Title: HIGH TEMPERATURE PROCESS

Abstract: A process for converting a starting material into a final product by reaction of the starting material with a gas in a furnace at elevated temperature followed by cooling of the final product using a cooler, wherein, prior to introduction of the gas into the furnace the temperature of the gas is elevated by use of a thermal exchange means which is provided between the furnace and the cooler and which facilitates the transfer of thermal energy associated with the final product to the gas.
HIGH TEMPERATURE PROCESS

The present invention relates to a process in which a starting material is converted into a final product by reaction of a gas at elevated temperature. The process is particularly concerned with using the thermal energy of the final product to raise the temperature of the gas prior to the reaction of the gas with the starting material. The intention here is to enhance the thermal efficiency of the system. The invention also relates to an apparatus suitable for carrying out the process.

The present invention will be described with particular reference to the reduction of nickel oxide by reaction with hydrogen at elevated temperature to form nickel metal. However, it is to be appreciated that the principle underlying the invention is more generally applicable and may be employed with other reaction systems that rely on the same basic tenets.

It is conventional in the art to reduce nickel oxide to nickel in a furnace at elevated temperature using hydrogen as the reducing agent. Hydrogen is also used to maintain a reducing atmosphere for the product when formed in order to prevent re-oxidation of the metal at elevated temperature. Furthermore, hydrogen is used in the cooling system (cooler) employed to lower the temperature of the product prior to discharge to the air.

In such cooling systems hydrogen is passed over the hot product (nickel) thereby achieving rapid cooling. The hydrogen also provides a reducing atmosphere and this prevents re-oxidation of the product. Heat is removed from the hydrogen by thermal exchange with a suitable medium, such as water, which is then piped away for heat removal before being re-circulated to extract further heat from the hydrogen. The cooled hydrogen is re-circulated and re-used to provide rapid cooling of hot product. The use of hydrogen as coolant means that the rate of cooling is greatly accelerated when compared with quiescent cooling. In turn, this means that a more compact (shorter) cooling system can be employed when hydrogen is used.

Hydrogen which is used in the cooling process is used upstream in the furnace for the
reduction reaction. However, as this hydrogen exits the cooling system at a temperature of about 150°C, it is necessary to increase the temperature of it significantly before it is delivered to the furnace, and here heaters may be used to pre-heat the hydrogen. Alternatively, the temperature of the hydrogen may be increased using heat energy from the furnace, resulting in a drop in temperature of the furnace. Additional energy is invariably also supplied to the furnace to counteract the chilling effect caused by introduction of hydrogen at a temperature relatively lower than the operating temperature of the furnace. This leads to an increase in the cost of constructing a reduction reactor due to the need to employ additional equipment (heaters for the hydrogen) and in operating the reactor due to higher energy demands.

The present invention seeks to overcome these disadvantages by using thermal energy of the final product to heat the gas reactant (hydrogen in the case illustrated) to a temperature higher than that achieved using the conventional technique described above. The invention also seeks to provide an apparatus which includes specific structural components to achieve this end. These structural components may add to the overall cost of the apparatus but this expense would be at least off-set by the savings in energy and/or the reduction in other furnace hardware associated with the invention.

Accordingly, in one aspect the present invention provides a process for converting a starting material into a final product by reaction of the starting material with a gas in a furnace at elevated temperature followed by cooling of the final product using a cooler, wherein, prior to introduction of the gas into the furnace the temperature of the gas is elevated by use of a thermal exchange means which is provided between the furnace and the cooler and which facilitates the transfer of thermal energy associated with the final product to the gas.

Central to the present invention is the use of a thermal exchange means to transfer thermal energy from the final product to the gas used to effect conversion of the starting material. The thermal exchange means is intended to absorb radiant heat from the final product and convey this heat to the gas by convection and conduction. As will be explained in more
detail below, the thermal exchange means may be configured and positioned to maximise heat transfer to the gas.

In the process of the present invention the conversion of starting material to final product takes place at elevated temperature. The resultant final product exits the furnace at elevated temperature. The present invention resides in using thermal energy associated with the final product to heat the gas which is used in the conversion reaction. This heat transfer takes place upstream of the cooler which is used to cool the final product.

The gas being heated by use of the thermal exchange means is the same gas as used to effect conversion of the starting material to the final product in the furnace. Contacting the final product with this gas therefore also prevents any reverse reaction that would otherwise lead to reformation of the starting material. Thus, if the conversion is the reduction of nickel oxide using hydrogen, the use of hydrogen in the thermal exchange means maintains a reducing atmosphere that prevents oxidation of the nickel product. In this way the gas used in the thermal exchange means provides cooling of the final product under conditions that will prevent reformation of the starting material. Hydrogen is also used during annealing of steel and stainless steel continuous strip to prevent oxidation that would otherwise occur. Cooling of the final product by use of the thermal exchange means will also reduce the load on the cooler to which the final product is subsequently delivered.

The present invention may be applied to a variety of chemical conversions in which a starting material is reacted with a gas at elevated temperature to yield a final product which is also at elevated temperature. For instance, the conversion may be a reduction in which a metal oxide is reacted with a reducing gas, to yield the metal. One such conversion is that of nickel oxide to nickel using hydrogen. This usually takes place at a temperature of about 800 to about 1200°C, for example, about 900 to about 1000°C. Usually, the starting material and final product are both solids, although this is not essential. The invention is especially useful in processes that require the same gas for effecting the chemical reaction and for contributing to cooling of the final product. As explained above, hydrogen is often used as process gas and coolant. The invention may also be useful for processes in which
impurities are removed from a starting material by reaction with a gas at elevated temperature. For example, hydrogen may be used to remove sulphur from metal (e.g. nickel) briquettes.

It will be appreciated that the present invention relies on the existence of a final product at elevated temperature in order to heat the gas used for the necessary chemical conversion. It follows from this that the present invention is not useful on start-up. However, the chemical conversions to which the present invention is applicable tend to be run continuously on an industrial scale. Thus, once start-up has been effected the process of the present invention may also be run continuously. Typically, when the process of the invention is up and running, all of the gas delivered to the furnace will have been heated in accordance with the present invention without requiring the addition of energy from an external source.

An important aspect of the present invention is the thermal exchange means which is used to transfer heat energy of the final product to the gas before the gas is introduced into the furnace where the required chemical conversion takes place. Preferably, the thermal exchange means is configured to optimise the amount of heat energy transferred from the final product to the gas. This will enhance the overall thermal efficiency of the system. Typically, the final product will cool at a slower rate than the gas temperature increases because the final product has a greater thermal mass.

Heat transfer to the gas may also be optimised by providing the thermal exchange means immediately adjacent the furnace. This is because it is preferred from the viewpoint of maximising radiant heat transfer that the temperature of the final product be as high as possible as it is introduced into the thermal exchange means from the furnace. If the temperature of the final product cools to any significant degree before entering the thermal exchange means, the effectiveness of radiant heat transfer to the gas via the thermal exchange means will be diminished. This effect can be minimised by positioning the thermal exchange means immediately adjacent the furnace so that the final product from the furnace undergoes minimal cooling before being processed by the thermal exchange
means. This principle can be applied to optimise the amount of heat transferred from the final product to the gas. It is also desirable to use a gas having high conductivity and specific heat, such as hydrogen, although this will obviously depend upon the chemical conversion being undertaken.

In one embodiment the thermal exchange means comprises a series of individual baffle plates which are parallel to each other and inclined at an angle of from 30 to 60°, preferably 45°, to the horizontal. The plates are inclined in the direction of intended gas flow. The number, size, geometry, inclination and spacing of the plates are intended to cause turbulence in the gas thereby optimising heat transfer by ensuring intimate contact between incoming gas and the surfaces of the plates. Desirably, to maximise heat transfer, the flow of incoming gas will contact a large surface area of the plates before exiting the thermal exchange means. The spacing between the baffle plates should be adjusted to ensure suitable upflow of gas between adjacent plates. If the spacing is too small, increased flow resistance occurs which reduces upflow.

To assist in elevating the temperature of the baffle plates, at least on start-up, the material from which they are made preferably has high thermal conductivity. However, it will be appreciated that once thermal equilibrium has been reached and the plates have attained a steady temperature, the amount of energy withdrawn from the hot product will substantially equal the amount of energy conveyed to the gas passed over the plates. In this case the conductivity of the plates is not particularly relevant (nor is their weight or thickness.) Usually, the plates are made of steel (such as stainless steel) and are blackened to maximise radiant heat transfer. This blackening may be done by techniques known in the art, such as chemical oxidation. However, here it will be necessary to take into account the conversion that is to take place in the furnace. If the conversion involves reduction of a starting material, it will probably not be appropriate to use oxidation–blackened plates since the reduction may reverse the blackening process. Obviously, the material from which the plates are formed should have sufficient structural integrity at the temperatures likely to be encountered in operation.
To ensure a high degree of heat uptake by the baffle plates they are located in close proximity to the (hot) final product. Usually, the baffle plates are positioned above (and adjacent) the product as the product is transported through (and out of) the thermal exchange means, the spacing between the trailing (lower) edge of the plates and the product being as little as possible. It has been found that a significant portion of gas can pass beneath the plates in the space immediately above the product. Reducing the clearance between the baffle plate adjacent the inlet and the product as it is being transported can help to prevent this and thus enhance performance. In an attempt to minimise the spacing between the trailing edge of the baffle plates and the hot product, the trailing edge of each plate may be provided with a flap which is easily displaced by contact with the product. Use of such an arrangement allows the trailing edge of the each baffle plate to be in as close thermal proximity to the product as possible but enables variations in product height to be taken into account. The flap will usually be formed of the same material as the baffle plate and be attached (loosely) to the plate by a hinge permitting the flap to move relative to the baffle plate. After being displaced by product being transported the flap will swing back into a resting position. One function of the flaps is to encourage gas flow over the baffle plates.

The fact that the baffle plates are located adjacent the final product being transported means that, at thermal equilibrium, there is an essentially constant rate of radiant heat transfer from the product to the plates (and conductive heat transfer from the plates to the circulating gas in contact with the plates). The gas is passed over the plates generally in a direction counter to that of the final product as it is being transported.

In one embodiment the final product is transported through the thermal exchange means on a conveyor belt. In this case the trailing edge of each baffle plate will be arranged so as to be in close thermal proximity to the product as it is being transported. It is likely that the starting material enters and moves through the furnace on the same conveyor belt. The baffle plates will be positioned at a location within the thermal exchange means such that they are adjacent the final product as it enters the thermal exchange means and is transported through it.
In another embodiment no conveyor belt is used and here the product may be transported over a series of mandrels or rollers. This would be the case for example in a continuous strip furnace. Similar considerations will then apply as described above with respect to use of a conveyor belt. It will be appreciated that the exact manner in which the final product is transported through the thermal exchange means is not especially critical provided that the intended thermal relationship between the final product and the thermal exchange means is preserved.

In an embodiment of the invention the efficacy of the thermal exchange means may be enhanced by positioning the baffle plates below and adjacent the final product as it is transported. The reason for this is that gas (for the conversion) entering the thermal exchange means is cooler, and thus heavier, than gas already present. The natural tendency of this "fresh" gas is to flow downwards. Positioning the thermal exchange means below the final product being transported is likely to mean that more of this "fresh" gas will contact the thermal exchange means. It is of course possible to have thermal exchange means above and below the final product as it is transported.

In one embodiment the baffle plates are corrugated to impart greater turbulence and offer increased surface area for gas contact. The thermal exchange means includes a suitable housing in order to ensure flow of gas over (and between) the baffle plates as required. This housing will be provided over the hot product as it is transported after exiting the furnace.

The thermal exchange means includes an inlet for "cold" gas and an outlet for "heated" gas. The inlet and outlet are provided in close proximity to the hot product being transported. Thus, with respect to the thermal exchange means, the gas outlet corresponds to the inlet for the final product, and vice versa. This is the simplest arrangement although, in principle, the gas inlet and outlet may be entirely distinct from the product inlet and outlet. Gas delivered to the thermal exchange means gas may already have been used repeatedly (by means of recirculation and instream cooling) downstream of the thermal
exchange means. The outlet delivers gas at an elevated temperature to the furnace.

In one embodiment in order to generate turbulence over the plates, the gas is delivered under pressure. This is desirable since impingement of the gas with the final product and/or with heat exchange surfaces within the thermal exchange means may enhance the rate of heat uptake by the gas. In one embodiment, the gas may be directed from a pressure chamber of the cooler downstream of the furnace (and thermal exchange means). In another embodiment gas is delivered to the thermal exchange means via an inlet provided close to the roof thereof. This has also been found to assist in creating gas turbulence in the thermal exchange means. Alternatively, or additionally, a circulating fan may be provided to enhance the rate of convection heat transfer between the baffle plates and the gas.

In one embodiment the thermal exchange means also includes a guide means which is provided adjacent the outlet of the thermal exchange means and which is configured to gather and funnel heated gas towards the outlet. In one embodiment this guide means takes the form of a plate which extends across the height of the thermal exchange means and which is inclined in the opposite direction to the other plates. Gas impinging upon this plate is deflected towards the outlet of the thermal exchange means. It has been found that the presence of this guide (exit) plate contributes to the overall performance of the thermal heat exchanger.

In one embodiment the guide plate extends above the height of the baffle plates. The effect of this is to divert more of the upper-level flow in the thermal exchange means close to the guide plate.

The position of the guide plate adjacent the gas outlet may also influence the velocity of gas flowing across this plate. This may cause some of the gas flowing parallel to and adjacent the final product to be diverted upwards thereby increasing the net flow over the top of the guide plate.
The baffle and guide plates are usually attached to the housing at their edges. Typically, the plates are supported at one edge only. The supporting structures should be configured to minimise flow disruption and distortion on expansion of the plates. In practice, both sides of the plates may be supported.

Preferably, by use of the present invention, the gas to be used in the furnace is heated to 70-90%, more preferably 80-90% of the furnace temperature. Prior to the present invention considerable energy input would otherwise have been required to achieve a corresponding temperature increase. This is especially so using hydrogen because of the high specific heat of hydrogen and the elevation of temperature required. The present invention thus affords a significant energy saving. Furthermore, in accordance with the present invention the gas temperature is raised to a value which is relatively close to the operating temperature of the furnace. This greatly reduces the temperature slump that would occur in the furnace if gas were introduced unheated or at a temperature significantly lower than that of the furnace operating temperature. This also means that the chemical reaction in the furnace is likely to progress more immediately since little or no additional thermal energy needs to be supplied.

The gas which is used in the process of the present invention will obviously vary depending upon the chemical conversion being undertaken. Mixtures of two or more suitable gases may be used. In reduction reactions, such as the conversion of nickel oxide to nickel, hydrogen, or a mixture of hydrogen and nitrogen at a volume ratio of 75:25 respectively, are typically used. Hydrogen is especially useful as it has a high specific heat and high thermal conductivity.

Once delivered to the furnace the gas effects conversion of the starting material to the final product. Exhaust process gases from the furnace are removed and handled in a conventional manner. The final product is removed from the furnace, typically on a conveyor belt as mentioned, and after passage through the thermal exchange means is delivered to a cooler where the product is cooled. Conventional coolers may be used in this respect.
The present invention also provides an apparatus suitable for carrying out the process described herein. The apparatus comprises a furnace provided upstream of a thermal exchange means as described, the thermal exchange means being provided upstream of a (product) cooler. In this context, the term "upstream" is intended to denote the relative position of these components of the apparatus, the starting material being introduced at the upstream end and the final product cooled at the downstream end. The furnace and thermal exchange means are in communication with each other in that the final product exiting the furnace is delivered to the thermal exchange means for heat uptake by the gas. These two components are also in communication in order to allow hot gas from the thermal exchange means to be delivered to the furnace. As noted above, the gas outlet is also the final product inlet to the thermal exchange means, and vice versa. The cooler receives final product which has been "processed" by the thermal exchange means. Usually, the same conveyor belt or mandrels/rollers will do this. When at least a portion of (pressurised) gas is fed from the cooler to the inlet of the thermal exchange means for the purpose of increasing turbulence, suitably arranged piping will generally be used.

The accompanying non-limiting figure illustrates a thermal exchange means which may be used in accordance with the present invention.

The figure shows a thermal exchange means (1) which includes a housing (2) provided over a conveyor belt (3) upon which final product is transported after leaving the furnace (not shown). The housing includes an inlet (4) for feed gas at relatively low temperature and an outlet (5) for delivery of heated gas to the furnace. The thermal exchange means (1) includes a series of baffle plates (6) which are provided at about 45° to the horizontal. These plates (6) are inclined in the direction of intended gas flow from inlet (4) to outlet (5). The plates (6) are in close proximity to the conveyor belt (3) and in use will be heated by hot product transported on the conveyor belt (3) (from left to right in the figure and thus counter to the direction of gas flow through the thermal exchange means (1)). Gas flow within the thermal exchange means (1) is turbulent resulting in gas flowing across and between the baffle plates (6). This causes the temperature of the gas to increase, the baffle
plates (6) communicating thermal energy from the final product on the conveyor belt (3) to the gas. The thermal exchange means is also provided with a guide plate (7) which is provided at the outlet (5) end of the thermal exchange means (1). This guide plate (7) extends across the height of the housing (2) and is inclined in the opposite direction to the baffle plates (6). The function of the guide plate (7) is to channel hot gas towards the outlet (5).

Embodiments of the present invention will now be illustrated by the following non-limiting example.

Example

**Thermal exchange means – dimensions and characteristics**

Housing: stainless steel.

Length: 2640mm.

Height (roof to conveyor belt): 650mm.

Inlet/outlet dimension: 150mm, provided at opposite ends of the thermal exchange means 100mm above the product on the conveyor belt. Practically, this dimension will be dependant on the product thickness, and it is desirable to minimise the distance between the product and the bottom of the plates in order to discourage laminar flow over the product as this can by-pass the plates.

A stainless steel plate separates the thermal exchange means from the adjacent compartment of the apparatus.

**Baffle plates**

Stainless steel plates, 2mm thick, first plate (inlet end) 368mm in length remaining plates, 354mm in length inclined at 45° to the horizontal. The leading edge of the last plate is 665mm from outlet of thermal exchange means.

Plate spacing: 125mm (measured along the horizontal).
Clearance from conveyor belt: 140mm (first plate, inlet end); 150mm (remaining 12 plates).
Clearance from roof: 250mm

5 Guide plate

Stainless steel, 2mm thick, 500mm in length inclined at 60° to the horizontal in opposing direction to baffle plates, located 100mm from outlet.
Clearance from conveyor belt: 140mm

10 It will be appreciated that the accompanying figure illustrates this thermal exchange means schematically.

Nickel powder is transported on the conveyor belt at 1m/min at a temperature of 980°C. A mixture of nitrogen and hydrogen at a volume ratio N₂:H₂ of 25:75 was introduced at 150°C at an entry rate of 500m³/hr. The gas exit temperature was found to be about 700°C. The surface temperature of the nickel powder was found to decrease by on average about 150°C during transit through the thermal exchange means. It was also found that the highest gas velocity occurred at the outlet where the heated and expanded gas is forced through a relatively small exit aperture.

20 It will be appreciated that there are numerous variables associated with the present invention. In practice testing will be employed to determine the most efficient way in which to put the invention into effect for a given system. This would be within the abilities of one skilled in the art.

25 Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.
THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A process for converting a starting material into a final product by reaction of the starting material with a gas in a furnace at elevated temperature followed by cooling of the final product using a cooler, wherein, prior to introduction of the gas into the furnace the temperature of the gas is elevated by use of a thermal exchange means which is provided between the furnace and the cooler and which facilitates the transfer of thermal energy associated with the final product to the gas.

2. A process according to claim 1, wherein all of the gas delivered to the furnace is heated by use of the thermal exchange means without requiring the addition of energy from an external source.

3. A process according to claim 1, wherein the conversion is a reduction in which a metal oxide is reacted with a reducing gas to yield the metal.

4. A process according to claim 3, wherein the reduction is of nickel oxide to nickel using hydrogen.

5. A process according to claim 4, wherein the reduction takes place at a temperature of about 800 to about 1200°C.

6. A process according to claim 1, wherein the conversion involves removal of impurities from a starting material by reaction with a gas at elevated temperature.

7. A process according to claim 6, wherein hydrogen is used to remove sulphur from metal briquettes.

8. A process according to claim 1, wherein the thermal exchange means is configured to optimise the amount of heat energy transferred from the final product to the gas.
9. A process according to claim 1, wherein the thermal exchange means comprises a series of individual baffle plates.

10. A process according to claim 9, wherein the baffle plates are parallel to each other and inclined at an angle of from 30 to 60° to the horizontal.

11. A process according to claim 9, wherein the baffle plates are made of steel and are blackened to maximise radiant heat transfer.

12. A process according to claim 9, wherein the baffle plates are positioned above and adjacent the final product as it is transported through the thermal exchange means, the spacing between the trailing (lower) edge of the baffle plates and the final product being as little as possible.

13. A process according to claim 12, wherein a trailing edge of each baffle plate is provided with a flap which is easily displaced by contact with the final product as it is transported.

14. A process according to claim 13, wherein the flap is formed of the same material as the baffle plate and is attached to the plate by a hinge permitting the flap to move relative to the baffle plate.

15. A process according to claim 9, wherein the baffle plates are positioned below and adjacent the final product as it is transported through the thermal exchange means.

16. A process according to claim 9, wherein the baffle plates are corrugated to impart greater turbulence and offer increased area for gas contact.

17. A process according to claim 9, wherein the thermal exchange means includes a suitable housing in order to ensure flow of gas over and between the baffle plates.
18. A process according to claim 9, wherein in order to generate turbulence over the baffle plates the gas is delivered under pressure.

19. A process according to claim 9, wherein the thermal exchange means includes a guide means which is provided adjacent an outlet of the thermal exchange means and which is configured to gather and funnel heated gas toward the outlet.

20. A process according to claim 19, wherein the guide means takes the form of a plate which extends across the height of the thermal exchange means and which is inclined in the opposite direction to the baffle plates.

21. A process according to claim 1, wherein the gas to be used in the furnace is heated to 70-90% of the furnace temperature.

22. An apparatus suitable for carrying out the process claimed in claim 1, the apparatus comprising a furnace provided upstream of a thermal exchange means, the thermal exchange means being provided upstream of a cooler, wherein the thermal exchange means facilitates the transfer of thermal energy associated with the final product to the gas.

23. The apparatus of claim 22, wherein the thermal exchange means is configured to optimise the amount of heat energy transferred from the final product to the gas.

24. The apparatus of claim 22, wherein the thermal exchange means comprises a series of individual baffle plates.

25. The apparatus of claim 24, wherein the baffle plates are parallel to each other and inclined at an angle of from 30 to 60° to the horizontal.

26. The apparatus of claim 24, wherein the baffle plates are made of steel and are blackened to maximise radiant heat transfer.
27. The apparatus of claim 24, wherein the baffle plates are positioned above and adjacent the final product as it is transported through the furnace, the spacing between the trailing (lower) edge of the baffle plates and the final product being as little as possible.

28. The apparatus of claim 27, wherein the trailing edge of each baffle plate is provided with a flap which is easily displaced by contact with the final product as it is transported.

29. The apparatus of claim 28, wherein the flap is formed of the same material as the baffle plate and is attached to the plate by a hinge permitting the flap to move relative to the baffle plate.

30. The apparatus of claim 22, wherein the baffle plates are positioned below and adjacent the final product as it is transported through the thermal exchange means.

31. The apparatus of claim 24, wherein the baffle plates are corrugated to impart greater turbulence and offer increased area for gas contact.

32. The apparatus of claim 24, wherein the thermal exchange means includes a suitable housing in order to ensure flow of gas over and between the baffle plates.

33. The apparatus of claim 24, wherein the thermal exchange includes a guide means which is provided adjacent an outlet of the thermal exchange means and which is configured to gather and funnel heated gas toward the outlet.

34. The apparatus of claim 32, wherein the guide means takes the form of a plate which extends across the height of the thermal exchange means and which is inclined in the opposite direction to the baffle plates.
### INTERNATIONAL SEARCH REPORT

**INTERNATIONAL APPLICATION No.**

**PCT/AU2004/000837**

**A. CLASSIFICATION OF SUBJECT MATTER**

Int. Cl. 7: F27D 13/00, 15/02, 17/00, C22B 5/12, 23/00

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)

REFER ELECTRONIC DATABASE CONSULTED

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

Electronic database consulted during the international search (name of database and, where practicable, search terms used)

DWPI, IPC: F27D 13/00, 15/02, 17/00, C22B 5/12, 23/00 and COOL+, EXCHANGE+

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<td>X</td>
<td>GB 16275 A (ALBERT HIOORT) 11 July 1912 whole document</td>
<td>1, 3, 6, 8, 22, 23</td>
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<td></td>
<td>FR 2373612 A [INSTITUT DE RECHERCHES DE LA SIDERURGIE FRANÇAISE (IRSID)] 7 July 1978</td>
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<tr>
<td>X</td>
<td>page 2, lines 3 to 24, page 5, line 26 to page 6, line 19 and fig. 3</td>
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<td>A</td>
<td>US 5730775 A (MEISSNER et al.) 24 March 1998 whole document</td>
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<td>US 6482351 B (KAMIKAWA et al.) 19 November 2002 whole document</td>
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[ ] Further documents are listed in the continuation of Box C  [X] See patent family annex

- "A" Special categories of cited documents:
  - "A" document defining the general state of the art which is not considered to be of particular relevance
  - "E" earlier application or patent but published on or after the international filing date
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  - "O" document referring to an oral disclosure, use, exhibition or other means
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- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

**Date of the actual completion of the international search**

13 August 2004

**Date of mailing of the international search report**

2 3 Aug 2004

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Form PCT/ISA/210 (second sheet) (January 2004)
This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX