Nomograms for Obtaining the Compound Composition of Hydrated Limes From the Oxide Analysis

by Ernest M. Levin

National Bureau of Standards Miscellaneous Publication 196
Issued December 30, 1949

Nomograms for Obtaining the Compound Composition of Hydrated Limes From the Oxide Analysis

by Ernest M. Levin

National Bureau of Standards Miscellaneous Publication 196
Issued December 30, 1949
Contents

I. Introduction .................................................. 1
II. Derivation of Equations ................................. 2
III. Description of Nomograms ............................. 2
IV. Illustrative Examples ..................................... 3
V. Accuracy of the Nomograms ............................ 5
VI. References .................................................. 5

TITLES OF NOMOGRAMS

1. General nomogram for obtaining the compound composition of any commercial hydrated lime from the oxide analysis.
2. Special nomogram for obtaining the compound composition of regularly hydrated and highly hydrated dolomitic limes from the oxide analysis.
Nomograms for Obtaining the Compound Composition Of Hydrated Limes From the Oxide Analysis

by Ernest M. Levin

Two nomograms are presented for rapidly obtaining the compound composition of hydrated limes from the oxide analysis. The general nomogram can be applied to any commercial hydrated lime and gives values accurate to within 0.3 percent. The special nomogram is applicable only to regularly hydrated and highly hydrated dolomitic limes and is accurate to within 0.1 percent. The equations for calculating the compound composition are derived, and the significance of the unhydrated oxide content is stressed.

I. Introduction

Hydrated limes can be classified broadly into three major groups on the basis of total magnesia content [1] as follows: (1) high-calcium, containing less than 5 percent total magnesia; (2) dolomitic, containing more than 25 percent of magnesia; and (3) magnesian, containing between 5 and 25 percent of magnesia. Dolomitic limes can be further subdivided on the basis of the degree of hydration of the magnesia, as follows: regularly hydrated, in which the major portion of the magnesia has been left unhydrated, and highly hydrated, in which the major portion of the magnesia has been hydrated.

Studies [4] have been in progress for several years at the National Bureau of Standards of a particular type of plaster failure, associated only with regularly hydrated dolomitic limes and characterized by the formation of bulges, or large blisters, in the white-coat. It has been found that this type of failure results from a delayed expansion of the set, white-coat plaster. The regularly hydrated dolomitic lime that was mixed originally with the calcined gypsum and water to compound the wet plaster was not completely hydrated; and, consequently, the plaster contained unhydrated magnesium oxide (MgO) at the time of application. The unreacted MgO continues to hydrate slowly after the plaster has set, eventually causing the disruptive expansion of the white-coat.

As an outcome of these studies, the Bureau, assisted by other Government agencies, formulated a specification that would exclude partially hydrated dolomitic limes containing a high percentage of unhydrated oxides. Accordingly, the following tentative amendment to Federal Specification SS-L-351 for hydrated lime [5] is in effect: "The total free (unhydrated) calcium oxide (CaO) and magnesium oxide (MgO) in the hydrated product shall not exceed 8 percent by weight (calculated on the 'as received' basis).

The 8-percent limit of the unhydrated oxide in hydrated limes has been included in recent specifications of the American Society for Testing Materials [3] and in those of the American Standards Association [6], for the hydrated lime to be used in white-coat plaster.

Numerous manufacturers of regularly hydrated dolomitic lime are producing at the present time a more completely hydrated lime that meets the 8-percent maximum limit. In most instances the additional hydration is accomplished by treating the calcined limestone in an autoclave maintained at an elevated temperature and pressure. This type of lime has been referred to earlier in the paper as highly hydrated.

Determination of the unhydrated oxide content of a lime is of obvious importance in regard to the 8-percent limit, both to the manufacturer and to the prospective purchaser of highly hydrated dolomitic lime. Investigations [7] carried on at the Bureau have established a method for calculating the compound composition, including the unhydrated oxide content, from the chemical analysis. The chemical analysis includes determinations for "free" H₂O, combined H₂O, CO₂, SiO₂, R₂O₃, CaO, and MgO.
II. Derivation of Equations

The method of calculating the compound composition is based essentially on the premise that CaO hydrates completely before MgO and then carbonates before MgO [7]. In the calculations, CO₂ (usually under 2%) is allotted to an equivalent amount of CaO, to obtain the amount of CaCO₃ present. The remaining CaO is allotted to an equivalent amount of combined H₂O, to obtain the amount of Ca(OH)₂ present. The remaining combined H₂O is allotted to an equivalent amount of MgO, to obtain the amount of Mg(OH)₂ present. Finally, the remaining MgO represents the unhydrated oxide content.

If the amount of combined H₂O is insufficient to account for all of the available CaO, some of the CaO is also unhydrated. In this event the combined H₂O is allotted to an equivalent amount of CaO to obtain the amount of Ca(OH)₂ present. The remaining CaO exclusive of that which is carbonated is unhydrated, and this value is added to the MgO to obtain the total unhydrated oxides.

It should be noted that in the calculations the SiO₂ and R₂O₃ are considered uncombined; but, fortunately, only a small percentage of these oxides is usually present.

In the following derivation of the percentage of unhydrated oxide in a lime, the formula for the oxide represents the percentage of that component present. Also, the derivation is carried out only for the most usual case, in which all of the CaO is hydrated.

\[
\begin{align*}
\text{CaO equivalent to CO}_2 &= 1.275 \text{ CO}_2 \\
\text{CaO remaining} &= \text{CaO} - 1.275 \text{ CO}_2 \\
\text{Combined H}_2\text{O equivalent to CaO} &= 0.3213(\text{CaO} - 1.275 \text{ CO}_2) \\
\text{remaining} &= \text{Comb. H}_2\text{O} - 0.3213(\text{CaO} - 1.275 \text{ CO}_2) \\
\text{Combined H}_2\text{O remaining} &= 2.238 [\text{Comb. H}_2\text{O} - 0.3213(\text{CaO} - 1.275 \text{ CO}_2)] \\
\text{Hydrated MgO} &= \text{Total MgO} - 2.238 [\text{Comb. H}_2\text{O} - 0.3213(\text{CaO} - 1.275 \text{ CO}_2)] \\
\text{Unhydrated MgO (percent)} &= \text{Hydrated MgO} \\
\text{obtained simply by addition or subtraction of the appropriate terms, as follows:}
\end{align*}
\]

\[
\begin{align*}
\text{CaCO}_3 &= \text{CO}_2 \\
\text{Ca(OH)}_2 &= (\text{CaO remaining}) + (\text{CaO equivalent to CO}_2) \\
\text{Mg(OH)}_2 &= (\text{Combined H}_2\text{O remaining}) + (\text{Combined H}_2\text{O equivalent to CaO remaining}) \\
\text{Unhydrated MgO} &= (\text{Total MgO}) - (\text{Hydrated MgO}) \text{ (Value obtained from the last step in the derivation)}
\end{align*}
\]

The purpose of this publication is to present two nomograms from which the compound composition of a hydrated lime can be easily and rapidly determined from the oxide analysis, thus saving time and labor of calculation.

III. Description of Nomograms

The general nomogram (nomogram 1) is designed to give the compound composition of any commercial hydrated lime, from the oxide analysis. It can be applied to limes of the high-calcium, magnesian, and dolomitic groups, with an accuracy of better than 0.3 percent.

The special nomogram (nomogram 2) is designed so as to give values of the compound composition accurate to within 0.1 percent, but the nomogram can be applied only to the regularly hydrated and highly hydrated dolomitic limes. Not only are the scale divisions in nomogram 2 larger than for nomogram 1, but also a better disposition of the scales, themselves, has been achieved.
IV. Illustrative Examples

Figure 1 illustrates the method of using nomogram 1 for obtaining the compound composition of a hydrated lime, as applied to a high-calcium hydrate.

The oxide analysis of the lime is as follows:

<table>
<thead>
<tr>
<th>OXIDE ANALYSIS</th>
<th>Percent</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>0.70</td>
<td>&quot;Free&quot; H₂O</td>
</tr>
<tr>
<td>CaO</td>
<td>72.60</td>
<td>SiO₂</td>
</tr>
<tr>
<td>Combined H₂O</td>
<td>23.06</td>
<td>FeO₂</td>
</tr>
<tr>
<td>Total MgO</td>
<td>1.04</td>
<td>Subtotal</td>
</tr>
<tr>
<td>Subtotal</td>
<td>97.40</td>
<td>Total</td>
</tr>
</tbody>
</table>

On the scale for CO₂, locate the point a, corresponding to the value of 0.70 percent. At the intersection of the horizontal projection from point a with the scale for CaCO₃, read the equivalent percentage of CaCO₃ (1.6). On the scale for CaO, locate the point b, corresponding to the value of 72.6 percent, and lay a straightedge across the nomogram from a to b. At the intercept, point c, read the percentage of Ca(OH)₂ (95.0). On the scale for combined H₂O, locate the point d, corresponding to the value of 23.1 percent. Lay the straightedge through points c and d, and locate the point e, on the scale for hydrated MgO. On the adjacent scale, read the equivalent percentage of Mg(OH)₂ (0.0). On the scale for total MgO, locate the point f, corresponding to the value of 1.04 percent, and lay the straightedge across the nomogram from e to f. Finally, at point g, the intersection of the line ef with the scale for unhydrated MgO, read the percentage of unhydrated MgO (1.0).

Figure 1. Illustrative example of the procedure for using nomogram 1 (general nomogram) to obtain the compound composition of a hydrated lime, as applied to a high-calcium hydrate.
Table 2. Illustrative example of the procedure for using nomogram 2 (special nomogram) to obtain the compound composition of a hydrated lime, as applied to a regularly hydrated dolomitic lime.

OXIDE ANALYSIS

<table>
<thead>
<tr>
<th>Oxide</th>
<th>Percent</th>
<th>Oxide</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>0.63</td>
<td>&quot;Free&quot; H₂O</td>
<td>0.30</td>
</tr>
<tr>
<td>CaO</td>
<td>46.72</td>
<td>SiO₂</td>
<td>0.94</td>
</tr>
<tr>
<td>Combined H₂O</td>
<td>17.96</td>
<td>Fe₂O₃</td>
<td>0.36</td>
</tr>
<tr>
<td>Total MgO</td>
<td>33.08</td>
<td>Subtotal</td>
<td>1.60</td>
</tr>
<tr>
<td>Subtotal</td>
<td>98.39</td>
<td>Total</td>
<td>99.99</td>
</tr>
</tbody>
</table>

PROCEDURE

1. Locate line ab (CO₂, % to CaO, %): At (a) read CaCO₃
2. Locate line of (Ca(OH)₂, % to combined H₂O, %) and extend to c (hydrated MgO, %): At (c) read Ca(OH)₂
3. Locate line of (Mg(OH)₂, % to total MgO, %): At (e) read Mg(OH)₂

Subtotal: 98.3
Figure 2 illustrates the method of using nomogram 2 for obtaining the compound composition of a hydrated lime, as applied to a regularly hydrated dolomite line.

The oxide analysis of the lime is as follows:

<table>
<thead>
<tr>
<th>Percent</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>0.63</td>
</tr>
<tr>
<td>CaO</td>
<td>46.72</td>
</tr>
<tr>
<td>Combined H₂O</td>
<td>17.96</td>
</tr>
<tr>
<td>Total MgO</td>
<td>9.98</td>
</tr>
</tbody>
</table>

Subtotal 99.39

On the scale for CO₂, locate the point a, corresponding to the value of 0.63 percent. On the adjacent scale read the equivalent percentage of CaCO₃ (1.4). On the scale for CaO, locate the point b, corresponding to the value of 46.72 percent, and lay a straightedge across the nomogram from a to b. At the intercept, point c, read the percentage of Ca(OH)₂ (60.7). On the scale for combined H₂O, locate the point d, corresponding to the value of 17.96 percent. Lay a straightedge through the points c and d, and locate the point e, on the scale for hydrated MgO. On the adjacent scale read the equivalent percentage of Mg(OH)₂ (10.1). On the scale for total MgO, locate the point f, corresponding to the value of 33.08 percent, and lay the straightedge across the nomogram from e to f. Finally, at point g, the intersection of line ef with the scale for unhydrated MgO, read the percentage of unhydrated MgO (25.8).

To a certain extent the nomograms also provide for the unusual case in which the combined H₂O is insufficient to account for all of the available CaO, that is, none of the MgO is hydrated and some unhydrated CaO is present. For such a case, the point e (figs. 1 and 2) on the appropriately established line c-d-e will be located on the two adjacent scales designated as unhydrated CaO and equivalent Ca(OH)₂. The unhydrated CaO value must then be added separately to the total MgO in order to obtain the total of unhydrated oxides. The reading on the Ca(OH)₂ scale must also be corrected by subtracting from it the Ca(OH)₂ equivalent of the unhydrated CaO.

V. Accuracy of the Nomograms

Comparison of the compound composition obtained both from the full-sized nomogram and by calculation, for the two examples cited, is given in the following tabulation:

<table>
<thead>
<tr>
<th>Compound</th>
<th>High-calcium hydrate lime</th>
<th>Regularly hydrated dolomite lime</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nomogram 1</td>
<td>Calculated</td>
</tr>
<tr>
<td>CaCO₃</td>
<td>95.0</td>
<td>94.75</td>
</tr>
<tr>
<td>Ca(OH)₂</td>
<td>0.0</td>
<td>0.97</td>
</tr>
<tr>
<td>Mg(OH)₂</td>
<td>1.0</td>
<td>0.99</td>
</tr>
<tr>
<td>Unhydrated MgO</td>
<td>97.6</td>
<td>97.40</td>
</tr>
</tbody>
</table>

The reading error for nomogram 1 is under 0.3 percent and that for nomogram 2 is under 0.1 percent. The nomograms presented here provide an accurate and rapid means for obtaining the compound composition of hydrated limes and should be especially helpful to the analyst making numerous routine determinations.

The author expresses appreciation to Marcella Lindeman Phillips of the National Bureau of Standards, whose lectures on the subject of nomography motivated this work.

VI. References


Nomogram 1. General nomogram for obtaining the compound composition of any commercial hydrated lime from the oxide analysis.

[To accompany National Bureau of Standards Miscellaneous Publication 196, issued December 30, 1949]