PATENT SPECIFICATION

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567

PROVISIONAL SPECIFICATION

Improvements in the Production of Water Gas

I, FREDERICK LINDLEY DUFFIELD, of 701-713, Salisbury House, London Wall, London, E.C.2, a British Subject, do hereby declare the nature of this invention to be as follows:—

This invention relates to an improved method of making water gas from solid carbonaceous matter and steam by which varying proportions of Hydrogen, Carbon Monoxide and Carbon Dioxide can be produced to accord with the requirements of its intended use. It is particularly directed to the production of a gas having a high Hydrogen and Carbon Dioxide content and a low Carbon Monoxide content, the Carbon Dioxide being easily eliminable by known washing methods, the residual gas being essentially Hydrogen.

To attain this result without incurring serious efficiency losses, the considerations affecting ordinary water gas generation having as its objective the production of a gas in which Hydrogen and Carbon Monoxide are present in substantially equal volumes, require to be modified.

Whilst the present invention is based on the principle underlying the production of water gas, namely, the passing of steam through a column of carbon which has been previously heated by the admission of air, it is differentiated therefrom by the introduction of methods and a design of plant to meet the fundamental alteration in the conditions essential to maximum Hydrogen production from the minimum of Carbon. Thus:—

(1) $C + H_2O = CO + H_2$—28,900 Cals.

(2) $C + 2H_2O = CO_2 + 2H_2$—18,920 Cals.

In case No. 1 above 12 lb. Carbon and 18 lb. Water produce 2 lb. Hydrogen with a heat reaction expenditure of 28,900 lb. cals., and in case No. 2, 12 lb. Carbon and 36 lb. Water produce 4 lb. Hydrogen with a heat reaction expenditure of 18,920 lb. cals.

In the first instance the temperature at which the reaction substantially occurs exceeds that of 1,000° C. and over 99% of the steam present is decomposed, but in the second instance the temperature at which the reaction occurs is in the region of 600° C. but at this low temperature less than 5% of the steam present is decomposed.

My invention relates to methods of overcoming the disadvantage associated with the abnormal proportions of undecomposed steam at the same time securing the advantages of operating at low temperatures in respect to the greater production of hydrogen from a unit of carbon and the lower heat of absorption associated with the reaction $C + 2H_2O = CO_2 + 2H_2$.

In normal water gas generators, the production of gas proceeds throughout the steam blow with ever diminishing temperatures in the producer occasioned by the gradual exhaustion of heat stored in the coke bed, and as a consequence the gas at the start of the steam blow contains a high percentage of Carbon Monoxide and its production is associated with only a small percentage of undecomposed steam, and at the end of the steam blow Carbon Dioxide occurs in increasing quantities, to the detriment of the gas for its usual purposes, and this condition is associated with a less quantity of the gas and a greater quantity of undecomposed steam.

According to this invention a substantially constant temperature is maintained throughout the steam blow (and preferably the operation is carried out at a pressure above normal atmosphere), whereby a regular consistency of gas is obtained. The relative contents of Hydrogen, Carbon Dioxide and Carbon Monoxide, and the percentage of undecomposed steam depend upon that temperature selected for the reaction according to the intended requirements.

The following list gives the relationship of gas contents and undecomposed steam for certain temperatures where the operation is carried out at atmospheric pressure.

Temperature °C.	Percentage of H_2O decomposed.	Composition by volume of Water Gas.		
		H_2	CO	CO_2
675	8 to 9	65.2	4.9	29.8
760	25 to 26	65.2	7.8	27.0
840	41 to 42	61.9	15.1	22.9
955	70 to 72	53.3	39.3	6.8
1,010	94 to 96	48.8	49.7	1.5
1,060	98	50.7	48.0	1.3
1,125	99.4	50.9	48.5	0.6

I have found that the percentage of decomposed steam can be substantially increased at these lower temperatures by operating at pressures above normal atmosphere and by preheating the steam to that temperature at which it will contain a calorific content equal to the reaction requirements concerned at the selected temperature of operation so that no dependence is placed on the stored up superheat of the coke bed to supply such heat of reaction.

By the ability of my method to furnish a substantially constant temperature of steam containing the requisite superheat of reaction throughout the steam blow both gas consistency and equilibrium ratio of decomposed steam to undecomposed steam are rendered reasonably certain, and the heat requirements of such steam are known quantities capable of being catered for.

For instance, operating at a reaction temperature of 760° C. at normal atmospheric pressure only 25% to 26% of the steam is decomposed, but working with a superheat in the steam consistent with its supplying the heat absorbed in the reaction, the percentage of decomposed steam is increased to an extent beyond that which for thermal and economic advantages hereafter explained in the operation of my process, it is necessary to attain.

Therefore I base my explanation on only 25% of the steam used being decomposed. To produce a gas consisting of 65.2% H_2, 7.8% CO and 27% CO_2 at a reaction temperature of 760° C., I find that for each 1 lb. of steam decomposed 797 lb. cals. are absorbed in the reaction, and that 4 lb. of steam superheated to 1.160° C. will supply the required 797 lb. cals. and the produced gas and the 3 lb. of undecomposed steam will leave the coke bed at 760° C.

At the start of the steam blow, the superheat of the steam is regulated momentarily to a temperature below 1.160° C. so that on contact with any stored up heat in the coke bed above 760° C. the requisite reaction exhausts such stored up heat to 760° C., and during this momentary operation the consistency of the gases is thereby preserved, and such stored up excess heat in the coke bed advantageously utilised.

In the production of gas having a high hydrogen and carbon dioxide content necessitating operation at low temperatures, a large excess of steam over and above that decomposed is inevitable, and constitutes an unwieldy imposition in its cooling effect on the stored up heat in the coke bed under ordinary water gas practice. Especially is this so in view of the fact that in producing such stored up heat in a body of coke by a blast of air it is not possible to avoid the tendency to producer gas reaction by which a considerable proportion of the heat of complete combustion is reduced by the reaction $C + CO_2 = 2CO$. Heat produced by semi-combustion to CO releases only 2,430 lb. cals. per lb. of carbon against 8.100 lb. cals. per lb. carbon to CO_2.

In my process I objectively proceed to semi-combustion (CO) by preheated air in the coke bed instead of establishing a stored up heat zone of highly incandescent coke as the source of total heat for reaction, which in any case would be prejudicial to the production of a gas of the consistency required for maximum hydrogen production, and I advantageously utilise the hot CO gases from the coke bed for complete combustion in raising a mass of highly conducting material to the highest possible temperture compatible with the refractory qualities of such mass, the sensible heat of such complete combustion products being transferred thereto in such manner that their residual heat content on leaving such mass is reduced to a temperature only slightly higher than the succeeding entry temperature of the saturated steam from a boiler.

The inevitable use of excess steam consistent with the high hydrogen-carbon dioxide gas required instead of being a burden on the efficiency and cost of operation, establishes, under my process, an advantageous medium of utilising the unavoidable potential calorific value of gases leaving the coke bed during the air blast period by rendering such steam a useful heat carrier to the zone of reaction, and thereafter I use a similar highly conductive mass to absorb the major sensible heat of the produced gases and undecomposed steam, such absorbed heat being imparted to the air for combustion and semi-combustion on the succeeding period of heat restoration.

I have found that the respective heat values involved in each compartment of my regenerator during the heating period are substantially in accord with the respective heat values required in each compartment during the steaming period.

I have further found that in the application of air to a column of coke a more uniformly distributed heat by combustion to CO is obtainable when such air and resultant gaseous products are directed horizontally through a vertically narrow coke mass by admission of such air through numerous port holes disposed in the vertical wall on the one side of the coke mass and similarly disposed port holes in the vertical wall on the other side for the exit of the gaseous products.

I have found that in the application of superheated steam to a column of heated coke through such-port holes, as described, so that the steam and resultant gases traverse such heated coke bed in horizontal planes in contra direction to the preceding air and combustion products, an improved intimacy of contact between steam and Carbon is obtained as the result of avoidance of channelling as is liable to occur in ascensional flow.

I find that the traversing of air and its combustion products and the traversing of steam and its water gas products in a horizontal plane enables a much greater surface being uniformly treated than is practical in any column alternately ascensionally and descensionally treated as in existing practice. This in fact enables a unit of plant to produce greater quantities per unit of time than is practical in standard systems.

It will be understood from the foregoing that I establish my major superheat supply in a mass of conductive material by the complete combustion of hot gases produced by the incomplete combustion of coke by air in the coke bed wherein I establish my minor superheat supply.

The relative proportions of the quantity of heat above 760° C. thus deposited respectively in the coke bed and in the mass of conductive material are in the ratio of 1:4. The heat in the coke bed is produced by incomplete combustion of carbon with preheated air with resultant gaseous products leaving such coke bed at an average temperature of 900° C. The heat in the mass of conductive material is produced by the complete combustion of such hot gases with similarly preheated air and products leaving at 300° C.

The heat of complete combustion deposited in the mass of conductive material is of a higher temperature order than the heat deposited in the coke bed. Whereas the latter is heated by semi-combustion to a temperature of 1,000° C. the mass of conductive material is heated to approximately 1,500° C. at the top of the mass whereat the combustion products enter, down to approximately 200° C. at the bottom, whereat the heat-spent gases (300° C.) leave.

The steam from the boiler, preferably at a pressure of 300 lb. per square inch having a saturated steam temperature of 214° C., enters the generator at two levels, one below the mass of conductive material which has been heated as above described, and one above the mass of conductive heated material. At the start of the steam blow a regulated quantity of steam is admitted at the top level which reaches the coke bed only slightly superheated by contact with the combustion chamber walls and this steam utilises the superheat of the coke bed above 760° C. to superheat such initially entering cool steam to effect reaction in the region of 760° C.

Thereafter a gradually decreasing proportion of total steam entering at top level and a gradually increasing proportion entering at bottom level secures a regular quantity of steam at constant temperature at, in this instance 1,160° C., through the cooling, by the cooler steam entering the top level, of the steam from the bottom level, which has attained a temperature in excess of 1,160° C. from the stored up heat in the mass of conductive material. Upon exhaustion of superheat in the mass of conductive material rendering the temperature of the bottom steam less than 1,160° C. the steam blow ends, the high pressure steam and residual gas within the generator is released firstly to half pressure by transference of half its steam and residual gas contents to the second generator immediately prior to the latter starting its steaming period, and secondly to atmospheric pressure to a regenerator suitably disposed as a connecting unit filled with a mass of conductive material which substantially absorbs the sensible heat of released steam and the accompanying negligible percentage of residual gas, for use in preheating the air used in the steam boiler. The release of high pressure steam to a volume 12 times its compressed volume serves to purge the water gas generator which in the heat restoration period is operated at atmospheric pressure.

The water gas and undecomposed steam leaving the coke bed at a temperature in the region of 760° C. enter a mass of conductive material which absorbs the sensible heat of such gases and undecomposed steam down to a temperature of 300° C. which establishes a stored up heat supply to be transferred in the heating period to the air required for combustion to CO in the coke bed and for the complete combustion of resultant CO gases leaving the coke bed in the compartment containing the mass of conductive material constituting the stored up superheat supply for steam superheat.

In the course of cooling the water gases containing a proportion of CO in the presence of adequate supplies of undecomposed steam at high pressure (300 lb. per square inch approximately 20 atmospheres) the whole being in a turbulent state in its descensional traverse through the voids of the mass of conductive material, it is established that further reaction occurs in the direction of $CO + H_2O = CO_2 + H_2$, thus increasing the Hydrogen content by conversion to readily eliminable CO_2 and consequent diminution of the undesirable CO in cases where maximum Hydrogen is the intended purpose.

This exothermic reaction adds further sensible heat to the mass of conductive material thus desirably increasing the stored up heat for transfer to the air supply during the succeeding heat restoration period.

By working at a pressure during the steam blow period, a longer time of contact of steam poundage with carbon is secured making for a substantial increase in the proportion of steam decomposed. At 300 lb. per square inch absolute pressure 1 lb. of steam has a volume of 1.552 cubic feet whereas at atmospheric pressure 1 lb. of steam has a volume of 26.77 cubic feet. This contraction of volume permits of a greater weight of steam traversing the coke bed per unit of time and still allows in addition a longer time contact and this further admits of the steam blow and the air blast being of equal duration which allows twin generators to act in unison thus producing a continuous supply of gas, which is an important condition in relation to the washing period for the elimination of CO_2 under pressure, enabling the latter to be a continuous operation.

It is known in practice that substantial elimination of CO_2 can be effected only under a pressure above 10 atmospheres. The mechanical compression of gas having high Hydrogen content is an expensive operation on account of the Horse-power involved. In my process, the washing operation is effected under the pressure common to the complete generator unit during the steaming period such pressure being derived from the pressure head developed in the steam boiler.

As two generators are worked in unison, viz., whilst one is being heated the other is steaming, the connecting unit constituting a means of cooling the gases and condensing the undecomposed steam together with washing apparatus for elimination of CO_2 is common to both generators, being alternately connected with either generator during its period of steaming which enables the pressure in such connecting unit to be continuous.

The apparatus for cooling the gases and condensing the undecomposed steam may constitute a means of recovering the sensible and part of the latent heat of the undecomposed steam by imparting such heat to the water required for the steam boiler.

The mass of the conducting material for absorbing the bulk of the heat of complete combustion of the gases arising from the coke bed during the heating period and thereafter transferring such absorbed heat to the steam undergoing superheating, may consist of any refractory material having a high coefficient of conductivity such as compressed graphite protected from oxidation by a neutral refractory coating, carborundum, or heat resisting metals. The mass may be composed of a multiplicity of segments of such conductive refractory material, in the shape of spheres resting *en masse* or diamond shaped pieces suitably spaced by intermediate projecting flanges. or of a variety of shapes loosely packed or in constructed formation in such manner to cause turbulence by deflection.

The mass of conductive material for absorbing the major sensible heat of the water gas and undecomposed steam from the coke bed and thereafter transferring such absorbed heat to the air required for combustion during the heating period, may similarly consist of refractory material having a high coefficient of conductivity ensuring a high state of thermal emissivity and diffusivity. As the temperatures concerned are. however, lower than its previously described counterpart, materials of less refractoriness. but having known qualities of influencing the reaction $CO + HO_2 = CO_2 + H_2$ by catalytic or alternate oxidising and reducing effect, may be used.

The water gas generator may be externally cooled by applying water to the steel casing by any known method. This tends to maintain a regular temperature of the steel casing throughout its length and breadth, thus neutralizing any differential expansion effects which may otherwise occur through any local difference in internal temperatures of the generator.

Dated this 20th day of September, 1943.
MEWBURN, ELLIS & CO.,
70 & 72, Chancery Lane, London, W.C.2,
Chartered Patent Agents.

COMPLETE SPECIFICATION

Improvements in the Production of Water Gas

I, FREDERICK LINDLEY DUFFIELD, of 701-713, Salisbury House, London Wall, London, E.C.2, a British Subject, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to an improved method of making water gas from solid carbonaceous matter and steam by which varying proportions of hydrogen, carbon monoxide and carbon dioxide can be produced to accord with the requirements of its intended use. It is particularly directed to the production of a gas having a high hydrogen and carbon dioxide content and a low carbon monoxide content, the carbon dioxide being easily eliminable by known washing methods, the residual gas being predominantly hydrogen.

To attain this result without incurring serious efficiency losses, the considerations affecting ordinary water gas generation having as its objective the production of a gas in which hydrogen and carbon monoxide are present in substantially equal volumes, require to be modified.

Whilst the present invention is based on the principle underlying the production of water gas, namely, the passing of steam through a column of carbon which has been previously heated by the admission of air, it is differentiated therefrom by the introduction of methods and a design of plant to meet the fundamental alteration in the conditions essential to maximum hydrogen production from the minimum of carbon. Thus:—

(1) $C + H_2O = CO + H_2 — 28,900$ Cals.

(2) $C + 2H_2O = CO_2 + 2H_2 — 18,920$ Cals.

In case No. 1 above 12 lb. carbon and 18 lb. water produce 2 lb. hydrogen with a heat reaction expenditure of 28,900 lb. cals., and in case No. 2, 12 lb. carbon and 36 lb. water produce 4 lb. hydrogen with a heat reaction expenditure of 18,920 lb. cals.

In the first instance the temperature at which the reaction substantially occurs exceeds that of 1,000° C. and over 99% of the steam present is decomposed, but in the second instance the temperature at which the reaction occurs is in the region of 600° C. but at this low temperature less than 5% of the steam present is decomposed.

My invention relates to methods of overcoming the disadvantage associated with the abnormal proportions of undecomposed steam at the same time securing the advantages of operating at low temperature whilst obtaining the greater production of hydrogen from a unit of carbon and the lower heat of absorption associated with the reaction

$$C + 2H_2O = CO_2 + 2H_2.$$

In normal water gas generators, the production of gas proceeds throughout the steam blow with ever diminishing temperatures in the producer occasioned by the gradual exhaustion of heat stored in the coke bed, and as a consequence the gas at the start of the steam blow contains a high percentage of carbon monoxide and its production is associated with only a small percentage of undecomposed steam, and at the end of the steam blow carbon dioxide occurs in increasing quantities, to the detriment of the gas for its usual purposes, and this condition is associated with a less quantity of the gas and a greater quantity of undecomposed steam.

According to this invention a substantially constant temperature is maintained throughout the steam blow (and preferably the operation is carried out at a pressure above normal atmosphere), whereby a regular composition of gas is obtained. The relative contents of hydrogen, carbon dioxide and carbon monoxide, and the percentage of undecomposed steam depend upon that temperature selected for the reaction according to the intended requirements.

The following list gives the relationship of gas contents and undecomposed steam for certain temperatures where the operation is carried out at atmospheric pressure.

Temperature °C.	Percentage of H_2O decomposed.	Composition by volume of Water Gas.		
		H_2	CO	CO_2
675	8 to 9	65.2	4.9	29.8
760	25 to 26	65.2	7.8	27.0
840	41 to 42	61.9	15.1	22.9
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1,010	94 to 96	48.8	49.7	1.5
1,060	98	50.7	48.0	1.3
1,125	99.4	50.9	48.5	0.6

I have found that the percentage of decomposed steam can be substantially increased at these lower temperatures by operating at pressures above normal atmosphere and by preheating the steam to that temperature at which it will contain a calorific content equal to the reaction requirements concerned at the selected temperature of operation so that no dependence is placed on the stored up superheat of the coke bed to supply such heat of reaction.

On account of the ability of my method to furnish a substantially constant temperature of steam containing the requisite superheat of reaction throughout the steam blow, it is possible to render both gas composition and equilibrium ratio of decomposed steam to undecomposed steam reasonably certain, since the heat requirements of such steam are known quantities capable of being catered for.

For instance, operating at a reaction temperature of 760° C. at normal atmospheric pressure only 25% to 26% of the steam is decomposed, but working with a superheat in the steam consistent with its supplying the heat absorbed in reaction, the percentage of decomposed steam is increased to an extent beyond that which is necessary for the thermal and economic advantages hereafter explained in the operation of my process.

Therefore I base the following calculation on only 25% of the steam used being decomposed. To produce a gas consisting of 65.2% H_2, 7.8% CO and 27% CO_2 at a reaction temperature of 760° C., I find that for each 1 lb. of steam decomposed 797 lb. cals. are absorbed in the reaction, and that 4 lb. of steam superheated to 1,160° C. will supply the required 797 lb. cals. and the produced gas and the 3 lb. of undecomposed steam will leave the coke bed at 760° C.

At the start of the steam blow, the superheat of the steam is regulated momentarily to a temperature below 1,160° C. so that on contact with any stored up heat in the coke bed above 760° C. the gas making reaction exhausts such stored up heat to 760° C., and during this momentary operation the composition of the gases is thereby preserved, and such stored up excess heat in the coke bed advantageously utilised.

In the production of gas having a high hydrogen and carbon dioxide content necessitating operation at low temperatures, a large excess of steam over and above that decomposed is inevitable, and constitutes an unwieldy imposition in its cooling effect on the stored up heat in the coke bed under ordinary water gas practice. Especially is this so in view of the fact that in producing such stored up heat in a body of coke by a blast of air it is not possible to avoid the tendency to producer gas reaction by which a considerable portion of the heat of complete combustion is reduced by the reaction $C+CO_2=2CO$. Heat produced by semi-combustion to CO releases only 2,430 lb. cals. per lb. of carbon against 8,100 lb. cals. per lb. carbon to CO_2.

In my process I purposely proceed to semi-combustion (CO) by preheated air in the coke bed instead of establishing a stored up heat zone of highly incandescent coke as the source of total heat for reaction, which in any case would be prejudicial to the production of a gas of the composition required for maximum hydrogen production, and I advantageously utilise the hot CO gases from the coke bed for complete combustion in raising a mass of highly conducting material to the highest possible temperature compatible with the refractory qualities of such mass, the sensible heat of such complete combustion products being transferred thereto in such manner that their residual heat content on leaving such mass is reduced to a temperature only slightly higher than the succeeding entry temperature of saturated steam from a boiler.

The inevitable use of excess steam consistent with the high hydrogen-carbon dioxide gas required instead of being a burden on the efficiency and cost of operation, establishes, under my process, an advantageous medium of utilising the unavoidable potential calorific value of gases leaving the coke bed during the air blast period by rendering such steam a useful heat carrier to the zone of reaction; and thereafter I use a similar highly conductive mass to absorb the major part of the sensible heat of the produced gases and undecomposed steam, such absorbed heat being imparted to the air for semi-combustion on the succeeding period of heat restoration.

I have found that the respective heat values involved in each compartment of my regenerator during the heating period are substantially in accord with the respective heat values required in each compartment during the steaming period.

I have further found that in the application of air to a column of coke a more uniformly distributed heat by combustion to CO is obtainable when such air and resultant gaseous products are directed horizontally through a vertically narrow coke mass by admission of such air through numerous port holes disposed in the vertical wall on the one side of the coke mass and similarly disposed port holes in the vertical wall on the other side for the exit of the gaseous products.

I have found that in the application of superheated steam to a column of heated coke through such port holes, as described, so that the steam and resultant gases traverse such heated coke bed in horizontal planes in contra direction to the preceding air and combustion products, an improved intimacy of contact between steam and carbon is obtained as the result of avoidance of channelling as is liable to occur in ascensional flows.

I find that the traversing of air and its combustion products and the traversing of steam and its water gas products in a horizontal plane enables a much greater surface being uniformly treated than is practical in any column alternately ascensionally and descensionally treated as in existing practice. This in fact enables a unit of plant to produce greater quantities per unit of time than is practical in standard systems.

It will be understood from the foregoing that I establish my major superheat supply in a mass of conductive material by complete combustion of hot gases produced by the incomplete combustion of coke by air in the coke bed wherein I establish my minor superheat supply from semi-combustion to CO.

The relative proportion of the quantity of heat above 760° C. thus deposited respectively in the coke bed and in the mass of conductive material is in the ratio of 1:4. The heat in the coke bed is produced by incomplete combustion of carbon with preheated air with resultant gaseous products leaving such coke bed at an average temperature of 900° C. The heat in the mass of conductive material is produced by the complete combustion of such hot gases with similarly preheated air and products leaving at 300° C.

The heat of complete combustion deposited in the mass of conductive material is of a higher temperature order than the heat deposited in the coke bed. Whereas the latter is heated by semi-combustion to a temperature of 1,000° C. the mass of conductive material is heated to approximately 1,500 C. at the top of the mass whereat the combustion products enter, down to approximately 200° C. at the bottom, whereat the heat-spent gases (300° C.) leave.

The steam from the boiler, preferably at a pressure of 300 lb. per square inch having a saturated steam temperature of 214° C., enters the generator at two levels, one below the mass of conductive material which has been heated as above described, and one above the mass of conductive heated material. At the start of the steam blow a regulated quantity of steam is admitted at the top level which reaches the coke bed only slightly superheated by contact with the combustion chamber walls and the superheat of the coke bed above 760° C. is utilised to superheat such initially entering cool steam to effect reaction in the region of 760° C.

Thereafter a gradually decreasing proportion of total steam entering at the top level and a gradually increasing proportion entering at the bottom level secures a regular quantity of steam at constant temperature at, in this instance, 1,160° C., through the cooling, by the cooler steam entering at the top level, of the steam from the bottom level which has attained a temperature in excess of 1,160° C. from the stored up heat in the mass of conductive material. Upon exhaustion of superheat in the mass of conductive material rendering the temperature of the bottom steam less than 1,160° C. the steam blow ends.

The water gas and undecomposed steam leaving the coke bed at a temperature in the region of 760° C. enters a mass of conductive material which absorbs the sensible heat of such gases and undecomposel steam down to a temperature of 300° C. which establishes a stored up heat supply to be transferred in the heating period to the air required for combustion to CO in the coke bed and for the complete combustion of resultant CO gases leaving the coke bed in the compartment containing the mass of conductive material constituting the stored up superheat supply for steam superheat.

In the course of cooling the water gas containing a proportion of CO in the presence of adequate supplies of undecomposed steam, the whole being in a turbulent state in its descensional traverse through the voids of the mass of conductive material, it is established that further reaction occurs in the direction of $CO + H_2O = CO_2 + H_2$, thus increasing the hydrogen content by conversion to readily eliminable CO_2 and consequent diminution of the undesirable CO in cases where maximum hydrogen content is the intended purpose.

This exothermic reaction adds further sensible heat to the mass of conductive material thus desirably increasing the stored up heat for transfer to the air supply during the succeeding heat restoration period.

By working at a pressure during the steam blow period, a longer time of contact of steam poundage with carbon is secured making for a substantial increase in the proportion of steam decomposed. At 300 lb. per square inch absolute pressure 1 lb. of steam has a volume of 1.552 cubic feet whereas at atmospheric pressure 1 lb. of steam has a volume of 26.77 cubic feet. This contraction of volume permits of a greater weight of steam traversing the coke bed per unit of time and still allows in addition a longer time contact and this further admits of the steam blow and the air blast being of equal duration which allows twin generators to act in unison thus producing a continuous supply of gas, which is an important condition in relation to the washing period for the elimination of CO_2 under pressure, enabling the latter to be a continuous operation.

It is known in practice that substantial elimination of CO_2 can be effected only under a pressure above 10 atmospheres. The mechanical compression of gas having high hydrogen contents is an expensive operation on account of the horse-power involved. In the case of operating my process under pressure, the washing operation is effected under the pressure common to the complete generator unit during the steaming period, such pressure being derived from the pressure head developed in the steam boiler.

The apparatus for cooling the gases and condensing the undecomposed steam may constitute a means of recovering the sensible and part of the latent heat of the undecomposed steam by imparting such heat to the water required for the steam boiler.

The mass of the conducting material for absorbing the bulk of the heat of complete combustion of the gases produced from the coke bed during the heating period and thereafter transferring such absorbed heat to the steam undergoing superheating, may consist of any refractory material having a high coefficient of conductivity such as compressed graphite protected from oxidation by a neutral refractory coating, carborundum, or heat resisting metals. The mass may be composed of a multiplicity of segments of such conductive refractory material, in the shape of spheres resting *en masse* or diamond shaped pieces suitably spaced by intermediate projecting flanges, or of a variety of shapes loosely packed or in constructed formation in such manner to cause turbulence by deflection.

The mass of conductive material for absorbing the major part of the sensible heat of the water gas and undecomposed steam from the coke bed and thereafter transferring such absorbed heat to the air required for combustion during the heating period, may similarly consist of refractory material having a high coefficient of conductivity ensuring a high state of thermal emissivity and diffusivity. As the temperatures concerned are, however, lower than its previously described counterpart, materials of less refractoriness, but having known qualities of influencing the reaction $CO + H_2O = CO_2 + H_2$ by catalytic or alternate oxidising and reducing effect, may be used.

The water gas generator may be externally cooled by applying water to the steel casing by any known method. This tends to maintain a regular temperature of the steel casing throughout its length and breadth, thus neutralising any differential expansion effects which may otherwise occur through any local difference in internal temperatures of the generator.

The working of the process may be more clearly understood from the following description of a particular apparatus and method for carrying it out in practice, but the invention is not limited to details of such apparatus or method.

Fig. 1 of the accompanying drawing shows a cross sectional elevation of the apparatus.

Fig. 2 shows sections on an enlarged scale along the lines A—A and B—B of Fig. 1.

The arrows drawn in full lines show the direction of air flow and the arrows drawn in dotted lines show the steam flow.

Heating Period

Through a system of reversing valves, cold air is supplied to main *a*, from which through branches, it enters the flues *b* supporting the conductive mass *d*.

The roof *c* of these flues is perforated with the necessary rows of holes needed to disperse the cold air evenly throughout the whole length of the conductive mass. The air passing up through this conductive mass is heated by absorbing the heat given up to the mass in the steam period.

On reaching zone *e*, the air now being preheated, continues through numerous port holes *f* disposed in the vertical wall and is directed horizontally through a coke or coal bed, to similarly disposed port holes *g* in the vertical wall on the other side. The resultant gaseous products leaving port holes *g*, enter the combustion chamber *h*, whereby, with the admission of cold air supplied at *j*, complete combustion takes place.

These combustion products descend through the conductive mass *k* giving up their heat to this mass, and hence through the perforated roof into the flue *l*. The perforated roof for the flue *l* supporting the conductibe mass *k*, is similar to that of *b* and *c*. The combustion products make their exit through branches into a main *m*, and hence through a system of reversing valves to be disposed of.

During this period an additional supply of cold air is introduced, through a system of reversing valves at *n*, the purpose of which is twofold, firstly, to reduce any carbon which may have reached the grate level without complete combustion, and secondly, to serve as a medium for cooling the grate bars and ash.

Steaming Period

Through a system of reversing valves, low temperature steam is supplied to main *m*. The low temperature steam leaves main *m* by two exits and so supplying steam to the generators at two levels. At the start of the steam blow a regulated quantity of steam is admitted at the top level *h*, through the branch pipe *o* and regulating valve *p*, also a regulated quantity of steam is admitted at the bottom level, through the branches into the flue *l* and hence up through the conductive mass *k*. After the start of the blow a gradually decreasing proportion of total steam enters at the top level and a gradually increasing proportion enters the bottom level.

On reaching zone *h* the steam admitted at the bottom level is now superheated and mingles with the steam admitted at the top level, which has been only slightly superheated. This gives a steam of uniform temperature which passes through th numerous port holes *g*, and horizontally through the coke or coal bed and out through the similarly disposed port holes *f* on the other side, as described in the heating period.

The water gas and undecomposed steam leaving the coke or coal bed through the port holes *f*, enter the zone *e* and descend through the conductive mass *d* giving up the major part of their sensible heat to this mass, and hence through the perforated roof *c* into the flue *b*.

The water gas makes its exit through branches into the main *a* and hence through a system of reversing valves to the cooling and condensing apparatus.

During the steaming period an additional supply of saturated steam is introduced through a system of reversing valves at *n*, again as in the heating period, the purpose is twofold, firstly, to react with that reduced carbon which may have reached the grate level as described in the heating period, and secondly, for cooling the grate bars and ash.

During the steaming period the supply of cold air at *j* has been shut off.

During the process the carbonaceous fuel is gradually reduced to ash on its descent to the grate level, it being practically completely reduced to ash at level *q*. A regular flow of fuel is introduced at *r* by means of double bell charging hoppers.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. A process for the production of water-gas having a high proportion of hydrogen and a low proportion of carbon monoxide characterised by the feature that the supply of heat required by the endothermic reaction is delivered by a quantity of steam having a constant superheat throughout the period of the gas-making run.

2. A process for the production of water-gas according to Claim 1 by intermittently causing air and steam respectively in contra flow relation to traverse in a horizontal direction through the narrow width of a vertical elongated mass of carbonaceous matter, such as coal or coke, and with a supplementary intermittent supply of air at atmospheric temperature and non-superheated steam admitted vertically at the base of the carbonaceous mass in amount requisite for the cooling of the grate and descend-

ing ash residue of the carbonaceous matter.

3. A process for the production of water-gas according to Claim 1 or Claim 2 whereby the temperature of the heat supply, viz. the superheat of the steam, is rendered uniform throughout the steaming period by causing progressively diminishing proportions of non-superheated steam to combine with the highly superheated steam in accord with the progressively diminishing temperature of the latter during the steaming period.

4. A process for the production of water-gas according to any of the preceding Claims characterised by the feature that the air during the air blast traverses the carbonaceous matter at a rate which limits the heat generated in the bed of carbonaceous matter to that producing a temperature resulting in the generation of CO, to the substantial exclusion of CO_2, in order that by admission of secondary air the greatest possible heat is made available for providing the stored up heat in the regenerators for interchange to the steam in course of superheating.

5. A process for the production of water-gas according to any of the preceding Claims in which the process is carried out under pressure.

6. A process for the production of water-gas by the method herein particularly described and using the apparatus shown in the accompanying drawings.

7. Apparatus for producing water-gas substantially as shown in the accompanying drawings.

Dated this 11th day of October, 1944.
MEWBURN, ELLIS & CO.,
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Chartered Patent Agents.

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[This Drawing is a reproduction of the Original on a reduced scale.]

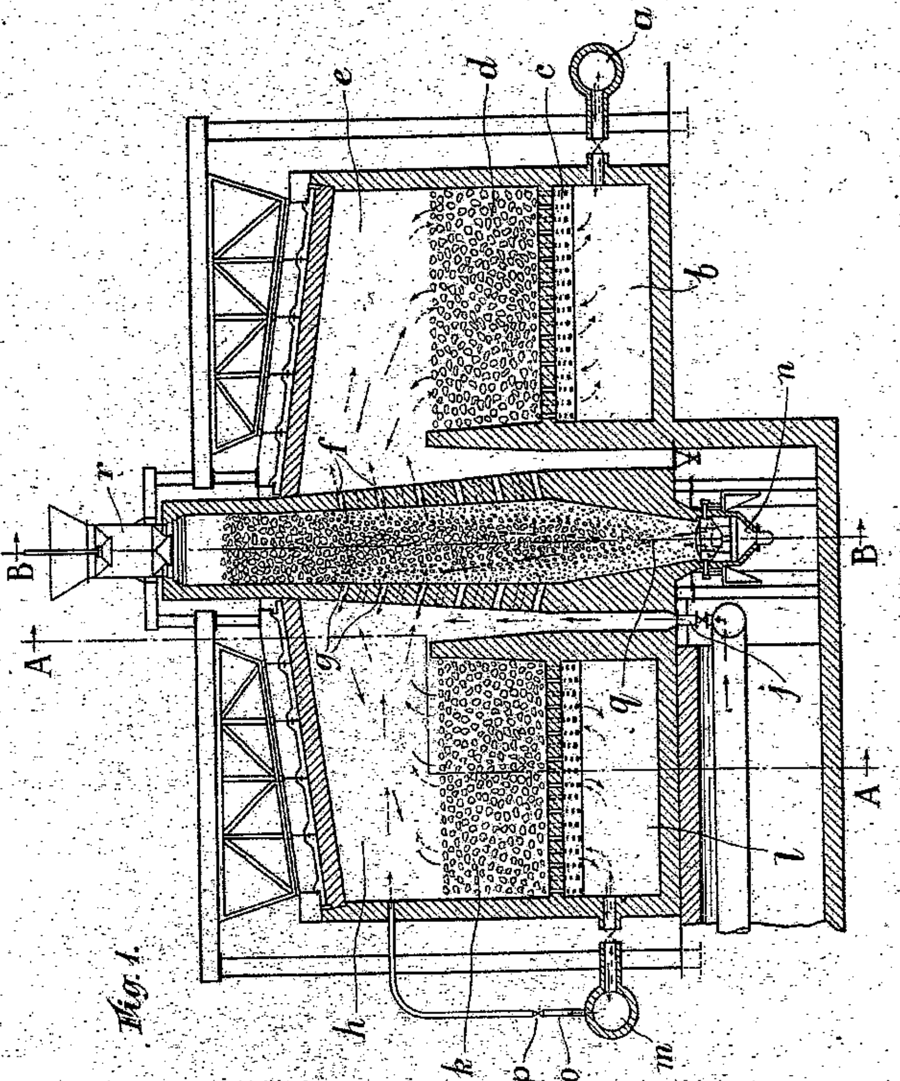

Fig. 1.

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Fig. 2.