

UNITED STATES PATENT OFFICE.

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METHOD OF MANUFACTURING SULFURIC ACID.

1,205,723.

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No Drawing.

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To all whom it may concern:

Be it known that I, ANDREW MILLER FAIRLIE, a citizen of the United States, residing at Copperhill, in the county of Polk and State of Tennessee; have invented certain new and useful Improvements in Methods of Manufacturing Sulfuric Acid, of which the following is a specification.

My invention relates to processes for the manufacture of sulfuric acid which use some compound of nitrogen (for example nitrogen oxids, nitrate of soda, or nitric acid, hereinafter referred to as nitrogen-oxygen compound) as a means for causing the oxidation of sulfur dioxid in the presence of moisture. As an example of such processes, the method of manufacture known as the chamber process may be cited.

Broadly speaking, the object of my invention is to so control the process that precisely that proportion of nitrogen-oxygen compounds and sulfur dioxid may be continuously introduced at the beginning of the acid making apparatus, as will produce at the end of such apparatus a mixture of the different oxids of nitrogen in that proportion which will be most completely absorbed in the apparatus for the absorption of oxids of nitrogen; the ultimate object being, by inducing more complete recovery of the nitrogen compounds at the end of the apparatus, to effect greater economy in the consumption of nitrogen compounds. My invention consists, broadly speaking (a) in gaging or measuring the proportion of nitrogen compounds which have been introduced at the beginning of the acid-making apparatus, in relation to the sulfur dioxid present in the gases, by determining the percentage of sulfur dioxid in the gaseous mixture, after the aforesaid nitrogen compounds have been introduced; (b) in adjusting the quantity of nitrogen compounds introduced at the beginning of the apparatus, to suit the requirements as indicated by the aforesaid sulfur dioxid determinations; and (c) in an improved method for determining the percentage of sulfur dioxid in gas mixtures containing nitrogen-oxygen compounds.

In the following detailed description of my invention, reference is made for the sake of simplicity and clearness to only one type of those processes using nitrogen-oxygen compounds in the manufacture of sulfuric acid—namely, the chamber process. My

claims, however, are not to be understood as restricted to the chamber process only, but on the contrary I here state explicitly that they are applicable to all processes in which any nitrogen-oxygen compound or compounds are used in the manufacture of sulfuric acid.

As is well known, the five prominent elements of a chamber plant are: 1. The burners, or furnaces, for generating sulfur dioxid. 2. The niter plant, in which raw nitrogenous material (usually NaNO_3) is introduced. 3. The Glover tower, in which the chamber acid is concentrated, and the nitrous vitriol is denitrated. 4. The chambers—the oxidizing, hydrating and condensing apparatus. 5. The Gay-Lussac tower, where the valuable oxids of nitrogen are recovered by conversion into nitrous vitriol. The sulfur-bearing gas, generated in the burners, or furnaces, passes through the other four parts of the apparatus in the order named above. The percentage of sulfur dioxid present in the gas (assuming no dilution by air or other gases) remains constant from the time of leaving the burners until the niter plant is reached (or Glover tower if there be no niter plant). Thereafter the percentage of sulfur dioxid is gradually reduced, as the gases traverse the several parts of the apparatus, owing to the constant oxidation of sulfur dioxid, induced by the nitrogen compounds. This oxidation of sulfur dioxid will proceed the more rapidly, the greater the quantity of nitrogen-oxygen compounds introduced at the niter plant and Glover tower, in proportion to the sulfur dioxid admitted. The converse of this is also true. The economical operation of the process demands that such a quantity of nitrogen-oxygen compounds be introduced at the niter plant and Glover tower as will induce oxidation of the sulfur dioxid in the chambers at that rate of speed which is found by experience to yield the most complete absorption of the oxids of nitrogen in the Gay-Lussac tower. If too much of the nitrogen-oxygen compounds be introduced at the niter plant and Glover tower, the oxidation of sulfur-dioxid will proceed so rapidly as to permit an excess of nitrogen peroxid, above the desired proportion of that gas to nitric oxid in the gases about to enter the Gay-Lussac tower, resulting in inefficient operation of that tower, and escape of unabsorbed oxids of nitrogen into

the atmosphere. If, on the other hand, too little of the nitrogen-oxygen compounds be introduced at the beginning of the apparatus, the oxidation of the sulfur dioxid will be so retarded that an excess of nitric oxid, above the desired proportion, will exist in the gases about to enter the Gay-Lussac tower, resulting in inefficient operation and loss of values as before.

10 Prior to my invention, the means used to indicate to the acid plant operator the proportion of the oxids of nitrogen to sulfur dioxid in the chamber gases gave tardy information, or were unreliable and inexact.

15 As examples of the best of such unreliable means I mention (a) inspection of the color of the chamber gases through glass windows or "sights"; and (b) observance of the difference between the temperatures of the 20 gases at certain fixed places in the chamber system.

(a) Since on account of the white mists and fumes existing in the front chambers it is impossible there to detect slight variations 25 in the color of the gases, it is customary to view the color of the gases in an intermediate chamber or in the last chamber, where variations in shade are more easily perceptible. Such information as is gained 30 from noting the color changes in these chambers comes, however, too late to be of much practical use to the observer. For if anything is wrong with the proportions of the various gases in the chambers, the fact is 35 not known until the chambers are full of the troublesome gas mixture up to the point of observation of the color of the gases, and it is then impossible to apply the remedy in time to avoid losses in the Gay-Lussac tower.

40 Furthermore, observance of the differing colors of the chamber gases gives information which is at best unreliable and inexact, and incapable of being expressed quantitatively.

45 (b) The observance of the differences between chamber temperatures is liable to lead to erroneous conclusions, and to the application of improper remedies, because changes in the temperature differences may 50 be due to a number of different causes, such as changes in the composition of burner gas, changes in the atmospheric temperature, rain, or excessive or deficient supply of nitrogen compounds. On this account the observance 55 of temperature changes alone is an unsafe guide in regulating the chamber process, and leads at times to serious losses. This method of controlling the chambers is moreover an inexact method.

60 Prior to my invention it was impossible to regulate the proportion of nitrogen oxids to sulfur dioxid in the chambers by means of chemical analysis of the chamber gases, because, first, no reasonably accurate and 65 quick method was known, prior to my in-

vention, of determining the percentage of sulfur dioxid or of any other component of chamber gas, with a sufficient degree of accuracy and with at the same time sufficient speed to be of practical use for the purpose; 70 and secondly, because prior to my discovery it was not known that definite ratios could be established between the percentage of sulfur dioxid in the burner gas, and a corresponding percentage of sulfur dioxid 75 desirable for any chosen point in the front end of a chamber plant. It was impossible, prior to my invention, to obtain accurate, definite, and immediate information regarding the composition of the gas mixture 80 within the chambers, at the very beginning of the acid-condensing system. Consequently it was impossible to apply proper remedies for existing trouble in the composition of chamber gas immediately, intelligently, and 85 with certainty of securing the desired results. In short, prior to my invention the proper proportion of oxids of nitrogen to sulfur dioxid in the chamber gases could not be accurately maintained by the means then 90 known, and consequently the proportion of nitric oxid to nitrogen peroxid desirable in the Gay-Lussac tower was not constant, and values were lost, which by my process are 95 recoverable.

By the application of my invention, it is now possible to maintain the correct proportion of oxids of nitrogen to sulfur dioxid in the chamber gases continuously, to correct immediately any threatened excess of either nitrogen oxids or sulfur dioxid, and in this way to effect great economy in the operation of the chamber process. Whereas the old methods of controlling the chamber process give tardy information, in time of 105 trouble, that something is wrong, my method gives immediate information as to precisely what is wrong, and to what extent.

The method which I have invented for the indication of the proportion of nitrogen oxids to sulfur dioxid in chamber gases, and hence for the accurate control of the quantity of nitrogen compounds introduced at the niter plant and Glover tower, consists in the determination of the percentage of sulfur dioxid in the chamber gases at any point or points in the chamber system where the percentage of sulfur dioxid should be normally more than seven-tenths of one per cent. by volume (but preferably at a point 110 in the first half of the chamber space near enough to the Glover tower to be reached by the gases within twenty minutes or less after leaving that tower) and in the intelligent comparison of such determinations 115 with sulfur dioxid determinations made on the gas at some other point or points in the acid plant.

I have discovered that, at any given point 120 in the chambers or chamber gas connections 125

near the Glover tower, or in the Glover tower itself, the percentage of sulfur dioxid in the gases bears a definite ratio to the percentage of sulfur dioxid in the burner or 5 furnace gases which are free from nitrogen compounds, for any one grade of burner gas, provided the oxids of nitrogen and the sulfur dioxid in the chambers are maintained in the proportion required to produce 10 the most complete recovery of nitrogen oxids in the Gay-Lussac tower. I have found further that any excess of oxids of nitrogen will be definitely indicated, by a decrease in the sulfur dioxid ratio, below what is desirable; and conversely that any deficiency of 15 oxids of nitrogen will be definitely indicated by an increase in the sulfur dioxid ratio, above what is desirable; such decrease or increase in the said ratio being an accurate 20 measure of the extent of the excess or deficiency of nitrogen oxids. I have found that, by adjusting the quantity of nitrogen compounds, or of sulfur dioxid (or of both) admitted to the chambers, in such a way as 25 to meet the requirements as indicated by the sulfur dioxid determinations on chamber gas, at pre-determined points in the system, it is possible to maintain the desired proportion 30 of nitrogen oxids to sulfur dioxid indefinitely, resulting in a marked increase in the quantity of nitrogen oxids recovered in the Gay-Lussac tower, and hence in much greater economy of operation of the chamber process.

35 To secure definite and valuable results, it is only necessary to select a suitable point in the chamber system, to determine once for all by repeated sulfur dioxid determinations, what is the desirable ratio between the 40 percentage of sulfur dioxid at the point selected and the percentage of sulfur dioxid in the burner or furnace gas, for each of the various grades of burner gas (meaning by 45 "grade of gas" its percentage of sulfur dioxid) and thereafter to so adjust the quantities of nitrogen compounds and sulfur dioxid admitted to the chambers as to maintain the desired sulfur dioxid ratio corresponding to the particular grade of gas.

50 I have ascertained that the nitrogen oxids are absorbed in the Gay-Lussac tower most advantageously when the percentage of sulfur dioxid in the gases about to enter the 55 Gay-Lussac tower is (under normal weather conditions) between five one-hundredths (.05) and fifteen one-hundredths (.15) of one per cent. by volume, the lower percentages say .05 to .11 per cent. being desirable in cold weather, and the higher percentages, say .09 to .15 per cent. being desirable in 60 warm weather. I have found, moreover, that while the desirable percentage of sulfur dioxid in the chamber gas, at any chosen 65 point in or near the Glover tower, will fluctuate with fluctuations in the grade of the bur-

ner gas, the desirable sulfur dioxid percentage in the gases about to enter the Gay-Lussac tower is, within the limits specified, a fixed quantity, regardless of fluctuations in the grade of the burner gas. I have found 70 that the percentage of sulfur dioxid in the gases about to enter the Gay-Lussac tower can be maintained indefinitely within the desirable limits above stated by establishing and maintaining the desirable ratios 75 between the percentage of sulfur dioxid in the gases at any chosen point in the Glover tower, or front chambers, and the percentage of sulfur dioxid in the burner gas, for each possible grade of burner gas. I have found 80 that sulfur dioxid tests made on the gases comparatively near the end of the system, for example those about to enter the Gay-Lussac tower, in combination with sulfur dioxid determinations made at a point or 85 points in the chamber system nearer to the Glover tower (or even inside that tower) are a useful guide in determining the desirable ratio in sulfur dioxid percentages, referred to above. And furthermore, I have found 90 that sulfur dioxid determinations made on the gases comparatively near the end of the system, for example those about to enter the Gay-Lussac tower, in combination with sulfur dioxid determinations made at a point 95 or points in the acid-making system nearer to the Glover tower (or even in that tower itself) are a useful guide in checking the accuracy of the operator making the latter determinations; and that therefore such a 100 combination of tests for sulfur dioxid is a useful and valuable one in controlling the acid making process, although with reliable tests at the front of the chamber system, the sulfur dioxid tests at the back of the 105 system are not essential to economical operation.

At the time of making my early experiments with the determination of sulfur dioxid in chamber gas, I found that the 110 known methods for such determinations were not at once sufficiently rapid and accurate to secure the results desired. The most rapid and convenient method was that known as Reich's method—the method in 115 common use for the determination of sulfur dioxid in burner gas. According to this method, the gas under examination is aspirated through water containing a measured quantity of standard iodin solution, 120 colored blue by starch solution, and contained in an "absorption bottle" provided with two glass tubes, one long and one short; the long one being connected by rubber tubing to the chamber or flue containing the gas 125 to be treated, and the short one to the top of a large bottle containing water, and fitted as an aspirator by having an outlet for the water near the bottom, with rubber tube and regulating cock. Water is allowed to run 130

from the aspirating bottle into a measuring cylinder, thus aspirating gas through the absorption bottle. The sulfur dioxid in the gas reacts with the iodin in the absorption bottle, converting the iodin into hydriodic acid. When nearly all of the iodin has been thus converted, the blue color of the absorption liquid will lose its intensity, and when all of the iodin has been converted into hydriodic acid, the liquid will lose all trace of color and become perfectly clear. When this happens the stopcock regulating the flow of water from the aspirating bottle is instantly closed. The volume of water collected in the measuring cylinder is a measure of the volume of gas aspirated through the iodin solution, and so of the percentage of sulfur dioxid in the gas. By reference to published tables the volume of water collected may be readily interpreted into the percentage of sulfur dioxid. This method is sufficiently accurate for burner gas, but when applied to gases containing oxids of nitrogen, it is found that these oxids tend to decompose the hydriodic acid as formed in the absorption bottle, liberating free iodin again. It is obvious that if the known quantity of iodin which is introduced into the absorption bottle for the purpose of making an accurate assay be increased by an unknown quantity liberated by the oxids of nitrogen from the hydriodic acid formed in the early stages of an assay or in a previous assay, the results are vitiated. This liberation of free iodin from the products of a preceding assay, or of the early stages of an assay, is attested by the prompt recurrence of the starch-iodin blue color immediately after that color has been discharged, when operating on gases containing oxids of nitrogen. The inference is that this liberation of free iodin is progressing all the time that the gas is being aspirated; hence that at least more iodin is acted upon by the gas than the measured quantity introduced for the assay; hence that more gas is drawn through the absorption bottle than would have been necessary to decolorize exactly the amount of iodin introduced for the assay; hence that the indicated result, in percentage of sulfur dioxid, is too low. Furthermore, duplicate tests made on the same gas in rapid succession will not, if oxids of nitrogen be present, produce corroborative results, thus indicating that the action of the oxids of nitrogen in liberating free iodin is uncertain and irregular, and cannot be correctly allowed for in calculating results.

In the front and intermediate chambers, where the percentage of sulfur dioxid is relatively high as compared with that of the last chamber, it is usually possible, in attempting to make an estimation of sulfur dioxid by the ordinary Reich test, sooner or later to discharge the blue color of the solu-

tion; but the indicated results will invariably be too low, and corroborative results cannot be obtained. The "end point" is uncertain, and often the operator, when under the impression, from the increasing paleness of the solution, that the color is about to be completely discharged, finds that the blue color suddenly becomes more intense, instead of continuing to fade. In the last chamber, where the percentage of sulfur dioxid approaches the minimum, it is often entirely impossible to decolorize the solution at all, so quick and effective is the action of the oxids of nitrogen in restoring the iodin in uncombined form to the solution, due to the larger ratio of the higher oxids of nitrogen to sulfur dioxid therein.

It is therefore plain that the ordinary Reich test fails to give accurate and reliable indication of the SO_2 content when applied to gases containing the oxids of nitrogen present in chamber gas, and in the last chamber of a sulfuric acid plant often fails to give any indication whatever. However, the Reich test, as applied to gases free from oxids of nitrogen, is so convenient, rapid, and accurate, that it seemed the most desirable method possible for testing chamber gas, if only some means could be found to prevent the interfering action of the oxids of nitrogen, without impairing the reliability of the test. I have succeeded in finding such a means.

I have invented an improvement in Reich's method for sulfur dioxid determinations, by the adoption of which the recurrence of the blue color may be either prevented altogether, or may be so delayed as not to interfere with the accuracy of a test, to any perceptible degree. My improvement consists in the addition to the absorption bottle or absorption liquid, of a Reich's or other sulfur dioxid determination apparatus, of a salt of some base (either in solution or otherwise) such as the carbonate, sulfate, acetate, or other salt of potassium, sodium, zinc, or other base (but preferably the acetate of sodium) together with a sufficient amount of acid (for example, sulfuric, acetic, or hydrochloric acid or an acid anhydrid, said acid being without oxidizing or reducing action on hydriodic acid or iodin) to render the solution acid.

Without limiting myself to the exact materials or amounts given, I give the following example of the solution to be used in the absorption bottle: N/10 iodin solution, 1 c. c.; water, 100 c. c.; starch solution, 5-6 drops, and sodium acetate mixture, 10 c. c. This "sodium acetate mixture" may be prepared by adding one volume of acetic acid (say 95%) to five volumes of saturated sodium acetate solution.

I do not limit myself to the particular

chemicals just mentioned, as the use of a salt of any base in combination with an acid or acid anhydrid (having no oxidizing or reducing action) in the iodin test for sulfur dioxid, would be but carrying out the principle of my invention. By means of my improvement in the Reich test for sulfur dioxid it is possible at any time to make sulfur dioxid determinations in duplicate 10 on gas mixtures containing oxids of nitrogen which will check each other within one one-hundredth (.01) of one per cent.—a degree of accuracy which is not attained by any other method for the analysis of such 15 gas mixtures, so far as I am aware. Since my improved method requires no longer time for its execution than the ordinary Reich test, its value for the purposes hereinafter described is obvious.

20 I have discovered that my improved method for making sulfur dioxid determinations can be most usefully applied to my hereinbefore described method of controlling the proportions of nitrogen oxids and 25 of sulfur dioxid, by means of sulfur dioxid determinations on the chamber gases made at a point comparatively near the Glover tower, either at that one point alone, or in combination with similar tests made on 30 gases containing nitrogen oxids at a point or points nearer to the Gay-Lussac tower, or even inside that tower.

Although I have invented the above described improvement in the method of making determinations of the percentage of sulfur dioxid in gas mixtures containing oxids of nitrogen, which improvement I have discovered to be useful in connection with my improved method for the control 40 of processes for the manufacture of sulfuric acid, I desire to state explicitly that my improved method of controlling processes for the manufacture of sulfuric acid, described above, is not necessarily limited to the 45 use of my own improved method for sulfur dioxid determinations. On the contrary it is to be clearly understood, that my invention for the control of sulfuric acid processes comprises the use of sulfur dioxid determinations made at any part of the chamber system where the percentage of sulfur dioxid, in gas mixtures containing oxids of nitrogen is normally more than seven-tenths (.7) of one per cent. by volume (in whatever way such determinations may be made, and regardless of whether such determinations be made at one point only, or at more than one point in the chamber system, or in combination with similar tests made on the 50 gases comparatively near the end of the chamber system, or about to enter or in the bottom of the Gay-Lussac tower) for the purpose of controlling the proportions of nitrogen compounds and sulfur dioxid (or either of these) admitted to the chambers.

While I have mentioned, in my description of the secondary or checking test on gases containing oxids of nitrogen, that this is applicable to the gases about to enter the Gay-Lussac tower, which would normally contain .05 to .15 per cent. sulfur dioxid, I will state that this test can if desired be made at other points in the latter part, say, at least the latter third of the chamber space. Thus this secondary or checking test might be made on gases which would not reach the Gay-Lussac tower for as much as fifteen or twenty minutes, or perhaps even longer; and the normal percentage of sulfur dioxid in the gases chosen for the 75 secondary test might be as high as .65 per cent. or in some cases even higher. Any point in the latter part of the chamber system where the desirable percentage of sulfur dioxid remains substantially constant, 80 regardless of fluctuations in the percentage of sulfur dioxid in the burner gas, may be chosen for the secondary or checking test, or for tests to be used in establishing desirable sulfur dioxid ratios.

The method of determining sulfur dioxid in gas mixtures such as those referred to in the present application, namely mixtures containing sulfur dioxid and also containing oxids of nitrogen, are not claimed 90 in the present application, but form the subject matter of my copending application Ser. No. 80,037 filed February 23, 1916.

What I claim is:—

1. In the manufacture of sulfuric acid, 100 the step of regulating the relative amounts of nitrogen-oxygen compounds and sulfur dioxid introduced, in such a manner as to maintain at a predetermined given place in the acid-making system, a predetermined 105 substantially uniform percentage of sulfur dioxid in the gases, said percentage being more than 0.7% by volume.

2. In the manufacture of sulfuric acid, 110 the improvement which consists in determining that ratio between the percentages of sulfur dioxid in the gases at two predetermined places in the acid-making system, best adapted to a commercially complete absorption of nitrogen-oxygen compounds, 115 at least one of said places being located in that part of the system where the normal percentage of SO_2 should be over 0.7%, and thereafter maintaining said ratio, by regulation of the relative amounts of nitrogen- 120 oxygen compounds and sulfur dioxid introduced into the system.

3. In the manufacture of sulfuric acid, 125 the improvement which comprises determining, by means of analyses of the gases at a plurality of separated points of the acid making plant, the proper ratio between the percentage of sulfur dioxid in the gases free from nitrogen-oxygen compounds entering the acid making system, and the per- 130

centage of sulfur dioxid in the gases containing nitrogen-oxygen compounds at a predetermined point in the acid making system where the percentage should normally be more than 0.7% by volume, and maintaining the proper ratio substantially constant, by regulating the relative amounts of nitrogen-oxygen compounds and sulfur dioxid introduced into the acid making system.

4. In the manufacture of sulfuric acid, the improvement which comprises determining the proper ratio between the percentages of sulfur dioxid in the gases free from nitrogen-oxygen compounds entering the acid-making system, and the percentage of sulfur dioxid in the gases containing nitrogen-oxygen compounds at a predetermined point in or near the Glover tower, by means of analyses of said gases, and maintaining said ratio substantially constant by regulating the relative amounts of nitrogen-oxygen compounds and sulfur dioxid introduced.

5. In the manufacture of sulfuric acid the step of determining the proper ratio for sulfur dioxid containing gases of different grades, between the percentages of sulfur dioxid in the gases free from nitrogen-oxygen compounds entering the acid making system and the percentages of sulfur dioxid in the gases containing nitrogen-oxygen compounds at a predetermined place in the acid making system where the percentage of sulfur dioxid should normally be more than 0.7% by volume, and thereafter regulating the amounts of oxygen-nitrogen compounds introduced, in accordance with the amount and grade of said incoming gases, in such a manner as to maintain the above mentioned proper ratio corresponding to the particular grade of gas being employed.

6. The herein described method of controlling the manufacture of sulfuric acid, which method comprises determining the desirable ratio between the percentage of sulfur dioxid at any given point in a sulfuric acid plant, where the gas mixture normally contains nitrogen-oxygen compounds, and the percentage of sulfur dioxid in the incoming gases free from nitrogen-oxygen compounds, and in so regulating the relative amounts of nitrogen-oxygen compounds and of sulfur dioxid supplied to the apparatus, as to substantially maintain such ratio, substantially as described.

7. In the manufacture of sulfuric acid, the improvement which comprises determining the proper ratio between the percentages of sulfur dioxid in the gases at two predetermined points in the acid making appara-

tus, at least one of said points being located in that portion of the system where the percentage of sulfur dioxid is normally over 0.7%, and thereafter maintaining said ratio substantially constant, by regulating the relative amounts of nitrogen-oxygen compounds and sulfur dioxid introduced into the gases at the front part of the system.

8. The herein described improvement in the manufacture of sulfuric acid, said improvement comprising determining the amount of sulfur dioxid in the gases containing nitrogen-oxygen compounds at a predetermined point comparatively near the front end of the acid making system, and determining the amount of sulfur dioxid in the gases at a predetermined point comparatively near the Gay-Lussac tower or towers, and so regulating the operation of the chambers as to maintain a predetermined percentage of sulfur dioxid in the gases at said last mentioned point.

9. The improvement in the art of making sulfuric acid which comprises making sulfur dioxid determinations on gas mixtures containing oxids of nitrogen at any point in a sulfuric acid plant where the percentage of sulfur dioxid would normally be more than 0.7%, thereby determining the ratio between the percentages of sulfur dioxid in the gases at different parts of a plant, and proportioning the relative amounts of nitrogen compounds to sulfur dioxid in the gases supplied to the acid making apparatus, so as to maintain said ratio substantially uniform.

10. The herein described improvement in the sulfuric acid manufacture, said improvement comprising the steps of determining at frequent intervals, the percentage of sulfur dioxid (a) in the gases at a predetermined point in the acid making system and near the front end thereof, and (b) in the burner gases which contain no oxids of nitrogen and (c) in the gases at a predetermined point near the rear end of the system; and regulating the proportions of sulfur dioxid and of nitrogen-oxygen compounds admitted to the chambers so as to maintain that ratio between the percentages of sulfur dioxid at the points (a) and (b) which will produce and maintain a desirable predetermined percentage of sulfur dioxid in the gases at the point (c).

In testimony whereof I affix my signature in presence of two witnesses.

ANDREW MILLER FAIRLIE.

Witnesses:

MINNIE HARMON,
W. A. CHANABERRY.