Although the types of soil such as are found in Hawaii may not occur in this country, on account of the simplicity and convenience of the ammonium carbonate method it was thought desirable to secure such a modification as would include such soils.

The soils used in this study were Hawaiian soils kindly furnished by Mr. McGeorge. After a number of trials to ascertain the most suitable conditions, the following method was adopted:

Prepare the solution as described in the official method, but decant the solution instead of filtering. Place 100 cc. in a graduated flask, add 2 grams ammonium carbonate, and heat on the steam bath for one hour. Allow to stand over night, pipette off 50 cc. of the supernatant solution, and evaporate to dryness in a tared dish. Dry three hours at 100° C., weigh, ignite, and weigh again. The loss in weight represents the humus.

The results for humus and humus ash are shown in the table along with the humus and ash by the official and original ammonium carbonate methods. All determinations here reported were made on the same solutions.

Method	No. 6185		No. 6187	
	Humus	Ash	Humus	Ash
Official.....	5.44	7.90	7.31	34.80
Ammonium carbonate.....	5.16	6.68	5.13	17.20
This modification.....	3.80	0.18	2.70	0.10
	3.68	0.40	2.75	0.18

The original ammonium carbonate method reduced the ash by about 15 per cent. in No. 6185 and by about 50 per cent. in No. 6187. This modification of the ammonium carbonate method reduced the ash in sample No. 6185 from 7.90 to 0.29 per cent., and in No. 6187 from 34.80 to 0.14 per cent.

The humus which was 5.44 per cent. in No. 6185 by the

official method was reduced to 3.74 per cent. by this modification of the ammonium carbonate method, and in No. 6187 was reduced from 7.31 to 2.73 per cent. The differences do not represent humus, but are probably entirely due to the loss of water on ignition of the hydrated clay and oxides of iron and aluminum.

The solutions obtained by this modification were free from all turbidity. It was found that with these soils the clay could not be filtered off and the aliquots were therefore removed with a pipette. The introduction of the ammonium carbonate increases the volume of the solution, and after standing over night, it is about 100.5 cc. This would make the results about 0.01 per cent. too low (in percentage of humus in soil). Since this is well within the limit of error with these soils, it is disregarded.

The Hawaiian soils studied are said to be of volcanic origin and are very rich in iron. Although the original ammonium carbonate method gives unsatisfactory results with these soils, we believe soils of this type will rarely be met with in the United States, since as stated before the method has given entire satisfaction on a number of the soil types of this country.

SUMMARY

The ammonium carbonate method for the removal of clay from humus solutions has given uniformly good results on a number of the soil types of the United States, but on exceptional soils, like some of those of Hawaii, a slight modification of the method is necessary to remove the clay. The modification consists essentially in increasing the amount of ammonium carbonate to 2 grams per hundred cubic centimeters, and heating for one hour.

TEXAS AGRICULTURAL EXPERIMENT STATION
COLLEGE STATION, TEXAS

LABORATORY AND PLANT

THE NEW HIGH FORM OF SULFURIC ACID CHAMBER

By F. J. FALDING AND W. R. CATHCART

Received January 20, 1913

Since the Sulfuric Acid Chamber-process has existed, the two important factors which have been uppermost in the minds of manufacturers, engineers, and chemists, are: *First*, economy of chamber space, which of course means economy of lead; and *Second*, economy of nitration. These economies have been accomplished in a very high degree and in a most satisfactory manner, by the use of a new form of lead chamber, which embodies a scientific principle heretofore ignored on account of a misconception of its importance.

HISTORICAL OUTLINE OF THE LEAD CHAMBER

The evolution of the Chamber-process is well known. At first intermittent—then continuous but without recovery of nitrogen oxides—next the addition of

Gay-Lussac towers, and finally the Glover tower.

The chambers, however, have been always simply a series of enlargements of the flue or gas conduit connecting, at first, the sulfur burners with the outer air or exit, and later the Glover and Gay-Lussac towers. These enlargements of the flue retarded the speed of the gases, permitting them to mingle and react.

As the chambers have been almost universally framed with timber construction, the height and width have varied principally in conformity with considerations of carpentry, a width of thirty feet and a height of twenty-four feet having been rarely exceeded; whereas a length of one hundred to two hundred feet or over, for each chamber, used to be quite common. Lead chambers have been constructed empirically, and of many shapes and sizes. Sometimes the gas would pass through from four to ten chambers in series having a total length of from four hundred to one thousand feet in all.

The principal dimension of the chamber space has been always the horizontal axis in the same direction as the travel of the gas.

¹ Covered by U. S. Patent No. 932,771 and Canadian Patent No. 124,132; owned by the Chemical Improvement Company, 220 Broadway, New York City. Also patented in England, Germany, France, Belgium and other countries.

It is an admitted observation that, irrespective of the length of the first chamber of a series, all the active work of such a chamber is performed within the first thirty or forty feet of its length. The remainder of the chamber is practically inactive, and reaction is not resumed until the gas has been again mixed by passing through a comparatively small flue or special apparatus in the nature of a surface condenser, when a new zone of activity is induced in a succeeding chamber. The condition existing in the first chamber is reproduced, but in a lesser degree of intensity, due to the diminished percentage of the sulfur dioxide content of the gas, as evidenced by a reduced temperature of the active zone. The same conditions with increasing reduction of activity apply to all subsequent chambers of the series, until the absence of sulfur dioxide in the final chambers sometimes actually permits

space. These attempts have been known as efforts "to reduce the chamber space." Among the schemes tried are the following:

(1) The French "système intense," the principle of which is to increase the proportion of nitrous oxides to the sulfur dioxide in circulation—thereby increasing the speed of the initial reaction.

(2) Shortening the first chamber and passing the gas through surface or spray condensers before admission to succeeding chambers so as to increase the intensity of secondary reactions (Lunge plate columns, Gilchrist pipe columns, Hoffmann intensifiers, Pratt converters, etc.).

(3) Division of the initial volume of gas into two or more chambers in parallel instead of in series with a reduction of the secondary chamber space.

(4) The Meyer tangential admission of the gas into

Diagram of the recent plants. The Vandergrift plant has only one cooling tower and no Peterson Regulator.

the conversion of the nitrous gases into nitric acid and nitrogen peroxide, causing severe losses of niter and rapid destruction of the lead. It has even been the practice in some cases to admit a fresh supply of burner gas into the last chamber to counteract such conditions. (Benker.)

Mention should be made of the fact that, in earlier days, the chamber space consisted in some instances of a single, long, horizontal chamber, and, that the reaction was completed in this chamber, and to that extent was quantitative. This was accomplished, however, at so great an expense of chamber space relatively to the volume of gas reacting, that it was long since discontinued and a series of chambers adopted.

In recent years various attempts have been made to secure a quantitative reaction, or at least an intensive reaction in the first part of the chamber

cylindrical chambers working on the assumption that the spiral passage of the gas near to the cool chamber sides would accelerate the reaction.

Most of these propositions have produced considerable economies but none have been entirely successful. The first reaction has not been quantitative and the inert gas leaving the first zone of reaction has contained sufficient unoxidized sulfur dioxide to make succeeding chambers, with further zones of reaction of decreasing intensity necessary.

The first considerable alteration in the shape of the lead chamber was introduced by Dr. Theodor Meyer in January, 1900. To use his own words, quoting from a pamphlet issued by him at Halle in 1907: "A tangent chamber is a hollow cylinder of approximately the same diameter and height, whose feed pipe is attached near the top in the direction of a

tangent, and whose exhaust pipe is in the center of the floor of the chamber. An important factor in a large capacity is the height of the chambers (as I considered probably as early as 1900), for the highest capacity is shown by those two plants, whose chambers are highest: Griffith & Boyd, Baltimore, and Guilini Works, Ludwigshafen on Rh. (with 35 and 42 feet height). The height of the old oblong chambers has also been increased lately. Hartman & Benker built theirs up to 32.8 feet high. While this figure, however, is near the limit of profitable use of chamber-room (for oblong chambers), there is no such limit to the tangent chambers, for it is only necessary to keep width and height in proper proportion. If a chamber were to be changed into a tower the consequence would probably be a gradual retardation of

As regards the Benker chambers, Lunge¹ quotes from a personal communication from Benker, who states he "employs only narrow chambers, say 18 to 20 feet wide, and from 25 to 33 feet high. Such chambers are, in the first instance, better adapted for water spraying, but they also afford a better mixture of the gases, especially if the sides are cooled, by employing an open bratticing for the side passages (2½ in. laths with 1½ in. clear space) and a roof-rider. The cold gases descending along the sides must rise again in the center; but in the case of very wide chambers a dead space remains where the velocity is very slight, and where the mist of nitrous vitriol sinks down without acting on the gaseous constituents. Benker objects to Meyer's tangential chambers that there is no question of tangential action, that in the center of

ALGOMA STEEL CORPORATION, LIMITED—COKE PLANT DEPT., SAULT STE. MARIE, ONT.
Daily Report of Sulfuric Acid Plant, for 24 hours ending 7 A.M. Sunday, Dec. 29, 1912

Hour ending	Furnace Gas Per cent. SO ₂ Station 1	Niter (NaNO ₂) Pounds	Glover Bottom		Peterson regulator Percent. N ₂ O ₃	Gay-Lussacs Percentage N ₂ O ₃		CHAMBER							Drips ° B.
			° F.	° B.		No. 1	No. 2	Temps. at stations, ° F.			Difference, ° F.				
								1	2	3	1-2	2-3	1-3		
8 A.M.	7.5	4	232	58	5.00	2.00	0.87	167	147	65	20	92	102	46½	
9 A.M.		4	232	58	5.00	2.00	0.87	165	147	67	18	80	98	46½	
10 A.M.	7.5	4	232	58	5.00	2.00	0.50	167	149	69	18	80	98	47	
11 A.M.		4	236	58	5.00	2.00	0.50	168	150	69	18	81	99	47½	
12 Noon.	7.5	4	237	58½	5.00	2.00	0.50	170	153	69	17	84	101	47½	
1 P.M.		4	237	58½	5.00	2.00	0.50	175	156	69	19	87	106	48	
2 P.M.	7.5	4	237	58½	5.00	1.86	0.50	176	158	69	18	89	107	48	
3 P.M.		4	237	58½	5.00	1.86	0.50	179	160	69	19	90	109	50	
4 P.M.	7.5	4	237	58½	5.00	1.86	0.50	180	160	70	19	90	109	50	
5 P.M.		4	236	58½	4.60	1.86	0.50	181	162	71	19	90	109	51	
6 P.M.	7.5	4	236	58½	4.60	2.00	0.45	183	162	72	21	90	111	49	
7 P.M.		4	236	58½	4.60	2.15	0.50	183	163	72	20	91	111	48	
8 P.M.	7.5	4	236	58½	4.60	2.15	0.50	183	163	72	20	91	111	48	
9 P.M.		4	236	58	4.60	2.15	0.50	183	163	72	20	91	111	48	
10 P.M.	7.5	4	237	58	4.60	2.15	0.50	184	164	73	20	91	111	48	
11 P.M.		4	237	58	4.60	2.15	0.50	185	166	73	19	93	112	48½	
12 Midnight.	7.5	4	237	58	4.60	2.15	0.50	186	167	74	19	93	112	48½	
1 A.M.		4	237	58	4.60	2.15	0.50	186	167	74	19	93	112	48½	
2 A.M.	7.5	4	237	58	5.00	2.00	0.50	186	166	74	20	92	112	48½	
3 A.M.		4	237	58	5.00	2.00	0.63	184	165	74	19	91	110	48½	
4 A.M.	7.5	4	236	58	5.00	2.00	0.63	182	163	73	19	90	109	49	
5 A.M.		4	235	58	5.00	2.00	0.63	175	159	72	16	87	103	48½	
6 A.M.	7.5	4	235	58	5.00	2.00	0.63	174	158	72	16	86	102	48	
7 A.M.		4	235	58	5.00	1.86	0.61	175	158	72	17	86	103	47	
Total.		96													
Average, 24 hours.	7.5		58		4.85	2.02	0.60	178	159	71	19	88	107	48+	

RAW MATERIAL USED

Name of ore—"Helen Mine."
Pounds charged in 24 hours—20,700
Per cent. NaNO₂ on S—burnt, 1.16

Per cent. S—40.34
Per cent. S available—40
Per cent. S in cinder—0.36 A.M., 0.4 P.M.

the spiral-movement toward the lower part. The best ratio is an approximate equality of diameter and height."

This proportion has been observed in all his installations. In the United States the Griffith & Boyd chambers are 33 feet diameter and 35 feet high and the chambers of the Mountain Copper Company in California are 39.4 feet wide by 42.6 feet high.

Again to quote from Dr. Meyer: "Aside from the small end chambers the most rational shape and size of a tangent chamber is a cylinder of 32 ft. to 48 ft. height and with a capacity of 28,000 to 72,000 cubic feet." This would give respectively a diameter of 33.5 feet and 44 feet.

these circular chambers gases of different concentrations get mixed up, and that they would be too expensive if the only proper way was followed, *viz.*, building many small circular chambers in a set."

Neither in the case of Meyer or Benker does the question of the convection currents seem to have been seriously considered. Benker's chambers are of the long horizontal type 75 to 85 feet long and are arranged in a series of three chambers.

Meyer evidently considered that the question of height is merely a question of chamber space and says that "If a chamber were changed into a tower the consequence would probably be a gradual retarda-

¹ "Sulfuric Acid and Alkali," Vol. I, 3rd Ed., page 459.

tion of the spiral movement toward the lower part." He therefore increases the diameter in proportion with the height.

In this short history of the lead chamber, it has not, of course, been possible to mention all the forms of chambers which have been used at different times, but it is submitted that they all contain the same defect, in that they practically ignore the convection currents of the reacting gases, that they are all virtually enlargements of the horizontal axis of the flue and that they all involve a series of reaction zones of decreasing intensity.

The practical ignoring of the laws of convection is responsible for the comparative failure of the above described forms of chamber construction.

THE THEORY OF THE HIGH CHAMBER

The technical gas mixture admitted to a chamber

process. This 5 per cent. excess oxygen will be found in the exit gases.

During the passage of this gas mixture through the Glover tower the percentage of sulfur dioxide it contains is further reduced by partial oxidation to the trioxide (SO_3) and partly by the addition of nitrous oxides, and partly by water vapor derived from the evaporation taking place in the Glover.

The gas on leaving the Glover tower enters the lead chambers, and just at this point it is better fitted in every respect to react rapidly and quantitatively, than it will be at any subsequent stage of its passage toward the exit; and any means that can be devised for holding the active zone at this point, until the reaction is completed, and securing a rapid separation of the inactive from the active gas, permitting only the inactive gas to go forward to the Gay-Lussac

TENNESSEE COPPER CO. ACID CHAMBERS, SHOWING STORAGE TANKS (7000 TONS) AND GAS FLUE

sulfuric acid system is diluted with a large percentage of nitrogen. This nitrogen takes no active part in the chemical reactions, but absorbs and carries away a large amount of the heat of the exothermic reactions taking place in the chamber.

A good technical gas mixture, when produced from the oxidation of pyrite, will contain approximately, omitting minor impurities:

	Per cent. volume
Sulfur dioxide.....	7.5
Oxygen.....	9.0
Nitrogen.....	83.5
	<hr/> 100.0

Such a gas mixture will contain oxygen sufficient for the oxidation of the sulfur dioxide to the trioxide, and also provide the necessary excess of 5 per cent. of oxygen for the satisfactory operation of the chamber

towers and exit, will surely be advantageous.

Remembering that the gas mixture under consideration is dilute in active constituents and contains a large percentage of nitrogen which does not enter into the reaction at all, and that the reactions entered into by the active gases are strongly exothermic, it follows that if proper opportunity is given for the action of convection, there will result a rapid and complete separation of the heat-producing gases and the inactive and non-heat-producing gases.

To secure this separation by convection would clearly necessitate increasing the height of the chamber in relation to the horizontal sectional area so as to allow relative zones of reaction and inaction therein, the incoming gas being admitted to the zone of reaction, and the outgoing gas being drawn from the zone of inaction.

The horizontal sectional area of the chamber would have to be proportionate to the volume of gas admitted and the height proportionate to the time necessary for the quantitative reaction of such volume, and the gas travel would be vertically downward, subject to convection currents, instead of horizontally forward.

Bearing these considerations in mind, it becomes clear what may be the effect of increasing the length of the vertical axis of the chambers or, in other words, the height in relation to other dimensions.

The gas mixture, admitted to the chamber, immediately sets up a strong exothermic reaction. If the chamber is high, convection currents will be induced and the reacting gas will immediately tend to rise

THE RESULTS OF THE HIGH CHAMBER IN PRACTICE

The considerations which have been mentioned appeared to have such force, that in March, 1905, these views as to this high chamber construction were placed before the United States Steel Corporation, who were about to erect a sulfuric acid plant. They decided to adopt this construction and a plant was ultimately erected at Vandergrift, Pa., consisting of one chamber 50 feet square by 70 feet high, together with one Glover, two Gay-Lussacs and a small unpacked cooling tower 9.5 feet square by 50 feet high located between the chamber and the Gay-Lussac towers. This plant was put into operation on January 1, 1907, and the results amply justified expectations, and proved the following facts:

ALGOMA STEEL CORPORATION, LIMITED—COKE PLANT DEPT., SAULT STE. MARIE, ONT.
Daily Report of Sulfuric Acid Plant, for 24 hours ending 7 A.M., Jan. 19, 1913

Daily Report of Sulfuric Acid Plant, for 24 hours ending 7 A.M., Jan. 19, 1913															
Hour ending	Furnace gas Per cent. SO ₂ Station 1	Niter (NaNO ₃) Pounds	Glover Bottom		Peterson regulator Percent. Na ₂ O ₃	Gay-Lussacs Percentage Na ₂ O ₃		CHAMBER							Drips, ° B.
			° F.	° B.		No. 1	No. 2	Temps. at stations, ° F.			Difference, ° F.				
								1	2	3	1-2	2-3	1-3		
8 A.M.	7.5	8	241	59	4.3	2.90	0.61	180	161	79	19	84	101	47	
9 A.M.		8		59				176	156	78	20	78	98	47	
10 A.M.	7.5	7	240	59	4.3	2.80	0.58	172	154	78	18	76	94	46½	
11 A.M.		5		59				174	154	77	20	77	97	46½	
12 Noon	7.5	4	240	59	4.3	2.33	0.57	174	154	77	20	77	97	46½	
1 P.M.		4		59				176	157	76	19	81	100	47	
2 P.M.	7.5	4	240	59	4.3	2.33	0.56	178	158	76	20	82	102	48	
3 P.M.		4		59				178	159	76	19	83	102	48	
4 P.M.	7.5	4	240	59	4.3	2.33	0.50	178	159	76	19	83	102	48	
5 P.M.		4		59				178	159	75	19	84	103	48	
6 P.M.	7.5	4	240	59	4.3	2.33	0.46	178	159	75	19	84	103	48	
7 P.M.		4		59				178	158	75	20	83	103	48	
8 P.M.	7.5	4	240	59	4.3	2.33	0.50	178	158	75	20	83	103	48	
9 P.M.		4		59				176	155	73	21	82	103	47	
10 P.M.	7.5	4	240	59	4.3	2.33	0.46	176	155	73	21	82	103	47	
11 P.M.		4		59				176	156	73	20	83	103	47	
12 Midnight	7.5	4	240	59	4.6	2.33	0.46	176	157	73	19	84	103	47½	
1 A.M.		4		59				176	157	73	19	84	103	47½	
2 A.M.	7.5	4	238	59	4.6	2.54	0.56	178	158	73	20	85	105	47½	
3 A.M.		4		59				178	159	73	19	86	105	47½	
4 A.M.	7.5	4	238	59	4.6	2.54	0.62	178	159	74	19	85	104	48	
5 A.M.		4		59				172	153	77	19	76	95	48	
6 A.M.	7.5	4	240	59	4.6	2.54	0.72	177	158	78	19	80	99	46	
7 A.M.		4		59				178	160	78	18	82	100	45½	
Total		108													
Average, 24 hours	7.5			59	4.4	2.47	0.55	177	157	76	20	81	101	47¼	

RAW MATERIAL USED

Name of ore—"Helen Mine."	Per cent. S—40.34
Pounds charged in 24 hours—21,000	Per cent. S available—40.00
Per cent. NaNO ₃ on S—burnt, 1.29	Per cent. S in cinder—0.32 A.M., 0.42 P.M.

DIARY

Chamber man increased soda from 4 to 6 lbs. during night. This was not necessary. Took it off first thing this morning.
The 172° top temperature at 5 A.M. was due to pump breakdown. Had no acid upstairs to run over Glover tower.
W. E. T.

and to remain at the top so long as the reaction goes on, only the inert, non-reacting, non-heat-producing, and therefore cooler gases tending to return to the bottom of the chamber. If the relationship of the height to the area and the volume of gas admitted is correct, the reaction taking place in the chamber will be quantitative and the gas drawn from the chamber at the bottom will consist entirely of nitrous compounds and inert nitrogen with some oxygen. In other words, the process will be completed in one chamber and the necessity of further chambers (which cost just as much as the first active chamber) for more and more sluggish processes (or decreased efficiency in work done) will be obviated and a great economy in cost of chamber space will be secured.

(1) A large production of sulfuric acid with a minimum of chamber space.

(2) A quantitative reaction in the single chamber, the SO₂ being completely converted in the chamber itself as proved by tests at the chamber exit.

(3) An insufficiency of cooling capacity—the gases on leaving the cooling tower being too hot and too moist to permit the best work in the Gay-Lussac towers.

(4) That in spite of this insufficiency of cooling capacity a reasonable consumption of niter could be attained—*i. e.*, an average between 2 and 3 per cent. of NaNO₃ based on the sulfur burned, while frequently for days together the consumption of NaNO₃ did not exceed 1.5 per cent. The insufficiency of

cooling capacity clearly interfered with a maximum output of product and a minimum consumption of NaNO_3 .

Before this plant had been completed, the Tennessee Copper Company, who were being pressed by the Government to abate the nuisance caused by the sulfur dioxide fumes produced in their copper smelting operations, decided to erect a plant at Copperhill, Tennessee, consisting of twelve chambers of the same dimensions as those at Vandergrift. This plant now consists of thirty-six of these chambers. The work, from a technical standpoint, is not perfect, as it entails a considerable consumption of NaNO_3 . However, the Company claims that their net profits from the production of sulfuric acid are equal to their profits from copper and other sources. This irregularity of working is due to the character of the smelter gases which contain from 4 to 6 per cent. of CO_2 , and in which the percentage of SO_2 fluctuates greatly.

a concentrating tower. No additional labor is involved in the concentration, and the fuel cost is represented by a consumption of 100 pounds per hour of a mixture of coke breeze and slack coal fed by means of a special smokeless stoker, or a consumption of less than 70 pounds of fuel per ton of 66° B. acid.

(2) For the Dominion Iron and Steel Company, Limited, at Sydney, Cape Breton, Nova Scotia, a chamber 50 feet square by 70 feet high; specified capacity in 24 hours, forty to forty-five tons of 60° B. sulfuric acid. This plant includes one Glover tower 10 feet in diameter by 26 feet high, two Gay-Lussacs 9.5 feet square by 50 feet high and two packed cooling towers of the same dimensions as the Gay-Lussacs, placed between the chamber and the Gay-Lussacs.

(3) For the Algoma Steel Corporation, Limited, at Sault Ste. Marie, Canada, a chamber 35 feet square by 70 feet high; specified capacity in 24 hours, twenty to twenty-five tons 60° B. sulfuric acid. This

TENNESSEE COPPER CO. SMELTER AND ACID PLANT

With the advantage of the data obtained at Vandergrift and Copperhill three plants have been subsequently erected as follows:

(1) For the Cleveland Cliffs Company, at its Pioneer Iron Works plant at Marquette, Michigan, one chamber 50 feet square by 70 feet high; specified capacity in 24 hours, thirty to thirty-five tons of concentrated 66° B. sulfuric acid. This plant includes one Glover tower 10 feet in diameter by 26 feet high, two Gay-Lussacs 10 feet in diameter by 50 feet high, and two packed cooling towers 10 feet in diameter by 50 feet high, placed between the chamber exit and the Gay-Lussacs. The pyrite used at this plant is a remarkably pure concentrate, practically free from dust and arsenic; and the arrangement of the towers is such that the hot Glover tower acid is run directly by gravity from the Glover tower at a temperature of 310° to 320° F., by means of fused silica conduits into

plant is equipped with one Glover tower 8 feet in diameter by 25 feet high, two Gay-Lussacs 8 feet in diameter by 50 feet high, one packed cooling tower following the chamber exit and one Petersen regulator tower between the cooling tower and the Gay-Lussac, both these towers being of the same dimensions as the Gay-Lussacs.

Not one of the above installations has been made for a concern previously engaged in, or familiar with, the manufacture of sulfuric acid. In every instance the operatives are drawn from the ordinary labor available in the locality. In at least two cases the trained chemists in charge of the process had never previously seen a sulfuric acid plant. In view of these conditions, it is submitted, that the results of actual operation are entirely satisfactory. In each case (with the exception of the Tennessee Copper Company's plant, where for obvious reasons no regularity

could be assured) the consumption of niter of not over an average of three per cent. was stipulated, and also a minimum output as stated in the preceding paragraph. This output in terms of chamber space was as follows:

(1) One pound of sulfur to 7.8 cubic feet of chamber space;

(2) One pound of sulfur to 7.2 cubic feet of chamber space;

ANALYSIS OF RECENT TYPICAL DAILY REPORTS OF THE VANDERGRIFF AND ALGOMA STEEL CORPORATION SULFURIC ACID PLANTS

Averages—Daily reports, etc.	First Plant erected U. S. Steel Corporation Vandergrift(a) Plant brimstone	Last Plant erected Lake Superior Corporation Ltd. Algoma Steel(b) Corp'n Ltd. Plant pyrites—"fines" (Dec. 29, 1912)
Pyrites "fines" charged in 24 hours (pounds)...		20,700
Pyrites contain sulfur per cent.		40.34
Cinders contain sulfur per cent.		0.38
Sulfur charged (pounds)...	15,345	8,350
Sulfur available or burned (pounds).....		8,280
Per cent. of SO ₂ in gas...	10.4	7.5
Nitrate of soda—per cent. on sulfur charged....	1.56	1.15
Nitrate of soda—per cent. on sulfur burned....		1.16
Per cent. N ₂ O ₃ in Petersen regulator.....		4.85
Per cent. N ₂ O ₃ in nitrous vitriol.....	2.60	2.02
Per cent. N ₂ O ₃ in final Gay-Lussac tower....	0.17	0.60
Temp. of gas—8 ft. from top of chamber(c)....	205° F.	179° F.
Temp. of gas—5 ft. from bottom of chamber....	190° F.	160° F.
Temperature of gas at entrance to Gay-Lussacs.	127° F.	72° F.
Difference of temperature between top and bottom of chamber.....	15° F.	19° F.
Difference of temperature between bottom of chamber and Gay-Lussacs.....	63° F.	88° F.
Drip—Degrees U. S. B....	46.5° B.	48° B.
Average strength of acid in chamber pan (U. S. B.).....	52 to 53° B.	53 to 54° B.
Average strength of finished acid.....	62° B.	58 to 59° B.
Dimensions of chamber (feet).....	50' × 50' × 70' high	35' × 35' × 70' high
Outside dimensions of towers—except Glover (feet).....	9'6" × 9'6" × 50' high	8' diam. × 50' high
Outside dimensions of Glover tower (feet)....	9'6" × 9'6" × 24' high	8' diam. × 24' high

(a) The Vandergrift Plant has been in operation some years and was the first of this character of plant built.

(b) The Algoma Plant has been operated less than three months.

(c) Temperatures taken on side of chamber with usual bent thermometer.

(3) One pound of sulfur to 6.4 cubic feet of chamber space, or a maximum output of one pound of sulfur to 6 cubic feet of chamber space, or a minimum output of one pound of sulfur to 8 cubic feet of chamber space, or an average output of one pound of sulfur to 7 cubic feet of chamber space. In all cases these specifications have been carried out and easily exceeded. The plants have been taken over and paid

for and are operating to the satisfaction of the owners.

TEMPERATURE OF REACTION IN THE HIGH CHAMBER

In the ordinary operation, readings are taken from the usual bent thermometers placed, the one about 12 feet from the top of the chamber in the side lead, and the other about 4 feet from the bottom of the pan, in the side lead. In practice the temperatures are read only on one side of the chamber. At first thermometers were placed on all four sides of the chambers, and not only near the middle of the sides, but also near the corners, until it was found that the variation in these thermometers at equal height in the chamber was practically nil.

When the chamber was first used, thermometers were placed also vertically 5 feet apart on all four sides of a chamber, and an extended series of readings taken, all of which showed a gradual diminution of temperature from the top to the bottom. This decrease in temperature, of course, was more rapid in the lower part of the chamber, but was distinctly marked after the first fifteen feet from the top, or the first two readings.

The difference between the upper thermometer (10 feet from the top) and the bottom thermometer will range from 22° F. to 7° F., according to the intensity with which the system is being driven, *i. e.*, the proportion of the amount of sulfur burned to the cubic feet of chamber space.

When the system is in normal operation, repeated tests show no more than the usual traces of SO₂ in the gases leaving the chamber. The packed cooling tower which follows the chamber serves to dry the gases leaving the chamber (by condensing the mist of sulfuric acid) before admission to the Gay-Lussac towers, and a further cooling of from 75° to 100° F. takes place in this apparatus, bringing the final temperature of the gases entering the Gay-Lussac towers to 60° to 80° F.

DRIPS

One drip reading has been found, by elimination, to be sufficient. This has been placed, by reason of convenience, near the lower thermometer about four feet from the bottom at the middle of the chamber side. If this drip is carried at 47°–48° B., the pan acid will be found invariably between 52° and 54° B. At one plant a table drip has been employed, and the readings respectively of the table drip, the side drip and the chamber acid as drawn to the storage tank, were 55° B., 47° B., and 53.6° B.

CONSUMPTION OF NITER

Some of these plants are of course not doing as regular work as they would do if operated by skilled labor. The consumption of nitrate of soda is frequently for considerable periods as low as 1 to 1½ per cent., a record which undoubtedly could be uniformly maintained by competent operatives (see tables).

THE ADVANTAGES OF THE HIGH CHAMBER

The advantages of this chamber are noteworthy:
I. *The Saving of Lead.*—For purposes of comparison,

take a chamber fifty feet square and seventy feet high, representing a capacity of 175,000 cubic feet (4952.5 cubic meters). This comparison has no reference whatsoever to the actual efficiency of such chamber space. The largest chambers which Meyer has built are probably those of the Mountain Copper Company, which he states are 12 meters in diameter and 13 meters high. These would therefore have a capacity of 1470 cubic meters

the top, and five feet at the bottom. The straps for the sides six-pound, and for the top seven-pound. (These straps consist of a five-inch strip of lead burned onto the chamber sides, and extending horizontally continuously around the chamber at vertical intervals of about 5 ft. The straps are then bolted by means of clamp bars to horizontal angles, in such a way that the side lead does not touch the support-

VANDERGRIFF PLANT IN COURSE OF ERECTION—TWO TOWERS NEARLY COMPLETED

each. Three chambers of this size would be required, together with a small chamber 9 meters diameter and 6.5 meters high to give the same capacity as one high chamber 50 feet square by 70 feet high. In actual construction the weights of lead used in this chamber are as follows:

The top and bottom, seven-pound lead; the sides, six-pound lead, rolled to eight-pound for two feet at

ing angles or posts at any place.) The total weight of lead, including everything in connection with the chamber, is 141,000 pounds. A corresponding plant, according to the Meyer system, would require at least 220,000 pounds of lead, while a plant of three chambers of equal cubic capacity, built according to the old rectangular, horizontal system, would require from 240,000 to 300,000 pounds of lead. The saving

in lead, therefore, is from 35 per cent. to more than 50 per cent. for equal cubic capacity, even supposing that the high chamber space is not more efficient.

II. Greater Efficiency of the High Chamber Space.—An efficiency of chamber space representing from 6 to 7 cubic feet of chamber space to one pound of sulfur burned, without the assistance of any auxiliary apparatus such as surface condensers, needs no further comment.

III. Great Economy of Ground Area and Foundations.—The fifty-foot chamber, allowing seven feet to the outside of the building for the width of the trusses, occupies only 4,096 square feet, whereas in the case of the old horizontal chambers the same chamber space would occupy about three times this area, and the Meyer Tangential System would require from two to three times this amount, depending on the size of the chambers.

IV. Fire-proof and Storm-proof Construction.—The method of construction, being entirely of steel and reinforced concrete, is fire-proof and storm-proof. The cost of this construction is about the same or rather less for equal chamber capacity than what is considered a good type of construction of the old chamber plants, where wooden frames and buildings are used.

V. Economy of Labor.—The compact arrangement of this Plant reduces the amount of labor required to the minimum. For any Plant up to 100 tons of 66° B. sulfuric acid in 24 hours the labor is as follows (12-hour shift):

When using brimstone, one chamber man who is also day foreman, one chamber man who is also night foreman, one day burner man, one night burner man—four men in 24 hours.

When using "fines" pyrite, one or two laborers will be required to handle the ore and cinder, making a total of 5 to 6 men in 24 hours.

When using lump pyrite, additional men will be needed, depending on the construction of the lump burners.

The operation of the high chamber (towers, pumping, concentration, etc.) requires only one man per shift of 12 hours.

The scope of this article could scarcely be considered as including a detailed description of the methods of steel construction and lead work.¹ It is sufficient to say that the difficulties connected with the same have been solved in a most satisfactory manner, both with reference to protection against fire and storms, and the durability of the lead work. The plants which have been longest in operation have demonstrated that the item of repairs has been considerably reduced, being approximately only about 20 per cent. of the amount usually attending the horizontal chamber construction.

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¹ Ingenieur Awe in an article on the construction of lead-chamber walls (*Z. angew. Chem.*, **25**, 2523-2524 (1912)) describes a method of construction which was first used on the "Falding High Chamber" several years ago and has been continuously used since in all of the Falding installations.

TECHNICAL ACCOUNTING AND CHEMICAL CONTROL IN SUGAR MANUFACTURE¹

By DAVID L. DAVOLL, JR.

INTRODUCTION

For the technical supervision of the manufacture of sugar, whether from beet or cane or whether the purpose be to make raw sugar or refined granulated, the activities of the chemist may well be directed along three lines of endeavor.

First, The sampling and analysis of all raw material such as coal, coke and limestone or lime. Almost without exception in the beet industry and in exceptional cases with the cane, this includes the daily systematic valuation of beets and sugar-cane deliveries for purposes of purchase. Further, it will include the analysis of field samples to determine maturity of crop in general and the effect of certain influencing factors in particular districts.

Second, The frequent and rapid testing of initial material, intermediate products at the several "stations" of manufacture and the final products, together constituting what is known as "chemical control."

Third, The keeping of the sugar account and the daily calculation of the efficiency of the various pieces of machinery and of the several intermediate processes of manufacture.

Chemical control is essentially diagnostic in character and takes advantage of the knowledge we have of how the sugar-bearing material should behave at the "stations" as now interpreted through chemical tests and of what constitutes recognized, unavoidable losses, to put in the hands of the foremen in charge the proper data.

Successful sugar accounting calls for good organization first and conscientious, well-trained chemists to carry it out. Success or failure depends upon the presence or absence of suitable conveniences, accurate factory weights and measures, calibration of utensils and the exercise of great care in the sampling, sub-sampling, compositing and preserving.

In the beet industry the polarization is practically the true sucrose (with raffinose absent) while in the cane industry the polarization is never the true sucrose but is the algebraic sum of the several optical activities, of all the participating bodies, not removable by lead acetate. Therefore, in this article the term polarization or "sugar" signifies the polariscopic reading when reduced to terms of 26 grams of material in 100 metric cubic centimeters. Sucrose refers to the Clerget figure.

A few terms, peculiar to the cane industry, may well be defined here.

Normal Juice.—Strictly speaking this is the whole juice of the cane as it exists in the tissues, or the combined juice of all the mill units when milling without the application of water of Saturation. It still has considerable significance in cane work but none in the beet. It usually runs from 0.1 to 0.7 degree Brix lower than the so-called First Mill Juice; it is also lower in purity. Owing to its variability under changing conditions it should be determined by actual run, without water, at stated intervals.

¹ Paper presented at the Fifth Annual Meeting of the American Institute of Chemical Engineers, Detroit, December, 1912.