

imately 500° to 600°, or such that the time for driving off the heavy volatile material was noticeably prolonged, though still practically completed within the two minutes allowed in Table II. These results show that the lower temperatures cause a larger fixation of carbon and a consistently lower percentage of volatile matter, thus confirming the proposition as stated under (d) as to variations caused by the speed of the preliminary decomposition. Also by the close agreement of the duplicates there is added further confirmation to the proposition under (c) as to the constancy of the hydrogen discharge at a high temperature.

(d) *Carbonization Variables*.—Under (d) the variations which occur in the first part of the carbonization bear a direct relation to the speed with which that part of the process is carried out. It is true that a higher or lower temperature will influence the rapidity with which decomposition takes place, but this is by no means the only factor. For example, with the same crucible and the same temperature, a higher volatile discharge will be recorded if the mass of coal is spread with a concave surface so that more of the coal is brought into contact with the metal. Or to reverse the conditions, a small 10-gram crucible will have less superficial contact with the metal than a 30-gram crucible. If in each case the coal is allowed to assume its natural shape with level surface, the larger crucible will discharge the larger amount of volatile matter. Again the same 10-gram crucible will yield more volatile if the coal is spread around the sides, giving it a concave surface, and increasing the area exposed to the crucible. These four sets of conditions are illustrated in the following table:

TABLE IV.—SHOWING VARIATIONS DUE TO SPEED OF VOLATILIZATION.

Lab. No.	Kind of coal.	A. 30-g. plat. cruc. coal with flat surface.	B. 30-g. plat. cruc. coal with concave surface.	C. Com- pare B with A. Per cent.	D. 10-g. plat. cruc. coal with flat surface.	E. 10-g. plat. cruc. coal with concave surface.	F. Com- pare E with D. Per cent.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
4389	Bureau Co., Ill. . . .	47.03	47.95	+0.92	45.82	46.48	+0.66
1889	Logan Co., Ill. . . .	42.94	44.65	+1.71	42.29	43.21	+0.92
213	Lignite, N. D. . . .	56.93	57.18	+0.25	55.61	55.44	-0.17
2775	Rock Island Co., Ill.	46.02	47.44	+1.42	45.02	45.56	+0.54
1810	Franklin Co., Ill. . .	38.39	38.72	+0.33	37.76	38.31	+0.55
2773	Anthracite.	9.23	9.01	-0.18	8.58	8.67	+0.09
	Average.			+0.78			+0.43

It seems evident from the above data that the greatest source of variation resides in that part of the process which involves the distillation of the fat or heavy volatile portion of the coal. These variations also are due to seemingly small influences, as high as 1.7 per cent. in one instance, in sample No. 1889, Table IV, being due to the disposition of the charge against the sides of the crucible. If comparison were made as between the large and the small crucible as in column A and D, a variation of 1.21 per cent. is shown in sample 4389, due to this cause alone. It is evident, therefore, that in standardizing this part of the procedure, more than the simple matter of temperature must be taken into account.

Other evidence, all in the same direction, has been obtained wherein a weighed amount of clean, ignited sea-sand was mixed with the coal. This procedure gives a coke of uniform texture and obviates any tendency on the part of the coke to swell. But the yield of volatile matter is consistently lower, owing to the small retardation of the decomposition processes. Another bit of evidence in the same direction is the use of a porcelain crucible which again retards the process and gives lower results by from one to two per cent. This reduction in yield with a porcelain crucible can be very largely counteracted by using a correspondingly higher temperature, but more data is necessary before a conclusion can be drawn as to the conditions wherein porcelain can be substituted for platinum.

Other influences, such as the presence or absence of free moisture, especially in lignites, the use of a muffle instead of a flame, etc., have been partially tested but not sufficiently to be reported upon at this time, further than to say that the Méker burner promises to afford a much more even temperature than the ordinary Bunsen burner; or rather, it delivers a large amount of heat instead of a small localized zone at the tip of a small flame. There is a decided advantage also in the larger volume of flame which more completely envelops the crucible and furnishes at the same time an atmosphere with but little oxidizing property.

It is not the purpose of this paper to make recommendations as to the best procedure since the whole matter is under consideration by the committee on revision of methods for coal analysis. It may be said, however, that the experiments indicate certain essentials, outlined as follows:

1. Definiteness of temperature.
2. The employment of a temperature not below 900° or 950°.
3. Use of a crucible of given size and shape.
4. A capsule cover fitting inside of the crucible and not on top.
5. The use of kerosene to moisten the charge.
6. If a burner is to be used, the Méker type has a great advantage in furnishing a larger volume of heat less localized than that of the ordinary Bunsen type.
7. A small crucible is preferable to a large one, as it is more readily enveloped completely by the flame of the burner and the coal mass is less subject to variations in form. This is very important in view of the large variables that may enter into the early stages of decomposition.

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MONEL METAL.

By RICHARD H. GAINES.
Received January 6, 1912.

HISTORY.

About seven years ago, one of the large smelting companies began investigating the chemical and physical properties of an alloy that had been reduced directly from a nickel-copper matte, without the

previous separation of the two metals. This alloy was found to possess not only the more valuable properties of nickel, but other desirable properties in addition, that would ensure a wide usefulness, and owing to the simple method of production, was obtainable at about one-third the cost of nickel. The alloy consists primarily of nickel and copper in the proportion of three parts of nickel to one part of copper, this being the proportion in which the two metals are found together in nature in the great deposits of nickel ore at Copper Cliff in Canada.

The old Swedish and German miners supposed the mineral *kupfernickel* to be a counterfeit or base ore of copper. A fuller knowledge of nickel led to its being better appreciated, and it is now worth nearly three times as much as copper.

Nickel and copper are associated in enormous pyrrhotite deposits in the Sudbury district of Ontario, Canada, and one of the most difficult problems in the treatment of these ores has been that of separating the two metals. In 1905-6, the International Nickel Company, considering, no doubt, that for many purposes there was no need to separate the amicable metals nickel and copper, took up the problem of reducing them together and obtaining an alloy of the two metals in the proportions in which they occur in the ore. The method adopted consists merely in eliminating the impurities, except a small percentage of reduced iron and a minor quantity of other substances which remain with the alloy.

PROCESS OF MANUFACTURE.

Synopsis.—The ore from the mines is first reduced to a matte, which is blown until the iron is nearly eliminated, the sulphur is removed by roasting, and the combined oxides remaining are reduced to metal.

The general method of production includes roasting the ore in heaps, followed by smelting in a blast furnace, and further enriching in a converter, which yields a high-grade matte containing about 80 per cent. nickel and copper, from 1-2 per cent. iron, and the rest sulphur. By careful attention to the furnace charge, it now is claimed that a Bessemer matte can be produced within 1 per cent. of the required proportion. The rich matte is shipped to the Orford refinery, where it is ground and roasted in hand rabbled reverberatory furnaces to remove the sulphur, carbonate of soda being used to finish the elimination of the sulphur. The product should be oxides of nickel and copper, with a small proportion of iron, and only a trace of sulphur. This is charged with charcoal into a reverberatory melting furnace fired with oil. The nickel and copper oxides are thus reduced to metal, and melted.

The alloy thus obtained was found to possess such valuable properties as would ensure it a very wide use on its own account. It was named Monel metal after Mr. Ambrose Monel, the president of the International Nickel Company.

COMPOSITION.

The ores of the Sudbury district vary both in the amount and proportion of nickel and copper, and, therefore, the proportions of these two metals in the alloy will vary within certain limits with the composition of the ore treated. The ore from which the Monel metal is derived contains generally about 4.85 per cent. of nickel to about 1.75 per cent. copper. When this ore, as it occurs in nature, is reduced to metal, the resulting alloy contains from 66-70 per cent. nickel, from 23-28 per cent. copper and from 3-5 per cent. of other metals, including iron, and a small proportion of manganese.

ANALYSES OF CAST MONEL METAL.
Samples taken at the foundry of the Bayonne Casting Co., Bayonne, N. J.
Per cent.

Lab. No.	Description.	Copper.	Carbon.	Iron.	Nickel.	Silicon.	Manganese.	Cobalt.	Total.
1146	Heat 301.....	26.59	0.27	3.19	68.22	1.10	0.26	Trace	99.63
1147	Heat 307.....	27.02	0.31	2.40	68.49	1.08	0.49	Trace	99.79
1148	Heat 308.....	26.59	0.43	2.87	68.23	1.24	0.44	Trace	99.80
1149	Heat 312.....	27.04	0.39	2.68	68.10	1.17	0.37	Trace	99.75
1150	Heat 315.....	27.27	0.39	2.40	68.50	1.23	0.09		99.88
1151	Heat 318.....	26.81	0.38	2.54	68.30	1.36	0.23		99.62
1152	Heat 329.....	27.53	0.31	2.16	68.28	1.41	0.14		99.83
1153	Heat 335.....	27.38	0.25	3.33	68.46	1.24	0.11		99.77

ANALYSES OF ROLLED MONEL METAL.
Samples taken at the foundry of the Bayonne Casting Co., Bayonne, N. J.
Per cent.

Lab. No.	Description.	Copper.	Carbon.	Iron.	Nickel.	Silicon.	Manganese.	Cobalt.	Total.
1154, No. 1	Test 275.....	26.57	0.28	2.09	69.04	0.16	1.32	Trace	99.46
1155, No. 2	Test 275.....	26.71	0.44	2.11	68.81	0.17	1.35	Trace	99.59
1156, No. 4	Test 275.....	26.99	0.37	2.07	68.89	0.18	1.26	Trace	99.76
1157, No. 6	Test 275.....	24.76	0.33	2.44	69.83	0.37	1.82	Trace	99.55
1158, No. 7	Test 275.....	26.94	0.39	2.16	68.48	0.12	1.54	Trace	99.63
1159, No. 8	Test 275.....	26.21	0.43	2.41	68.63	0.20	1.73	Trace	99.61

ANALYSES OF FORGED MONEL METAL.
Sample submitted by the Bayonne Casting Co., Apr. 6, 1911.
Per cent.

Lab. No.	Description.	Copper.	Nickel.	Manganese.	Iron.	Carbon.	Total.
1021	Specimen taken midway between center and outside of billet	26.69	69.45	1.38	2.13	0.19	99.84
1022	Specimen from center of billet.....	26.78	69.52	1.50	2.14	0.17	100.11
1023	Specimen from outside of billet.....	26.83	69.54	1.48	2.19	0.18	100.22

C. F. Burgess and James Aston¹ give the following analysis of a sample of Monel metal examined in 1909:

	Per cent.
Nickel.....	67.96
Copper.....	26.00
Iron.....	2.80
Manganese.....	1.62

Analyses of Monel metal quoted by A. Stansfield,² C.E., in *Transactions of the Canadian Society of Civil Engineers* are as follows:

	Cast bar.	Rolled bar.
Nickel.....	68.90	67.55
Copper.....	26.55	26.25
Iron.....	3.30	3.25

On looking through the literature of the subject, no very recent analyses were found. The analyses of cast, rolled, and forged metal (given on page 355) were made at the laboratory of the Board of Water Supply, New York City, during the latter half of 1911.

For such a material as Monel metal, which is not a pure alloy, the feature of these analyses is the remarkable approach to uniformity in composition. If compared with the earlier published analyses, it would appear that the manufacturers have perfected the methods of reduction from ore and matte to such a degree as nearly to control the composition. In the present process of manufacture, the claim is made that the physical properties of Monel metal are not materially affected within the limits of variation in which the constituents occur. If this is true, a closer uniformity in the results of physical tests must be looked for from improvements in the heat treatment. As a matter of fact, the effect of variation in the copper-nickel ratio, as well as the influences of the presence of varying amounts of carbon, iron, silicon and manganese have not hitherto been studied, and are, therefore, not yet understood. A comparison of the chemical analyses with the physical tests made at the laboratory affords some deductions.

NICKEL-COPPER RATIO.

On looking over the results of the physical tests, it would seem that the variations found bear little relation to the chemical composition. Specimens of the cast metal in which the nickel-copper ratio was about the same, and other constituents in close agreement, gave a considerable difference in strength and yield point. For example, the specimen from heat 307 showed an ultimate strength of 69,100, and elastic limit 38,450, with a nickel-copper ratio of 68.49-27.02, while the specimen from heat 312 with a nickel-copper ratio of 68.10-27.04 and other constituents nearly identical, gave an ultimate strength of 73,750, and elastic limit 44,550. The difference of 10 per cent. in ultimate strength and 15 per cent. in elastic limit here is plainly due to some other cause than composition.

CARBON.

In accordance with previous examinations of this material, only the total carbon was determined in the samples submitted. With respect to the influence

of this element, test 275, No. 1, gave ultimate strength 85,250, yield 51,250, and carbon 0.28. Same test, No. 2, showed ultimate strength 86,200, yield 58,250 and carbon 0.44, with other chemical constituents agreeing closely. Same test, No. 4, representing only a different section from the same rod, gave ultimate strength 85,500, yield 51,300, with carbon 0.37. The ultimate strength and yield in these three cases appear to follow in some measure the carbon content. In future study of Monel metal, it would be well to ascertain the carbon relations, for unless it is known in what form the carbon exists in the metal (whether free or combined, and in what ratio) it is fruitless to attempt deductions.

IRON.

Generally speaking, iron hardens, whitens and increases the strength of Monel metal, but reduces the elastic limit. In the tests on the cast metal, heat 301, with an iron content of 3.19 per cent., showed ultimate strength 71,600 and elastic limit 39,600. In heat 315, where the iron was 2.40 per cent., the ultimate strength was 66,800 and the elastic limit 46,950. In the rolled metal where the iron is high, the tensile strength is high, but with these tests, the limit of elasticity does not appear to follow any rule.

SILICON AND MANGANESE.

In the narrow limits of variation in which these metals were found, no indication was observed of any material effect on physical properties. Manganese is an advantage as a dioxidizer, and it serves a useful purpose in rendering harmless any sulphur that might be present, forming as it would manganese sulphide.

The results of the analyses in general show that the chemical composition alone is an insufficient guide to the strength or other physical properties of Monel metal, which depend, as in steel, so largely upon other influences, and especially heat treatment. Much light on these could be obtained from investigation with the microscope. A metallographic examination of the structure of the various specimens under test would be of great assistance in revealing segregation, the form in which the carbon is present, and other facts having an important bearing on the physical and chemical constitution of the metal.

While the laws governing the nickel-copper alloys are not thoroughly understood, some progress has been made in this study. There are no chemical compounds of copper and nickel, neither is there any eutectic mixture. The metals unite in all proportions without any separation on cooling. Hence, it is inferred that the two metals form solid solutions or mixed crystals in all proportions.

Working with pure metals, Hiorns³ found that nickel dissolves in copper up to a certain percentage forming homogeneous solid solutions, and, on the other hand, taking nickel as the solvent, copper dissolves in nickel, forming homogeneous solid solutions up to a certain limit. These two solutions are

¹ *Metallurgical and Chem. Eng.*, 8, 452.

² *Canadian Society of Civil Engineers, Transactions*, 23, 302-309 (1909).

³ A. H. Hiorns, on "Copper-Nickel Alloys," in *Metal Industry*, August and September, 1911.

miscible in all proportions. These facts have a direct bearing on observations made by David H. Browne,¹ Metallurgist of the Canadian Copper Company, after five years' study of copper matte and copper-nickel matte in the Bessemer converter, and in the manufacture of Monel metal. He submits the following conclusions:

1. Nickel-copper alloys act in the matte-blow like one metal.
2. Nickel-copper alloys follow during the matte-blow exactly the same laws that govern the behavior of copper alone.

Browne presents much data to prove that copper-nickel alloys form, as far as conversion is concerned, one homogeneous metal. In conversion, copper and nickel act together, presenting the same curious resistance to oxidation, and their relations toward iron are exactly similar to the relations of copper alone. The resistance to oxidation in the converter may be in some way connected with the resistance of the finished Monel metal to oxidation and corrosion. These facts seem to suggest the idea that the metal is an entity by itself.

As the component metals have never been separated from each other, the particles of each seem to be in more intimate contact than can be attained by any synthetic method of manufacture. It is claimed that melting the constituent metals together has produced no alloy having the same physical properties as the Monel metal obtained direct from the matte. The metal must therefore owe some of its remarkable properties to the grouping of its constituents. Small quantities of foreign substances which ordinarily affect the structure of alloys in general may be of negligible effect in an alloy of this type.

In certain of its chemical as well as physical properties, Monel metal closely resembles nickel. It is slowly dissolved by hydrochloric acid and by sulphuric acid, but dissolves rapidly in nitric acid with the evolution of nitric oxide. It is apparently unaffected by alkalis and shows the same stability as nickel in the presence of other corrosive chemicals. Like both nickel and iron, Monel metal is magnetic, a property which it loses above a certain temperature. Like nickel and iron, it absorbs carbon, and like steel, its physical properties are profoundly influenced, not only by the percentage of carbon, but the form in which it exists in the metal.

In the examination of Monel metal at the laboratory, the carbon present was observed in some samples in the free form as graphite, and in a smaller degree as combined carbon, the differential relations apparently depending as in iron on the rate of cooling.

PROPERTIES.

In appearance, Monel metal resembles nickel in color. It takes a brilliant polish, nearly equal to that of silver, which it retains indefinitely. On long exposure, the surface assumes a grayish cast, which may be removed with a polishing cloth. It is somewhat tougher than mild steel, but, nevertheless, it machines very easily. A lathe can be run at about

the same speed on Monel metal as on mild steel, and the metal can be soldered, brazed, electrically welded, and successfully drawn.

SOME OF THE PHYSICAL CONSTANTS OF MONEL METAL.¹

Melting point.....	1360° C. or 2480° F.
Specific gravity (cast).....	8.87
Weight per cu. in. (cast).....	0.319 lb.
Weight per cu. in. (rolled).....	0.323 lb.
Coefficient of expansion, 20° to 100° C.....	0.00001375 per 1° C.
Electrical resistivity temperature coefficient 0.0011 per 1° F. = 256 ohms per mil-foot.	
Electrical conductivity (copper 100 per cent.) .	4 per cent.
Heat conductivity.....	1/5 of that of copper.
Shrinkage.....	1/4 inch per foot.
Hardness, cast material (Shore scleroscope)...	20 to 23
Hardness, hot rolled rods (average Shore scleroscope).....	27

A comparison of some of the properties of copper, nickel and Monel metal, as reported by a recent authority,² is given below:

	Copper rolled.	Nickel rolled.	Monel metal.		
			Cast.	Rolled.	Annealed.
Tensile strength, lbs. per square inch.....	34,000	75,500	85,000	100,000	110,000
Elastic limit, lbs. per square inch.....	18,000	21,000	40,000	50,000	80,000
Elongation in 2 inches per cent.....	52	43.9	25	30	25
Contraction, per cent.	57	57	25	50	50
Melting point.....	1084° C.	1500° C.	1360° C.		

Recent tests³ of Monel metal at laboratory of William Sellers, Philadelphia, Pa., are:

	Hot rolled rods.	Sand castings.
Elastic limit, lbs. per sq. in.....	58,873	37,427
Breaking strength, lbs. per sq. in.....	86,899	78,236
Elongation in 2 inches, per cent.....	40.0	38.5
Reduction of area, per cent.....	60.5	34.0
Modulus of elasticity.....	22,000,000 to 23,000,000	

In all the technical reports relating to Monel metal, it is referred to as a non-corrosive alloy. Redfield⁴ and other writers claim that the castings have the strength and many other properties of cast steel, while they have greater resistance to corrosion from sea water, superheated steam and corrosive chemical solutions than the bronzes. Owing to its remarkable stability in sea water, the government is now equipping its battleships with propellers of this material, these being cast in single pieces. Propellers have already been made for the North Dakota and for battleships of other countries, some of the latter being 15 ft. 6 in. in diameter in a single piece, weighing 16,000 lbs. After 18 months' service, it is said that the wear and corrosion of these propellers was found to be practically negligible. It was further found that they resist bending to such an extent that they are not so subject to loss of efficiency as propellers which yield under heavy backward pressure against the water.

Experiments made at the laboratory indicate that Monel metal possesses about the same resistance to corrosive action as the better known bronzes. Speci-

¹ Physical data in part from John F. Thompson, in *Eng. and Mining Journal*, **91**, 1911.

² *Transactions of the American Institute of Mining Engineers*, **41**, 310 (1910).

³ *Ibid.*, 1911.

⁴ S. B. Redfield, *American Machinist*, **34**, I, 513-514.

¹ *Mining World*, **30**, 470.

mens of several bronzes, Monel metal, and steel were weighed and embedded in rich earth, which was kept wet for six months by periodical additions of very dilute solutions of corrosive salts. At the end of the test period all the specimens were taken out, scrubbed, dried and weighed to ascertain the comparative loss from corrosion. The results were as follows:

	Per cent. loss.
Phosphor bronze.....	0.09
Tobin bronze.....	0.11
Monel metal.....	0.12
Parsons manganese bronze.....	0.12
Muntz metal.....	0.33
Steel.....	1.04

Another test of the same kind, under somewhat different conditions, but the same period, gave about the same relative results.

One advantage in favor of Monel metal in these tests was that it presented the least change in appearance as a result of the corrosive action.

CASTING.

While no trouble has been experienced in rolling Monel metal, considerable difficulty has been met with in some foundries in getting sound castings. Incidentally, it may be remarked that nickel-copper alloys have a great tendency to develop blow-holes on casting, due to occluded gases. This is another indication of the absence of a chemical compound, since the presence of a compound in an alloy seems to have the influence of preventing blow-holes, and closing the grain. Monel metal requires special precautions in casting on account of dissolved oxides and gases, which, if not removed, would render the ingots unsound. Successful castings have been made in small foundries by adding 2 ounces of magnesium per 100 lbs. of the alloy, before pouring.

Unsound castings may also arise from gases that are liberated in the cores of the patterns, and from the fact that the freezing point of the metal is so many hundred degrees above that of brass or bronze that these gases cannot escape before they are trapped by the freezing metal. This necessitates the use of the same methods as for fine steel castings. It must be remembered that the actual temperature of Monel metal cannot be much lower than 1550° C. The art of casting Monel metal is closely related to the art of casting steel, as distinct from the art of casting brass, bronze or cast iron. It really involves the art of handling the finest steel castings. The practice of casting Monel metal is, therefore, very similar to that followed in steel foundries. The melting equipment of the plant consists of standard reverberatory furnaces which are fired with oil, the fuel being fed by gravity. The metal is charged into the furnace in the form of pigs or slabs which are about 15 × 8 × 3 inches in dimensions, and weigh about 85 lbs. The melting point is about 2500° F. and eight hours are required to the heat. No fluxes nor alloys are necessary. Because of the relatively scant knowledge of nickel and its peculiarities, the handling of Monel metal requires expert attention in the melting.

The industry of making Monel metal castings is

now past the experimental stage, and is being successfully accomplished in at least three foundries in New York and New Jersey. Mr. Leonard Waldo, consulting engineer, is authority for the statement that notable success has been achieved at the Johnson Foundry of Spuyten Duyvil in the casting of this metal. The Bayonne Casting Company, of Bayonne, N. J., and the Riverside Steel Company, of Newark, N. J., are other foundries that are making good castings.

USES.

Although a comparatively new alloy, because of its resistance to corrosion, its strength and the readiness with which it may be machined, Monel metal has already found many important uses. These include pump cylinders for handling salt water, propeller wheels, rudders, centre boards, deck fittings, mining screens, water ends of pumps, linings, valves, shafts, piston rods and plumbing fixtures subject to corrosive influences.

In the rolled metal, there is a wide range of usage. Striking instances in the past include the roofs of the new terminals of the Pennsylvania Railroad in New York, and the Chicago & Northwestern Railroad in Chicago, which were covered with Monel metal. The sheets have also been used on several large office buildings in New York, and on industrial plants subject to severe corrosive conditions where copper had proved unsatisfactory.

Rigid physical specifications should be the rule wherever Monel metal is considered for use in any form of engineering construction. With reference to chemical specifications, it would be impracticable to set any narrow limits as to chemical constituents, owing to the somewhat variable character of the ore and the method of manufacture. It is not believed, moreover, that such limits are necessary in order to insure the desired physical properties of strength and durability. If too close limits are set on chemical constituents, the metal so specified might be obtained, but at a cost that would render its use prohibitory.

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NEW YORK CITY.

FREE LIME IN PORTLAND CEMENT.¹

By H. E. KIEFER.

Received January 2, 1912.

It is to be regretted that the majority of chemists engaged in the manufacture of Portland cement have very little time for research work. Some of us have considerable time for experimental work, but the time and money spent are expected to produce commercial results rather than contribute to the stock of purely scientific knowledge. This latter we are compelled to leave to the research chemist, and as he usually lacks a practical manufacturing experience we may be able to supply a few facts and suggestions.

One of the most troublesome arguments which the cement chemist has to meet is on the subject of *Free Lime*. We hear it discussed by chemists and engi-

¹ Read at the Forty-fifth annual meeting of the A. C. S., at Washington, December, 1911.