(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 270 144**
A1

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **87201987.2**

(51) Int. Cl.4: **C23G 5/00**

(22) Date of filing: **16.10.87**

The title of the invention has been amended (Guidelines for Examination in the EPO, A-III, 7.3).

(30) Priority: **31.10.86 NL 8602760**

(43) Date of publication of application:
08.06.88 Bulletin 88/23

(84) Designated Contracting States:
AT BE CH DE ES FR GB GR IT LI LU NL SE

(71) Applicant: **N.V. BEKAERT S.A.**
Bekaertstraat 2
B-8550 Zwevegem(BE)

(72) Inventor: **Coppens, Wilfried**
Cyriel Verschaevestraat 7
B-8510 Kotrijk-Marke(BE)
Inventor: **Lievens, Hugo**
Nederzwijnaardestraat 45
B-9710 Gent(BE)

(74) Representative: **Demeester, Gabriel et al**
N.V. Bekaert S.A. Bekaertstraat 2
B-8550 Zwevegem(BE)

(54) Process and apparatus for continuously cleaning elongated substrates, and objects thus cleaned.

(57) The invention relates to a process for the continuous cleaning of an elongated substrate, such as a wire, a strip, a cord, etc., whereby the substrate (11) to be cleaned is guided through a high vacuum chamber (12, 13), whereby an inert sputtering gas , such as argon, is introduced into this chamber and a sufficiently high voltage difference and current is maintained between the substrate (11) used as cathode and an anode (18) present in the chamber, so that an electrical discharge occurs between these two electrodes, as a result of which the substrate (11) is cleaned by the impact of inert gas ions when passing through the vacuum chamber (12, 13).

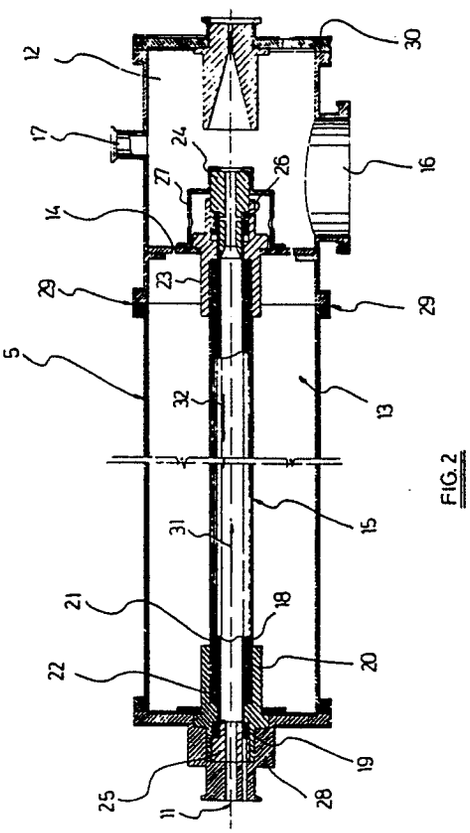

FIG.2

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PROCESS AND APPARATUS FOR THE CLEANING OF AN ELONGATED SUBSTRATE, SUCH AS A WIRE, A STRIP, A CORD, ETC. AND OBJECTS THUS CLEANED

The invention related in the first place to a process for the continuous cleaning of an elongated substrate such as a wire, a strip, a cord, etc.

Elongated metal objects, such as steel wires, are made by special techniques such as wire drawing, during which the cross section of the objects is reduced. This reduction in cross section is generally carried out in appropriate equipment using suitable lubricants. Residues of these lubricants must generally be removed from the fabricated objects, if these objects are subsequently to be used successfully. This may also be the case for non-metallic, elongated objects, such as man-made fibres, on the surface of which residues of other materials may be left after the manufacturing process.

The continuous cleaning of elongated substrates is particularly important if these substrates have to be coated subsequently of if these substrates have to be subsequently embedded as a reinforcement, because the adhesion between substrate and coating or between substrate and material to be reinforced is substantially improved when the substrate has been adequately cleaned.

It is an object of the invention to provide a suitable process for the continuous and highly effective cleaning of an alongated substrate.

It is a further object of the invention to provide a process that allows this cleaning to be carried out at high speed.

To this end, the invention proposes that the elongated substrate to be cleaned is guided through a high vacuum chamber and that an inert sputtering gas, such as argon, is introduced into this chamber and that a sufficiently high voltage difference and current is maintained between the cathodic substrate and an anode provided in this chamber, so that an electrical discharge is generated between these two electrodes and a plasma results, whereby the substrate is cleaned by the impact of inert gas ions from the plasma while passing through the vacuum chamber.

Preferably, the anode is formed by an elongated casing, such as a circular cylindrical surface, whereby the substrate is guided longitudinally through the anode while the elongated substrate is kept at ground potential.

It is most preferable to guide the inert sputtering gas and the substrate to be cleaned through the anode, for example a copper tube, in opposite directions.

In particular, the substrate to be cleaned is precleaned by induction heating under vacuum prior to the plasma cleaning in the high vacuum chamber.

The invention also related to an apparatus for the continuous cleaning of an elongated substrate, such as a wire, a cord, a strip, etc. in which this apparatus is at least provided with a chamber with means to evacuate this chamber to a high vacuum, with an anode in this high vacuum chamber, and with means to introduce an inert sputtering gas, such as argon, into this high vacuum chamber. The apparatus according to the present invention is characterized in that the apparatus is also provided with means for the continuous guiding of the elongated substrate through the high vacuum chamber and with means for maintaining a sufficiently high potential difference and current between the cathodic substrate and the anode present in the chamber, so that a glow discharge is established between these two electrodes and a plasma is formed.

Preferably, the anode is an elongated casing, such as a circular, cylindrical surface.

Finally, the invention also related to elongated substrates that are cleaned according to the process and in the apparatus according to the invention.

The invention will now be further explained in the following detailed description and accompanying drawing, wherein :

Figure 1 represents a flow chart of a complete line of which the apparatus according to the invention forms a part, and

Figure 2 represents a longitudinal section of an apparatus according to the invention.

In Figure 1 parts of a complete line are indicated by number 1 - 9, whereby the number 5 indicates the apparatus according to the invention. The elongated substrate to be cleaned is reeled off a coil or such means in station 1 and is fed through chambers 2 and 3 with vacuum seal lock 4 into the actual cleaning apparatus 5, whereupon it is rewound onto a coil 6, thereby passing through chamber 3′ with vacuum seal lock 4′ and chamber 2′. Such a line has for instance been described in U.K. patent 1.362.735 in which a high vacuum chamber is preceded and succeded by two vacuum chambers.

The vacuum chambers 2 and 2′ are connected to a Roots vacuum booster 7 known per se, whereas chambers 3 and 3′ are connected to a rotary vacuum pump 8. The high vacuum chamber 5 is connected to a turbomolecular pump 9. Between the atmosphere (unwinding and rewinding stations 1 and 6) and the chambers 2 and 2′ respectively, suitable means of passage 10 and 10′ are provided. Between the chambers 3 and 5 and between

the chambers 3' and 5 vacuum tight valves (4 and 4' respectively) are present.

The line operates as follows. With the Roots vacuum booster 7, with for instance a capacity of 500 m^3 per hour, a vacuum of 10^{-1} to 10^{-2} Torr is achieved in chambers 2 and 2'. The chambers 3 and 3' are evacuated still further with pump 8, with for instance a capacity of 10 m^3 per hour, to a final pressure of for example 10^{-2} Torr or lower. The high vacuum chamber 5 is evacuated using the turbomolecular vacuum pump 9 to a high vacuum, for instance 10^{-4} to 10^{-7} Torr. During the evacuation of the chamber 5, the valves 4 and 4' are completely closed. After this situation has been reached, the line is ready to start the process for cleaning the elongated substrate 11, whereupon valves 4 and 4' are opened.

Figure 2 shows the longitudinal section of a typical vacuum chamber 5. This chamber 5 consists of two sections 12 and 13, interconnected by the openings 14. The actual piece of equipment 15 for the cleaning of the elongated substrate 11 is contained in section 13. The section 12 is provided with connectors 16 for the turbomolecular pump 9 and with connectors 17 for the supply of an inert gas, such as argon, nitrogen, etc.

The piece of equipment 15 comprises a circular cylindrical anode 18 with cable connectors 19 to provide the electrical potential. This anode may for instance be a copper tube. This anode 18 is supported by a tube 20, made for instance fom stainless steel, and subsequently by a tube 21 made from insulating material, for instance aluminium oxide. The both ends of the tubes 20 and 21 are incorporated in the insulating supports 22 and 23. The tubes 20 and 21 can in theory be replaced by a single tube made from insulating material, in which case the wall thickness of this single tube is about equal to the sum of the wall thicknesses of the tubes 20 and 21. The ends of the anode 18 are incorporated into the insulating supports 24 and 25. Between the end of the anode 18 and the insulating support 24, a spring 26 has been provided. The supports 24 and 25 fit into clamping devices 27 and 28. The clamping device 27 has been fixed to the wall between sections 12 and 13, whereas the clamping device 28 cen be screwed onto the end of the section 12. It is clear that the spring 26 can be slackened by loosening the clamping device 28, as a result of which the anode 18 is expelled and can thus easily exchanged for another tube 18. In addition, the vacuum chamber 5 is also provided with a flange connection 29, which permits the removal of the anode 18 without loosening the clamping devices 27 and 28. The lid 30 of the section 12 also has a flange connection. The diameter of the tube 18 is for example about 20 mm, whereas its length is for instance about 500 mm.

The process for cleaning an alongated substrate 11, such as a wire, a strip, etc, is as follows. When the line is ready to operate the process, the substrate 11 to be cleaned is fed through the piece of equipment 15 as indicated by the arrow 31. The pump 9 is switched off and an inert sputtering gas, such as argon, is fed into the vacuum chamber 5 or into sections 12 and 13 in a continuous manner until a pressure between 0.01 and 10 Torr has been reached. A sufficiently high voltage difference is maintained between the anode 18 and the substrate 11 (the cathode), so that a glow discharge is established and a plasma is formed. This may occur at a voltage difference of 100 to 1.000 V and a current between 50 and 200 mA. The substrate 11 is then cleaned by the impact of the inert argon ions from the plasma between the substrate 11 (the cathode) and the cylindrical tube 18 (the anode). The substrate 11 will be preferably kept at ground potential. It is also possible to apply an alternating potential between the anode 18 and the substrate 11 (the cathode) in order to attain the so-called RF-state. Triode sputtering is also possible with the apparatus according to the invention.

An important characteristic of the process according to the invention is that the inert sputtering gas, such as argon is led through the anode 18 in the direction of the arrow 32. This means that the substrate 11 and the sputtering gas move in opposite directions within the evacuated section 12 and in particular within the anode 18. This can for example be achieved by ensuring a lower pressure in the chamber 3 than in the chamber 3', or by making sure that the resistance between the chambers 3 and 5 is smaller than the resistance between the chambers 3' and 5.

The process according to the invention is particularly suitable for metal substrates, such as steel wires, steel cords, etc. which have been coated with zinc, brass, etc. These elongated steel products, whether coated or uncoated, generally carry residues of lubricants which are difficult to remove. It has been found that elongated substrates are efficiently cleaned when fed at high speeds(20 m per minute or more) when using the process according to the invention.

The process according to the invention is further characterized in that the substrate 11 to be cleaned is pre-cleaned by induction heating under vacuum, prior to cleaning in the high vacuum chamber or prior to the plasma cleaning. This precleaning can be carried out for example in the chamber 2 at temperatures up to about 300°C.

Within the context of the invention, improvements can be introduced, both with regard to the process and to the apparatus. For instance, a coil can be fitted around the anode 18 in the section

13, so as to generate a magnetic field between the anode 18 and the substrate 11, which further improves the quality of the cleaning of the substrate.

Claims

1. Process for the continuous cleaning of an elongated substrate, such as a wire, a strip, a cord, etc., characterized in that the substrate (11) to be cleaned is guided through a high vacuum chamber (12, 13), that an inert sputtering gas , such as argon, is introduced into this chamber and a sufficiently high voltage difference and current is maintained between the substrate (11) used as cathode and an anode (18) present in the chamber, so that an electrical discharge occurs between these two electrodes, as a result of which the substrate (11) is cleaned by the impact of inert gas ions when passing through the vacuum chamber (12, 13).

2. Process according to claim 1, characterized in that the anode (18) consists of an elongated casing, inside which the elongated substrate is guided in the longitudinal direction.

3. Process according to claim 2, characterized in that the elongated casing (18) is a circular, cylindrical surface.

4. Process according to one or more of the preceding claims 1-3, characterized in that the elongated substrate (11) is kept at ground potential.

5. Process according to one or more of the preceding claims 1-4, characterized in that an alternating voltage is applied between the two electrodes (11, 18).

6. Process according to one or more of the preceding claims 1-5, characterized in that the inert sputtering gas and the substrate (11) to be cleaned are fed through the anode (18) in opposite directions.

7. Process according to one or more of the preceding claims 1-6, characterized in that the elongated substrate (11) to be cleaned is metal, in particular steel.

8. Process according to claim 7, characterized in that the metal substrate is provided with a coating.

9. Process according to claim 8, characterized in that the coating is brass or zinc.

10. Process according to one or more of the preceding claims 1-9, characterized in that the substrate to be cleaned in the high vacuum chamber (plasma cleaning) is pre-cleaned by induction heating under vacuum.

11. Apparatus for the continuous cleaning of an elongated substrate such as a wire, a strip, a cord, etc., comprising at least a chamber with means to evacuate this chamber, an anode mounted inside this high vacuum chamber, means for introducing an inert sputtering gas, such as argon, in this vacuum chamber, characterized in that the apparatus (5) is also provided with means to continuously guide the elongated substrate (11) through the high vacuum chamber (12, 13) and with means to maintain a sufficiently high voltage and current difference between the substrate (11) as cathode and the anode (18) present in the chamber, so that a glow discharge is established between the two electrodes (11, 18).

12. Apparatus according to claim 11, characterized in that the anode (18) is an elongated casing.

13. Apparatus according to claim 12, characterized in that the elongated casing is a circular cylindrical surface.

14. Apparatus according to one or more of the preceding claims 11-13, characterized in that the high vacuum chamber (12, 13) consists of two sections, interconnected by openings (14).

15. Apparatus according to one or more of the preceding claims 11-14, characterized in that the ends of the anode (18) are incorporated between insulating supports (24, 25) in the walls of one section (13) of the high vacuum chamber (12, 13), and that the other section (12) of the high vacuum chamber is provided with an inlet (17) for an inert gas.

16. Apparatus according to claim 15, characterized in that a spring (26) is provided between one end of the anode (18) and its corresponding insulating support (24).

17. Apparatus according to one or more of the preceding claims 11-16, characterized in that means are provided to guide the inert sputtering gas and the substrate (11) to be cleaned through the anode (18) in opposite directions.

18. Metal elongated substrate, characterized in that the substrate is cleaned according to the process according to one or more of the preceding claims 1-10.

19. Metal elongated substrate according to claim 18, characterized in that the substrate is made of steel.

20. Metal elongated substrate according to claim 18 or 19, characterized in that the substrate is provided with a coating.

21. Metal elongated substrate according to claim 20, characterized in that the coating has been chosen from brass and zinc.

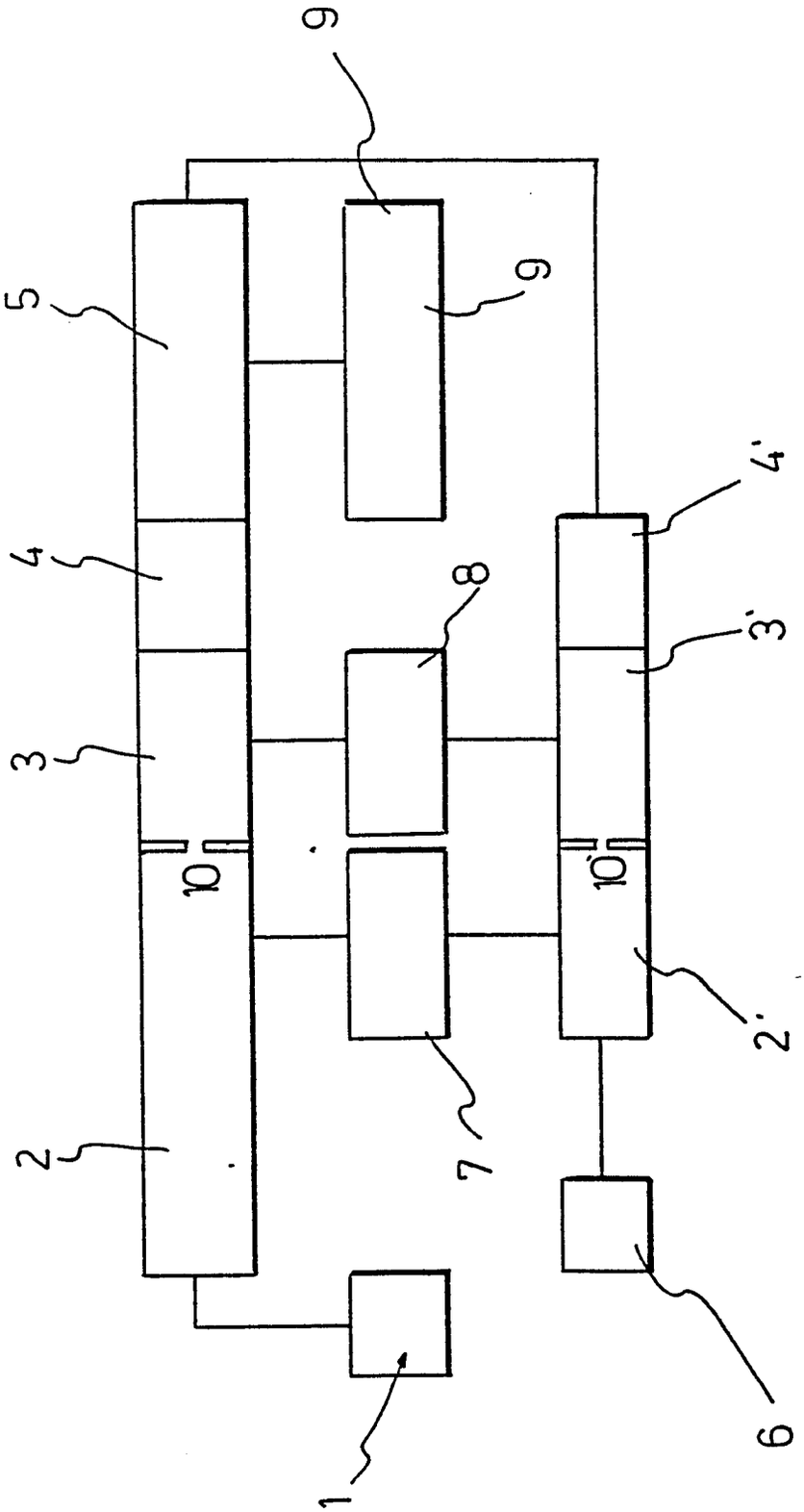

FIG.1

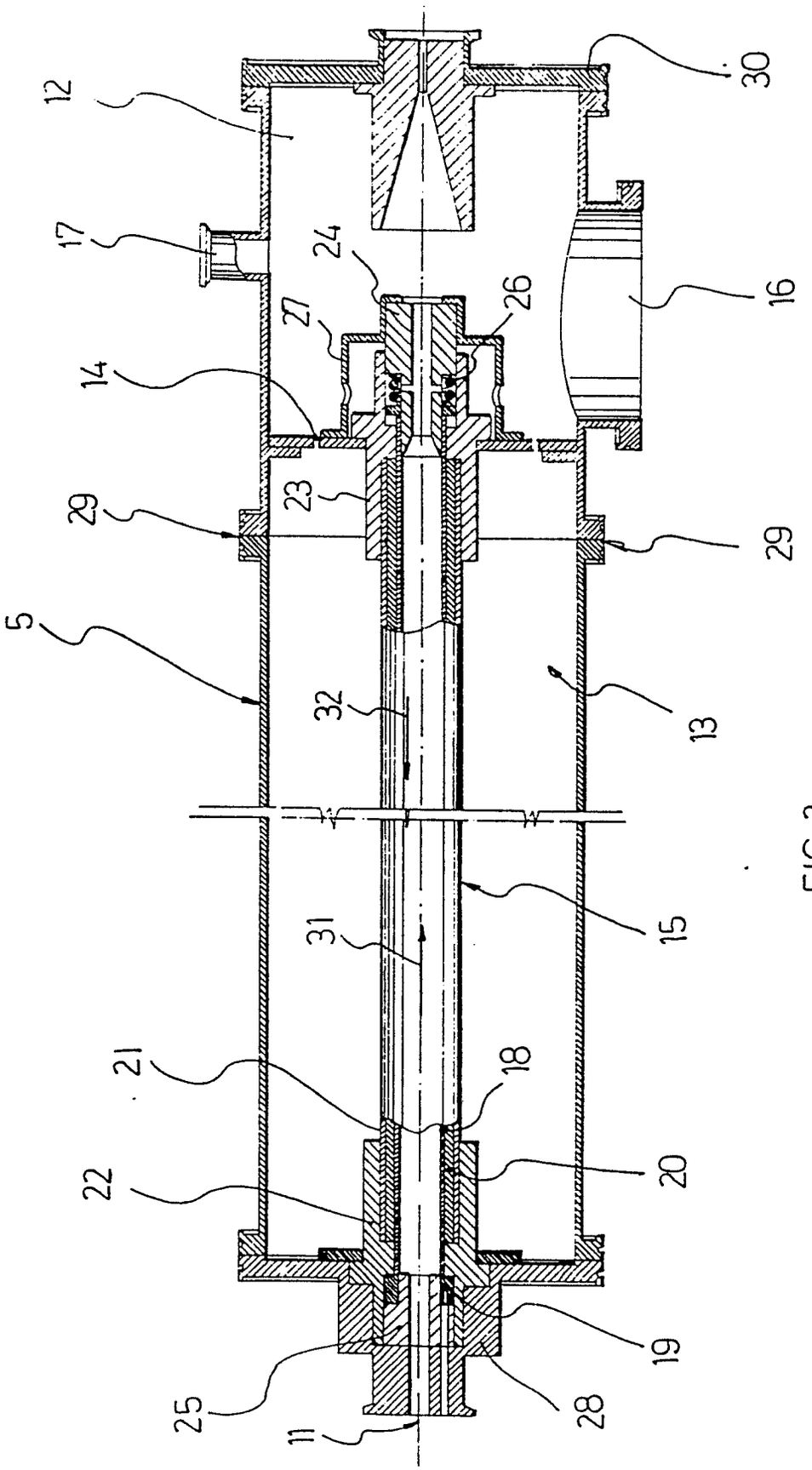

FIG. 2

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EUROPEAN SEARCH REPORT

Application Number

EP 87 20 1987

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	CHEMICAL ABSTRACTS, vol. 90, no. 24, June 1979, page 242, abstract no. 190706p, Columbus, Ohio, US; & JP-A-79 01 242 (AGENCY OF INDUSTRIAL SCIENCES AND TECHNOLOGY) 08-01-1979 * Abstract; figure 1 *	1,4,7, 11,18, 19	C 23 G 5/00
Y	---	2,5,12	
Y	US-A-3 654 108 (H.R. SMITH) * Claim 1; column 2, lines 19-23; column 7, lines 18-20; figures 1,2 *	2,5,12	
A	--- PATENT ABSTRACTS OF JAPAN, vol. 4, no. 173 (C-32)[6551], 29th November 1980; & JP-A-55 110 782 (HITACHI SEISAKUSHO K.K.) 26-08-1980		
A	--- GB-A- 948 554 (J.E. HARLING)		
A	--- DE-B-1 283 645 (UNION CARBIDE)		TECHNICAL FIELDS SEARCHED (Int. Cl.4)
A	--- SOVIET INVENTIONS ILLUSTRATED, Section M, week 8650, 28th January 1987, class M, page 19, no. 83-331189/50, Derwent Publications Ltd, London, GB; & SU-A-1 227 280 (MAGN. MINE METAL INS) 30-04-1986		C 23 G 5/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	05-02-1988	TORFS F.M.G.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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