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NATIONAL BUREAU OF STANDARDS • E. U. Condon, *Director*

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

by Ernest M. Levin

National Bureau of Standards Miscellaneous Publication 196

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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] [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,[2] in which the major portion of the magnesia has been left unhydrated, and highly hydrated,[3] 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" H_2O, combined H_2O, CO_2, SiO_2, R_2O_3, CaO, and MgO.

[1] Figures in brackets indicate the literature references at the end of this paper.
[2] Also designated as normal hydrated lime [2].
[3] Also designated as special hydrated lime [3].

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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, CO_2 (usually under 2%) is allotted to an equivalent amount of CaO, to obtain the amount of $CaCO_3$ present. The remaining CaO is allotted to an equivalent amount of combined H_2O, to obtain the amount of $Ca(OH)_2$ present. The remaining combined H_2O 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 H_2O is insufficient to account for all of the available CaO, some of the CaO is also unhydrated. In this event the combined H_2O 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 SiO_2 and R_2O_3 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.

CaO equivalent to CO_2	$=1.275\ CO_2$
CaO remaining	$=CaO-1.275\ CO_2$
Combined H_2O equivalent to CaO remaining	$=0.3213(CaO-1.275\ CO_2)$
Combined H_2O remaining	$=$Comb. $H_2O-0.3213(CaO-1.275\ CO_2)$
Hydrated MgO	$=2.238$ [Comb. $H_2O-0.3213(CaO-1.275\ CO_2)$]
Unhydrated MgO (percent)	$=$Total MgO-2.238 [Comb. $H_2O-0.3213(CaO-1.275\ CO_2)$]

After the above calculations have been performed for determining the percentage of unhydrated oxide, the compound composition is obtained simply by addition or subtraction of the appropriate terms, as follows:

$CaCO_3$	$=CO_2$	+(CaO equivalent to CO_2)
$Ca(OH)_2$	=(CaO remaining)	+(Combined H_2O equivalent to CaO remaining)
$Mg(OH)_2$	=(Combined H_2O remaining)	+(Hydrated MgO)
Unhydrated MgO	=(Total MgO)	−(Hydrated MgO) (Value obtained from the last step in the derivation)

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:

OXIDE ANALYSIS

	Percent		*Percent*
CO_2	0.70	"Free" H_2O	0.53
CaO	72.60	SiO_2	.74
Combined H_2O	23.06	R_2O_3	.60
Total MgO	1.04		
		Subtotal	1.87
Subtotal	97.40		
		Total	99.27

On the scale for CO_2, 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 $CaCO_3$, read the equivalent percentage of $CaCO_3$ (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 H_2O, 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).

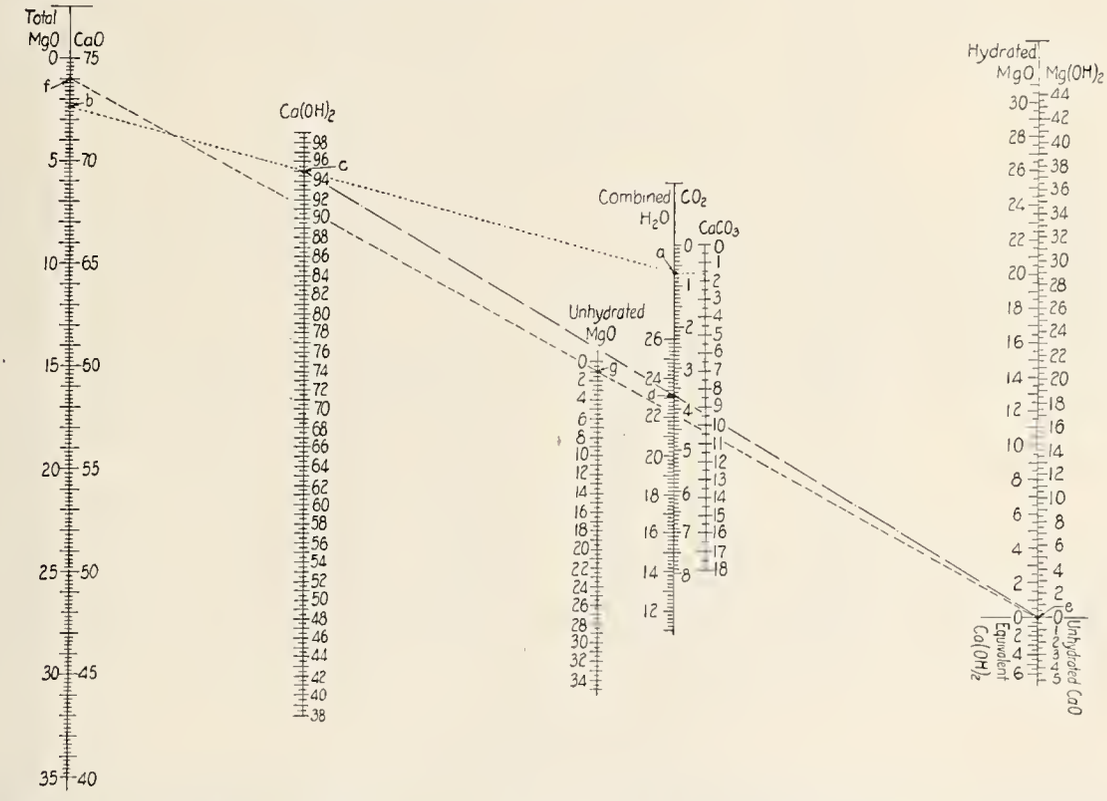

FIGURE 1. *Illustrative example of the procedure for using nomogram 1 (general nomogram) to obtain the compound composition of a hydrated lime, as applied to a high-calcium hydrate.*

OXIDE ANALYSIS

	Percent		*Percent*
CO_2	0.70	"Free" H_2O	0.53
CaO	72.60	SiO_2	.74
Combined H_2O	23.06	R_2O_3	.60
Total MgO	1.04		
		Subtotal	1.87
Subtotal	97.40		
		Total	99.27

PROCEDURE

	Percent
1. Locate line *ab* (CO_2, % to CaO, %):	
At right of (a) read $CaCO_3$	1.6
At (c) read $Ca(OH)_2$	95.0
2. Locate line *cd* ($Ca(OH)_2$, % to combined H_2O, %) and extend to *e* (hydrated MgO, %):	
At (e) read $Mg(OH)_2$	.0
3. Locate line *ef* ($Mg(OH)_2$, % to total MgO, %):	
At (g) read unhydrated MgO	1.0
Subtotal	97.6

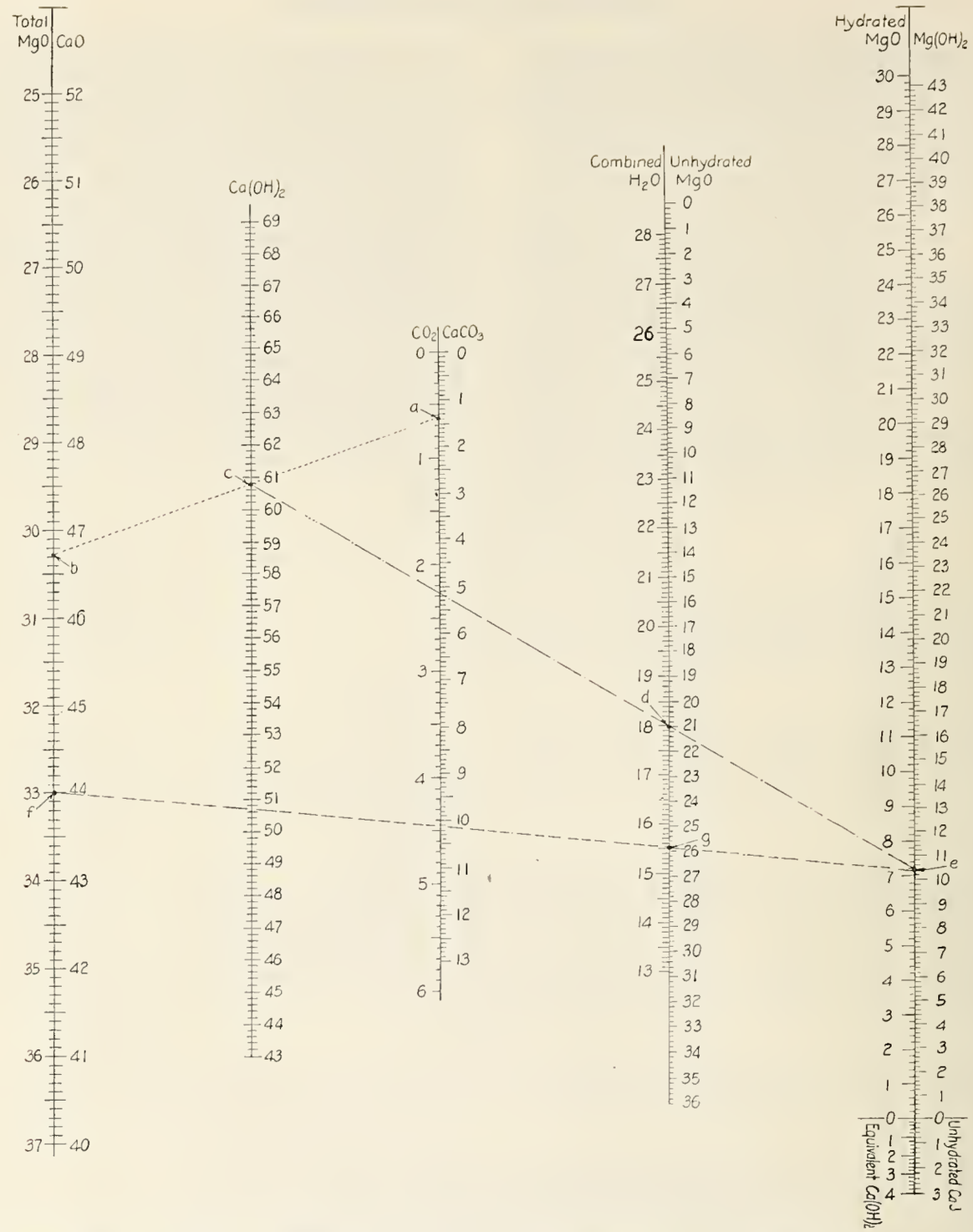

FIGURE 2. *Illustrative example of the procedure for using nomogram 2 (special nomogram) to obtain the compound composition of a hydrated lime, as applied to a regularly hydrated dolomitic lime.*

OXIDE ANALYSIS

	Percent
CO_2	0.63
CaO	46.72
Combined H_2O	17.96
Total MgO	33.08
Subtotal	98.39

	Percent
"Free" H_2O	0.30
SiO_2	.94
R_2O_3	.36
Subtotal	1.60
Total	99.99

PROCEDURE

	Percent
1. Locate line *ab* (CO_2, % to CaO, %):	
At (a) read $CaCO_3$	1.4
At (c) read $Ca(OH)_2$	60.7
2. Locate line *cd* ($Ca(OH)_2$,% to combined H_2O,%) and extend to *e* (hydrated MgO,%):	
At (e) read $Mg(OH)_2$	10.4
3. Locate line *ef* ($Mg(OH)_2$,% to total MgO,%):	
At (g) read unhydrated MgO	25.8
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 dolomitic lime.

The oxide analysis of the lime is as follows:

	Percent		Percent
CO_2	0.63	"Free" H_2O	0.30
CaO	46.72	SiO_2	.94
Combined H_2O	17.96	R_2O_3	.36
Total MgO	33.08		
Subtotal	98.39	Subtotal	1.60
		Total	99.99

On the scale for CO_2, locate the point *a*, corresponding to the value of 0.63 percent. On the adjacent scale read the equivalent percentage of $CaCO_3$ (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 H_2O, 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 $Mg(OH)_2$ (10.4). 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 H_2O 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:

Compound	High-calcium hydrated lime		Regularly hydrated dolomitic lime	
	Nomogram 1	Calculated	Nomogram 2	Calculated
	Percent	*Percent*	*Percent*	*Percent*
$CaCO_3$	1.6	1.59	1.4	1.43
$Ca(OH)_2$	95.0	94.75	60.7	60.67
$Mg(OH)_2$	.0	.07	10.35	10.39
Unhydrated MgO	1.0	.99	25.82	25.90
Total	97.6	97.40	98.27	98.39

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

[1] L. S. Wells, W. F. Clarke, and E. M. Levin, Expansive characteristics of hydrated limes and the development of an autoclave test for soundness, J. Research NBS **41**, 179 (1948) RP1917.

[2] Tentative Specifications for Normal Finishing Hydrated Lime; ASTM Designation: C6–46T. ASTM Standards, Part II, 1304 (1946); and Tentative Specifications for Hydrated Lime for Masonry Purposes; ASTM Designation: C207–46T (Type N—normal hydrated lime for masonry purposes) ASTM Standards, Part II, 1308 (1946).

[3] Tentative Specifications for Special Finishing Hydrated Lime; ASTM Designation: C206–46T. ASTM Standards, Part II, 1306 (1946); and Tentative Specifications for Hydrated Lime for Masonry Purposes; ASTM Designation: C207–46T (Type S—special hydrated lime for masonry purposes) ASTM Standards, Part II, 1308 (1946).

[4] L. S. Wells, W. F. Clarke, E. S. Newman, and D. L. Bishop, Investigation of failures of white-coat plaster. Publication pending.

[5] Proposed amendment to Federal Specification SS–L–351 for lime; hydrated (for) structural purposes. Date of amendment, Feb. 2, 1940.

[6] Standard specifications for gypsum plastering including requirements for lathing and furring, American Standards Assn. A. 42.1–1946.

[7] L. S. Wells and K. Taylor, Hydration of magnesia in dolomitic hydrated limes and putties, J. Research NBS **19**, 215 (1937) RP1022.

Washington, July 28, 1949.

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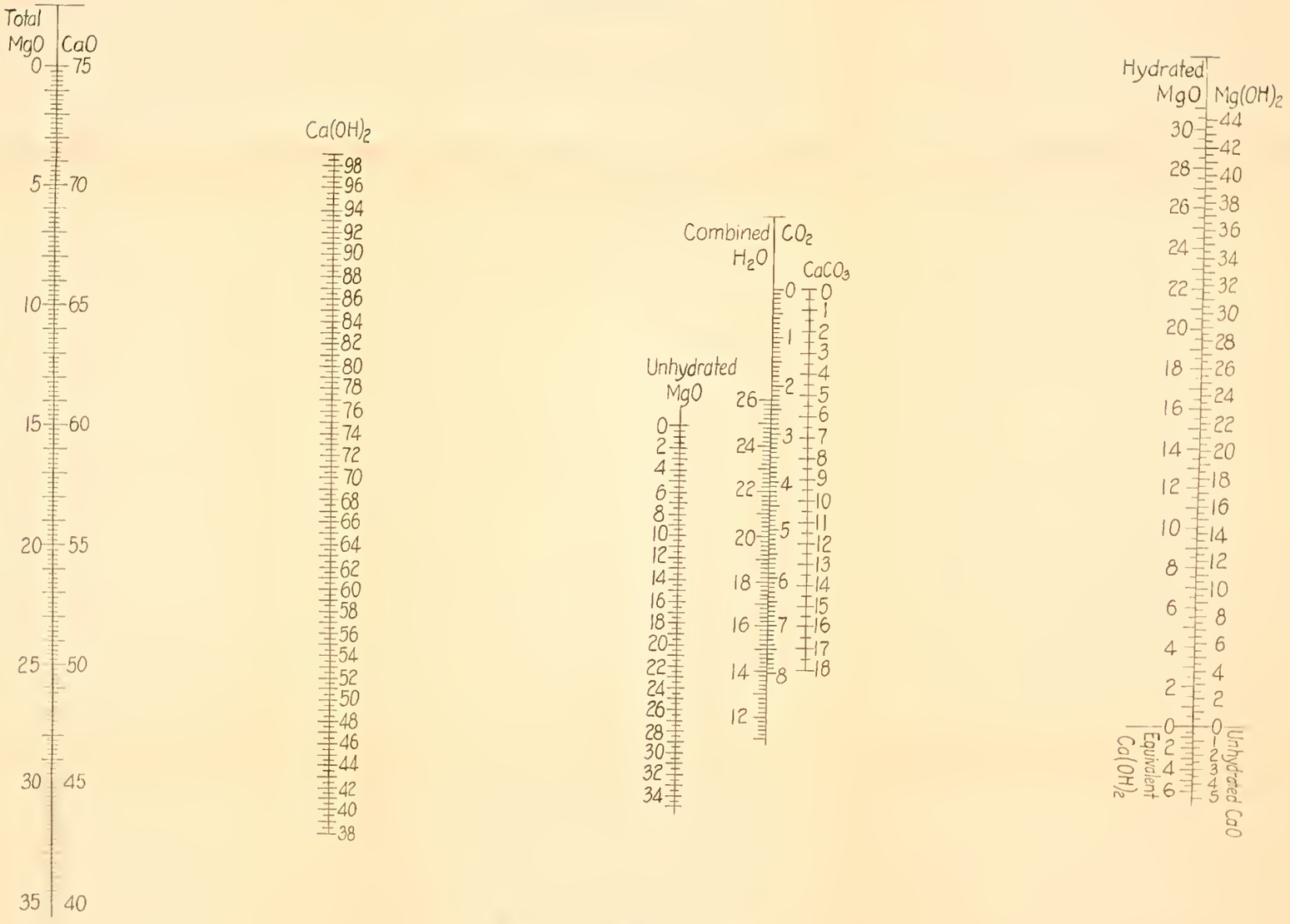

Nomogram 1. [illegible] nomogram for obtaining the compound composition of any commercial hydrated lime from the oxide analysis

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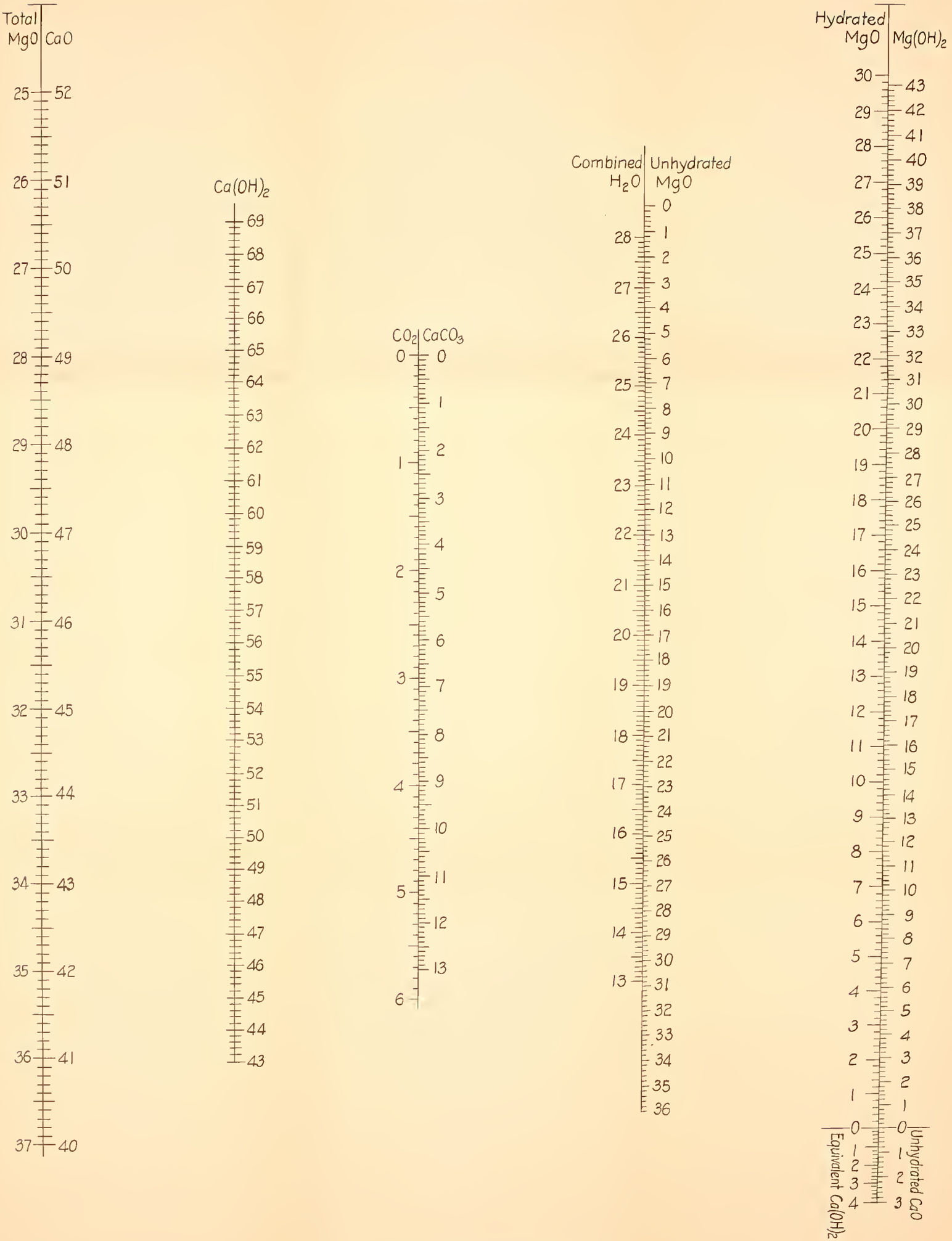

Nomogram 2. Special nomogram for obtaining the compound compositron of regularly hydrated and highly hydrated dolomitic limes from the oxide analysis.

(To accompany National Bureau of Standards Miscellaneous Publication 196, issued December 30, 1949)

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

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