by the above method, will be regarded as the phosphorus content of the various steels purchased in accordance with Pennsylvania Railroad specifications.

Samples of steel in which the phosphorus has been determined will be sent to parties asking for the same in order to enable them to make such comparisons as they may desire.

In formulating the method given above, the published work of Emerton, Wood, Drown, Hundeshagen, Colby, Shimer, Handy, and Jones, has been freely consulted and used. It would be difficult to state in detail what is due to each.

METHOD OF DETERMINING CARBON IN IRON AND STEEL.

OPERATION.

Put three grams of fine borings of the iron or steel in a sixteen ounce beaker or pint dissolving jar, and add 200 cc. of an acid solution of the double chloride of copper and potassium which is at a temperature not above 100° F. Allow to dissolve, taking pains to agitate the liquid during solution. As soon as the separated copper has all disappeared, allow to stand a little while to settle if necessary, and then pour the supernatant liquid, on an asbestos filter in a platinum boat, taking pains at the last to pour out all the liquid, and at the same time leave as much of the separated carbon in the beaker or dissolving jar as possible. Now add about ten cc. of dilute hydrochloric acid (sp. gr. 1.1) to the beaker or jar and so manipulate that this acid shall touch all parts of the beaker or jar which has been in contact with the solvent liquid. Pour this acid on the filter, and wash the carbon out of the beaker or jar by means of a wash bottle containing acid of the same strength. Continue the washing with the acid until all color has disappeared from the washings, and then wash with water until the washings no longer react for hydrochloric acid. After the washing is complete the filtrate should be poured into a large beaker and diluted with clean water, and acid added if necessary to hold the sub-chloride of copper in solution, until it is possible to see whether any carbon has escaped the filter. If any is found, of course the liquid must be passed through the filter again, or the material all thrown away, and a fresh start made. Dry the carbon at a temperature not above 212° F., and then place the boat with the dried material in it in the combustion furnace. While the drying is going on, weigh the absorption potash bulb and prolong, which have been previously prepared as described below, and place them in their proper position, in connection with the combustion train, which has likewise been previously prepared as described, and in which the preheating furnace has been lighted long enough, so that its porcelain tube is fairly red for at least five or six inches of its length. Start the combustion by turning on enough burners at the front end of the combustion tube to embrace about three inches of it with flame, and at the same time see that the connection to the air gas holder is closed, and then open the connection between the oxygen gas holder and the combustion tube, and then adjust at the aspirator so as to allow about three bubbles a second to show in the absorption potash bulb. As soon as the combustion tube above the burners already lighted becomes perceptibly red, turn on enough more burners to embrace a couple of inches more of the tube and allow this portion likewise to become perceptibly red. From this point turn on one or two burners at a time, allowing the tube above them to get red before turning on more, until enough have been turned on to heat the tube red a couple of inches toward the rear end from where the boat lays inside. Continue the combustion after the last burner is lighted about fifteen minutes for steel and not less than thirty minutes for pig or cast iron, taking care to keep the flow of oxygen to the combustion tube sufficient to maintain a slight pressure in this tube, and at the same time not allow over about three bubbles per second to pass the absorption potash bulb. After the burning is completed, turn down the gas supply to the burners by means of a cock one-half, or turn out every other burner so as to allow the combustion tube to cool down slowly, and then shut off the oxygen supply and turn on the air supply for aspiration. Allow not less than a liter of air to pass through the absorption potash bulb, at a rate of not over three bubbles a second. While the aspiration is going on diminish the gas supply to the burners by means of the cock, or turn out additional ones as fast as the tube will stand it. When the aspiration is complete, detach the potash bulb and prolong from the furnace, close the ends with rubber caps, and place in the balance case. Allow to stand fifteen minutes, and then weigh.

APPARATUS AND REAGENTS.

We prefer to use in dissolving the iron or steel a jar of thick heavy glass, rather than a beaker. The jars we have found useful hold about a pint and have a nose for pouring. One is shown in Figure 1.

The agitating apparatus shown in Figure 2 consists, as will be seen, of a slight modification of the well-known stirring machine shown in "The Chemical Analysis of Iron," by A. A. Blair, arranged to stir twelve beakers at once. The shaft carrying the stirring rod consists of a five-eighth inch diameter brass tube, carrying at the bottom a disk which revolves with it. This disk, which is four and one-half inches in diameter and slightly turned up at the edges, serves very satisfactorily as a cover to the beakers in place of the perforated glass plate. The disk should revolve within about one-eighth inch of the top of the beakers. The hole in the brass tube used as a shaft serves to receive the cork carrying the glass rod which, as is observed, is bent at the lower end so that it will just nicely revolve in the beakers or dissolving jars. The frame of the apparatus is made of wood about eleven and one-half inches wide and about forty inches long. The two horizontal parts at the top of the frame are perforated with five-eighth inch holes five inches apart each way, which holes, without any bushing, serve as bearings for the hollow tubular shafts. The top of each shaft carries a wooden pulley four inches in diameter, which has a brass bushing and set screws by means of which it is fastened to the shaft. Brass washers between the pulleys and the top of the frame carry the weight of the revolving parts and diminish the friction. A little tallow and graphite on the rubbing surfaces is also valuable for the same purpose. We use an electric motor for power, and the glass stirring rods revolve about four hundred revolutions per minute. By taking care to wash the stirring rods both before and after using they may be adjusted once for all and left in position. The beakers or dissolving jars are supported on

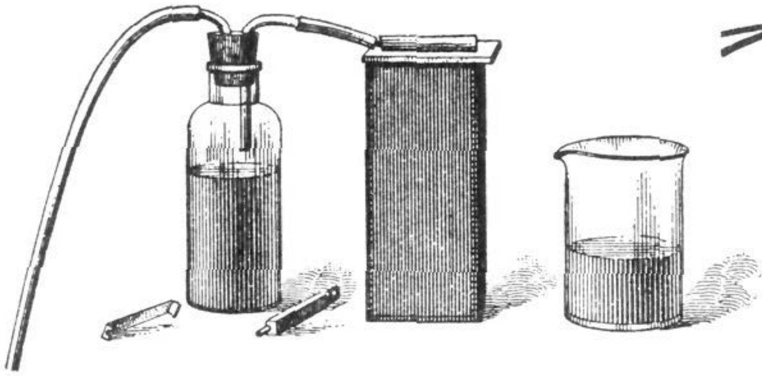
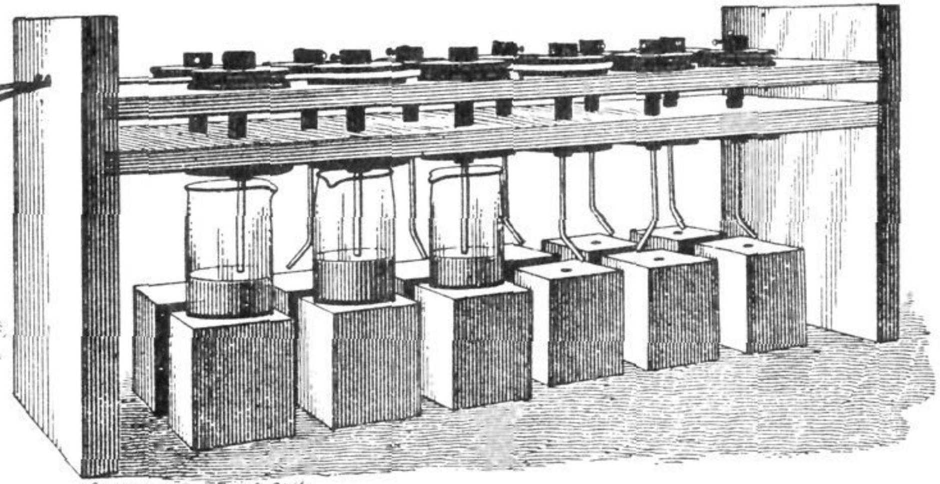


FIGURE 1.



Crosscup & West Eng Co Phila

FIGURE 2.

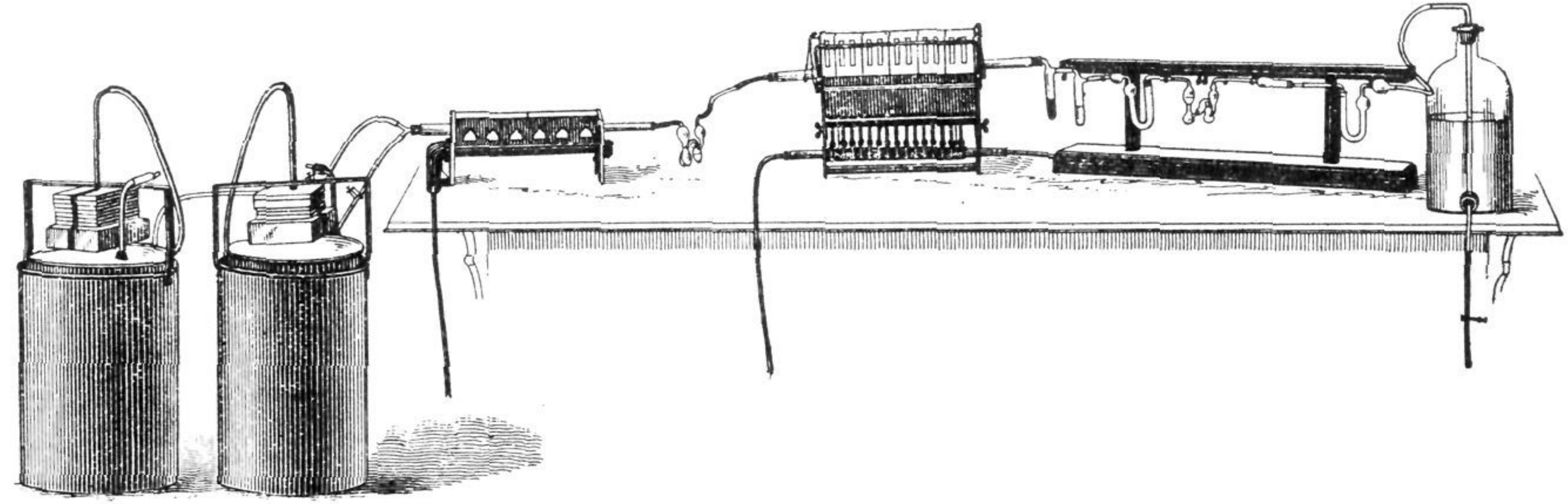


FIGURE 3.

wooden blocks of the proper height, which blocks are movable, so as to allow the beakers or dissolving jars to be put in position, or removed from the same without difficulty. With this stirring apparatus and the amounts of material previously prescribed, complete solution takes place in from seven to forty-five minutes, depending on the size of the borings and the nature of the steel or iron.

As will be seen by the cut, Figure 1, the devices for filtration consist of a receptacle to receive the filtrate, which is connected at the outlet with the exhaust pump or suction, and at the inlet with the platinum boat. The platinum boat is about three inches long, one-half inch wide at top, seven-sixteenths inch wide at bottom and about three-eighths inch high. It is fitted with a perforated false bottom, which leaves a clear space underneath it of about one-eighth inch. The boat is also fitted with a tubular opening at one end, which serves both as a means of connection to the inlet of the filtrate receptacle, and also as a passage-way from the boat for the filtrate. The boat rests on a clean glass plate, supported on a block, which glass plate serves to catch anything that may escape from the boat during filtrations with a chance to recover the same if desired. This form of boat is as efficient as any we have ever seen, and seems to give less difficulty about keeping tight joints than those with perforated bottom. They may be obtained by special order from any dealer in chemical platinum.

The asbestos which we have found to give best results is the mineral known as "actinolite." We consider it essential to ignite the material as received after it has been picked up and cut with shears into short lengths, either in a platinum dish over a Bunsen burner, or in the combustion tube itself, in a current of oxygen. After a quantity of the ignited material has been prepared it should be mixed with water in a beaker and kept under cover as stock supply. To prepare the filter in the boat everything is put in position just as for a filtration and the suction started. The asbestos and water mixture, which should be pretty well diluted, is first stirred up well, in order to make some of it float, and then poured on the boat its whole length, taking care to have the asbestos evenly distributed. The suction removes the water as fast as it is poured on and shows where to pour next. A filter about one-sixteenth inch thick seems to work very satisfactorily. It is usually not necessary to make a fresh filter after each combustion, especially if the copper is completely dissolved before filtration, and if proper care is taken to wash the carbon clean. Under these conditions the same filter may be used over and over again by simply scraping off a little of the top and freshening it up with a little of the asbestos and water mixture after each combustion.

The drying of the carbon on the filter may be done either in the well-known drying oven with hot water or in the drying oven with hot air. We use the latter with an automatic regulator on the gas supply to maintain constant temperature.

The combustion train is shown in Figure 3. Beginning at the left hand, first are two gas holders, one for oxygen gas and the other for air. These are simple copper gas holders with movable weights for pressure. They are adjusted so that the pressure will just cause the gas to bubble through the purifying potash bulb, next to the combustion furnace, but not cause it to pass through the bubble tube containing iron sulphate, just to the right of the combustion furnace. The connection between these gas holders and what we call the preheating furnace, is by means of rubber tubes, and a glass Y tube. These rubber tubes should, of course, be closed by a cock or clamp, so that gas can be taken from either without contamination from the other. The preheating furnace is, as will be observed, a simple twelve-inch Fletcher furnace, fitted with a porcelain combustion tube five-eighths inch in diameter and twenty inches long, which contains granulated oxide of copper for about eight or ten inches of its length inside the furnace. A second combustion furnace would do equally well for a preheating furnace. The corks used with this and also with the combustion furnace are rubber; also rubber tubes are used for connections. The placing of the porcelain tube in the preheating furnace should be such that not less than four or five inches of its length projects towards the combustion furnace, so that this end may not become heated, with consequent danger of volatilizing hydrocarbons from the rubber cork. Also to prevent overheating of the porcelain tube, the gas holes in the gas tube of the preheating furnace are stopped up about two and one-half inches each way from the ends. Next beyond the preheating furnace is an ordinary Geissler potash bulb, which may be called the purifying potash bulb, properly filled with caustic potash solution, to retain any carbon dioxide that may be in the oxygen or air used, or that may be formed in the preheating furnace from the combustion of any vapors containing carbon in these gases. The connection between this potash bulb and the porcelain tube in the preheating furnace should be so arranged that the glass tubes, which are embraced with the rubber tube, should have square ends and should touch, so as to avoid exposure of the current of gas to the rubber tube as much as possible. This same remark applies to all other rubber tube connections. Next beyond the purifying potash bulb is the combustion furnace. The fourteen inch Bunsen furnace gives excellent results. We use coal gas for fuel. The combustion tube is royal Berlin porcelain, glazed inside and outside, five-eighths inch internal diameter, and twenty-four inches long. The tube should be placed symmetrically in the furnace, that is, should project five inches at each end. It should be prepared for use by placing a small plug of asbestos or three or four disks of copper gauze, which are large enough to fit tightly at a point six inches from the right hand end of the tube. Then put in granulated oxide of copper, followed by another asbestos plug or copper gauze disks for four and one-half inches toward the left hand end of the tube. Then make a roll of metallic silver foil, two inches long, rolled moderately closely, until it almost fills the bore of the tube, and place this next to the material already in the tube. This leaves abundant space in the tube for the boat, which should be pushed in so as to touch the silver roll. Next beyond the combustion tube is a bubble tube, not quite half full of acid ferrous sulphate solution, which serves to catch any free chlorine which may escape from the combustion tube, and next beyond this is a bubble tube, not quite half full of silver sulphate and water, which serves to catch any hydrochloric acid that may come out of the combustion tube, or from the ferrous sulphate bubble tube. The solubility of the silver sulphate being rather meagre, it is desirable to add some of the solid salt to the bubble tube in order to prevent the necessity of too frequent charging of this tube. Next beyond the silver sulphate bubble tube, is an ordinary chloride of calcium tube. In order to save space, we prefer the U form. Next is the absorption potash bulb. We prefer the Geissler form, and have them made so that when filled, they with the prolong, weigh from fifty to sixty grams. The ordinary size weigh from eighty to ninety grams. Next is the prolong, which is simply a small chloride of calcium tube filled with granulated chloride of calcium only. Next is another ordinary chloride of calcium tube to protect the prolong from moisture from the aspirator bottle. This bottle finishes the train. It is provided, as will be observed, with inlet at the top and side outlet at the bottom, which latter is also provided with glass tube of sufficient length to give the necessary suction, and a clamp on the rubber hose connection to regulate the flow.

The double chloride of copper and potassium solution is made by dissolving ten pounds of the commercial salt in thirteen liters of water, filtering through ignited asbestos, and adding one liter of concentrated C. P. hydrochloric acid (sp. gr. 1.20).

The caustic potash solution used both in the purifying potash bulb and the absorption potash bulb, is made by dissolving one pound of commercial stick caustic potash in a small amount of water, and then diluting until the resulting liquid when cold shows a sp. gr. of 1.27. A pound of potash makes about a quart of solution.

The granulated oxide of copper may be made by igniting the nitrate in a Hessian crucible until nitrous fumes cease to come off, but not fusing the material; or may be obtained in the market. If the ignition of the nitrate is properly conducted, a porous granular material is obtained, which gives very satisfactory results. Most of the material in the market has been fused and is very dense, and liable to contain impurities. We regard it essential, therefore, to place this fused material in the preheating and combustion tubes, as described, fitting them at the exit end with a small jet tube, then place in the furnace and reduce with hydrogen gas. It is essential during the reduction that the tube where the oxide of copper is, should be heated to a full red heat, and in order to insure complete reduction, the gas should be passed for half an hour after it will burn at the jet. This being accomplished, allow the tube to cool and then replace the hydrogen with air, then heat up again, and pass oxygen gas until the reduced material is oxidized, which will take some time. The use of coal gas in place of hydrogen for the above reduction is admissible, provided the porcelain tube is heated two burners more each way, during the subsequent oxidation, than during the reduction in order to burn out any separated carbon that may have deposited in the tube.

The silver foil may be easily obtained in the market.

The acid ferrous sulphate solution is made by dissolving crystallized ferrous sulphate in water to nearly a saturated solution, and adding three or four drops of sulphuric acid to every fifty cc.

The sulphate of silver is made by precipitating nitrate of silver with carbonate of soda. Filter and wash thoroughly. Then place the precipitate in the vessel in which it is designed to keep the salt with a little water, and then add sulphuric acid at last, drop by drop, with thorough agitation, until all the carbonate is decomposed and the liquid is clearly acid to test paper. In filling the bubble tube shake the vessel and pour in enough of the milk to have one-fourth inch of the solid salt in the bottom when it has settled, and then fill the bubble tube about half full of water. If care is taken to wash the carbon in the boat thoroughly, once filling of the sulphate of silver bubble tube will be sufficient for thirty or forty combustions. Sulphate of silver may be obtained in the market, but we have no experience with this material.

The granulated chloride of calcium used in the chloride of calcium tubes and prolong is obtained in the market. We use the grade marked C. P., and like to have it as free as possible from other substances. The size we prefer is what will pass through holes about a tenth of an inch square and not pass through holes a twentieth of an inch square. Before filling the chloride of calcium tubes it is essential to dry the material, best in a platinum dish over a Bunsen burner for twenty minutes or half an hour, taking care, however, not to fuse it. Of course the chloride of calcium used should not be alkaline, but for fear that it will be sufficiently so to absorb carbon dioxide, even if not sufficiently so to show by test, it is recommended to pass dry carbon dioxide into each freshly filled chloride of calcium tube and allow it to remain over night, and then replace with dry air, before using such tubes in actual work.

The oxygen gas used may be obtained in the market in cylinders compressed to almost any desired pressure. We transfer to the small gas holders shown in the cut, rather than take the gas direct from the cylinders, since the gas holders can be adjusted to give uniform pressure in the tube. This commercial material may be contaminated by oil or vapors containing carbon from the pump used in compressing it, and we accordingly deem it essential to pass it through the preheating tube as described before it goes into the combustion furnace.

After the combustion train is arranged as above described, it is essential to see that there are no leakages, and to make not less than two blank combustions. For the first of these, close the connection from the gas and air holders, and then open the cock controlling the flow from the aspirator bottle, which has been previously filled with water. This puts suction of a column of water twelve to eighteen inches high on the train, and is abundant to indicate any leaks. After the suction has had time to act on the whole apparatus and come to rest, it is satisfactory if nothing passes the absorption potash bulb for five minutes. If this result does not follow, the leaks must of course be found and stopped. The combustion train being found tight, the two blank combustions should be made in every respect as though they were real ones, except of course no iron or steel should be put in the dissolving jar. If these blanks change the weight of the absorption potash bulb and prolong more than about one milligram, something is wrong, and the apparatus and chemicals should not be regarded as satisfactory until one or more blanks are obtained which come within the limit above mentioned. In this conection the paragraph below on necessary errors should be read.

CALCULATIONS.

Since the carbon is weighed as carbon dioxide, and since three-elevenths of the carbon dioxide is carbon, the percentage of carbon in the iron or steel under test may always be found by the following formula, $a : 100 :: \frac{3}{11} b : x$, in which a represents the amount of iron or steel taken, expressed in grams; b the increase in weight of the absorption potash bulb and prolong expressed likewise in grams; and x the carbon sought. This proportion reduces to the form $x = 300b \div 11a$, and when three grams are used to start with, it becomes $x = 100b \div 11$. When three grams are taken to start with, this may be briefly stated as follows: Express the increase in weight of the absorption potash bulb and prolong in grams, move the decimal point two places to the right, and divide by 11. The result will be the percentage of carbon in the sample. Thus if the increase in weight is 0.1661 gram, the carbon will be (16.61 ÷ 11) 1.51 per cent.

NOTES AND PRECAUTIONS.

It will be observed that this method releases the carbon from the iron or steel by dissolving the metal in an acid solution of the double chloride of copper and potassium, and after filtration and thorough washing burns the carbon in a tube in oxygen gas, and after freeing the carbon dioxide formed from impurities, catches it in caustic potash solution, the amount being determined by the increase in weight of the absorbing material.

There is much reason to believe that many discrepancies in duplicate analyses, as well as between different chemists, are due to the borings or drillings. The place from which the drillings are taken; the size of the drill; the depth of the hole; whether it goes through the sample or not, and especially whether the drillings are partly coarse and partly fine, are all believed to have considerable influence on the final result. This difficulty will be diminished (1) by drilling the hole as near through the sample as practicable; (2) by having this hole transverse to the line of final solidification, and cutting it, and (3) by having the drillings as fine as possible, and thoroughly mixing them. This latter precaution, *viz.*, to have the drillings fine, is also important in its influence on the rapidity of subsequent work.

The use of acid and the use of the potash double salt, rather than the ammonium double salt to dissolve the metal, both of which differ from old practice, are copied from the work of the American Committee on International Standards for the Analysis of Iron and Steel. It will be remembered that the work of this committee seemed to show very conclusively that these changes lead to much more accurate results.

If the solution contains more of the double salt than is recommended above, solution will not be so rapid. A saturated solution works very slowly.

The influence of stirring on the rapidity and completeness of solution is very great. With the stirring apparatus recommended above, if the borings are fine it is not at all rare, especially in the case of steels, to get such complete solution in fifteen to twenty minutes that but little more than a stain is left on the asbestos filter in the boat, after the combustion is finished. The reason why stirring is essential will be readily understood. Without stirring, that part of the liquid in immediate contact with the borings which reacts at once is soon used up, leaving the borings surrounded with either a neutral, or an acid liquid containing no active copper salt. Neither of these conditions is favorable to accurate results.

In washing the carbon in the boat, after it is transferred from the beaker or dissolving jar, loss of substance is apt to result, if the jet from the wash bottle is used direct. It is better to always put the liquids into the beaker or dissolving jar, and then pour them into the boat. Too great care can hardly be taken to wash thoroughly. A little sub-chloride of copper or a little chloride of iron left in the asbestos filter, or in the boat, may cause difficulty in the combustion tube later on.

The carbon from some steels, and in general from pig iron, filters readily like sand, but from other steels it seems to separate in such a form as to clog the filters badly. This gelatinous carbon does not seem to be characteristic of any special kind of steel, but may occur in any. We know of no way to facilitate filtration in such cases, except to follow the directions closely.

In drying the carbon in the boat, too high temperatures should be avoided. There are indications that loss of substance may result from neglect of this precaution, although we have not positively demonstrated this.

The use of the preheating furnace complicates the train somewhat, but no other method of freeing the oxygen gas from possible injurious impurities has proven so successful in our experience as this one. It is clear that if there is anything in the gas that would react with oxygen or with oxide of copper in a red hot tube, and later be absorbed by caustic potash, this material must be removed from the gas by the preheating furnace and purifying potash bulb, before the gas goes into the combustion tube. Purifying the oxygen gas without preheating does not seem so satisfactory.

The use of rubber corks and rubber tubes is open to some objection, but we do not know of any successful substitutes for these materials.

The combustion tube we recommend is longer than customary, but we think not longer than essential. The danger of volatile matter from corks affecting the result is considerably diminished by this additional length. We prefer the porcelain tube, although we have never used platinum ones. Tubes of larger bore enable a little larger boat to be used, but they are much slower to heat, and do not in our experience give any more reliable results.

The use of a roll of fine copper gauze in the combustion tube in place of granulated oxide of copper has been recommended. In our experience, it is difficult to be sure that the metallic copper is all oxidized before regular work is begun. If this is not so, and if the metallic copper contains any carbon, there would, of course, be danger of error, due to the slow progressive oxidation of the metal and carbon during combustion.

Many devices have been suggested to prevent the possibility of hydrochloric acid, chlorine or chlorine compounds, which may be formed in the tube during combustion from reaching the absorption potash bulb, and thus introducing error. We have tried many that we have seen suggested, but have found none that seem so efficient as the roll of metallic silver foil. If proper care is taken in the washing of the carbon, if the tube is arranged as described and in good order, and if the rate of movement of the gases is not too rapid, neither chlorine nor hydrochloric acid escapes from the tube. If, however, the washing is incomplete, leaving some sub-chloride of copper or ferrous chloride and free hydrochloric acid in the boat, which latter is not expelled by the drying; if the tube is foul from having been used for many combustions, without cleaning and recharging, or reduction by hydrogen, and especially if the combustion is hurried, resulting in a too rapid movement of the gases in the tube, the silver roll may not be a complete protection. We accordingly introduce into the train an acid ferrous sulphate, and a silver sulphate bubble tube as additional precaution, the former to catch chlorine, and the latter hydrochloric acid. Direct experiments with each of these tubes separately show that they are a complete protection against the gases mentioned, provided the rate of movement is not more than four or five bubbles a second, and also provided the amount of these gases is not greater than would arise in even the rather carelessly managed combustion mentioned above. Of course it may be questioned whether these two bubble tubes do not retain carbon dioxide and thus cause error. Direct experiments made by taking a weighed potash bulb and prolong, properly filled with water, protecting it with chloride of calcium tubes at each end, and charging it full of carbon dioxide, and re-weighing and then aspirating air through it with frequent weights during the aspiration show that a very much less amount of air than that used for aspiration in a regular combustion, is sufficient to remove the carbon dioxide completely from the amount of liquid in the bubble tubes.

It is highly desirable to pass hydrogen or coal gas, preferably the former, through the combustion tube, as described above, after a tube has been used for fifty or sixty combustions. In lieu of this, the tube should occasionally be cleaned out and filled with fresh material. The frequency with which either of these should be done, depends largely on how completely the carbon is freed from other substances during the solution, washing, and drying.

A slight pressure in the tube is thought to be less liable to lead to error from leakages than to have a vacuum in the tube, caused by drawing everything through the train by means of the aspirator bottle. It will be observed that the pressure specified is equal to about half the column of water in the first bubble tube. From this point the aspirator bottle is relied on to move the gases forward.

The combustion tube should always be kept closed, and after a combustion is finished, the connection between the air, gas holder, and the train should be left open, or the liquid in the bubble tubes will suck back into the combustion tube as it cools. We also deem it essential after the furnace has been standing idle some time, to make a blank before proceeding with regular work in order to be sure that everything is right.

It is quite essential that the chloride of calcium tube which precedes the absorption potash bulb and the prolong should dry the gases to the same extent and no more. If one is more efficient than the other, error may result. Thus if the gases which go into the absorption potash bulb, are drier than they are after they leave the prolong, it is obvious that moisture that has been weighed is lost. On the other hand, if the gases that go into the absorption potash bulb are not as dry as when they leave the prolong, it is equally obvious that something besides carbon dioxide has increased the weight of the absorption potash bulb and prolong. It seems probable that some of the difficulty in getting absolute blanks may be accounted for in this way. It is a little hazardous to use a freshly filled chloride of calcium tube with an old prolong, and vice versa. Likewise it is not advisable to use sulphuric acid or other means of drying the gases between the furnace and the chloride of calcium tube.

It is not necessary to recharge the absorption potash bulb for each combustion. Depending of course on the amount of carbon in the sample, they may be used for from three to six or eight combustions without recharging. We have made agreeing duplicates on the same sample, one with a potash bulb, freshly charged, and the other with a potash bulb showing a cloudiness in the first bulb due to bicarbonate.

The weight of the potash bulb and prolong before and after the combustion, is affected by a number of circumstances, other than the carbon dioxide absorbed. It is obvious that if all the conditions are the same at the second weight, which prevailed at the first, there is no error due to weighing. But it seems to be difficult to get these conditions exactly the same. Temperature, barometric pressure, the deposit of something from the air of the laboratory, or from the fingers on the parts weighed, and especially the humidity of the air, may all be different at the second weighing than at first. If we may trust our experience, it is almost impossible to make satisfactory combustions in showery weather.

Where combustions are made in large numbers, say sixteen to eighteen a day, by one operator, with two furnaces, very satisfactory results may be obtained by weighing direct from the furnace, finishing the aspiration with oxygen, instead of air, and using the last weight of one combustion as the first weight of the next one. Of course in arbitration work, this would hardly be satisfactory.

Direct experiments show that with the apparatus arranged as above, the oxygen in the potash bulb and prolong is all removed by air during aspiration, when about 800 cc. of water has been run out of the aspirator bottle. The experiments were made by weighing a potash bulb and prolong, introducing it in the train, passing oxygen until it was filled, then reweighing, and then aspirating air with frequent weighings until the first weight was obtained.

If the aspirator bottle is fitted with a tube reaching nearly to the bottom as shown, the suction on the train will be the same irrespective of the amount of water in the bottle, until the bottom of the tube is reached.

Notwithstanding all precautions, there seem to be some almost unavoidable sources of error in the combustion method of determining carbon. Among these may be mentioned the possibility of hydrocarbon vapors from the rubber tubes and corks, the unequal drying of the gases by the chloride of calcium tube and prolong, the difficulty of getting absolute blanks, and especially the difficulty of making the second weight, under exactly the same conditions as prevailed when the first one was made. We do not think all these errors combined should amount to more than one or two hundredths of a per cent. of carbon.

[Note.—Dr. Dudley informs the editor that the methods for sulphur in steel and sulphur in pig and wrought iron are nearly ready for publication.]