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(54) Title: INDUCTION HEATING OF METAL STRIP AND WIRE WITH GAS IMPINGEMENT COOLING

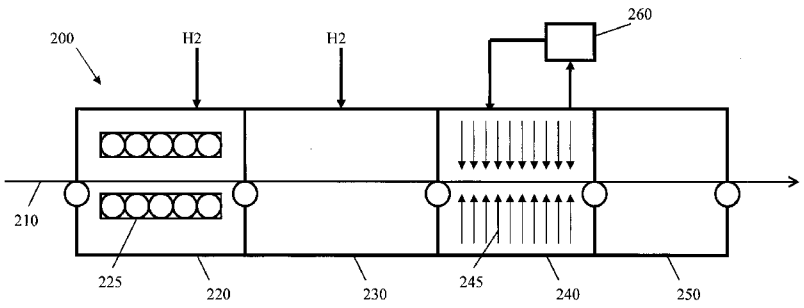

FIG. 2

(57) Abstract: Induction annealing of metals, such as stainless steel is carried out in a gas atmosphere. Cooling following the induction annealing is performed by impingement of cooling gases. The gases that may be used include hydrogen, nitrogen, argon, helium, water vapor, carbon dioxide, carbon monoxide, hydrocarbons and mixtures thereof.

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INDUCTION HEATING OF METAL STRIP AND WIRE WITH GAS IMPINGEMENT COOLING

FIELD OF THE INVENTION

(001) The present invention relates to manufacturing of metal strips and wires, primarily to stainless steel metal strips and wires.

BACKGROUND OF THE INVENTION

(002) Stainless steel is used in a wide range of applications because of its resistance to staining and rusting, attributable to the chromium content, usually from 12 to 20 percent of the stainless steel alloy. There are numerous alloys that are included in the stainless steels family that are used in a large number of applications and industries, including bulk material handling equipment, building exteriors, roofing, automobile components, chemical process plants, pulp and paper manufacturing, refining, water supply, consumer products, sporting goods, shipbuilding, transportation, etc.

(003) Several types of stainless steel exist for various uses depending on the microstructure of the alloy. Austenitic stainless steels exhibit good corrosion resistance and high ductility. Ferritic stainless steels have high resistance to stress corrosion but are difficult to weld. Martensitic stainless steels contain iron with a needle-like structure. Duplex stainless steels provide good resistance to pitting and crevice corrosion as well as resistance to cracking.

(004) The manufacture of stainless steel involves a series of processes. The raw materials to make the desired stainless steel are first melted and then cast into one of several shapes, such as blooms (rectangular), billets (round or square), slabs, rods or tubes. Further forming steps can be carried out and then the stainless steel is heat treated

followed by cleaning and polishing. The stainless steel is then ready for shipment to end users.

(005) The forming operations begin with hot rolling wherein the steel is heated and rolled. Blooms and billets are generally processed into bar or wire, while slabs become plate, strip, or sheet. Once the initial forming has been completed, annealing is carried out. Annealing comprises heating and cooling the steel under controlled conditions to reduce internal stresses and to achieve the desired characteristics for higher strength.

(006) There are several known methods for annealing of stainless steel. For example, the stainless steel may be annealed in air followed by pickling, the use of a nitric-hydrofluoric acid bath to remove scaling. A further example is the use of transverse flux induction heating to anneal the stainless steel followed by cooling in air or water. Pickling is again necessary to remove oxide layers formed during the annealing stage. Another example is bright annealing in Radiant Tube Furnaces (RTF) or Electrically Heated Furnaces (ERH) in a reducing atmosphere, used mainly a finishing stage for thin strips. One known method is the induction heating of stainless steel pipes in a controlled atmosphere (such as hydrogen) following be contact cooling with solid graphite blocks in a hydrogen filled encapsulation (from Oppermann Rohrtechnik GmbH).

(007) An example of an induction heating process is shown in Figure 1, wherein the system 100, includes an induction heating stage 20, a final heating/soaking stage 30, a cooling stage 40 and an optional quench stage 50. In this system a strip 10 of stainless steel to be processed is feed through the system 100. The strip 10 is first heated in the induction heating stage 20 using induction coil heaters 25. The induction heating is carried out in air. The strip 10 then passes through the final heating/soaking stage 30 which may comprise radiant, electrical or induction heating. The strip 10 is then cooled in the cooling stage 40 by air or water. The optional quench stage 50 quenches the strip 10 in water or air.

(008) There remains a need for improvements to stainless steel processing.

SUMMARY OF THE PRESENT INVENTION

(009) The present invention provides improved techniques for treating stainless steel.

BRIEF DESCRIPTION OF THE DRAWINGS

(010) Figure 1 is a schematic diagram of a prior art stainless steel annealing process.

(011) Figure 2 is a schematic diagram of a stainless steel annealing process according to the invention.

(012) Figure 3 is a schematic diagram of a stainless steel annealing process according to the invention.

(013) Figure 4 is a schematic diagram of a stainless steel annealing process according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

(014) The invention provides new stainless steel annealing processes. The invention will be described with reference to the drawing figures. Figure 2 shows an annealing process system 200 similar to that shown in Figure 1. In particular, the system 200 includes an induction heating stage 220, a final heating/soaking stage 230, a cooling stage 240 and an optional quench stage 250. In this system a strip 210 of stainless steel to be processed is feed through the system 200. The strip 210 is first heated in the induction heating stage 220 using induction coil heaters 225. A hydrogen atmosphere is maintained

in the induction heating stage 220. The strip 210 then passes through the final heating/soaking stage 230 which may comprise radiant, electrical or induction heating also in a hydrogen atmosphere. The strip 210 is then cooled in the cooling stage 240. According to the invention the cooling may be carried out using cooling gas impingement shown by arrows 245. The gas used may be one or more of hydrogen, nitrogen, argon, helium, water vapor, carbon dioxide, carbon monoxide, and hydrocarbons. The cooling gas may be recycled and reused through the use of a recycling means 260, which may be a heat exchanger, cooler and fan, compressor, etc. The strip 210 may be optionally quenched in quench stage 250 with water or air.

(015) Another embodiment of the invention is shown in Figure 3 which shows an annealing process system 300. In particular, the system 300 includes an induction heating stage 320, a final heating/soaking stage 330, a cooling stage 340 and an optional quench stage 350. In this system a strip 310 of stainless steel to be processed is feed through the system 300. The strip 310 is first heated in the induction heating stage 320 using induction coil heaters 325. A hydrogen atmosphere is maintained in the induction heating stage 320. In this embodiment of the invention, the induction heating stage 320 is encapsulated within a gas tight housing 322. The strip 310 then passes through the final heating/soaking stage 330 which may comprise radiant, electrical or induction heating also in a hydrogen atmosphere. The strip 310 is then cooled in the cooling stage 340. According to the invention the cooling may be carried out using cooling gas impingement shown by arrows 345. The gas used may be one or more of hydrogen, nitrogen, argon, helium, water vapor, carbon dioxide, carbon monoxide, and hydrocarbons. The cooling gas may be recycled and reused through the use of a recycling means 360, which may be a heat exchanger, cooler and fan, compressor, etc. The strip 310 may be optionally quenched in quench stage 350 with water or air.

(016) A further embodiment of the invention is shown in Figure 4 which shows an annealing process system 400 that includes an induction heating stage 420, a cooling

stage 440 and an optional quench stage 450. In this system a strip 410 of stainless steel to be processed is feed through the system 400. The strip 410 is first heated in the induction heating stage 420 using induction coil heaters 425. A hydrogen atmosphere is maintained in the induction heating stage 420. In this embodiment of the invention, the induction heating stage 420 is again encapsulated within a gas tight housing 422. The final heating/soaking stage is not used in this system and the strip 410 passes directly to the cooling stage 440. According to the invention the cooling may be carried out using cooling gas impingement shown by arrows 445. The gas used may be one or more of hydrogen, nitrogen, argon, helium, water vapor, carbon dioxide, carbon monoxide, and hydrocarbons. The cooling gas may be recycled and reused through the use of a recycling means 460, which may be a heat exchanger, cooler and fan, compressor, etc. The strip 410 may be optionally quenched in quench stage 450 with water or air.

(017) The invention provides many advantages. By using induction heating for the annealing of the stainless steel, the need for an extensive pickling process can be eliminated. For example, process steps related to pickling following air annealing that can be eliminated by using induction heating are oxidizing, scale braking, neolytic pickling, rinsing and brushing, acid pickling, rinsing and skin pass rolling. Induction heating is also advantageous as compared to bright annealing because the capex and footprint for equipment related to bright annealing are much greater that those needed for induction heating and the annealing capacity for bright annealing is more limited than that for induction heating.

(018) The invention wherein a reduced atmosphere is maintained in the induction heating stage provides advantages over prior art induction heating in air. In particular, by carrying out the heating in a reducing gas atmosphere according to the invention, the need for subsequent oxidizing, scale braking, neolytic pickling, rinsing and brushing, acid pickling and rinsing can be eliminated. Further, by cooling with impingement of reducing gas additional processing stages can be eliminated.

(019) The invention has been describe with reference to stainless steel production, but is equally applicable to other metals, such as steel of all types, titanium and titanium alloys, aluminum and aluminum alloys, and copper and copper alloys. The invention can be used with any type of induction heater, e.g. selenoidal, transverse flux, etc., and can be used for processing of all different types of products, including rolled strips, wire, rods, plates. Etc.

(020) It is anticipated that other embodiments and variations of the present invention will become readily apparent to the skilled artisan in the light of the foregoing description, and it is intended that such embodiments and variations likewise be included within the scope of the invention as set out in the appended claims.

CLAIMS

What is claimed:

1. A system for annealing of metal comprising:
an induction heating stage; and
a cooling stage;
wherein a hydrogen atmosphere is maintained in the induction heating stage.

2. The system according to claim 1, wherein the induction heating stage comprises induction heating coils.

3. The system according to claim 1, wherein the induction heating stage comprises a selenoidal induction heater or a transverse flux induction heater.

4. The system according to claim 1, wherein the cooling stage comprises cooling gas impingement.

5. The system according to claim 4, wherein the cooling gas is hydrogen, nitrogen, argon, helium, water vapor, carbon dioxide, carbon monoxide, or a hydrocarbon.

6. The system according to claim 4, further comprising recycling means associated with the cooling stage for recycling the cooling gas.

7. The system according to claim 6, wherein the recycling means comprising a heat exchanger, a cooler and fan, or a compressor.

8. The system according to claim 1, further comprising a heating/soaking stage located between the inducting heating stage and the cooling stage.

9. The system according to claim 8, wherein the heating/soaking stage comprises radiant, electrical, or induction heating.

10. The system according to claim 8, wherein a hydrogen atmosphere is maintained in the heating/soaking stage.

11. The system according to claim 1, further comprising a quench stage.

12. The system according to claim 11, wherein the quench stage utilizes water or air.

13. The system according to claim 1, wherein the induction heating stage is encapsulated in a hydrogen atmosphere.

14. The system according to claim 1, wherein the metal is stainless steel.

15. The system according to claim 1, wherein the metal is titanium, a titanium alloy, aluminum, an aluminum alloy, copper, or a copper alloy.

16. The system according to claim 1, wherein the metal is in the form of a rolled strip, a wire, a rod, or a plate.

17. A method for annealing of metal comprising:

subjecting the metal to be annealed to induction heating in an induction heater having a hydrogen atmosphere maintained therein; and

following induction heating, subjecting the metal to a cooling operation.

18. The method according to claim 17, wherein the induction heater comprises induction heating coils.

19. The method according to claim 17, wherein the induction heater comprises a selenoidal induction heater or a transverse flux induction heater.

20. The method according to claim 17, wherein the cooling operation comprises cooling gas impingement.

21. The method according to claim 20, wherein the cooling gas is hydrogen, nitrogen, argon, helium, water vapor, carbon dioxide, carbon monoxide, or a hydrocarbon.

22. The method according to claim 20, further comprising recycling the cooling gas.

23. The method according to claim 22, wherein recycling comprises a heat exchanger, a cooler and fan, or a compressor.

24. The method according to claim 17 further comprising following induction heating and before the cooling operation, subjecting the metal to a heating/soaking operation.

25. The method according to claim 24, wherein the heating/soaking operation comprising radiant, electrical or induction heating.

26. The method according to claim 24, wherein the heating/soaking operation is carried out in a hydrogen atmosphere.

27. The method according to claim 17, further comprising following the cooling operation, subjecting the metal to a quench operation.

28. The method according to claim 27, wherein the quench operation comprises quenching in water or air.

29. The method according to claim 17, wherein the metal is stainless steel.

30. The method according to claim 17, wherein the metal is titanium, a titanium alloy, aluminum, an aluminum alloy, copper or a copper alloy.

31. The method according to claim 17, wherein the metal is in the form of a rolled strip, a wire, a rod or a plate.

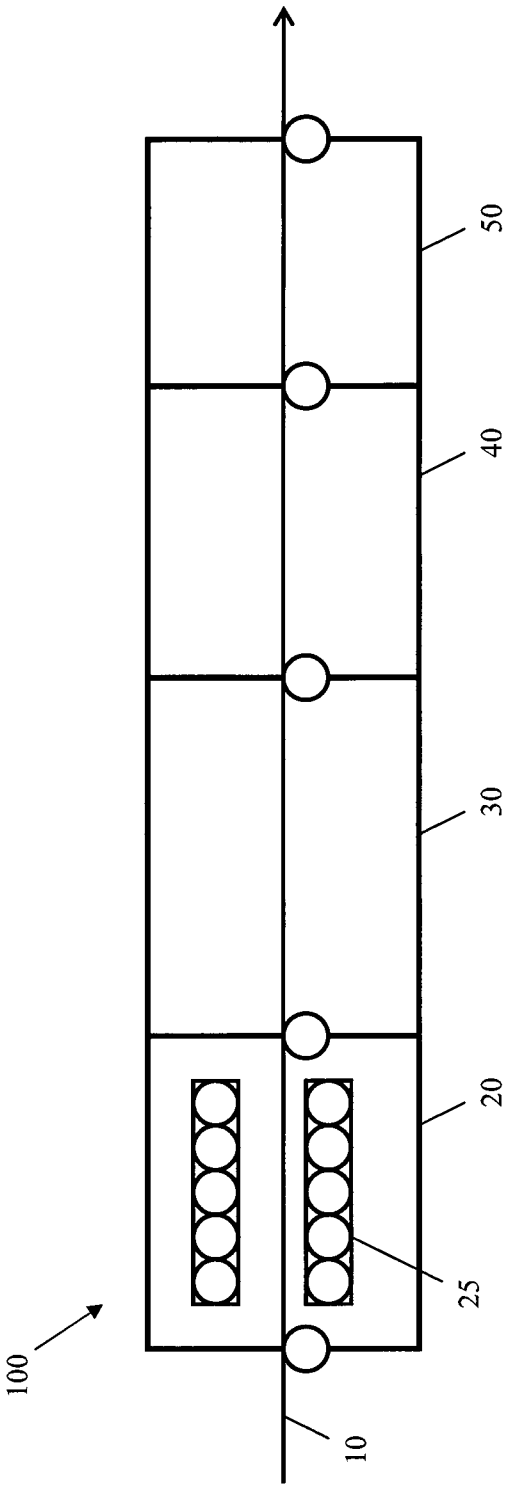

FIG. 1 PRIOR ART

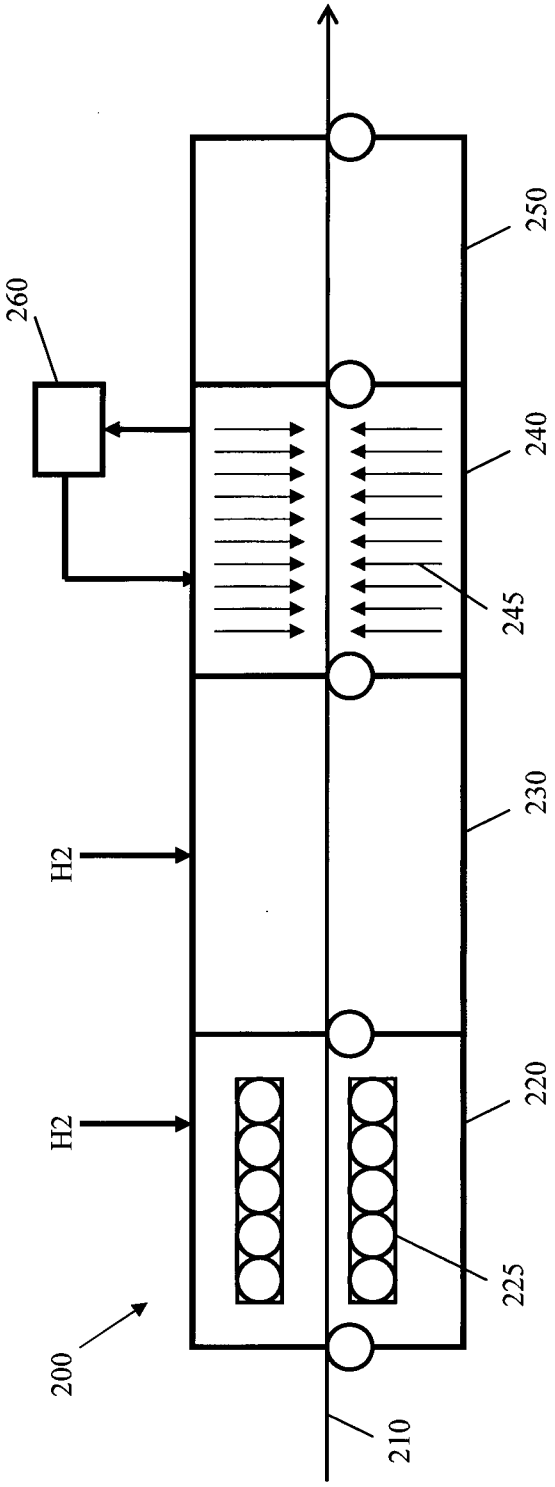

FIG. 2

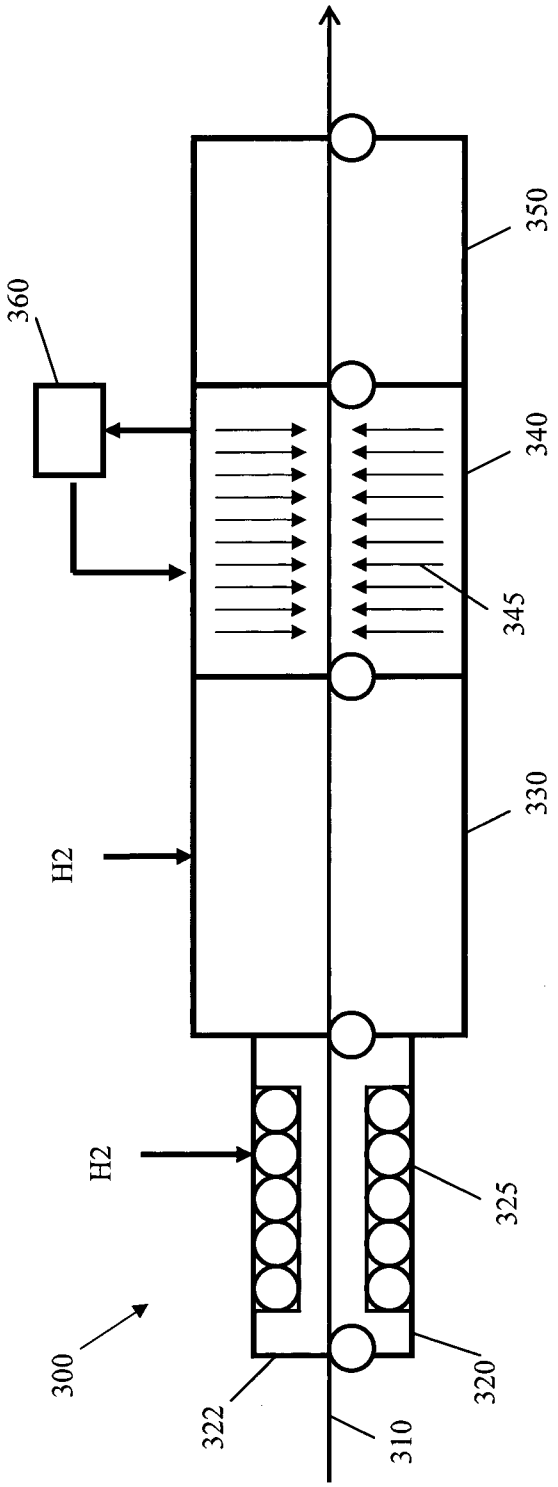

FIG. 3

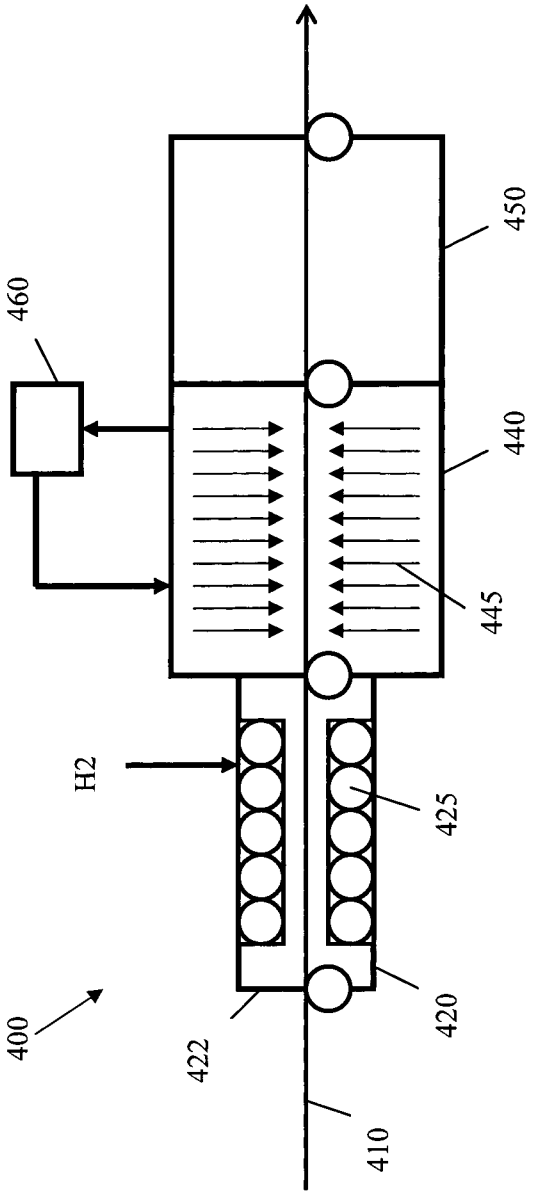

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/002744

A. CLASSIFICATION OF SUBJECT MATTER
INV. C21D9/56 F27D11/06 F27B9/24 C21D8/02 C21D9/60
F27B9/04 H05B6/02
ADD.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C21D F27D F27B H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, CHEM ABS Data, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	US 5 895 599 A (NIVOCHE CLAUDE ANDRE [FR]) 20 April 1999 (1999-04-20) page 3, line 18 - line 27	1-31
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
11 November 2013	18/11/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Badcock, Gordon

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/002744

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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X	WO 2008/000945 A1 (STEIN HEURTEY [FR]; CLUZEL XAVIER [FR]; GAILLARD CHRISTIAN [FR]; JODET) 3 January 2008 (2008-01-03) the whole document	1-31

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