	Grams HgI ₂
Powdered mercuric iodide—2 assays (0.1 gram sample).....	0.1004
	0.1024
	Grains HgI ₂
Tablet triturates, 1/30 grain—6 assays (sample, 30 tablets).....	0.97
	1.01
	0.97
	0.99
	0.98
	1.00

The method is simple and easy to manipulate and the results obtained were very satisfactory. It was also found to be useful for the assay of mercuric iodide and oleate of mercury.

ANALYTICAL DEPARTMENT, PARKE, DAVIS & Co.
DETROIT, MICHIGAN

LABORATORY AND PLANT

THE DEVELOPMENT OF THE ROTARY KILN AND ITS APPLICATION TO VARIOUS CHEMICAL AND METALLURGICAL PROCESSES¹

By RICHARD K. MEADE

BLACK ASH REVOLVERS

As early as 1848 W. W. Pattinson, an English chemical engineer, invented a revolving black ash furnace but the furnace as he built it was not a success. It remained for Elliott and Russell some five or six years later to design a furnace which would operate successfully and this was employed in the works of the Jarrow Chemical Company, South Shields, Eng., where the practical difficulties encountered in its operation were overcome by J. C. Stephenson. The apparatus became quite popular after this and was generally introduced into alkali works both in England and elsewhere.

The black ash furnace or "revolver" (Figs. 1 and 2) consisted of a horizontal cylinder of wrought iron about 30 ft. long by 10 ft. in diameter lined with fire brick and

FIG. 1—SODA-ASH REVOLVER

provided with two bearing rings or tires of steel which rested upon four small flanged wheels, or rollers. The cylinder was revolved by means of a girth gear meshing with a pinion, which latter was driven by means of a small steam engine. The cylinder was provided with openings at either end, communicating with a furnace and a lye evaporator respectively. The gases from the furnace passed through the cylinder and melted the charge, the cylinder being revolved meanwhile. The waste gases passed over into the lye evaporator and the heat was utilized there. The furnace was not continuous but was operated by charging the materials (a mixture of salt cake, Na₂SO₄, limestone and coal) into the cylinder through man-holes in the side of the former, from hoppers placed above the cylinder. These openings were then closed by suitable covers and when the charge was finished the covers were removed, the furnace tilted

¹ Presented at the 6th Semi-annual Meeting of the American Institute of Chemical Engineers, Troy, N. Y., June 17-20, 1914.

and the molten charge poured through the openings into cars placed below.

REVOLVING METALLURGICAL FURNACES

The counterpart of this furnace is found in the metallurgical industry in the Brückner ore roaster, largely used at one time in this country for calcining and desulfurizing copper ores. The Brückner roaster

FIG. 2—SODA-ASH REVOLVER, EMPTYING THE CHARGE

does not materially differ from the soda revolver except that the evaporator flue is omitted and often the fire box is a car running along a track at right angles to the center line of the furnaces. In this way, the car can be connected with any furnace and allowed to remain there until the sulfur ignites, when it may be

FIG. 3—SIEMENS REVOLVING STEEL FURNACE

wheeled to the next cylinder and a current of air allowed to pass through the first cylinder to burn off the sulfur.

In 1869, Siemens, the celebrated English metallurgist, applied a somewhat similar furnace (Fig. 3)

to the manufacture of steel direct from the ore and Danks, of Cincinnati, Ohio, about this time invented a rotary puddling furnace which worked upon the same principle. Both the Siemens and the Danks furnace were extensively used.

Crampton, another Englishman, in 1872, took out a patent upon a rotary puddling furnace (Fig. 4). He proposed to heat his furnace, however, with powdered coal. Crampton's first furnace was used at Woolwich

FIG. 4—CRAMPTON'S ROTARY PUDDLING FURNACE

Arsenal, in 1873, and also at other English iron works. His furnace differed from those of Siemens and Danks in that the cylinder was open at one end only, the jet of fuel and air being blown in below while the gases passed out above.

Crampton evidently understood the value of pulverized coal. It is of interest to note that this form of fuel, after nearly twenty years of successful use in the cement industry, is just beginning to be used to any extent for puddling iron, and yet Crampton suggested that it be so used over forty years ago. His furnace was designed not only to save the labor of fettling and rabbling the iron but also that of stoking the coal on the grate.

THE ROTARY CEMENT KILN

A few years after this, Crampton conceived the idea of using a rotary furnace heated by pulverized coal for burning cement, but, although he took out a patent in 1877 on his process, I can find no mention of his ever having put his invention into practical use.

In 1885, an English engineer, Mr. Frederick Ransome, received a patent upon a continuous rotary furnace process for burning Portland cement. Ransome's furnace differs from those which have been mentioned above in that it consisted simply of a straight cylinder, supported upon rollers and revolved by gears, tilted slightly at an angle to the horizontal. The effect of this tilting was that when material was fed into the upper end the revolutions of the cylinder caused the material to move through the furnace. As the lower end was left entirely open the action of the furnace was continuous, the material to be calcined passing in at the upper end and the burned material out at the lower in a steady stream. This is the present day "rotary kiln" (see Figs. 6 and 7).

Ransome's idea was faulty in that he expected to eliminate the necessity of grinding the burned clinker by his process rather than to effect any economy of labor or fuel in the burning process itself. His idea

was that by calcining the raw material in the form of a fine powder in such a furnace the clinker so obtained would be fine also and hence would not need to be ground. He entirely overlooked the fact that semi-fusion must take place in order to form Portland cement and that in this condition the material would be sure to stick together and form small nodules. Instead of making a clinker easier to grind the rotary kiln made a clinker much harder to grind than that burned by the upright kiln. Ransome's process was given quite a prolonged trial at a cement works at Grays, Essex, England, using gaseous fuel, but did not prove commercially successful.

In the same year, H. Mathey, of New York, took out a patent upon a revolving furnace (Fig. 5), somewhat similar to that of Ransome except that, instead

FIG. 5—MATHEY'S REVOLVING LIME AND CEMENT KILN

of inclining his furnace, he obtained the same effect by having the center line of the kiln horizontal but the kiln itself was made slightly cone shape, the material being fed in at the smaller end. He proposed to heat his kiln by a grate fire and to employ it for burning lime and hydraulic cement.

In this country, a small cement plant in Oregon attempted to use Ransome's kiln, in 1887, but the attempt here too proved a failure. About the same time the Atlas Portland Cement Company began to experiment with Ransome's kiln, first at East Kingston, New York, on wet materials and later with success upon the cement rock of the Lehigh District in Pennsylvania. In Ransome's original patent, he proposed to heat the kiln by producer gas but its development in this country was made possible by the use of crude oil. At first these kilns were only 40 ft. long, but it was soon found more economical to lengthen them to 60 feet, and now the usual length is between 100 and 150 ft. with diameters ranging from 7 to 9 feet.

The rotary kiln came quite generally into use in this country following the results obtained by the Atlas Portland Cement Company. About 1896, powdered coal in place of oil came into use and from that time on all new plants for the manufacture of Portland cement installed rotary kilns, employing pulverized coal as a fuel, except in localities where oil or natural gas are cheaper. Practically all Portland cement made in this country and much of that in England and Germany is now burned in rotary kilns.

It is not the purpose of the present paper to treat of the employment of the rotary kiln in cement burning, as the literature obtainable on the subject is voluminous, but instead to call attention to its employment in other industries and to suggest new uses to which it may be put.

DESCRIPTION OF THE ROTARY KILN

The rotary kiln (Fig. 6) in its usual form consists of a cylinder, from 6 to 9 feet in diameter, by from 60 to 150 feet long, made of steel sheets from $\frac{1}{2}$ to $\frac{9}{16}$ inch in thickness, lined with fire brick and inclined at a pitch of from $\frac{3}{8}$ to $\frac{3}{4}$ inch to the foot. The steel sheets are held together with single strap butt joints, as these joints resist expansion strains due to heating better than lap joints. This cylinder is supported on two or more tires made of rolled steel, and having a face of from 6 to 12 inches and a thickness of at least 4 inches. They run each on heavy friction rollers made of cast steel, which are often mounted in pairs on a rocker. The kiln is driven by a girth gear situated usually near its middle or upper end, and a train of gears, actuated either by a line shaft or a motor. The upper end of the kiln projects into a brick flue which is surmounted by a steel stack. The flue is provided with a door at the bottom to take out the dust which accumulates there.

The lower end of the kiln is closed by a hood into which the kiln projects. Sometimes this hood is made stationary with movable fire-brick doors, but oftener it is mounted on a movable carriage. The front wall of the hood is provided with two holes, one for the entrance and support of the burning apparatus, and the other for observing the operation of the kiln and for inserting bars to break up the rings formed and

FIG. 6—ROTARY KILN

repair the lining. The lower part of the hood is partly open and through this the clinker falls. Air for combustion also enters here. Fig. 6 represents a completed kiln.

The usual diameter of a 60 foot rotary kiln unlined is from 6 to 7 feet, of a 100 foot rotary from 7 to 8 feet and a 125 foot rotary 8 to $8\frac{1}{2}$ feet. Most of them are made the same diameter throughout, though some of them are made, say 6 feet 6 inches in diameter for the first 30 feet and then taper through 10 feet to a diameter of 5 feet 6 inches for the remaining 20 feet; others taper for the last 10 or 15 feet before

entering the stack. This latter plan has the effect of a damper, crowding the heat more to the front of the kiln. It probably lessens the output somewhat, since the choking cuts down the amount of coal that can be burned.

The short 60 foot kilns usually bear upon two or three tires and longer kilns often on four or more tires. The kilns are always provided with two or more horizontal thrust roller bearings to keep the kiln on the vertical roller bearings.

The material to be burned is fed into the kiln through a horizontal water-jacketed screw-conveyor, or more generally spouted directly into the kiln through an inclined pipe of cast iron. Wet materials are often pumped directly into the kiln. The raw material feeding device is attached directly to the driving gear of the kiln so that when the kiln stops the feed also stops. The material to be burned is stored in large steel bins above the feeding device so that a constant and regular supply may be always at hand.

The kiln is heated by a jet of burning fuel, usually powdered coal where the ash of this is not objectionable. Where the ash of the fuel is objectionable producer gas is usually employed. Where oil or natural gas are cheaper they are always used as they are also the most convenient fuel.

NODULIZING ORES, CINDER, ETC.

About 1900, various metallurgists were experimenting with the rotary kiln for nodulizing flue-dust, fine iron ores, etc. Edison conducted experiments, for example, on the nodulizing of the fine concentrates obtained from his magnetic separators and several iron and steel concerns experimented with the use of the kiln to nodulize flue-dust and fine iron ores. Within a few years plants were established for the latter purpose. The Pennsylvania Steel Company were among the early users of nodulizing kilns, employing one on Cornwall concentrates. From about the year 1904 on, the patent office has issued many patents on various processes for nodulizing ores.

The rotary kiln has furnished a simple means of utilizing the soft clayey ores, such as that of the Mayari field in Cuba. Practically all of the schemes tried for placing this ore in satisfactory condition for the blast furnace were unsatisfactory until the rotary kiln was tried. The plant in Cuba now consists of twelve kilns 100 feet long (eleven of these being 10 feet and one 9 feet in diameter), and has a capacity of from 1500 to 2000 tons of nodules per 24 hours.

Chemical manufacturers also began about 1904 nodulizing pyrites cinder or "blue billy" selling the nodules to the blast furnaces. This was possible because the process not only nodulized the cinder, but also desulfurized it. This practice has now become quite general and nearly all large sulfuric acid manufacturers whose locations permit of a ready sale of the product to the blast furnaces now nodulize their cinder. When copper bearing pyrites ore is roasted for the sulfuric acid and then leached for the copper, the iron oxide residue is now nodulized and sold to the blast furnaces, the wet residue being conveyed direct from the leaching tanks to the kiln.

During the past year, a great deal of interest has been aroused in the possibility of treating fine copper ores and smelter flue-dust in the rotary kiln and one of my associates, Mr. J. H. Payne, has succeeded in solving this problem. A rotary kiln installed and designed according to his specifications has now been working successfully on such material at the plant of the U. S. Metals Refining Co., Chrome, N. J., for over a year. The fine ore question is a very serious one to the copper smelter because of the fine condition of the ore resulting from concentration.

The New Jersey Zinc Co., also, have employed a rotary kiln for nodulizing fine franklinite ore. From ore containing 17.1 per cent zinc, nodules containing 20.4 per cent zinc were obtained with little or no loss of metal.

The process of nodulizing does not differ very materially from other rotary kiln processes. The main point to be watched is the regulation of the temperature and the principal difficulties encountered are the sticking of the charge to the walls of the kiln.

BURNING LIME

In 1885, a patent was granted to Henry Mathey of New York, on a process of making lime which consisted "in first crushing the stone to a suitable degree of fineness, then burning the crushed or pulverized stone in a revolving cylinder, whereby the particles of stone are subjected to a constant and uniform heat." In the description of his process, Mathey proposed to crush the limestone to pass a No. 4 or 6 mesh screen and to burn it in the rotary furnace which he invented and which has been described previously. Siemens also mentions the use of his rotary furnace for burning lime. I believe some experiments on burning lime in a rotary kiln were also made shortly after this at one of the cement plants in the Lehigh district and also by the California Portland Cement Co.

In 1905 or 1906, the New York Lime Co. started to burn lime at Natural Bridge, N. Y., using a 100 ft. $\times$ 6 ft. rotary kiln fired by producer gas, and shortly after this rotary lime kiln plants were built by both the Union Carbide Co. and the Aluminum Ore Co. There are now in operation quite a number of rotary kiln lime plants most of which, however, are supplying lime for chemical and metallurgical purposes for reasons given below.

An application of the rotary kiln to burning lime, of peculiar interest to the chemical industry, is the employment of the rotary kiln for burning lime from the waste carbonate of lime or "lime sludge" obtained from the manufacture of caustic soda by the action of lime on soda ash. Large quantities of this waste are produced by the paper-pulp manufacturers and also by caustic soda works. Lime-sludge is also produced by beet sugar manufacturers. The rotary kiln is now employed for burning waste lime from both industries. The rotary kiln is especially suited to burning these sludges as they can be introduced into the kiln in the form of a thin mud or "slurry."

For burning lime, producer gas is usually employed for heating the kiln but, when great purity and absence

of color are not required, pulverized coal can be used to advantage. The limestone to be burned is usually crushed to pieces of one-half inch and under, before being introduced into the kiln. The objection to the rotary kiln for lime burning is principally due to this latter fact. The lime produced is in the form of dust and small pieces, whereas for building purposes most users wish lump lime. This preference is due entirely to ignorance. Fine lime is usually the result of air slaking and, as air slaked lime is partly carbonated, it is natural that the builder should demand lime in lumps. On being supplied with rotary kiln lime, he supposes it is air slaked lime and refuses it. Such lime, however, is particularly suited to metallurgical, chemical and agricultural uses, and to hydrated lime manufacture, for all of which purposes crushing of the lime is necessary.

The advantages of the rotary kiln are its low labor cost of operating, the uniformity with which it burns if properly handled and its high fuel efficiency. The labor item of lime burning can be cut in half by operating a rotary kiln and a fuel efficiency of six tons of lime for one ton of fuel has been obtained. For this reason where lime is desired for chemical uses, for hydrate manufacture, for wood pulp plants, for fertilizer and in short, where lump lime is not necessary, the rotary kiln will make lime cheaper than any other form of kiln. The first cost of a rotary plant is, however, 50 per cent greater than that of an ordinary grate-fired vertical kiln plant of the same capacity but it is 25 per cent cheaper than a producer gas plant of like output.

One great advantage of the rotary kiln is the fact that small stone can be burned in it. It is also suited to burning stones which break up into smaller pieces and crumble on heating. Such stone cannot be burned in upright kilns because of the stopping up of the draft by the spalls.

A rotary kiln lime plant usually consists of a preliminary gyratory or jaw crusher for breaking down the big stone. This is followed by some form of break down mill or crusher to reduce the stone to pieces of $\frac{1}{4}$ inch in diameter and under. These secondary crushers are usually of the swing hammer type. The stone goes from the crusher to a bin and from this is fed automatically and evenly into the kiln. From the kiln the lime drops into a rotary cooler where it is cooled. It is then elevated into a bin from which it is drawn for shipment as needed. At several lime plants boilers are installed at the ends of the kiln making use of the waste gases from these to generate steam.

ROASTING OF BAUXITE, CHEMICALS, ETC.

Rotary kilns are now employed for drying and dehydrating many ores and chemicals. In 1902, a rotary kiln was installed for the dehydrating of bauxite, and this kiln has now come quite generally into use for this purpose. Producer gas is generally employed for heating such kilns, although oil or natural gas would be the most desirable fuel where either could be employed without too great expense.

A very high grade of ferric oxide pigment is now

made in the rotary kiln by heating the residues obtained from spent pickling solutions. In this case, the salt has merely to be dehydrated, the sulfur trioxide driven off and the ferrous oxide converted to the higher oxide.

One large chemical company has a rotary kiln plant for dehydrating salts containing chemically combined water. The plant consists of four rotary kilns, each 120 ft. long and 7 ft. in diameter. Producer gas is used to heat the kilns and the exit gases from the kiln are passed through a dust collecting and washing apparatus where they are scrubbed to recover valuable dust which they carry from the kiln.

The dust problem must always be considered in rotary kiln installations and where the dust represents a loss of valuable material or is likely to constitute a nuisance to the community arrangements should be made to catch this dust. With small installations, a settling chamber and water sprays will prove satisfactory but with large installations the problem is not so simple.

The rotary kiln, fired directly by a powdered coal, oil or gas flame, is one of the most economical methods of drying and dehydrating materials known. It is extensively used for drying blast furnace slag which has been granulated by water in the cement plants of the Universal Portland Cement Co. and would offer an excellent method of drying washed phosphate rock, ore, etc., where large quantities of very wet material are to be dried.

MAKING BICHROMATES

Mr. J. H. Payne, by employing a highly oxidizing atmosphere in the rotary kiln has been able to produce sodium chromate using this form of furnace in place of the reverberatory furnace now generally used for this purpose, and a patent has been granted him on this process.

BURNING PYRITES

Ducco, an Italian chemical engineer, in 1906 suggested the use of the rotary kiln for burning pyrites for the manufacture of sulfuric acid, the pyrites being fed in at one end and the air for combustion entering at the other. His first experiments on such a furnace were made in the works of Rifredi, near Florence, where the practicability of the scheme was demonstrated. Various other acid plants in Italy also use the rotary kiln for this purpose. As employed by Ducco, the internal surface of the kiln was provided with spiral grooves to facilitate the descending movement of the ore without the production of much dust.

In this country, the Pyrite Engineering, Co., Carthage, N. Y., are exploiting a system of roasting pyrites in a rotary kiln upon which they hold patents. They have installed such a kiln at the plant of the Hinckley Fiber Co., Hinckley, N. Y. This plant, at last accounts, was working successfully, burning an ore which sometimes ran as low as 20 per cent sulfur without employing any auxiliary heat. The pyrites is being roasted just as it comes from the ground, after being crushed to $\frac{3}{4}$ inch and down, using both lump and fines together. The lower end of the kiln is closed, a series of trap doors which work automatically allow

the cinder to fall from the kiln without the admission of too much air. When the kiln is first started, the pyrites ore is kindled by means of a jet of burning sulfur.

In view of the fact that the rotary kiln is much more simple than the ordinary mechanical rabble furnace, it is remarkable that more acid and pulp manufacturers have not given them a trial.

A novel use of the rotary kiln is in the production of sulfur trioxide. This process is in use at Höchst, at Hruschau and at Hamburg. Burnt pyrites, which has been soaked in ferrous sulfate solution, is passed into the upper end of a rotary kiln, the hot gases from the sulfur burners being admitted at the lower. The kiln (Fig. 7) is provided with shelves which pick the material up as the kiln revolves and cascade it in

FIG. 7—ROTARY TUBE FURNACE FOR MANUFACTURE OF SULFURIC ACID

a spray of fine material through the current of gas passing through the cylinder. In the upper and colder part of the tube, the sulfur dioxide gas is absorbed by the burnt pyrites. As this works its way down through the cylinder to the lower end, the heat liberates all the sulfur dioxide in the form of vapors of sulfur trioxide and sulfuric acid. The gases are freed from dust and absorbed as usual. The burnt pyrite falls into a chamber at the lower end of the kiln and is re-employed by soaking in ferrous sulfate solution obtained from the treatment of pyrites containing copper.

MANUFACTURE OF SULFIDES

By designing the kiln so as to cut down the amount of air entering the firing end, it is possible to procure a reducing atmosphere in the kiln so that it can be used for the reduction of sulfates to sulfides. In this case, the problem is a particularly easy one because of the low temperatures necessary in this work. Calcium and barium sulfate can both be reduced to sulfides with little trouble using a grate fire to heat the kiln. Both are now made commercially in rotary kilns. Indeed, all of the more modern plants for the manufacture of barium sulfide are equipped with rotary kilns, and a large quantity of this compound is now produced and employed in the manufacture of lithophone, blanc fixe, barium salts and in various chemical processes.

In manufacturing barium or calcium sulfide, the barytes or gypsum, as the case may be, is crushed and mixed with from 25 to 30 per cent of coarsely ground coal. The mixture is then passed through a tube mill or some other type of pulverizer where sufficient water

is usually added to make of the powdered mixture a thin mud or slurry of about the consistency of thick cream. The pulverizing is carried to the point where at least 90 per cent of the mixture will pass through a 100 mesh screen. The slurry is then fed into the kiln in a regular stream, and as it works its way through the kiln, reduction takes place. Some of the sulfide formed, however, changes to carbonate.

The product obtained usually consists of from 60 to 75 per cent water-soluble barium sulfide, 20-25 per cent acid-soluble (chiefly barium carbonate) and 5 to 20 per cent insoluble. When the ore is pure and a good reducing flame is maintained a reduction to 75 per cent of barium sulfide and only 5 per cent acid insoluble is obtainable.

The kiln is heated by a fire-box with a hand-fired grate, one man being sufficient to fire the furnace and look after the kiln. The fire-box should be designed to give a reducing flame and all joints should be tight so as to prevent excess air entering the kiln. A mechanical stoker would be the thing here. About 500-600 lbs. of coal per ton of barytes burned are required to heat the kiln and a similar quantity is mixed in with the barytes.

The red hot clinker from the kiln is usually conveyed immediately to the leaching tanks or other dissolving apparatus, where the sulfide leaches out very quickly. The insoluble is converted into barium chloride, unless it is high in barium sulfate when it is refurnaced. The barium chloride solution is purified, filtered and concentrated to the point where this salt crystallizes out. The barium sulfide solution is filtered and stored in large tanks.

A rotary kiln $7\frac{1}{2}$ ft. in diameter and 80 ft. long, rotating once every 2 minutes, will furnace from 50 to 60 tons of barytes per 24 hours. Close supervision is necessary, however, and hence many plants operate only 10-12 hours per day. This is possible because of the low temperature employed and the ease with which the kiln may be heated up. The material furnaces easily and without complications.

AGRICULTURAL CHEMICALS

When phosphate rock is mixed with from 15 to 20 per cent of certain alkaline fluxes such as the sulfates, carbonates and nitrates of the alkalis, finely ground and heated in a rotary kiln to the point of incipient fusion, a sintered mass is obtained in which practically all of the phosphoric acid is present in a form soluble in ammonium citrate solution. Numerous patents have been granted covering such processes but the basic principle was made known by Baskerville in 1898 and Wiborgh obtained a patent upon essentially this process the same year. The product is analogous to Thomas slag which is highly recommended as a source of phosphoric acid for plant food.

The process is commercially possible but the low price at which sulfuric acid has been obtained as well as the fact that the demand has been greatest for a water-soluble and not a citrate-soluble phosphate and the conflicting claims of the various patentees have all tended to retard the application of the process on a large scale.

The reaction whereby the potash can be made water-soluble by ignition with calcium carbonate and ammonium chloride is familiar to all analysts, as it is the basis of the determination of this element in silicates. The proposal has been made to ignite a finely ground mixture of limestone, calcium chloride and feldspar in a rotary kiln and thereby obtain a product in which the potash is soluble. The proposition has also been advanced to make white Portland cement from a mixture of feldspar and limestone, both practically free from iron, and obtain potash as a by-product, the latter being volatilized at the high temperatures employed in the cement kiln.

The first proposition for potash does not seem to promise much because of the small percentage of potash obtainable in the product—only about 3 or 4 per cent—and its consequent low value. With the second process the problem of catching the potash presents considerable mechanical difficulty.

Both the process for rendering phosphoric acid citrate-soluble and that for obtaining a potash-bearing material from feldspar have been the subjects of extensive experiments, some of which have even gone so far as trials with a full size rotary kiln, and practically all of the large manufacturers of agricultural chemicals have looked into the subject. In view of the possibilities of both processes and the heavy and sure demand for such chemicals, these processes present an attractive problem for research.

We have a small rotary kiln 20 ft. long and 2 ft. in diameter. In this we have been able to burn from mixtures of lime, soda-ash and phosphate rock, material running as high as 26 per cent citrate-soluble P_2O_5 . This experimental kiln is large enough to approach very nearly plant conditions and any results which we can obtain here should be easily obtainable in a large kiln.

FUTURE APPLICATIONS

In conclusion, we might say that the rotary kiln seems to us peculiarly adapted to certain chemical processes and, where it can be employed, will usually be found the most economical form of furnace, for the following reasons:

1—The rotary kiln can be operated with far less labor than other furnaces. Over upright shaft furnaces the saving amounts to from 50 to 60 per cent and over reverberatory and hearth furnaces from 50 to 75 per cent. One skilled man with the assistance of a laborer at the feed end who also attends to the oiling can easily look after two 8×125 ft. rotary kilns.

2—The upkeep of the rotary kiln is less than that of any mechanical furnace. The lining of course on some materials is subject to destruction from the scorifying action of the charge, but outside of this the repairs and renewals amount to almost nothing. Mechanical repairs on an average amount to \$2.00 per day for an 8×125 ft. kiln. There are no rabble arms to break and no metal parts are subject to corrosive gases.

3—The power required to drive the kiln is much

less than that needed for any mechanical furnace of similar capacity. The power required for the above size kiln amounts to about 20 H. P.

4—Its continuous action promotes fuel economy and large outputs per unit. No time or fuel is lost in heating up and cooling down the kiln as with intermittent furnaces and the steady flame of the jet of burning powdered coal gives a much more uniform temperature than is possible with furnaces which are fired by hand and hence into which cold air is continuously entering when the fire is stoked. The fuel saving of the rotary kiln over a reverberatory furnace amounts to from 30–50 per cent.

5—Wet materials may be furnaced as well as dry, the upper part of the kiln acting as a drier, and both fine material and lumps may be burned at the same time.

6—The charge is at all times under control and is advanced regularly through the kiln at the desired rate. This rate may be changed at will by quickening or retarding the speed at which the kiln revolves.

7—High temperatures may be obtained and any fuel desired employed. Both oxidizing and reducing flames may be secured.

As to processes to which the rotary kiln is most applicable, these would seem to us to be:

1—Processes in which carbon dioxide, combined water or other volatile constituents are to be driven off by heat and at temperatures below 2700° F.

2—The oxidation of ores, chemicals, etc., whether this is accompanied by burning of sulfur or other combustible elements or not.

3—The reduction of compounds where this can be accomplished by heat in a reducing atmosphere either with or without the use of a reducing agent. The kiln is particularly suited to reducing processes where these consist in mixing a reducing agent with the compound to be reduced and the mixture finely ground and furnaced.

4—Processes which consist in the formation of new compounds by partially fusing or sintering a mixture of two or more materials.

5—Processes which are designed to merely change the physical state of a substance by just heating the material (either alone when fusible or with some fusible binder when not itself fusible) to the point when the particles cohere to form nodules or clinker of the desired size.

Two or more of the above processes are often carried out in the same furnace, as for example in the manufacture of Portland cement, where the carbon dioxide is first driven off and then the silicates and aluminates of lime are formed.

The rotary kiln is not suited to reactions which are attended with marked fusion of the material, that is, when the mass must become fluid before or in order for the reaction to take place. When the fusion takes place above the temperature at which the reaction is completed, the rotary kiln may be employed with

proper care to control the temperature. Where only sintering takes place the kiln, of course, gives entire satisfaction and many reactions which ordinarily require fusion of the mass to take place may be carried out completely without having the mass either molten or even pasty, by simply grinding the components finely and heating only to the point of incipient fusion or sintering. Here the greater surface exposed allows the reaction to take place by diffusion. Examples of this are found in the process of making available phosphoric acid referred to above and also in the burning of cement clinker.

202 NORTH CALVERT ST.
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A COMBINATION WATER SOFTENER AND STORAGE TANK¹

By L. M. BOOTH

Any water purification process implies that the purified water is to be used. How best to store this water between the time it is purified and used is a matter for consideration. In some industrial plants, the rate of use of water is fairly constant throughout the day, the water is used as fast as it is softened and no storage is necessary. Most water users, however, have one or more considerable peaks in their load requiring the delivery of large volumes of purified water during a short space of time. The usual plan has been to provide a separate tank or reservoir.

During the past ten years a great many softeners equipped with excelsior filters, affording storage capacity for one hour's flow (more or less)—sufficient for ordinary requirements of an industrial or power plant—have been built. Usually, this storage capacity is provided by increasing the height of the tanks a few feet above the filter to gain the desired volume. A softener arranged to include storage capacity above the filter is shown in Fig. 1.

This provision for storage capacity, while adequate to serve the needs of most power plants, necessitates the use of raw water for, perhaps, half a day, twice each year, in order to provide opportunity to change the filtering material. To use raw water, pumped directly to the feed water heater for boiler feed, for such a brief interval, is not especially objectionable. For railway water stations, however, such a plan has very little to commend it, because during the periods of filter cleaning, there would be no water available, stored at sufficient height, to fill a locomotive tender in the usual short period.

The best water softening practice in vogue at the time the first modern water softeners were imported from Europe, late in the nineteenth century, called for the use of filters to clarify the imperfectly settled water. Usually, these filters were constructed of "excelsior" (wood shavings). Careful observations of softeners operated at a small fraction of the rated capacity—corresponding to more liberal design—readily demonstrated that if the rate of upflow in the settling space were restricted to a very slow flow,

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