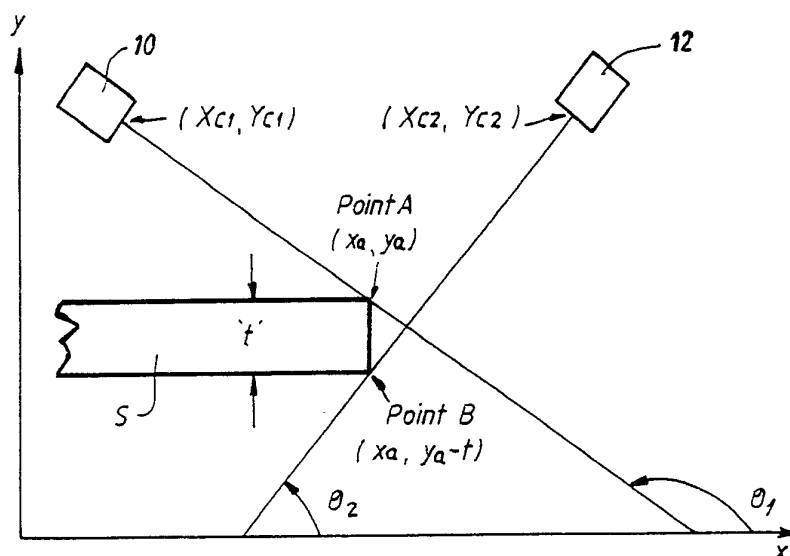




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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| <p>(51) International Patent Classification⁴ : G01B 11/02, 11/08, B21C 51/00</p> | <p>A1</p> | <p>(11) International Publication Number: WO 88/ 01366 (43) International Publication Date: 25 February 1988 (25.02.88)</p> |
| <p>(21) International Application Number: PCT/AU87/00237 (22) International Filing Date: 27 July 1987 (27.07.87) (31) Priority Application Number: PH 7429 (32) Priority Date: 13 August 1986 (13.08.86) (33) Priority Country: AU</p> <p>(71) Applicant (for all designated States except US): THE BROKEN HILL PROPRIETARY COMPANY LIMITED [AU/AU]; B.H.P. House, 140 William Street, Melbourne, VIC 3000 (AU).</p> <p>(72) Inventors; and (75) Inventors/Applicants (for US only) : VAN HOEK, Hendrik, Charles [AU/AU]; 17 Wolf Street, Wantirna South, VIC 3152 (AU). WILLIAMS, Daryl, Noel [AU/AU]; 4 Taylor Court, Mount Waverley, VIC 3149 (AU).</p> | | <p>(74) Agent: CLEMENT HACK AND COMPANY; 601 St. Kilda Road, Melbourne, VIC 3004 (AU).</p> <p>(81) Designated States: AT (European patent), AU, BE (European patent), CH (European patent), DE (European patent), FR (European patent), GB (European patent), IT (European patent), JP, KR, LU (European patent), NL (European patent), SE (European patent), US.</p> <p>Published With international search report.</p> |

(54) Title: DÉTERMINING A DIMENSION OF AN ARTICLE



(57) Abstract

At least two cameras (10, 12) view two points (A, B) displaced by a known distance on an article (S). Using a known relationship between the two points (A, B) and the known position of cameras (10, 12) in space the location of the viewed points (A, B) in space are determined by calculation. Similarly the co-ordinates of other points on to article (S) are determined and hence dimensions such as width are determined.

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DETERMINING A DIMENSION OF AN ARTICLE

5

This invention relates to a method and apparatus for determining a dimension of an article such as the width or thickness of a plate or slab produced in a steel mill.

The invention may be said to reside in a method of
10 determining a dimension of an article, said method comprising the steps of viewing two points on the article with a sensing means, said two points being displaced by a known relationship, using the known relationship and the two viewed points to determine the location in space of one of said

points, and using the absolute location in space of another point determining the dimension of said article between said one point and said another point.

The invention may also be said to reside in an
5 apparatus for determining the dimension of an article, said apparatus comprising two sensing means each sensing one of two points on said article which are displaced by a known relationship, processing means for resolving the location in space of one of said two points and for determining the
10 distance between said one point and another point to enable a dimension of an article to be determined.

The said another point could be a known fixed point. However according to the preferred embodiments of the invention, the said another point is determined by viewing a
15 second pair of points including said another point the second pair of points being displaced by a further known relationship and determining the location in space of said another point from the viewed second pair of points and the further known relationship.

20 Preferably two sensing means view one each of the first two points and a further two sensing means view one each of the second two points. However only two sensing means could be used with one sensing means viewing one of the first two points and one of the second two points and the other
25 sensing means viewing the other of the first two points and the other of the second two points. In one embodiment of the invention the two pair of points which are displaced by a known distance can comprise points at the edges of a generally rectangular cross-sectioned article and in a second embodiment
30 the pairs of points can be points on an arc of a circle of a curved portion of the article.

Preferred embodiment of the invention will be described with reference to the accompanying drawings in which:

35 Figure 1 is a view of the first embodiment of the invention;

Figure 2 is a view of a second embodiment of the invention;

Figure 3 shows a third embodiment; and

Figure 4 shows one preferred manner of making
5 calculations according to the preferred embodiment.

With reference to Figure 1 a system is shown for determining the width W of a plate or slab of generally rectangular cross-section. The system comprises a first sensor means comprising a first linescan camera 10 and a
10 second linescan camera 12. Located at the other end of the plate or slab S is a second pair of linescan cameras (which are not shown). The linescan camera 10 views the point A at the top edge of the slab S and the linescan camera 12 views the point B at the bottom edge of the slab S . The slab S
15 could be hot enough to provide illumination for the cameras 10 and 12 or a back light (not shown) could be utilized.

The points A and B are displaced by the known thickness T of the slab S and are assumed to be vertically displaced one above the other. Since the thickness T of the
20 slab S is known and the points A and B are vertically displaced, a computing apparatus (not shown) coupled to the linescan cameras 10 and 12 can resolve the location of point A in space from the images in the cameras. The other pair of linescan cameras (not shown) at the other end of the slab S
25 resolve the location of a corresponding point A at the top edge of the slab in a similar manner. Since the location in space of two points at the edges of the slab S are known the distance between the two points can be determined by simple geometry to enable the width W of the slab to be determined.

30 A second embodiment of the invention is shown in Figure 2 in which linescan cameras 20 and 22 view a slab S which has rounded corners C . As shown the points A and B viewed by the cameras 20 and 22 are points on the arc of a circle C where the arc of the circle C meets the substantially
35 flat top and side surfaces of the slab S . The corner radius of the curved portion C is a function of rolling practice and is predictable. Therefore the corner radius of the section C

is known and the points A and B are displaced by a known distance on the arc of the curved section C. Since the points A and B are displaced by a known distance, the location in space of the point A or the point B can be resolved from the 5 images in the linescan cameras 20 and 22.

Another sensing means which can comprise another pair of linescan cameras or a further linescan camera in combination with one of the cameras 20 or 22 can inspect points on another corner radius of the slab S so that another 10 point at that corner can be resolved in space to enable a dimension of the slab S to be determined. That dimension could be the width W of the slab or the thickness T of the slab depending on which other corner of the slab is viewed.

The arrangement illustrated in Figure 2 could also 15 be used to measure an unknown diameter of a round article by use of the knowledge that two edges seen by each of the cameras are points on a circle.

In Figure 3 a further embodiment is shown in which only two cameras are used. One camera 50 views one point A of 20 a pair of points A and B displaced by a known distance and also view one point B' of a second pair of points A' and B' displaced by a known distance. The second camera 52 views the remaining two points B and A'. The location in space of one of each pair of points A and B and A' and B' is determined in 25 the same manner as described above to enable a dimension of the article to be obtained.

One manner of calculating the location of points A and B will be described with reference to Figure 4. In Figure 4 X_c , Y_c , A, B, P, K are calibration constants determined in 30 the manner set forth in our Australian Patent Application No. 41143/85 which is hereby incorporated by this reference. M is the image location or camera pixel number corresponding to an edge seen on the object. From the above application we having the following relationship which locates the position of an 35 object coordinate in terms of distances x_d and y_d from the principal point of the lens.

M

$$x_d = Ky_d (B+AM - P) \quad \dots(i)$$

using equation (i) the coordinates of an object point (x_o, y_o) in a cartesian reference frame as above are related as

5 follows:

$$\frac{y_c - y_o}{x_c - x_o} = \tan \theta_o = K \left(\frac{M}{B+AM} - P \right) \quad \dots(ii)$$

10 θ_o is the angle of a ray drawn from principal point of the camera lens to the object coordinate with respect to the X axis. From the diagram above the following relationships for the object edge coordinates A and B can be derived with respect to the origin of the cartesian reference frame.

$$15 \quad y_a = \tan \theta_1 (x_a - X_{c1}) + Y_{c1} \quad \dots(iii)$$

$$y_a - t = \tan \theta_2 (x_a - X_{c2}) + Y_{c2} \quad \dots(iv)$$

Combining (iii) and (iv) to eliminate y_a gives the location x_a in terms of calibration constants, plate thickness and measure variables.

$$20 \quad x_a = \frac{X_{c2} \tan \theta_2 - X_{c1} \tan \theta_1 + Y_{c1} - Y_{c2} - t}{\tan \theta_2 - \tan \theta_1} \quad \dots(v)$$

Since modification within the spirit and scope of the invention may readily be effected by persons skilled
 25 within the art, it is to be understood that this invention is not limited to the particular embodiment described by way of example hereinabove.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method of determining a dimension of an article, said method comprising the steps of viewing two points on the article with a sensing means, said two points being displaced by a known relationship, characterized by using the known relationship and the two viewed points to determine the location in space of one of said points, and using the absolute location in space of another point determining the dimension of said article between said one point and said another point.
2. The method of Claim 1, wherein the said another point is determined by viewing a second pair of points including said another point the second pair of points being displaced by a further known relationship and determining the location in space of said another point from the viewed second pair of points and the further known relationship.
3. The method of Claim 2, wherein two sensing means view one each of the first two points and a further two sensing means view one each of the second two points.
4. The method of Claim 2, wherein two sensing means are used with one sensing means viewing one of the first two points and one of the second two points and the other sensing means viewing the other of the first two points and the other of the second two points.
5. The method of Claim 1, wherein the two points comprise points at the edges of a generally rectangular cross-sectioned article and the known relationship is the known thickness of the article.
6. The method of Claim 1, wherein the two points are on an arc of a circle of a curved portion of the article and the known relationship is the arc of the circle.
7. The method of Claim 1, wherein the location of the said two points (x_a, Y_a) ; (x_a, Y_{a-b}) are derived from the following equations wherein, x_c, Y_c are calibration constants, θ is the angle of a ray drawn from principal point of the

sensing means to the object coordinate with respect to the X axis, and the subscript 1, 2 denote the respective sensing means;

$$Y_a = \tan \theta_1 (x_a - X_{c1}) + Y_{c1} \quad \dots \text{(iii)}$$

$$Y_a - t = \tan \theta_2 (x_a - X_{c2}) + Y_{c2} \quad \dots \text{(iv)}$$

$$x_a = \frac{X_{c2} \tan \theta_2 - X_{c1} \tan \theta_1 + Y_{c1} - Y_{c2} - t}{\tan \theta_2 - \tan \theta_1} \quad \dots \text{(v)}$$

8. Apparatus for determining the dimension of an article, said apparatus comprising two sensing means each sensing one of two points on said article which are displaced by a known relationship, characterized by processing means for resolving the location in space of one of said two points and for determining the distance between said one point and another point to enable a dimension of an article to be determined.

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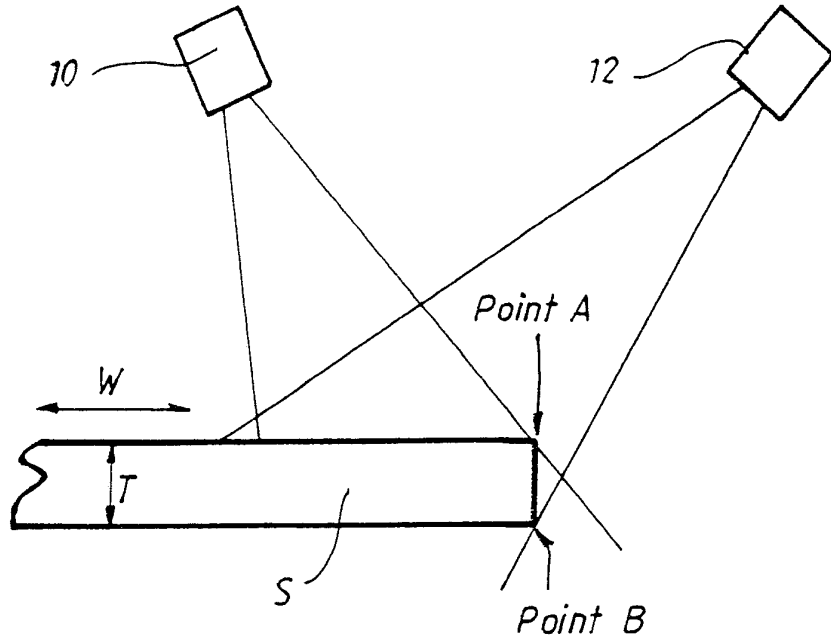


FIG. 1.

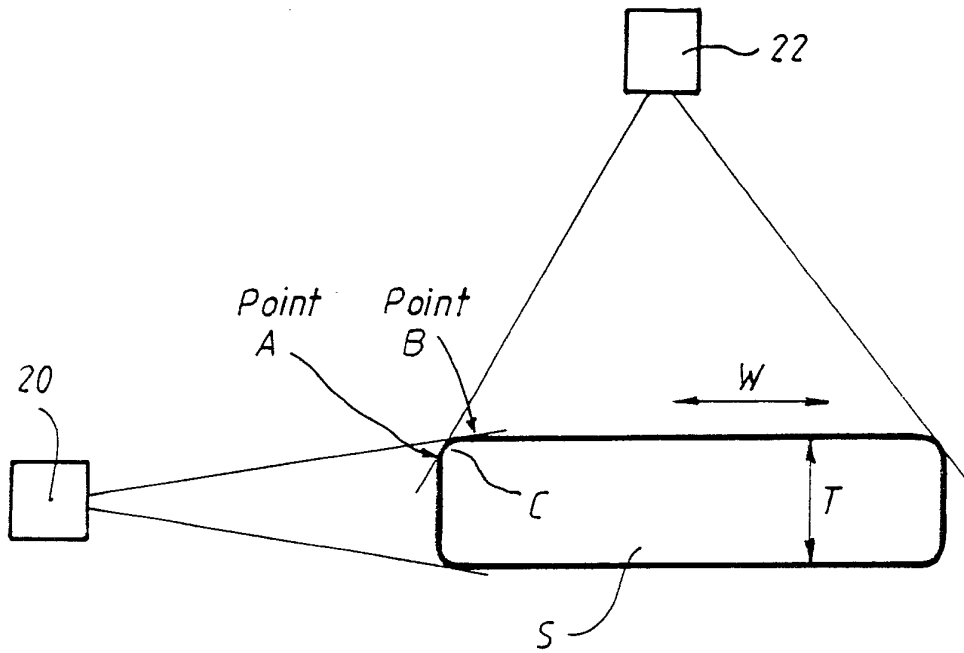


FIG. 2.

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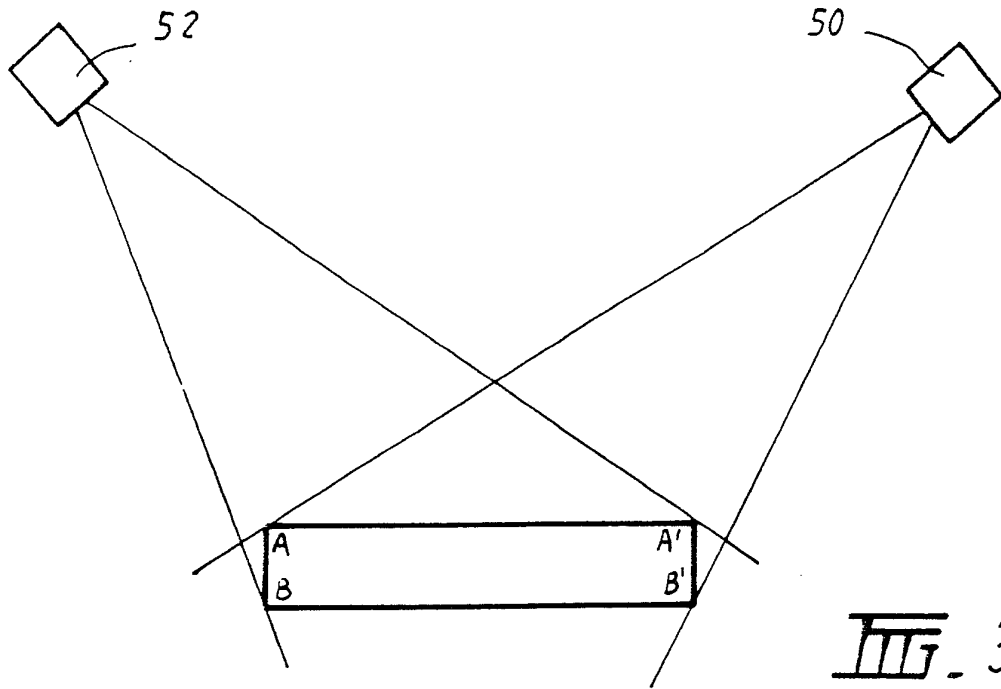


FIG. 3.

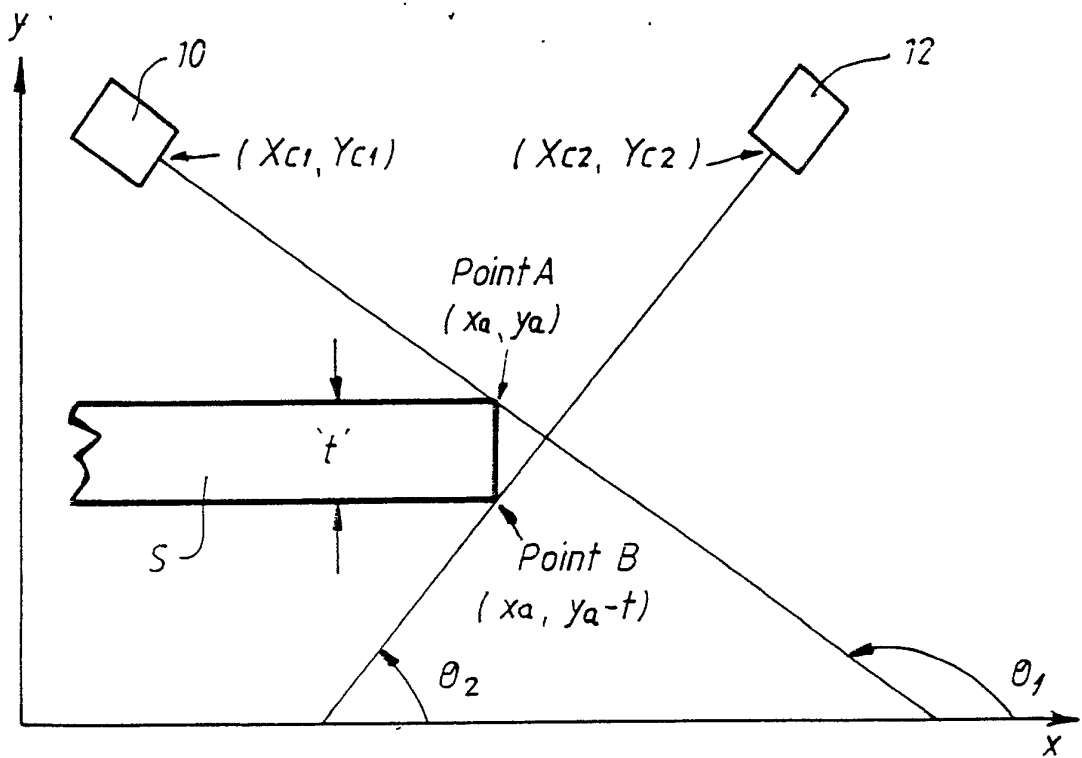


FIG. 4.

INTERNATIONAL SEARCH REPORT

International Application No PCT/AU 87/00237

| | | | | |
|--|--|---|--|--|
| I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ³ According to International Patent Classification (IPC) or to both National Classification and IPC Int. Cl. ⁴ G01B 11/02, 11/08, B21C 51/00 | | | | |
| II. FIELDS SEARCHED Minimum Documentation Searched ⁷ | | | | |
| Classification System | Classification Symbols | | | |
| IPC | G01B 11/02, 11/03, 11/04, 11/06, 11/08, 11/10, 11/24 | | | |
| Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸ | | | | |
| AU : IPC as above Engineering Index | | | | |
| III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹ | | | | |
| Category ¹⁰ | Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹² | Relevant to Claim No. ¹³ | | |
| X | GB,A, 2064102 (EUROPEAN ELECTRONIC SYSTEMS LTD) 10 June 1981 (10.06.81) | (1,8) | | |
| X | GB,A, 2072833 (EUROPEAN ELECTRONIC SYSTEMS LTD) 7 October 1981 (07.10.81) | (1,8) | | |
| X | WO,A, 85/04245 (THE BROKEN HILL PROPRIETARY COMPANY LIMITED) 26 September 1985 (26.09.85) | (1-5,8) | | |
| A | AU,B, 82260/82 (547436) (N.V. PHILIPS GLOEILAMPENFABRIEKEN) 7 October 1982 (07.10.82) | | | |
| <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; vertical-align: top; padding: 5px;"> ¹⁴ * Special categories of cited documents: 14 "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed </td> <td style="width: 50%; vertical-align: top; padding: 5px;"> "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 "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. "Z" document member of the same patent family </td> </tr> </table> | | | ¹⁴ * Special categories of cited documents: 14 "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed | "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 "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. "Z" document member of the same patent family |
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| IV. CERTIFICATION | | | | |
| Date of the Actual Completion of the International Search 15 October 1987 (15.10.87) | | Date of Mailing of this International Search Report (06.11.87) 6 NOVEMBER 1987 | | |
| International Searching Authority Australian Patent Office | | Signature of Authorized Officer <i>John Thomson</i> J.W. THOMSON | | |

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON
INTERNATIONAL APPLICATION NO. PCT/AU 87/00237

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.

| Patent Document Cited in Search Report | Patent Family Members | | | |
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| | JP 56097812 | JP 61221610 | US 4490617 | |
| | US 4499383 | US 4670659 | EP 94522 | |
| | GB 2072333 | GB 2055585 | GB 2072833 | |
| | CA 1150003 | EP 24126 | JP 56057446 | |
| | US 4315337 | | | |
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| WO 8504245 | AU 41143/85 | EP 174961 | ZA 8501768 | |
| <hr/> | | | | |
| AU 82260/82 | CA 1194178 | EP 63830 | ES 511051 | |
| | ES 8307404 | JP 57178101 | NL 8101669 | |
| | US 4425043 | | | |

END OF ANNEX