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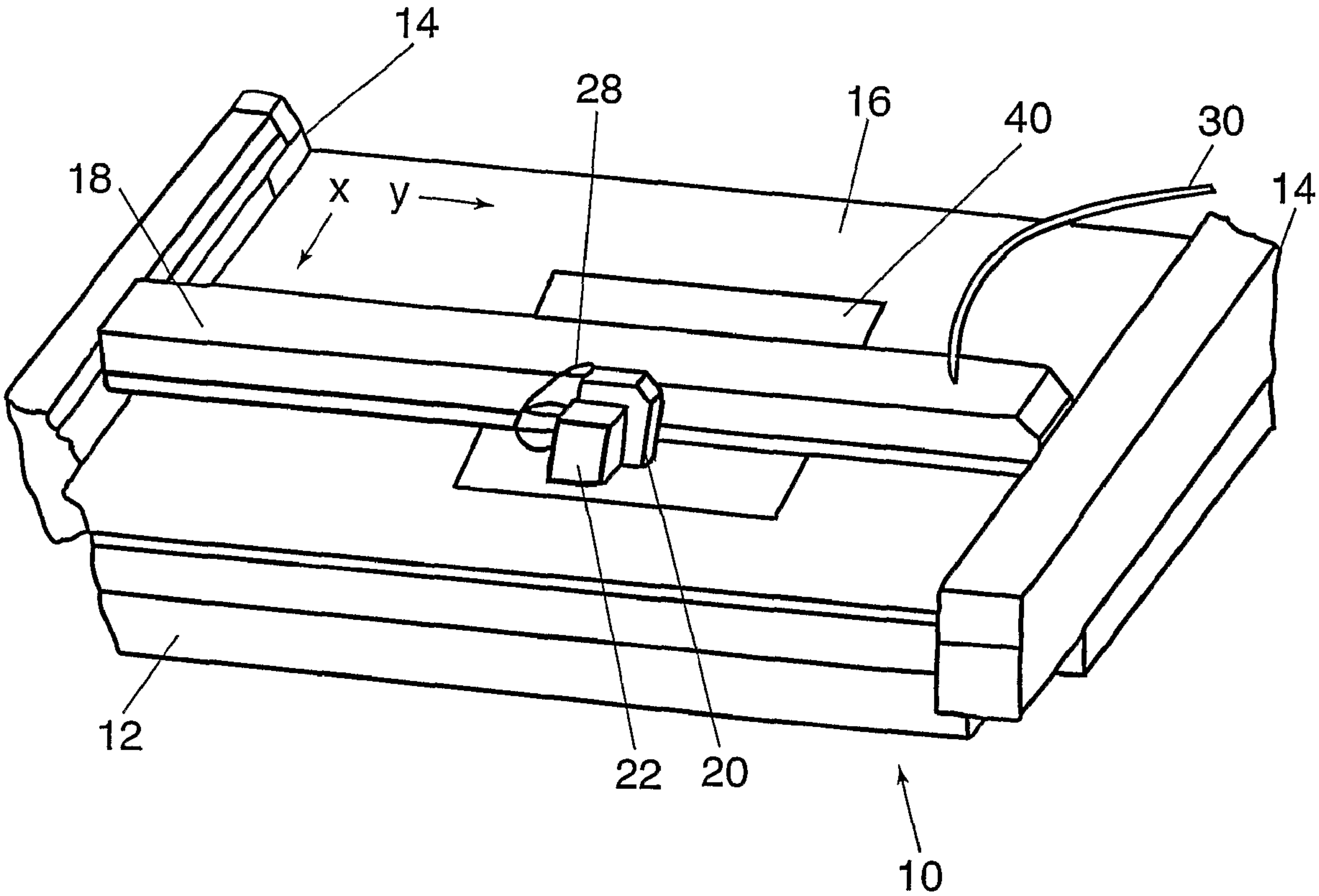
(54) **Titre :** PROCEDE ET APPAREIL AMELIORES DE DECOUPAGE PRECIS DE SURFACES GRAPHIQUES DANS DES FEUILLES
(54) **Title:** IMPROVED METHOD AND APPARATUS FOR PRECISION CUTTING OF GRAPHICS AREAS FROM SHEETS



(57) **Abrégé/Abstract:**
A method and apparatus (10) for cutting a graphics area (42a) from a sheet (40) of material which also includes a plurality of registration marks (44) at and about the graphics area in predetermined positions. The method involves steps to ascertain the

(57) Abrégé(suite)/Abstract(continued):
position and orientation of the sheet as placed on the apparatus, sensing the locations of the marks at the time of cutting, and cutting the graphics area from the sheet along a path determined in response to the sensed positions of the marks with respect to graphics area at that time. Certain embodiments use either (a) a subset (46) of marks which is applied on one side of graphics area or (b)certain reference features (49), such as edges and corners of the sheet and elements of the graphics area, to ascertain the position and orientation of the sheet on the apparatus. The invention provides rapid, automated, and precise cutting despite two-dimensional distortion of the sheet.

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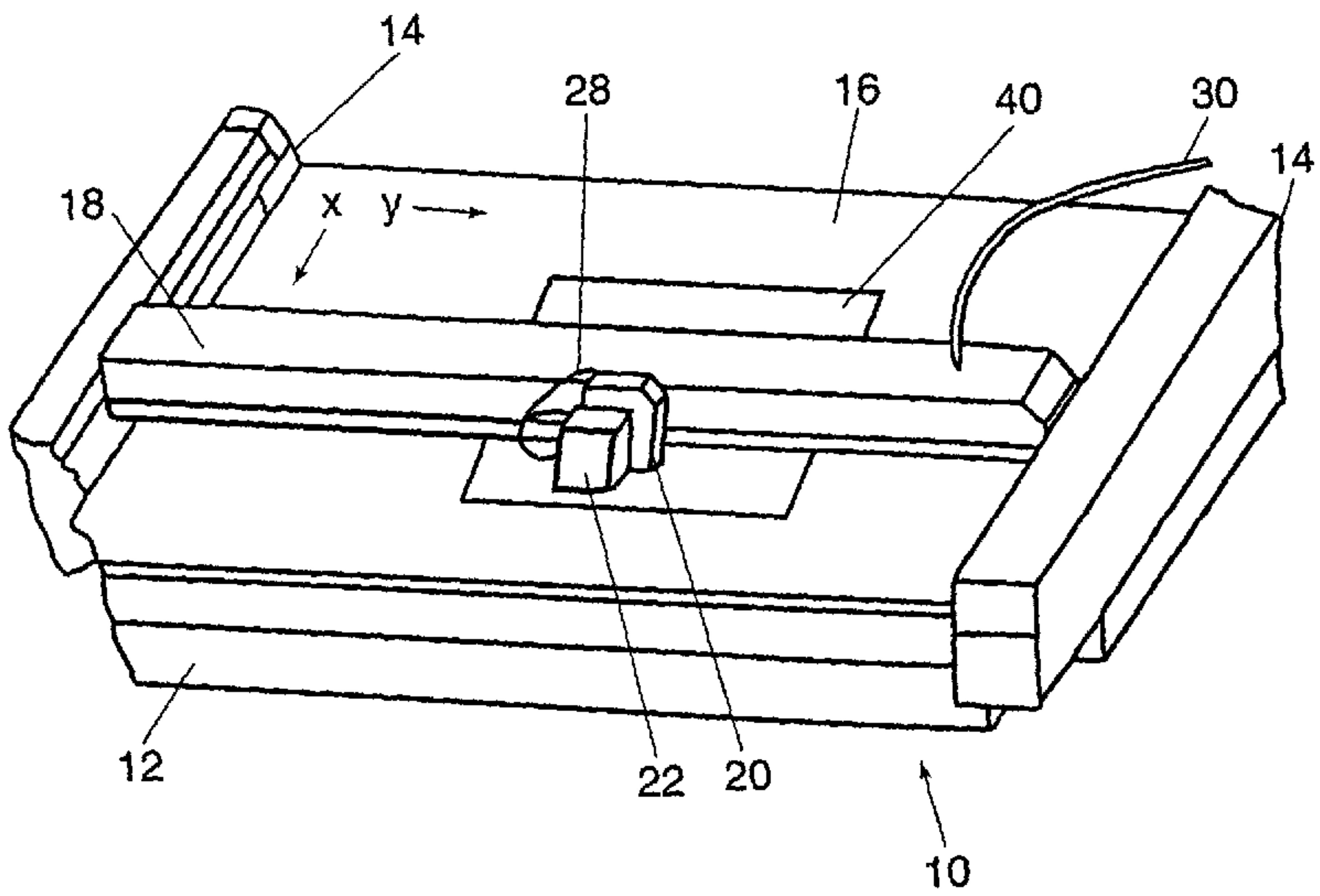
(54) Title: IMPROVED METHOD AND APPARATUS FOR PRECISION CUTTING OF GRAPHICS AREAS FORM SHEETS



(57) Abstract: A method and apparatus (10) for cutting a graphics area (42a) from a sheet (40) of material which also includes a plurality of registration marks (44) at and about the graphics area in predetermined positions. The method involves steps to ascertain the position and orientation of the sheet as placed on the apparatus, sensing the locations of the marks at the time of cutting, and cutting the graphics area from the sheet along a path determined in response to the sensed positions of the marks with respect to graphics area at that time. Certain embodiments use either (a) a subset (46) of marks which is applied on one side of graphics area or (b)certain reference features (49), such as edges and corners of the sheet and elements of the graphics area, to ascertain the position and orientation of the sheet on the apparatus. The invention provides rapid, automated, and precise cutting despite two-dimensional distortion of the sheet.

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IMPROVED METHOD AND APPARATUS FOR PRECISION CUTTING OF GRAPHICS AREAS FROM SHEETS

FIELD OF THE INVENTION

This invention is related generally to the field of cutting of graphics areas or the like from sheets for various purposes, and other narrow-path-processing about graphics areas on sheets.

BACKGROUND OF THE INVENTION

The technical field involving the cutting of graphic areas from sheets, or otherwise doing narrow-path-processing about graphics images on sheets, includes, for example, the face-cutting of laminate sheets to form decals. More specifically, a graphic-image area on the face layer of a laminate needs to be cut away from the remainder of the face layer so that the graphic area (decal) can subsequently be pulled away from the backing layer of the laminate and be applied elsewhere as intended. Highly accurate face-layer cutting about the graphics is obviously highly desirable.

This is but one example in which highly accurate sheet cutting is desirable. In many other situations, highly accurate sheet cutting may not involve face-cutting, but through-cutting, in which the full thickness of the sheet is cut about a graphics area on the sheet. And in many situations, rather than highly accurate cutting, highly accurate scoring, creasing, line embossing or the like, in each case, of course, along a line the varying direction of which is determined by the shape of the graphics area. Together these types of operations on sheets with respect to graphics areas thereon are referred to herein as "narrow-path-processing." For convenience, the prior art problems and the invention herein which solves such problems will be discussed primarily with reference to sheet-cutting apparatus.

A method and associated apparatus which addresses many of the problems encountered in such processing of sheet material is the i-cut™ vision cutting system from Mikkelsen Graphic Engineering of Lake Geneva, Wisconsin, and is the subject of a pending United States patent (serial number 09/678,594) filed on October 4, 2000. The invention described in such document is a method and apparatus for achieving highly improved accuracy in cutting around graphics areas in order to fully adjust for two-dimensional distortion in the sheets from which the graphics areas will be cut, including distortion of differing degrees in one dimension or along one direction on the sheet of material. The distortion may be from the printing process or from some other post-printing process such as material handling or during the cutting process itself. This invention also provides improved speed and accuracy in narrow-path-processing and greater efficiency of material usage.

In some cases, such as in the i-cut™ system from Mikkelsen Graphic Engineering, a flatbed plotter is used. These are devices having a positionally-controlled cutting implement above a flat work surface on which the sheet to be cut rests. The cutting implements are controlled based on controller-supplied instructions based on the X-Y coordinates necessary to achieve cutting along the intended path, such as about the graphics area.

Achieving greater speed and overall efficiencies in narrow-path-processing is a continuing challenge encountered with such systems. One source of inefficiency is the manual intervention often required to adjust the initial position and alignment of the sheet on the work surface of the cutting apparatus. Sheets of material on which graphics areas have been previously printed are placed on the work surface of the cutting apparatus, either manually or by automatic sheet-feeding equipment. In either of these set-up situations, the cutting apparatus must determine the position and orientation of the sheet on the work surface in order to proceed accurately with the cutting process. If the operator or automatic sheet-feeder places the sheet of material on the work surface such that it is outside of the area or region of alignment on the work surface which the cutting system expects to find the sheet, manual intervention may be necessary to adjust the placement of the sheet to within the required initial region in order for the process to continue beyond this initial set-up step. Another source of inefficiency is the time-consuming step which may be required to allow the system to determine the initial position and orientation of the sheet on the work surface.

Another measure of efficiency is the amount of material waste which is produced during narrow-path-processing. Depending on volumes of material processed and the cost of the material used, the amount of waste may be important to minimize in order to increase overall process efficiency.

Despite the significant advances represented by the i-cut™ system, these advances have not yet achieved the highest levels of performance which potentially can be reached by automated cutting systems. Further increases in efficiency (precision, speed of operation, and material usage) are highly desirable in automated cutting systems.

OBJECTS OF THE INVENTION

It is an object of this invention to provide an improved method and apparatus for precision cutting of graphics areas from sheets and other narrow-path-processing with respect to graphics on sheet materials of various kinds, thereby overcoming some of the problems and shortcomings of the prior art.

Another object of this invention is to provide a method and apparatus for reducing the time to determine sheet position and orientation in apparatus for cutting around graphics areas in order to fully adjust for two-dimensional distortion in the sheets from which the graphics areas will be cut.

Another object of the invention is to minimize or completely eliminate the need for manual intervention by an operator in the placement of sheets of material on apparatus for cutting about graphics areas which automatically adjust for a wide variety of sheet distortion.

Another object of this invention is to provide an improved method and apparatus which increases the speed of cutting and other narrow-path-processing of sheet material.

Another object of this invention is to provide an improved method and apparatus which automate the cutting and other narrow-path-processing of sheet material as much as possible.

Another object of this invention is to provide an improved method and apparatus which reduces material waste in cutting and other narrow-path-processing of sheet material.

These and other objects of the invention will be apparent from the following descriptions and from the drawings.

SUMMARY OF THE INVENTION

The instant invention overcomes the above-noted problems and shortcomings and satisfies the objects of the invention. The invention is an improved method and apparatus for cutting graphics areas from sheets, or other narrow-path-processing with respect to graphics images. Stated more broadly, the invention is an improved method and apparatus for narrow-path-processing with respect to graphics images on sheets, including by cutting, creasing, scoring or the like around such images. Of particular note is that the instant invention brings high speed and improved efficiency, including minimizing material waste and eliminating certain manual intervention, to the precision cutting of graphics images from sheets bearing such images, including without limitation in situations in which there has been distortion of various kinds in the sheets, including two-dimensional distortion.

The method of this invention, stated with respect to cutting graphics areas from sheets including such graphics areas, includes as a first step applying a plurality of registration marks on the sheet at and about the graphics area in predetermined positions with respect to the graphics area, or more particularly, with respect to the perimeter thereof which will be cut, the plurality of registration marks including an initial-position/orientation-determining subset which is located on no more than one side of the graphics area. This is done at the time the graphics which define such graphics area (or graphics areas) are applied.

As used herein, the word “perimeter” means the intended cutting path around a graphics area, whether or not the intended cutting path is an outer edge of the graphics area or an inner edge (such as from removal of the inside of the letter “D”).

The method involves: placing the graphics sheet with the initial-position/ orientation-determining subset adjacent to a registration mark sensor; sensing the subset to ascertain the position and orientation of the sheet of material and the approximate positions of the plurality of registration marks thereon; sensing the precise positions of the registration marks on the sheet of material; and cutting the graphics area from the sheet in response to the precise positions of the registration marks with respect to the graphics area at that time. This method allows the sensing of the registration marks to occur rapidly with a minimum of manual intervention and cutting to occur precisely despite two-dimensional distortion of the sheet prior to cutting.

In highly preferred embodiments of the invention, the initial-position/ orientation-determining subset is a pair of registration marks in tandem relationship to each other. The term "tandem relationship" as used herein means spaced closer to one another than the average spacing between other registration marks applied on the sheet of material. For example, on a sheet of material one meter by one meter in size with graphics areas applied including registration marks around the perimeters of the graphics areas, two registration marks applied near one corner of the sheet with a 25 mm space between the centers of the two marks are said to be in tandem relationship with each other.

In certain preferred embodiments, each of the registration marks of the pair is a round area, and the sensing step includes processing sensed data to find the mathematical centers thereof. Further, in highly preferred embodiments, all of the registration marks are round areas, and the sensing step includes processing sensed data to find the mathematical centers thereof.

It is highly preferred that the method of this invention include providing a controller to furnish instructions for the sensing and cutting operations so that the determinations involving sensing and cutting are carried out swiftly and on a continuing basis as one or more graphics areas are cut from a sheet and as additional sheets are processed. The controller further facilitates the efficiency improvements of this invention.

In highly preferred embodiments, the method includes the additional step of placing the sheet on a sheet-receiving surface having an X and Y coordinate grid and retaining the sheet at a user-selected location thereon such that the sheet of material overlaps the X and Y coordinate grid. In such preferred embodiments, the sensing of the precise positions of the registration marks on the sheet includes the step of acquiring the X and Y coordinates which are overlapped by the registration marks. Further, preferred embodiments of the invention include in the cutting process the step of comparing the X and Y coordinates which are overlapped by the registration marks with a reference set of X and Y coordinates. In highly preferred embodiments, the comparing step is carried out by the controller.

In certain preferred embodiments, the controller has a programmed set of predetermined cutting instructions which includes reference X and Y coordinates for the registration marks and also includes the predetermined positions thereof with respect to the perimeter of the graphics area when the graphics area and registration marks are first applied to the sheet. In such embodiments, the cutting step includes setting a final (optimized) cutting path based on the comparing step, such final cutting path corresponding to the perimeter of the graphics area of the sheet even though such perimeter is distorted during the uncut life of the sheet.

In certain preferred embodiments, the sheet is a laminate having (a) a face layer which bears one or more graphics areas and registration marks corresponding to each, and (b) a backing layer, and the cutting is face cutting only. This allows preparation of highly accurate decals, which can later be removed from the backing layer.

In many cases, depending on the size of the sheet, it is preferred that there be a plurality of graphics areas on each sheet and a corresponding plurality of sets of the registration marks at or about each graphics area.

In a highly preferred embodiment of the invention, the method involves: placing the sheet on a sheet-receiving surface; sensing the subset in the field of view of a main sensor to ascertain the position and orientation of the sheet and to infer the approximate positions of the plurality of marks; if the subset is not in an expected location, automatically determining the coordinate region of the subset on the sheet-receiving surface; sensing the precise positions of the marks; and cutting the graphics area from the sheet in response to the precise positions of the marks with respect to the graphics area. This embodiment of the method allows the sensing of the registration marks to occur rapidly with a minimum of manual intervention and cutting (or other narrow-path-processing) to occur precisely, whether or not two-dimensional distortion of the sheet is present prior to cutting.

In certain preferred embodiments of the invention, automatically determining the coordinate region of the subset includes moving the main sensor in a predetermined pattern surrounding the expected location of the subset and stopping the movement of the main sensor when the coordinate region of the subset is located within the field of view of the main sensor. In one such embodiment, movement of the main sensor is in the plane of the sheet-receiving surface. In another such embodiment, moving the main sensor includes rotating the main sensor such that the field of view changes.

In certain embodiments of the invention, the automatic determining step includes enlarging the field of view of the main sensor, thereby locating the coordinate region of the subset within an enlarged field of view. The main sensor is then repositioned, including shrinking the field of view of the main sensor, such that the subset is within the field of view of the main sensor. In one such embodiment, enlarging and shrinking the field of view of the main sensor is performed by zooming a lens of the main sensor. In another such embodiment, the enlarging and shrinking steps are performed by increasing and decreasing respectively the distance between the main sensor and the sheet-receiving surface.

In another embodiment of the invention, automatically determining the location of the coordinate region of the subset involves locating the coordinate region of the subset within the field of view of a secondary sensor.

In certain embodiments of the invention, automatic determination the coordinate region of the subset includes sensing directive indicia on the sheet of material which indicate the coordinate region of the subset, the directive indicia being extra marks printed on the sheet of material outside the coordinate region of the subset. In particular embodiments of the invention, the automatic determining step includes determining from the directive indicia the direction and distance from the expected location to the actual location and repositioning the main sensor by moving it in the determined direction for the determined distance.

Another aspect of the inventive technology disclosed herein involves an alternative approach to ascertaining the position and orientation of the sheet of material. The method involves: placing the sheet on a sheet-receiving surface; sensing a set of reference features of the sheet of material (such as edges, a corner, or elements of a graphics area printed on the sheet) in the field of view of a main sensor to ascertain the position and orientation of the sheet and to infer the approximate positions of the plurality of marks; if the reference features are not in an expected location, automatically determining the coordinate region of the reference features on the sheet-receiving surface and then sensing the metrics of the reference features in order to then ascertain such position and orientation and infer such approximate positions; sensing the precise positions of the marks; and cutting the graphics area from the sheet in response to the precise positions of the marks with respect to the graphics area.

The coordinate region of the set of reference features on the sheet-receiving surface is the area thereof which, when contained within the field of view of the main sensor, enables main-sensor sensing of the set with precision sufficient to determine the position and orientation of the sheet of material on the sheet-receiving surface such that the various registration marks can be automatically found to enable subsequent precision sensing thereof.

As used herein, the term "metrics," applied in characterizing a reference feature, refers to the numerical parameters which can be used by the device to describe the position and orientation of the reference feature and, in combination with other metrics of this and other reference features, can be used to ascertain the position and orientation of the sheet of material on the sheet-receiving surface. For example, a straight edge of a sheet of material defines a line which lies at an angle with respect to the coordinate system axes of the sheet-receiving surface. Such angle is one such "metric." The corner of a sheet defined by the intersection of two such edges defines a point within the coordinate system, and the x,y coordinates of the corner point are two more such "metrics." Other metrics might include, among other things, certain geometric descriptors of shapes, positions, and orientations of graphical images within the graphics area itself.

In a fashion similar to embodiments wherein a subset of initial-position/orientation-determining marks is employed, other embodiments of the inventive technology include the alternative use of a set of reference features.

The apparatus of this invention is a device for cutting a graphics area at the perimeter thereof from a sheet of material, the sheet having a plurality of registration marks at and about the graphics area, the plurality of registration marks including an initial-position/orientation-determining subset that is located on no more than one side of the graphics area. The registration marks are simply added during the printing of the graphics area.

The inventive apparatus includes: a sheet-receiving surface; a main sensor, preferably a CCD area image sensor; for sensing the subset in the field of view of the main sensor to ascertain the position and orientation of the sheet and to infer approximate positions of the plurality of marks and for sensing the precise positions of the marks; a cutter operatively connected to the main sensor and movable about the sheet-receiving surface, the cutter cutting the graphics area from the sheet of material in response to the precise positions of the registration marks sensed by the main sensor; and a controller for controlling movement of the cutter along the sheet-receiving, the controller including a set of initialization instructions corresponding to (a) predetermined approximate positions of the initial-position/orientation-determining subset on the sheet and (b) the relative positions of the remaining registration marks thereon with respect to the position of the subset. The invention, as already indicated, allows the sensing of the registration marks to occur rapidly and cutting to occur precisely despite two-dimensional distortion of the sheet prior to cutting.

In preferred embodiments, the initialization instructions of the controller also include instructions for sensing the precise position and orientation of the subset, whereby the approximate positions of the remaining registration marks are inferred to facilitate sensing of the precise positions of the remaining registration marks. Further, the controller includes a set of predetermined cutting instructions therein corresponding to the perimeter of the graphics area and the predetermined position thereof with respect to predetermined positions of the registration marks when the graphics area and registration marks are first applied to the sheet, the controller moving the cutter along the sheet-receiving surface in response to a comparison of (a) the locations of the registration marks sensed by the sensor on the sheet with (b) the set of predetermined cutting instructions.

In highly preferred embodiments of the invention, the apparatus also includes a coordinate region locator which, if the subset is not in an expected location, automatically determines the coordinate region of the subset on the sheet-receiving surface and in response thereto automatically repositions the main sensor to the coordinate region such that the subset is within the field of view of the main sensor.

In other highly preferred embodiments of the invention, the coordinate region locator includes a controller with a set of locating instructions for moving the main sensor in a predetermined pattern surrounding the expected location of the subset, and stopping the movement of the main sensor when the coordinate region of the subset is located within the field of view of the main sensor.

In certain preferred embodiments, the coordinate region locator includes a zoom lens on the main sensor and a controller with a set of locating instructions for (a) enlarging the field of view of the main sensor by zooming the lens, (b) locating the coordinate region of the subset within the enlarged field of view, (c) repositioning the main sensor in response to the locating step, and (d) shrinking the field of view of the main sensor by zooming the lens such that the subset is within the field of view of the main sensor.

Another embodiment of the coordinate region locator includes a main-sensor height adjustor and a controller with a set of locating instructions for (a) enlarging the field of view of the main sensor by increasing the distance of the main sensor from the sheet material, (b) locating the coordinate region of the subset within the enlarged field of view, (c) repositioning the main sensor in response to the locating step, and (d) shrinking the field of view of the main sensor by decreasing the distance of the main sensor from the sheet such that the subset is within the field of view of the main sensor.

In certain embodiments of the invention, the coordinate region locator includes a secondary sensor with a field of view larger than the field of view of the main sensor, and a controller with a set of locating instructions for (a) locating the coordinate region of the subset within the field of view of the secondary sensor, and (b) repositioning the main sensor in response to the locating step such that the subset is within the field of view of the main sensor.

In another embodiment of the invention, the coordinate region locator includes directive indicia printed on the sheet of material outside the coordinate region of the subset in predetermined positions and orientations with respect to the subset, and a controller with a set of locating instructions for determining the coordinate region of the subset by sensing the directive indicia, and repositioning the main sensor in response thereto, such that the subset is within the field of view of the main sensor.

Another aspect of the inventive apparatus disclosed herein involves an alternative approach to ascertaining the position and orientation of the sheet of material. In some highly preferred embodiments, the apparatus also includes a reference feature identifier which, if the reference features are not in an expected coordinate region on the sheet-receiving surface, automatically determines the coordinate region of the reference features, and which, when the coordinate region of the reference features is known, senses the metrics of the reference features in order to infer the approximate positions of the registration marks.

In a fashion similar to embodiments in which a subset of initial-position/ orientation-determining marks is employed, other embodiments of the inventive apparatus include the alternative use of a set of reference features.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a perspective view of an automatically controlled cutting apparatus employing the present invention.

FIGURE 2 is a top view of a sheet of sheet material with pre-printed graphics areas and registration marks, including an initial-position/orientation-determining subset of marks.

FIGURE 3A is a top view of a sheet of material on a sheet-receiving surface, illustrating a coordinate region of the subset and a field of view of a main sensor which does not contain the coordinate region of the subset.

FIGURE 3B is a top view of a sheet of material on a sheet-receiving surface, illustrating a coordinate region of a set of reference features and a field of view of a main sensor which does not contain the coordinate region of the set.

FIGURE 4A is a top view of a portion of a sheet-receiving surface, a portion of a sheet of material, and one predetermined pattern of movement of the main sensor, illustrated by consecutive fields of view of the main sensor.

FIGURE 4B is a top view of a portion of a sheet-receiving surface, a portion of a sheet of material, and a second predetermined pattern of movement of the main sensor, illustrated by consecutive fields of view of the main sensor.

FIGURE 4C is a top view of a portion of a sheet-receiving surface, a portion of a sheet of material, and one predetermined pattern of movement of the main sensor, illustrated by consecutive fields of view of the main sensor.

FIGURE 4D is a top view of a portion of a sheet-receiving surface, a portion of a sheet of material, and a second predetermined pattern of movement of the main sensor, illustrated by consecutive fields of view of the main sensor.

FIGURE 5 is a schematic side view of sheet-receiving surface and a main sensor with a zoom lens.

FIGURE 6 is a schematic side view of a sheet-receiving surface with a main sensor height adjustor.

FIGURE 7 is a schematic side view of a sheet-receiving surface with a main sensor and a secondary sensor.

FIGURE 8 is a schematic side view of a sheet-receiving surface with a main sensor which rotates to change its field of view.

FIGURE 9A is a top view of a sheet of material with pre-printed graphics areas, an initial-position/orientation-determining subset, and one type of directive indicia.

FIGURE 9B is a top view of a sheet of material with pre-printed graphics areas, an initial-position/orientation-determining subset, and two additional types of directive indicia.

FIGURE 10A is a top view of a sheet of material with pre-printed graphics areas and a set of reference features including a uniqueness feature comprising a corner cut-off.

FIGURE 10B is a top view of a sheet of material with pre-printed graphics areas, with a set of reference features including a portion of the graphics image near one corner of the sheet.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to FIGURE 1, a partially cut away view of a cutting device 10 is shown. Cutting device 10 has a housing 12 which may contain the controller (not shown) and a sheet-receiving surface 16. Cutting device 10, which is shown with a sheet 40 positioned on sheet-receiving surface 16, is also known as a flatbed plotter or cutter in the art and may be a Zund plotter, manufactured by Zund System Technik HG, or a Wild plotter, to give two examples.

Cutting device 10 includes two longitudinal guide rails 14 mounted on housing 12 and a transverse member 18 is suspended between longitudinal guide rails 14. Transverse member 18 is driven by a motor (not shown) along guide rails 14. A cutting tool 20 rides on transverse member 18. Cutting tool 20 has a cutting knife (not shown).

A main sensor 22 is shown attached to cutting tool 20. While sensor or detector 22 is shown attached to cutting tool 10, it is not necessary for it to be attached to it. Main sensor 22 may be an optical detector responsive to registration marks on sheet 40.

Cutting tool 20 moves along transverse member 18 and is driven by a motor (not shown). Cutting tool 20 is capable of moving laterally or longitudinally along work surface 16. Cutting tool 20 may have pressure and tangential controlled tungsten carbide blades, tungsten carbide blades, other blades that are generally known or lasers, which are not shown. The cutter driver (not shown) which controls cutting tool 20 is standard and is known in the art.

Referring to FIGURE 2, registration marks 44 are pre-printed on sheet 40. Sheet 40 has many registration marks 44 preprinted thereon, including several around each of the graphics areas 42a and 42b which are intended to be cut from sheet 40. (A variety of shapes, sizes, and colors for the marks are possible. In some embodiments, registration marks are circles, either filled or unfilled, of equal size. They may be anywhere from 3mm to 12mm in diameter, with a preferred outer diameter of 6.3 mm.) Registration marks 44 are adjacent to, but not contiguous with, the perimeters of preprinted graphics areas 42a and 42b.

The registration marks include an initial-position/orientation-determining subset 46 of marks which is on only one side of the graphics areas 42a and 42b. This subset 46 is placed only to one side of graphics areas 42a and 42b to facilitate rapid determination of the positions of subset 46 relative to work surface 16. It is possible for there to be more than one subset of unique initial-position/orientation-determining marks, but in such cases only one such subset need be sensed.

Main sensor 22 is connected to the input of the controller, part of the coordinate region locator (not shown as a discrete element) by cables 28 and 30. The controller is also connected to and drives cutting tool 20. The controller receives the input external data and compares it to the format and content of information which it has stored in it. For each graphics area 42a and 42b, the information stored in the controller is the location of the perimeter of the graphics area relative to the locations of registration marks 44 as printed on sheet 40. Specifically, the controller has information defining the position of the registration marks 44 and the intended cutting paths, information defining the position of the registration marks 44 with respect to initial-position/orientation-determining subset 46 of marks, and information defining the expected location of subset 46 on sheet-receiving surface 16.

After graphics areas 42a and 42b and registration marks 44 and initial-position/orientation-determining subset 46 of marks have been printed on sheet 40, sheet 40 is placed on sheet-receiving surface 16 at an initial position and orientation. When the controller instructs main sensor 22 to sense subset 46 but subset 46 is not found in the location expected by the controller, the controller instructs main sensor 22 to move in a predetermined pattern in order to determine the coordinate region of subset 46.

The controller instructs sensor 22 to find the precise positions of the mathematical centers of initial-position/orientation-determining subset of marks 46 and defines these positions in X-Y coordinates of work surface 16. This information is then used to determine the position and orientation of sheet 40 on work surface 16. Once the position and orientation of sheet 40 are known, the controller uses the stored information on the relative location of registration marks 44, in conjunction with sensors 22, to determine the precise positions of registration marks 44.

The controller compares the actual distance between the three registration marks (44) which are closest to a point on the intended cutting point, and adjusts the cutting path according to the changes between these registration marks using the information for their locations when printed on sheet 40. The adjustments are made by making changes in the X-Y coordinates of points along the cutting path.

The sensor or detector 22 may be a CCD camera, which is known in the art. The cutter drivers (not shown) are also known in the art. In operation, sensor 22 is caused to be positioned over a registration mark 44. Sensor 22 finds the mathematical center of a registration mark 44 and defines its position in X-Y coordinates of work surface 16. Two other registration marks 44 are located and their centers are defined by X-Y coordinates in like manner.

These data are inputted to the controller where the actual locations of registration marks 44 on ready-to-be-cut sheet 40 are compared to those of the registration marks in the predetermined cutting instructions. The predetermined cutting path which is a collection of X-Y coordinate sets is adjusted according to the actual X-Y coordinates of registration marks 44. These comparisons are made interactively throughout the cutting process, making the process a dynamic process.

The cutting path is adjusted according to the actual coordinates of the three registration marks 44 closest to a cutting point. When the cutting of an individual graphics area is completed, cutting tool 20 is caused to be lifted and moved to the next graphics area and the process is repeated.

In the operating mode, sheet material 40 is placed on work surface 16 and may be held in place by a vacuum which acts through the work surface. The cutting of graphics areas 42a and 42b is effected by movement of computer-controlled cutting tool 20 and computer-controlled transverse rail 18. The predetermined cutting instructions contained in the controller are based upon the graphics area which was originally printed on sheet 40. The cutting path is defined in X-Y coordinates.

As already noted, sensor 22 finds the locations of registration marks 44 and defines them in X-Y coordinates. This information is compared to the predetermined X-Y coordinates of the registration marks, and the cutting path along the perimeters of the graphics areas are adjusted according to the changes in the location of the three registration marks are closest to each cutting point. The cutting path is optimized and modified dynamically as the cutting proceeds; i.e., an appropriate final cutting path is determined.

FIGURE 3A illustrates sheet 40 placed on sheet-receiving surface 16 such that coordinate region 45 of subset 46 of marks is not within initial field of view 48 of main sensor 22. FIGURE 3A illustrates this situation within the context of a coordinate region locator. In the following detailed descriptions, two approaches for ascertaining the position and orientation of sheet 40 are described in parallel fashion; one is a coordinate region locator and the other is a reference feature identifier. Either of these approaches can be used during the process of ascertaining the position and orientation of sheet 40. The coordinate region locator uses subset 46; the reference feature identifier uses a reference feature set (e.g., see set 49 in FIGURE 3B). Such subset of registration marks and such reference feature set each, by itself, uniquely indicates such position and orientation.

Thus, referring to FIGURE 3B, within the context of a reference feature identifier, sheet 40 is shown placed on sheet-receiving surface 16. A reference feature set 49 (shown as two edges at one corner of sheet 40) is within coordinate region 47 of sheet-receiving surface 16, with region 47 not within initial field of view 48 of main sensor 22. Referring back to FIGURE 1, main sensor 22 is connected to the input of the controller, part of the reference feature identifier (not shown as a discrete element) by cables 28 and 30. The controller is also connected to and drives cutting tool 20. The controller receives the input external data and compares it to the format and content of information which it has stored in it. For each graphics area 42a and 42b, the information stored in the controller is the location of the perimeter of the graphics area relative to the locations of registration marks 44 as printed on sheet 40. Specifically, the controller has information defining the position of the registration marks 44 and the intended cutting paths, information defining the position of the registration marks 44 with respect to reference feature set 49, and information defining the expected location of set 49 on sheet-receiving surface 16.

After graphics areas 42a and 42b and registration marks 44 have been printed on sheet 40, sheet 40 is placed on sheet-receiving surface 16 at an initial position and orientation, illustrated in FIGURE 3B . When the controller instructs main sensor 22 to identify set 49 but set 49 is not found in the location expected by the controller, the controller instructs main sensor 22 to move in a predetermined pattern. The location expected by the controller is represented by initial field of view 48 of main sensor 22.

FIGURES 4A and 4B illustrate two predetermined patterns along which main sensor 22 is directed to move by the set of instructions of the coordinate region locator. In FIGURE 4A and 4B, one corner of sheet-receiving surface 16 is shown, along with one corner of sheet 40 containing subset 46. In both of these figures, movement of main sensor 22 is illustrated by consecutive fields of view F1, F2, F3..., etc., with initial field of view 48 (F1) aligning with the expected location of subset 46. FIGURE 4A illustrates a predetermined outwardly-expanding spiral pattern, and FIGURE 4B illustrates a predetermined L-shaped pattern. These examples of predetermined patterns are but two of many patterns which can be used in the coordinate region locator to place coordinate region 45 of subset 46 within the field of view of main sensor 22.

Information obtained by sensing subset 46 is then used to determine the position and orientation of sheet 40 on work surface 16. Once the position and orientation of sheet 40 are known, the controller uses the stored information on the relative location of registration marks 44, in conjunction with main sensor 22, to determine the precise positions of registration marks 44.

In a manner similar to FIGURES 4A and 4B, FIGURES 4C and 4D illustrate the same two predetermined patterns along which main sensor 22 is directed to move, but in this case by the controller of a reference feature identifier. The metrics obtained by sensing set 49 are then used to determine the position and orientation of sheet 40 on work surface 16. Once the position and orientation of sheet 40 are known, the controller uses the stored information on the relative location of registration marks 44, in conjunction with main sensor 22, to determine the precise positions of registration marks 44.

While FIGURES 4A through 4D illustrate predetermined patterns made of a series of discrete fields of view, the patterns of this invention also contemplate continuous movement and continuous viewing by the coordinate region locator or the reference feature identifier.

FIGURE 5 shows schematically another embodiment of the coordinate region locator. Main sensor 22 includes a zoom lens 26 which is used to enlarge the field of view of main sensor 22. When subset 46 is not in an expected location, the controller of the coordinate region locator instructs the zoom lens to zoom out to enlarge the field of view and determines the position of subset 46 in this enlarged field of view. Then, main sensor 22 is repositioned over sheet-receiving surface 16 such that coordinate region 45 of subset 46 is centered within the field of view of main sensor 22, after which main sensor 22 zooms back in, shrinking its field of view in order to allow precise sensing of the marks of subset 46. Two alternative procedures include zooming main sensor 22 back in either before or during such repositioning; regardless of which procedure is programmed, coordinate region 45 of subset 46 will end up within the shrunken field of view of main sensor 22.

FIGURE 5 also can be used to illustrate another embodiment of the reference feature identifier. Main sensor 22 includes a zoom lens 26 which is used to enlarge the field of view of main sensor 22. When reference feature set 49 is not in an expected location, the controller of the reference feature identifier instructs the zoom lens to zoom out to enlarge the field of view and determines the position of set 49 in this enlarged field of view. Then, main sensor 22 is repositioned over sheet-receiving surface 16 such that coordinate region 47 of set 49 is centered within the field of view of main sensor 22, after which main sensor 22 zooms back in, shrinking its field of view in order to allow precise sensing of the metrics of reference feature set 49. Two alternative procedures include zooming main sensor 22 back in either before or during such repositioning; regardless of which procedure is programmed, coordinate region 47 of set 49 will end up within the shrunken field of view of main sensor 22.

FIGURE 6 shows schematically yet another embodiment of the coordinate region locator. Main sensor 22 is mounted on main-sensor height adjustor 38. Main sensor 22 is moved along track 27 by a motor (not shown) away from and toward sheet-receiving surface 16 to enlarge and shrink respectively the field of view of main sensor 22. When subset 46 is not in an expected location, the controller of the coordinate region locator instructs main sensor 22 to move away from sheet-receiving surface 16, thereby enlarging the field of view of main sensor 22. The coordinate region locator then determines the position of subset 46 and directs the repositioning of main sensor 22 over sheet-receiving surface 16. Then, main sensor 22 is moved back toward sheet-receiving surface 16 to shrink the field of view, such that coordinate region 45 of subset 46 is within the field of view of main sensor 22.

In a similar fashion to the description of FIGURE 5, the physical configuration shown in FIGURE 6 also can be used as a portion of a reference feature identifier, with the controller (not shown) containing a set of instructions to instruct height adjustor 38 and to respond to reference feature set 49 (see FIGURES 4C and 4D).

FIGURE 7 shows schematically a coordinate region locator which includes secondary sensor 62 which has a larger field of view than main sensor 22. Operation of the coordinate region locator in this embodiment is similar to the operation of the embodiment illustrated in FIGURE 6, except that secondary sensor 62, the vertical position of which is fixed, takes the place of main sensor 22 in its raised position.

As with the descriptions of FIGURES 5 and 6, the physical configuration shown in FIGURE 7 also can be used as a portion of a reference feature identifier, with the controller (not shown) containing a set of instructions to instruct secondary sensor 62 and main sensor 22 and tailored to respond to reference feature set 49 (see FIGURES 4C and 4D).

FIGURE 8 illustrates schematically a coordinate region locator which includes rotation around one of two axes parallel to the plane of sheet-receiving surface 16. Rotation about one such axis is illustrated in FIGURE 8. When subset 46 is not in an expected location, the controller (not shown) of the coordinate region locator instructs main sensor 22 to rotate in a manner which changes the field of view of main sensor 22, thereby allowing the coordinate region locator to find coordinate region 45 of subset 46 outside of the initial field of view of main sensor 22. Main sensor 22 then determines the position of coordinate region 45 of subset 46, is repositioned over sheet-receiving surface 16, and rotated back to a normal vertical orientation such that coordinate region 45 of subset 46 is within the field of view of main sensor 22.

Again, as with the descriptions of FIGURES 5, 6, and 7, the physical configuration shown in FIGURE 8 also can be used as a portion of a reference feature identifier, with the controller (not shown) containing a set of instructions to instruct main sensor 22 to rotate in a manner which changes the field of view of main sensor 22, thereby allowing the reference feature identifier to find coordinate region 47 of set 49 (see FIGURES 4C and 4D) outside of the initial field of view of main sensor 22. Main sensor 22 then determines the position of coordinate region 47 of set 49, is repositioned over sheet-receiving surface 16, and rotated back to a normal vertical orientation such that coordinate region 47 of set 49 is within the field of view of main sensor 22.

FIGURES 9A and 9B illustrate several different types of directive indicia as part of other embodiments of a coordinate region locator. Shown in FIGURES 9A and 9B are corner portions of sheet-receiving surfaces 16 with corner portions of sheet 40 thereon. The corner portions of sheet 40 include subset 46.

FIGURE 9A shows circular directive indicia 80 which surround subset 46 such that the coordinate region locator can determine the location of coordinate region 45 of subset 46 when a portion of circular directive indicia 80 is within the field of view of main sensor 22, the curvature and orientation of circular indicia 80 indicating such location. Such circular directive indicia can be continuous as shown, or can be severely discontinuous as necessary to accommodate the graphics. In a similar manner, the size and orientation of arrow directive indicia 81 surrounding subset 46 in FIGURE 9B indicate the location of coordinate region 45 of subset 46.

FIGURE 9B also illustrates edges 83 of sheet 40, a corner 82 of sheet 40, and graphics image portion 84 which can be used in other embodiments of the coordinate region locator. These three types of directive indicia are but examples of alternative directive indicia which can be used by a coordinate region locator to locate coordinate region 45 of subset 46.

FIGURES 10A and 10B illustrate two additional types of reference feature sets (in addition to those illustrated in FIGURES 3B, 4C, and 4D) which can be identified by the reference feature identifier. Shown in FIGURE 10A is sheet 40 with graphics areas 42a and 42b thereon and reference feature set 41 at the upper left corner of sheet 40. Shown in FIGURE 10B is sheet 40 with graphics areas 42a and 42b thereon and reference feature set 51 at the upper left corner of sheet 40.

FIGURE 10A shows reference feature set 41 as a corner of sheet 40 which has a small section of the corner cut off. One group of metrics of set 41 includes the angle (with respect to the coordinate axes of surface 16, not shown) of the line defined by the edge of the cutoff corner and the two end points of the cutoff corner. If only one corner of sheet 40 has been cut off, then this group of metrics is adequate to uniquely ascertain position and orientation of sheet 40. Another group of metrics can include the angles of the cutoff edge and the two edges which meet the cutoff at its end points (all measured with respect to the coordinate axes of surface 16). In fact, there are numerous combinations of metrics which can be used based on such reference features. Further, if it can be assumed that the initial placement of sheet 40 on surface 16 is such that a particular corner is the corner nearest initial field of view 48 of sensor 22, then a smaller group of metrics is adequate for determining the position and orientation of sheet 40. In this way, the metrics of reference feature set 49 shown in FIGURES 3B, 4C, and 4D can be the angle of the edges of set 49 with respect to a known line of surface 16 or the angle of one edge and the coordinates of the corner point.

FIGURE 10B illustrates a different set 51 of reference features comprised of certain features of graphics area 42a and a corner of sheet 40. The group of metrics can be the coordinates of the three points indicated by the arrows from the number 51, one of which is the corner point itself. Just as in the description of set 41 in FIGURE 10A, it will be apparent to those familiar with this invention that other groups of metrics of set 51 can be used to adequately determine the position and orientation of sheet 40 on surface 16.

As indicated above, the method and apparatus of this invention significantly speed the process of locating precise positions of registration marks 44 and improve the efficiency of the overall process, and these advantages are made possible regardless of presence or absence of distortion in sheet 40 occurring after the graphics image and registration marks are printed thereon. In operation, sensor 22 is caused to be positioned over a registration mark 44. Sensor 22 finds the mathematical center of a registration mark 44 and defines its position on work surface 16. Two other registration marks 44 are located and their centers are defined in like manner. These data are inputted to the controller where the actual locations of registration marks 44 on sheet 40 are compared to those of the registration marks in the predetermined cutting instructions -- which are based on the pre-distortion positions of the graphics image(s) and registration marks 44. The predetermined cutting path is adjusted according to the actual (post-distortion) coordinates of registration marks 44. These comparisons are made interactively throughout the cutting process, making the process a dynamic process. The cutting path is adjusted according to the actual coordinates of the three registration marks 44 closest to a cutting point. When the cutting of an individual graphics area is completed, cutting tool 20 is caused to be lifted and moved to the next graphics area and the process is repeated.

The method and apparatus of this invention have a wide range of applications in a variety of industries. The invention also has application to sheets in the form of curved surfaces, in certain situations. Furthermore, the applicability of the invention is not limited to any particular kind or form of sheet.

Additionally, it should be noted that while two round marks are shown as initial-position/orientation-determining subset of marks 46, numerous other combinations of shapes and sizes of subset marks are sufficient to determine the position and orientation of sheet 40 on work surface 16. For example, with the sensor and controller properly programmed, a single rectangular mark would also provide sufficient information for this determination. In a similar fashion, the reference feature sets described are but a few of the many possible sets can be used in conjunction with a reference feature identifier to uniquely ascertain position and orientation of the sheet of material.

While the principles of this invention have been described in connection with specific embodiments, it should be understood clearly that these descriptions are made only by way of example and are not intended to limit the scope of the invention.

CLAIMS

1. A method for cutting a graphics area from a sheet of material which includes such graphics area, comprising:

- applying a plurality of registration marks on the sheet of material at and about the graphics area in predetermined positions with respect thereto at the time the graphics which define such graphics area are applied, the plurality of registration marks including an initial-position/orientation-determining subset which is located on no more than one side of the graphics area; and, at the time of cutting, performing the following steps:
- placing the graphics sheet of material on a sheet-receiving surface with the initial-position/orientation-determining subset adjacent to a registration mark main sensor;
- sensing the subset to ascertain the position and orientation of the sheet of material and to infer approximate positions of the plurality of registration marks thereon;
- sensing the precise positions of the registration marks on the sheet of material; and
- cutting the graphics area from the sheet of material in response to the precise positions of the registration marks with respect to the graphics area at that time,

whereby cutting occurs precisely despite two-dimensional distortion of the sheet of material prior to cutting.

2. The method of claim 1 wherein the sensing and cutting are carried out in response to a set of instructions from a controller.

3. The method of claim 2 wherein the sheet-receiving surface has an X and Y coordinate grid thereon and further comprising:

- retaining the sheet of material at a user-selected location thereon such the sheet of material overlaps the X and Y coordinate grid;
- the step of sensing the precise positions of the registration marks on the sheet of material including acquiring the X and Y coordinates which are overlapped by the registration marks;

- the cutting step including comparing the X and Y coordinates which are overlapped by the registration marks with a reference set of X and Y coordinates, the comparing being carried out by the controller, the controller having a programmed set of predetermined cutting instructions which includes reference X and Y coordinates for the registration marks and also includes the predetermined positions thereof with respect to the perimeter of the graphics area when the graphics area and registration marks are first applied to the sheet of material; and
- the cutting step further including setting a final cutting path based on the comparing step, such final cutting path corresponding to the perimeter of the graphics area of the sheet of material even though such perimeter is distorted after the applying step.

4. The method of claim 1 wherein the sheet has a plurality of graphics areas thereon and a corresponding plurality of sets of the registration marks.

5. The method of claim 1 wherein:

- the sheet of material is a laminate having (a) a face layer bearing the graphics area and registration marks and (b) a backing layer; and
- the cutting is face cutting only.

6. The method of claim 1 wherein the initial-position/orientation-determining subset is a pair of registration marks in tandem relationship to each other.

7. The method of claim 6 wherein:

- the registration marks are round areas having mathematical centers; and
- the sensing step includes processing sensed data to find the mathematical centers thereof.

8. In a method for cutting a graphics area from a sheet of material bearing such graphics area and a plurality of registration marks in predetermined positions with respect thereto, the improvement wherein a subset of the marks is an initial-position/ orientation-determining subset which is on no more than one side of the graphics area, and the method includes:

- placing the sheet of material on a sheet-receiving surface;
- sensing the subset in the field of view of a main sensor to ascertain the position and orientation of the sheet of material and to infer approximate positions of the plurality of marks;
- if the subset is not in an expected location, automatically determining the coordinate region of the subset on the sheet-receiving surface;
- in response to the determining step, automatically repositioning the main sensor to the coordinate region such that the subset is within the field of view of the main sensor;
- sensing the precise positions of the marks; and
- cutting the graphics area from the sheet in response to the precise positions of the marks with respect to the graphics area.

9. The method of claim 8 wherein:

- the automatic determining step includes enlarging the field of view of the main sensor and locating the coordinate region of the subset within the enlarged field of view; and
- the automatic repositioning includes shrinking the field of view of the main sensor such that the subset is within the field of view of the main sensor.

10. The method of claim 8 wherein the automatic determining step includes locating the coordinate region of the subset within the field of view of a secondary sensor.

11. The method of claim 8 wherein automatically determining the coordinate region of the subset includes sensing directive indicia on the sheet of material which indicate the coordinate region of the subset, the directive indicia being outside the coordinate region of the subset.

12. The method of claim 8 wherein automatically determining the coordinate region of the subset includes:

- moving the main sensor in a predetermined pattern surrounding the expected location of the subset; and
- stopping the movement of the main sensor when the coordinate region of the subset is located within the field of view of the main sensor.

13. The method of claim 8 wherein:

- the automatic determining step includes determining (a) the direction from the expected location to the actual location and (b) the distance between the expected location and the actual location; and
- the repositioning step is movement in the determined direction for the determined distance.

14. In a method for cutting at least one graphics area from a sheet of material bearing a combination of such graphics area(s) and a plurality of registration marks in predetermined positions with respect to the graphics area(s), such combination being in a predetermined approximate position and orientation with respect to a set of reference features of the sheet, the improvement comprising:

- placing the sheet of material on a sheet-receiving surface;
- automatically establishing whether the reference features are in an expected coordinate region on the sheet-receiving surface;
- if the reference features of the sheet of material are not in the expected coordinate region, automatically determining the coordinate region of the reference features on the sheet-receiving surface;
- sensing the metrics of the reference features to ascertain the position and orientation of the sheet of material;
- inferring there from the approximate positions of the registration marks;
- sensing the precise positions of the marks with a main sensor; and
- cutting the graphics area(s) from the sheet of material in response to such precise positions.

15. The method of claim 14 wherein automatically determining the coordinate region of the reference features includes:

- enlarging the field of view of the main sensor;
- locating the reference features within the enlarged field of view; and
- shrinking the field of view of the main sensor such that the reference features are within the field of view of the main sensor.

16. The method of claims 9 or 15 wherein enlarging and shrinking the field of view of the main sensor includes zooming a lens of the main sensor.

17. The method of claims 9 or 15 wherein:

- the enlarging step includes increasing the distance between the main sensor and the sheet of material; and
- the shrinking step includes decreasing the distance between the main sensor and the sheet of material.

18. The method of claim 14 wherein automatically determining the coordinate region of the reference features includes locating the reference features within the field of view of a secondary sensor.

19. The method of claim 14 wherein automatically determining the coordinate region of the reference features includes sensing an edge of the sheet of material.

20. The method of claim 14 wherein automatically determining the coordinate region of the reference features includes sensing an adjacent pair of edges of the sheet of material.

21. The method of claim 14 wherein automatically determining the coordinate region of the reference features includes sensing a predefined graphics feature of the sheet of material.

22. The method of claim 14 wherein automatically determining the coordinate region of the reference features includes sensing two predefined graphics features of the sheet of material.

23. The method of claim 14 wherein automatically determining the coordinate region of the reference features includes:

- moving the main sensor in a predetermined pattern surrounding the expected coordinate region of the reference features; and
- stopping the movement of the main sensor when the reference features are within the field of view of the main sensor.

24. The method of claims 12 or 23 wherein the moving step includes rotating the main sensor such that the field of view changes.

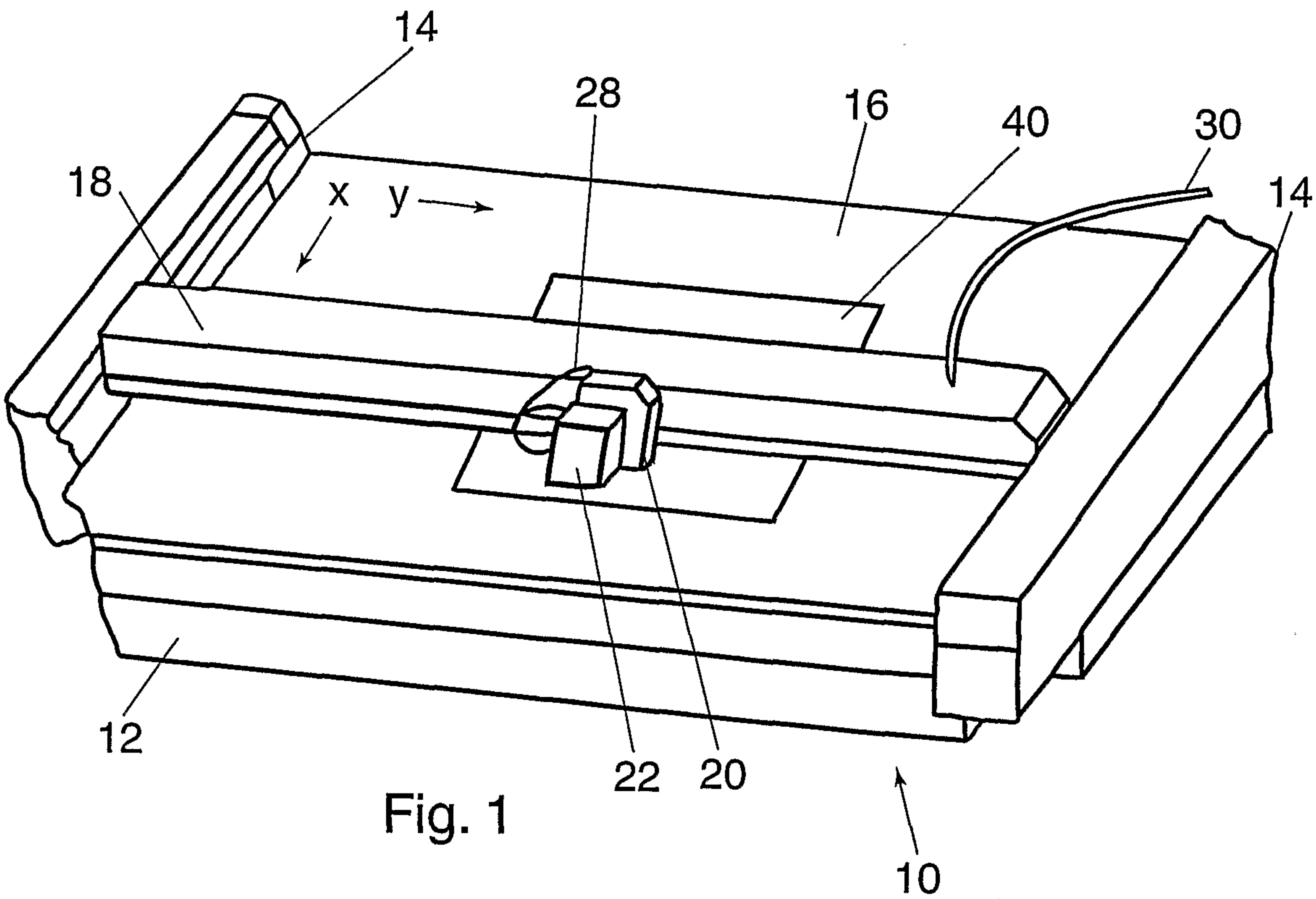


Fig. 1

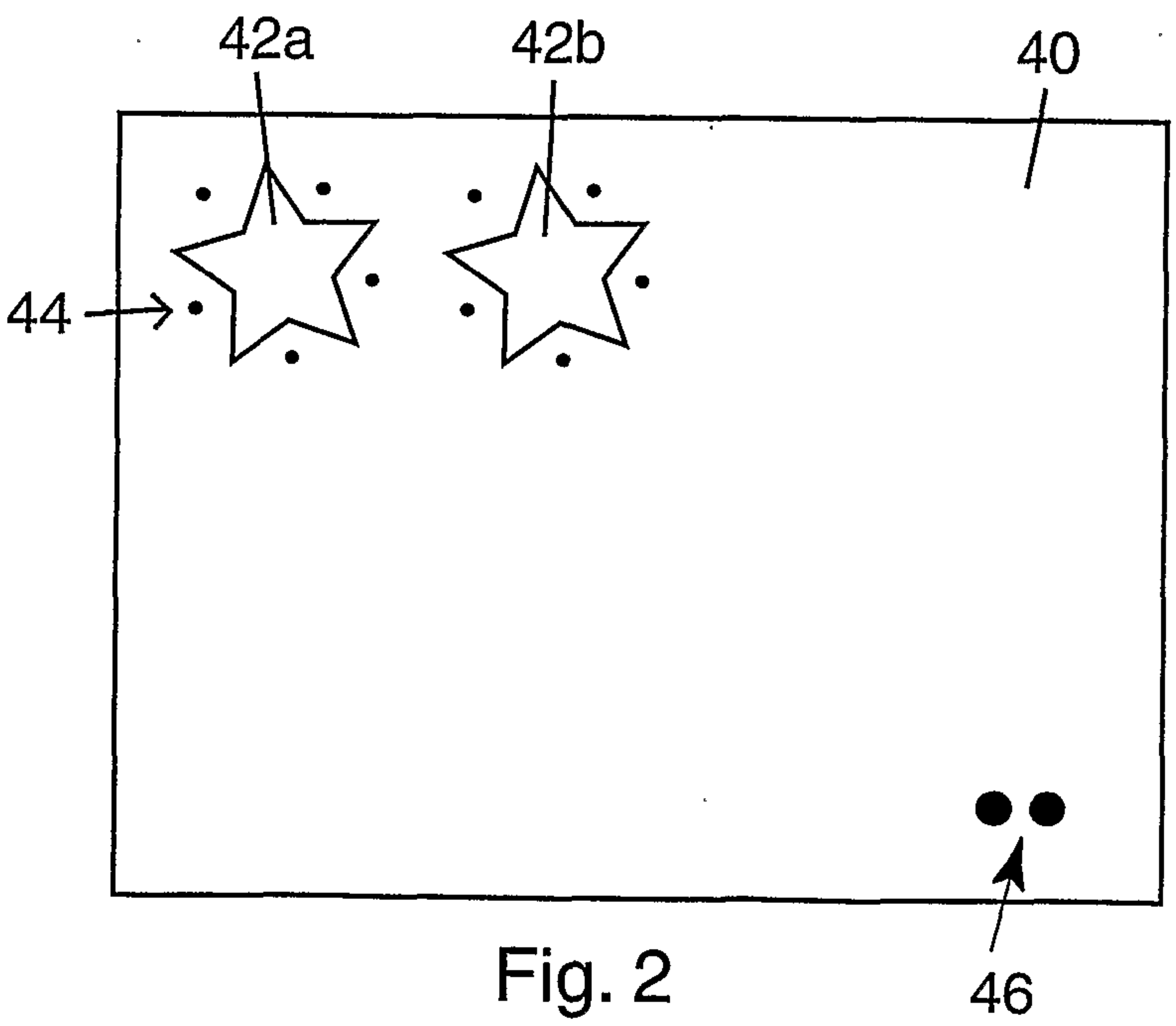


Fig. 2

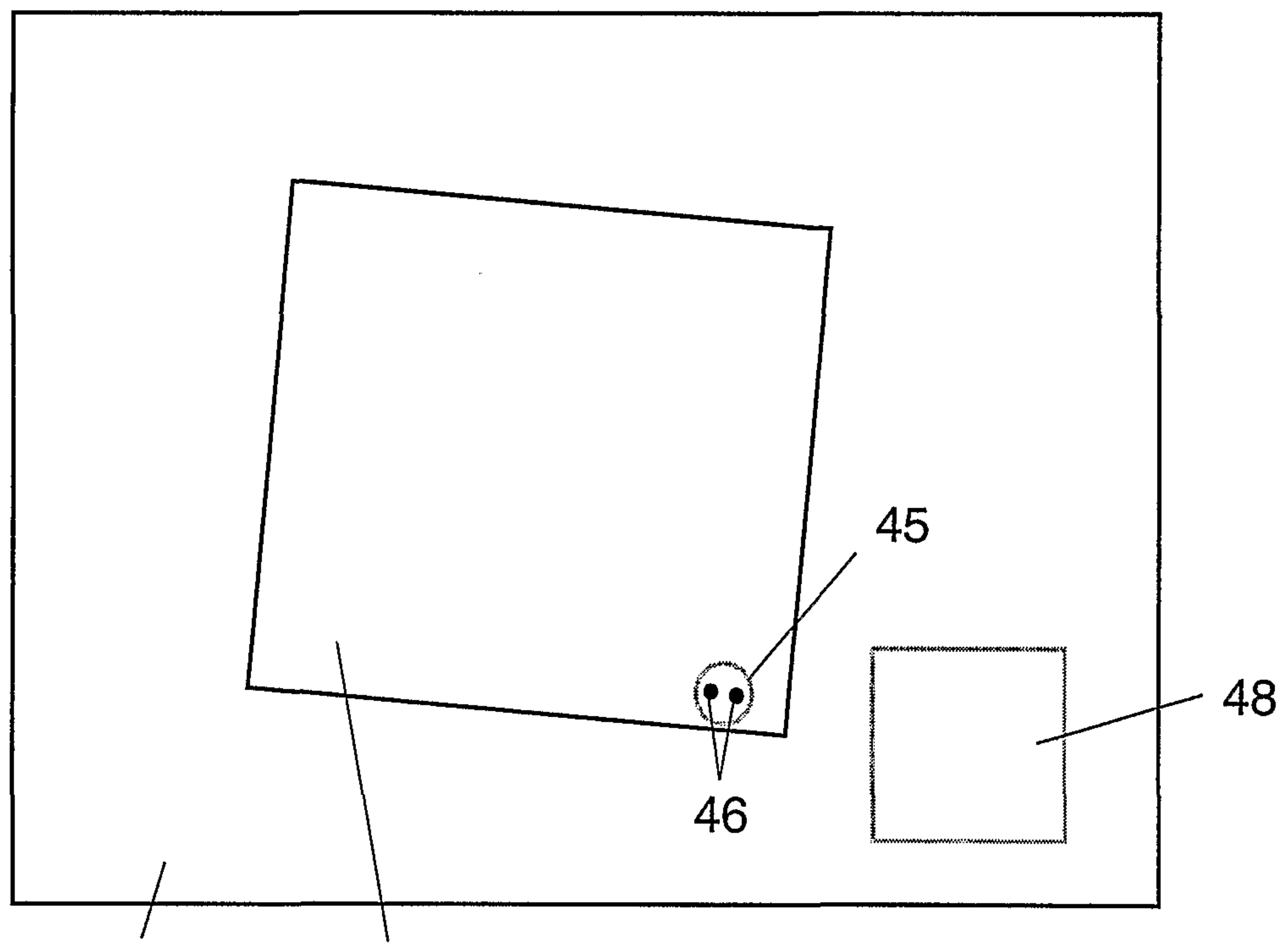


Fig. 3A

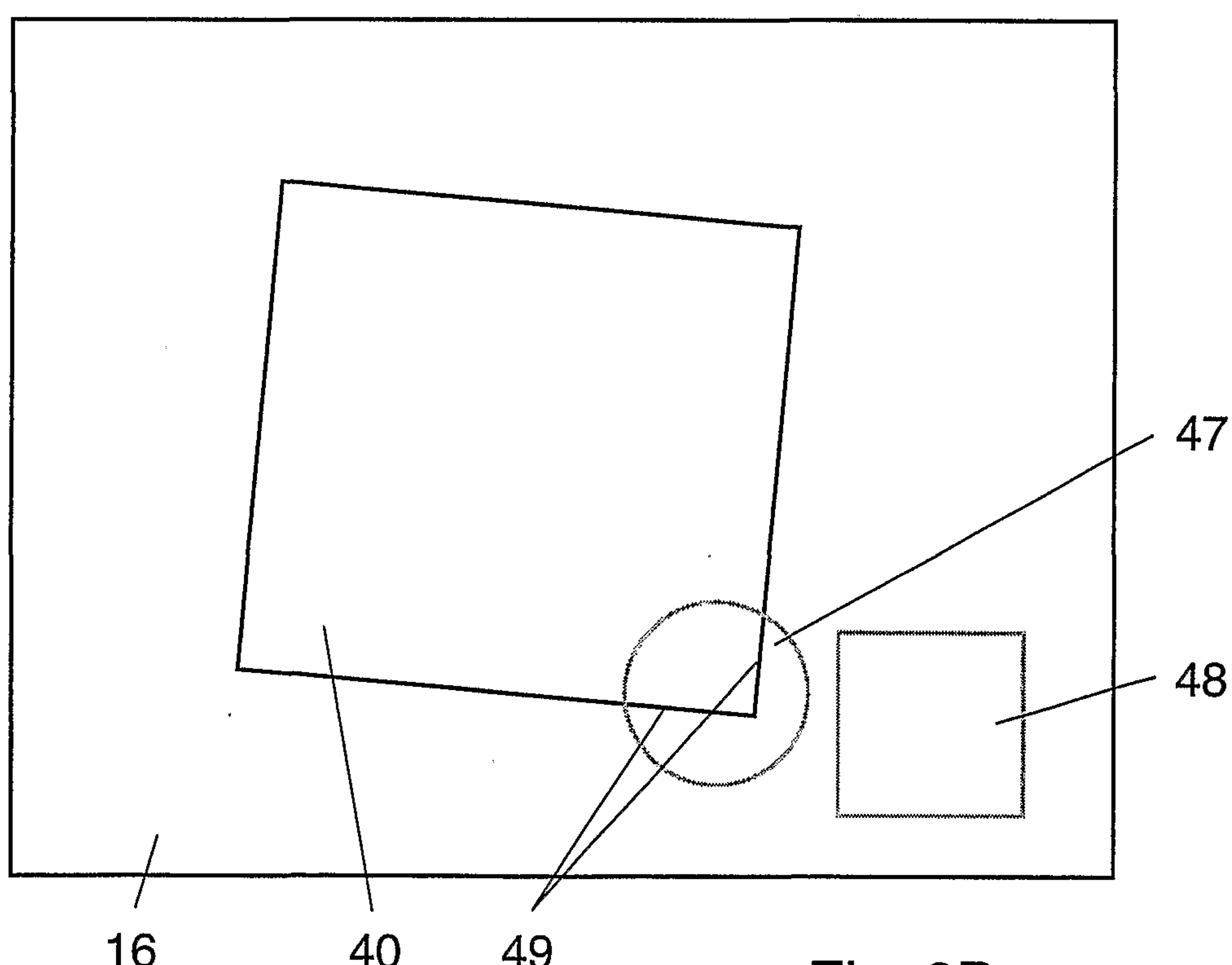
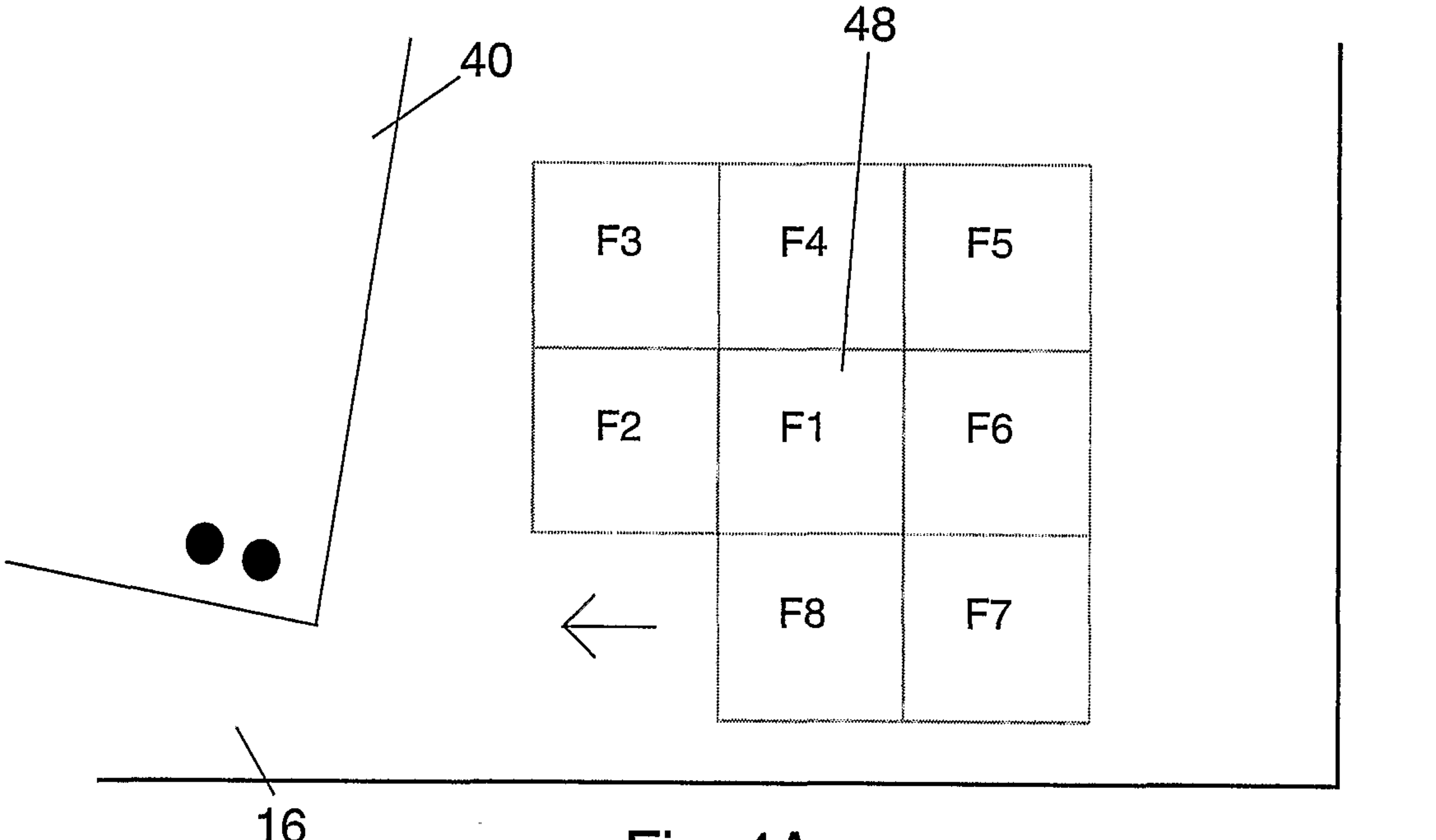


Fig. 3B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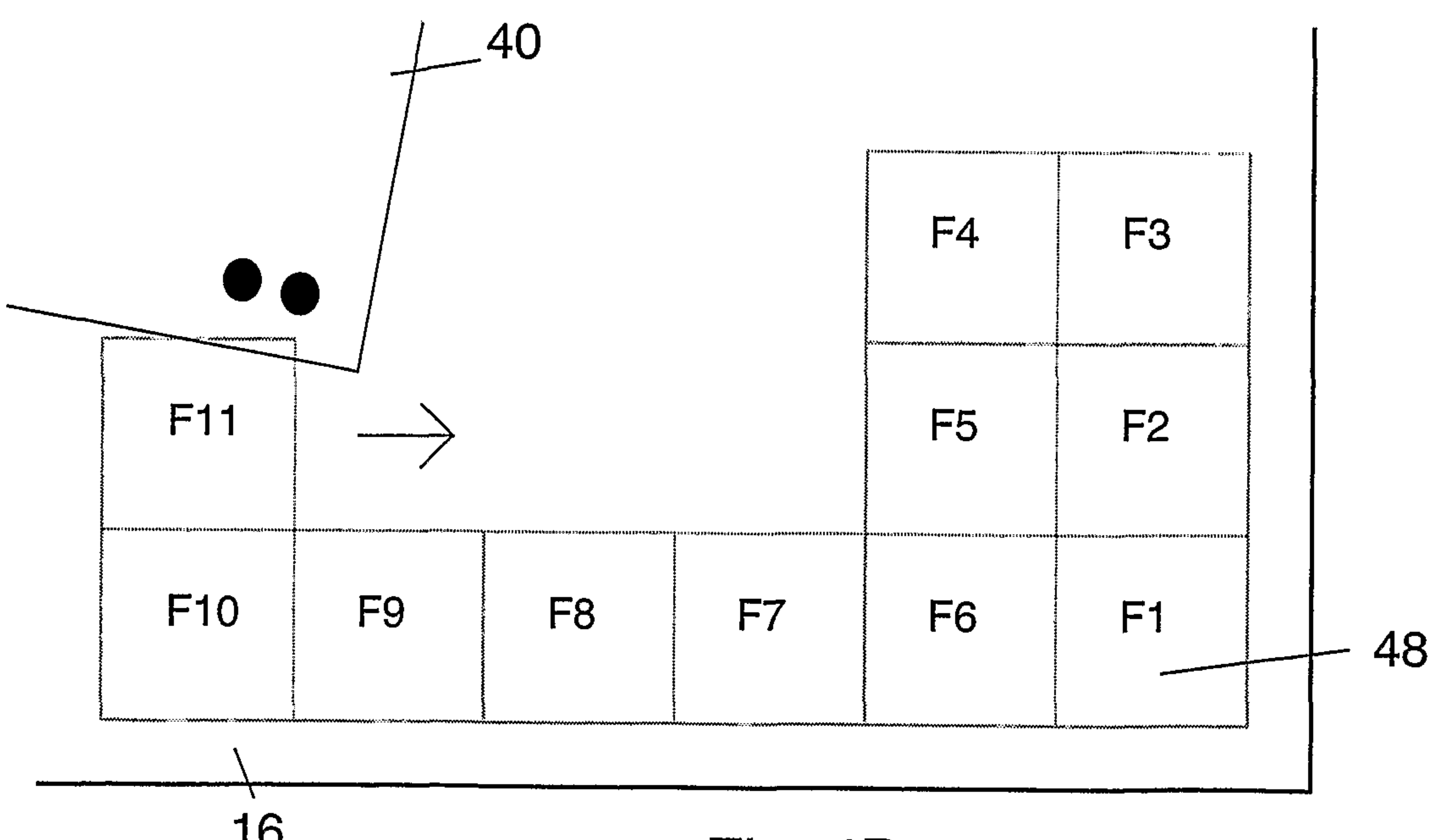
40
F3
F4
F5
F2
F1
F6
F8
F7
16

Fig. 4A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F9
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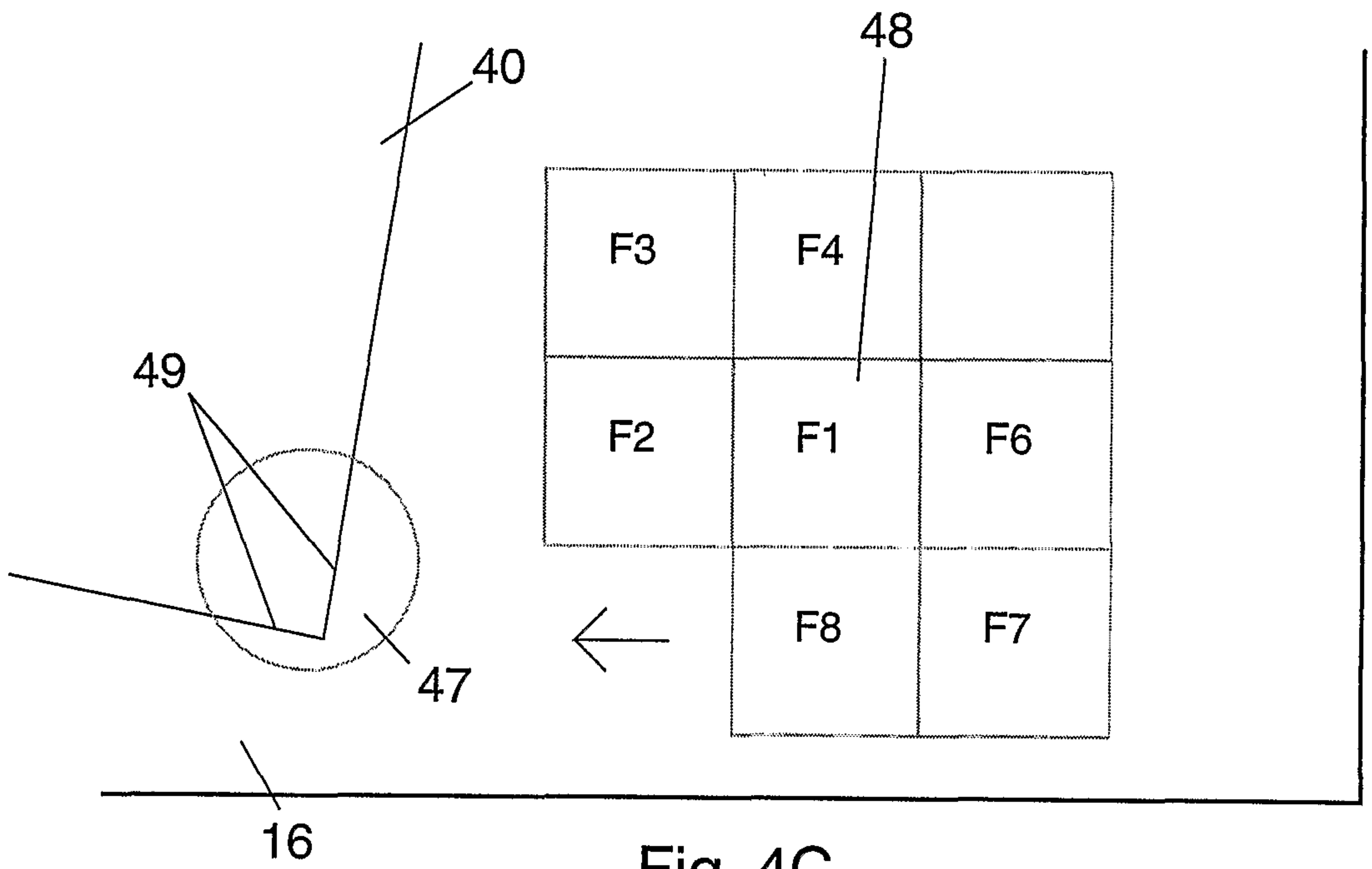
F7
F6
F1
48
16

Fig. 4B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F3
F4
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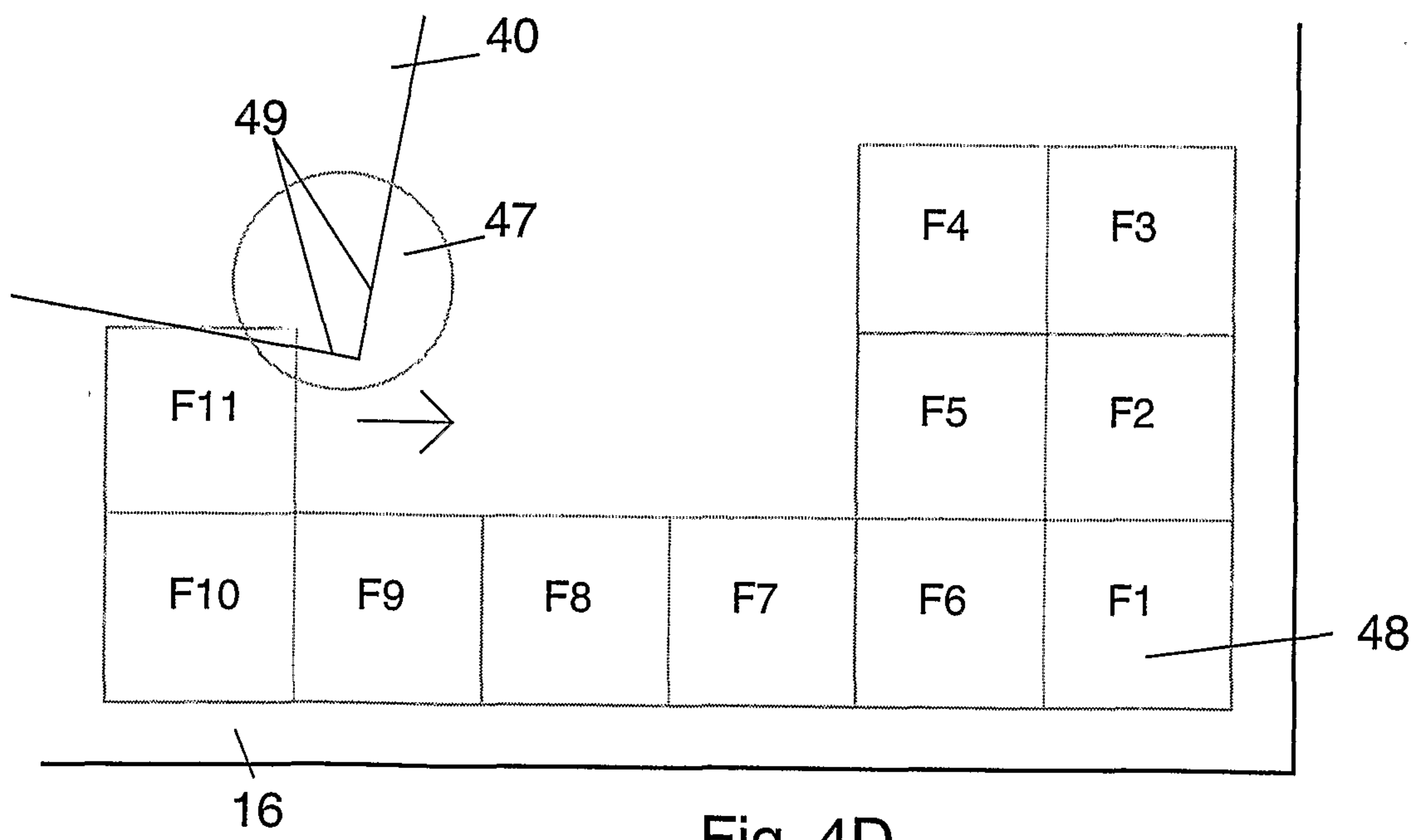
F2
F1
F6
F8
F7
47
16

Fig. 4C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F6
F1
48
16

Fig. 4D

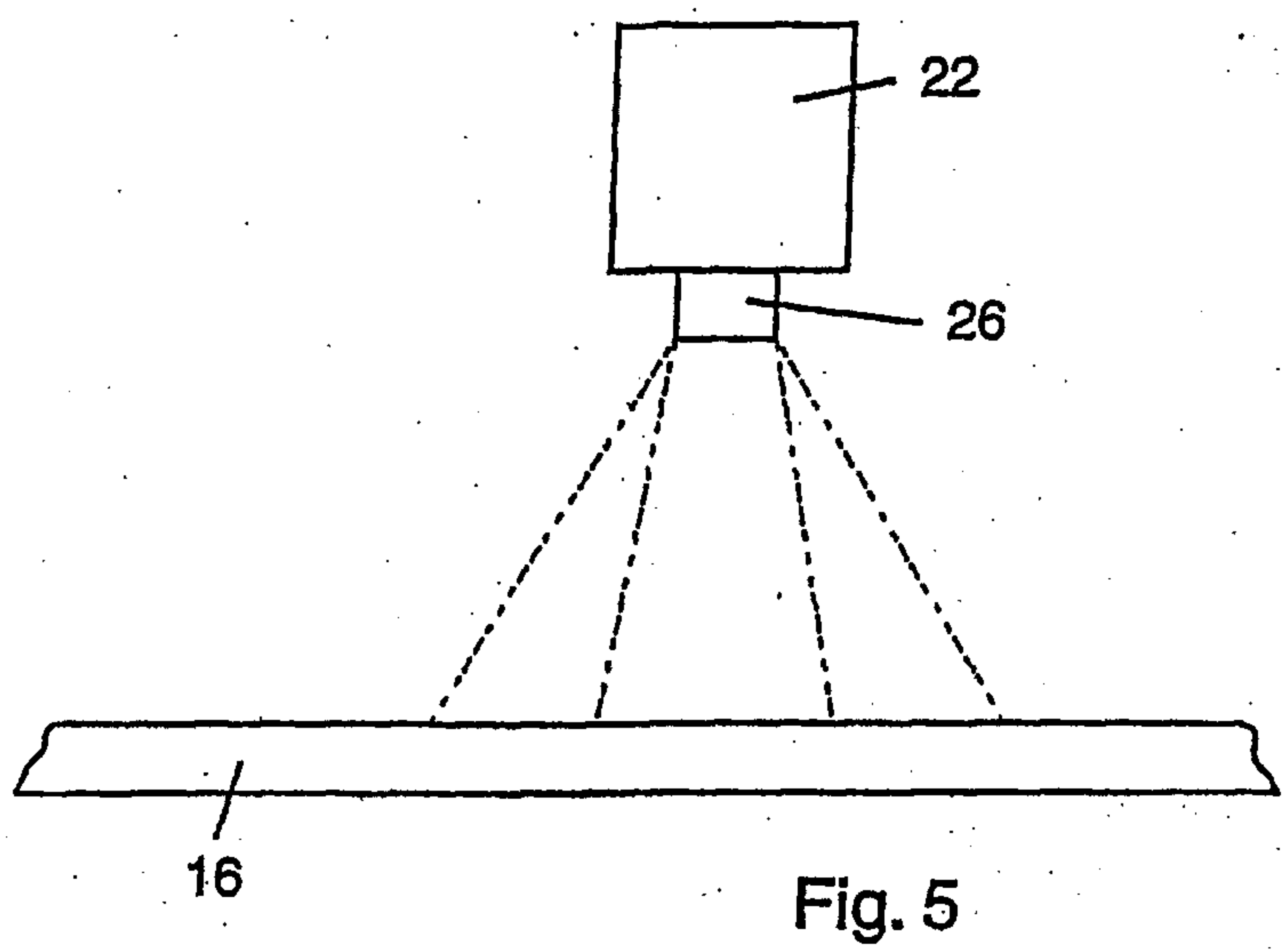


Fig. 5

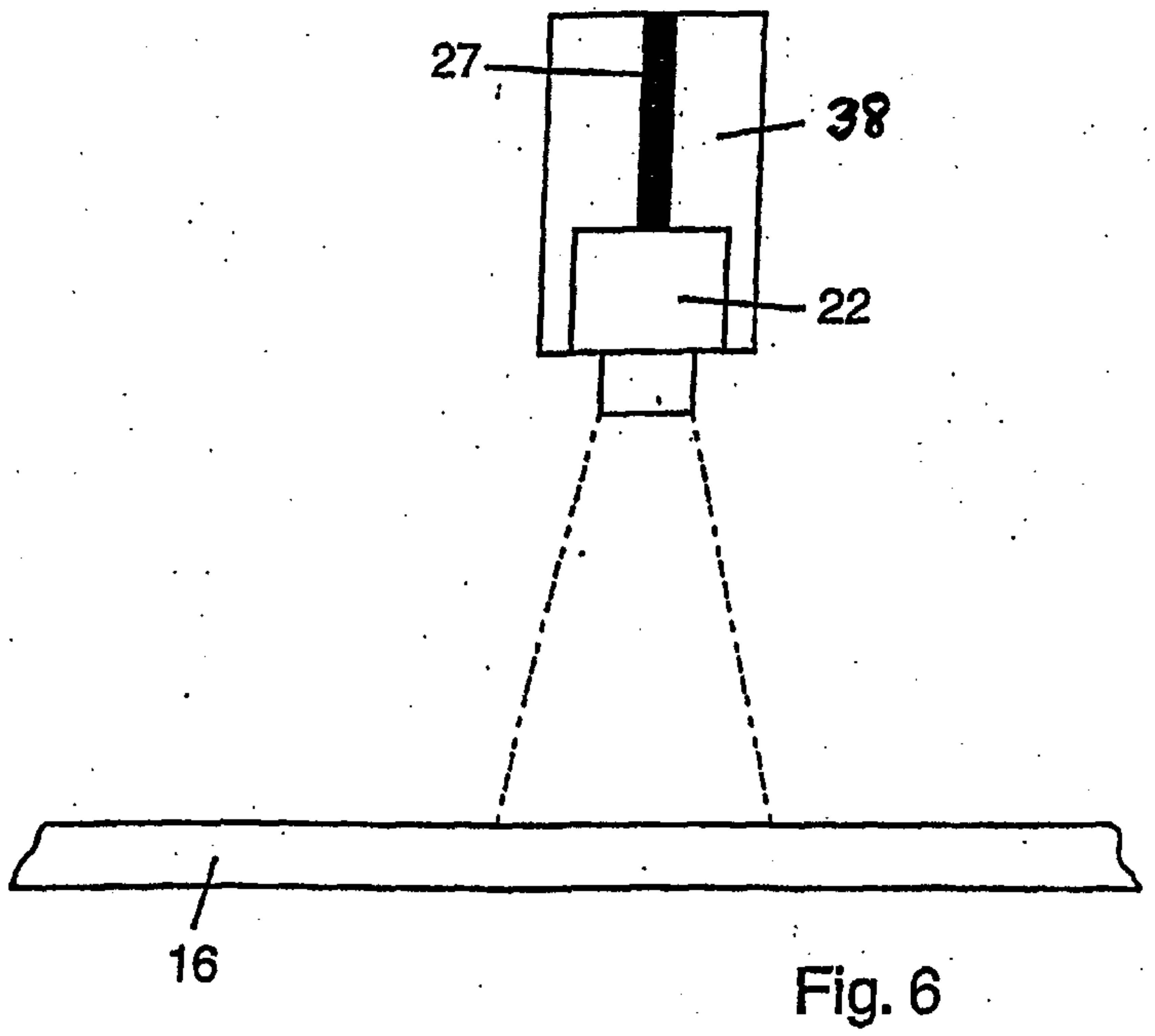


Fig. 6

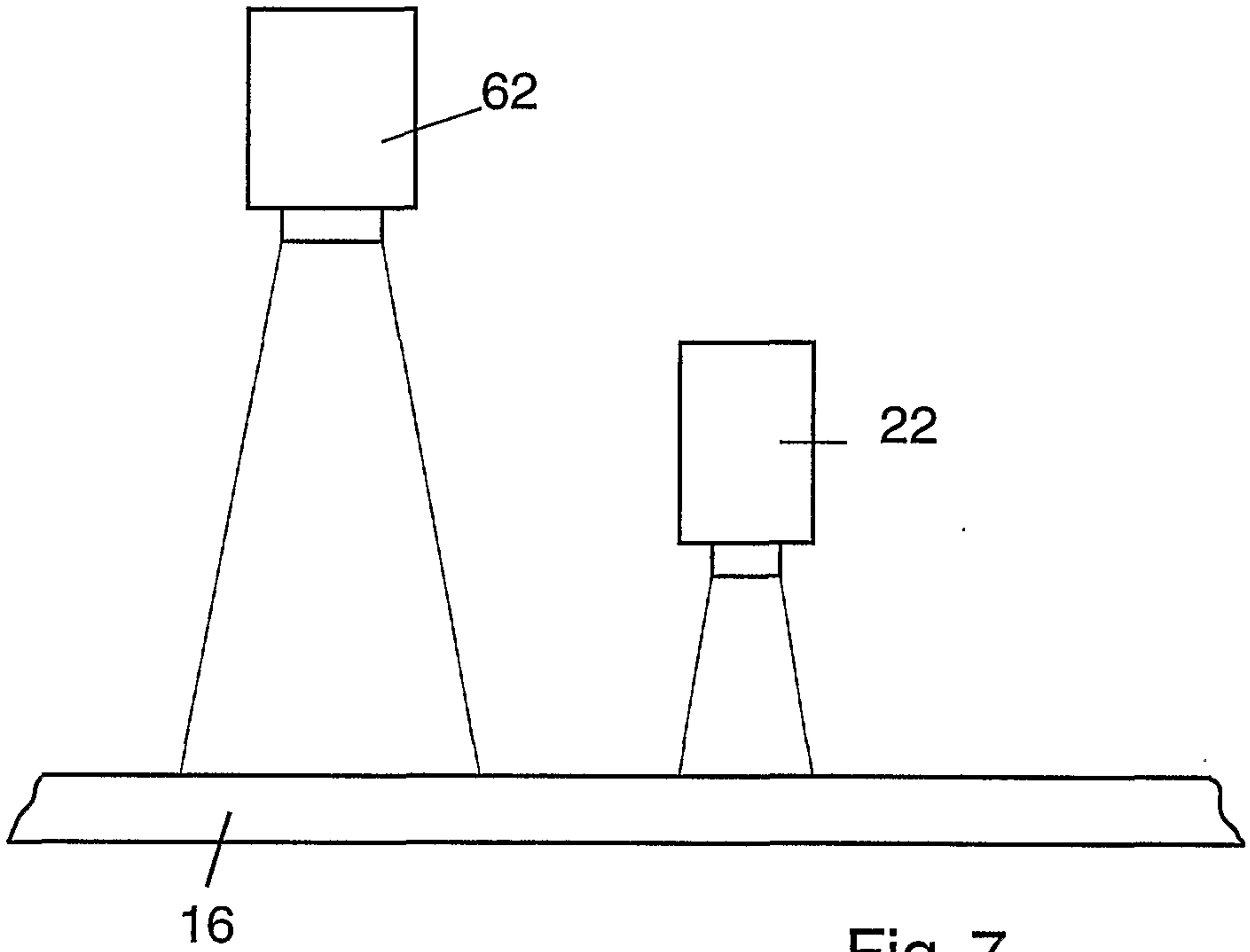


Fig. 7

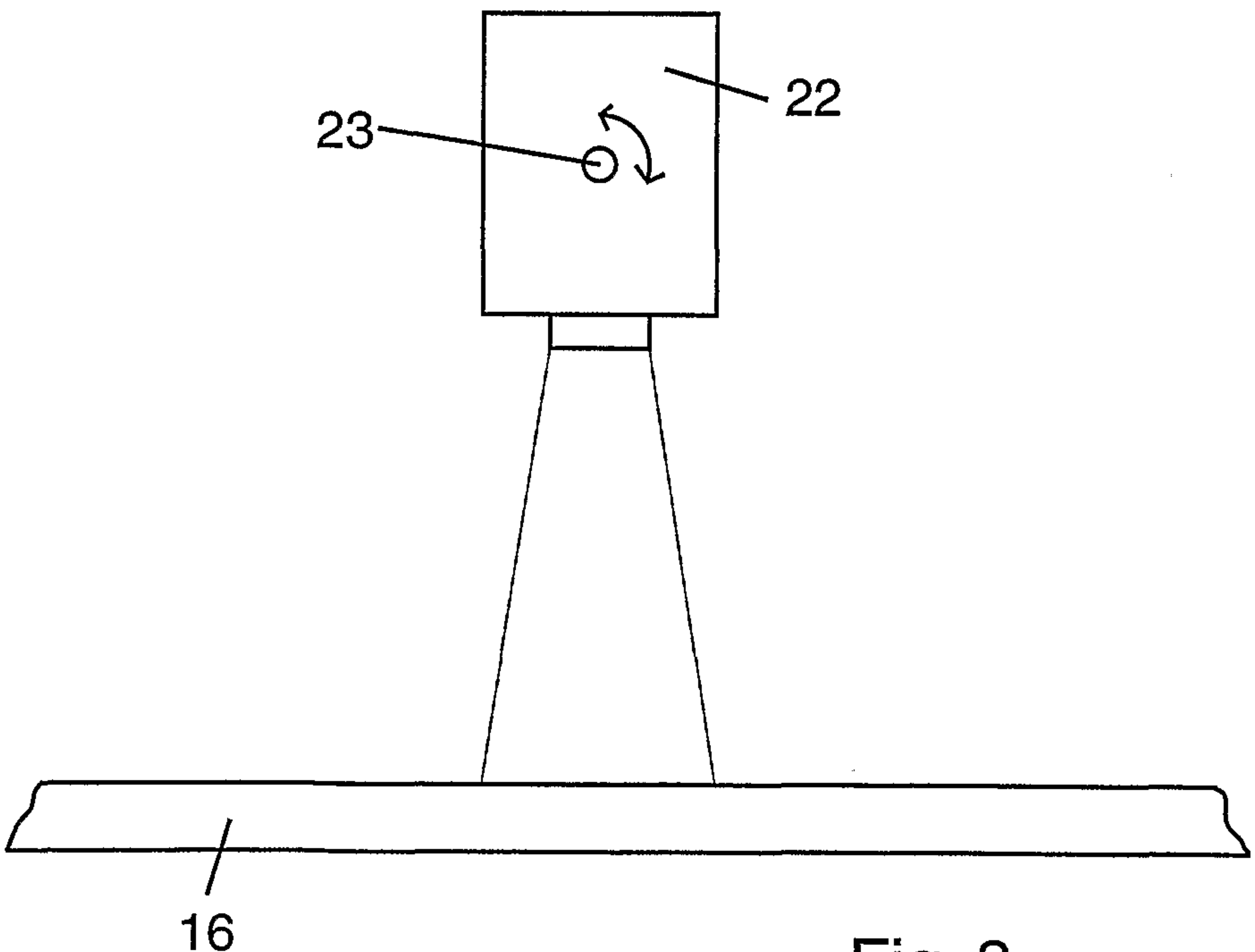


Fig. 8

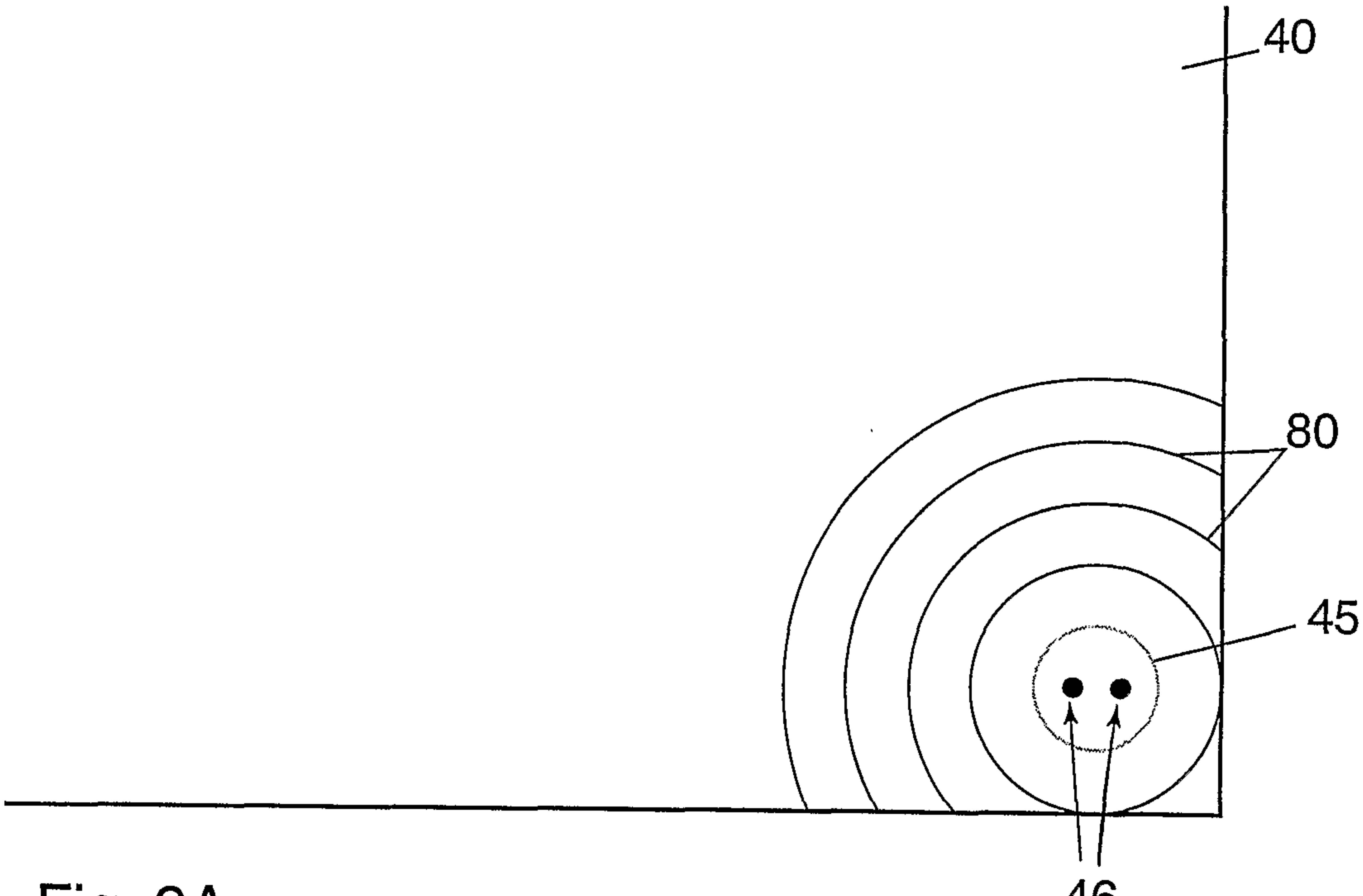


Fig. 9A

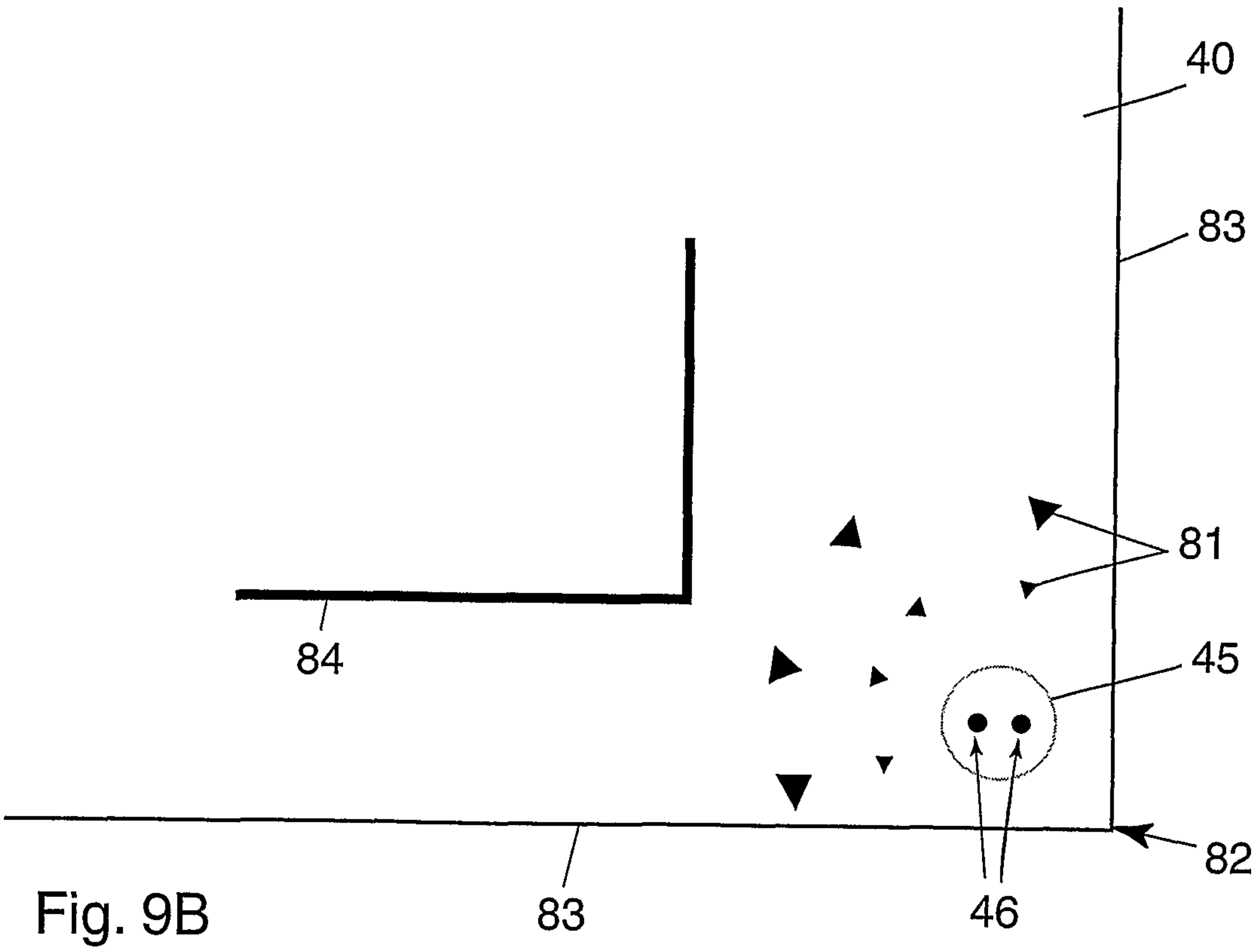


Fig. 9B

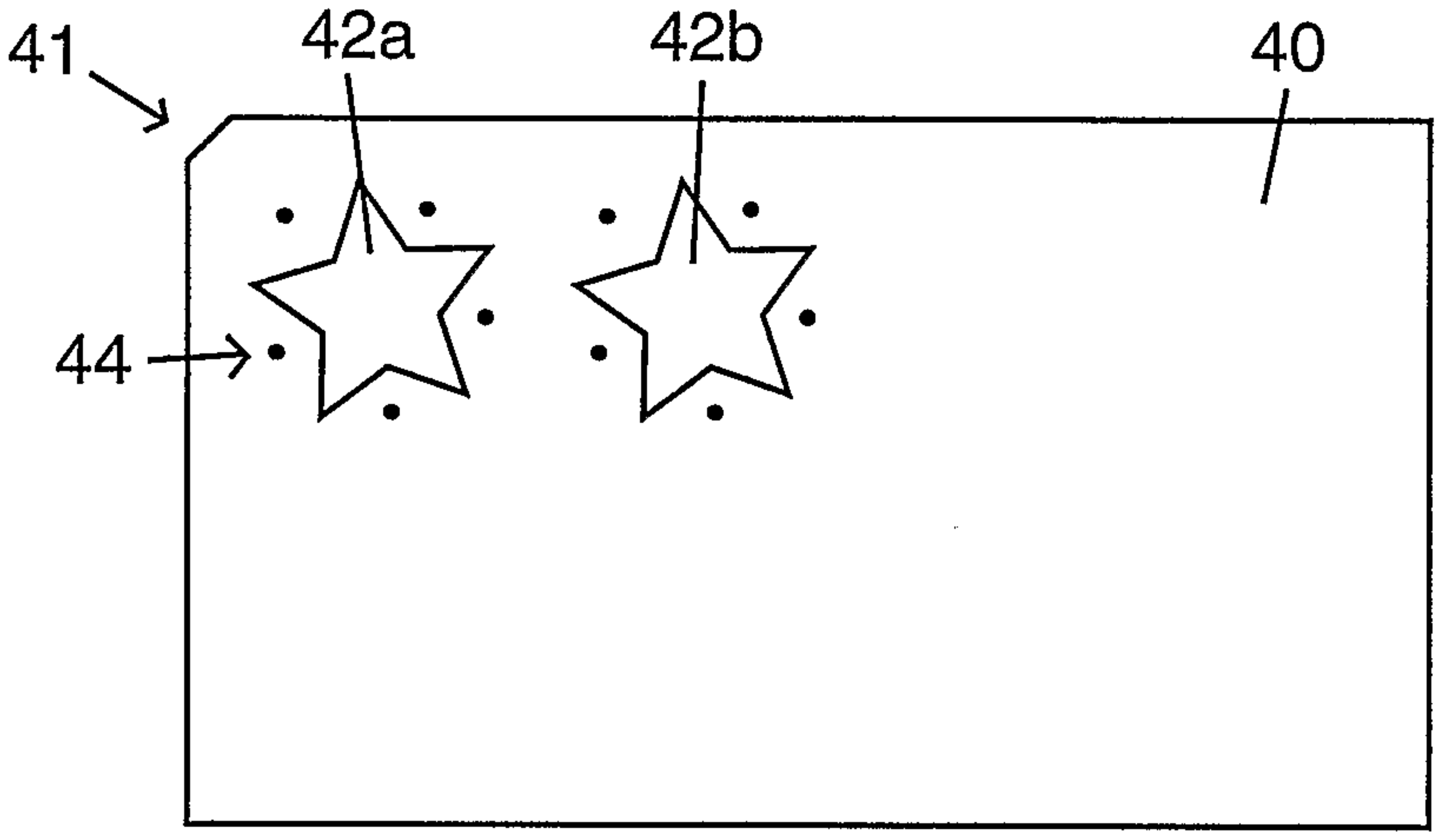


Fig. 10A

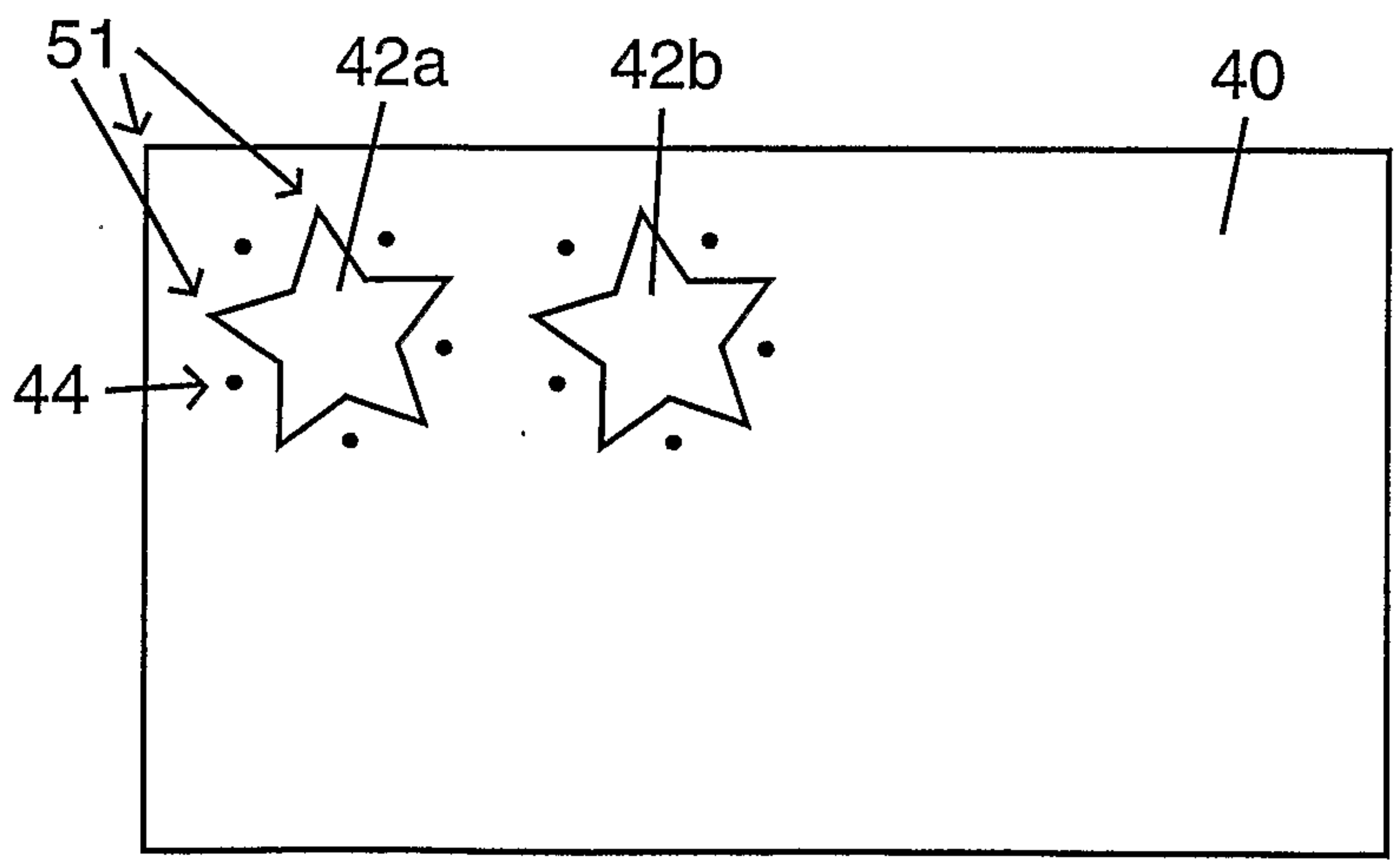
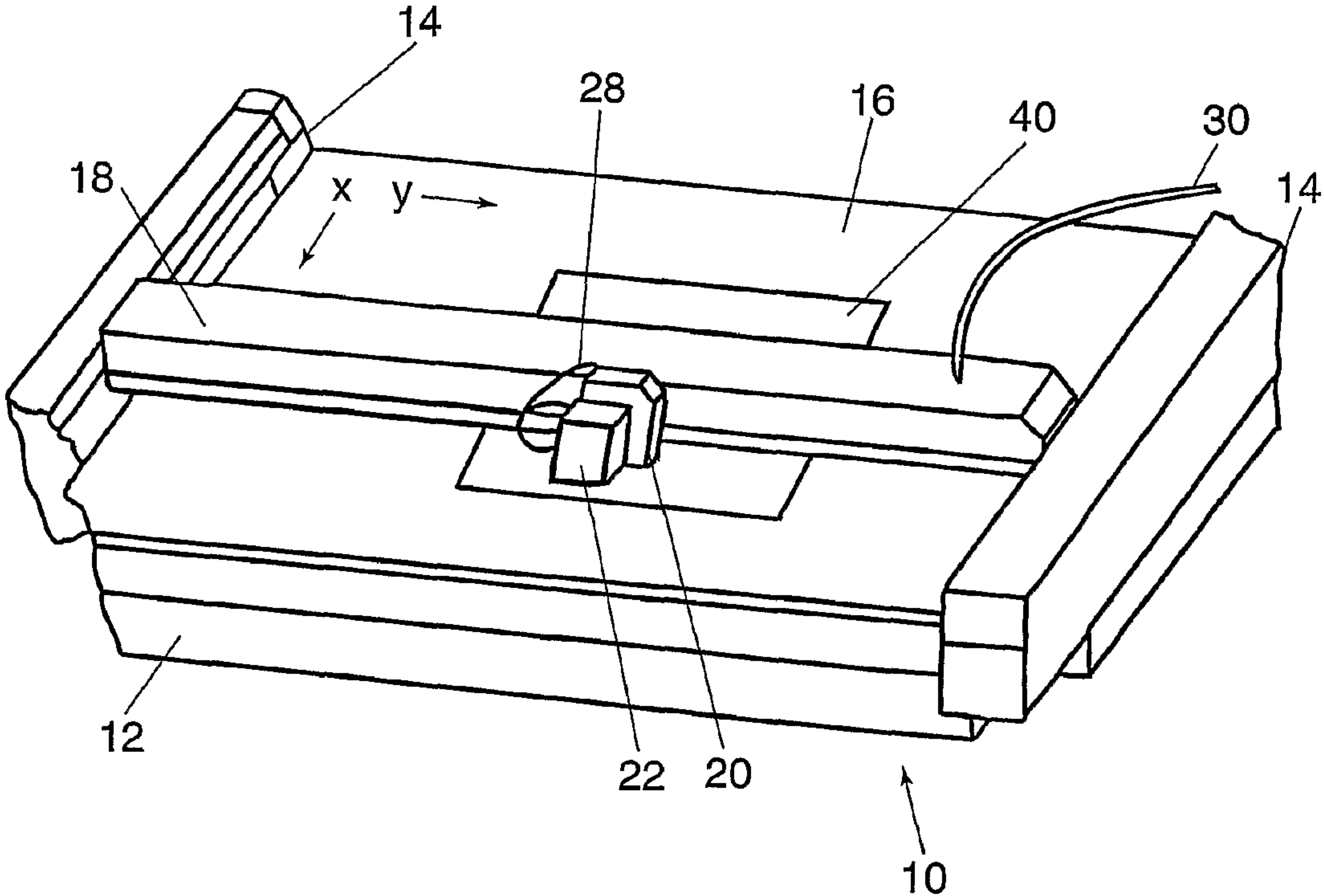


Fig. 10B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