Oct. 1, 1929. G. W. SCHWAB ET AL 1,730,247

CASE HARDENING PROCESS

Filed Jan. 12, 1926

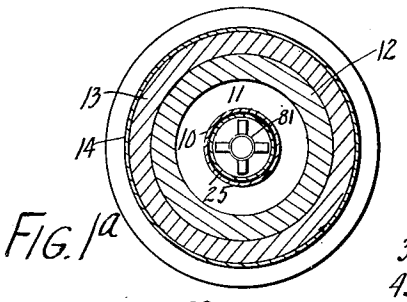

FIG. 1a

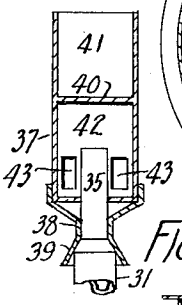

FIG. 4

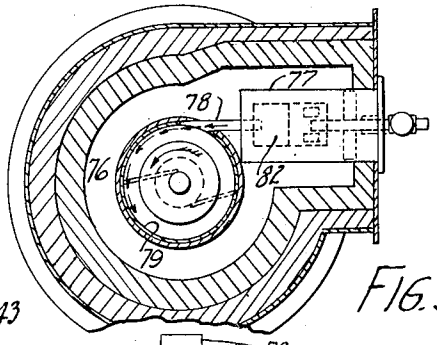

FIG. 3a

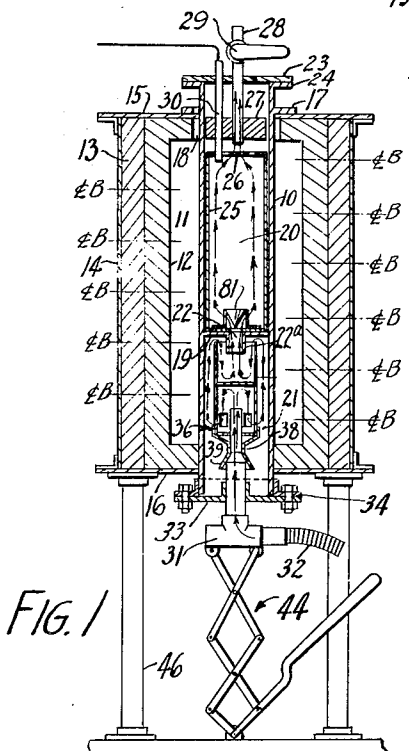

FIG. 1

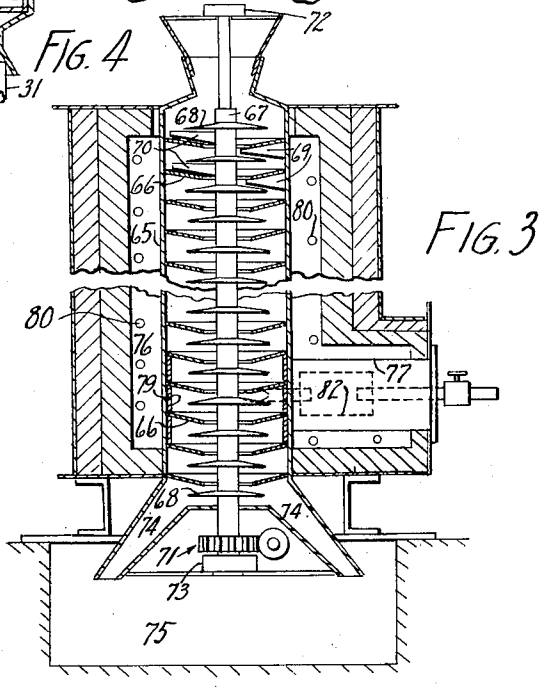

FIG. 3

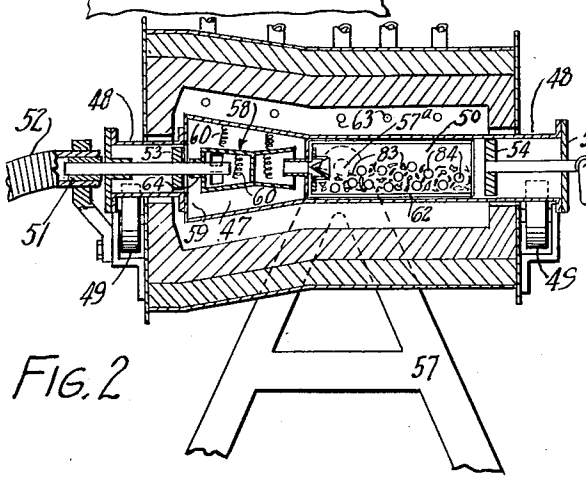

FIG. 2

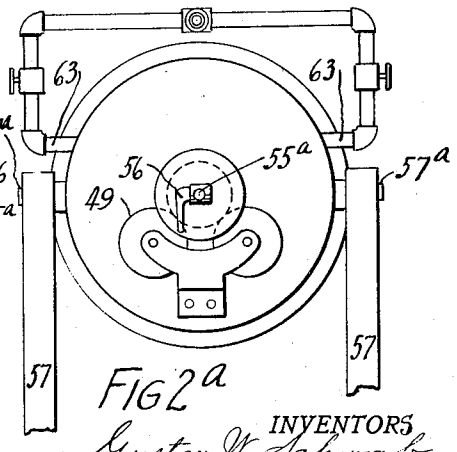

FIG. 2a

INVENTORS
Gustav W. Schwab
Frederick J. Schweiger Jr.
by B. C. Attorney
ATTORNEY

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UNITED STATES PATENT OFFICE

GUSTAV W. SCHWAB AND FREDERICK J. SCHWEIZER, JR., OF ELIZABETH, NEW JERSEY

CASE-HARDENING PROCESS

Application filed January 12, 1926. Serial No. 80,716.

It has been found in carburizing that more carbon is yielded from the gas than it is practicable for the iron or steel to absorb. Most of this excess carbon is formed by the decomposition of some of the more unstable carbonaceous constituents of the gas. This excess carbon is precipitated and deposited in the form of soot upon the articles in the carburizing retort, and is the cause of uneven cementation, unclean work and retardation of the carburizing process.

In the present invention the carburizing gas is pre-heated and the carbon is separated therefrom. One advantage gained is that there is obtained a more energetic and rapid reaction between the reduced or clarified carburizing gases and the articles in the retort.

In carrying out the invention the excess carbon is first precipitated by such pre-heating of the gas, preferably by introducing the gas into a compartment that is anterior to the main retort.

For conserving the fuel, this compartment is arranged so that the same application of heat which heats the retort may also heat the anterior compartment. The heat in the anterior compartment may be controlled and maintained at a lower point than the heat in the carburizing chamber. The anterior compartment should be subjected to such a degree of heat as will precipitate the excess carbon, but said compartment may be a part of the retort divided from the carburizing chamber proper by means of a partition having an opening through which the reduced or clarified carburizing gas may enter.

To accomplish a positive precipitation of the carbon that becomes dissociated from the original rich gas, the stream of gas as it is heated may be forced to pass a series of baffle devices within the anterior compartment. When the stream of gas, carrying the dissociated carbon, impinges upon and becomes diverted and reversed by the baffles the dissociated carbon is caused to be deposited in the anterior compartment, whence it may be easily removed, and does not enter the main carburizing retort whereby the deposit of soot upon the articles in the retort is minimized or eliminated.

Baffle devices are preferably arranged in a cylindrical drum or other unit, which may be mounted upon the gas supply inlet, and which may be made easily removable from the anterior retort chamber, so as to facilitate removal of the carbon deposits.

In a revoluble retort loose chains or similar devices may be fastened to the inner surfaces of the anterior chamber and the baffle unit, and as the retort is rotated these chains flop about, and prevent localized accumulations of carbon deposit.

When used with a main retort which is revoluble, the anterior chamber and baffle unit may have cone-shaped walls which facilitate the gravitation of the carbon deposits toward the end of the anterior chamber for convenient removal.

Another feature of this invention is the provision within the work-chamber of means whereby the carburizing reaction between the gas and the iron or steel articles in the work-chamber may be further substantially accelerated. For this purpose the inner surfaces of the work-chamber may be lined with a material which has a catalytic effect upon the reactions which occur in the carburizing process. A suitable catalyzer material is found in nickel or nickel alloys. Some of these alloys also have excellent heat-resisting properties. Particular provision is made for subjecting the pre-heated gas, as soon as it enters the work-chamber, to this catalytic influence. The orifice through which the gas enters the work-chamber is so arranged that the incoming gas impinges obliquely upon the lining of this catalyzer material, and is spread and diffused thereover. In some cases an inverted cone made of the catalyzer material may be placed in close proximity to and concentric with the orifice, so that the incoming pre-heated gas may impinge thereon, and thus be subjected to immediate catalytic influence.

For heating the retorts and carbon-separating chambers, other means than gas appliances may be used, for example an electric furnace, or an oil burning appliance.

The invention also applies to apparatus in

which carburizing gas is applied under high pressure during the carburizing operation.

The catalytic agent herein referred to, and which may be of any material having the desired catalytic properties, influences the decomposition of the carburizing gas in such manner that the carbon constituents evolved by said decomposition are applied in their nascent state to the articles being carburized. This causes a more rapid and energetic reaction between said articles and the carbon components of the carburizing gas.

The carburizing operation is much shortened. This increases output, saves fuel, and reduces the period during which the metal articles must remain subjected to the deteriorating action of the high carburizing heats. The work is usually discharged in a spotless, clean, condition, having a shiny, silvery, appearance.

Other features and advantages will hereinafter appear.

In the accompanying drawings,

Figure 1 is a sectional elevation of one form of upright carburizing apparatus having therein an upright vertical retort, said retort having an anterior chamber within which is arranged a unit of baffle devices.

Figure 1[a] is a sectional plan view of the apparatus shown in Figure 1.

Figure 2 is a sectional elevation of a normally-horizontal carburizing apparatus that may be tilted. This apparatus has a revoluble retort provided with an anterior chamber which contains a baffle unit and other devices.

Figure 2[a] is an exterior end view of the apparatus in Figure 2.

Figure 3 is a sectional elevation of a case-hardening apparatus into which the articles to be case-hardened may be progressively entered and processed and then discharged therefrom.

Figure 3[a] is a sectional plan view of the apparatus shown in Figure 3, and shows the arrangement of the carbon-separating chamber and the baffle unit.

Figure 4 is an enlarged view of the baffle unit and the inlet pipe upon which it is mounted.

In Figure 1 a retort 10 is supported within a furnace-chamber 11 having walls 12 made of a refractory material, the outer surface of which has a layer 13 of heat-conserving material. The furnace is covered with a metal casing 14 made of a side wall joined to upper plates 15 and lower plates 16. The retort 10 is cast of a suitable heat-resisting material, and by means of a flange 17, which is integral with the retort, bears and rests upon the upper plate 15. Said flange has suitable openings to permit escape of the products of combustion through annular passage 18 formed between the retort and the end of the furnace wall. Suitable burners, not shown, project through a suitable number of openings indicated by the center lines B, and heat the furnace-chamber 11 and the retort 10.

The retort 10, by means of a wall 19, is divided into an upper chamber 20, wherein are placed the articles to be carburized, and a lower chamber 21, into which the carburizing gas is introduced, pre-heated and separated from its excess carbon. Said wall 19 has an opening 22 formed by a nozzle 22[a], which extends into the lower chamber and through which the carburizing gas enters the upper chamber. The lower end of the retort is guided by a close fitting central opening in the lower end of the refractory furnace wall and the lower plate 16. The upper end of the retort is closed by a plate 23 supported upon flanges 24. The upper chamber 20 may be lined with a shell 25 made of a material which has a catalytic effect upon the carburizing process, thereby substantially accelerating the reaction between the carburizing gas and the articles to be carburized. Suitable materials for the catalyzer are nickel and some of its alloys. It will be understood, however, that the invention is not limited to a specific catalyzer material such as said nickel or its alloys. The upper end of the shell has a lid-like disk 26 perforated to permit free passage of the used carburizing gas. The articles to be carborized are placed within the space enclosed by the catalyzer material. A disk 27 made of a suitable material retains the heat within the retort, and thus conserves the fuel. Passing through an opening in said disk 27 and the upper plate 15 is a vent pipe 28 through which the carburizing gas escapes after it has done its work. A cock 29 regulates the passage of this used gas, which may be ignited and burned as it leaves the pipe, or it may be otherwise disposed of. A thermocouple 30 may be inserted in the upper retort-chamber through openings in the upper plate 15 and disk 27, and connected to a suitable temperature indicator, not shown.

The carburizing gas enters the lower chamber of the retort through a fitting 31, connected to a source of gas by means of a flexible hose 32. Said fitting 31 is secured to a plate 33, which is clamped to a flange 34 at the lower end of the retort 10, whereby removal is facilitated.

The upper end of the fitting 31 is constricted so as to form a nipple 35 and shoulder upon which a baffle unit 36, see Figures 1 and 4, may be supported. Said baffle unit consists of a cylindrical shell 37, see Figure 4, provided with a central sleeve 38 and seat 39, which fit the nipple 35 and its shoulder. Said shell 37 is open at its upper end, which extends substantially above the lower end of the nozzle 22[a], so as to form with the wall 19 a devious passage for the gas. The shell 37 is divided by a wall 40 into an open upper portion 41 and a lower chamber 42 having side openings

43. Said wall 40 has no openings. It will be noted that the nipple 35 extends well into the lower chamber 42 of the baffle unit, causing the incoming gas to impinge upon the wall 40 and reverse its direction of flow before it can reach and pass through the openings 43 into the lower chamber 21 of the retort. Passing through the openings 43 the gas partly impinges upon the inner sides of the lower chamber 21, and its flow is reversed and directed toward the dividing wall 19 of the retort. Impinging upon said wall 19 the gas in its flow is reversed again, passing through the annular space formed by the nozzle 22ª and the upper portion 41 of the shell 37. The gas then impinges upon the upper side of the wall 40, its direction of flow is again reversed, and the gas passes into the carburizing chamber 20.

This circuitous, devious and baffled passage of the gas from the nipple 35 to the carburizing chamber 20 causes the carbon, which is dissociated from the gas by the heat in the lower chamber 21, to be precipitated and deposited within said lower chamber and the baffle unit, whence it may be removed.

The removal of the carbon is facilitated by lowering the plate 33, to which are attached, as already set forth, the fitting 31 and the baffle unit 36.

To facilitate the lowering of the plate 33 with its aforesaid attachments, a suitable device, as indicated at 44, may be used.

When the clarified gas enters the upper chamber 20, it is spread and diffused by means of an inverted cone 81 placed in close proximity to the orifice. This cone is made of the aforesaid catalyzer material, and as the gas impinges thereon and is diffused, the beneficial catalytic action is immediately started.

The entire apparatus may be supported upon pipe legs 46.

A furnace with a revoluble retort, including a carbon-separating chamber 47, is shown in Figure 2 and Figure 2ª. By means of hollow journals 48, which project from the ends of the retort and extend through the ends of the furnace, the retort is supported upon a pair of rollers 49 at each end of the furnace. These rollers 49, by means not shown, may be geared to a suitable drive, which will cause them to rotate. Rotation of the rollers in turn causes the retort to rotate slowly, so that articles within a carburizing-chamber 50 are slowly tumbled about in order to expose all their surfaces to the action of the carburizing gas.

The gas inlet pipe is connected to a source of gas by means of a removable gland device 51, within which the inlet pipe rotates, and a flexible hose 52 attached to said gland. To conserve the heat within the furnace-chamber, closure disks 53 and 54 are provided at each end of the retort. The disk 54 and end plate 55 are joined by a vent pipe 55ª through which passes the used gas, and a cock 56 regulates this passage of gas. The outer sides of the furnace have trunnions or other means by which the furnace is mounted, so that it may be tilted. In this manner the furnace is supported by the frames 57 at 57ª.

The walls of the carbon-separating chamber 47 and the baffle unit 58 are cone-shaped, so that deposits of carbon thereon will gravitate toward the outer end 59 of said carbon-separating chamber, whence they may be removed. To facilitate this removal, the baffle unit and inlet pipe may be withdrawn and the furnace tilted about its bearings 57ª.

Loose chains 60 are suspended within the carbon-separating chamber and the baffle unit, and, as the retort rotates, these chains flop about and prevent accumulation of carbon deposits. Other features are the same or similar to the furnace shown in Figures 1 and 1ª. A cone 61 and lining shell 62, both made of catalyzer material, are provided for the carburizing chamber. Suitable burners 63 are lighted to supply the necessary heat. The baffle unit is secured to the inlet pipe at 64.

A continuously-operating apparatus for carburizing, in which the features of this invention are embodied, is shown at Figures 3 and 3ª. By means of this apparatus, work to be carburized may be entered at the upper end, whence it is conveyed through zones, where it is pre-heated, and on through a carburizing zone, finally passing through suitable openings at the lower end of the apparatus.

This apparatus includes a stationary vertical retort 65 having stationary funnel-shaped disks 66. A revoluble shaft 67 has similar disks 68 having upper surfaces which slope downward toward the outer edge thereof. Vanes 69 and 70 fastened to the stationary and rotating disks, respectively, facilitate the passage of the work from disk to disk as it gravitates toward the bottom of the apparatus when the shaft 67 is slowly revolved by driving means indicated at 71 which may be proportioned according to the speed at which the shaft 67 is to rotate and which may be connected to any well-known form of variable speed drive, as for example a variable speed electric motor. Said shaft has suitable upper and lower bearings 72 and 73. The work emerges through chutes 74 into a pit or receptacle 75 suitably enclosed to prevent escape of the carburizing gas. Said receptacle 75 may contain a quenching fluid.

A furnace-chamber 76, within which the retort is enclosed and heated, is expanded at its lower end (see Figure 3ª) to accommodate a carbon-separating chamber 77, within which is a baffle unit 82 similar to the one described for the apparatus shown in Figure 1.

An outlet pipe 78 enters the retort and is substantially tangent thereto, so that the clarified gas, as it enters through said pipe,

impinges upon the inner circular wall of the retort and is carried around said wall. This part of said wall is lined with catalyzer material, and the immediate contact of the preheated gas therewith accelerates the carburizing reactions, creating a zone of intense carburizing activity. The catalyzer lining 79 extends a suitable distance above and below the orifice where the pipe 78 enters the retort.

Suitable burner openings into the furnace chamber are indicated at 80. Other details of this furnace are similar to those already described.

The work is introduced into the upper end of the vertical retort 65, Figure 3, and becomes heated as it progresses downwardly toward the zone of the aforementioned intense carburizing activity. Said zone may be defined as that portion of the retort immediately above and below the gas-outlet pipe 78 and substantially within the limits of the catalyzer lining. The work, as it reaches and passes through said zone, should be at the proper temperature for carburization, say at fifteen hundred degrees to eighteen hundred degrees Fahrenheit. In order that the work may be at the proper carburization temperature as its reaches said zone, its progress toward said zone should be sufficiently protracted for the work to become heated to said temperature. The progress of the work through the retort is also governed, however, by the degree of carbon penetration to be effected as the work passes through said zone. In order that the work may be at the required temperature when it reaches said zone, it may be necessary to also grade the temperature at the various zones above the carburizing zone by regulating flames at the burner-openings 80 by means of the usual control valves, not shown. Thus, for example, the burners may, in some cases, heat the retort uniformly throughout its length, in which cases the speed of rotation of the shaft 67 would have to be adjusted so that the work attained the proper temperature as it reaches the aforesaid carburizing zone, that is to say, the work must not have been overheated when it reaches said zone as such overheating would be a waste of fuel and would tend to burn the surface of the work. Neither must the work be in an underheated state when it reaches said zone. If, in said cases, it is found that the work passes too fast or too slowly through the carburizing zone for proper penetration of the work, the speed of the shaft 67 would have to be adjusted so that the rate of passage of the work through the retort, and particularly through said zone, would be in accord with the degree of penetration desired. In this case, a compensating adjustment of the flames at the burners 80 would have to be made so that irrespective of the rate of passage of the work through the retort, said work would be at just the right temperature as it reached and passed through the aforesaid zone of intense carburizing activity.

It will be understood that the term "clarified gas" used herein means gas which is clarified or de-sootified as far as is practicably possible or necessary, to effect clean carburization. In some cases satisfactory carburizing results may be attained by only a partial de-sootification of the gas. The preheating makes a more homogeneous gas, resulting in better carburizing. It will be understood that the degree of clarification attained is governed largely by the construction of the baffle unit and the temperature to which the carburizing gas is pre-heated as it passes through said unit. The rate of passage through said unit would also be a controlling factor. The initial composition of the carburizing gas would also be a controlling factor.

It will be further understood that a certain amount of carburizing action may take place while the articles are progressing toward the aforesaid carburizing zone, the extent of such pre-carburizing depending upon the temperature which the articles attain during said progress, and the time it takes them to reach said main carburizing zone. The greater part of the carburizing action, however, is believed to take place in said main carburizing zone by reason of the aforesaid catalytic action within said zone and the proper degree of temperature which the articles will have attained when they reach said zone.

In Figure 2 the retort is shown partly filled with particles 83 of a catalyzer material mixed with the articles 84 to be carburized. Screens, not shown, of suitable mesh material are placed over the openings in the ends of the retort and retain the contents within said retort.

The invention is not limited to any specific carburizing gas or mixture, nor to any specific means for preparing such mixture for use in the apparatus.

The carburizing gas is maintained under pressure in the carburizing chamber, being supplied in compressed condition through 32, which delivers indirectly to the carburizing chamber 20 through the preheating chamber 21, the pressure of gas being maintained in the carburizing chamber 20, the gas supply 32, and the preheating chamber 21 which forms a communication between said gas supply and said carburizing chamber. Besides clarifying the carburizing gas, the preheating of the gas has the effect of speeding up the work of carburizing the articles in the retort, thus shortening materially the time required for cementation, and proportionally reducing the cost of maintaining the articles in heated condition for carburizing; and since it also materially increases the output of the retort, it

results that a small equipment, costing little and occupying little room, is capable of turning out an amount of work that has heretofore required a large and expensive equipment, occupying much valuable floor space.

Still greater increase in speed of carburizing is secured by the use of a catalyzer for the compressed gas that is admitted to the carburizing chamber in a preheated condition. There need not be a catalyzer in the preheating chamber, as it is preferred to expose to catalyzing effect the hot compressed gas as it flows upon the hot articles. The preheating of the compressed gas may be a little under the heat of carburization, or in the vicinity of carburizing heat. The agitated hot articles may thus be robbed of but little if any heat by the carburizing gas flowing thereover. They are thus constantly maintained at carburizing heat while receiving the benefit of fresh accessions of carburizing gas under pressure.

Since the carburizing gas is properly preheated under pressure at exactly the desired temperature for the work in hand, and while in this condition the clarified gas is brought into contact with a suitable catalyzer, a decomposition of the compressed heated gas is believed to be caused, and a stable balancing or conditioning of such prepared gas, whereby intimate co-operation is assured between the work and the gaseous fluid in its nascent state, and energetic carburizing.

The pressure is an advantage, but not necessary in all cases. Such clarification as occurs because of such preheating, is usually found sufficient to produce the desired result, with high speed of carburizing. The invention, however, is not limited in all cases to clarification of the gas, nor to the employment of heat for clarifying. It is one of the main features to bring gas up to a high heat preparatory to introducing it into the work retort; and so long as this is done, it is not essential in all cases that the gas become clarified by reason of such high preparatory heat, since in some cases the gas may not need clarifying, and in some other cases the advantage of high preparatory heating may be gained, even if some soot is found to be deposited upon the carburized articles.

In properly preheating the gas, thus tending to produce the required balanced condition which is so efficient for carburizing, a definite period of time is required, time being here an element, as it is in most chemical reactions; and the period of time can be measured, the separate heating chamber forming a convenience for measuring.

Variations may be resorted to within the scope of the invention, and portions of the improvements may be used without others.

Having thus described our invention, we claim:

1. The process of pre-heating an excessively carbonous hydrocarbon carburizing gas and reducing by means of heat its carbonaceous constituents, and heating low-carbon steel or iron articles in an atmosphere of such reduced gas to carburize the articles.

2. The process of heating an excessively carbonous hydrocarbon carburizing gas and causing dissociation of part of its carbonaceous constituents, causing the dissociated carbon to be deposited to clarify the gas, and then heating articles in an atmosphere of such clarified gas to carburize them.

3. The process of carburizing iron or steel articles including heating said articles in a retort to a carburizing temperature in an atmosphere of pre-heated and de-sootified carburizing gas circulating through said retort and in the presence of a catalytic agent, whereby the carburizing reaction between said gas and said articles is accelerated and intensified, said reaction proceeding for a predetermined length of time at the end of which the carburizing reaction is terminated by shutting off the influx of carburizing gas and shutting off the heat.

4. The process of carburizing including heating an excessively carbonous hydrocarbon carburizing gas in confinement, to cause partial dissociation of the carburizing gas, passing said confined and heated gas over depositaries, whereby dissociated carbon is deposited and the gas is clarified, and carburizing by means of the clarified and preheated gas in the presence of metallic catalytic agents.

5. The process of heating an excessively carbonous hydrocarbon carburizing gas to dissociate part of its carbonaceous constituents therefrom, precipitating said part of carbonaceous constituents to clarify said gas, applying said clarified gas to articles to be carburized mingled with particles of a catalyzer metal, and heating said mixture to a carburizing temperature.

6. The process of heating an excessively carbonous hydrocarbon carburizing gas to dissociate part of its carbonaceous constituents therefrom, precipitating said part of carbonaceous constituents to clarify said gas, distributing said clarified gas, while maintaining such heat, to a carburizing retort, heating said retort, and carburizing iron or steel articles contained in said retort in an atmosphere of said preheated clarified gas in the presence of catalytic agents in metallic form which cause an accelerated and intensified reaction.

7. The process of heating an excessively carbonous hydrocarbon carburizing gas to dissociate part of its carbonaceous constituents therefrom, precipitating said part of carbonaceous constituents to clarify said gas, distributing said clarified gas, while maintaining such heat, to a carburizing retort, which is pre-heated to carburizing heat together with the articles therein, carburizing iron

or steel articles confined in said retort in an atmosphere of said clarified gas, and accelerating and intensifying the carburizing reaction by causing it to proceed under the influence of catalytic agents having permanent metallic form.

8. The process of heating a carburizing gas to dissociate part of its carbonaceous constituents therefrom, precipitating said part of carbonaceous constituents to clarify said gas, distributing said clarified gas to one or more carburizing retorts, heating said retorts, carburizing iron or steel articles contained in said retorts in an atmosphere of said clarified gas, and accelerating and intensifying the carburizing reaction by causing it to proceed under the influence of catalytic agents consisting of nickel or nickel alloy.

9. The process of carburizing iron or steel articles including heating said articles to a carburizing temperature in an atmosphere of carburizing gas, and accelerating the carburizing reaction by causing said reaction to take place in the presence of a catalytic agent consisting of nickel or nickel alloy.

10. The process of case-hardening iron or steel articles including passing said articles through zones in which they progressively attain increasing degrees of temperature, grading said zones to one in which said articles attain a carburizing temperature, admitting a carburizing gas to said zone of carburizing temperature, causing said articles to become carburized while passing through said one zone of carburizing temperature, accelerating the carburizing reaction by causing it to take place in the presence of a catalytic agent consisting of nickel or nickel alloy within said one zone of carburizing temperature, and discharging said carburized articles into a receptacle or cooling bath.

11. The process of case-hardening iron or steel articles including passing said articles through zones in which they progressively attain increasing degrees of temperature, grading said zones to one in which said articles attain a carburizing temperature, heating an excessively carbonous hydrocarbon carburizing gas to dissociate part of its carbonaceous constituents therefrom, clarifying said gas by precipitating and separating, as far as practicable, said dissociated part of carbonaceous constituents therefrom, admitting said clarified gas to said one zone of carburizing temperature and causing said articles to become carburized while passing through said one zone of carburizing temperature.

12. The process of case-hardening iron or steel articles including passing said articles through zones in which they progressively attain increasing degrees of temperature, grading said zones to one in which said articles attain a carburizing temperature, heating an excessively carbonous hydrocarbon carburizing gas to dissociate part of its carbonaceous constituents therefrom, clarifying said gas by precipitating and separating, as far as practicable, said dissociated part of carbonaceous constituents therefrom, admitting said clarified gas to said one zone of carburizing temperature, causing said articles to become carburized while passing through said one zone of carburizing temperature, and accelerating the carburizing reaction by causing it to take place in the presence of a catalytic metal within said zone of carburizing temperature.

13. The process of carburizing including heating a carburizing gas to dissociate part of its carbon constituents therefrom, precipitating and separating said dissociated part of carbonaceous constituents from said gas, causing said clarified gas to be applied to iron or steel articles, agitating said articles to expose all their surfaces to said clarified gas, heating said articles to cause them to be carburized by said application of said gas, and accelerating the carburizing reaction by causing it to proceed under the influence of a catalytic agent consisting of nickel or nickel alloy.

14. The process which consists in carburizing iron or steel articles by means of a current of carburizing gas in the presence of a catalyzer in the form of a permanent metal.

15. The process which consists in permanently separating excess carbon from an excessively carbonous carburizing gas, and then subjecting iron or steel articles to the action of the clarified gas in the presence of a catalyzing metal.

16. The process which consists in permanently separating excess carbon from an excessively carbonous carburizing gas, and then subjecting iron or steel articles to the action of the clarified gas under high pressure and heat in the presence of a catalyzing material.

17. The process of carburizing iron or steel articles including heating said articles to a carburizing temperature in an atmosphere of pre-heated and de-sootified carburizing gas, and accelerating the carburizing reaction by causing said reaction to take place in the presence of a catalytic agent consisting of nickel or nickel alloy.

18. The process of carburizing iron or steel articles including pre-heating and de-sootifying a carburizing gas under high pressure, and then subjecting the iron and steel articles to the action of the clarified gas under high pressure in the presence of a catalyzing material.

19. The process of pre-heating a hydrocarbon carburizing gas, to nearly carburizing temperature, heating articles to be carburized to a carburizing temperature, and applying said pre-heated gas to said heated articles in the presence of a catalytic metal to carburize said articles.

20. The process of pre-heating a carburizing gas under high pressure, to nearly carburizing temperatures, heating articles to be carburized to a carburizing temperature, and applying said pre-heated gas under high pressure to said articles to carburize said articles in the presence of a catalyzing metal.

GUSTAV W. SCHWAB.
FREDERICK J. SCHWEIZER, JR.