(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 197 306 A2

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
**17.04.2002 Bulletin 2002/16**

(51) Int Cl.[7]: **B26F 1/44**

(21) Application number: **01308680.6**

(22) Date of filing: **11.10.2001**

(84) Designated Contracting States:
**AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR**
Designated Extension States:
**AL LT LV MK RO SI**

(30) Priority: **11.10.2000 US 686691**

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(54) **Flexible rotary cutting die**

(57) A rotary cutting die (10) includes a durable, flexible rotary die plate (14) having an inner surface and an outer surface. A cutting rule (12) that defines a cutting design is supported by the die plate. The cutting rule incluees a cutting edge (16) which extends above the outer surface of the die plate, and a support edge (20) disposed within the die plate. The support edge includes a plurality of keyhole shaped notches (22). Preferably, a plurality of S-shaped hooks (24) are connected to the key-hole notches, and serve to reinforce the rotary die plate and to support the cutting rule in the rotary die plate. The rotary die plate is preferably formed from a durable and flexible urethane-based material that exhibits a low shrink factor during curing or hardening.

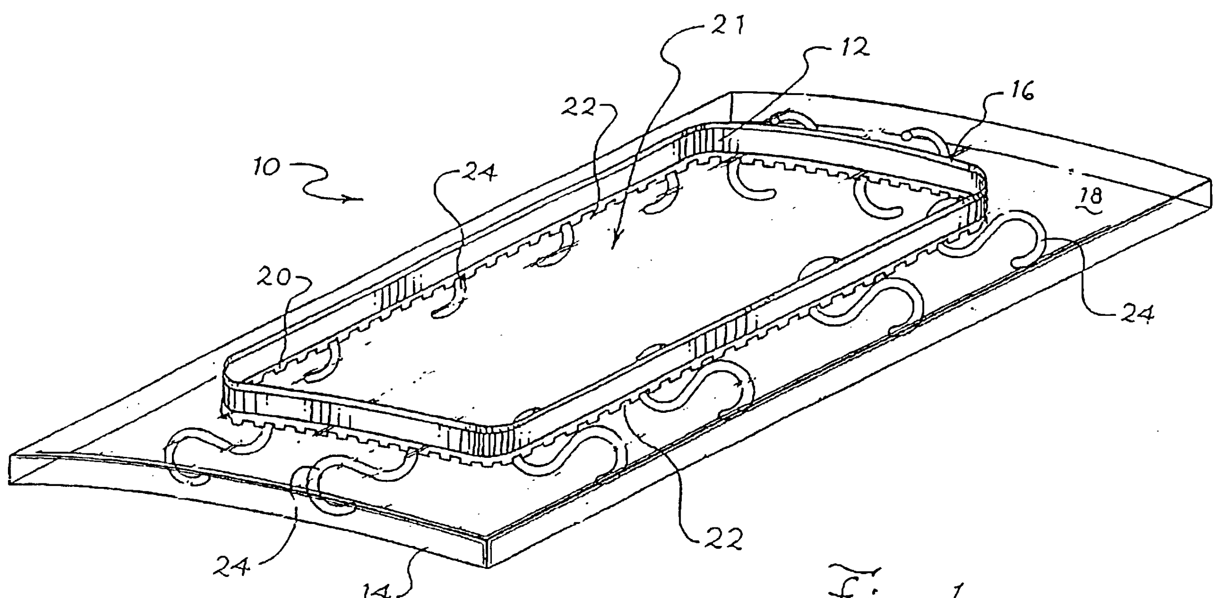


Fig. 1

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## Description

**[0001]** The invention generally relates to the field of rotary cutting dies used in rotary cutting machines, and more particularly, to an improved method and apparatus for making and using such dies.

**[0002]** Rotary cutting machines are widely used in such industries as the printing or converting industry to cut, score and perforate paper and other web-products such as plastic, cardboard, non-wovens and the like. In general, these rotary cutting machines have two cooperating cylinders, one of which carries a rotary cutting die having a knife or cutting rule, and the other cylinder that acts as an anvil against which the knife bears as the paper is cut. The cutting edge of the knife and the surface of the anvil cylinder normally rotate at the same speed and the paper is cut as the cutting edge of the knife moves into and out of engagement with the anvil surface.

**[0003]** Rotary cutting dies have been manufactured and used for numerous years. Conventionally, rotary cutting dies are formed from a rigid, epoxy-based material supporting a metallic cutting rule. The cutting rule extends above the surface of the rigid die plate and defines a cutting design. The design created by the metallic cutting rule is employed to cut, score or perforate material, such as paper, cardboard or the like, through the rotary cutting process.

**[0004]** Conventional rotary cutting dies are mounted on discrete sections of a rotary cutting machine die cylinder or along the entire surface thereof. To accommodate either type of die, the die cylinder typically contains a number of receiving holes spaced at predetermined intervals. The receiving holes are positioned in an array along the die cylinder, and are configured to receive screws or other fasteners that extend through or along the side of the rigid die plate so as to affix the cutting die to the die cylinder. Mounting holes are bored into the die plate to align with the receiving holes in the die cylinder. The rotary cutting die is thus aligned and positioned on the die cylinder to reflect the predetermined pattern for the cutting, scoring or perforating process.

**[0005]** Conventional rotary cutting dies must be sized to fit on the die cylinder. In particular, each rotary cutting die must be manufactured with a mounting radius that precisely matches the radius of the die cylinder on which the cutting die is to be mounted. Precise matching of the rotary die plate to the die cylinder is necessary to insure accurate cutting of the material by the cutting rule. Precise matching of these components is also necessary to eliminate excessive wear on the cutting rule. Imprecise or inaccurate matching may lead to premature wear due to fretting corrosion, and may even lead to breakage or failure of the rotary cutting die.

**[0006]** Manufacturing a rotary cutting die to precisely match the die cylinder can be difficult. For example, it may be difficult to accurately measure the radius of the die cylinder by conventional means. Moreover, conventional rotary cutting dies are typically manufactured from a molding process. Consequently, any deviance between the radius of the die cylinder and the radius of the manufacturing mold will necessarily lead to inaccuracies in the radius of the rotary cutting die.

**[0007]** Another reason for the difficulty in matching the rotary cutting die to the die cylinder is because the die plate of a conventional rotary cutting die is typically manufactured from a rigid; epoxy-based material. Epoxy-based materials tend to shrink during the curing process, thereby altering the radius or distorting the shape of the rotary die plate. Moreover, the amount and degree of shrinkage will very depending on the configuration or layout of the cutting rule. It is therefore nearly impossible to predict the shrinkage of the die plate with any precision. Shrinkage of the die plate material may also create internal stresses that may compromise the integrity of the rotary cutting die.

**[0008]** The use of a rigid, epoxy based material for the die plates of conventional rotary cutting dies results in a number of additional problems. For example, if the radius of the rotary cutting die does not precisely match the radius of the die cylinder, then the die plate must be "flexed" to fit onto the die cylinder. In other words, the die plate must be "flexed" or bent so as to eliminate any gaps between the die plate and the die cylinder. The rigidity of the epoxy-based material, however, will prevent any appreciable "flexing" of the die plate. If the die plate cannot be "flexed" sufficiently to fit onto the die cylinder, then the rotary cutting die is typically discarded. On the other hand, even if the die plate can be "flexed" sufficiently to fit onto the die cylinder, the rotary cutting die will tend to wear faster and have a shorter life span.

**[0009]** In the event that the rigid die plate is "flexed" to fit onto the die cylinder, additional mounting fasteners or clamps will usually be required to secure and hold the die plate tightly against the die cylinder. These additional mounting fasteners will necessarily require the installation of additional receiving holes in the die cylinder.

**[0010]** "Flexing" of the die plate to fit the die cylinder may also cause adverse stresses in the die plate. These adverse stresses may lead to premature wearing or failure of the rotary cutting die. Moreover, a failure of the rotary cutting die can create a dangerous situation. This is because the rigid die plate of a conventional rotary cutting die can shatter, thereby propelling shattered pieces of the die plate and the cutting rule outwardly from the die cylinder.

**[0011]** Accordingly, it would be desirable to have a cutting die that overcomes the disadvantages and limitations described above.

**[0012]** In view of the above, the present invention provides a unique rotary cutting die that overcomes the disadvantages and limitations described above. In particular, the rotary cutting die of the present invention includes a durable, flexible rotary die plate having an inner surface and an outer surface. The die plate supports a cutting rule that defines a cutting design. The cutting rule includes a cutting edge, which extends above the outer surface of the die plate, and a support edge disposed within the die plate. The support edge includes a plurality of keyhole shaped notches. Preferably, a plurality of S-shaped hooks are connected to the key-hole notches, and serve to reinforce the rotary die plate and to support the cutting rule in the rotary die plate.

**[0013]** The rotary die plate of the present invention is preferably formed from a durable and flexible urethane-based material that exhibits a low shrink factor during curing or hardening. The urethane-based material of the preferred embodiment, when cured, is more flexible than the rigid epoxy-based materials used for conventional rotary cutting dies. This flexibility allows the die plate to be flexed or deformed as necessary to fit onto the surface of the die cylinder, thereby eliminating the need to manufacture the die plate with a radius precisely matching the radius of the die cylinder. This flexibility likewise permits a single die plate to be mounted onto die cylinders of different radiuses.

**[0014]** The urethane-based material of the preferred embodiment also improves the distribution of adverse stresses that are often incurred by the cutting rule during jam-ups. The flexibility of the die plate permits the cutting rule to flex slightly during such jam-ups, dissipating the adverse stresses throughout the die plate. The flexible die plate is also less likely to shatter during jam-ups.

**[0015]** The preferred embodiment of the invention includes features in addition to those listed above. Moreover, the advantages over the current art discussed above are directly applicable to the preferred embodiment. but are not exclusive. The other features and advantages of the present invention will be further understood and appreciated when considered in relation to the detailed description of the preferred embodiment which now follows with reference to the accompanying drawings in which:

**FIG. 1** is a perspective view of a rotary cutting die of the invention having a cutting rule supported therein;

**FIG. 2** is a side view of the rotary cutting die shown in **FIG.1;**

**FIG. 3** is a side view of the cutting rule shown in **FIGS. 1** and **2,** including an end view thereof;

**FIG. 4** is a front plan view of a rotary cutting machine including the rotary cutting die shown in **FIGS. 1** and **2** mounted thereon;

**FIG. 5** is a perspective view of the transfer plate material disposed along a cutting cylinder;

**FIG. 6** is a side view of the transfer plate showing the cutting rule positioned therein;

**FIG. 7** is an elevational view of a three-roll curver for curving the cutting rule shown in **FIGS. 1-3**;

**FIG. 8** is a partially exploded perspective view of a rotary cutting die mold; and

**FIG. 9** is a side view of the rotary cutting die and transfer plate after being removed from the rotary cutting die mold shown in **FIG. 8**.

**[0016]** Referring now to the drawings, **FIGS. 1** and **2** show the preferred embodiment of the rotary cutting die **10** of the present invention. The rotary cutting die **10** includes a cutting rule **12** supported in a flexible rotary die plate **14**. The cutting rule **12** has a cutting edge **16**, which extends above the outer surface **18** of the rotary die plate **14**, and a support edge **20** disposed within the rotary die plate **14.** The cutting rule **12** forms a predetermined cutting design **21** on the rotary cutting die **10**.

**[0017]** The cutting edge **16** of the cutting rule **12** is preferably sharp to enable it to cut, score or perforate the design **21** into a given cutting material (not shown). Preferably, the cutting edge **16** extends approximately 1/8 inch above the outer surface **18** of the rotary die plate **14**. However, as those skilled in the art will appreciate, the cutting edge **16** can extend to any distance dictated by a specific application without departing from the spirit and scope of the invention.

**[0018]** As best shown in **FIG. 3**, the support edge **20** preferably includes a plurality of notches **22.** As shown in **FIGS. 1** and **2,** the notches **22** are connected to a plurality of interlocking connectors **24** disposed throughout the rotary die plate **14**. The interlocking connectors **24** serve both to reinforce the rotary die plate **14** and to secure the cutting rule **12** in the rotary die plate **14**. Preferably, the notches **22** are keyhole shaped notches and the interlocking connectors **24** are S-shaped hooks. As those skilled in the art will appreciate, other shapes for the notches **22** and the interlocking connectors **24** can be employed and are contemplated. For example, the notches **22** can comprise circular holes through the cutting rule **12**, and the interlocking connectors **24** can comprise metal pins or screws inserted through the circular holes.

**[0019]** The rotary die plate **14,** as best shown in **FIGS. 1** and **2,** may be formed of any suitable material and to any suitable thickness to obtain the desired flexibility and durability. Preferably, the rotary die plate **14** is formed of a urethane-based material that exhibits a low shrink factor upon hardening. The low shrink factor is desired to ensure that the design **21** formed by the cutting rule **12** is not skewed when the die plate **14** is formed, and to ensure that the required shape of the die plate **14** is retained. The rotary die plate **14** preferably has a thickness of between 1/4 to 7/16 inches, although other thicknesses dictated by particular uses for the rotary cutting die **10** are contemplated. For example, rotary die plates **14** having a thickness in the range of 3/16 to 5/8 inches have been used with satisfactory results. A preferred urethane-based material is distributed by Ciba Geigy Corp., located in East Lansing, Michigan, and is referred to as RP 6444R/TDT 178-87H Polyurea Elastomer. This particular material is a wear resistant, semi-rigid, black, two component polyurea elastomer having a hardness of approximately 60 ± 5 (Shore D). An alternative urethane-based material that can be used for the rotary die plate **14** is referred to as TDT 178-88R/RP 6444H Polyurea Elastomer. This alternative material has properties similar to the preferred material, but is red in color. Of course, any material, and particularly urethane-based materials, having the required properties can be used for the rotary die plate **14**.

**[0020]** The urethane-based material of the preferred embodiment can also be altered with additives, dyes or color pastes to change the color of the rotary die plate **14**. Changing the color of the material may be advantageous for a number of reasons, such as increasing the visibility of the rotary cutting die **10** on the die cylinder **26**, or of the cutting rule **12** on the die plate **14**. Since the die cylinder **26** is typically rotated at a high rate of speed, increasing the visibility of these components could enhance the safety to the operator. For example, manufacturing the rotary die plate **14** from a urethane-based material that has been dyed a light color such as white, yellow or red would improve the operators ability to see the contrasting dark colored cutting rule **12**, even when the die cylinder **26** is rotating. Different colorings could likewise improve the operator's ability to inspect the rotary cutting die **10** for wear or damage.

**[0021]** The urethane-based material of the preferred embodiment, when cured, is more flexible than the rigid epoxy-based materials used for conventional rotary cutting dies. The flexibility of the urethane-based material allows the die plate **14** to be flexed or deformed as necessary to fit onto the surface of the die cylinder **26.** This eliminates the need to manufacture the die plate **14** with a radius precisely matching the radius of the die cylinder **26**, thereby reducing manufacturing costs. Moreover, a single die plate **14** can be flexed to fit onto die cylinders **26** of different radiuses. This eliminates the need to manufacture individual rotary cutting dies **10** for each individual die cylinder **26**.

**[0022]** The urethane-based material of the preferred embodiment permits the manufacture of a thinner rotary die plate **14** than the conventional epoxy-based die plate. The urethane-based material therefore allows a more free flowing injection molding process with fewer, if any, air voids in the finished product.

**[0023]** The rotary cutting die **10** of the present invention is also a more durable and safer product. In particular, a die plate **14** manufactured from the urethane-based material of the preferred embodiment will distribute any adverse stresses that may be incurred by the cutting rule **12**. Such adverse stresses often occur during a jam-up, which typically places transverse loads on the cutting rule **12.** With a conventional rotary cutting die, these loads are transferred directly to the die plate, occasionally causing the die plate to shatter. The die plate **14** of the preferred embodiment, however, has sufficient flexibility to permit the cutting rule **12** to flex slightly, thereby alleviating most of the adverse stresses. Moreover, the flexibility of die plate **14** of the preferred embodiment makes the die plate **14** unlikely to shatter during such a jam-up, thereby reducing or eliminating potentially dangerous situations. Of course, the urethane-based material of the preferred embodiment must have sufficient stiffness so that the cutting rule **12** is supported and securely held in position by the die plate **14.**

**[0024]** Referring now to **FIG. 4,** the rotary cutting die **10** is preferably sized for use on a discrete section of a die cylinder **26** of a rotary cutting machine **28.** Alternately, however, the rotary cutting die **10** may be sized to cover all, or a substantial portion, of the die cylinder **26,** and numerous individual rotary cutting dies may be mounted on the die cylinder **26.** To properly fit on the die cylinder **26,** the radius of curvature of the rotary cutting die **10** should approximate that of the die cylinder **26.** However, and as discussed above, the urethane-based material of the preferred embodiment permits some disparity between the radius of the rotary cutting die **10** and the die cylinder **26.**

**[0025]** The preferred die cylinder **26** contains a plurality of receiving holes 30 positioned in a uniform matrix or array about its outer surface, as shown in **FIG. 4.** The rotary die **10** is mounted on the die cylinder **26** by means of a plurality of fasteners **32** disposed through mounting holes **34** located in the rotary die plate **14** of the die **10.** The fasteners **32** are secured within the receiving holes **30** in the die cylinder **26** to mount the rotary die plate **14** of the rotary die **10** to the die cylinder **26.** Any suitable form of fastener may be utilized to secure the rotary die **10** on the die cylinder **26.** In one preferred embodiment of the invention, the fasteners **32** comprise screws, or the like, that turn into the preferably threaded receiving holes **30** in the die cylinder **26.**

**[0026]** As shown in **FIG. 4,** the rotary cutting machine **28** also includes an opposing cylinder **36** positioned parallel to and in opposite rotary relationship with the die cylinder **26.** When the rotary cutting machine **28** is in operation, the opposing cylinder **36** rotates counter to the die cylinder **26.** During operation of the rotary cutting machine **28,** cutting material, such as paper, cardboard, plastic, polyethylene, non-wovens or paperboard, is fed between the die cylinder **26** and the opposing cylinder **36.** The cutting rule **12** in the rotary die plate **14,** which is mounted on the die cylinder **26,** and the opposing cylinder **36** cooperate to cut, score or perforate the cutting material in the pattern of the cutting design **21.**

**[0027]** A method for forming the rotary cutting die **10** of the present invention is described below. As shown in **FIGS. 5** and **6,** a curved cutting rule transfer plate **38,** preferably formed of phenolic material **56** and having an inner surface **40** and an outer surface **42,** is provided. The phenolic material **56** from which the transfer plate **38** is formed is fixedly secured to a cutting cylinder **54** having approximately the same radius of curvature as the die cylinder **26** on the rotary cutting machine **28.** Preferably, the phenolic material **56** is fastened to the cutting cylinder **54** by screws **58** or the like. Alternately, the phenolic material 56 may be adhered to the cutting cylinder **54** by the use of glue or spray mount.

**[0028]** A Computer Numeric Controlled (CNC) machine (not shown), which is operatively associated with the cutting cylinder **54** supporting the phenolic transfer plate material **56,** cuts the phenolic material **56** to form the transfer plate **38,** in a manner generally known in the art. In addition, the CNC machine forms a cutting rule channel **44** in the transfer plate **38** in the pattern of the cutting design **21.**

**[0029]** As shown in **FIG. 7,** a three-roll curver **46** is use to bend and shape the cutting rule **12** into the cutting design **21** cut into the transfer plate **38.** Because the transfer plate **38,** and the resulting rotary die plate **14,** are curved, the cutting rule **12** must be curved to the same radius of curvature.

**[0030]** Referring back to **FIGS. 5** and **6,** after the cutting rule **12** is curved in the three-roll curver **46,** the cutting edge **16** of the cutting rule **12** is inserted into the inner surface **40** of the transfer plate **38,** through the cutting rule channel **44,** until the cutting edge **16** is substantially flush with the outer surface **42** of the transfer plate **38.** At this point, the support edge **20** of the cutting rule **12** is exposed and extends beyond the inner surface **40** of the transfer plate **38.**

**[0031]** As shown in **FIG. 8,** the curved transfer plate **38** is placed in the rotary cutting die mold **50** with its inner surface **40,** and the support edge **20** of the cutting rule **12,** exposed. The interlocking connectors **24** are connected to or through the notches **22** present in the support edge **20,** as described above. Consequently, the interlocking connectors **24** are also exposed, as shown in **FIG. 8.**

**[0032]** After the mold cylinder **52** is lowered onto the inner surface **40** of the transfer plate **38** and the mold **50** is sealed, a urethane-based die plate material (preferably having a low shrink factor) is injected into the mold 50 at ambient temperature. The urethane-based material is cured at an elevated temperature until the urethane hardens and forms the durable, flexible rotary die plate **14** on the inner surface **40** of the transfer plate **38.** Preferably, the die plate material is cured at 180°F, although it is contemplated that various other curing temperatures could be used depending on the particular urethane-based material and the specific application.

**[0033]** As shown in **FIGS. 8** and **9,** subsequent to the rotary die plate **14** being formed, the mold cylinder **52** is raised, and the rotary die plate **14** and the transfer plate **38** are removed from the mold **50.** The transfer plate **38** is then physically removed from the rotary die plate **14,** and the resultant rotary cutting die **10** is formed. The rotary cutting die **10** may now be mounted to the die cylinder **26** for use on the rotary cutting machine **28.** As can be readily seen, it is contemplated that numerous individual rotary cutting dies may be mounted on a single die cylinder.

**[0034]** It should be appreciated that the present invention may be performed or configured as appropriate for the application. The embodiments described above are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is indicated by the claims rather than by the foregoing description. All changes, which come within the meaning and range of equivalency of the claims, are to be embraced within their scope.

## Claims

1. A rotary cutting die comprising:

    a urethane-base flexible rotary die plate comprising an inner surface and an outer surface, the rotary die plate being sized for use on a discrete section of a rotary cutting machine die cylinder;
    a cutting rule defining a predetermined design and comprising a cutting edge and a support edge, the cutting edge extending above the outer surface of the rotary die plate, the support edge comprising a plurality of notches; and
    a plurality of interlocking connectors connected through the notches in the cutting rule, the interlocking connectors operable to reinforce the rotary die plate and to secure the cutting rule in the rotary die plate.

2. A rotary cutting die as claimed in Claim 1, wherein the urethane-based flexible rotary die plate comprises a polyurea elastomer having a hardness of 60 ± 5 (Shore D).

3. A rotary cutting die as claimed in Claim 1 or Claim 2, wherein the urethane-based flexible rotary die plate plate comprises a thickness in the range of 3/16 to 5/8 inches thick.

4. A rotary cutting die as claimed in Claim 1 or claim 2, wherein the urethane-based flexible rotary die plate comprises a thickness in the range of 1/4 to 7/16 inches thick.

5. A rotary cutting die as claimed in any one of claims 1 to 4, wherein the urethane-based flexiblerotary die plate comprises a first colour and the cutting rule comprises a second colour, said first colour contrasting with said second colour.

6. A rotary cutting die of any of claims 1 to 5, wherein the urethane-based flexible rotary die plate comprises a yellow colour.

7. A rotary cutting die of any of claims 1 to 6, wherein the plurality of notches comprise circular holes through the cutting rule.

8. A rotary cutting die of any of claims 1 to 7, wherein the plurality of interlocking connectors comprise metal fasteners positioned through the circular

holes in the cutting rule.

**9.** A rotary cutting die of Claim 8, wherein the plurality of interlocking connectors comprise metal S-hooks positioned through the circular holes in the cutting rule.

**10.** A rotary cutting die comprising:

a urethane-based flexible rotary die plate comprising a polyurea elastomer having a hardness of 60 ± 5 (Shore D), the rotary die plate further comprising an inner surface, an outer surface and being sized for use on a discrete section of a rotary cutting machine die cylinder;
a cutting rule defining a predetermined design and comprising a cutting edge and a support edge, the cutting edge extending above the outer surface of the rotary die plate and the support edge being disposed within the rotary die plate, the support edge comprising a plurality of notches; and
a plurality of interlocking connectors connected through the notches in the cutting rule, the interlocking connectors operable to reinforce the rotary die plate and to secure the cutting rule in the rotary die plate.

**11.** A rotary cutting die of Claim 10, wherein the urethane-based flexible rotary die plate comprises a thickness in the range of 3/16 to 5/8 inches thick.

**12.** A rotary cutting die of Claim 10 or Claim 11, wherein the urethane-based flexible rotary die plate comprises a yellow colour.

**13.** A rotary cutting die comprising:

a urethane-based flexible rotary die plate comprising a polyurea elastomer having a hardness of 60 ± 5 (Shore D), said flexible rotary die plate further comprising an inner surface, an outer surface and a thickness, said thickness being in the range of 1/4 to 7/16 inches thick, said flexible rotary die plate being sized for use on a discrete section of a rotary cutting machine die cylinder;
a cutting rule defining a predetermined design and comprising a cutting edge and a support edge, the cutting edge extending above the outer surface of the flexible rotary die plate and the support edge being disposed within the flexible rotary die plate, the cutting rule comprising a plurality of openings near the support edge of said cutting rule; and
a plurality of interlocking connectors connected through the openings in the cutting rule, the interlocking connectors operable to reinforce the flexible rotary die plate and to secure the cutting rule in the flexible rotary die plate.

**14.** A rotary cutting die of Claim 13, wherein the urethane-based flexible rotary die plate comprises a yellow colour.

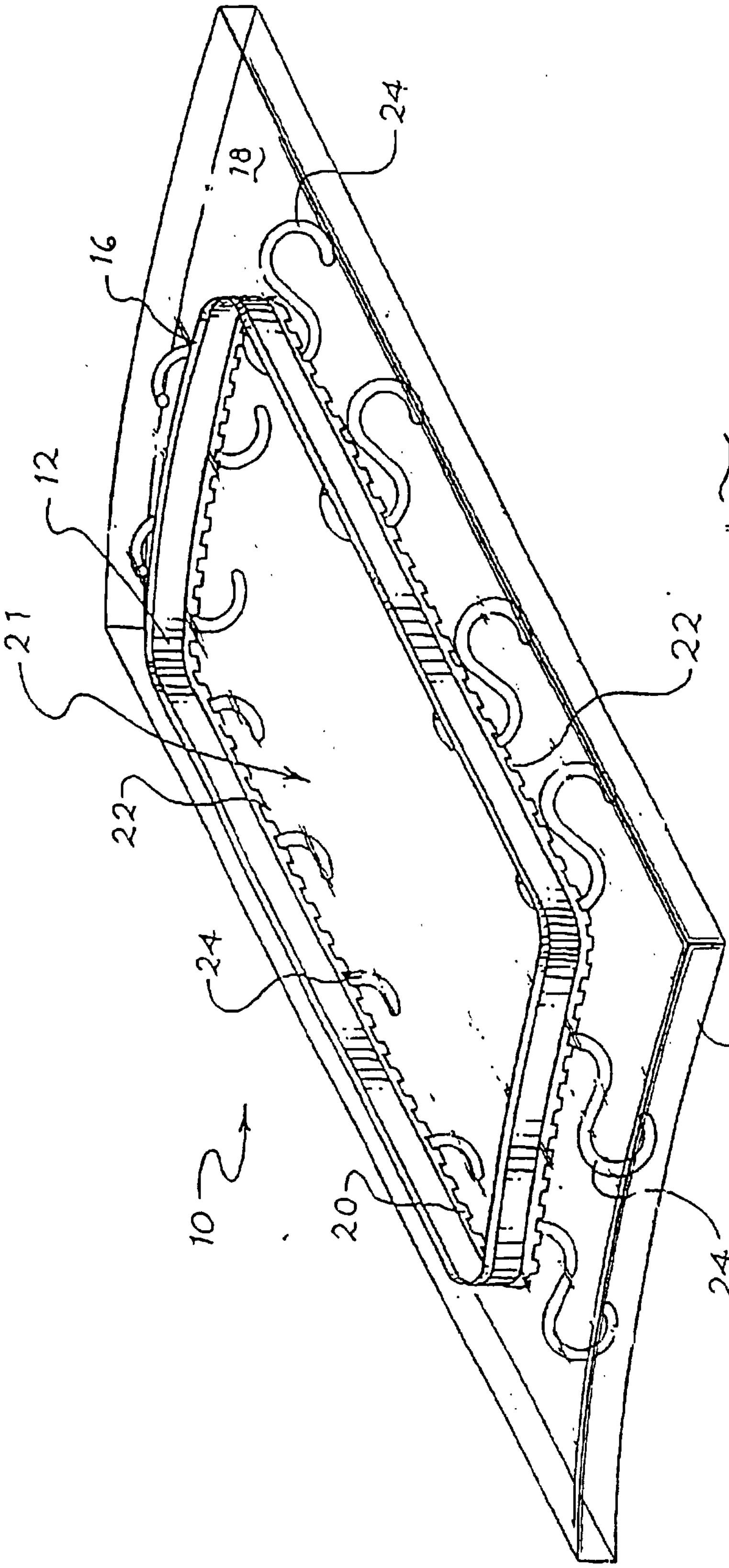



Fig. 1

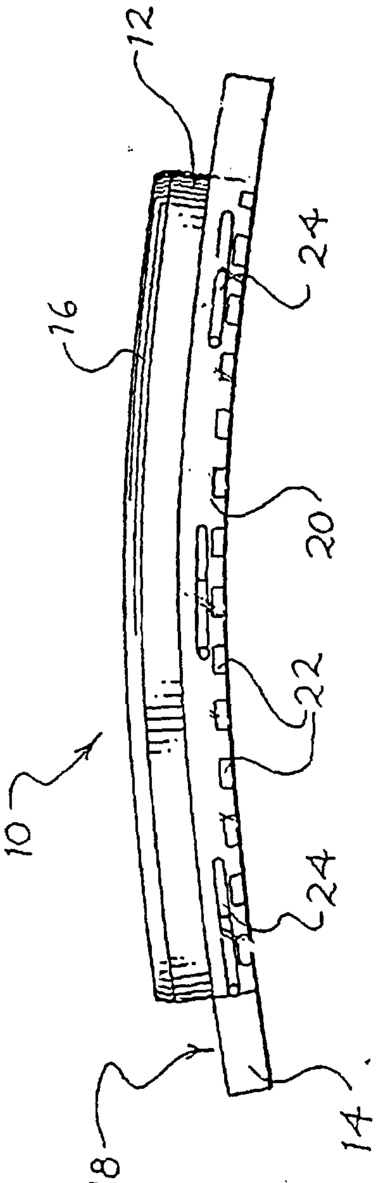



Fig. 2

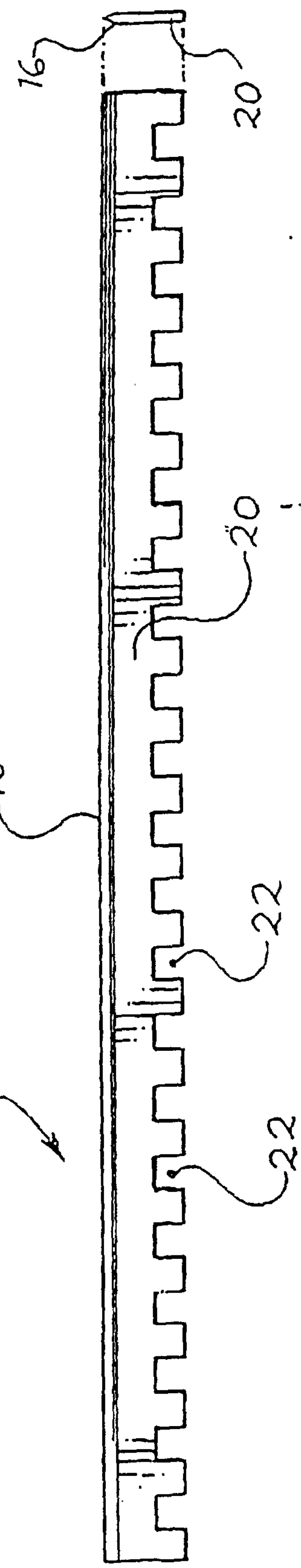



Fig. 3

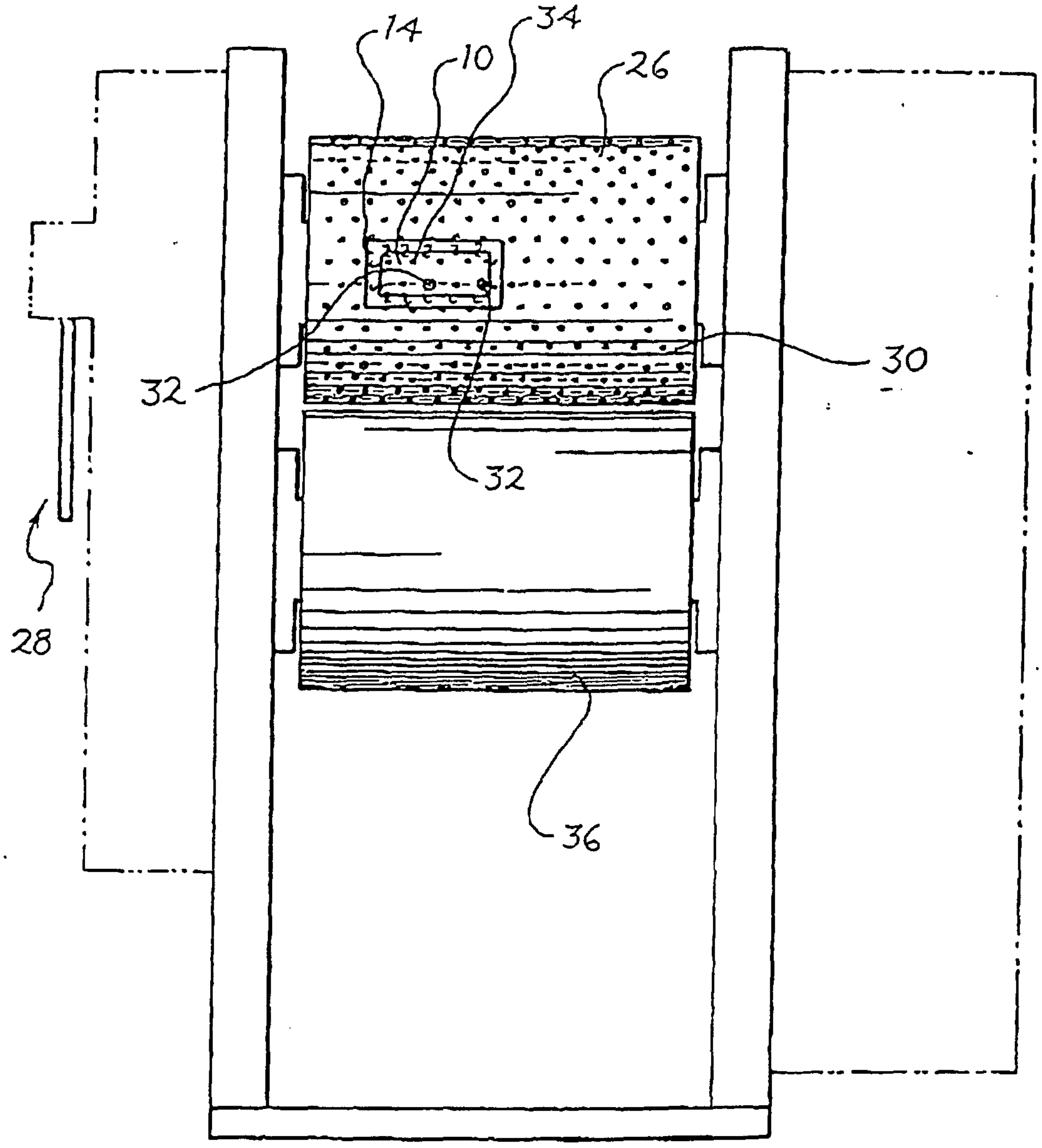



Fig. 4

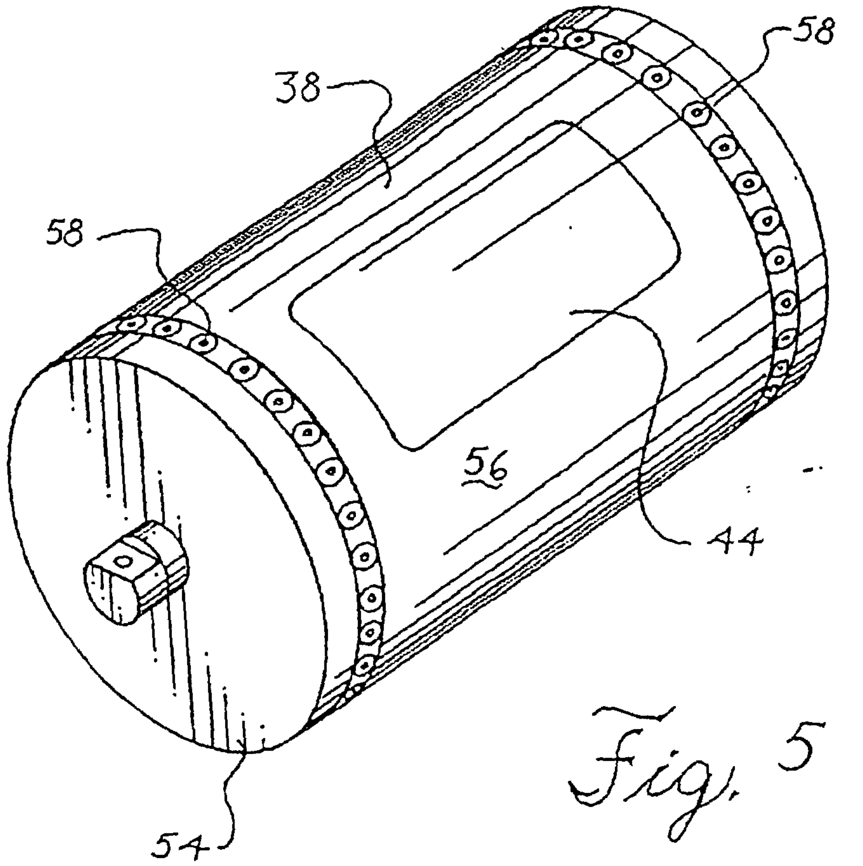



Fig. 5

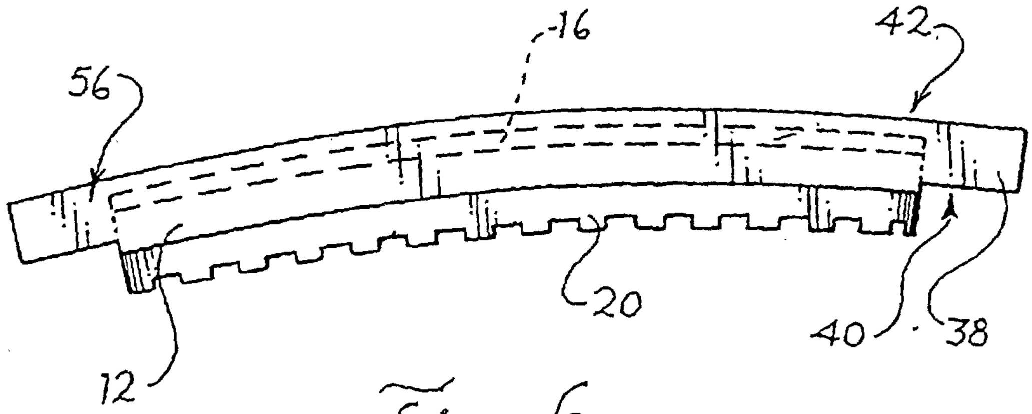



Fig. 6

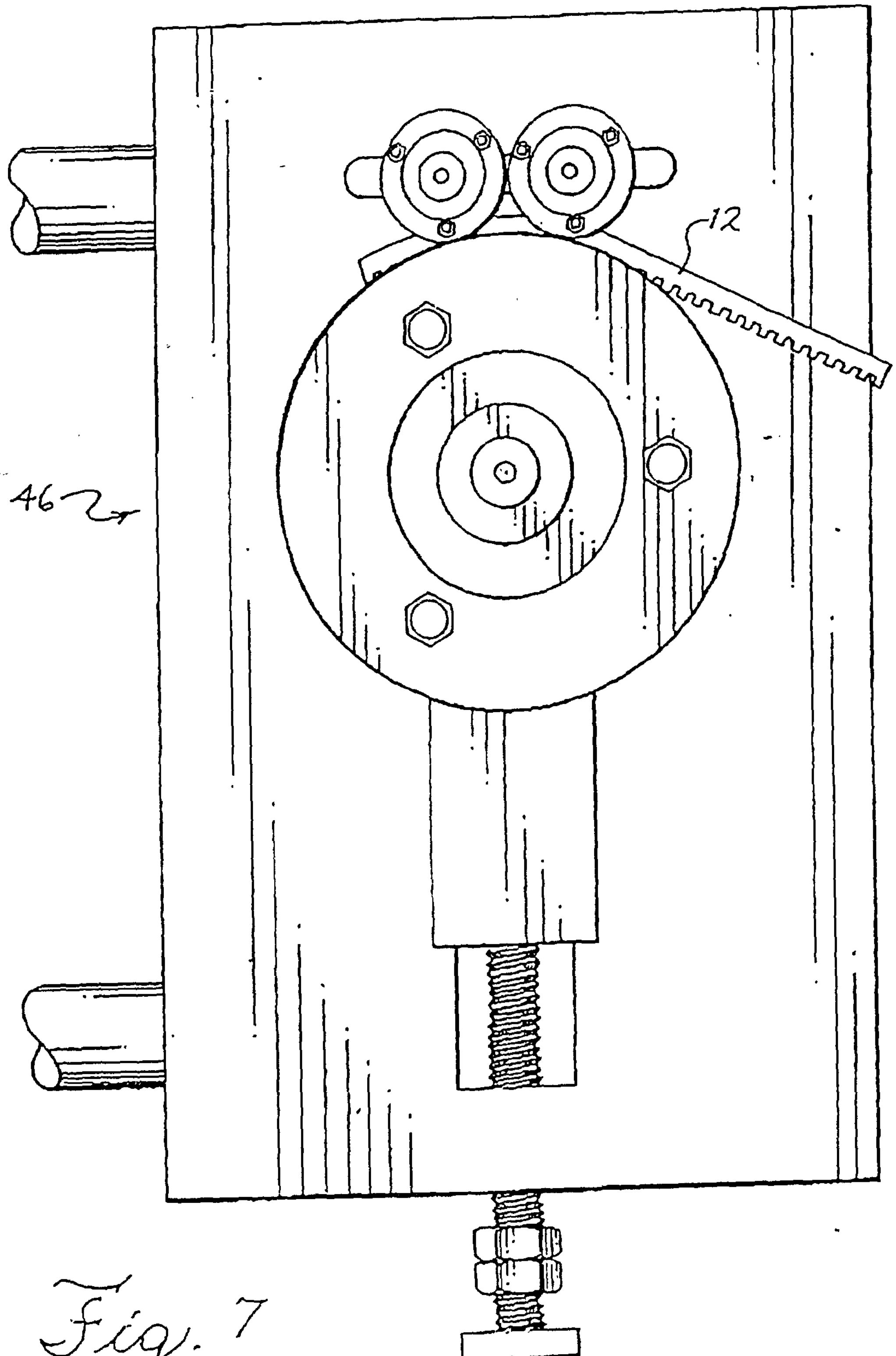
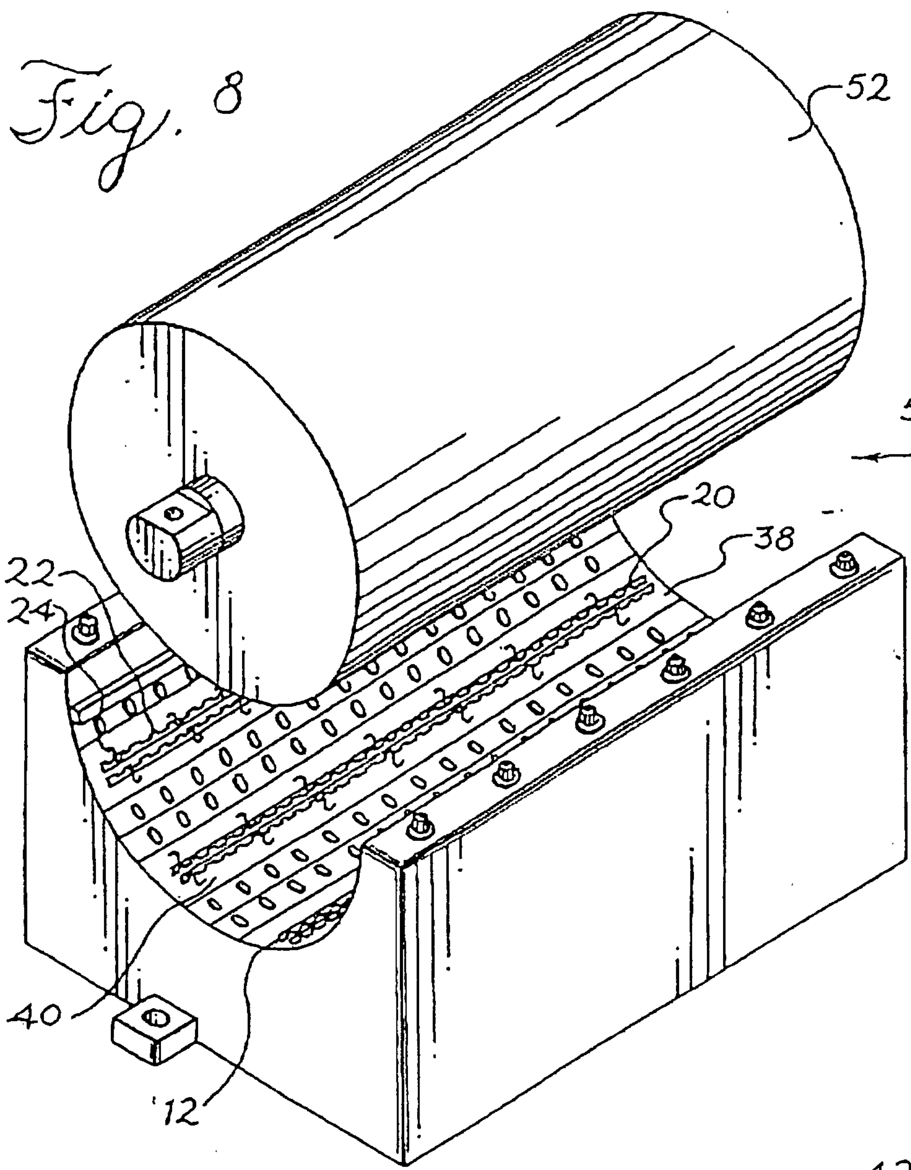



Fig. 7

Fig. 8



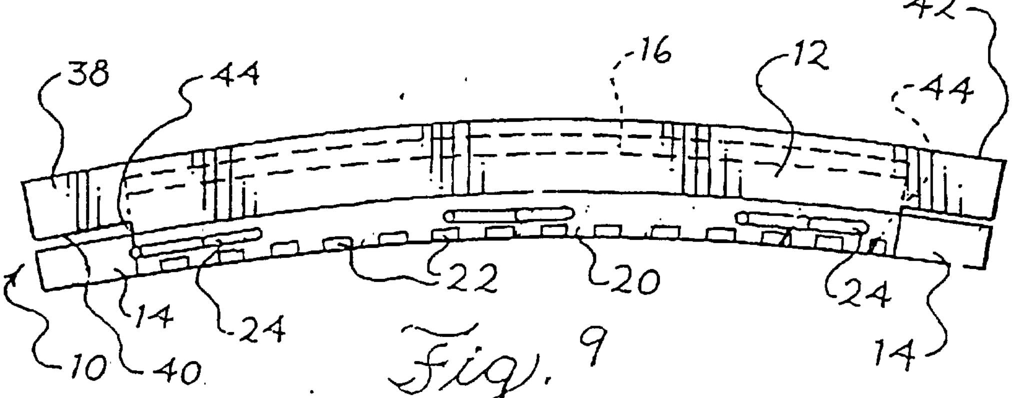




Fig. 9