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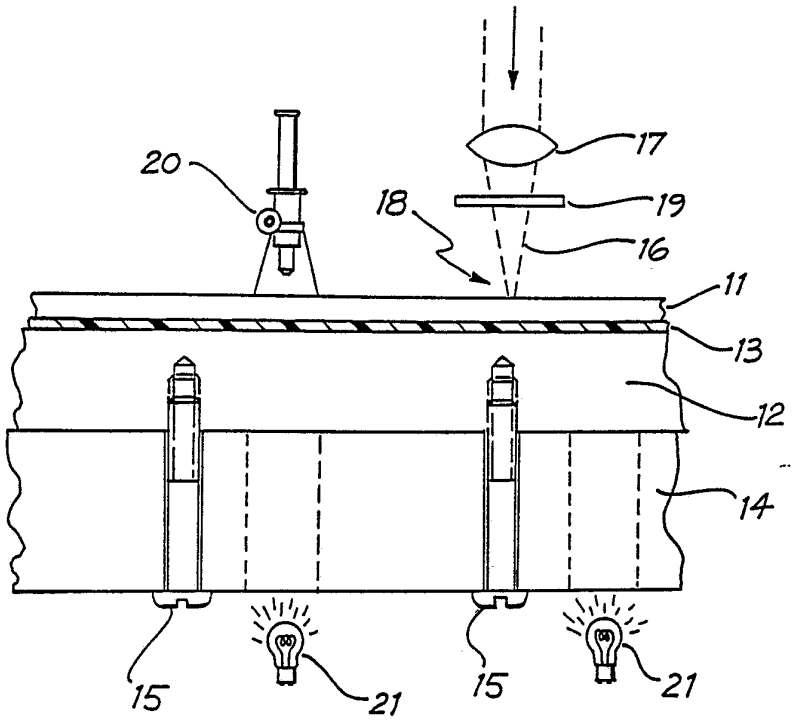
(54) Title: MANUFACTURE OF FINELY PERFORATED SHEET MATERIAL



(57) Abstract

A method of perforating a sheet material (11) comprising removably supporting the sheet material (11) on a support surface of a support body (12), exposing the sheet material to a laser beam (16) to form perforations in the sheet material (11) and removing the resultant perforated sheet material (11) from the support body (12). The support surface has a low reflectivity to the laser beam such that the geometry of the perforations is not significantly affected by reflected radiation.

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MANUFACTURE OF FINELY PERFORATED SHEET MATERIAL

BACKGROUND ART

This invention relates to the production of finely perforated sheets, for example screens or sieves used in centrifugal separators or filters. It includes the manufacture of sheet materials in which many fine perforations are involved, particularly if one side of the sheet as perforated is required to be smooth and the lips of the perforation at that side are required to be fairly sharp. For example, the invention has applications to the production of separating screens for use in so-called centrifugals used in sugar production for the separation of sugar crystals from massecuite sugar syrup, and will be described here in that context. It is to be understood, however, that the invention is in no way limited to that particular application. Other applications include sieve bend screens used in the food processing and mineral processing industries.

A screen typical of those presently employed in the sugar industry is formed from a number of sections each in the shape of a segment of an annulus, which together form a frusto-conical screen when supported within the centrifugal by means of a supporting basket or mesh. The screens are between 200 and 350 microns thick, and are conventionally formed by the electrodeposition of nickel with the use of a metal matrix master to define the slots through which the molasses passes from the centrifugal. These slots are typically 60 microns wide and 2000 microns long on the working side of the screen, and have sides which taper outwardly to larger dimensions on the outer side of the screen from which the molasses exits, to reduce the incidence of blockage of the slots by sugar crystals.

The slots are distributed uniformly over the surface of the screen, and are provided in various spacings to give open areas of between 6% and 15% of the area of the working side of the screen. The total area of such a screen is typically 1.2m for which an open area of 8%

requires 800,000 slots. In the case of screens presently employed a layer of chromium 15 to 20 microns thick is applied to provide a surface which has sufficient hardness and resistance to corrosion.

The useful life of such screens is limited by the gradual enlargement of the slots which occurs due to corrosion and erosion. The principle mechanism involved has been identified as arising from cracks in the chromium coating, which allow the hot molasses into regions between the chromium and the nickel. This leads to galvanic corrosion, eventually resulting in pitting of the nickel and flaking of the chromium. Once the softer nickel is exposed, it erodes or corrodes quickly, and the slot width increases. Increasing slot width significantly decreases the separation efficiency of the screen, which eventually must be replaced. The useful working life of such screens in continous centrifugals may be approximately six weeks.

The tensile strength of these screens must be sufficient to avoid stretching of the screen and its deformation into the gaps in the supporting basket. Such deformation may cause an increase in the size of the slots, and will also create resistance to the flow of material along the working surface of the screen.

It is important that the inner or working surface of the screen should be smooth in the immediate vicinity of the slots, and this must be taken into account in the choice of production method.

As mentioned, such screens or other sheet materials with fine perforations may be produced by an electrodeposition technique. Alternative techniques include mechanical punching, chemical etching (also known as photochemical machining), electrochemical machining, electrodischarge machining, and the use of focussed electron beams or laser beams. The most appropriate method for a particular application depends on many complex factors, but in the context of the present invention, it is significant that the use of a laser has some generally-accepted advantages. The perforation of

sheet materials by laser beams is a common practice in manufacturing industries throughout the world. Advantages of this approach include the ability to form very small perforations (holes with diameters of 60 microns are not uncommon), the good compatibility with computer-numerical-control (CNC) equipment for moving the workpiece sheet or the beam, the lack of tool wear, and the applicability to a wide range of materials (both metallic and non-metallic). The use of a laser enables perforations with a larger ratio of depth to width than those practicable with chemical etching, and consequently the use of a laser is not restricted to the production of very thin perforated sheets.

However, lasers have not been widely used to produce sheet materials in which a large number of fine perforations are required. Some screens or products similar to screens which have involved a laser manufacturing technique have been reported. The present invention involves a manufacturing technique which affords perforations of improved quality to be produced, and which enables a very high rate of producing such perforations. Particularly in the case of thin sheet materials (e.g. steel less than 1mm thick) it enables very severe problems usually associated with the use of a laser perforation technique to be overcome. These problems will become evident in the description below.

SUMMARY OF THE INVENTION

An object of the present invention is therefore to provide a method which enables such screens to be made from materials which combine adequate strength and hardness with corrosion resistance, such as stainless steel or titanium. Stainless steel cannot be electrodeposited, and electrodeposition of titanium is expensive, so a method has been sought which will enable the perforations to be produced in a sheet of the material by some form of cutting, drilling or punching. By the use of the techniques of the present invention,

laser drilling or laser cutting may be used for this purpose.

A major problem to be overcome in the successful use of laser drilling and cutting for the production of perforations having the geometry described above and traditional for fugal screens is the achievement of adequate perforation quality, often while working with an extremely thin workpiece. In the case of sugar screens, the screen must be thin, both in order that it will fit into the fugal, and in order that the depth of the slots will not be great enough to produce unacceptable drag as the molasses flows through. It is therefore desirable that the thickness of the material used for manufacturing the screen sections for sugar screens be in the region of 200-350 microns.

Such a thin workpiece must be supported during the laser drilling. In the practice of the present invention, the screen sections are supported on a support body for which the supporting surface has a low reflectivity to the laser beam. In this way the screen section is continuously supported without the sharp-edged and smooth character of the perforation on the beam-exit side of the screen section being marred by reflected radiation.

Thus, in one form, the present invention provides a method of perforating a sheet material comprising:

removably supporting said sheet material on a support surface of a support body;

exposing said sheet material to a laser beam to form perforations in said sheet material; and

removing the resultant perforated sheet material from said support body,

wherein said support surface of the support body has a reflectivity of less than about 20% to said laser beam. Preferably, the supporting surface of the support body has a reflectivity of less than about 10% to the laser beam.

In another form of the present invention, the reflectivity of the supporting surface to the laser beam is sufficiently low to prevent the perforation geometry

being significantly affected by reflected radiation.

The material of the support body preferably has a low absorption coefficient for the laser beam employed to minimize the rise in temperature of the material. The material of the support body may be substantially transparent to the laser beam, with the 0.1mm thickness of the support body adjacent to the supporting surface absorbing less than about 10% of the laser beam. If a highly absorptive material is used problems may thus arise from the consequent heating and perhaps melting of the lips of the perforation by conduction from the support body, or the loss of support due to local vaporization or melting of the support body. A highly absorbing material can of course be used where these disadvantages are tolerated or overcome.

The support body should present a firm supporting surface, and should preferably be compatible with adhesives which may be used to adhere the screen section to it, as described below.

In a perferred form of the invention, the support body is also substantially transparent to the visible spectrum to enable microscopic examination of the perforations during production.

A suitable material has been found to be an acrylic resin, such as polymethylmethacrylate, which is substantially transparent to many types of laser beams and which has a low reflectivity of approximately 4 to 6% to such laser beams and which if raised to a high temperature by conduction from the workpiece or by heated glue, will depolymerize and ablate cleanly rather than melt against and adhere to the workpiece. However, this invention is not restricted to the use of acrylic as the support body. Other suitable materials may include polycarbonates, glasses and quartz.

The means for supporting the sheet on the support body should preferably maintain the sheet in intimate contact with either the support body or with an adhesive or other filler substance. The filler substance may be provided at

the interface between the workpiece and the support body to eliminate voids and provide the intimate contact. The filler material should have a low reflectivity to the laser beam. Voids have been found to have a deleterious effect on the precision with which the perforations may be formed. The number of voids which is permissible will be dependent on the desired open area of the perforated sheet. It has been found that the intimate contact results in the molten and gaseous material produced by the incidence of the laser beam on the sheet being ejected in a direction away from the support body and that very little material resolidifies in the perforations or on the smooth face of the perforated sheet.

A further problem which must be overcome if satisfactory perforated sheets of thin material are to be manufactured by the method described herein, arises from the tendency of the workpiece sheet progressively to buckle as the making of successive perforations proceeds. The tendency of the sheet to buckle can be quite severe in many cases, particularly if the sheet is large and/or the areal density of perforations is high. Severe stresses can then be transferred to the support body during the process of perforating, tending to make the support body distort from its preferred flat form. Breakage of the support body may even be induced. The mechanism responsible for the tendency of the sheet to buckle is thought to be thermal expansion in the immediate vicinity of the slots. In any case it is found that, unless suitably prevented, the workpiece progressively distorts to an extent which exceeds the depth of focus which may practically be realized using a laser beam and which may also exceed the ability to control adequate depth of focus via automatically controlled tracking of the lens. (Such tracking by means of a sensor which provides information as to the position of the surface at any instant may be used in the practice of the present invention). It will be appreciated that the problem is exacerbated as the number of perforations for a given size of perforated

sheet is increased.

This problem for thin workpiece sheets is solved by another aspect of the invention in its preferred forms, whereby the workpiece is adhered to the support body by means of an adhesive which can be applied over the support body for the entire area that is to be perforated. The use of such an adhesive has the further advantage of taking up small irregularities in the surface of the support body, thereby increasing the flatness of the workpiece during production of the perforations.

Preferably, the adhesive should provide sufficient bond strength to prevent the sheet separating from the support body during the perforation process and have sufficient shear strength to prevent buckling. The adhesive should preferably either ablate cleanly leaving little or no residue in the perforations or be non-absorbing of the laser beam such that the adhesive is unaffected by the laser beam.

In the case of a stainless steel workpiece and an acrylic support body, a suitable adhesive has been found to be a high strength epoxy resin. For large workpiece sheets, two large fixed rollers with a suitably adjusted gap between them may be used to squeeze the sheet and the support body together.

The method of removal of the workpiece from the support body will of course depend on the materials used. In the case of stainless steel and acrylic with epoxy adhesive, it has been found that the perforated sheet and the support body may be separated by mechanical means simply by peeling or prising apart. Alternatively, the workpiece and the support body may be separated by heating or cooling to affect differential expansion or contraction. For example, it has been found that the use of liquid nitrogen is often advantageous in this respect. The epoxy may subsequently be removed from the stainless steel by immersing it in a tank of a mixture of toluene and ethanol, sold under the registered trade mark "Eposolve-70". The epoxy may be removed from the acrylic by

light sandpapering, and the acrylic may then be reused. It has been found that using these techniques, fugal screen sections can be manufactured which require no post-machining. Other methods suitable for supporting thicker workpieces on the support body may include clamping, suction and magnetic attachment.

BRIEF DESCRIPTION OF THE DRAWING

Preferred embodiments of the present invention shall now be further described with reference to the accompanying drawings, in which:

Figure 1 is a schematic cross-sectional representation of the method of the present invention; and

Figure 2 is an end view of a preferred method of removing the perforated sheet from the support body.

As shown in Figure 1, a sheet material (11) to be perforated is attached to a laser-transparent support body (12) by a layer of adhesive (13). The support body is in turn supported by an added support body (14) and the assembly is mounted on a work table (not shown) for controlled translation in the plane of the sheet material (11). The support body may be attached to the added support body by means of bolts (15) which pass through the added support body into threaded, blind holes in the support body.

The added support body need not be non-reflective of the laser beam and may be made of a metal such as aluminium as the laser beam (16) has its focal point near the sheet material and the beam diverges past the focal point. Providing a reasonable thickness of support body, for example 10mm, is interposed between the sheet material and the added support body, any radiation reflected from the added support body will be of quite low intensity. The added support body may not be required for applications where the tendency to buckle the sheet and the support body is low, or a thicker support body may be used to eliminate the need for the added support body. Alternative means of attaching the support body to the

added support body may be used.

A laser beam (16) is directed onto the sheet material by beam-focussing optics (17), and the sheet moves with respect to the beam in order to perforate the sheet. The material removed from the sheet by the laser beam is blown clear of the path of the laser beam by a gas jet (18) and the optics are protected by a sacrificial plate (19) which is substantially transparent to the laser beam and which is periodically replaced.

The support body and adhesive are preferably substantially transparent to visible wavelengths and the perforated sheet may be inspected by microscope (20), with a light source (21) being located below the support body.

As illustrated in Figure 2, the perforated sheet (11) may be simply removed from the support body (12) by inserting a knife edge (22) and peeling apart.

Screens having circular or rectangular perforations have been produced using the method of this invention, and other shapes may be used by suitable adjustment of the beam optics.

As has been discussed above, in the case of sugar fugal screens it is necessary that the slots taper outwardly from the working side of the screen to the molasses exit side, and it is therefore necessary to produce this taper with the laser beam. This can conveniently be achieved if the laser beam is directed at the molasses exit side of the screen material, and the laser beam parameters are adjusted appropriately using existing techniques.

While the invention has been described herein in detail in relation to a specific embodiment, it will be understood that this has been for the purposes of facilitating the description of the invention, and is not to be taken as implying that the principles of the invention are narrow in their application. Many variations in the techniques described above are possible within the scope of the invention as defined by the claims. For example, while the preferred material for the

screen is stainless steel of suitable composition, there may be applications where titanium or other metals, or non-metallic materials, may be preferred.

CLAIMS

1. A method of perforating a sheet material comprising:

removably supporting said sheet material on a supporting surface of a support body;

exposing said sheet material to a laser beam to form perforations in said sheet material; and

removing the resultant perforated sheet material from said support body,

wherein said supporting surface of the support body has a reflectivity of less than about 20% to said laser beam.

2. A method according to claim 1 wherein said supporting surface of the support body has a reflectivity of less than about 10% to the laser beam.

3. A method according to claim 1 wherein the absorption coefficient of the material of the support body for the laser beam employed is sufficiently low that the temperature of the support body adjacent the sheet material does not rise to a temperature sufficient to affect the edges of the perforations or sufficient to cause vapourization of the material of the support body.

4. A method according to claim 1 wherein a 0.1mm thickness of the support body adjacent to said supporting surface absorbs less than about 10% of the laser beam which is transmitted through the supporting surface.

5. A method according to claim 4 wherein said support body is also substantially transparent to visible wavelength radiation to enable visual examination of the perforated sheet.

6. A method according to claim 4 wherein said support body is formed from an acrylic resin, polycarbonate, glass or quartz.

7. A method according to claim 6 wherein said support body is formed from polymethylmethacrylate.

8. A method according to claim 1 wherein the sheet material and the support body are separated by a layer of

material which is capable of filling voids between the sheet material and the support body.

9. A method according to claim 8 wherein said sheet material is attached to said support body by a layer of adhesive material.

10. A method according to claim 9 wherein said adhesive material is an epoxy resin.

11. A method according to claim 9 wherein the perforated sheet material is removed from the support body by mechanical separation.

12. A method according to claim 9 wherein the perforated sheet material is removed from the support body by heating or cooling the support body and sheet material to affect differential expansion or contraction of the support body and the sheet material.

13. A method of perforating sheet material comprising:

removably supporting said sheet material on a supporting surface of a support body;

exposing said sheet material to a laser beam to form perforations in said sheet material; and

removing the resultant perforated sheet material from said support body,

wherein the reflectivity of said supporting surface of the support body to the laser beam is sufficiently low to prevent perforation geometry being significantly affected by reflected radiation.

14. A method according to claim 13 wherein the absorption coefficient of the material of the support body for the laser beam employed is sufficiently low that the temperature of the support body adjacent the sheet material does not rise to a temperature sufficient to affect the edges of the perforations or sufficient to cause vapourization of the material of the support body.

15. A method according to claim 13 wherein a 0.1mm thickness of the support body adjacent to said supporting surface absorbs less than about 10% of the laser beam which is transmitted through the supporting surface.

16. A method according to claim 15 wherein said support

body is also substantially transparent to visible wavelength radiation to enable visual examination of the perforated sheet.

17. A method according to claim 15 wherein said support body is formed from an acrylic resin, polycarbonate, glass or quartz.

18. A method according to claim 17 wherein said support body is formed from polymethylmethacrylate.

19. A method according to claim 13 wherein the sheet material and the support body are separated by a layer of material which is capable of filling voids between the sheet material and the support body.

20. A method according to claim 19 wherein said sheet material is attached to said support body by a layer of adhesive material.

21. A method according to claim 20 wherein said adhesive material is an epoxy resin.

22. A method according to claim 20 wherein the perforated sheet material is removed from the support body by mechanical separation.

23. A method according to claim 20 wherein the perforated sheet material is removed from the support body by heating or cooling the support body and sheet material to affect differential expansion or contraction of the support body and the sheet material.

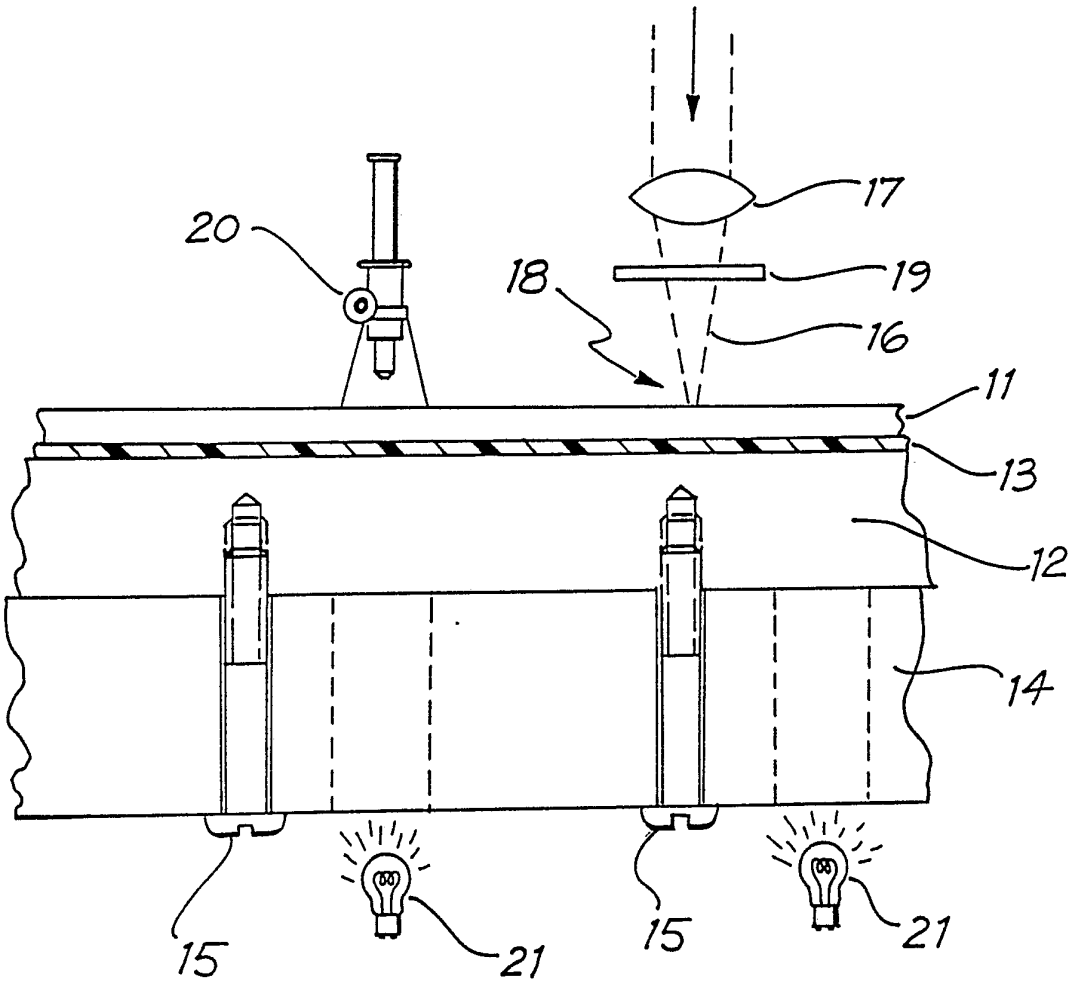

FIG. 1

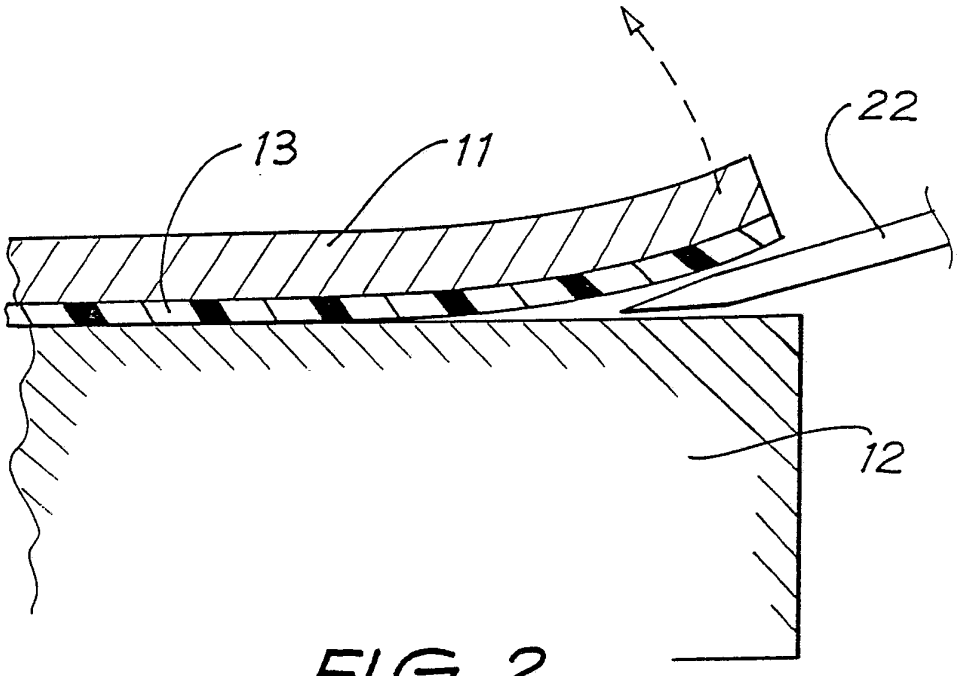

FIG. 2

INTERNATIONAL SEARCH REPORT

International Application No. PCT/AU 89/00336

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) 6

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.[4] B23K 26/10, 26/00

II. FIELDS SEARCHED

Minimum Documentation Searched 7

Classification System	Classification Symbols
IPC	B23K 26/10,26/00 B26F 1/30

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched 8

AU: IPC AS ABOVE

III. DOCUMENTS CONSIDERED TO BE RELEVANT 9

Category*	Citation of Document, 11 with indication, where appropriate, of the relevant passages 12	Relevant to Claim No 13
X	DE,A, 2423750 (TEXAS INSTRUMENTS DEUTSCHLAND GMBH) 27 NOVEMBER 975 (27.11.75)	(1-7, 13-18)
X	Patents Abstracts of Japan, M-609, page 140, JP,A, 62-40985 (NIPPEI TOYAMA CORP) 21 FEBRUARY 1987 (21.02.87)	(1-7, 13-18)
X	US,A, 3828159 (ZOOT) 6 AUGUST 1974 (06.08.74) particularly column 1 line 50 to column 2 line 2	(1-4, 13-16)
X	GB,A, 1235653 (NATIONAL RESEARCH DEVELOPMENT CORPORATION) 16 JUNE 1971 (16.06.71) particularly page 3 lines 111 to 117	(1,2,13)
	CONTINUED	

* Special categories of cited documents: 10

"A" document defining the general state of the art which is not considered to be of particular relevance

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"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.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
30 OCTOBER 1989 (30.10.89)	9 November 1989
International Searching Authority	**Signature of Authorized Officer**
Australian Patent Office	E KNOCK

Form PCT/ISA/210 (second sheet) (January 1985)

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

X	FR,A, 2414384 (DELORME) 10 AUGUST 1979 (10.08.79) particularly page 3 lines 28 to 36	(1,2,13)
X	US,A, 3981230 (LEE) 21 SEPTEMBER 1976 (21.09.76)	(1,2,13)
A	US,A, 3226527 (HARDING) 28 DECEMBER 1965 (28.12.65) including column 2 line 68 to column 3 line 37 and column 4 lines 29 to 32	
A	US,A, 4458133 (MACKEN) 3 JULY 1984 (03.07.84)	
A	CA,A, 1138936 (UNITED TECHNOLOGIES CORP) 4 JANUARY 1983 (04.01.83)	

V. [] OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE 1

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.[] Claim numbers ..., because they relate to subject matter not required to be searched by this Authority, namely:

2.[] Claim numbers .., because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3.[] Claim numbers ..., because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4 (a):

VI. [] OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING 2

This International Searching Authority found multiple inventions in this international application as follows:

1.[ ] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2.[ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.[ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4.[ ] As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

[] The additional search fees were accompanied by applicant's protest.

[] No protest accompanied the payment of additional search fees.

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON
INTERNATIONAL APPLICATION NO. PCT/AU 89/00336

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned internation 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		
DE 2423750			
GB 1235653	DE 2000846 NL 7000380	FR 2028091 SE 371952	GB 1235653 US 3612814
FR 2414384			
US 3226527			
US 3828159	BE 761671 FR 2075651 SE 376729	CH 523738 GB 1301611 US 3828159	DE 2101325 JP 50018639
US 3981230	DE 2544371 JP 51061378	FR 2286700	GB 1528451
US 4458133	CA 1194557 JP 58188594	DE 3314959	GB 2118885
CA 1138936			

END OF ANNEX