

The present invention relates to a low pressure carburization process applied to metal alloy parts and more particularly steel parts, as well as to an installation permitting the performance of said process.

Carburization is widely used in metallurgy, when it is a matter of hardening the surface of metal parts over a certain depth, whilst excluding the internal portions thereof, which must retain a certain flexibility so as not to inopportunately break. According to a standard metallurgical process carbon is incorporated by gaseous carburization.

Thus, US-A-4 108 693 and Metallurgical Transactions B, 13B, June 1982, pp.267-273 disclose steel carburization processes by heat treatment by means of gaseous mixtures including nitrogen, hydrogen and a hydrocarbon at atmospheric pressure.

Low pressure carburization processes are known which have certain advantages compared with those operating at atmospheric pressure, as described on pp.47-48 of Advanced Materials and Processes, 137(3), March 1990, pp.41-48.

As is more particularly described in the Hayes French patent 2 154 398, the articles to be carburized are placed in a vacuum furnace, in which circulation takes place of gaseous hydrocarbons essentially based on methane or propane and treatment only takes place at temperatures above approximately 950°C. Working takes place at a pressure below atmospheric pressure. This ensures the absorption and thermal diffusion of the carbon on the surface of the article. It should be noted that the performance of this process involves the need to use a pulsation effect for diffusing the carbon to the desired depth in the treated part.

According to a process described in the Ipsen French patent 2 361 476, use is also made of a methane-based fuel gas. The latter suffers from the disadvantage of dissociating, whilst producing a large amount of carbon, which is transformed into lampblack and hinders carburization by dirtying the treated parts and also the furnace.

Other furnace designers still use a vacuum plasma discharge to attempt to obviate the difficulties inherent in the use of the aforementioned hydrocarbons and this is known as ionic carburization.

The aim of the present invention is to eliminate such disadvantages by carrying out a carburization process at a pressure below atmospheric pressure where use is made of a fuel mixture constituted by hydrogen and ethylene with 2 to 60% by volume ethylene and the furnace is heated at between approximately 820 and approximately 1100°C, as a function of the nature of the metals forming the parts and as a function of the desired content and depth of the carbon on the surface of the parts.

The process according to the invention is particularly suitable for the treatment of parts used in advanced industries and in the car industry such as bearings, gears, slide bars, cams, piston rods, etc.

As a result of this process, it is possible to carburize all the alloys treated by the presently known processes, but under better quality and usually speed conditions. It is also possible to treat certain alloys, whose naturally very passive surface has hitherto required a prior depassivation treatment. Other alloys which could not be treated, even after depassivation, can be treated as a result of the inventive process.

More specifically, the process according to the invention essentially comprises the following stages:

- a) forming a preliminary vacuum in the furnace vessel to a pressure of 10^{-1} hPa so as to eliminate the air,
- b) filling the vessel with purified nitrogen at atmospheric pressure,
- c) loading the vessel containing the metal parts,

- d) placing the vessel under a vacuum at 10^{-2} hPa,
- e) heating to the austenitization temperature and maintaining at this temperature for homogenizing the parts,
- f) introducing hydrogen up to 500 hPa,
- g) carbonization by introducing ethylene-based fuel gas at a pressure of 10 to 100 hPa, as a function of the particular case,
- h) vacuum diffusion at 10^{-1} hPa and
- i) introduction of nitrogen for unloading.

The performance of the process involves the use of a particular device, whose characteristics will be given hereinafter. This device, described in the case of a double vacuum furnace and claimed in claim 12, is also usable in a cold wall furnace.

Other advantages and features of the invention can be gathered from the following description of several non-limitative embodiments of the carburization of different alloys and with reference to the attached drawings, wherein show:

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|-----------------------|--|
| Figs. 1a, 1b & 1c | relating to example 1 dealing with the carburization of 16 NCD 13 steel parts over the standard depth of 1.80 mm. |
| Figs. 2a, 2b, 2c & 2d | relate to example 2 concerning the carburization of parts having a difficult geometry and blind or open bores made from 14 NC 12 steel, Fig. 2c relating to example 2 being a diagram showing the arrangement of the parts during treatment. |
| Figs. 3a, 3b & 3c | relate to example 3 concerning carburization of 16 NCD 13 steel parts over a very small depth of 0.25 mm. |

Figs. 4a,4b and 4c relate to example 4 concerning the carburization of Z 15 CN 17.03 steel parts.

Figs. 5a,5b and 5c relate to example 5 concerning the carburization of Z 20 WC 10 steel parts.

- 5 Figs. 6a,6b and 6c relate to example 6 concerning the carburization of Z 38 CDV 5 steel parts.

Figs. 7a and 7b relate to example 7 concerning the carburization of Co : KC 20 WN-based superalloy parts.

- 10 Fig. 8 the carburization vessel incorporating the device for circulating the fuel gas in the vessel.

Fig. 9 a double vacuum (hot wall) carburization furnace.

To facilitate the understanding of the seven following examples, certain basic details are given.

The composition of the metal alloys undergoing carburization

15

Percentage by weight

<u>AFNOR Standard</u>	<u>C</u>	<u>Ni</u>	<u>Cr</u>	<u>Mo</u>	<u>W</u>	<u>V</u>	<u>Co</u>
16 NCD 13 Steel	0.16	3.2	1	0.25			
14 NC 12 Steel	0.14	3	0.75				
Z 15 CN 17.03 Steel	0.15	3	17				
20 Z 20 WC 10 Steel	0.20		3		10		
Z 38 CDV 5 Steel	0.38		5	1.3		0.4	
KC 20 WN Alloy	0.10	10	20		15		Remainder

Use of carburized metal alloys

16 NCD 13 Steel: gears, hubs, shafts, bearing races, aeronautical safety parts in general.

14 NC 12 Steel: gears, hubs, shafts, etc.

- 5 Z 15 CN 17.03 Steel: stainless bearing races, integrated stainless roller track parts (aeronautics).

Z 20 WC 10 Steel: detachable or loose roller tracks for hot use (aeronautics).

- 10 Z 38 CDV 5 Steel: tool parts in general, e.g. dies, punches and moulds.

Cobalt KC 20 WN-based superalloy: gas turbine parts in general.

Compositions of reagents used for microetching:

Nital: Nitric acid d = 1.38 : 2% ethyl alcohol.

- 15 Italien: Hydrochloric acid 80 ml, acetic acid 48 ml, crystallized picric acid 12 g and ethyl alcohol 800 ml.

Dichromate: Sulphuric acid 10 ml, potassium dichromate 10 g and demineralized water 1000 ml.

EXAMPLE 1: Depth 1.80 mm (16 NCD 13 Steel).

Experimental Conditions.

Carburization at 980°C

(phases 1 to 5 chronological order)

Use Treatment.

1) Austenitization (980°C)

Maximum vacuum : 10^{-2} hPa

Maintained for : 30 min.

3) Carbonization (980°C)

Absolute pressure : 35 hPa

Maintained for : 2h

Ethylene fuel gas : 130 l/h (at atm.p)

% residual ethylene

in evacuated gas : 7

Austenitization at 825°C

in vacuo

Oil hardening

Tempering at 140°C

2) Breaking the vacuum with hydrogen (980°C)

Absolute pressure : 500 hPa

Not maintained

4) Diffusion (980°C)

Absolute pressure : $\leq 10^{-1}$ hPa

Maintained for : $3\frac{1}{2}$ h

5) Breaking vacuum with nitrogen at atm.p

EXAMPLE 2: Blind and open bores, 14 NC 12 Steel.

Experimental Conditions.

Carburization at 880°C

(phases 1 to 5 in chronological order)

Use Treatment

1) Austenitization (880°C)

Maximum vacuum : 10^{-2} hPa

Maintained for : 30 min.

3) Carbonization (880°C)

Absolute pressure : 30 hPa

Maintained for : 85 min

Ethylene fuel gas : 145 l/h
(at atm.p)

% residual ethylene
in evacuated gas : 20

Austenitization at 825°C

in vacuo

Oil hardening

Tempering at 140°C

2) Breaking the vacuum with hydrogen (880°C)

Absolute pressure : 500 hPa

Not maintained

4) Diffusion (880°C)

Absolute pressure : $\leq 10^{-1}$ hPa

Maintained for : 20 min.

5) Breaking vacuum with nitrogen at atm.p

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EXAMPLE 3: Depth 0.25 mm (16 NCD 13 Steel).

Experimental Conditions.

Carburization at 820°C

(phases 1 to 5 in chronological order)

1) Austenitization (820°C)

Maximum vacuum : 10^{-2} hPa

Maintained for : 30 min.

2) Breaking the vacuum with hydrogen (820°C)

Absolute pressure : 500 hPa

Not maintained

3) Carbonization (820°C)

Absolute pressure : 25 hPa

Maintained for : 1h

Ethylene fuel gas : 150 l/h
(at atm.p)

% residual ethylene
in evacuated gas : 30

4) Diffusion (none)

5) Breaking vacuum with nitrogen at atm.p

Use Treatment

Austenitization at 820°C

in vacuo

Oil hardening

Tempering at 140°C

EXAMPLE 4: Z 15 CN 17.03 Steel

Experimental Conditions.

Carburization at 980°C (phases 1 to 8 in chronological order)

- 1) Austenitization (1020°C)
Maximum vacuum : 10^{-2} hPa
Maintained for : 30 min.
Cooling in
furnace to : 980°C
- 2) Breaking vacuum with hydrogen (980°C)
Absolute pressure : 500 hPa
Not maintained
- 3) Carbonization (980°C)
Absolute pressure : 35 hPa
Maintained for : 45 min.
Ethylene fuel gas : 135 l/h (at atm.p)
% residual ethylene in evacuated gas : 8
- 4) Diffusion (980°C)
Absolute pressure : $\leq 10^{-1}$ hPa
Maintained for : 10 min.

- 5) Breaking vacuum with hydrogen (980°C)
Absolute pressure : 500 hPa
Not maintained
- 6) Carbonization (980°C)
Absolute pressure : 35 hPa
Maintained for : $6\frac{3}{4}$ h
Ethylene fuel gas : 135 l/h
(at atm.p)
% residual ethylene
in evacuated gas : 8
- 7) Diffusion (980°C)
Absolute pressure : $\leq 10^{-1}$ hPa
Maintained for : $4\frac{3}{4}$ h
- 8) Breaking vacuum with nitrogen at atm.p

Use Treatment

Austenitization at 1020°C
in vacuo
Oil hardening
Passing to cold -75°C
Tempering at 250°C

EXAMPLE 5: Z 20 WC 10 Steel

Experimental Conditions.

Carburization at 940°C (phases 1 to 8 in chronological order)

- 1) Austenitization at 1010°C
Maximum vacuum : 10^{-2} hPa
Maintained for : 30 min.
Cooling in
furnace to : 940°C
- 2) Breaking vacuum with hydrogen (940°C)
Absolute pressure : 500 hPa
Not maintained
- 3) Carbonization (940°C)
Absolute pressure : 30 hPa
Maintained for : 45 min.
Ethylene fuel gas : 140 l/h (at atm.p)
% residual ethylene in evacuated gas : 10
- 4) Diffusion (940°C)
Absolute pressure : $\leq 10^{-1}$ hPa
Maintained for : 10 min.

- 5) Breaking vacuum with hydrogen (940°C)
Absolute pressure : 500 hPa
Not maintained
- 6) Carbonization (940°C)
Absolute pressure : 30 hPa
Maintained for : $1\frac{1}{4}$ h
Ethylene fuel gas : 140 l/h
(at atm.p)
% residual ethylene in evacuated gas : 10
- 7) Diffusion (none)
- 8) Breaking vacuum with nitrogen at atm.p

Use Treatment

Austenitization at 1100°C
in vacuo
Hardening with neutral gas
Passage to cold -75°C
First tempering at 560°C
Second tempering at 560°C

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EXAMPLE 6: Z 38 CDV 5 Steel

Experimental Conditions.

Carburization at 960°C (phases 1 to 8 in chronological order)

1) Austenitization (980°C)

Maximum vacuum : 10^{-2} hPa
Maintained for : 30 min.
Cooling in
furnace to : 960°C

2) Breaking vacuum with hydrogen (960°C)

Absolute pressure : 500 hPa
Not maintained

3) Carbonization (960°C)

Absolute pressure : 30 hPa
Maintained for : 30 min.
Ethylene fuel gas : 135 l/h (at atm.p)
% residual ethylene in evacuated
gas : 9

4) Diffusion (960°C)

Absolute pressure : $\leq 10^{-1}$ hPa
Maintained for : 10 min.

5) Breaking vacuum with hydrogen (960°C)

Absolute pressure : 500 hPa
Not maintained

6) Carbonization (960°C)

Absolute pressure : 30 hPa
Maintained for : 1h
Ethylene fuel gas : 135 h/l
(at atm.p)
% residual ethylene
in evacuated gas : 9

7) Diffusion (960°C)

Absolute pressure : $\leq 10^{-1}$ hPa
Maintained for : 2h

8) Breaking vacuum with nitrogen at atm.p

Use Treatment

Austenitization at 990°C
in vacuo
Air hardening
Passage to cold -75°C
Tempering at 200°C

EXAMPLE 7: Co:KC 20 WN-based Superalloy

Experimental Conditions.

Carburization at 1100°C (phases 1 to 5 in chronological order)

- 12 -
- | | |
|---|--|
| 1) Austenitization (1100°C) | 3) Carbonization (1100°C) |
| Maximum vacuum : 10^{-2} hPa | Absolute pressure : 40 hPa |
| Maintained for : 30 min. | Maintained for : 4h |
| | Ethylene fuel gas : 150 l/h (at atm.p) |
| 2) Breaking vacuum with hydrogen (1100°C) | % residual ethylene |
| Absolute pressure : 500 hPa | in evacuated gas : 3 |
| Not maintained | |
| | 4) Diffusion (1100°C) |
| | Absolute pressure : $\leq 10^{-1}$ hPa |
| | Maintained for : 2h |
| | |
| 5) Breaking vacuum with nitrogen at atm.p | |

Fig. 1a shows the carbon profile of a part carburized according to example 1. It is possible to see the carbon percentage incorporated as a function of the depth P.

Fig. 1 shows the microhardness HV 0.5 kg as a function of the depth
5 for parts treated according to example 1.

Fig. 1c is a section of a cylindrical part 10 surface carburized according to example 1 after 2% nital etching and respective magnification of 2 and 500 X revealing the great regularity of the macrograph and the structural homogeneity on the micrograph.

10 Examples 2 to 7 are illustrated in the same way as with respect to example 1.

Fig. 2c shows the exploded view arrangement over three stages in the furnace vessel of blind bores 11 and open bores 12. Remarkable results were obtained by using tubes having a length of 85mm, an
15 external diameter of 14mm and a bore diameter of 8mm.

Fig. 2a shows the dispersion band of the carbon profiles obtained for the parts shown in fig. 2c.

Fig. 2b shows the dispersion band of the microhardness profiles obtained for the parts in fig. 2c.

20 Fig. 2d is a section of a tubular part 20 carburized on its surface, periphery and in the bore according to example 2 after 2% nital etching and respective magnification of 2 and 500 X showing the great regularity and homogeneity of the carburized layer.

Fig. 8 shows the vessel 3 and the internal device, together with
25 the cover 5. Gas supply pipes 7,8,9 traverse the cover and respectively issue at the first I, second II and third III vessel stages

at at least three outlets per stage which are regularly distributed in the manner of 21,22 and 23 for stage II in particular.

Thermocouples TC installed at each stage are permanently connected to a not shown microcomputer, which ensures that all the operations
5 of the installation are correctly performed.

Each stage comprises a perforated plate on which rest the articles to be carburized. At their entry, the gases flow through the charge in the direction of the two outlets, the main one at the top of the vessel and the other branched off at the bottom of the vessel
10 following the path indicated by the arrows, being finally sucked up at the top of the cover by a large pipe 26 connected to a circulating pump 28. A relative flow rate curve as a percentage of the carburizing gas is shown to the right of the furnace.

The installation shown in fig. 9 comprises a so-called double vacuum
15 furnace 5 in the sense that the vacuum is established both in the vessel 55 and in the annular space 56 surrounding the vessel. The carburizing gases enter by pipes 51 for hydrogen and 52 for ethylene and are directed towards several stages, where they are regularly distributed. The circulation of the gases takes place in the vessel
20 in the manner described in fig. 8. The gases are then directed towards the pumping means 62 by a pipe 59 with a sample branched off to a gas analyser 60 linked with a microcomputer. Two other pipes 53 for nitrogen, as well as 54 and 57 for the air issue respectively at the top of the vessel 55 and the space 56. The data
25 such as temperatures, pressure, flow rates and composition of the gases are collected by an acquisition means connected to a microcomputer 61.

Further to the details given in the various examples, the following information is provided. Before starting the treatments, air is
30 eliminated from the vessel. This involves a preliminary vacuum

formation at a pressure of 10^{-1} hPa and the vessel is filled with nitrogen purified at atmospheric pressure. The loading of the vessel containing the parts to be treated then takes place and the first austenitization phase is carried out by heating at different temperatures as a function of the particular case and with a maximum vacuum of 10^{-2} hPa.

The vacuum is broken by introducing hydrogen until a pressure of 500 hPa is obtained. Carbonization takes place by introducing ethylene at a pressure generally close to 30 hPa, followed by a diffusion at an absolute pressure equal to or below 10^{-1} hPa. The vacuum is then broken with nitrogen at atmospheric pressure and a use treatment is carried out, which makes it possible to obtain the final characteristics desired for the carburized parts. In the case of examples 4,5 and 6, following diffusion, the vacuum is broken with hydrogen and a second carbonization is carried out, followed by a diffusion, which precedes the breaking of the vacuum with nitrogen at atmospheric pressure.

The process is performed under the control of a microcomputer to which are supplied all the programmed technical parameters, such as the steel grades, the temperatures of the different points of the furnace, the pressure in the enclosure, the durations of the enrichment (carbonization) at diffusion sequences, the general flow rates of the gases at each stage, the composition of the gases and adjustments as a function of the analysis of the discharged gases.



91 401 792.6

C L A I M S

1. Process for carburization at a pressure below atmospheric pressure of metal alloy and more specifically steel parts, in which treatment takes place in a furnace of the metal alloy parts by subjecting them to the action of a fuel mixture based on gaseous hydrocarbons, characterized in that use is made of a fuel mixture constituted by hydrogen and ethylene with 2 to 60% by volume ethylene and that the furnace is heated at between approximately 820°C and approximately 1100°C, as a function of the nature of the metals constituting the parts and the desired incorporation depth for the carbon.

2. Carburization process according to claim 1, characterized in that it comprises the following stages:

- a) forming a preliminary vacuum in the furnace vessel to a pressure of 10^{-1} hPa so as to eliminate the air,
- b) filling the vessel with purified nitrogen at atmospheric pressure,
- c) loading the vessel containing the metal parts,
- d) placing the vessel under a vacuum at 10^{-2} hPa,
- e) heating to the austenitization temperature and maintaining at this temperature for homogenizing the parts,
- f) introducing hydrogen up to 500 hPa,
- g) carbonization by introducing ethylene-based fuel gas at a pressure of 10 to 100 hPa, as a function of the particular case,
- h) vacuum diffusion at 10^{-1} hPa and
- i) introduction of nitrogen for unloading.

3. Carburization process according to claim 2 in which the metal parts are of 16 NCD 13 steel, characterized in that it comprises the five following stages:

- 1) vacuum austenitization for 30 minutes at 980°C,
- 2) breaking the vacuum at 980°C with hydrogen until a pressure of 500 hPa is reached,
- 3) carbonization at 980°C by the action of an ethylene-based fuel gas for 2 hours and at a pressure of 35 hPa,



4) diffusion at 980°C for 3 1/2 hours at a pressure equal to or below 10^{-1} hPa and

5) breaking the vacuum with nitrogen at atmospheric pressure,

followed by a use treatment at 825°C and carburization is carried out over a depth of 1.80 mm, so as to obtain the sought carbon percentage as a function of the depth.

4. Carburization process according to claim 2, in which the metal parts are of 14 NC 12 steel, characterized in that it comprises the five following stages:

1) vacuum austenitization for 30 minutes at 880°C,

2) breaking the vacuum with hydrogen at 880°C until a pressure of 500 hPa is obtained,

3) carbonization at 880°C by the action of an ethylene-based fuel gas for 85 minutes at a pressure of 30 hPa,

4) diffusion at 880°C for 20 min. at a pressure equal to or below 10^{-1} hPa and

5) breaking the vacuum with nitrogen at atmospheric pressure,

followed by a use treatment at 825°C and carburization is carried out over a depth of 0.55 mm, whilst obtaining the sought carbon percentage as a function of the depth.

5. Carburization process according to claim 2, in which the metal parts are of 16 NCD 13 steel, characterized in that it comprises the five following stages:

1) vacuum austenitization for 30 min. at 820°C,

2) breaking the vacuum with hydrogen at 820°C until a pressure of 500 hPa is obtained,

3) carbonization at 820°C by the action of an ethylene-based fuel gas for 1 hour and at a pressure of 25 hPa,

4) no diffusion,

5) breaking the vacuum with nitrogen at atmospheric pressure,

followed by a use treatment at 820°C and carburization is carried out over a depth of 0.25 mm, whilst obtaining the sought carbon percentage as a function of the depth.

6. Carburization process according to claim 2, in which



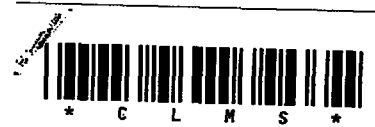
the metal parts are of Co : KC 20 WN-based superalloy, characterized in that it comprises the five following stages:

- 1) vacuum austenitization for 30 min. at 1100°C,
 - 2) breaking the vacuum with hydrogen at 1100°C until a pressure of 500 hPa is obtained,
 - 3) carbonization at 1100°C by the action of an ethylene-based fuel gas for 4 hours and at a pressure of 40 hPa,
 - 4) diffusion at 1100°C for 2 hours and a pressure equal to or below 10^{-1} hPa and
 - 5) breaking the vacuum with nitrogen at atmospheric pressure,
- carburization being carried out over a total depth of 0.8 mm.

7. Carburization process according to claim 1, characterized in that it comprises the following stages:

- a) forming a preliminary vacuum in the furnace vessel to a pressure of 10^{-1} hPa so as to eliminate the air,
- b) filling the vessel with purified nitrogen at atmospheric pressure,
- c) loading the vessel containing the metal parts,
- d) placing the vessel under a vacuum at 10^{-2} hPa,
- e) heating to the austenitization temperature and maintaining at this temperature for homogenizing the parts,
- f) introducing hydrogen up to 500 hPa,
- g) carbonization by introducing ethylene-based fuel gas at a pressure of 10 to 100 hPa, as a function of the particular case,
- h) vacuum diffusion at 10^{-1} hPa and
- i) breaking the vacuum with hydrogen,
- j) carbonization by introducing an ethylene-based fuel gas at a pressure of 10 to 100 hPa,
- k) diffusion and
- l) breaking the vacuum with nitrogen at atmospheric pressure

8. Process according to claim 7, characterized in that



it comprises a complementary diffusion stage between stages j) and k).

9. Carburization process according to claim 8, in which the metal parts are of Z 15 CN 17.03 steel, characterized in that it comprises the eight following stages:

1) austenitization in vacuo for 30 min. at 1020°C and cooling in the furnace to 980°C,

2) breaking the vacuum with hydrogen at 980°C until a pressure of 500 hPa is obtained,

3) carbonization at 980°C by the action of an ethylene-based fuel gas for 45 min. and at a pressure of 35 hPa,

4) diffusion at 980°C for 10 min. and at a pressure equal to or below 10^{-1} hPa,

5) breaking the vacuum with hydrogen at 980°C and at a pressure of 500 hPa,

6) carbonization at 980°C by the action of an ethylene-based fuel gas for 6 3/4 hours at a pressure of 35 hPa,

7) diffusion at 980°C for 4 3/4 hours and at a pressure equal to or below 10^{-1} hPa and

8) breaking the vacuum with nitrogen at atmospheric pressure, followed by a use treatment at 1020°C and carburization is carried out over a depth of 1 mm giving the sought carbon percentage as a function of the depth.

10. Carburization process according to claim 7, in which the metal parts are of Z 20 WC 10 steel, characterized in that it comprises the eight following stages:

1) vacuum austenitization for 30 min. at 1010°C and cooling in the furnace to 940°C,

2) breaking the vacuum with hydrogen at 940°C until a pressure of 500 hPa is obtained,

3) carbonization at 940°C by the action of an ethylene-based fuel gas for 45 min. and at a pressure of 30 hPa,

4) diffusion at 940°C for 10 min. and at a pressure equal to or below 10^{-1} hPa,

5) breaking the vacuum with hydrogen at 940°C until a pressure of 500 hPa is obtained,



6) carbonization at 940°C by the action of an ethylene-based fuel gas for 75 min.,

7) no diffusion and

8) breaking the vacuum with nitrogen at atmospheric pressure,

followed by a use treatment at 1100°C and carburization is carried out over a depth of 1 mm giving the sought carbon percentage as a function of the depth.

11. Carburization process according to claim 8, in which the metal parts are of Z 38 CDV 5 steel, characterized in that it comprises the eight following stages:

1) vacuum austenitization for 30 min. at 1010°C and cooling in the furnace to 960°C,

2) breaking the vacuum with hydrogen at 960°C until a pressure of 500 hPa is obtained,

3) carbonization at 960°C by the action of an ethylene-based fuel gas for 30 minutes and at a pressure of 30 hPa,

4) diffusion at 960°C for 10 min. and at a pressure equal to or below 10^{-1} hPa,

5) breaking the vacuum with hydrogen at 960°C until a pressure of 500 hPa is obtained,

6) carbonization at 960°C by the action of an ethylene-based fuel gas for 1 hour,

7) diffusion at 960°C at a pressure equal to or below 10^{-1} hPa and

8) breaking the vacuum with nitrogen at atmospheric pressure,

followed by a use treatment at 990°C and carburization is carried out over a depth of 1 mm, whilst obtaining the sought carbon percentage as a function of the depth.

12. Installation for the carburization of metal alloys, characterized in that it essentially comprises a so-called double vacuum furnace (50), constituted by a vessel (55) with its internal carburizing gas distribution device, an annular space (56) surrounding the vessel, a cover traversed by hydrogen (51) and ethylene (52) supply and pumping pipes issuing at different stages of the vessel and at several



regularly distributed locations, thermocouples (TC) and other probes giving information on the pressure, the flow rate and composition of the gases at different points of the furnace and linked with a data acquisition means, which is itself connected to a microcomputer (61) and several reception stages for the parts to be carburized with perforated plates in order to permit a free circulation of gases.