to report the result to this society as soon as possible. We must see, *first*, at what cost we can make sulphuric acid from the sulphuretted hydrogen evolved in the decomposition. *Secondly*, we must also tell you the quantity of chloride of magnesium we waste, so to speak, mechanically. When these experiments are finished, I will take an early opportunity of reporting thereon; and I hope we may see Mr. Weldon back, after his trip, in restored health, and that he may no longer be placed under the disadvantage of having to conceal the development of the process by Schaffner, which, he leads us to fear, may upset the third part of our process. We shall not cease our operations, however, until we have thoroughly and exhaustively tested the process in its present form.

Mr. CRESSWELL: The analyses that I made, and after all it is but one or two that I made, came out thus:—

	Per cent.
Carbonate of lime	81.27
Lime in other forms insoluble in water	0.77
Calcium chloride	0.62
Magnesium chloride	1.62

And here I may point out that that refers to one of the sorts of mechanical loss mentioned by Mr. Chance.

	Per cent.
Magnesia (which points to incomplete carbonation)	2.80
Sulphate of lime	3.31
Oxide of iron and alumina	3.95
Insoluble silicious matter	1.61
Organic matter (such as coal)	2.77

98.98

The sulphur there is not entirely in the form of sulphuric acid. It is calculated in that form because it is in such a small quantity. The lime mud gave off no sulphuretted hydrogen whatever.

Mr. WELDON: I quite agree with Mr. Chance that in order to recover sulphur from yellow liquors economically by means of waste chloride of iron the latter must be close at hand. As regards the carbonate of lime obtained when the regeneration of the magnesium chloride used in Schaffner and Helbig's process is performed by the method upon which Mr. Chance is experimenting, I am not sanguine as to its being fit for use in the manufacture of more black-ash; but there are other applications for which it will be suitable, so that it will at least have some value. In the new form of Schaffner and Helbig's process, the magnesium chloride will be regenerated, not only without any pumping, but by a method which need not involve the slightest loss.

Mr. CHANCE: With regard to the question of mechanical loss, I always allow for some margin. I am sure all present will not fail to see the importance of the success of this process, as 95 per cent. at least of the sulphur in the alkali waste will be recovered. Ninety-five per cent. being thus obtained as a starting point, represents a good sum of money as the saving to be kept in view by the operations we are conducting. *The great fact is* that no hydrochloric acid whatever is used except in the chloride of magnesium at starting, but, after that, the carbonic acid gas required is wholly obtained from a limekiln, and may perhaps eventually be in part or entirely obtained from the waste gases of the black-ash furnaces.

The CHAIRMAN: Although every single subject with which Mr. Weldon has dealt in so interesting a manner this evening has been most instructive, I think the one I have listened to with the greatest interest is that connected with the recovery of sulphur from alkali waste. During the two or three years in which it was my duty to act as one of the royal commission in connection with noxious vapours arising from factories, my attention was for some considerable period devoted to this matter, and I need

hardly say that this subject was one of the most prominent with which future legislation had to deal. It is most satisfactory to find that there is no sooner a prospect for legislation in a particular direction for social improvement than those who unwittingly bring about this legislation at once perceive the prospect of immediate advantage in mending their ways, so I am delighted to hear that men like Mr. Chance no sooner saw that an Act of Parliament was in prospect than they began to bestir themselves not only to benefit their own pockets, but also to benefit their neighbours. I am sure they will not be discouraged by the process of Mr. Schaffner. No doubt when Mr. Weldon returns and communicates to us the interesting results which he has seen—which Mr. Schaffner and his colleagues have arrived at—that Mr. Chance will be able to say—"Sir, we have been in this country able to do what has been done abroad." There is no doubt that this yellow liquor, which is continually polluting the atmosphere with its smell, carries away valuable material which the chemist should deal with successfully and profitably, and I think I may say that this Society, which brings us together to discuss and communicate the results obtained in applied chemistry, will deal in no direction more importantly than the utilisation of waste products. There are many other points of interest which have been dealt with by Mr. Weldon, which I wish I could enlarge upon. I was interested to hear about the application of vanadium salts in connection with the production of aniline black. I remember when vanadic acid was sold at twenty guineas an ounce. I will not detain you a moment longer, but only ask you to return our heartfelt thanks to Mr. Weldon, who, not merely at personal inconvenience, but, I may say, at personal suffering, has attended here this evening, and I hope that we shall all welcome him back perfectly restored.

MEETING OF THIS SECTION.

Chemical Society's Rooms, Burlington House, W.

March 13th: "The Manufacture of Alum." By B. E. R. Newlands, F.C.S.

Liverpool Section.

Chairman: E. K. Muspratt, Seaforth Hall, Liverpool.

Committee:

Dr. Campbell Brown.	F. G. Goswage.
Holbrook Gaskell, Jun.	S. M. Harrison.
J. C. Gamble.	W. Douglas Herman.
H. Tate, Jun.	J. L. Muspratt.
Dr. Hurter.	A. Norman Tate.
J. H. Crossley.	Dr. A. R. Garrick.
J. F. Allen.	A. E. Fletcher.

Hon. Sec.: Dr. A. R. Garrick, Eccleston Park, near Precoat.

DYNAMIC THEORY OF THE MANUFACTURE OF SULPHURIC ACID.

BY FRED. HUNTER, F.I.D.

As it appears now, the amounts of sulphuric acid produced in each successive chamber of a series form convergent geometric progressions, and hence the amounts of heat produced in each chamber form a decreasing geometric progression also.

Now, it is well known that the amount of heat which a hot body loses in a unit of time is approximately proportional to the difference of temperature between the hot body itself and the surrounding objects. Thus the amounts of heat dissipated by equally large chambers under similar circumstances as to surroundings will be proportional to the excess of temperature of these chambers over the temperature of the surrounding objects. The chambers will have arrived at their equilibrium, as regards temperature, when the amount of heat dissipated by the chamber

walls is equal to the amount generated within, and this will be the case for the various chambers of a set when the temperatures have so adjusted themselves that the excess temperatures form a geometric convergent series.

For six chambers this series will be something like the following:—

Temp. 65° 43·8° 32·0° 26·8° 23·5° 22°
Chamb. No. I. II. III. IV. V. VI.
Of course this is of no great practical importance, but it leads on to the following consideration, which is of importance.

It is generally supposed that there is one particular temperature for a leading chamber (the first of a series) which is better than any other. I wish to show that the temperature of the leading chamber depends upon the number of chambers which are connected to one set, or, better, upon the ratio of the cubical contents of the leading chamber to the cubical contents of the whole system.

Supposing we have two different sets of chambers—one containing m , the other n , chambers. Let the individual chambers of both sets be equally large, and suppose that in both cases the chamber space per pound of sulphur is the same also, then of course the amounts of sulphurous acid passing through the two systems in equal times are as $m:n$. Supposing the two systems equally effective, the loss of sulphur will be equal in both. Say we represent it by the fraction l , then by formula (5) we have, replacing C by m —

$$\text{Log. } \frac{S_1}{S_i} = -\frac{k_{own}}{V} \cdot m = \log. l,$$

and the fraction indicating the proportionate amount of sulphur issuing from the first chamber will be

$$\text{Log. } \frac{S_1}{S_i} = -\frac{k_{own}}{V} \cdot l = \frac{1}{m} \log. l.$$

Consequently, the sulphur escaping the first chamber will be

$$S = l^{\frac{1}{m}} S_i,$$

and for the other system, with n chambers, it will be

$$S = l^{\frac{1}{n}} S_i.$$

The difference between S_i and S is the sulphur converted in the chamber into sulphuric acid—

$$S_i - S = S_i \left(1 - l^{\frac{1}{m}}\right),$$

and the ratio of both expressions becomes

$$\frac{1 - l^{\frac{1}{m}}}{1 - l^{\frac{1}{n}}}$$

which, as the total amounts of sulphur passing are not equal, must be multiplied by $\frac{n}{m}$ to represent the relative amounts of sulphuric acid made in the leading chambers of both systems. This gives the ratio of work done.

$$(6) \quad \frac{m}{n} \cdot \frac{\left(1 - l^{\frac{1}{m}}\right)}{\left(1 - l^{\frac{1}{n}}\right)} = \frac{m}{n} \cdot \frac{\left(1 - l^{\frac{1}{m}}\right)}{\left(1 - l^{\frac{1}{n}}\right)}$$

which is also the ratio of the amount of heat evolved, and, as we have just discussed, is also the ratio of the excess of temperature of the chambers.*

The product $m \left(1 - l^{\frac{1}{m}}\right)$ increases continually as m increases—in other words, the excess temperature

* In reading the paper the derivation of this formula was not given. I have added it here to meet a wish of Professor Schuster, F.R.S.

of a leading chamber is the higher the greater the number of chambers which are connected to one system.

As regards the production of sulphuric acid, it has not been found that the number of chambers connected to one system has any very great influence, and in various works we find series of chambers varying from a single chamber to ten or even twelve chambers. As far as I am aware, nobody has yet contended that a larger consumption of nitro is necessitated for a series of greater than for a series of a smaller number of chambers. But if a higher temperature in the chambers should be proved to be associated with a larger loss of nitrogen compounds, then the practical importance of these considerations is, that it is bad to have a large number of chambers

FIG. 3.

connected to one system, and if there is one temperature of a chamber which is better than another, then it follows that there is one particular number of chambers, and only one, which will give satisfactory results, or, what is practically the same, there must be one form of chamber, as regards ratio of surface to cubical capacity, which is better than any other. Table 3, graphically represented by diagram 3, shows the relative amounts of work done in leading chambers of various sets of chambers, and the corresponding temperature, calculated on the assumption that the temperature of a leading chamber of a set of two is 50° C.

TABLE No. 3.

No. of Chambers connected to one system.	Per cent. of total Acid made in leading Chamber.	Relative Amount made.	Temperature of Chambers.
1	99.5	100	30°
2	93.0	180	50°
3	82.9	249	60.3°
4	73.4	298	68.3°
5	65.4	330	73°
6	58.7	354	76°
7	53.2	378	79°
8	48.5	392	83°
9	44.5	405	86°
10	41.2	414	88°

As regards the influence of steam on the amount of chamber space, it must be borne in mind that at any given temperature the tension of aqueous vapour inside a sulphuric acid chamber is not that due to the presence of pure water but is that due to the presence of a fine mist of sulphuric acid of a given strength, and, consequently, is only a certain fraction of the tension of aqueous vapour in presence of water. What this fraction is, we learn from Regnault's determinations of the tensions of aqueous vapour in presence of sulphuric acid of different strength, which are contained in the following table:—

TABLE NO. 4.

Molecules H ₂ O on 1mol. H ₂ SO ₄ .	Per cent. of H ₂ SO ₄ in Acid.	Specific Gravity.	Vapour Tension.
	0	1.000	1.00
13	20.51	1.220	0.64
11	33.10	1.249	0.70
9	37.69	1.258	0.63
7	43.75	1.341	0.49
5	52.12	1.419	0.33
4	57.05	1.475	0.21
3	64.47	1.547	0.13
2	73.13	1.651	0.06
0	100.00	1.842	0.00

From these results I have constructed diagram No. 6, which permits to find approximately the vapour tension belonging to any intermediate strength

according to the formula (5), simply the product of the capacity of the chamber into the vapour tension (10) obtaining in this chamber.

But before we can know the absolute tension of vapour in a chamber we must know the temperature. When that is given we find the tension by multiplying the ordinary tension of aqueous vapour belonging to the given temperature by the fraction corresponding to the strength of vitriol made in that chamber, as found from diagram 6. Then we multiply the capacity of each chamber by its vapour tension, which gives the effective value of the chamber; and in order to find the work done after passing through the various successive chambers, we divide the horizontal line on diagram 1 into unequal parts, corresponding to the various effective values of the chambers, when we can read off the amount of acid made on the ordinates drawn to the various points obtained by this method; or we can calculate the result directly by assuming the total effective value of the chamber space of the system = Σe , and the effective values of the single chambers = e_1, e_2, e_3 , etc., by the formula—

$$(7) \quad P_{c,3} = 1 - \left(\frac{\Sigma e}{l} \right) e_1 + e_2 + + \dots$$

when $P_{c,3}$ means the amount of acid produced after the third chamber, when l is the loss of sulphur after the last, both l and P being referred to unity of either sulphur or acid. The following table shows the successive steps of such a calculation, l being assumed as 0.5% = 0.005. The first column shows the number of the successive chambers; their capacity

TABLE NO. 1.

Chamber No.	Temperature.		H ₂ SO ₄ Strength	Tension.			Effective Value.		Per cent. H ₂ SO ₄ made.		
	Excess.	Actual.		Relative.	Water.	In Ch.	C.	$\Sigma(e)$.	Calculated.	Nuclear.	Calculated.
1	45	65	155	.02	180	3.72	.736	.736	31.92	32.03	31.55
2	12.3	62.3	150	.03	162	1.86	.918	1.671	58.80	62.11	63.10
3	31	51.0	130	.06	111	0.66	1.300	2.971	79.3	80.13	81.50
4	9.7	29.7	61	.33	30	15.9	3.101	6.087	96.0	93.11	95.00
5	0.0	20.0	51	.32	20	8.3	1.621	7.702	98.3	98.11	98.00
6	1.9	21.9	58	.60	19.6	11.7	2.291	10.00	99.5	99.50	99.50
I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.

of acid. The abscissae represent degrees Twaddle, the ordinates give the corresponding relative vapour tension. As we see the vapour tension differs very much for different strengths of acid, we must, in

FIG. 6.

constructing a diagram of the works of a set of chambers, take notice of the strength of vitriol which each chamber is to produce. The value of each chamber as regards production of sulphuric acid is,

is assumed as equal. The second volume gives the excess of temperature of the chambers over the surroundings, which are assumed at 20° C., the excess being calculated, as before indicated; the third column gives the temperature of the chamber; the fourth column contains the proposed strength of the sulphuric acid to be made in each chamber; the fifth column shows the relative tension of aqueous vapour in presence of sulphuric acid of the strength proposed in column No. iv.; the sixth column contains the absolute tension of aqueous vapour for the temperature assumed in column No. iii.; and the next column (No. vii.) is the tension really obtaining in the chamber, being the product of the two previous figures; the next column (No. viii.) gives the effective value of the chamber (C), on the assumption that the total effective value of the six chambers is 10; the next column (No. ix.) shows $\Sigma(e)$; the following column (No. x.) gives the values calculated by formula (6) for the successive chambers; whilst column No. xi. shows the actual percentage of sulphuric acid made by a set of six chambers, producing acid of the strength proposed, as published

by Mr. Mactear, in his paper on "Some Recent Improvements in the Alkali Manufacture," read before the Society of Arts, May, 1878.

The temperatures are first calculated from the figures in column XI., so as to correspond as nearly as possible to the set of chambers the work of which is to be calculated. On comparing columns x. and XI. it will be found that they do not agree. The reason of this is that the fourth chamber is stated by Mr. Mactear to have made very dilute acid, only 64° Tw. strong. I think this figure standing in between 130° and 84° is an error. On the assumption that the acid in chamber No. 4 was 84°, the results of column XII. are calculated, and it will be seen that these results correspond much better with Mr. Mactear's own figures. The whole of these results are graphically represented by diagram No. 7, and I think this diagram does not place the theory into a bad light, considering the difficulties of exactly ascertaining the amount of sulphuric acid made by each of a set of chambers, and the fact that the geometric progression

FIG. 7.

on which the whole of the diagram is based is at best a rough approximation, as I have stated before.

It will be now easier to understand why the results of the works E, in table I, differ so much from the results of the other four works. The tension of vapour in works E was to that in works B, C, and D, as 0.18 is to .00, and to that of works A as 0.18 : 0.12, and hence it could readily give as good a produce as works A, with a chamber space which was as 16 : 23. Thus, in comparing working results, we must know chamber space, nitro used, strength of acid made, and loss of sulphur if we wish to arrive at valid conclusions.

I turn now to the concluding portion of this investigation, viz., the relation between chamber space and the amount of oxygen and sulphurous acid contained in the gaseous mixture. It is well known that opinion as regards the proper amount of oxygen which the gases ought to contain when leaving the chambers differs widely. Some hold 5 per cent., some 10 per cent., as the proper amount. For the purpose of ascertaining the composition of the gas which will yield a given produce in the minimum of chamber space, our formula for the chamber space No. 6 is not sufficiently accurate. It is absolutely necessary to consider the oxygen and the total volume of the

gaseous mixture as variable. I will not enter into minute details as to the transformation of formula 5, but state here the final result for the chamber space, which is a much more complicated expression than that of formula 5. It is for this reason that I have preferred, so far, the approximation to the correct expression. The former is easily applicable to numerical calculations, while the latter is very unwieldy and troublesome, and does not, as regards steam and nitrogen compounds, differ from the former. The expression is—

$$(S) C = k \cdot \frac{V}{ANW} \left[(B^2 \log \frac{SI}{Sc} - (B-A)^2 \log \frac{A+SI}{A+Sc}) + \dots \right]$$

where A and B are—

$$A = 0.12 - 3.533 S \\ B = 2 - 3 S$$

Equation (8) is not quite complete. I have omitted some terms which affect its value but slightly. In possession of this formula it is easy to ascertain for what percentage of sulphurous acid in the gas the chamber space becomes a minimum. The result of this calculation differs according to the circumstances of the working of different chambers. It is different for chambers working with brimstone or pyrites. It is slightly different for different kinds of pyrites. The constants in formula (8) are calculated for Spanish pyrites yielding 45 per cent. of sulphur as sulphurous acid, and 71.3 per cent. of burned cinders, both figures being averages of three years' work. For the results I am about to state it is further assumed that the same quantity of pyrites is burnt each day, and that the nitrogen compounds in the gas vary with the sulphurous acid in the gas, because the usual practice is to put so many pounds of nitro per ton of pyrites charged into the kilns.

The result arrived at in this way for the composition of the gas which demands the least amount of chamber space for the conversion of sulphurous acid into sulphuric acid is—

At inlet to chambers	SO ₂	8.11°
	O	10.15
	N	81.11
At outlet of chambers	O	6.78
	N	93.22

If, on the other hand, it is assumed that the colour of the gas at the outlet of the chambers is kept an equally deep shade of brown, the result is—

At inlet of chambers	SO ₂	6.07
	O	12.34
	N	81.00
At outlet of chambers	O	10.00
	N	90.00

And we may thus assume that the best composition of the gas lies between these two. Such an intermediate result is easily obtained from formula (8) by disregarding the factor in brackets, which is due entirely to the contraction of the volume of the gas. By doing so, and assuming that the nitrogen compounds vary in proportion to the sulphurous acid, the formula yields the following as the composition of the gas requiring a minimum of chamber space:—

At inlet	SO ₂	7.81
	O	10.92
	N	81.21
At outlet	O	7.16
	N	92.07

In all these analyses the sulphurous acid includes its equivalent of any sulphuric anhydride which may have been formed in the kilns.

The oxygen at the outlet is the best criterion for the proper composition of the gas.

Thus this theory has given a result for the best composition of the gaseous mixture intermediate between the various opinions regarding it. It may not be without interest to give an idea of the varia-

* Due to a suggestion of Professor Schuster, F.R.S.

tion of the chamber space which is necessary to insure an equally perfect production of sulphuric acid, as we depart from the best composition of gases on either side. Table No. 7 shows the amount of chamber space necessary to convert 99.5% of the sulphurous acid into sulphuric acid, on the assumption that equal amounts of nitre per 100 of sulphur are used, that the strength of the acid produced be the same, and that for the gas containing 6.66% oxygen at the exit exactly 16 cubic feet of chamber space per pound of sulphur or 1 cubic metre per kilogramme per 24 hours is ample. The last column of this table, on the other hand, shows how great the loss of sulphur would be if only 1 cubic metre chamber space per kilogramme of sulphur were at our disposal for all the different gaseous mixtures, supposing the loss with the best mixture to be $\frac{1}{2}\%$.

TABLE 7.

SO ₂ Inlet.	% O Outlet.	Chamber Space for 99.5% Loss of Sulphur.		Loss of Sulphur with 1 cub. metre.
		C. ft. per lb.	C. m. per kilo.	
4	14.77	41.00	2.563	12.66%
5	13.05	28.33	1.771	5.03
6	11.30	21.76	1.360	2.03
7	9.5	18.14	1.134	0.93
7.5	8.56	17.04	1.065	0.69
8	7.62	16.33	1.021	0.55
8.5	6.68	16.00	1.000	0.50
9	5.69	16.09	1.006	0.52
10	3.70	18.08	1.130	0.92
11	1.61	28.03	1.752	4.88

This table shows very distinctly that within from 6 to 10% of SO₂ at the outlet, or 11 to 4% oxygen at outlet, the loss of sulphur remains within those limits which usually occur in practice. Only when the composition of the gases varies very widely from that which the theory indicates and practice has found to be the best, only then the losses make themselves felt severely. Surveying the results we have arrived at we find that according to this theory (1) the work done by a given set of chambers depends upon the quantity of nitre used, and upon the strength of vitriol produced. (2) The work of the successive chambers of a series decreases nearly in geometric progression, and so does the excess of temperature of the chambers over the surroundings. (3) The temperature of a leading chamber depends upon the number of chambers which are connected to one system, or on the fraction of the chamber space which the first chamber represents. (4) The composition of the gases to yield a given produce with a minimum of chamber space is that which gives about 7.95% oxygen in the exit for Spanish pyrites as described. This application of a principle of chemical dynamics has given us in a comparatively short time, and with greater precision, results which it has otherwise taken a century's experience to arrive at.

APPLICATIONS OF THE WILSON GAS PRODUCER.

BY EDWARD CROWE.

A LONG experience with gas firing in the manufacture of glass and steel, and for other purposes requiring a high temperature, has conclusively proved that gas firing, coupled with regeneration, effects a saving of from 50 to 80 per cent. of the fuel necessary, as compared to ordinary coal firing. Even for steel melting and glass melting, however, where the saving is so great, gas furnaces have by no means supplanted

coal-fired furnaces, although they are rapidly doing so. The reason that the adoption of gas furnaces for such purposes has not been more rapid arises partly from the cost of the plant and partly from the large amount of room necessary for the gas-producing plant of the type mostly used in past years, and these reasons, coupled with the fact that non-regenerative gas furnaces have been seldom recommended, have up to recently almost precluded the adoption of gas firing as a general system applicable with great economy and advantage to manufactures of every kind. The speciality of the Wilson gas producer, a model of which is before you, is, therefore, to reduce first cost and space, for a given amount of work done in a given time, and to utilise the cheapest fuel for firing both regenerative and non-regenerative furnaces and boilers. The old form of gas producer gasifies coal at the rate of about 13lb. per square foot of grate area per hour, whilst the Wilson gas producer gasifies fine slack at the rate of from 26lb. to 30lb. per square foot of hearth area per hour. Referring now to the model and figure, the producer may be described as follows: It is about 8ft. external diameter and 10ft. high, consisting of an iron casing lined with brickwork, without any grate bars. A box runs across the centre of the hearth having tuyeres in its sides, and two doors are provided, one at each side the central tuyere, for removing ashes and clinkers. The air is forced in by two small steam jets, each blowing down a taper pipe outside, as shown. The upper portion of the producer forms a kind of retort, with an annular flue communicating with a branch pipe through which the gas escapes. At the top there is a bell and hopper for charging the fuel. The action of the producer may be thus briefly described: The interior is nearly full from top to bottom of coal which rests on the solid hearth. Into the centre of this mass of fuel, near the hearth and as far as possible from the side walls, air and steam are injected from each side of the central tuyere, which communicates with the steam jet blowers outside. A rapid combustion takes place in the vicinity of the tuyere, where the carbon is decomposed into carbonic oxide at a bright red heat, and with the hydrogen also decomposed from the steam passes upwards and escapes by the outlet ports into the annular flue surrounding the top portion of the chamber. The coal is charged from time to time, say every half-hour, through the bell and hopper at the top, and the hydrocarbons are for the most part distilled in the retort portion, which is above the ports, and have to pass downward to escape, along with the carbonic oxide and hydrogen from the bottom. The top portion of the fuel is comparatively cool, because the hot gases from the bottom do not pass through it, and hence the distillation of the hydrocarbons is gradual and uniform—no great flushes of gas occurring just at the moment of charging. This conduces to regularity in the production of gas, and has the further advantage of causing a decomposition of the tarry gases in their passage downwards, through a hot layer of fuel, so that they do not afterwards readily deposit tar. To obviate confusion between similar designs, it may here be remarked that the special arrangement of the Wilson producer was patented in 1876. The comparatively small first cost, and small space necessary for the establishment of this gas producer, coupled with the advantages of delivering the gas hot and under a positive pressure, have accelerated its adoption in many instances where the more cumbersome and costly arrangements hitherto generally used were considered inadmissible. Thus the great advantages of heating by gas are obtained for purposes of a very varied character, and these advantages are now further developed by newly designed methods of

application, not before in practical use. Before describing some of these particulars in detail, a few remarks on the subject of the regeneration of heat may be admissible, as this subject is of so much importance in connection with certain applications of gas for furnace purposes. Regeneration is understood to imply "any means for recovering waste heat." The regenerator introduced by Dr. Siemens, consisting of chambers containing loosely stacked firebricks through which the waste gases and the air and gas for combustion are alternately passed, may be termed the "reversing surface regenerator." It is the form used in open hearth steel melting, and many glass furnaces. It is the most perfect form of regenerator, but the complication of the reversing valves and the cost of its establishment seem to limit its use to those furnaces only in which the very highest temperatures are absolutely necessary. There are several other forms of regenerator of a simpler type, which, although incapable of producing steel melting heats, are nevertheless workable and desirable forms for ordinary purposes. A regenerator should be applied, if possible, to every furnace, from which the waste gases pass to the chimney at more than 600° Fahrenheit. What is required, is a simple means of transferring heat from waste gases to the air for supporting combustion, without reversing valves, occupying little room, and not of great cost. To fulfil these conditions the regenerator must be of the continuous conductor type, not of the reversing surface type. The continuous conduction may be either through iron or through brick—both answer well under different conditions. A furnace with continuous conduction regenerator in brickwork is to be further referred to presently. If brick walls are used for transferring the heat, by conduction from the waste gases to the air, the furnace must be worked by draught, and a high temperature may be obtained—in fact, in the Ponsard steel furnace, with continuous regenerator of hollow bricks, a sufficiently high temperature for steel melting is obtained, but if cast-iron pipes are used the air must be forced through them, by a fan or blower, in order to transfer the heat rapidly. Iron pipes exposed to waste gases, so as to heat the air passed through them to 1,000° Fahrenheit, will stand for years, if the air is forced so as to secure a constant current, and consequent uniform withdrawal of heat from the pipes. It should be clearly understood that the regenerator principle in any form is not a necessary accompaniment of gas firing for many purposes—regeneration is a means for obtaining very high temperatures, and also a means for obtaining economy at lower temperatures—but for applying gas to many purposes it is not at all essential to heat the air previous to combustion. For instance, in applying gas to boilers the temperature is quite high enough by admitting the gas with cold air at the front—and a Green's economiser is the best regenerator—an application to a salt pan, or to any evaporating process, is under the same conditions. In describing certain of the numerous applications which are at work by the Wilson gas producer, those may be first noticed which have surface regeneration by stacks of brickwork. One of the most important of these is in the manufacture of Siemens steel, in the open hearth furnace, according to Dr. Siemens's arrangement. The make of this excellent material is increasing largely every year, and as several works applied the Wilson producer to these furnaces with marked success, there is now a considerable number in addition being erected for the purpose. The Monk Bridge Iron Co., Leeds, have also adopted this producer for working pot furnaces, in the manufacture of their celebrated crucible steel tires, etc., while Messrs Robert

Heath and Son, Stoke-on-Trent, have applied it to regenerative pile-heating furnaces, designed for their rolling mills, and have expressed their entire satisfaction with the result. They use fine slack coal, and only one-half the weight of what they previously used of large coal. Messrs. Russell and Co., Walsall, have applied six of these producers to their regenerative tube-welding furnaces. Turning to the manufacture of glass, which may be more familiar to some present, it may be stated that Messrs. Pilkington and Bros., St. Helens, conspicuous as usual for their well-rewarded enterprise, were amongst the first to adopt this producer on a considerable scale, and have now erected 16 of them in their sheet and plate glass works. Another very interesting application of this producer in connection with a reversing current surface regenerating furnace, has been made in smelting nickel ore in Birmingham. The nickel-smelting furnaces of Messrs. Henry Wiggin and Sons, were fired by large coal in the ordinary manner like copper-smelting furnaces. The regenerative gas furnace which they now use saves them 75 per cent. in cost of fuel over the old method, in addition to other advantages. The regenerative chambers do not stop up with dust from the ore, the special arrangement of the furnace preventing it. Gentlemen who are copper smelters say they are quite wishful to use gas for their smelting furnaces, but they cannot get them hot enough without regenerators, and the regenerators must stop up with dust from the ore. Now if an arrangement prevents a regenerator from stopping up when working nickel ore, it is submitted that the same might apply to copper ore. But to remove this ground of objection, Mr. Wilson has designed the copper-smelting furnace, with continuous wall regenerator. This cannot clog up, but if there is any deposit, it may be removed by a scraper from one end. As far as at present appears, our British copper smelters are quite content to be led by a restless American company in probing this matter to its utmost solution. In steel-melting and glass-melting furnaces, the temperature is so high that fire bricks of highly-approved marks for most purposes, will not stand, and resort is had to a brick composed as nearly as possible of pure silica. These contain 96 to 97 per cent. of silica, if of proper quality, with 1 to 2 per cent. of lime, to cause cohesion, and only small fractions per cent. of soda, potash, and other fusible bases. The silica-gamister brick stands the best for crowns of regenerative furnaces, for the very highest temperatures, but they expand very much with heat, and are liable to destruction by disintegration from the effects of heating and cooling. For hard wear and endurance under very high temperature and resistance to the effects of heating and cooling the Glenboig star fire bricks have earned the highest reputation. The fluxing action of alkalis on firebricks at a high temperature has undoubtedly acted as a check on the adoption of regenerative arrangements to chemical furnaces. Basic bricks are now, however, becoming an ordinary marketable product, and it is likely that by the judicious use of these bricks, simple regenerative arrangements may be applied to black-ash furnaces, with economical results. Passing now to applications with regeneration on the continuous conduction plan, the copper smelting furnace may be taken as a type. In this case the waste gases and the air for subsequent combustion pass through channels below the furnace separated by walls, and the air receives heat by continuous conduction through the brickwork, the draught from the chimney being relied upon to pull the air through the flues. Some furnaces are at work on this plan, for various purposes, which have given very satisfactory results with the brick division 9 in. thick. For higher temperatures, several furnaces are now constructing

in which the gas for combustion is passed through brickwork channels on this plan, so that the waste gases give up their heat first to the gas, and subsequently pass over a stack of cast-iron pipes to heat air, which is forced through them by a blower, and afterwards mixed with the gas, on the blow-pipe plan. Allowing the waste gases from a high temperature furnace to first heat gas by conduction through brickwork deprives them of the keenness of their heat, so that they are then suitable for heating blasts in iron pipes before passing to the chimney. In case they are not cool enough to safely pass the iron pipes, a by-pass flue is provided to allow a portion of them to go direct to the chimney, the respective flues being regulated by dampers. In pottery furnaces the system of heating is of considerable interest. Biscuit ware, which has been covered by a coating of silicates and oxides in a ground state, has to be brought to a very high temperature to flux the glaze and run it over the surface of the ware in an even manner. Each kiln is in the form of a muffle, and the flame surrounds the muffle but does not enter it. The muffles are about 7 ft. long, 6 ft. high, and 3 ft. broad, and are packed full of ware from bottom to top, resting upon shelves and supports. There is a longitudinal combustion chamber below the floor of the kiln, and the gas and air are mixed at one end of this on the blow-pipe system, which injects a very hot clear flame along under the muffle, and the gases pass up its sides through the hollow bricks into a flue running along the top. Before the waste gases reach the chimney, however, they are conducted over a stack of cast-iron pipes, through which the air from the blower is passed on its way to the blow-pipe. The air is heated in this manner to about 800° F. without any risk of injuring the cast-iron pipes. The blow-pipe nozzles are about 8 in. diameter, and the temperature in the combustion chamber is probably sufficient to melt steel. Starting with all cold, a kiln of ware is by this means heated up throughout to a very bright red heat in about eight hours, the heat being entirely transmitted to it by conduction through the walls of the kiln. Although in the vicinity of such a high temperature the cast-iron blow-pipes do not suffer at all, owing to the cooling effect of the gas and air enveloping them up to the point of combustion, and the hottest part is some 3 ft. or 4 ft. from the blow-pipe end. This system of combustion on the blow-pipe plan for heating large furnaces, although for such purposes as yet but recently introduced, is destined to be largely adopted. Most gentlemen present are aware of the beautiful control over temperature, oxidising or reducing atmosphere, etc., which is had by the miniature blow-pipe. This great facility of manipulation and wonderful control may be equally obtained for large furnaces by gas from the Wilson producer and with a Root's blower. Smoke is, of course, absolutely avoided—in fact, it is not possible to tell there is anything whatever proceeding from a chimney top to which these blow-pipe furnaces are attached. Mr. Howson, of Middlesbrough, was the first to practically demonstrate the great advantages of this plan of combustion on a commercial scale in connection with his revolving puddling furnace. Messrs. Charles Tennant and Co., of St. Rollox, Glasgow, have had a couple of these producers working some time. They are applied to a Mactear decomposing furnace, the mechanical arrangement of which will have struck any gentleman who has seen it. Common slack coal, costing 3s. 6d. per ton delivered, was at once substituted for coke, and the quantity used does not exceed 5 cwt. per ton of salt-cake. The make of the furnace at first somewhat fell off, but a little modification of the gas burners has been made, and Mr. Mactear now authorises the statement that

the make of salt-cake is up to the highest make with coke, namely, a little over 1 ton per hour. The air for burning the gas is heated to about 600° Fahrenheit, by a simple arrangement of cast-iron pipes, exposed to a separate gas jet. Mr. Gamble, of St. Helens, introduced this plan for heating air for chemical furnaces some ten years since. The Wilson producer is also used for distilling phosphorus; by sugar refiners, at Greenock, for revivifying animal charcoal in retorts; and is being applied for distilling oil, making spelter from the ore, reducing cryolite, and amongst other things, mention of the application for firing boilers must not be omitted. The use of gas for boiler firing, though necessarily slow of introduction, is destined, in the author's opinion, ultimately to become general. The gas is carried by preference below ground in a culvert, this is the cheapest plan of distribution, and prevents loss by radiation. This gas producer is at work raising steam in Cornish, Lancashire, and plain cylindrical boilers; and before long, evidence in favour of the economy and advantages of the system for steam raising is likely to be available from so many quarters as to satisfy all inquirers. Mr. Beeley, the eminent boiler-maker, of Hyde, is now making five very large boilers, to the order of a cotton-spinning firm, which are to be fired on this system, and by the blow-pipe arrangement. In this case, at any rate, smoke will be next to impossible.

MEETINGS OF THIS SECTION.

UNIVERSITY COLLEGE, ASHTON STREET, LIVERPOOL.
Third Wednesday in the month, viz., 10th April, 1882.
7.30 p.m.

PAPER:

On 19th April: "On the Abatement of Smoke in Furnace Fires," by Mr. A. Norman Tate, Liverpool.

Communications.

SOCIETY OF GERMAN ALKALI MAKERS.*

BY PROF. LUNGE, OF ZURICH.

X.—DETERMINATION OF LIME AND OF CAUSTIC ALKALIES IN PRESENCE OF CARBONATES.

For the quantitative analysis of a mixture of alkaline hydrate and carbonate, one of two methods has been usually employed, viz., either precipitating with barium nitrate, and estimating the alkali in the filtrate, or titrating the barium carbonate precipitated; or, secondly, a direct determination of the carbonic acid by expulsion. Although the latter method is the more tedious, it is often preferred, on account of the difficulty experienced in the former of avoiding the error due to the action of atmospheric carbonic acid, which, in a works laboratory, is often very great.

Quite recently a process has been devised by Degener (*"Zeitschr. d. Ver. f. d. Rubenzucker Industrie,"* May, 1881, p. 357; abstract *Chemiker Zeitung*, 9th June, p. 400), based upon the property of a certain reagent, of giving colour reactions with the caustic alkalies distinct from those of their salts, including the carbonates. The subject appeared to deserve investi-

* Report presented at their General Meeting, 18th September 1881.