CALIBRATION OF TOTAL-COUNT GAMMA RAY PROBES FOR ESTIMATION OF URANIUM RESOURCES

D. C. George

Delta Epsilon Instruments Inc.
P.O. Box 327
Delta, CO 81416
TEL(970) 243-4072

sales@deltaepsilon.com

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Introduction

The use of total-count gamma-ray logging probes to determine uranium resources in the ground is a long-standing practice. Probes used in this manner must be calibrated in order to determine their efficiency and the conventional and still best way to do this is by using full-size calibration models. Calibration models are available in the U.S., Canada, and Australia.

Fundamentals

Calibration is based on the assumption that observed count rate is proportional to ore grade when ore grade is expressed as a weight fraction of its host rock. But to make this proportionality hold, a few corrections must be made to the observed count rates.

- Corrections must be made for the instrumental dead time, because practical instruments do not respond proportionately at high counting rates.
- Corrections must be made for water in the borehole and for borehole casing, since those two things reduce the observed count rate.
- A correction must be made for the moisture in the ore body if that moisture is significantly different from the moisture content at calibration, known as a standard condition.
- A correction must be made for ore-body secular equilibrium since the gamma-ray tool observes counts primarily from Ra-226; and the 'grade' of Ra-226 is not the same as the grade of uranium unless the ore body is in secular equilibrium.
- A correction must be made for the so-called Z-effect in cases where there are high ore grades (several or more weight-% U_3O_8) and where small and unfiltered detectors are used.

The calibration equation is

$$GT = KA \qquad (1)$$

$$A = F_w F_c F_m F_q \sum \left(F_d(R_{obs}) F_z(R_{obs}) R_{obs} \right) \Delta z$$

where G = Grade of Ore zone
T = Thickness of Ore Zone
K = Constant of calibration known as the K-Factor
F_w = Water (Hole Size) Correction Factor
F_c = Casing Correction Factor
F_m = Moisture Correction Factor
F_q = Disequilibrium Correction Factor
$F_d(R_{obs})$ = Dead-Time Correction Factor
$F_z(R_{obs})$ = Z-Effect Correction Factor
R_{obs} = Observed Count Rate.
Δz = Data Acquisition Interval

Calibration Procedure

The purpose of calibration is to determine all of the factors, except for the corrections for moisture and disequilibrium, because those factors are particular properties of an ore body.

Note that F_d and F_z are both functions of the observed count rate. In practice, these two factors are usually combined into a single factor F_{dz}. Otherwise, the manufacturer must determine dead time of his instrumentation and the user should verify that determination, and accurate measurement of dead time is not a trivial measurement in the laboratory. Since the Z-effect correction factor is not significant except for the richest of ore-bodies, the combined factor is primarily a correction for dead time.

The first step in calibration is to determine F_{dz}. This is accomplished by observing count rates at mid ore-zone in a series of models having ore-grades spanning a decade or more. At Grand Junction, Colorado, the models are identified as N3, U3, U2, and U1. Counting rates at mid ore zone are obtained by averaging the observed counting rates over a one-foot interval in the center of the ore zone. Then a graph is plotted of Ore Grade versus Observed Counting Rate. A third order polynomial with zero/zero intercept is fitted to the data. Dividing the second order and third order coefficients by the first order coefficient gives the correction function F_{dz}.

Hole size corrections and casing corrections are not routinely included in an individual calibration but they are routinely determined for a particular configuration of hardware. These factors tend to be relatively constant for a given probe-model with a given detector size. The factors can be determined once, and the curves used routinely without periodic re-calibrations. Sample curves are included herein. The procedure for determining these factors is to observe the count rate at a fixed position in a calibration model, with and without water, or with and without casing. At Grand Junction, the model used is the WF model.

The last step in calibration is to prepare a calibration certificate. A sample certificate is included herein.

Note that the K Factor in this calibration is a factor for standard conditions, where standard conditions are defined as the conditions within the calibration model known as N3 at Grand Junction. In particular, this means a 4.5-inch dry hole, 13.3% formation moisture, and ore in equilibrium.

When the Grade-Thickness product for a given case is being computed, the moisture correction factor, F_m must be applied. The moisture correction factor is

$$F_m = \frac{(1 - M_c)}{(1 - M_f)}$$

where M_c= Moisture content by weight at calibration (0.133), and
M_f= Moisture content by weight in the ore zone of interest.

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DEpsilon@iti2.net

CALIBRATION CERTIFICATE

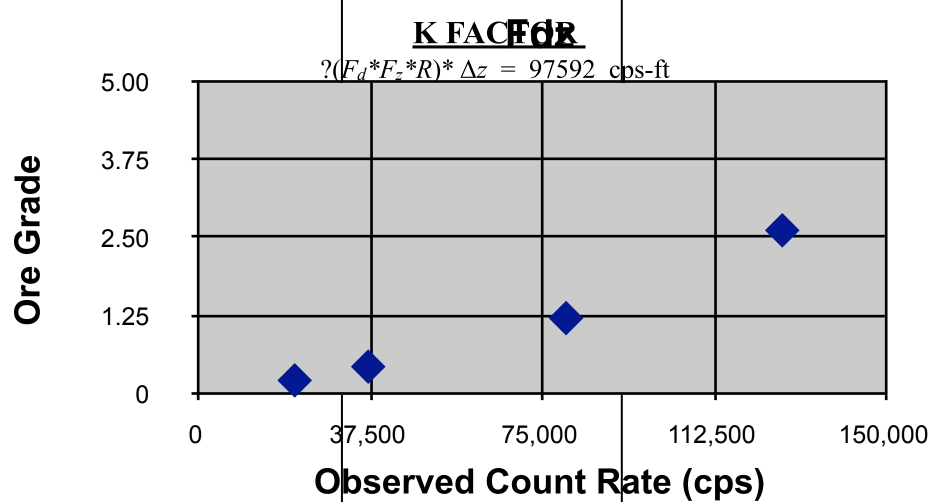
NATURAL GAMMA RAY PROBE MODEL GE9409
SERIAL NO 0022
DATE OF CALIBRATION: 22 August 1997
PRIMARY CALIBRATION: Model N3 at Grand Junction, CO

DEAD TIME AND Z-EFFECT CORRECTION FACTOR, F_{dz}

	Count Rate (cps)	AssignedOre Grade %eU_3O_8
N3	21335	0.241
U3	37358	0.53
U2	80492	1.06
U1	127638	2.2

K FACTOR

?(F_d*F_z*R)* Δz = 97592 cps-ft

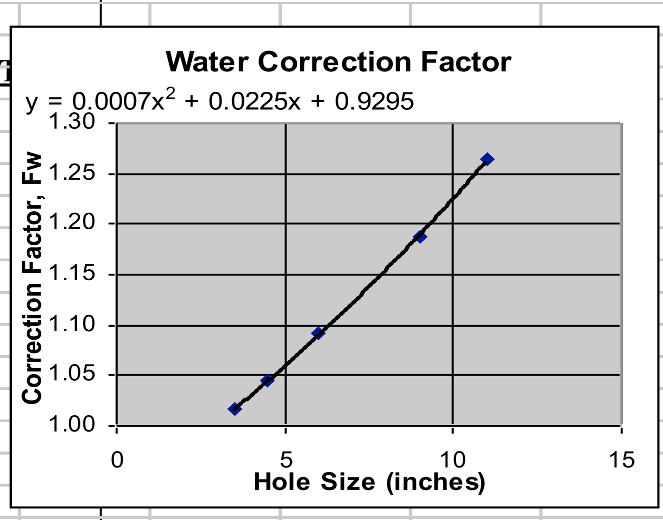


Calibration by ______________________________ Date __________________________

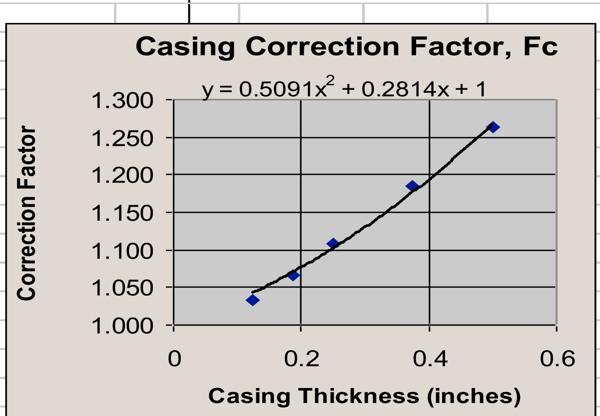
WATER FILLED HOLE SIZE CORRECTION FACTOR

Hole Diameter (inches)	Dry Count Rate (cps)	Wet Count Rate (cps)	Correction Factor Fw
3.5	37122	36532	1.02
4.5	37080	35477	1.05
6	37001	33873	1.09
9	37321	31433	1.19
11	37245	29455	1.26

CASING CORRECT



Casing Thickness (inches)	No Casing Count Rate (cps)	Casing Count Rate (cps)	Correction Factor Fc
0.125	37224	36021	1.033
0.1875	37423	35122	1.066
0.25	37832	34132	1.108
0.375	37000	31223	1.185
0.5	36987	29277	1.263



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OBSERVED COUNT RATES

Depth	N3	U3	U2	U1	N3, Corrected
3	167	137	164	347	167
3.2	160	146	163	493	160
3.4	196	152	230	558	196
3.6	171	187	287	820	171
3.8	186	223	385	1206	186
4	204	308	546	1907	204
4.2	232	420	846	3098	232
4.4	225	672	1437	5550	225
4.6	240	1191	2616	9115	240
4.8	280	2137	4524	20514	280
5	369	4248	8826	36405	369
5.2	434	7875	17049	63121	435
5.4	643	23537	50321	111552	644
5.6	915	30437	65104	120194	917
5.8	1650	34057	72870	124443	1658
6	3076	35265	77380	125581	3104
6.2	5874	36316	77994	125988	5981
6.4	9986	36965	79872	128509	10312
6.6	14649	37498	79070	127306	15391
6.8	18230	37213	80326	126839	19426
7	19723	37310	80140	127777	21145
7.2	20439	37506	80362	127631	21978
7.4	20819	37537	80364	127894	22423
7.6	20725	37153	80304	129063	22313
7.8	21341	37287	81293	126626	23035
8	21257	37444	79801	127640	22937
8.2	21408	37270	79899	126593	23114
8.4	21134	36669	78521	125724	22792
8.6	21522	36018	78442	124231	23249
8.8	21479	34560	75816	117237	23198
9	21211	31384	71591	106079	22882
9.2	21247	25732	63542	82444	22925
9.4	21361	17296	46817	53480	23059
9.6	21177	9495	28423	30341	22843
9.8	20437	4724	14576	15555	21976
10	20498	2588	8000	8436	22047
10.2	18813	1443	4318	4718	20095
10.4	16695	830	2334	2733	17681
10.6	12475	522	1363	1604	13000
10.8	7658	318	831	1012	7845
11	4407	243	556	668	4466
11.2	3285	175	345	464	3317
11.4	2298	161	278	360	2314
11.6	1865	138	205	284	1875
11.8	1554	120	171	250	1561
12	1418	114	144	216	1424
12.2	1359	105	144	192	1364
12.4	1329	96	117	172	1334
12.6	1346	96	112	154	1351
12.8	1274	99	104	149	1279

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13	1255	94	96	149	1260

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