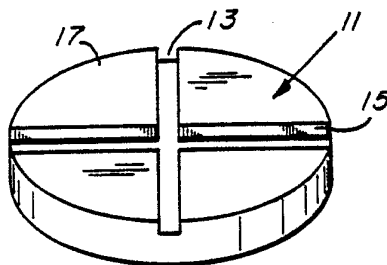




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁴ : F16C 37/00	A1	(11) International Publication Number: WO 87/ 07343 (43) International Publication Date: 3 December 1987 (03.12.87)
(21) International Application Number: PCT/US86/02321 (22) International Filing Date: 27 October 1986 (27.10.86) (31) Priority Application Number: 864,788 (32) Priority Date: 19 May 1986 (19.05.86) (33) Priority Country: US (71) Applicant: SMITH INTERNATIONAL, INC. [US/US]; 4490 Von Karman, Newport Beach, CA 92660 (US). (72) Inventors: McPHERSON, James, N. ; 2915 East Van Owen Street, Orange, CA 92667 (US). HALL, David, R. ; 738 East 268 North Street, Provo, UT 84604 (US). (74) Agent: GESS, Albin, H.; Price, Gess & Ubell, 4740 Von Karman, Ste. 100, Newport Beach, CA 92660 (US).	(81) Designated States: AT (European patent), BE (European patent), BR, CH (European patent), DE (European patent), FR (European patent), GB (European patent), IT (European patent), LU (European patent), NL (European patent), NO, SE (European patent). Published <i>With international search report.</i>	

(54) Title: COOLING NETWORKS FOR PCD BEARING SURFACES



(57) Abstract

Polycrystalline diamond wear surfaces (17) in bearing structures (11) are maintained at temperatures that prevent thermal degradation in spite of exceptionally high loads. This temperature control is accomplished by segmenting the diamond wear surface to provide interrupt channels (13, 15) through which the energy build-up at the diamond wear surface is maintained below the thermal degradation level. Cooling fluid may be caused to flow through the interrupt channels, the higher the velocity of fluid flow around the diamond bearing surface, the greater the cooling effect.

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COOLING NETWORKS FOR
PCD BEARING SURFACES

1. Field of the Invention

The subject invention relates to bearings and particularly to polycrystalline diamond bearings having dramatically increased load carrying capabilities.

2. Description of the Prior Art

Polycrystalline diamond (PCD) bearings have found application in oil drilling and other environments demanding high load carrying ability under extreme wear conditions. Diamond bearings have been constructed which have inserts comprising tungsten carbide discs with a polycrystalline diamond surface layer.

Polycrystalline diamond bearings in oil drilling applications have exhibited a useful but limited load carrying ability. Load carrying ability is typically measured in units of "PV", the pressure or unit load to which the bearing is subjected multiplied by its velocity. Quantitatively, "PV" is a unit of heat or energy. When the PV limit of the polycrystalline diamond bearings is reached, the bearings begin to degrade and ultimately disintegrate. Replacement of any bearing in a downhole environment is expensive because of the nature of the parts and the downtime involved. A bearing having high load carrying ability and a long life cycle has been earnestly pursued by the drilling industry and others.

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It is therefore an object of the invention to provide a bearing structure having hitherto unobtainable load carrying ability and longevity.

Another object of the invention is to extend the PV range within which PCD bearings can operate without exhibiting wear.

It is another object of the invention to provide enhanced cooling mechanisms for the PCD surface areas employed in bearings.

It is yet another object of the invention to provide bearings for oil drilling applications that have increased life and load bearing capacity in the drilling involvement.

Summary of The Invention

Those objects and the general purpose of the invention are accomplished by providing a diamond bearing construction that is maintained below its degradation temperature by a cooling mechanism that is convenient to the bearing application. The cooling mechanism utilized is directed towards removing the energy build-up generated at the surface of the diamond bearing as a result of the rubbing friction between the bearing surfaces. The energy build up at the surface is controlled by a mechanism that reduces the time periods of heat or energy build up between cooling. Some mechanisms that function to this end are an array of numerous small diamond pads combining to make up a bearing surface, diamond bearing segments with interrupt grooves formed at their peripheries, or solid diamond bearing surfaces with interrupt grooves or channels cut into the diamond surface. A

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fluid is advantageous in removing the energy build up (heat) from the surface of the diamond in any of the above mechanisms. An alternate mechanism for controlling the energy build-up on the surface of the diamond is to immerse the entire bearing in a cooling medium.

Brief Description of The Drawings

Other objects and many of the attendant advantages of this invention will be readily appreciated as the invention becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings in which like reference numerals designate like parts throughout the figures thereof and wherein:

Fig. 1 shows a perspective of a PCD insert according to a preferred embodiment of the invention;

Fig. 2 is a side view of a thrust bearing employing PCD inserts according to a preferred embodiment;

Fig. 3 is a perspective of the thrust bearing of Fig. 2;

Fig. 4 is a sectional view of a roller cone bearing including PCD inserts;

Fig. 5 is a graph of PV vs. wear;

Fig. 6 illustrates an arterial cooling fluid network;

Fig. 7 is a cross-section of the network of Fig. 6 taken along 7-7;

Fig. 8 illustrates a matrix cooling fluid network;

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Fig. 9 illustrates a directional cooling fluid network;

Fig. 10 illustrates a flow network in an annular surface;

5 Fig. 11 illustrates an array of PCD tiles creating a matrix network.

Description of The Preferred Embodiments

Background Discussion

10 It was been recognized that at some PV level, thermal degradation and graphitization of the PCD begins to occur, i.e. the PCD begins to return to the state of graphite from which it was originally formed. PCD diamond has a certain amount of Cobalt material in it. Cobalt has a thermal expansion coefficient that is ten times that of diamond. At 15 730 C the Cobalt has expanded to the point of causing the diamond to fracture. At 1200 C the diamond starts to graphatize. A procedure that discloses use of thermal degradation for the purpose of buffing diamond bearing surfaces is disclosed in a patent application entitled 20 Burnishing Diamond filed June 20, 1985, and having USSN 747,163.

It appears that energy build-up at the bearing surfaces (heat) is the primary contributor to the thermal degradation problem. It was discovered that by keeping the 25 diamond bearing surface below its degradation temperature regardless of the load, the amount of load the PCD bearings can accomodate without wear increases appreciably. It was

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surprising that this phenomena was true for exceptionally high loads (PV). The limiting factor appears to be the effectiveness of the surface energy controlling mechanism.

5 The build up of surface energy can be controlled by providing interrupt grooves in the diamond bearing surface and introducing cooling fluids into the surface area. This prevents thermal degradation, which includes graphitization, and resulting in a dramatic improvement in load carrying and wear characteristics. Various channel configurations are possible for introducing the fluid so as to optimize the energy dissipation effect in different environments and applications in which the bearings may be used.

10 Unlike other materials, PCD exhibits no appreciable wear until thermal degradation beings, leading to graphitization. By proper application of the principles of the invention, bearings accomodating heretofore unheard of loads without noticeable wear can be fabricated. PCD bearings fabricated with surface cooling means have performed at PV levels on the order of 16 million without noticeable wear. No bearings known to the inventors have achieved this performance. It appears that bearings accomodating even higher loads are quite possible.

Detailed Description Of Embodiments

20 A preferred embodiment of a PCD bearing insert 11 having interrupt grooves or channels 13, 15 through which cooling fluid flows is shown in Fig. 1. The grooves 13, 15 are preferably created in the PCD surface 17 by EDM

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(electrical discharge machining). Either wire EDM or plunge EDM may be used. They may also be created by laser cutting or other applicable methods such as molding, for example. For one application they are 1/32" wide by 1/32" deep.

5 Such PCD inserts may be used in an endless variety of bearing applications, for example in a cylindrical thrust bearing element (Fig. 2 and 3) or in a conical roller cone bearing element 16 (Fig. 4). The conical element 16 accomodates both thrust and radial forces, and bearings
10 accomodating either thrust or radial forces alone can be fabricated using inserts according to the preferred embodiment. The use of PCD inserts in thrust bearings is more specifically described in a patent application entitled Diamond Bearing and Manufacture Thereof, filed May 20, 1986,
15 and having USSN 865,159. The use of PCD inserts in roller cones is more specifically described in a patent application entitled Polycrystalline Diamond Bearing System for a Roller Cone Rock Bit, filed May 19, 1986, and having USSN 864,681, and patent application entitled Transition Layer
20 Polycrystalline Diamond Bearing, filed May 19, 1986, having USSN 864,683.

 In a thrust bearing such as shown in Fig. 2 and 3, planar faced bearing inserts may be brazed into equally spaced wells arrayed on a circle on a cylindrical steel mounting
25 member 14. Alternatively, such inserts may be press-fit into through holes in an annular steel mounting ring. The mounting

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ring and inserts together with an annular brazing ring may then be registered in place on a steel mounting member and the assembly heated to attach the inserts and ring to the mounting member. In a downhole oil drilling application, the fluid
5 used to cool the PCD in such a thrust bearing is the drilling fluid.

Tests results of a thrust bearing such as illustrated in Figs. 2 and 3 using inserts .529 inches in diameter are shown in Fig. 5. Fig. 5 maps bearing wear rate along the
10 vertical axis and generated heat (PV) in (lbs./sq.in.) times (ft./min.) along the horizontal axis. The design load capability without regard to surface energy control is illustrated by dashed line 22 at PV = 3.5 million. When the height h (Fig. 2) of the PCD surface above its mounting
15 surface 21 is set at 1/8 inch and the space between the inserts w is set to provide a cooling fluid flow velocity of approximately 25 ft./second past and around the inserts, wear begins to occur at about 6 million PV as shown at 23 in Fig. 5. When the height h is set at 1/16 inch and the fluid flow
20 velocity is at approximately 50 ft./second, wear does not begin to occur until about PV = 8 million, as shown at 24.

When interrupt grooves 13, 15 are added to the inserts 11 at h = 1/32 inches and velocity equals 50 to 100 ft./second, a dramatic improvement occurs in that the bearing
25 may be operated out to PV equals 5 to 16 million without any noticeable wear, as shown at 25. It is believed that even higher PV may be obtained with the interrupt grooves 13, 15.

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The actual limit of this structure has not been determined because the test equipment available to the inventors cannot create PV higher than 16 million.

The foregoing improvement in wear capability has been verified in both high velocity, low pressure and high pressure low velocity embodiments. A downhole motor thrust bearing such as illustrated in Fig. 2 and 3 has a relatively high velocity, low pressure application. A roller cone such as shown in Fig. 4 has a high pressure, low velocity application.

The discoveries set forth above suggest that enhanced fragmentation of the PCD surface area through more intricate structures can achieve even greater wear capability, possibly up to 100 million PV or more without wear. Embodiments of more intricate structures are illustrated in Figs. 6-11.

Figs. 6 and 7 shows a structure comprising successively smaller grooves or channels, 33, 35, 37 referenced as arteries 33, veins 35, and capillaries 37. Fig. 8 illustrates a matrix structure having channels 39 crossing channels 40. Fig. 9 shows a structure designed to promote surface energy control by using the relative motion of the insert 46 with respect to the fluid as a pump. When operating in a pool of fluid, a network which acts as a pump to pull fluid through the network, is highly desirable.

Fig. 10 illustrates flow channels 41 created in an annular PCD surface layer 43. Fluid flow-up through the central cylindrical opening 44 of the annulus (perpendicular to the plane of the paper in Fig. 10) and out through the flow channels 41 provides energy control of the PCD surface.

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Fig. 11 shows an embodiment employing PCD "tiles" 45 which have bevelled or otherwise descending surfaces 51 at their interior edges 49, 51, 53. When the tiles are placed adjacent one another, a matrix grooved PCD surface results.

5 A variety of structures, including modifications, extensions or adaptations of those just disclosed, will be evident to those skilled in the art from the foregoing disclosure. Therefore, it is to be understood that, within the scope of the appended claims, the invention may be
10 practiced other than as specifically described herein.

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WHAT IS CLAIMED IS:

1. An improved bearing structure comprising:
a diamond bearing surface; and
cooling fluid flow channel means in said diamond
5 bearing surface.
2. The bearing structure of claim 1 wherein said diamond
is polycrystalline diamond (PCD).
3. The bearing structure of claim 1 or 2 wherein said
fluid flow channel means comprises at least one flow groove.
- 10 4. The bearing structure of claim 1 or 2 wherein said
fluid flow channel means comprises first and second grooves
disposed perpendicularly to one another.
5. The bearing structure of claim 1 or 2 wherein said
fluid flow channel means comprises a matrix of flow grooves.
- 15 6. The bearing structure of claim 1 or 2 wherein said
fluid flow channel means comprises a plurality of branching
flow grooves of descending fluid carrying capability.
7. The bearing structure of claim 1 or 2 wherein said
flow channel means further acts to draw cooling fluid through
20 said surface.
8. An improved bearing structure comprising:
a polycrystalline diamond bearing surface; and
means for preventing thermal degradation of said
surface in the presence of heat build-up resulting
25 from high bearing loads.
9. The structure of claim 8 wherein said means comprises
cooling fluid flow groove means in said surface.

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11. An improved bearing structure comprising:
a PCD bearing surface area; and
a cooling fluid network in said surface area.

12. A bearing structure comprising:

5 a plurality of bearing inserts each having a
bearing face;

means for conducting fluid flow through a
plurality of said faces; and

10 means for mounting said bearing inserts in
bearing position.

13. The bearing structure of claim 12 wherein said
inserts comprise cylindrical inserts having a diamond face.

14. The bearing structure of claim 12 wherein said fluid
flow providing means includes a flow channel in each said
15 bearing face.

15. The bearing structure of claim 12 wherein said fluid
flow providing means comprises cross channels in each said
bearing face.

16. The bearing structure of claim 13 wherein said fluid
20 flow providing means comprises cross channels scribed into the
diamond faces of said inserts.

17. The bearing structure of claim 15 wherein said
channels are one-thirty second of an inch wide by one-thirty
second of an inch deep and wherein the bearing surface
25 provided by said face is one-thirty second to one-sixteenth
inch above the surface of said mounting means.

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18. The bearing structure of planar faces and claim 12, 13, 14, 15, 16, and 17 wherein said inserts are mounted by said mounting means such that their planar faces all lie in a common place.

5 19. The bearing structure of claims 13, 14, 15, 16, or 17 wherein said mounting means comprises a conically shaped bearing element.

20. A bearing structure comprising:

10 a plurality of cylindrical bearing inserts having planar diamond faces;

means for mounting said inserts in a circular array such that their faces lie substantially in a common plane; and

15 fluid flow channel means formed in each of a plurality of the faces of said inserts.

21. The bearing structure of claim 20 wherein said diamond is polycrystalline diamond.

22. A bearing comprising:

20 an array of a plurality PCD surfaced tiles; and descending surface means at the edges of said tiles for forming cooling grooves in said array.

23. A bearing comprising:

an annular planar PCD surface having a central cylindrical opening; and

25 flow channel means in said PCD surface for conducting fluid from said central cylindrical opening through said surface.

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24. An improved bearing structure, comprising:

a diamond bearing surface; and

means for maintaining the energy build-up on the surface of said diamond bearing below the thermal degradation level at high bearing loads.

25. The improved bearing structure of claim 24 wherein said diamond bearing surface comprises a plurality of individual segments having channels therebetween.

26. The improved bearing structure of claim 25 wherein said means for maintaining energy build-up comprises cooling fluid circulating in said channels at high velocity.

27. The improved bearing structure of claim 24 wherein said diamond bearing surface is segmented by channels cut into the diamond surface.

28. The improved bearing structure of claim 27 wherein said means for maintaining energy build-up comprises cooling fluid circulating in said channels at high velocity.

29. An improved bearing structure, comprising:

a diamond on diamond bearing interface; and

means for maintaining the energy build-up on the surface of said diamond bearing below its thermal degradation level at high PV values.

30. The improved bearing structure of claim 29 wherein the PV values exceed 8×10^6 (lbs./sq.in) (ft./min.)

31. The improved bearing structure of claim 31 wherein said mean for maintaining energy build-up comprises said bearing surfaces being a plurality of individual segments having channels therebetween.

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32. The improved bearing structure of claim 31 wherein said means for maintaining energy build-up further comprises cooling fluid circulating in said channels at high velocity.

33. The improved bearing structure of claim 31 wherein
5 said means for maintaining energy build-up comprises channels cut into the bearing surface creating or plurality of segments.

34. The improved bearing structure of claim 33 wherein
10 said means for mounting energy build-up further comprises cooling fluid circulating in said channels at high velocity.

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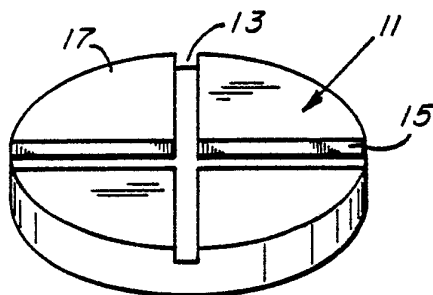


FIG. 1

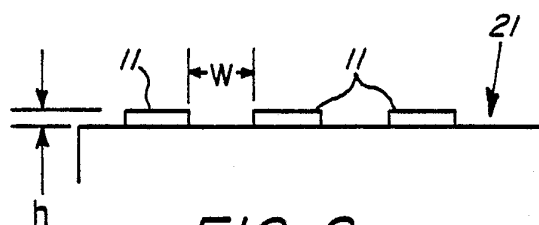


FIG. 2

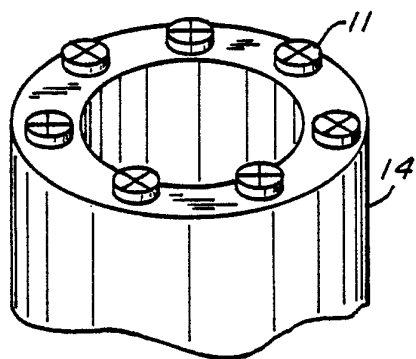


FIG. 3

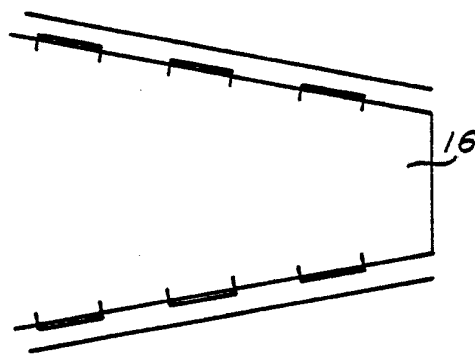


FIG. 4

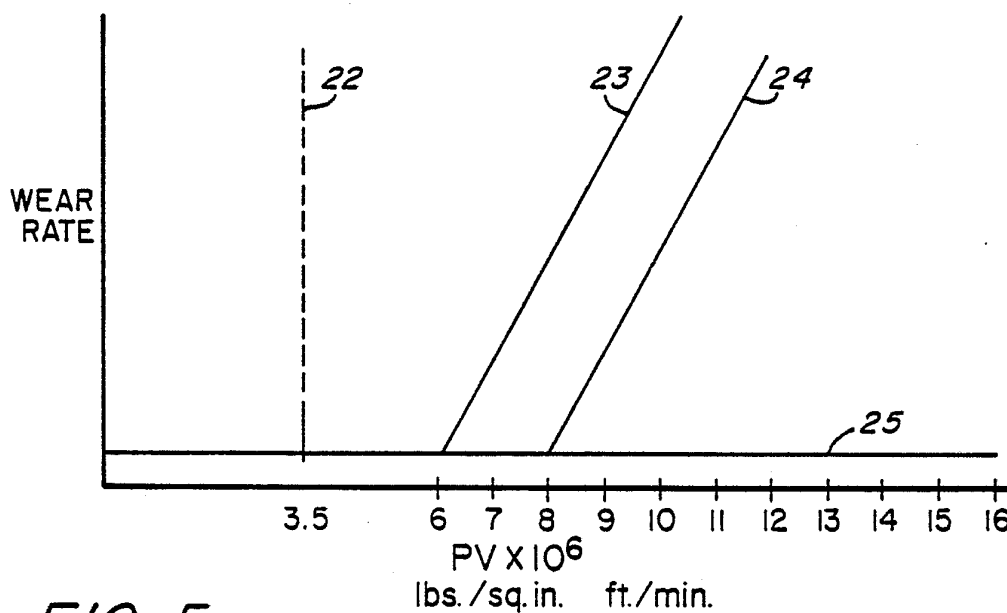


FIG. 5

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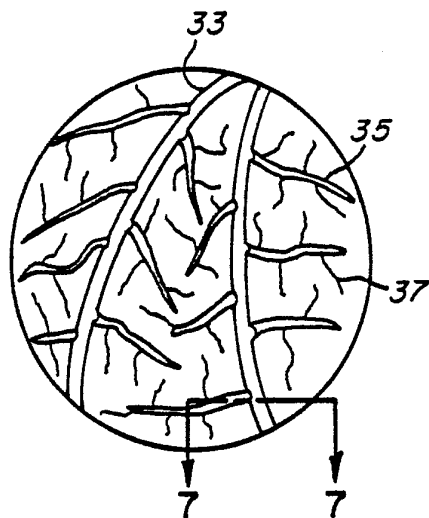


FIG. 6

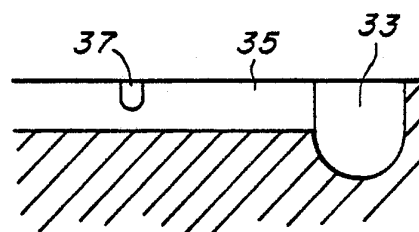


FIG. 7

BUTTON RELATIVE
MOTION

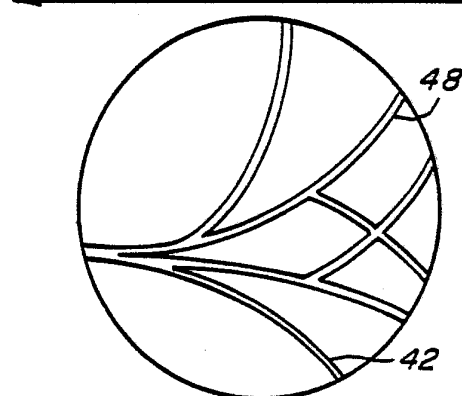


FIG. 9

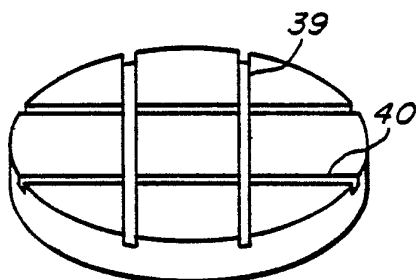


FIG. 8

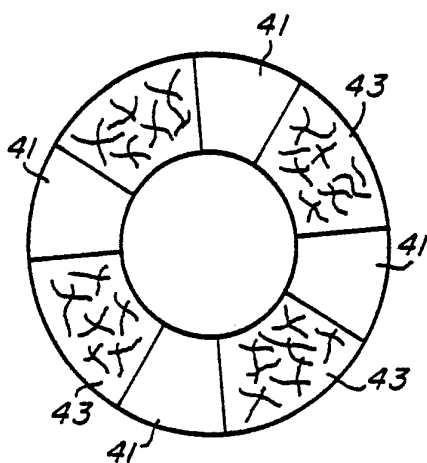


FIG. 10

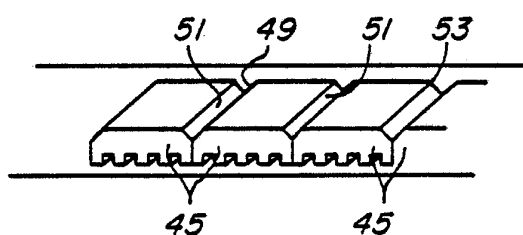
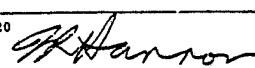


FIG. 11

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US86/02321

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. Class (4) F16C 37/00 U.S. Class 384/317						
II. FIELDS SEARCHED Minimum Documentation Searched ⁴ <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 5px;"> <tr> <th style="width: 20%;">Classification System</th> <th style="width: 80%;">Classification Symbols</th> </tr> <tr> <td style="text-align: center; vertical-align: top;">U.S.</td> <td>384/95, 110, 112, 123, 282-285, 291-293, 297, 313-321, 370, 371, 907.1 175/320</td> </tr> </table> Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁵			Classification System	Classification Symbols	U.S.	384/95, 110, 112, 123, 282-285, 291-293, 297, 313-321, 370, 371, 907.1 175/320
Classification System	Classification Symbols					
U.S.	384/95, 110, 112, 123, 282-285, 291-293, 297, 313-321, 370, 371, 907.1 175/320					
III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹⁴						
Category ⁶	Citation of Document, ¹⁶ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸				
Y	US,A, 473,473 Published 26 April 1892, Peck.	1-34				
Y	US,A, 4,468,138 Published 28 August 1984, Nagel.	1-34				
Y	US,A, 3,549,214 Published 22 December 1970, Neilson.	22				
A	US,A, 4,560,014 Published 24 December 1985, Geczy.	1-34				
A	US,A, 4,345,798 Published 24 August 1982, Cortes.	1-34				
A	US,A, 4,190,301 Published 26 February 1980, Lachonius et al.	1-34				
A	US,A, 3,455,619 Published 15 July 1969, McGrath.	1-34				
¹⁵ * 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 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. "&" document member of the same patent family						
IV. CERTIFICATION						
Date of the Actual Completion of the International Search ¹		Date of Mailing of this International Search Report ²				
6 January 1986		13 FEB 1987				
International Searching Authority ¹		Signature of Authorized Officer ²⁰				
ISA/US		 Thomas Hannon				