IMPLEMENTATION OF NUCLEAR GAGE MOISTURE STANDARDS

by

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Research Engineer

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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SUMMARY

A prepared dry sand standard representing zero moisture content was found to yield nuclear moisture readings similar to those obtained on a magnesium density block. Therefore, the magnesium block was adopted in place of the sand standard for use as a zero moisture calibration standard. Magnesium sulfate was mixed with dry sand at two ratios to yield 9.0 lb./ft.^{3} (144 kg/m^3) and 20.1 lb./ft.^{3} (322 kg/m^3) moisture calibration standards. From an evaluation over several months, the standards were determined to be stable and suitable for use in calibrating nuclear gages.

A computer program was incorporated into the nuclear gage calibration procedure to handle the input data from the new moisture standards. The input for this new program is considerably simpler than that used in the old calibration program. The output format was modified to facilitate nuclear gage moisture measurements.

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MOISTURE STANDARDS

In early 1969 the Virginia Highway and Transportation Research Council undertook a study to develop reliable nuclear gage moisture calibration standards.[1] The Department of Highways and Transportation needed such moisture standards at least once a year to calibrate its 150 nuclear gages, because the moisture calibration curve for each gage varied a small amount from year to year due to small electronic and radiological changes. In addition, moisture standards are necessary for calibrating the gages after any repair work is performed. The first phase of the study was to determine the shape of the moisture calibration curve or curves from different soils with various properties at different moisture contents. Due to a time limitation this study was terminated with a final report in June 1970 after ten soils were tested with a Troxler Model 227 gage.[2] It was found that this model gage, which the Department had replaced with newer models prior to June 1970, had two moisture calibration curves rather than one curve as thought prior to the study (Figure 1).

At the conclusion of the first phase, further research was undertaken to fulfill the uncompleted objectives.[3] The determination of the moisture calibration curve or curves for the Troxler Model 2401 gage from tests on the ten soils previously tested plus some additional soils was the first objective of this additional work. After the shape and accuracy of the calibration curve or curves for the Model 2401 gage had been established, primary moisture standards were to be developed.

It was determined in the extended study that with the newer Model 2401 gages only one moisture calibration curve was necessary. The calibration curve for the Research Council's

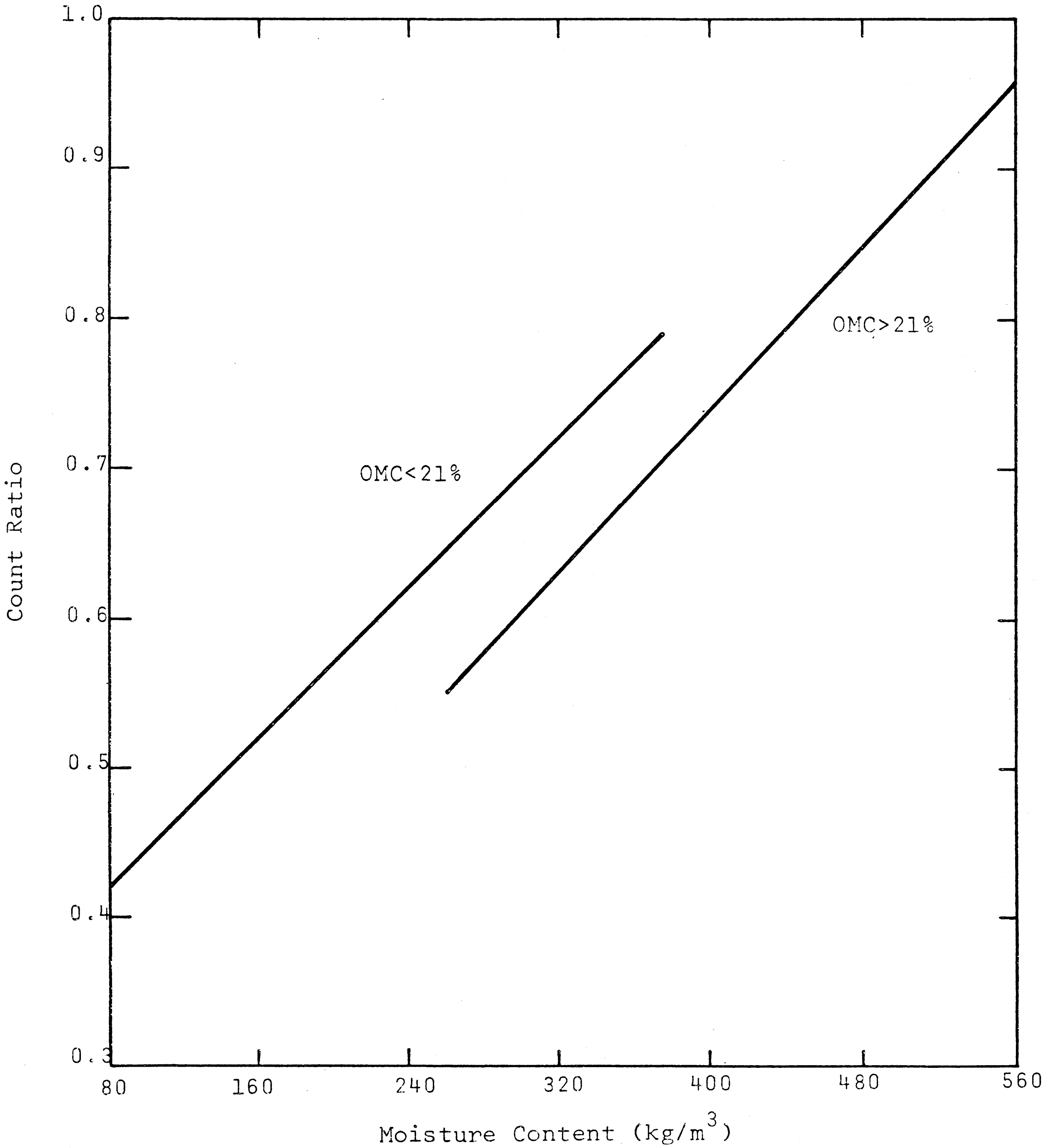

Figure 1. Calibration curves for Research Council's Model 227 gage (1 kg/m^3 = 0.06 lb./ft.^{3}).

new gage (Figure 2) was determined to have a standard error of 1.7 lb./ft.^{3} (27.2 kg/m^3).

At this point, the development of moisture calibration standards was initiated.

At the start, it was apparent that two problems needed to be solved. First, a standard material had to be found that exhibited the same properties at all times. The standard could not be made with water mixed with another material since the evaporation and movement of the water would make the moisture content continuously variable.

In actuality, the nuclear gage determines the amount of hydrogen present in a standard rather than the amount of water. With this fact in mind, researchers have attempted to develop reliable moisture calibration standards from chemicals containing hydrogen. However, in using chemical standards, a second problem evolves; with these standards, it is not possible to obtain a density of 80 lb./ft.^{3} (1,282 kg/m^3), which is the lowest density of highway materials measured in the field.

In developing the standards, the first step was to make a zero moisture content standard. Dry Ottawa C-190 silica sand was compacted to the maximum obtainable density in a lucite box approximately 4.0 ft.^{3} (0.11 m^3) in volume (2 ft. [0.61 m] by 2 ft. [0.61 m] by 1 ft. [0.31 m]). A dry density of 109.5 lb./ft.^{3} (1,754 kg/m^3) was obtained on this standard.

In developing higher moisture content standards, it was decided to use Ottawa C-190 silica sand to provide most of the density and one of the three stable chemicals listed in Table 1 to provide the hydrogen for the moisture content reading.

Table 1

Suggested Stable Chemicals for Use in Standards

Chemical	Molecular Weight (g)	Water Fraction
$MgSO_4 \cdot 7\ H_2O$	246.48	0.511
$Na_3PO_4 \cdot 12\ H_2O$	380.12	0.568
$Na_2SO_4 \cdot 10\ H_2O$	322.19	0.559

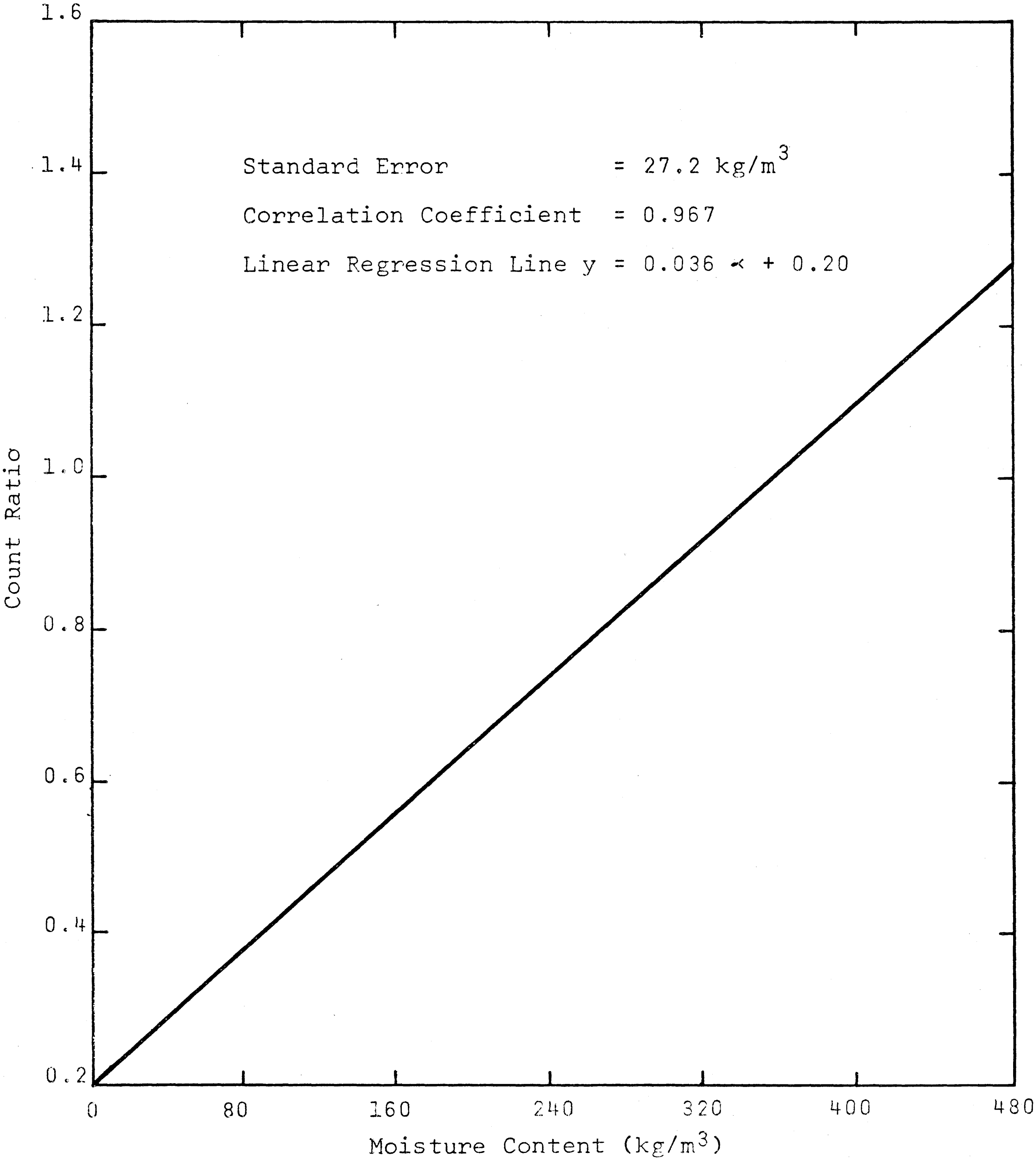

Figure 2. Single calibration curve for Research Council's Model 2401 gage (1 kg/m^3 = 0.06 lb./ft.^{3}).

Mixed uniformly, the sand and one of the chemicals would provide hydrogen chemically held in the water molecules as moisture and a density similar to those found on highway materials in the field, 80 lb./ft.^{3} (1,282 kg/m^3) or more. Without the sand, the chemicals would have a density much lower than 80 lb./ft.^{3} (1,282 kg/m^3) and would influence the moisture content reading. For densities lower than 80 lb./ft.^{3}, (1,282 kg/m^3), the nuclear gage would yield moisture readings for moisture contents actually higher than that of the standard.

In Table 1 the first column indicates the chemical used and the number of water molecules chemically held. The second column indicates the molecular weight, including the weight of the water molecules, for each of the stable chemicals. The last column can be derived by dividing the weight of the water molecules by the molecular weight in column 2. Another way of viewing the water fraction is that for every pound (0.45 kg) of the chemical being tested, the nuclear gage reads the water fraction ratio shown in Table 1 as moisture content. For example, if 1 lb. (0.45 kg) of $MgSO_4 \cdot 7H_2O$ is tested with a nuclear gage, the moisture content reading would indicate 0.511 lb. (0.23 kg) of hydrogen, or moisture, present.

Eight moisture calibration standards made by mixing sand with one of the three chemicals in Table 1 were molded in lucite boxes with an approximate volume of 4 ft.^{3} (0.11 m^3) as was done for the dry sand standard. Four of the chemical standards were discarded due to a lack of uniformity in the mix or to duplication. Table 2 summarizes the design values and the measured values for the four standards retained.

Table 2

Summary of Data on Moisture Standards
(1 kg/m^3 = 0.06 lb./ft.^{3})

Standard No.	Chemical	Design Values kg/m^3		Actual Values kg/m^3	
		Density	Moisture Content	Density	Moisture Content
1	$MgSO_4 \cdot 7H_2O$	1,727	160	1,608	149
2	$Na_3PO_4 \cdot 12H_2O$	1,738	320	1,402	258
3	$MgSO_4 \cdot 7H_2O$	1,602	400	1,344	336
4	$MgSO_4 \cdot 7H_2O$	1,602	560	1,182	413

Figure 3 shows the relationship between the manufacturer's, soils, and standards' curves for the Research Council's Troxler Model 2401 gage.(4) The standard errors for the three calibration curves are also shown in Figure 3.

INITIATION OF IMPLEMENTATION PROJECT

In January 1976 the Research Council initiated an effort to incorporate the moisture standards developed by the Research Council into the Department's calibration procedure.(5) It was proposed that several of the moisture calibration standards would be reproduced in the Department's Materials Laboratory for use in calibrating gages. In addition, the computer program for determining the calibration curve for the Department's gages would be modified to make it compatible with the new calibration data. A third phase of this implementation effort was to instruct the Department's nuclear staff in the use of the new moisture standards and the computer program.

Methodology and Results

Moisture Standards

For the implementation project, three standards were developed in the Department's Materials Laboratory: a dry sand standard at zero moisture content; and two $MgSO_4 \cdot 7H_2O$ and Ottawa C-190 sand standards, one at approximately 9 lb./ft.^{3} moisture (144 kg/m^3) and the other at 21 lb./ft.^{3} (336 kg/m^3). Table 3 summarizes the design and measured values of density and moisture content for the three standards.

Table 3

Summary of Data on Moisture Standards
(1 kg/m^3 = 0.06 lb./ft.^{3})

Standard No.	Design Values, kg/m^3		Measured Values, kg/m^3	
	Density	Moisture Content	Density	Moisture Content
1 (sand)	Max.	0	1,757	0
2	1,727	160	1,546	144
3	1,602	400	1,288	322

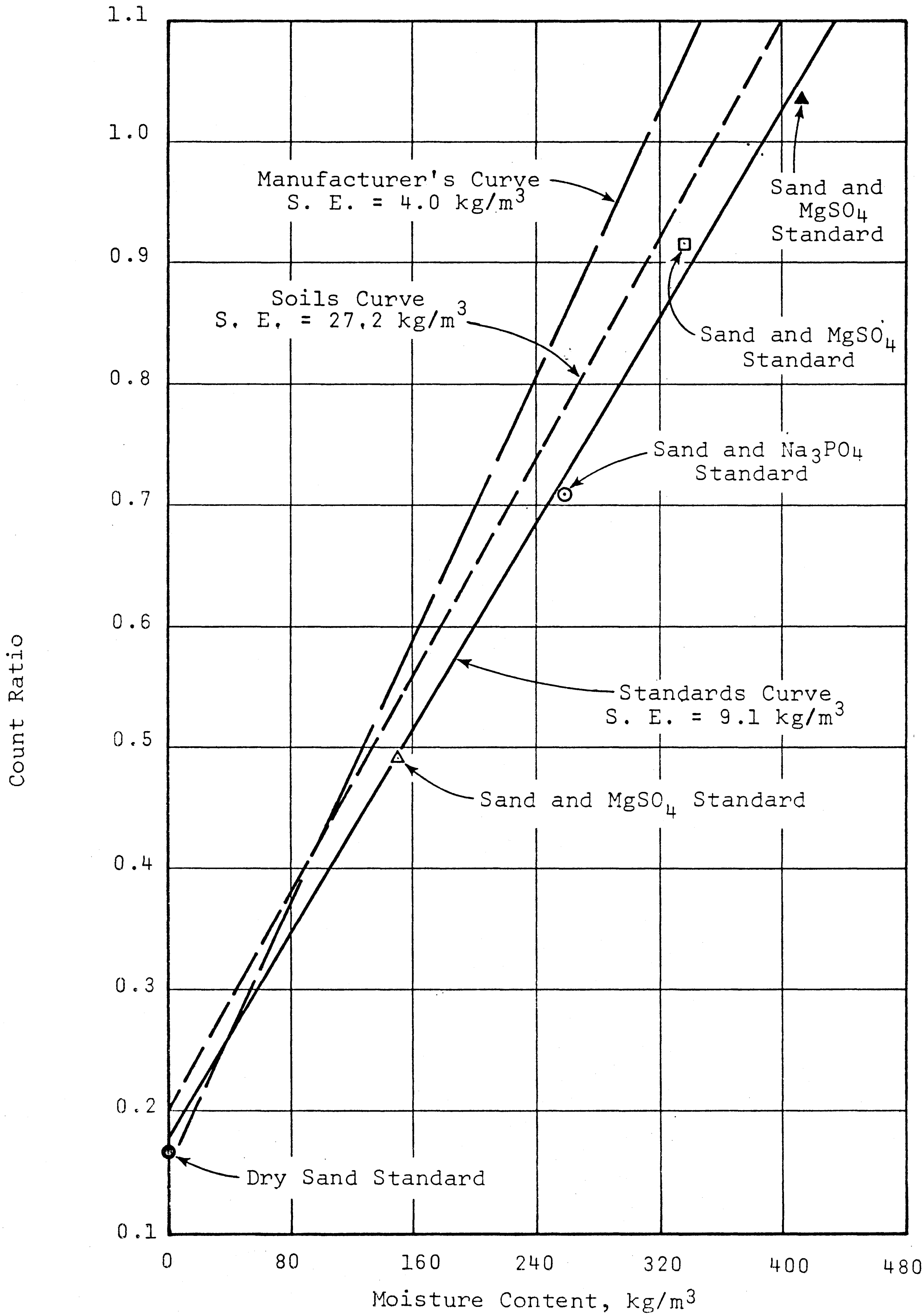

Figure 3. Moisture calibration curves for Research Council's Model 2401 gage. (1 kg/m^3 = 0.06 lb./ft.

To illustrate the procedure followed in developing the standards, the design values of 100.0 lb./ft.^{3} (1,602 kg/m^3) density and 25.0 lb./ft.^{3} (400 kg/m^3) moisture content for standard number 3 in Table 3 are used. To determine the amount of $MgSO_4 \cdot 7H_2O$ needed for a 4.0 ft.^{3} (0.11 m^3) mold, the design moisture content of 25.0 lb./ft.^{3} (400 kg/m^3) was divided by the water fraction for $MgSO_4 \cdot 7H_2O$ of 0.511 (Table 1). This quotient of 48.92 lb./ft.^{3} (784 kg/m^3) was multiplied by the volume of the mold (4.0 ft.^{3} [0.11 m^3]) to yield the amount of $MgSO_4 \cdot 7H_2O$ required for this moisture standard.

The total weight of the sand and $MgSO_4 \cdot 7H_2O$ required for the design density of 100.0 lb./ft.^{3} (1,602 kg/m^3) is 400 lb. (181 kg), or 100 lb./ft.^{3} (1,602 kg/m^3) times 4.0 ft.^{3} (0.11 m^3), the volume of the mold. Subtracting the required total amount of $MgSO_4 \cdot 7H_2O$ determined earlier from the total weight of 400 lb. (181 kg) yields the amount of dry Ottawa C-190 sand needed. The total weight of $MgSO_4 \cdot 7H_2O$ and sand was divided into 20 equal portions. Each portion was thoroughly mixed to assure as uniform gradation as possible prior to placing the material in the mold. After ten portions were placed in the mold, an immersion-type vibrator was used to compact the mixture. The remaining ten portions were prepared and placed in the mold separately until the mold was nearly filled. The vibrator was then reinserted the full depth of the standard to obtain maximum density. While the standard was being compacted, most of the remaining portions were added until the mold was completely filled. Since some of the mix was left over, the design density was not obtained.

It was determined that the actual density was 80.4 lb./ft.^{3} (1,288 kg/m^3) rather than 100 lb./ft.^{3} (1,602 kg/m^3) as designed. Since the designed density was not achieved and some of the mixture was not used, the designed moisture content also was not reached. The deficiency in moisture content was in the same proportion as the deficiency in density, since the portions were assumed to be uniform. Therefore, the actual corrected moisture content for this standard was determined to be 20.1 lb./ft.^{3} (322 kg/m^3).

The above procedure was followed for the second moisture calibration standard listed in Table 3. The zero moisture content standard was developed by obtaining the maximum density possible on dry Ottawa C-190 sand in one of the 4.0 ft.^{3} (0.11 m^3) molds.

After determining the mass density of each standard by gravimetric and volumetric means, nuclear tests were run. The nuclear tests were repeated every day for several weeks, at which time the frequency of testing was reduced to once a week, to determine if the standards remained stable. Table 4 shows the average and range of the count ratios for the three standards developed.

Table 4

Summary of Count Ratios on Moisture Standards

Standard No.	Moisture Content kg/m^3	Average	Range
1 (sand)	0	.185	.178 - .189
2	144	.521	.511 - .530
3	322	.902	.895 - .915

$1\ kg/m^3 = 0.06\ lb./ft.^3$

Using the average count ratios and the moisture contents shown in Table 4, a simple regression analysis of the three data points yielded the sand standard results shown in Table 5.

At this point it was felt that if one of the density standards could double for the zero moisture content standard, then there would be one less standard to have to accommodate in the Materials Laboratory nuclear room. Of the five density standards the magnesium block provided moisture content readings closest to those of the dry sand standard, so it was adopted for use.

Table 5

Results of Simple Regression Analyses

Zero Moisture Standards	Correlation Coefficient	Slope	Intercept	Standard Error, kg/m^3
Sand	99.97	.0356	.191	5.4
Magnesium	99.88	.0371	.167	11.1

1 kg/m^3 = 0.06 $lb./ft.^3$

Substituting the magnesium count ratio for the zero moisture content count ratio in Table 4, a second simple regression analysis was run. The results of this analysis are also shown in Table 5.

The two curves are almost identical over the moisture content range most commonly encountered in the field (10 to 25 $lb./ft.^3$ [160 to 400 kg/m^3]). Over the range of 0 to 35 $lb./ft.^3$ (0 to 561 kg/m^3) moisture contents, the two curves differ by a little more (0.8 $lb./ft.^3$ [12.8 kg/m^3]) than 1 standard error of the magnesium curve (0.69 $lb./ft.^3$ [11.1 kg/m^3]).

Before sealing the moisture calibration standards with polyethylene sheeting as done in the research study,[(4)] additional tests were run on the magnesium block with the polyethylene sheeting between the block and the nuclear gage to determine what effect, if any, the sheeting would have on the moisture content reading. In addition, the 1 in by 1 in (2.54 cm by 2.54 cm) aluminum angles with a thickness of 1/16 in (0.16 cm) used to support the nuclear gage over the moisture standards were also tested on the magnesium block to determine any effect they might have on the readings. Table 6 shows the average count ratio on the magnesium block alone, with the sheeting, and with both the sheeting and angles. As shown in Table 6 the polyethylene and angles had no effect on the moisture count ratio. Therefore, it was decided to use the polyethylene and angles on the chemical standards during the calibration process.

Table 6

Count Ratios on Magnesium Block for Different Conditions

Materials	Magnesium Block Only	Magnesium Block and Polyethylene	Magnesium Block, Polyethylene, and Angles
Count Ratio	.155	.156	.155

Figure 4 shows the soils curve developed from the many soils tested at the Research Council,(4) the curve developed from the five moisture calibration standards molded at the Research Council, and the magnesium standards curve from Table 5. As shown in this figure, the Materials Laboratory calibration curve is closer to the soils curve than is the Research Council's curve except at the very low moisture contents (less than 3 lb./ft.^{3} [48 kg/m^3]). Even at these low moisture contents the difference (0.9 lb./ft.^{3} [14.4 kg/m^3]) between the new moisture calibration curve and the soils curve is only a half of one standard error of the soils curve. Near 25 lb./ft.^{3} (400 kg/m^3) moisture content the two curves are within 0.2 lb./ft.^{3} (3.2 kg/m^3), which is statistically insignificant.

Computer Program Modifications

Prior to putting the new moisture calibration standards into use, the Department's Materials Laboratory had used the magnesium density block for a zero lb./ft.^{3} moisture content standard and a standard made from asbestos for a higher moisture content. The asbestos standard had an assigned moisture provided by the manufacturer. Several times the manufacturer changed the assigned moisture content of the standard due to the asbestos standard changing its moisture content properties.

Therefore, the computer data deck for each gage calibrated by the Materials Laboratory staff had to have the assigned moisture content of that standard inputted. Each time a nuclear gage was calibrated, 19 computer cards were inputted to obtain the moisture and density calibration curves (see Appendix A). In order to obtain the moisture calibration curve for each gage, 3 computer cards were necessary. The calibration program required

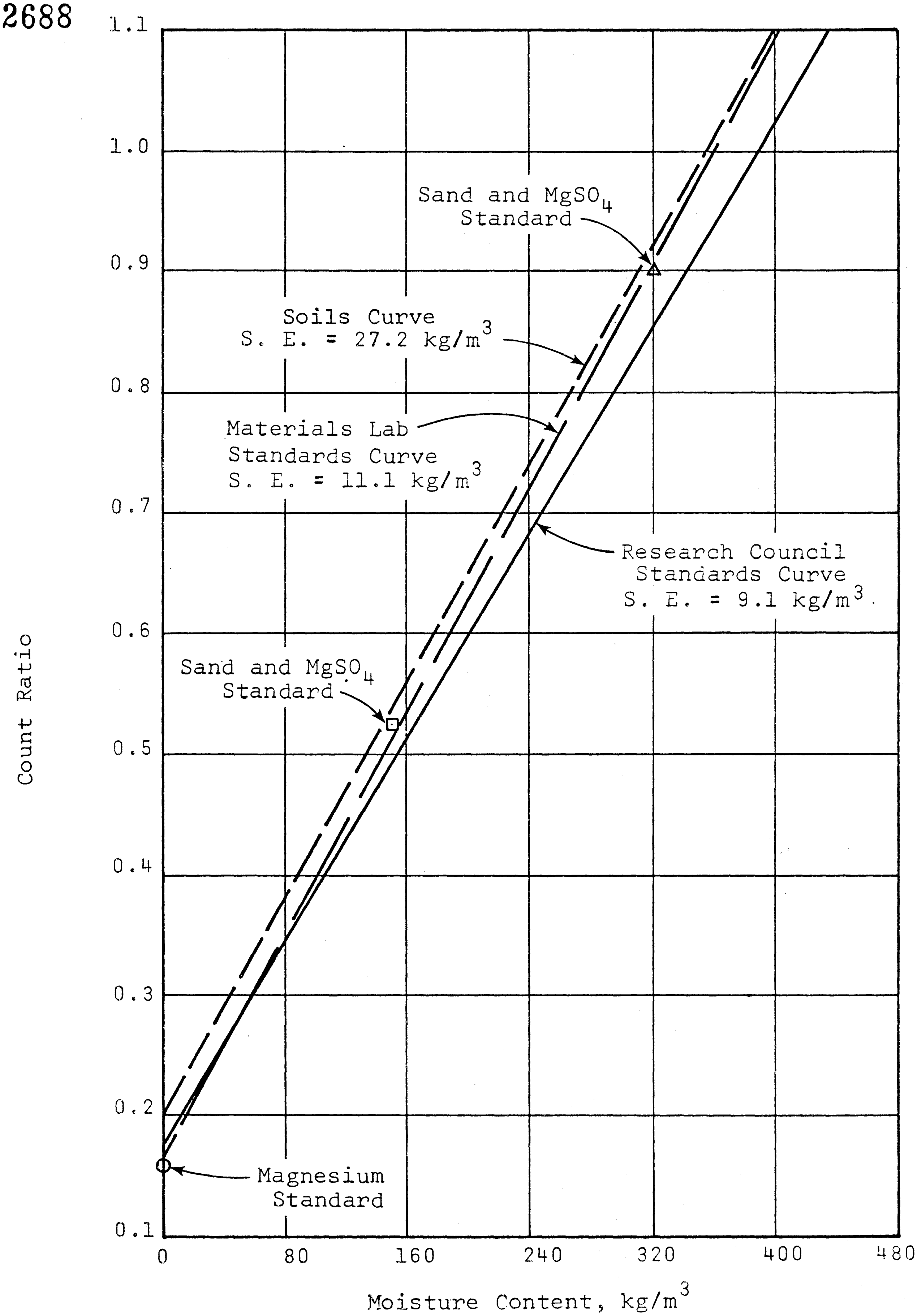

Figure 4. Moisture calibration curves for Research Council's Model 2401 gage. (1 kg/m^3 = 0.06 $lb./ft.^3$)

that 17 inputs be placed on these 3 cards. Of these 17 inputs, 9 values were constant for all nuclear gages and thus were unnecessary.

In addition, several almost identical header cards were used in the input for the old program. To eliminate duplication, the number of data cards were reduced to 7 by placing the fixed values in the computer program rather than inputting them. The number of header cards was reduced to 1 and several input items that were not needed or were never used were eliminated (see Appendix B).

Since the new moisture standards did not include the asbestos standard, an entirely new program was placed in the computer. This change was also necessary since the old computer program accepted only two sets of moisture data (the magnesium count ratio and the asbestos count ratio) for each gage calibration. The new program had to accept three sets of data (the magnesium count ratio, the 9.0 lb./ft.^{3} [144 kg/m^3] moisture standard count ratio, and the 20.1 lb./ft.^{3} [322 kg/m^3] moisture standard count ratio). This new program was a simple regression analysis originally capable of accepting any number of sets of data, but was limited to take only 3 sets.

The printout resulting from the old computer program provided the nuclear gage operator, in most cases an inspector, a lot of useless results. These results, such as standard error and amount of bend, were not of interest nor help to the inspector. In addition, the results were outputted in reverse order, with the moisture content in the first column and the moisture count ratio in the second column. (In making measurements, the moisture count ratio is determined from the gage and then the moisture content is obtained from the computer output.) With the printout giving the results in reverse of the order operators were accustomed to, extrapolation between two printed values of moisture content initially was difficult for each new inspector.

Another problem confronting the inspectors when a second gage replaced the original gage during the construction was the step sizes (the amount of increase in moisture content) between the rows in the column. All the gages being used by the Department were being stepped in moisture content and not in count ratio. Also, the step size for one gage may be one size and a second gage may have an entirely different step size. The last problem noticed with the moisture calibration printout was the inconsistency of the range the printout covered. One gage may have a range from 0 to 32 lb./ft.^{3} (0 to 513 kg/m^3) and another gage a range from 0 to 70 lb./ft.^{3} (0 to 1,121 kg/m^3).

The output for this new program was changed to make it easier for the nuclear gage operator to determine the moisture content from his moisture count ratio (see Appendix C). The new output includes the following features.

1. The moisture count ratio is outputted in the first column rather than in the second column on the printout.

2. The moisture count ratios are stepped in equal increments of .005 or some multiple of .005.

3. The moisture content in lb./ft.^{3} covers a range from near 0 lb./ft.^{3} moisture content to a point just a little larger than 30 lb./ft.^{3} (480 kg/m^3) moisture content. (The step size of the moisture count ratio [whether .005 or some multiple of .005] is selected in order for the moisture content values to cover the above range.)

4. A statement explaining when to use this chart, rather than the standard deviation and other technical information not of interest to the gage operator, is printed at the top of the output.

5. The moisture calibration chart is outputted in triplets with the above statement printed on two of the three copies, while the third copy has the standard deviation and other technical information of interest to the Central Office Materials Laboratory nuclear staff. Thus, after calibrations, the nuclear staff would keep one of the copies with the statement and the third copy, and send the other copy with the statement to the construction project along with the nuclear gage.

Instruction Phase

Upon conclusion of the first two phases of the implementation effort, the Department's nuclear staff was instructed in the use of the new moisture standards and computer program. For the collection of data, the staff needed only to be shown the proper direction in which to place the nuclear gages on the new moisture standards and the proper alignment of the aluminum strips for support of the gages. Most of the instruction phase dealt with the input data for the computer program, because the number of input cards was reduced two-thirds. After sets of data for several gages were inputted and the printouts were checked and verified by Research Council personnel, complete responsibility for the program was turned over to the nuclear staff.

RECOMMENDATION

It is recommended that the Department use the magnesium block and the two $MgSO_4 \cdot 7H_2O$ and Ottawa sand standards developed in the Materials Laboratory for moisture calibration purposes. In addition, the Department should use the new computer program as described in this report.

2692

REFERENCES

1. Anday, M. C. and C. S. Hughes, "Working Plan — Nuclear Measurement of Soil Properties", Virginia Highway Research Council, February 1969.

2. ________, "Final Report — Nuclear Measurement of Soil Properties", Virginia Highway Research Council, June 1970.

3. Wyant, David C., M. C. Anday, and C. S. Hughes III, "Working Plan — Refinement of Moisture Calibration Curves for Nuclear Gage", Virginia Highway Research Council, September 1970.

4. ________, "Final Report — Refinement of Moisture Calibration Curves for Nuclear Gage", Virginia Highway Research Council, December 1973.

5. Wyant, David C., "Working Plan — Implementation of Nuclear Gage Moisture Standards", Virginia Highway and Transportation Research Council, December 1975.

APPENDIX A

Shown below is the input required for each calibration with the old computer program. A total of 19 input cards, which included 5 header cards, 5 duplicates of card no. 2, one moisture count card, 4 duplicates of card no. 4, and 4 density count cards (backscatter and 4-inch, 6-inch, and 8-inch [10.2-cm, 15.2-cm, and 20.3-cm] direct transmission).

Card No.	Input
1 (Header)	Gauge model and serial nos., reference standard serial no., direct transmission depth, air gap, mode, and job.
2	Density of the 5 density standards and the water equivalence of the asbestos standard.
3	Moisture calibration counts on the asbestos and magnesium standards, moisture standard count of the gauge, and moisture background count.
4	Air gap density calibration counts on the 5 density standards.
5	Backscatter and direct transmission density calibration counts on the 5 density standards, density standard count of the gauge, and density background count.

2696

APPENDIX B

The following input cards are needed for the new computer program in the order shown for the calibration of each gage.

Card No.	Input
1 (Header)	Gauge model and serial nos., mode, job, date, density and moisture standard counts.
2	Moisture calibration counts on the 3 moisture standards and the moisture background count.
3	Air gap density calibration counts on the 5 density standards and the density background count.
4	Backscatter and direct transmission density calibration counts on the 5 density standards and the density background count.

The card labeled number 4 above will actually be 4 cards. The first one should have the backscatter counts. The three following cards should contain the direct transmission counts for the 4-inch, 6-inch, and 8-inch (10.2-cm, 15.2-cm, and 20.3-cm) depths. The 7 required data cards are these 4 cards, the header card, the moisture data card, and the air gap data card.

APPENDIX C

Shown below is an example of the new output provided to the nuclear gage operator.

MODEL- 2401 SER.- 810 JOB RES DATE 08/26/76

MOISTURE CALIBRATION

CR IS MEASUREMENT COUNT/STANDARD COUNT

STANDARD COUNT= 704.00

TO BE USED WHEN TESTING FOR MOISTURE
ON SOILS, AGGREGATE BASES AND SUBBASES.

CR	PCF	CR	PCF	CR	PCF	CR	PCF
0.220	1.79	0.470	8.97	0.720	16.16	0.970	23.34
0.225	1.93	0.475	9.12	0.725	16.30	0.975	23.49
0.230	2.08	0.480	9.26	0.730	16.45	0.980	23.63
0.235	2.22	0.485	9.41	0.735	16.59	0.985	23.77
0.240	2.36	0.490	9.55	0.740	16.73	0.990	23.92
0.245	2.51	0.495	9.69	0.745	16.88	0.995	24.06
0.250	2.65	0.500	9.84	0.750	17.02	1.000	24.20
0.255	2.80	0.505	9.98	0.755	17.16	1.005	24.35
0.260	2.94	0.510	10.12	0.760	17.31	1.010	24.49
0.265	3.08	0.515	10.27	0.765	17.45	1.015	24.64
0.270	3.23	0.520	10.41	0.770	17.59	1.020	24.78
0.275	3.37	0.525	10.55	0.775	17.74	1.025	24.92
0.280	3.51	0.530	10.70	0.780	17.88	1.030	25.07
0.285	3.66	0.535	10.84	0.785	18.03	1.035	25.21
0.290	3.80	0.540	10.99	0.790	18.17	1.040	25.35
0.295	3.95	0.545	11.13	0.795	18.31	1.045	25.50
0.300	4.09	0.550	11.27	0.800	18.46	1.050	25.64
0.305	4.23	0.555	11.42	0.805	18.60	1.055	25.78
0.310	4.38	0.560	11.56	0.810	18.74	1.060	25.93
0.315	4.52	0.565	11.70	0.815	18.89	1.065	26.07
0.320	4.66	0.570	11.85	0.820	19.03	1.070	26.22
0.325	4.81	0.575	11.99	0.825	19.18	1.075	26.36
0.330	4.95	0.580	12.13	0.830	19.32	1.080	26.50
0.335	5.09	0.585	12.28	0.835	19.46	1.085	26.65
0.340	5.24	0.590	12.42	0.840	19.61	1.090	26.79
0.345	5.38	0.595	12.57	0.845	19.75	1.095	26.93
0.350	5.53	0.600	12.71	0.850	19.89	1.100	27.08
0.355	5.67	0.605	12.85	0.855	20.04	1.105	27.22
0.360	5.81	0.610	13.00	0.860	20.18	1.110	27.37
0.365	5.96	0.615	13.14	0.865	20.32	1.115	27.51
0.370	6.10	0.620	13.28	0.870	20.47	1.120	27.65
0.375	6.24	0.625	13.43	0.875	20.61	1.125	27.80
0.380	6.39	0.630	13.57	0.880	20.76	1.130	27.94
0.385	6.53	0.635	13.72	0.885	20.90	1.135	28.08
0.390	6.68	0.640	13.86	0.890	21.04	1.140	28.23
0.395	6.82	0.645	14.00	0.895	21.19	1.145	28.37
0.400	6.96	0.650	14.15	0.900	21.33	1.150	28.51
0.405	7.11	0.655	14.29	0.905	21.47	1.155	28.66
0.410	7.25	0.660	14.43	0.910	21.62	1.160	28.80
0.415	7.39	0.665	14.58	0.915	21.76	1.165	28.95
0.420	7.54	0.670	14.72	0.920	21.91	1.170	29.09
0.425	7.68	0.675	14.86	0.925	22.05	1.175	29.23
0.430	7.82	0.680	15.01	0.930	22.19	1.180	29.38
0.435	7.97	0.685	15.15	0.935	22.34	1.185	29.52
0.440	8.11	0.690	15.30	0.940	22.48	1.190	29.66
0.445	8.26	0.695	15.44	0.945	22.62	1.195	29.81
0.450	8.40	0.700	15.58	0.950	22.77	1.200	29.95
0.455	8.54	0.705	15.73	0.955	22.91	1.205	30.09
0.460	8.69	0.710	15.87	0.960	23.05	1.210	30.24
0.465	8.83	0.715	16.01	0.965	23.20	1.215	30.38

2700