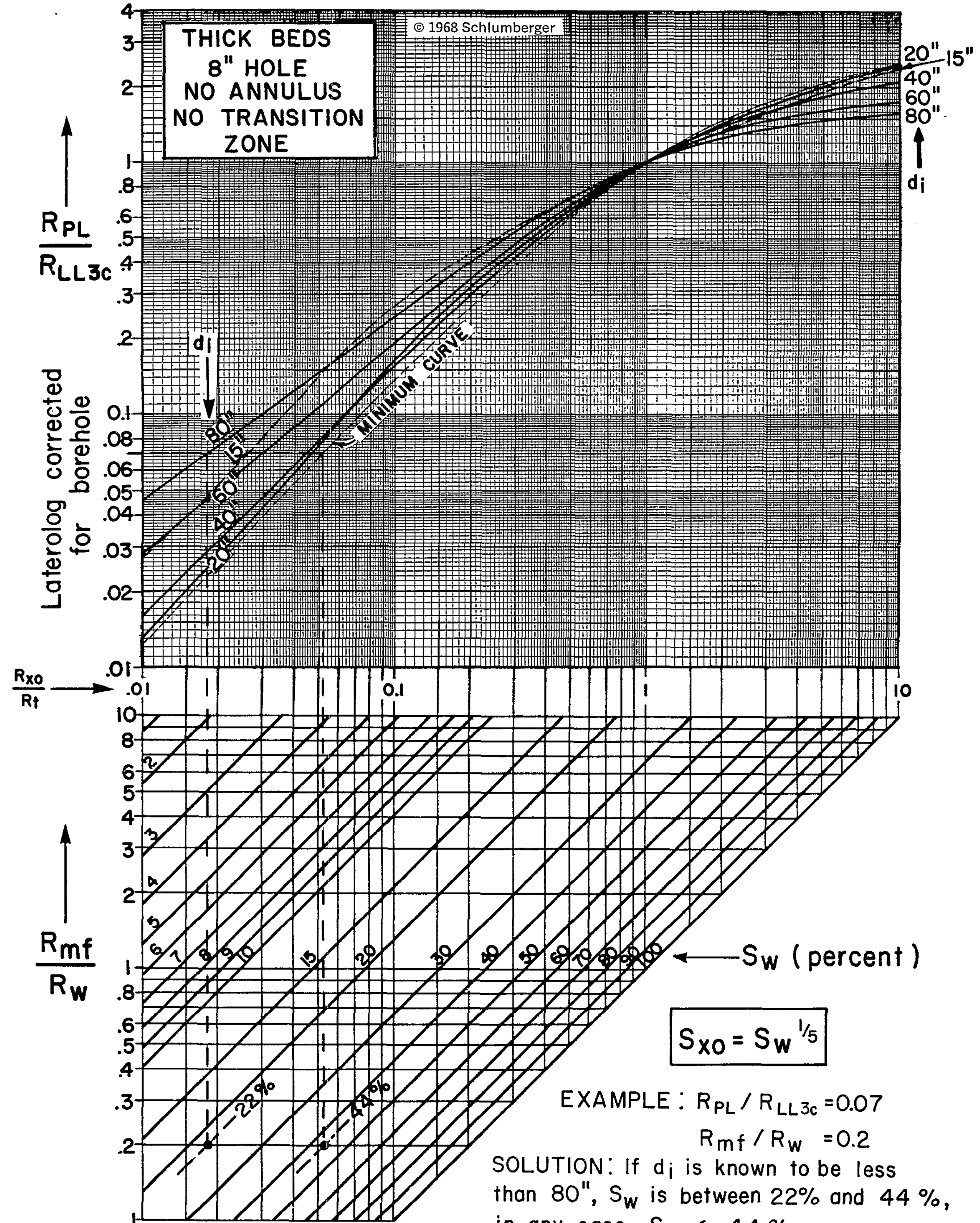
Sw-4a

DETERMINATION OF S_w
$LLd - R_{xo}$



Sw-4b

DETERMINATION OF S_w
LATEROLOG 3 (5 FT. GUARDS) or LL7 – PROXIMITY LOG



EXAMPLE: $R_{PL} / R_{LL3c} = 0.07$

$R_{mf} / R_w = 0.2$

SOLUTION: If d_i is known to be less than 80", S_w is between 22% and 44 %, in any case, $S_w < 44$ %

Sw-6

Schlumberger | Wireline & Testing

SMP-7030