(No Model.)

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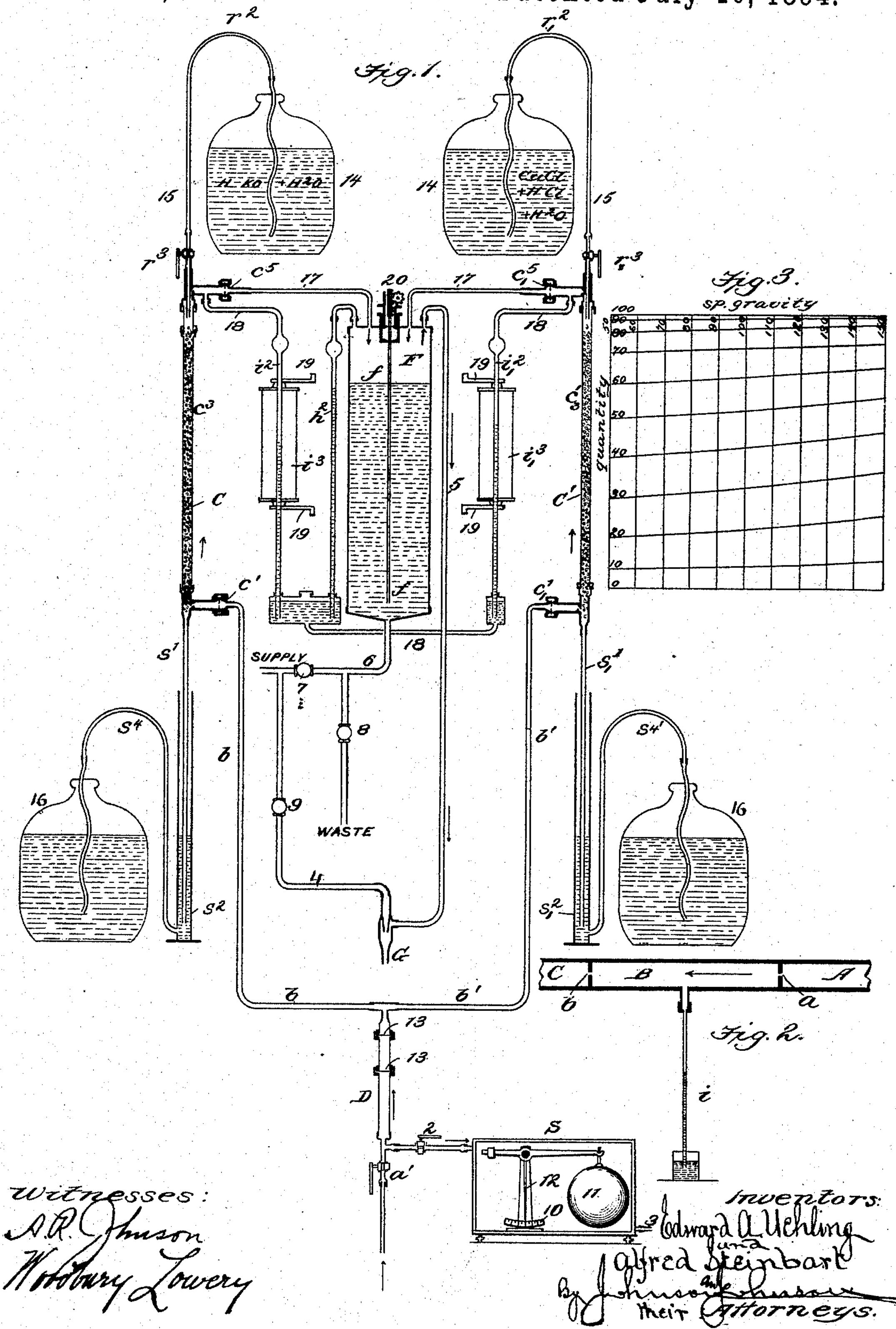
PROCESS OF AND APPARATUS FOR ANALYZING GASES.

No. 522,746. Patented July 10, 1894.



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UNITED STATES PATENT OFFICE.

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PROCESS OF AND APPARATUS FOR ANALYZING GASES.

SPECIFICATION forming part of Letters Patent No. 522,746, dated July 10, 1894.

Application filed February 26, 1894. Serial No. 501,896. (No model.)

To all whom it may concern:

Be it known that we, EDWARD A. UEHLING, a citizen of the United States, and ALFRED STEINBART, a subject of the Emperor of Germany, (having declared his intention of becoming a citizen of the United States,) both residing at Birmingham, in the county of Jefferson and State of Alabama, have invented certain new and useful Improvements in Methods of and Apparatus for Analyzing Gases, of which the following is a specification.

Our invention has for its object the continuous and automatic determination of the percentage of various gases in a gas mixture, in such manner that the actual composition of the gas mixture may be observed at all times, and read off as often as necessary.

So far as we are aware, and can determine, the various components of a gas mixture have never before been automatically and continuously analyzed during the production of the gas.

Although our invention is applicable to the analysis of gas mixtures derived from any source from which quantities of the same may be taken, yet the main object is to effect the quantitative analysis of a gas mixture during its production with a view to facilitating the production of gases of any desired composition. The methods heretofore resorted to in analyzing gases are extremely tedious and expensive, and are carried out as follows: A sample of gas is taken from the source of its production and is conveyed in a suitable vessel to the laboratory where a small portion is measured off with great care by means of a graduated tube, and is then transferred to an absorption pipe, in which one of the components of the gas is absorbed by a suitable reagent, the remaining gas is again returned into the graduated pipe, the quantitative loss determined and known. The remaining gas is transferred into a second absorption pipe and exposed to a second reagent whereby a second portion or component of the gas is absorbed, the remaining gas being reconducted to the graduated pipe and the quantitative loss again determined as before. This operation has to be repeated for each component of the gas mixture, and from the quantitative losses after each absorption the components of the mixture must be determined. This method although the best of all those now known is extremely tedious and can only be carried out by one skilled in the art. The process is very expensive, and requires such a length of time that for practical purposes the method is practically useless in that the analysis can only determine the percentage of components of a gas mixture at the time of the taking of the sample. For these reasons gases are seldom analyzed as often as would be necessary for controlling the manufacture of a definite gas mixture, and even not then where a knowledge of the composition of a gas mixture is of great importance or value. Such a control would for instance be very important to the manufacture of illuminating gas, and generator gases used in the smelting of steel and in other metallurgical processes. Our invention is designed to obviate all these difficulties.

An apparatus constructed according to our invention can be applied directly to a gas conduit from which it continuously takes a small quantity of the gas mixture and continually analyzes the same, so that the composition of the mixture can at all times be read off from a suitable scale. In this manner, without manipulation and expense other than that of the reagents, any abnormal composition of the gas mixture is at once visible, so that a change in said composition is rendered possible, which is invaluable to the manufacturer as well as to the consumer.

Our invention may, for instance be used for the purpose of watching the composition of the gases from blast furnaces. A knowledge of this composition is of great utility for the determination of any irregularity in the smelting process which if not remedied will often lead to serious difficulties.

Furthermore, our invention may be used for controlling heating plants of any kind in view of the fact that an analysis of the smoke will show at all times the percentage of carbon di-oxide or monoxide, thereby indicating the more or less perfect combustion of the fuel, and whether the greatest heating power has been attained.

In order that the operations above stated may be carried out, and the results obtained, our invention consists in a novel method of operation, and novel parts and combination of parts hereinafter described and shown in the form of an apparatus in the accompanying drawings, and specifically set out in the claims concluding this specification.

Referring to the drawings: Figure 1 represents in sectional elevation an apparatus in its complete organization for carrying out our invention. Fig. 2 is a detail view illustrating the principle of our invention; and Fig. 3 is a view of a graphical development of an index used to read off the percentage of the gas to be determined.

The principle of our invention for the analysis of gas mixtures may be stated as follows: If a tube be divided into three compartments by partitions containing very small apertures, and one of the exterior compartments be filled with gas of a higher tension than the other and if the tensions in both of these compartments remain constant the following will take place: The gas of the higher tension will flow toward the compartment of the lower tension passing on its way through the central compartment in which it will assume a constant tension which we will call the "normal tension." If now, a part of the gas in the central compartment is continuously taken away, a change of tension will take place in this compartment which change of tension will depend on the quantity taken away. Again, if the specific gravity of the gas be changed in the central compartment, the tension will be also affected and the degree of this change of tension is dependent on the degree of change of the specific gravity of the gas in the compartment. These facts we have utilized in our invention in that we employ the central compartment as an absorption chamber into which the gas of the first compartment with constant tension continuously flows and from which it escapes continuously into the third compartment of lower constant tension. The inlet and outlet consist of small apertures; and the absorption chamber is connected with an instrument for measuring tension. The specific gravity of the gas is measured either before entering or after leaving the absorption chamber by a suitable gravity meter. If a component of the gas be taken away continuously by absorption by means of a suitable reagent, which is introduced into the absorption chamber without affecting the tension, then a change of tension will take place in the absorption chamber and the quantity of gas corresponding to the change of tension can be read off on the manometer by suitable indices. The form of these indices depends upon the specific gravity of the total gas mixture and the specific gravity of the component absorbed. These statements are explained and proven as follows:

Referring to the illustration shown in Fig. 2, if two compartments, one of which is filled with a gas of higher tension and the other with a gas of lower tension be united by a very small aperture the gas will flow from the compartment of higher tension through the opening into that of the lower tension. The velocity of the flow through the opening depends according to the laws of areomechanics: First, upon the difference of tension in the two compartments. Second, upon the specific gravity of the gas of higher tension. A gas of higher specific gravity flows slower through the opening than a gas of lower specific gravity, under similar conditions, because a greater mass has to be set in motion being impelled by equal forces. Now suppose the gas to be analyzed to be forced through a tube by connecting the one end of the same with the vessel containing the gas mixture and the other end with a vessel filled with gas of a lower tension. Let this tube be divided into three compartments by two partitions which are provided with very small openings; let the central compartment which we will call "absorption chamber" be connected with a manometer as shown in Fig. 2. This combination consisting of the two compartments A and C, the absorption chamber B, the partitions with the small apertures *a* and *b* and the manometer *i* connected with B, we will in the following call "absorption meter." In the first of the compartments A in Fig. 2 the gas mixture has the tension b_0 (the higher tension), in the third compartment C the gas has the tension b_2 (the lower tension). Under these conditions the gas will flow through the aperture in the partition *a* into the absorption chamber B and from there through the aperture in the partition *b* into the compartment C. If the tension b_0 and b_2 are constant, that is, if the tension b_0 remains the same no matter how much gas flows toward C and the tension b_2 remains the same irrespective of the quantity of the gas which flows into it from the compartment A, then the tension in the absorption chamber B will also become constant; this tension (the normal tension) is measured by the manometer *i* connected with chamber B. As soon as this equilibrium is established, equal weights of gas will pass through both apertures in the same space of time, because the same gas has to pass through both openings. The velocity of flow through the respective apertures will also become constant. The velocity through the aperture *a* depends upon the difference of tension between b_0 and b_1, (the tension in B) and the velocity through the partition *b* depends upon the difference of tension between b_1 and b_2. The specific gravity of the gas mixture is the same at both apertures, because the gas remains unchanged and exerts no influence. The conditions however become quite changed if in the absorption chamber B a component of the gas mixture is continually taken away which may take place by absorption, combustion or condensation, or in any other manner. As soon as this occurs that tension in B is reduced, in consequence of which the gas will flow more slowly through the aperture in *b* and more rapidly through the aperture in *a* respectively out of and into the absorption chamber. For this reason the tension will continue to decrease only until as much gas enters at the aperture in *a*, as escapes at the aperture in *b*, plus the quantity taken away, and then again becomes constant, but lower than the normal tension.

If no change of specific gravity of the passing gas is caused by the taking away of the component of the gas, then the tensions in the chamber B will correspond to the percentages of the gas removed, which tensions we therefore employ to measure the quantity of gas absorbed by means of a manometer and an index, the "normal index of the absorption meter."

The gas mixtures to be analyzed however may consist of gases of various specific gravities, for example: Carbon di-oxid in relation to air has the specific gravity of about one and one half, carbon monoxide about one, hydrogen about 0.07. That is carbon di-oxid is about one and one-half times as heavy as air, hydrogen however is fourteen times lighter. If carbon di-oxid is absorbed from a gas mixture containing eighty percentum of carbon di-oxid, ten percentum of air and ten percentum of hydrogen, the specific gravity of the total mixture is much greater, than that of the remaining gas mixture which is composed of equal parts of hydrogen and air. The specific gravity of the former is 1.3 and of the latter only 0.53 in relation to air; the remaining mixture will therefore pass through the second opening in *b* easier and quicker than it would, if its specific gravity was the same as that of the total mixture. The consequence of this is, that the tension in absorption chamber B will fall more than it would if the specific gravity of the remaining mixture were the same as that of the total mixture, the eighty percentum of the carbon di-oxid being taken away.

The change of the specific gravity in the absorption chamber takes place because the specific gravity of the total mixture is not always the same as that of the gas absorbed. The change of the specific gravity of the total mixture causes a different relation between the specific gravity of the total mixture and the specific gravity of the remaining mixture with the same percentages of the gas absorbed. For this reason a change in the specific gravity of the total mixture will cause a deviation of the tension in the absorption chamber from that indicated by the normal index for the same percentage of the gas absorbed, so that for every change in the specific gravity of the total mixture the normal index must be correspondingly rectified. The normal index can according to this also be rectified by the specific gravity of the remaining gas mixture which flows from the absorption meter.

In order to determine the exact percentage of the component of the gas mixture absorbed, we can therefore either determine the specific gravity of the total gas mixture or that of the remaining mixture by a suitable instrument for measuring specific gravities. The rectified index corresponding to the specific gravity so determined is then applied to the manometer and the percentum of the gas absorbed read off.

If in practice we wish to determine several components of the gas mixture it is necessary to employ a corresponding number of absorption meters. These may according to circumstances be arranged either side by side, or in succession.

In the arrangement side by side, a fraction of the gas purified by filtration or other means, passes directly through one of the absorption meters, another fraction through a second absorption meter, a third fraction through a third absorption meter and so on.

In the arrangement where the absorption meters are placed in succession, the remaining mixture of the first absorption meter passes into the second and the remaining mixture of the second passes into the third absorption meter, and so on. An absorption tube may also precede an absorption meter in which a component of the gas, whose value is not necessary to be determined can be taken away. The arrangement side by side is that most generally employed. Finally the absorption meters may be arranged side by side and in succession in the same apparatus.

In a large number of cases in practice the percentages of a gas can be determined with sufficient accuracy without measuring the specific gravity, because the change of the specific gravity of the remaining gas mixture is so small that it can be neglected.

Where the determination of the specific gravity becomes necessary one apparatus for determining the same will suffice for all absorption meters, if the specific gravity of the total mixture is measured by it.

Referring to the apparatus illustrated in Fig. 1 of the drawings, the following is a description of a structure for carrying out one form of our invention.

S indicates an instrument for determining the specific gravity of the gas.

D indicates a filter.

C, C′ indicate two absorption chambers.

F indicates a regulator in connection with an aspirator G.

S_2 and S^1_2 indicate seals.

The apparatus is adapted to the analysis of a gas mixture for carbon di-oxide and carbon monoxide, where the specific gravity of the remaining mixture may vary between wide limits, for instance the waste gases of blast furnaces and the producer gases. The gas which before entering the apparatus, is cleaned from dust and condensible constituents, is continuously furnished from the gas main under slight pressure. It enters the apparatus through the stop-cock *a′* just behind which is inserted a **T** piece, through which a portion of the gas flows by the pipe 2 to the specific gravity meter S and thence to the atmosphere by the pipe 3. If the stop-cock a' is only slightly opened the gas after passing it will be under atmospheric pressure because it is in connection with the atmosphere at 3. This pressure corresponds to the higher tension b_0. The lower tension b_2 is created by the aspirator G and kept constant by the connected regulator F. The regulator consists of an air-tight vessel partially filled with water into which the gas mixture from the absorption meters slowly flows. The aspirator G actuated by water, air, or steam, in this case by water, through a pipe 4 with valve 9 continually draws by a pipe 5 connecting the upper end of the regulator, a larger volume of gas from the regulator than can be supplied by the absorption meters. The deficiency is supplied through the tube f, f depending centrally within said regulator. This tube is immersed into the water in the regulator to a depth of two feet and being open at both ends and communicating with the atmosphere at its upper end. As soon as the aspirator decreases the tension in the regulator, the atmospheric pressure will correspondingly depress the water in the tube f, f. This continues until the air bubbles up through the liquid column in the regulator, in which manner the tension is maintained constant. The manometer h_2 connects with the top of the regulator and indicates the tension therein. Since the tension in the regulator depends upon the water column in the tube f, f, the latter is provided with a rack and pinion 20 at its upper end by means of which it can be raised or lowered in order to regulate the tension. The bottom of the regulator is provided with a pipe 6 for supplying and drawing off the water by means of the stop cocks 7, and 8. The tension in the regulator is not absolutely constant, but is, by a certain amount, lower than that of the atmosphere which, for the apparatus however is equivalent to a constant tension, since the gas enters the apparatus under atmospheric pressure. The flow of gas is divided behind the stop cock a'; the greater part passes through the specific gravity meter S, the remainder into the absorption meters C, C′. The specific gravity meter S may consist of any suitable instrument for the purpose. We illustrate the form known as the Dürre Siebert dasymeter, which consists of a glass case, which is constantly kept filled with the gas mixture to be analyzed which constantly flows through it. In the case is located a scale 10 upon which a hollow sphere 11 filled with air is balanced. Accordingly as the passing gas is of higher or lower specific gravity, the ball will weigh more or less and the specific gravity will thereby be continuously indicated by a pointer 12 on a proper index, and can be read off as often as desired. The smaller portion of the gas passes through the filter D which is composed of two compartments separated by gauze disks 13 made of platinum. This construction makes it possible, to clean the lower compartment without disturbing the upper compartment, which rarely requires attention. In this filter the last traces of fine dust are removed, which is necessary in order to prevent clogging of the minute apertures. After leaving the filter the gas is divided into two parts, one flowing through the pipe b, b, to the absorption meter C in order to be analyzed for carbon di-oxide; the other through the pipe b', b', to the absorption meter C′, to be analyzed for carbon monoxide; and after passing through the small openings c^1 and c^1_1 respectively, enters the absorption chambers. These absorption chambers are formed of tubes c_3 and c^1_3, which are filled with small fragments of material which is not attacked by the reagent, as glass or feldspar, through which the reagents, a solution of caustic potash in the tube c_3 and a hydrochloric solution of cuprous chloride in the tube c^1_3, percolate so that the gases come in contact with a large surface moistened by the reagents. The reagents are supplied from reservoirs 14 as shown, and their flow through pipes 15 is regulated by stop cocks r_3, r^1_3. They flow out through the waste pipes s^1 and s^1_1 respectively into the vessels s_2 and s^1_2 and from there through the communicating tubes s_4 and s^1_4 into the reservoirs 16 as shown. The gas mixture flows up through the particles in the absorption chambers moistened by the reagents and the components to be determined are absorbed; in the chamber c_3 carbon dioxid, and in the chamber c^1_3 carbon monoxid. The remaining gasses pass respectively through the small openings c_5 and c^1_5 by the pipe 17 into the top of the regulator F and from there they are sucked off through the tube 5 by the aspirator G.

The manometers i_2 and i^1_2 which are respectively connected by the tubes 18 with the absorption chambers, between the absorption tubes c^1 and c^1_1 and the apertures c_5 and c^1_5 serve to measure the tensions, between the apertures, which depends upon the percentages of the gases absorbed. A cylinder i_3 and i^1_3 is used with each of these manometers and is provided with an index, which graphically represents the percentages of the component of the gas absorbed, indicated by the tension, for every specific gravity of the total gas mixture. The cylinders which are rotatable about an axis supported by the brackets 19, are placed directly behind the manometers i_2 i^1_2.

In the graphical index the specific gravities are represented as abscissas and the tensions depending thereon are represented by the ordinates. In this manner curves representing the percentages are obtained. Fig. 3 shows in development the principle of such an index. Whenever the exact composition of the gas is to be observed the abscissas corresponding to the specific gravity of the gas mixture, which is indicated by the specific gravity meter S, are placed opposite the respective manometer tubes i_2 and i^1_2 by simply turning the cylinders about their axes the required extent, and the percentages directly read off. The composition of the gas may however vary very largely without a change in the specific gravity in the gas mixture. It is therefore only necessary to move the index when the specific gravity meter indicates a change of specific gravity.

We claim—

1. The herein described method of analyzing gases and determining the different or required constituents thereof, which consists in filtering the gas, then passing it through an absorption chamber having a minute inlet and outlet aperture and abstracting from the gas, during its passage through the said absorption chamber a constituent, whereby a change of tension from the normal is caused therein, and using this change of tension as a means to determine the percentage of said constituent.

2. The herein described method of analyzing gases and determining the different or required constituents thereof, which consists in continuously passing the gas to be analyzed through a filter and a corresponding number of absorption chambers, each having a minute inlet and outlet aperture, and abstracting from the gas during its passage through each of the said absorption chambers a constituent, whereby changes from the normal tensions are caused in each and using these changes as measures to determine the percentages of the different constituents required.

3. The herein described method of analyzing gases, which consists in passing the gas to be analyzed under a normal tension through an absorption chamber having minute inlet and outlet apertures, second, abstracting a constituent from the gas during its passage through said absorption chamber whereby a change in tension from the normal is caused therein and using this change in tension as a measure to determine the percentage of the said constituent, third, drawing off the gas from said absorption chamber at a tension less than normal, and fourth, automatically admitting air to the gas as it is drawn to increase its volume when there is a deficiency of gas drawn from the absorption chamber and thereby preserve a uniform tension of the gas as it is drawn off.

4. In an apparatus for analyzing gas, the combination of a chamber for containing an absorbent having a minute inlet and outlet aperture, a chamber for containing a fluid connected to the outlet aperture of said absorption chamber, a manometer connecting both chambers, and an aspirator connecting the air space of the fluid containing chamber, with a device adjustably operated within the chamber containing the fluid to supply air therein to cause the gas to be continuously drawn from the absorption chamber at a uniform tension in the way and for the purpose stated.

5. In an apparatus for analyzing gas, the combination of absorption chambers each having a minute inlet and outlet aperture, a manometer for each absorption chamber, and a chamber for containing a fluid connecting said absorption chambers and manometers, with an aspirator connecting the air space of said fluid containing chamber, a tube opening into said fluid and open to the outer air, and means for regulating the depth of said tube within the fluid for the purpose stated.

6. In an apparatus for analyzing gases and determining the percentages of the different or required constituents by continuous process, the combination with an absorption chamber with minute inlet and outlet apertures, a manometer and a specific gravity meter in communication, the manometer indicating the change in the tension from the normal caused by abstracting a constituent from the gas, of a graphical scale graduated to correspond with the differences and changes in tension and specific gravities to be applied to the manometer to enable the percentage of the required constituent to be read off.

7. In an apparatus for analyzing gases and determining the percentages of the different or required constituents thereof, the combination of an absorption chamber, a manometer connected therewith a specific gravity meter in communication, and a graphical scale applied to the manometer and movable therewith to enable the percentages of the required constituent to be read off with reference to the specific gravity of the gas mixture.

8. In an apparatus for analyzing gases and determining the different or required constituents thereof, the combination of an absorption chamber, a manometer in connection therewith, a specific gravity meter in communication, and a cylinder mounted behind the manometer and movable about an axis and provided with a graphical scale whereby the percentage of the required constituent can be read off with reference to the specific gravity of the gas mixture.

9. In an apparatus for analyzing gases and determining the different or required constituents thereof, the combination of an absorption chamber, a manometer connected therewith, and a regulator connected with the outlet aperture, of the absorption chamber and comprising a fluid containing receptacle and a vertically adjustable tube open throughout its length and external to said receptacle at its upper end, and an aspirator connected with the regulator.

10. The apparatus herein described and for the purpose stated, consisting of a corresponding series of absorption chambers each having a minute inlet and outlet aperture, a manometer for each absorption meter, a pipe

for supplying the gas to the absorption chambers under a constant tension, a filter for filtering the gas, a specific gravity meter in communication with said pipe, a regulator connected with the outlet apertures of the absorption meters, and graphical scales movable in proximity of the manometers to facilitate the reading off the percentages of the required constituents.

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In presence of—
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