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(57) Abrégé/Abstract:
A storage rack vibration isolator for a storage rack system installed on a floor comprising a first mounting plate connectable to the storage rack system, a second mounting plate connectable to the floor. An elastomeric component extending between these mounting plates and is operatively attached to them so that during seismic events the first and second mounting plates remain attached to the elastomeric component as the elastomeric component is placed in shear while said first and second mounting plates are able to move in planes substantially parallel to each other. The elastomeric component comprises at least one elastomeric member made of material that is capable of absorbing and dissipating the energy of ground movement imparted to the storage rack system during seismic events, while the material enables the storage rack system to move a sufficient distance relative to the floor to lower the natural frequency of the storage rack system in at least one horizontal direction.

Abstract

A storage rack vibration isolator for a storage rack system installed on a floor comprising a first mounting plate connectable to the storage rack system, a second mounting plate connectable to the floor. An elastomeric component extending between these mounting plates and is operatively attached to them so that during seismic events the first and second mounting plates remain attached to the elastomeric component as the elastomeric component is placed in shear while said first and second mounting plates are able to move in planes substantially parallel to each other. The elastomeric component comprises at least one elastomeric member made of material that is capable of absorbing and dissipating the energy of ground movement imparted to the storage rack system during seismic events, while the material enables the storage rack system to move a sufficient distance relative to the floor to lower the natural frequency of the storage rack system in at least one horizontal direction.

Storage Rack Vibration Isolators and Related Storage Racks

Background

Commercial and industrial storage rack systems are designed to hold various quantities of items and materials of different sizes, shapes and weights. While they vary in structure, storage rack systems normally include a series of interconnected steel columns, each of which rests on a solid floor such as a large slab of concrete. Beams are normally installed across adjacent pairs of columns. Shelving or pallets installed across pairs of beams normally hold the items or materials being stored. The columns bear the weight of the stored items or materials and transfer that weight to a base at the bottom of each column and from the base to the floor on which the columns are installed.

Storage rack systems can be installed in outdoor areas, factories, warehouses and large box retail stores located in all geographic areas. In some of these areas, storage rack systems are subjected to potentially significant seismic forces resulting from earthquakes. While storage rack systems can withstand the vibrations caused by low and moderate levels of seismic forces, increased levels of seismic forces can cause damage to storage rack systems or can cause items or materials to fall off the shelves or pallets of the storage rack systems on which they are stored.

Summary

The effects of seismic forces on a storage rack system mounted on a floor are reduced through the use of storage rack vibration isolators constructed according to this invention and installed on the storage rack systems. According to one embodiment, a storage rack vibration

isolator comprises a first mounting plate connectable to the storage rack system, a second mounting plate connectable to the floor, and an elastomeric component extending between and operatively attached to said first and second mounting plates. During seismic events the first and second mounting plates remain attached to the elastomeric component while the first and second mounting plates are able to move in planes substantially parallel to each other. The elastomeric component is made up of at least one elastomeric member made of material that is capable of absorbing and dissipating the energy of ground movement imparted to the storage rack system during seismic events so as to lower the natural frequency of the storage rack system in at least one horizontal direction.

Controlling the stiffness characteristics of the elastomeric members within certain preselected limits can optimize the reduction of the seismic forces on a storage rack system. The elastomeric component could be chosen to reduce the natural frequency of the storage rack system to about 0.9 Hz or less or ideally to about 0.5Hz or less. The elastomeric member could also be made from material that has a damping loss factor greater than about 0.1.

According to another embodiment, the storage rack vibration isolator also comprises a first mounting plate connectable to the storage rack system, a second mounting plate connectable to the floor, and an elastomeric component extending between and operatively attached to said first and second mounting plates such that during seismic events the first and second mounting plates remain attached to the elastomeric component while the first and second mounting plates are able to move in planes substantially parallel to each other. In this embodiment the elastomeric component is made up of at least two elastomeric members with at least one intermediate plate positioned between every two of the at least two elastomeric members.

The elastomeric members could be made of material such as polyisoprene, polyisoprene blend, butyl rubber, acryl rubber, polyurethane, flurorubber, polysulfide rubber, ethylene-

propylene rubber (EPR and EPDM), Hypalon, chlorinated polyethylene, ethylene-vinyl acetate rubber, epichlorohydrin rubber, chloroprene rubber, silicone, or other heavily damped elastomer.

According to various other embodiments, an advantage can be obtained by using a structure to restrict the movement of the elastomeric component of the storage rack vibration isolator to substantially one horizontal direction, or to substantially restrict its movement in the vertical direction, or substantially restrict its movement in both the one horizontal direction and in the vertical direction. Nevertheless, even with such substantial restriction of movement, there is some advantage to allow a limited amount of movement in the restricted directions.

In a storage rack system with a plurality of columns installed on a floor, that is constructed according to this invention, at least one of the storage rack vibration isolators described herein is connected to the storage rack system and to the floor. The plurality of columns have lower ends that are moveable with respect to the floor. The at least one storage rack vibration isolator comprises a first mounting plate connectable to the storage rack system, a second mounting plate connectable to the floor, and an elastomeric component extending between and operatively attached to said first and second mounting plates. During seismic events the first and second mounting plates remain attached to the elastomeric component while the first and second mounting plates are able to move in planes substantially parallel to each other. The elastomeric component is made up of at least one elastomeric member made of material that is capable of absorbing and dissipating the energy of ground movement imparted to the storage rack system during seismic events so as to lower the natural frequency of the storage rack system in at least one horizontal direction.

The storage rack vibration isolator or isolators could be mounted between the lower end of one or more of the columns and the floor. Alternatively, the storage rack vibration isolator or isolators are mounted adjacent the lower end of one or more of the columns.

Those skilled in the art will realize that this invention is capable of embodiments that are different from those shown and that details of the structure of the enclosed storage rack

vibration isolators and storage rack systems can be changed in various manners without departing from the scope of this invention. Accordingly, the drawings and descriptions are to be regarded as including such equivalent storage rack vibration isolators and storage rack systems as do not depart from the spirit and scope of this invention.

Brief Description of the Drawings

For a more complete understanding and appreciation of this invention, and its many advantages, reference will be made to the following detailed description taken in conjunction with the accompanying drawings.

FIG. 1 is a perspective view of a storage rack vibration isolator welded to the bottom of a storage rack column;

FIG. 2 is an exploded view of the storage rack vibration isolator of FIG. 1;

FIG. 3 is a top view of the storage rack vibration isolator of FIG. 1;

FIG. 4 is a front and partial cross sectional view of the storage rack vibration isolator of FIG. 1;

FIG. 5 is an exploded view of a storage rack vibration isolator welded to the bottom of a rack column;

FIG. 6 is an exploded view of a storage rack vibration isolator welded to the bottom of a rack column;

FIG. 7 is a perspective view of a storage rack vibration isolator welded to the bottom of a rack column;

FIG. 8 is an exploded view of the storage rack vibration isolator of FIG. 7;

FIG. 9 is a perspective view of a storage rack vibration isolator in which the bottom of a column is welded to a column base that becomes a portion of the vibration isolator;

FIG. 10 is an exploded view of the storage rack vibration isolator shown in FIG. 9;

FIG. 11 is a perspective view of a storage rack vibration isolator fastened to a base plate to which the bottom of a rack column is welded;

FIG. 12 is an exploded view of a storage rack vibration isolator shown in FIG. 11;

FIG. 13 is a perspective view of another storage rack vibration isolator fastened to a base plate welded to the bottom of a storage rack column;

FIG. 14 is an exploded view of the storage rack vibration isolator shown in FIG. 13;

FIG. 15 is a perspective view of another storage rack vibration isolator fastened to a base plate welded to the bottom of a storage rack column;

FIG. 16 is an exploded view of the storage rack vibration isolator shown in FIG. 15;

FIG. 17 is a perspective view of another storage rack vibration isolator fastened to a base plate welded to the bottom of a storage rack column;

FIG. 18 is an exploded view of the storage rack vibration isolator shown in FIG. 17;

FIG. 19 is a perspective view of another storage rack vibration isolator fastened to a base plate welded to the bottom of a storage rack column;

FIG. 20 is an exploded view of the storage rack vibration isolator shown in FIG. 19;

FIG. 21 is a perspective view of another storage rack vibration isolator fastened to a base plate welded to the bottom of a storage rack column;

FIG. 22 is an exploded view of the storage rack vibration isolator shown in FIG. 21;

FIG. 23 is a partial side view of a structure that can be used to construct storage rack vibrators;

FIG. 24 is a partial side view of a structure that can be used to construct storage rack vibration isolators;

FIG. 25 is a perspective view of another storage rack vibration isolator fastened to a base plate welded to the bottom of a storage rack column;

FIG. 26 is an exploded view of the storage rack vibration isolator shown in FIG. 25;

FIG. 27 is a perspective view of another storage rack vibration isolator with a storage rack vibration isolator welded to the bottom of a cross brace between two storage rack columns and attached to the floor;

FIG. 28 is an exploded view of a portion of FIG. 27 showing the storage rack vibration isolator attached to the cross brace;

FIG. 29 is a perspective view of two storage rack vibration isolators welded to the bottom of a cross brace between two storage rack columns and attached to the floor;

FIG. 30 is a perspective view of another storage rack vibration isolator welded to the bottom of a cross brace between two storage rack columns and attached to the floor;

FIG. 31 is a perspective view of two storage rack vibration isolators welded to the bottom of a cross brace between two storage rack columns and attached to the floor;

FIG. 32 is a perspective view of another storage rack vibration isolator in which the fixed base pad is a single pad extending between two storage rack columns and attached to the floor;

FIG. 33 is a partial side view of another structure that can be used to construct storage rack vibration isolators;

FIG. 34 is a perspective view of an application of the structure depicted in FIG. 33 installed on the bottom of a storage rack column;

FIG. 35 is a perspective view of an application of the structure depicted in FIG. 33 installed on the bottom of cross brace between two storage rack columns;

FIG. 36 is a partial side view of a structure that can be used to construct storage rack vibration isolators;

FIG. 37 is a perspective view of an application of the structure depicted in FIG. 36 installed on the bottom of a storage rack column;

FIG. 38 is a perspective view of an application of the structure depicted in FIG. 36 installed on the bottom of cross brace between two storage rack columns;

FIG. 39 is a perspective view of another storage rack vibration isolator installed on the bottom of a rack column;

FIG. 40 is a perspective view of two storage rack vibration isolators installed on the bottom of a cross brace between two storage rack columns and attached to the floor;

FIG. 41 is a perspective view of another storage rack vibration isolator installed on the bottom of a rack column;

FIG. 42 is a perspective view of two storage rack vibration isolators installed on the bottom of a cross brace between two storage rack columns and attached to the floor;

FIG. 43 is a perspective view of another storage rack vibration isolator installed on the bottom of a rack column;

FIG. 44 is a perspective view of two storage rack vibration isolators installed on the bottom of a cross brace between two storage rack columns and attached to the floor;

FIG. 45 is a perspective view of two storage rack vibration isolators installed on the bottom of a cross brace between two storage rack columns and attached to the floor;

FIG. 46 is a perspective view of two storage rack vibration isolators installed on the bottom of a cross brace between two storage rack columns and attached to the floor;

FIG. 47 is a perspective view of two storage rack vibration isolators attached to the storage racks by being attached to the sliding base pad that extends between two storage rack columns and attached to the floor by being attached to a restriction element that connects the vibration isolators to the fixed base pad;

FIG. 48 is a perspective view of a storage rack system with storage rack vibration isolators welded to the bottom of each column of the storage rack system;

FIG. 49 is a perspective view of a storage rack system with storage rack vibration isolators attached to the storage rack system at cross braces that connect pairs of columns; and

FIG. 50 is a perspective view of a storage rack system with storage rack vibration isolators attached to the storage rack system at cross braces that connect pairs of columns.

Detailed Description

Referring to the drawings, some of the reference numerals are used to designate the same or corresponding parts through several of the embodiments and figures shown and described. Variations in corresponding parts are denoted in specific embodiments with the

addition of lowercase letters. Subsequent variations in components that are depicted in the figures but have not been described are intended to correspond to the specific embodiments mentioned earlier and are discussed to the extent that they vary in form or function. It will be understood that generally variations in the embodiments could be interchanged without deviating from the invention.

Every storage rack system has a natural frequency based on how the structure is designed and built. The natural frequency of the storage rack system is also related to its stiffness and provides clues as to how the storage rack system will behave in a seismic event. Typically a storage rack system is more flexible (i.e. it has a lower natural frequency) in the down-aisle direction and less flexible (i.e. it has a higher natural frequency) in the cross-aisle direction. It has been determined that typical upright frame storage racks manufactured by Ridg-U-Rak, Inc. have natural frequencies of about 0.9 Hz in the down-aisle direction and about 1.6 Hz in the cross-aisle direction. It is expected that most storage racks systems are similarly designed and are similarly more rigid in the cross-aisle direction than a down-aisle direction. During a seismic event, the storage racks vibrate to counteract the stresses imparted on the storage racks from ground movement such that the storage racks will move in response to an earthquake. The vibrations imparted on the storage rack system increase depending on the strength of the earthquake, but storage rack systems will typically experience some damage when the frequency of vibrations imparted from an a seismic event go over 1.5 Hz. As typical storage rack systems already have a natural frequency of 1.6 Hz in the cross-aisle direction, it does not take a strong earthquake to damage them.

Lowering the natural frequency of the storage rack system will decrease the effect of seismic events. In order to do this, additional flexibility must be given to the storage rack system without sacrificing its stability and strength. This can be accomplished by essentially leaving the structure of the storage rack untouched while modifying how the storage rack is attached to the floor. Storage rack vibration isolators coupled to the floor and attached to the storage racks

serve as the interface between the floor and the storage rack such that the storage racks are now connected in one way or another to the storage racks vibration isolators and not directly attached to the floor.

One of the ways to reduce the natural frequency of the storage rack system is to allow the storage rack system to move a selected distance back and forth in response to the ground movement during seismic events. Such movement, or compliance, increases the overall flexibility of the storage rack system and serves to dissipate the energy imparted to the storage rack system from earthquakes. However, the acceleration experienced by the storage rack system during this movement is also transmitted to the product stored on the shelves, and if it is not tied down to the storage rack shelves, there is a risk that the product could fall off the racks. Therefore another consideration in the design of the storage rack vibration isolators across a range of seismic events is to control the acceleration of the storage rack system such that sufficient movement is achieved to reduce the natural frequency to a desired level, while at the same time not exceeding an acceleration threshold over which product will fall off the shelves.

Dissipation of the energy imparted to the storage rack system from ground movement during an earthquake is achieved through energy dissipation as a result of hysteresis losses and/or secondary friction as the vibration isolators move a sufficient distance back and forth to reduce the natural frequency of the storage rack system when the storage rack system moves in response to the earthquake. In a storage rack system without storage rack vibration isolators, the energy imparted on the storage rack system during an earthquake is transmitted directly to the storage rack system. Because this energy is not dissipated, the storage rack system without storage rack vibration isolators suffers significant damage. However, in a storage rack system equipped with storage rack vibration isolators, a significant portion of this energy is used to make the storage rack system move. Therefore the ability of the storage rack systems to move serves as a significant energy dissipation factor during seismic events.

Referring to FIGS. 1-4, a storage rack vibration isolator **20a** comprises a first mounting plate **22a**, a second mounting plate **24a** and an elastomeric component. In the embodiment depicted in FIGS. 1-4, the elastomeric component comprises one elastomeric member **26a** that extends between the first and second mounting plates **22a** and **24a**. The elastomeric component is operatively attached to the first and second mounting plates **22a** and **24a** such that during seismic events the first and second mounting plates **22a** and **24a** remain attached to the elastomeric component while the first and second mounting plates **22a** and **24a** are able to move in planes substantially parallel to each other while placing the elastomeric components in shear. The elastomeric member made of material that is capable of absorbing and dissipating the energy of ground movement imparted to the storage rack system during seismic events so as to lower the natural frequency of the storage rack system in at least one horizontal direction. For example, the elastomeric member **26a** can be constructed from polyisoprene, polyisoprene blend, butyl rubber, acryl rubber, polyurethane, flurorubber, polysulfide rubber, ethylene-propylene rubber (EPR and EPDM), Hypalon, chlorinated polyethylene, ethylene-vinyl acetate rubber, epichlorohydrin rubber, chloroprene rubber, silicone, or other heavily damped elastomer such as those manufactured by Corry Rubber Corporation of Corry, PA. The elastomeric member **26a** can also be constructed out of any elastomeric material that will withstand the loading on the storage rack system and has the desired stiffness characteristics as set forth below.

The first and second mounting plates **22a** and **24a** can be made out of any metal or nonmetal material that will withstand the loading and forces to which it will be subjected as a component of the storage rack vibration isolator **20a**. In one embodiment, the first and second mounting plates **22a** and **24a** are stamped out of steel plate, the first mounting plate **22a** being stamped to include semicircular plate spaces **27a** at two ends. Similarly, the elastomeric member **26a** also includes semicircular member spaces **29a** at two ends.

Relative thicknesses of the first mounting plate **22a**, elastomeric member **26a**, and second mounting plate **24a** may depend on specific requirements of an application of the storage rack vibration isolator **20a**. For example, 1/8 inch-thick first mounting plates **22a** can be implemented with a 1/2 inch-thick elastomeric member **26a** and 3/8 inch-thick second mounting plate **26a**. It will be appreciated that other thicknesses are possible and within the contemplated scope of the invention.

An adhesive material is placed between the first mounting plate **22a** and elastomeric member **26a** and between the elastomeric member **26a** and second mounting plate **24a**. The adhesive material forms a substantial bond that is sufficient to prevent the first and second mounting plates **22a** and **24a** from losing contact with the elastomeric member **26a**, even when the storage rack vibration isolator **20a** is subjected to substantial external forces. Appropriate adhesives include Chemlok® 8560F, Chemlok® 8210/8560S, and Chemlok® 236A, all manufactured by Lord Corporation, or other adhesive substances that are suited to providing such substantial bonds between elastomers and rigid materials.

As best understood by comparing FIG. 1 with FIG. 2, the semicircular plate spaces **27a** of the first mounting plate **22a** and semicircular member spaces **29a** of the elastomeric member **26a** are in approximate alignment when the first mounting plate **22a** is adhesively bonded to the elastomeric member **26a**. The combined semicircular plate spaces **27a** and semicircular member spaces **29a** create bolt spaces **25a** at two ends of the storage rack vibration isolator **20a**. The respective configurations of the bolt spaces **25a** can be further understood by comparing the top view of the storage rack vibration isolator **20a** in FIG. 3 with its side, partial cross sectional view of FIG. 4.

The storage rack vibration isolator **20a** also includes a pair of anchor bolts **28a**, a pair of base nuts **30** that are adjacent to the second mounting plate **24a** when they are installed on the anchor bolts **28a**, a pair of rectangular washers **32** and a pair of washer nuts **34** that are adjacent to the upper side of the washers **32** when they are installed on the anchor bolts **28a**.

The washer nuts **34** hold the washers **32** in place against the first mounting plate **22a**. The lower portions of the anchor bolts **28a** should be formed in such a manner that they are held firmly by the flooring material on which the storage rack system using the storage rack vibration isolator **20a** is installed. The anchor bolts **28a** shown in FIGS. 1-4 are constructed to be installed and held firmly in a pad of concrete. In this embodiment, the unthreaded end of each of the anchor bolts **28a** is tapered inwardly toward the center of the anchor bolt to increase resistance to the anchor bolt's removal from a concrete floor. The threaded portions of anchor bolts **28a** fit through the holes **36a** in the second mounting plate **24a**.

The anchor bolts **28a** do not directly contact the first mounting plate **22a** or elastomeric member **26a**, but instead extend from the second mounting plate **24a** through the bolt spaces **25a** to the washers **32**. The bolt spaces **25a** are generally sufficiently large to prevent the anchor bolts **28a** from significantly interfering with movement of the first mounting plate **22a** and/or elastomeric member **26a** during a seismic event. The bolt spaces **25a** are also generally sufficiently large to allow for the use of a wrench or other tool for the tightening or loosening of the base nuts **30**.

First and second mounting plates **22a** and **24a** can be assembled together before the storage rack vibration isolator **20a** is shipped to the location where the storage rack system with which it is used is to be installed. This invention is not limited to storage rack vibration isolators manufactured by one process or manufactured using any particular material. However, the polyisoprene, polyisoprene blend, butyl rubber, acryl rubber, polyurethane, flurorubber, polysulfide rubber, ethylene-propylene rubber (EPR and EPDM), Hypalon, chlorinated polyethylene, ethylene-vinyl acetate rubber, epichlorohydrin rubber, chloroprene rubber, silicone, or other material of the elastomeric member **26a** of the storage rack vibration isolators **20a** can be manufactured by mixing a batch of raw materials, in a manner well known to those skilled in the art, required to produce rubber having the physical characteristics, such as various types of stiffness and dampening, desired for use in the storage rack vibration isolator **20a**.

When the batch is mixed, it can be removed from the mixer, dropped into a mill, blended and sheeted off in a size that is appropriate for feeding an injection molding machine. After the batch is cooled and tested to ensure it has the required stiffness and dampening characteristics, it can then be loaded into an injection molding machine. The washers **32** can be metal stampings that are treated with zinc phosphate or other corrosion resistant coatings.

When the adhesive materials are applied between the first mounting plate **22a** and elastomeric member **26a** and between the elastomeric member **26a** and second mounting plate **24a**, Chemlok® 8007, manufactured by Lord Corporation, can be applied followed by a coat of Chemlok® 8560S. Many other adhesives manufactured by Lord Corporation or other companies can be used as alternatives for this illustrated manufacturing process.

The metal washers **32** can be loaded into a mold form in an injection molding machine. The rubber that had been loaded into this machine can then be injected into the mold, and the resulting sandwich of plates **22a** and **24a** rubber elastomer **26a** can then be cured. Typically, this assembly is subsequently removed from the mold and trimmed.

The bottom end of a storage rack column **38** is welded to the first mounting plate **22a** at weld **31a**. The elastomeric layer **26a** and adhesives bonding the elastomeric layer **26a** to the first mounting plate **22a** and second mounting plate **24a** are capable of withstanding heat stresses from the welding of column to the first mounting plate **22a**. It has been found that such heat stress resistance is present where polyisoprene, polyisoprene blend, or butyl rubber have been used to form the elastomeric layer **26a**. These materials have also been found to resist the type of compression, bumping, and lateral stresses that are encountered when the column is placed on and then attached to the first mounting plate **22a**.

The threaded ends of anchor bolts **28a** are placed through the holes **36a** of the second mounting plate or plate **24a**, and the base nuts **30** are tightened against the second mounting plate **24a** so as to hold the second mounting plate **24a** tightly against the floor in which the bottoms of anchor bolts **28a** have been embedded. The rectangular washers **32** are placed over

the tops of anchor bolts **28a** and the washer nuts **34** are tightened against the upper ends of the washers **32**. This causes the rectangular washers **32** to apply a downward force against first mounting plate **22a**, the elastomeric member **26a** and second mounting plate **24a**. The weight of the storage rack system and articles or material stored on the storage racks and coupled through the column **38** further loads the storage rack vibration isolator **20a**.

Referring to FIGS. 1 through 4, when a seismic event such as an earthquake occurs, the earth moves and sets up vibrations in multiple directions. This movement also imparts an acceleration that the storage rack system tries to match. If the columns of the storage rack were fixed to the floor, this acceleration could significantly damage the structural components of the storage rack system. In addition, items stored on the storage rack shelves could fall off the racks. The storage rack vibration isolators **20a** are able to absorb and dissipate some of the forces that the storage rack system experiences during seismic events. Since the bottoms of anchor bolts **28a** are held firmly within the concrete floor in which they are embedded, and the base nuts **30** fasten the second mounting plate **24a** against the floor, the second mounting plate **24a** vibrates laterally with the floor during seismic events. The acceleration due to this lateral movement is transmitted through the storage rack vibration isolators **20a** and causes the storage rack system to move with the elastomeric component. This movement, or compliance, of the elastomeric component increases the overall flexibility of the storage rack system and serves to dissipate the energy imparted to the storage rack system from the seismic event. In addition the elastomeric component also dampens vibrations imparted to the storage rack system from ground movement during the earthquake. The storage rack vibration isolators **20a** reduce the natural frequency of the storage rack system such that the storage rack system is better able to withstand seismic events.

While any reduction in the natural frequency of the storage rack system will provide some protection against seismic events, the goal is to reduce the natural frequency of the storage rack system such that damage to the storage racks is reduced and product stored on

the storage racks does not fall off. It is preferable to reduce the natural frequency of the storage rack system to less than about 0.9 Hz, or ideally to less than about 0.5Hz. Storage rack vibration isolators are selected that can achieve such frequencies depending on the target natural frequency to be achieved and the expected maximum load on the storage rack system. Both these parameters can be accounted for by selecting the static and dynamic modulus, or stiffness, of the elastomeric material used in the elastomeric component.

The static stiffness of an elastomeric material can be measured by several factors, including the compression stiffness, $K_{compression}$ and the shear stiffness K_{shear}. The compression stiffness is a measure of the force required to deflect an elastomer such as a block of rubber a vertical distance, and is measured in pounds per inch, while the shear stiffness K_{shear} is a measure of the amount of force required to deflect a block of rubber a particular lateral distance, measured in pounds per inch.

Among the dynamic characteristics that make elastomeric materials useful for absorbing energy during seismic events is the fact that such materials have elastic and inelastic components that cause force and displacement to be out of phase, allowing for energy dissipation or "damping" to occur. The dynamic characteristics of an elastomeric mount include damping stiffness K", representing inelastic stiffness as reflected in the "lag time" between a displacement and a subsequent force exerted by the material, and elastic stiffness K', representing the stiffness that is in phase with a displacement of the material. Damping stiffness K" and elastic stiffness K' are both measured in pounds per inch. The damping loss factor of a particular rubber is the ratio of its damping stiffness divided by its elastic stiffness,

$$L_{dlf} = K'' / K'$$

A dynamic test machine is used to dynamically load an elastomeric material and measure the extent to which the spring response of the material is dampened by the material's physical characteristics. Rubber or another elastomeric material should have a damping loss factor greater than about 0.1, i.e.

$$K'' / K' > 0.1$$

The energy dissipated by an elastomeric material per cycle of vibration is equal to:

$$\pi K'' x^2$$

where K" is the dampening stiffness and x is the peak-to-peak distance of movement of the ends of the elastomeric material during a vibration, that is, the total distance of a vibration in both directions. Thus, the energy dissipated per cycle of vibration increases with the square of the increase of the peak-to-peak distance of the movement between the ends of the vibrating elastomeric material. Additionally, the material frequency of the rack system decreases as the increased distance of movement between the ends of the elastomeric material increases the distance the lower ends of the rack columns move per cycle of vibration. It was determined that the lower ends of rack columns should be allowed to move at least about two inches and preferably more than about four inches, in each direction from their resting position during each cycle of seismic vibration.

The stiffness parameters discussed above are also related to the hardness of the elastomer, measured in durometer. The higher the durometer value of a particular elastomer the stiffer it is.

Polyisoprene, polyisoprene blend, silicone, acryl rubber, polyurethane, flurorubber, polysulfide rubber, ethylene-propylene rubber (EPR and EPDM), Hypalon, chlorinated polyethylene, ethylene-vinyl acetate rubber, epichlorohydrin rubber, chloroprene rubber, and butyl rubber are among the materials that have been determined to meet these general requirements for being suitably implemented in the elastomeric member. However, it will be appreciated that other materials that generally meet these requirements may also be suitable and are contemplated to be within the scope of the invention.

It will also be appreciated that variations in the configuration of the first or second mounting plates or the elastomeric member are possible and within the contemplated scope of

the invention. For example, FIG. 5 depicts a storage rack vibration isolator **20b** in which the elastomeric component includes an elastomeric member **26b** with a top recessed surface **39** and a booted edge **40**. A first mounting plate **22b** is sized to fit within the booted edge **40** and be adhesively attached to the top recessed surface **39** of the first mounting plate **22b** when the storage rack vibration isolator **20b** is assembled. Thus, the major surface footprint of the first mounting plate **22b** should be sized slightly smaller than the footprint of the elastomeric member **26b** to allow for accommodation within the booted edge **40**. The semicircular member spaces **29b** of the elastomeric member **26b** must also be increased in their vertical dimensions to allow the ends of the semicircular plate spaces **27b** of the first mounting plate **22b** to become enclosed by the booted edge **40** upon assembly.

In some embodiments, the semicircular plate spaces of the first mounting plate and/or elastomeric member can be replaced with other suitable space configurations that create bolt spaces allowing for relative movement between the bolts and plates so that the elastomeric member can be placed in shear to absorb and dissipate the energy of movement during a seismic event. The semicircular plate spaces also create room to allow for the use of a wrench to adjust the base nuts. FIG. 6 depicts a storage rack vibration isolator **20c** in which the semicircular plate spaces depicted in the previous embodiments are replaced with enlarged bolt accommodation holes **42**. The bolt accommodation holes **42** are combined with the semicircular member spaces **29c** of the elastomeric members **26c** to form bolt spaces **25c** that are sized to be significantly larger than the thickness of the individual anchor bolts **28c** to allow movement of the bolts **28c**. Although FIG. 6 only shows replacement of the semicircular plate spaces with bolt accommodation holes **42**, it will be appreciated that in some embodiments, the semicircular member spaces **29c** can also be replaced with similar hole-like accommodation configurations. Such accommodation configurations would also be added to the combined bolt spaces of the first mounting plate and elastomeric member.

Although the invention has been shown and described with a first mounting plate and elastomeric component that are further secured to the second mounting plate and concrete floor with rectangular washers attached to extended bolts, it will be appreciated that the inclusion of rectangular washers and/or other clamping mechanisms is generally not necessary and sufficient structural stability can normally be achieved with the use of adhesives alone between the first mounting plate, elastomeric member, and second mounting plate. FIG. 7 depicts an assembled storage rack vibration isolator **20d** in which the anchor bolts **28d** do not extend above the first mounting plate **22d** and in which no rectangular washers or other clamping mechanisms are present. An exploded view of the storage rack vibration isolator **20d** of FIG. 7 is shown in FIG. 8.

The storage rack vibration isolator **20d** relies on adhesives applied between the first mounting plate **22d** and the elastomeric component comprised in this embodiment of a single elastomeric member **26d** for anchoring and structural stability. Bolts **28d** need only extend sufficiently above the second mounting plate **24d** to allow for engagement of nuts **30** to secure the second mounting plate **24d** to the floor. The semicircular plate spaces **27d** of the first mounting plate **22d** and the semicircular member spaces **29d** of the elastomeric member **26d** are included to retain a bolt space **25d** that allows for the use of a wrench or other tool for adjusting the base nuts **30**.

In some applications of the invention, it may not be possible to weld a column to the first mounting plate at the site of assembly or it may be otherwise preferable to attach the column to the first mounting plate prior to assembly. FIG. 9 depicts an assembled storage rack vibration isolator **20e** that is similar to the storage rack vibration isolator **20d** of FIG. 7. However, FIG 10, an exploded view of the storage rack vibration isolator **20e** of FIG. 9, depicts the column **38** as having been welded to the first mounting plate **22e** to form a welded attachment member **44e** prior to assembly of the storage rack vibration isolator **20e**.

Although the invention has been shown and described with columns of storage racks that are permanently welded to first mounting plates of storage rack vibration isolators, it will be appreciated that some embodiments of the invention may allow for the detachment of columns from otherwise assembled storage rack vibration isolators without requiring detachment of the adhesively connected first mounting plate, elastomeric component, and second mounting plate. FIG. 11 depicts an assembled storage rack vibration isolator **20f** having a separate rack base plate **46f** welded to a storage rack column **38** to form a welded attachment member **44f**. As best understood by comparing FIG. 11 with the exploded view of the storage rack vibration isolator **20f** in FIG. 12, a rack base plate **46f** includes stud holes **48** and enlarged bolt accommodation holes **50** that all extend through the rack base plate **46f**.

The first mounting plate **22f** includes multiple studs **52** that extend upward from the top surface of the first mounting plate **22f**. The studs **52** can be compression fit and/or welded or otherwise attached to the first mounting plate **22f**. As best understood by comparing FIGS. 11 and 12, each stud **52** is aligned to engage the stud holes **48** of the rack base plate **46f** when the base plate **46f** is positioned on the first mounting plate **22f**, with each stud **52** penetrating and extending above the top surface of the base plate **46f** when the storage rack vibration isolator **20f** is assembled, as depicted in FIG. 11.

The studs **52** preserve the relative alignment of the first mounting plate **22f** with the rack base plate **46f** when the storage rack vibration isolator **20f** is assembled. Although the first mounting plate **22f** is adhesively attached to the elastomeric member **26f** of the elastomeric component, which is in turn adhesively attached to the second mounting plate **24f**, in this illustrated embodiment there is no adhesive attachment of the first mounting plate **22f** to the rack base plate **46f**. This allows the rack supported by the column **38** to be removed from the storage rack vibration isolator **20f** after installation without requiring cutting or destructive detachment of the column **38** from the first mounting plate **22f**.

The bolt accommodation holes **50** of the base plate **46f** are enlarged to allow for the insertion of the anchor bolts **28f**, which are attached to the rectangular washers **32** with washer nuts **34**. Like the semicircular plate spaces **27f** and semicircular member spaces **29f**, the bolt accommodation holes **50** help define the total bolt spaces **25f** that allow for the free movement of the anchor bolts **28f** and dissipation of energy by the elastomeric member **26f** during a seismic event. Although the rack base plate **46f** is shown and described with bolt accommodation holes **50**, it will be appreciated that semicircular spaces similar to the semicircular plate spaces **27f** of the first mounting plate **22f** and semicircular member spaces **29f** of the elastomeric member **26f** could also be used within the contemplated scope of the invention.

When the column **38** is installed on the storage rack vibration isolator **20f**, the rectangular washers **32** prevent detachment of the rack base plate **46f** from the first mounting plate **22f** and thus prevent column **38** and welded attachment member **44f** from upward lifting away from the storage rack vibration isolator **20f**. The rectangular washers **32** move with the anchor bolts **28f** when the anchor bolts **28f** move due to the movement of the ground during the seismic event. The washers **32** can be removed by loosening and removing the washer nuts **34**, thereby allowing the column **38** to be removed without cutting or damaging the storage rack vibration isolator **20f** by lifting the rack base plate **46f** away from the first ~~rigid~~ mounting plate **22f**. Other configurations allowing for alignment between a first mounting plate and rack base plate are also possible. Referring now to FIG. 13, a storage rack vibration isolator **20g** is shown having keys **54** extending downward from the rack base plate **46g**. As best understood by comparing FIG. 13 to the exploded view of FIG. 14, the keys **54** can be formed by cutting two parallel slits into the rack base plate **46g** for each key **54** and then by bending tabular segments between each pair of slits downward to form the individual keys **54**. Key notches **56** are cut into the first mounting plate **22g** and are sized to engage the keys **54** and align the rack base plate **46g** with the first mounting plate **22g** when positioned thereon without restricting movement of

the rack base plate **46g** in the upward direction. The keys **54** and key notches **56** therefore allow the column **38** and rack base plate **46g**, which together comprise the welded attachment member **44g**, to be removed by upward lifting from the first mounting plate **22g** without requiring cutting or damaging of the storage rack vibration isolator **20g** when the washer nuts **34** and rectangular washers **32** are removed.

It will also be appreciated that some embodiments can allow for the removal and attachment of a column and/or a welded attachment member without the use of washers and washer nuts. For example, a storage rack vibration isolator **20h** is depicted assembled in FIG. 15 and in an exploded view in FIG. 16 that includes a welded attachment member **44h** in which the rack base plate **46h** includes base plate holes **58h** at two corners that are aligned with mounting plate holes **60h** of the first mounting plate **22h** when assembled. The base plate holes **58h** and mounting plate holes **60h** are sized to accommodate plate screws **62h** which provide attachment between the base plate **46h** and first mounting plate **22h** and which can be tightened into position with plate nuts **64h**.

The plate screws **62h** and plate nuts **64h** allow the rack base plate **46h** to be detached from the first mounting plate **22h** without requiring cutting or damage to the storage rack vibration isolator **20h**. In this embodiment the elastomeric component comprises a single elastomeric member **26h**. Attachment of the first mounting plate **22h** to the elastomeric member **26h** and the elastomeric member **26h** to the second mounting plate **24h** is dependent on the adhesives placed therebetween. Anchor bolts **28h** and base nuts **30** are located at two corners of the second mounting plate **24h**. The elastomeric member **26h** includes four access notches **66h** to accommodate a wrench or similar tool for adjustment of the base nuts **30** and plate nuts **64h**.

The use of threaded members can eliminate the need for nuts in some embodiments and further facilitate detachment of the column and rack base plate from the storage rack vibration isolator. FIG. 17 depicts an assembled storage rack vibration isolator **20i** in which the

first mounting plate **22i** includes mounting plate holes **60i** that are female threaded, as best understood by comparing FIG. 17 with the exploded view of the storage rack vibration isolator **20i** in FIG. 18. When the storage rack vibration isolator **20i** is assembled, plate screws **62i** having male threads extend through the base plate holes **58i** of the rack base plate **46i** to engage the female threads of the mounting plate holes **60i** to secure the rack base plate **46i** to the first mounting plate **60i**. The female threads of the mounting plate holes **60i** will generally have a sufficient number of turns to sufficiently engage the plate screws **62i** without the need for additional hardware, further simplifying installation and removal. A sufficient number of turns is generally present when the first mounting plate **60i** is constructed from 1/4 inch-thick plate material. Such sizing can also generally allow the plate screws **62i** to be sized to bottom out within the first mounting plate **60i**, hiding the male threads of the screws **62i** entirely within the first mounting plate **60i**.

Variations in the anchoring to the ground are also within the intended scope of the invention. A few of the many possible variations are described below and shown in the drawings. FIGS. 19 and 20 depict assembled and exploded views of a storage rack vibration isolator **20j** that is anchored to the floor with j-bolts **68**. The j-bolts **68** can be cast in place in concrete and shaped to hook to the concrete or can be hooked to other structures beneath the ground level of the second mounting plate **24j**. The j-bolts **68** include threaded ends that can extend through holes **36j** to engage base nuts **30j** for securing the storage rack vibration isolator **20j** to the ground. Access notches **66j** in the elastomeric member **26j** allow for the accommodation of a wrench or other tool for tightening the j-hooks against the second mounting plate **24j**.

FIGS. 21 and 22 depict assembled and exploded views of a storage rack vibration isolator **20k** that is anchored to the floor with anchor bolts **28k** that are threaded to allow male threads to be inserted through holes **36k** of the second mounting plate **24k** to create female threads in a floor or ground member (not shown) on which the second mounting plate **24k** is

supported. The access notches **66k** of the elastomeric member **26j** allow for the accommodation of a wrench or other tool which tightens the anchor bolts **28k** against the second mounting plate **24k** to secure the storage rack vibration isolator **20k** to the ground.

It will be further appreciated that variations in the cross sectional geometry of the mounting plates and elastomeric member or members are also contemplated within the intended invention scope. For example, FIG. 23 depicts a cross sectional view of a storage rack vibration isolator **20l** having an elastomeric component with an elastomeric member **26l** having an increased thickness. For purpose of comparison, the elastomeric member **26l** is shown with an increased cross sectional thickness with respect to the cross sectional thicknesses of the first mounting plate **22l** and second mounting plate **24l**. Shear stiffness is inversely proportional to the thickness of the elastomeric member **26l**. Although compression stiffness is not linearly related to the thickness of the elastomeric member **26l**, an increase in the thickness of the elastomeric member **26l** as shown allows for reductions in both the shear stiffness and compression stiffness of the elastomeric member **26l** where such reductions are desired.

In some applications, it may be desirable to reduce shear stiffness without creating a substantial reduction in compression thickness. FIG. 24 depicts a storage rack vibration isolator **20m** having an elastomeric component with two intermediate plates **70m** that are positioned between laminated elastomeric layers **26m**, the combined intermediate plates **70m** and laminated elastomeric layers **26m** being positioned between the first mounting plate **22m** and second mounting plate **24m**. An appropriate adhesive material bonds each plate **22m**, **24m**, or **70m** to its adjacent laminated elastomeric layer(s) **26m**. The intermediate plates **70m** may be rigid or nonrigid.

Assume that each of the three divided elastomeric layers **26m** of the elastomeric component of the storage rack vibration isolator **20m** of FIG. 24 is one-third the thickness of the single elastomeric layer **20l** of FIG. 23. Since the total shear stiffness is inversely proportional to the total combined thicknesses of the divided elastomeric layers **26m**, the total shear stiffness of

the storage rack vibration isolator **20m** of FIG. 24 is approximately the same as the total shear stiffness of the storage rack vibration isolator **20l** of FIG. 23. However, as noted above, compression stiffness is not linearly related to the total thickness of the elastomeric layers **26m**. The divided elastomeric layers **26m** and the placement of intermediate plates **70m** therebetween cause the storage rack vibration isolator **20m** of FIG. 24 to be almost significantly stiffer in the compressive direction than the storage rack vibration isolator **20l** of FIG. 23.

A storage rack vibration isolator **20n** having an elastomeric component with multiple laminated elastomeric layers **26n** is depicted in FIG. 25 with an exploded view being depicted in FIG. 26. Referring to FIGS. 25 and 26, an intermediate plate **70n** is positioned between the elastomeric layers **26n** and secured in place with an adhesive. It is contemplated that the adhesive between the elastomeric layers **26n** and the first mounting plate **22n**, intermediate plate **70n**, and second mounting plate **24n** would be alone sufficient for adequate bonding therebetween, though washers such as the rectangular washers **32** with extended bolts **28n** as shown in FIG. 1 or other such additional clamping mechanisms could also be added.

Intermediate plate spaces **71** at each end of the intermediate plate **70n** align with the semicircular member spaces **29n** and semicircular plate spaces **27n** to form the bolt spaces **25n** allowing access to the base nuts **30**. One embodiment of the isolator **20n** would incorporate two approximately 1/2" thick elastomeric layers **26n** separated by one approximately 1/16" thick intermediate plate **70n**, though it is further contemplated that other numbers and relative thicknesses of elastomeric members and intermediate plates are possible and within the intended scope of the invention.

It has been shown above that the storage rack vibration isolators can be attached to the storage racks underneath the columns of the storage rack. However it will be appreciated that connecting the storage rack vibration isolators to other locations on the storage rack system will also provide protection during seismic events. FIG. 27 depicts an assembled storage rack vibration isolator **20o** according to one embodiment in which the storage rack vibration isolator

20o assembly is located between two columns **38** of a storage rack system. FIG. 27 depicts an assembled storage rack vibration isolator **20o** attached to a cross brace **90o** welded between two storage rack columns **38**. FIG 28 depicts an exploded view of the storage rack vibration isolator **20o** attached to the cross brace **90o**. As best understood by comparing FIG 27 and FIG 28, the cross brace **90o** includes an attachment member **46o** welded to correspond to where the storage rack vibration isolator **20o** will be installed along the cross brace **90o**. The attachment member includes base plate holes **58o** at the corners that are aligned with mounting plate holes **60o** of the first mounting plate **22o** when assembled. The base plate holes **58o** and mounting plate holes **60o** are sized to accommodate plate screws **62o** which provide attachment between the attachment member **46o** and first mounting plate **22o** and which can be tightened into position with plate nuts **64o**. The plate screws **62o** and plate nuts **64o** allow the attachment member **46o** to be detached from the first mounting plate **22o** without requiring cutting or damage to the storage rack vibration isolator **20o**.

In this embodiment the elastomeric component comprises a single elastomeric member **26o**. Attachment of the first mounting plate **22o** to the elastomeric member **26o** and the elastomeric member **26o** to the second mounting plate **24o** is dependent on the adhesives placed therebetween as described earlier. The second mounting plate **24o** includes base plate holes **36o** at the four corners. The threaded ends of anchor bolts **28o** are placed through the holes **36o** of the second mounting plate **24o**. The base nuts **30o** are tightened against the second mounting plate **24o** so as to hold the second mounting plate **24o** tightly against the floor in which the bottoms of anchor bolts **28o** have been embedded.

The lower ends of the columns **38** are welded to a sliding base pad **92o** at welds **31o**. The sliding base pad is sited on top of fixed base pad **94o**. The fixed base pad **94o** includes base plate holes (not shown) at the four corners. The threaded ends of anchor bolts **28o** are placed through the holes (not shown) of the fixed base pad **94o**. The base nuts **30o** are tightened against the fixed base pad **94o** so as to hold the fixed base pad **94o** tightly against the

floor in which the bottoms of anchor bolts **28o** have been embedded. The lower surface of the sliding base pad **92o** and/or the upper surface of the fixed base pad **94o** could have a layer of material having a low coefficient of friction. The fixed base pads **94o** are sized to cover the area that the storage rack may move in a seismic event.

When a seismic event such as an earthquake occurs, the earth moves and sets up vibrations in multiple directions. The bottoms of anchor bolts **28o** are held firmly within the concrete floor in which they are embedded, and the base nuts **30o** fasten the second mounting plate **24o** and the fixed base pad **94o** against the floor. As described earlier the second mounting plate **24o** vibrates laterally with the floor during the seismic event while the elastomeric component absorbs lateral and vertical vibrations and helps to isolate the storage rack from the vibrations caused by the seismic events. The columns **38** are not fixed to the floor and are free to slide over the fixed base pad **94o**. As a result, the storage rack vibration isolator **20o** reduces the effects of seismic events on the storage rack system and on the items or materials stored on its storage racks. The potential energy stored in the elastomeric component will tend to return the storage rack system to its original position at the end of a seismic event.

The embodiments that are shown and described with the storage rack vibration isolators are configured to allow for detachment of the cross brace **90o** from the storage rack vibration isolator **20o.** It will be appreciated that other methods of attaching the storage rack vibration isolators to the cross brace and to the floor may be used, in addition to any of the embodiments described earlier that show various other means and methods for attaching the storage rack vibration isolator to the columns of the storage rack system and to the floor.

While the storage rack vibration isolator **20o** could be located anywhere along the length of the cross brace **90o**, if only one storage rack vibration isolator **20o** is used between a pair of columns **38** it is preferable for the storage rack vibration isolator **20o** to be located equidistant from either column.

It will also be appreciated that variations in the configuration vibration isolators are possible and within the contemplated scope of the invention. For example, while FIG. 27 depicts a storage rack vibration isolator system with only one storage rack vibration isolator **20o** attached to the cross brace **90o**, it will be appreciated that more than one storage rack vibration isolator may be attached to a cross brace. FIG. 29 depicts a storage rack vibration isolator system according to another embodiment in which two storage rack vibration isolators **20p** are coupled to the cross brace **90p**. As with the embodiment depicted in FIG 27, the storage rack vibration isolators **20p** have corresponding attachment members **46p** located where the storage rack vibration isolators **20p** will be situated along the cross brace **90p.** As with the previously described embodiments, it will be appreciated that other methods of attaching the storage rack vibration isolators to the cross brace may be used in addition to any of the embodiments described earlier that show various other means and methods for attaching the storage rack vibration isolator to the columns of the storage rack system.

A storage rack vibration isolator **20q** having an elastomeric component with multiple laminated elastomeric layers **26q** with a single storage rack vibration isolators **20q** attached to the cross brace **90q** is depicted in FIG. 30 An intermediate plate **70q** is positioned between the elastomeric layers **26q** and secured in place with an adhesive. It is contemplated that the adhesive between the elastomeric layers **26q** and the first mounting plate **22q**, intermediate plate **70q**, and second mounting plate **24q** would be alone sufficient for adequate bonding, though washers such as rectangular washers (FIG. 1, **32**) with extended bolts (FIG. 1, **28a**) or other such additional clamping mechanisms could also be added.

One embodiment of the isolator **20q**, would incorporate two approximately 1/2" thick elastomeric layers **26q** separated by one approximately 1/16" thick intermediate plate **70q**, though it is further contemplated that other numbers and relative thicknesses of elastomeric members and intermediate plates are possible and within the intended scope of the invention. The storage rack vibration isolator **20q** is attached to the cross brace **90q** similarly as has been

described for FIG. 28. The cross brace **90q** includes an attachment member **46q** welded to correspond to where the storage rack vibration isolator **20q** will be installed along the cross brace **90q**. It will be appreciated that this embodiment may be attached to the storage rack system in a manner similar to any of the other embodiments disclosed herein.

While FIG. 30 depicts a storage rack vibration isolator system with only one storage rack vibration isolator **20q** attached to the cross brace **90q**, it will be appreciated that more than one storage rack vibration isolator may be attached to a cross brace. Two storage rack vibration isolators **20r** having elastomeric components with multiple laminated elastomeric layers **26r** attached to the cross brace **90r** is depicted in FIG. 31.

It will also be appreciated that the low friction bases **94o - 94r** described and shown in FIGS. 27-31 do not have to be separate pieces for each column **38**. FIG. 32 depicts a storage rack vibration isolator system with two storage rack vibration isolators **20s** with elastomeric components having multiple laminated elastomeric layers **26s** attached to the cross brace **90s**. The storage rack vibration isolators **20s** are coupled to the fixed base pad **94s** that extends under and across the columns **38**. The columns **38** of the storage rack system are welded to sliding base pads **92s** that rest on the fixed base pad **94s**. The fixed base pad **94s** is itself coupled to the floor through the storage rack vibration isolators **20s**. The lower surface of the base plate **92s** and/or the upper surface of the fixed base pad **94s** could have a layer of material having a low coefficient of friction. The fixed base pads **94s** are sized to cover the area that the storage rack may move in a seismic event. It will be appreciated that this single piece fixed base pad **94s** would be applicable to any variation that requires a fixed base pad for the columns **38**.

It will also be appreciated that the sliding base pads **94o - 94s** described and shown in FIGS. 27-32 could be replaced by or supplemented with equivalent structures that would allow or assist the columns **38** to slidably move in relation to the storage rack vibration isolator system in the event of seismic activity such as ball bearings, wheels, casters, etc.

In some embodiments, the cross sectional geometry of the ~~rigid~~ mounting plates and elastomeric member or members of the elastomeric component can also be used to control storage rack vibration isolator stability. This would additionally create a structure that restricts the movement of the elastomeric component to substantially one horizontal direction. FIG. 33 depicts a storage rack vibration isolator **20t** having a curved first mounting pate **22t** and a second mounting plate **24t** having a curved upper surface **74t**. An elastomeric member **26t** is positioned between the curved first mounting plate **22t** and second mounting plate **24t** and bonded to the first and second mounting plates **22t** and **24t** with an adhesive. The elastomeric member **26t** is also curved in shape so that a compression component is exerted against the elastomeric member **26t** by the curved first mounting plate **22t** and/or curved upper surface **74t** of the second mounting plate **24t** when a force is applied to the first and/or second mounting plates **22t** and **24t** that includes a component in a lateral or side direction. As the elastomeric member **26t** absorbs and dissipates such exerted forces, the curved shaping tends to cause the storage rack vibration isolator **20t** to return to a stable and upright position as shown. Thus the particular shaping of the mounting plates **22t** and **24t** and elastomeric component allows compression components to be used to improve overall stability during a seismic event.

Since the first mounting plate **22t** and second mounting plate **24t** are curved along the lateral or side-to-side directions, the shear stiffness K_{shear} increases along the same directions. Thus, the storage rack vibration isolator **20t** of FIG. 33 is especially useful where it is desirable to increase the shear stiffness K_{shear} along only one axis without effecting such an increase along a perpendicular axis (e.g. along the front and back directions) and without changing the overall compression stiffness, $K_{compression}$ of the isolator **20t**. In effect, the storage rack vibration isolator **20t** functions in substantially one horizontal direction and should be incorporated into a rack system to take advantage of such effects.

FIG. 34 depicts the storage rack vibration isolator depicted in FIG. 33 as applied to the bottom of the column **38**. The storage rack base isolator **20t** is welded to the column **38** at weld

31t. The configuration of the elastomeric component will restrict movement to substantially one horizontal direction as indicated by directional arrows **100**. FIG. 35 depicts the storage rack vibration isolator depicted in FIG. 33 as applied to a cross brace **90t** of a storage rack system. The storage rack base isolator **20t** is welded to the cross brace **90t**. The structure of the elastomeric component will restrict movement to substantially one horizontal direction as indicated by directional arrows **100**.

FIG. 36 depicts a storage rack vibration isolator **20u** that includes a structure that restricts the movement of the elastomeric component to substantially one horizontal direction. The elastomeric component has multiple flat surfaces that manipulate compression components for enhanced stability. The first mounting plate **22u** includes a top contact surface **76u**, a first side contact surface **78u** and a second side contact surface **80u**. The second mounting plate **24u** includes a top positioning surface **82u**, a first side positioning surface **84u** and a second side positioning surface **86u**. The elastomeric member **26u** is positioned between the first and second mounting plates **22u** and **24u** and is adhesively bonded to each of the surfaces **76u**, **78u**, **80u**, **82u**, **84u**, and **86u**.

When a compression component is exerted against the elastomeric member **26u** by the top contact surface **76u** of the curved first mounting plate **22u** and/or by the top positioning surface **82u** of the second mounting plate **24u**, the downward and/or upward compression component(s) can be absorbed and dissipated by the elastomeric member **26u**. If a lateral component is exerted by the first or second side contact surfaces **78u** or **80u** of the first mounting plate **22u** or the first or second side positioning surfaces **84u** or **86u** of the second mounting plate **24u**, as the elastomeric member **26u** absorbs and dissipates such exerted forces, contact with the side surfaces **78u**, **80u**, **84u**, and **86u** will tend to cause the elastomeric member **26u** to return the storage rack vibration isolator **20u** to a stable and upright position as shown, thereby using laterally-exerted compression components to improve overall stability during a seismic event.

Contact by the elastomeric member **26u** with the first and second side contact surfaces **78u** and **80u** and the first and second side positioning surfaces **84u** and **86u** also increases shear stiffness K_{shear} along the lateral or side-to-side directions. Thus, the storage rack vibration isolator **20u** also allows an increase in shear stiffness K_{shear} along only one axis without effecting such an increase along a perpendicular axis (e.g. along the front and back directions) without changing the overall compression stiffness $K_{compression}$ of the isolator **20u**. In effect, similarly to the storage rack vibration isolator of FIG. 36, the storage rack vibration isolator **20u** functions in substantially one horizontal direction and should be incorporated into a rack system to take advantage of such effects.

FIG. 37 shows the storage rack vibration isolator depicted in FIG. 36 as applied to the bottom of the column **38**. The storage rack base isolator **20u** is welded to the column **38** at weld **31u**. The configuration of the elastomeric component will restrict movement to substantially one horizontal direction as indicated by directional arrows **100**. FIG. 38 depicts the storage rack vibration isolator depicted in FIG. 36 as applied to a cross brace **90u** of a storage rack system. The storage rack base isolator **20u** is welded to the cross brace **90u**. The structure of the elastomeric component will restrict movement to substantially one horizontal direction as indicated by directional arrows **100**.

Limiting the seismic dampening effect of the storage rack vibration isolators in only one direction has certain advantages in storage rack systems. By the nature of their construction and design, many storage rack systems are much more flexible in the down-aisle direction and are significantly stiffer across the aisle. One solution to creating unidirectional seismic dampening is as suggested by the structure of the vibration dampeners described in FIGS. 33 to 38. Another solution would be to incorporate a structure outside the elastomeric component that mechanically restricts the movement of the seismic isolation system. In essence this would function as a unidirectional seismic dampening system. Such modifications could additionally

provide protection to the storage rack vibration isolator assembly from side impacts in high-traffic areas.

FIG. 39 depicts a storage rack vibration isolator **20v** attached to the bottom of a column **38.** The U-shaped restriction element **95v** is a structure that restricts movement of the storage rack vibration isolator 20v to substantially one horizontal direction parallel to the restriction element **95v** in the direction depicted by the directional arrows **100**. While the restriction element substantially restricts movement perpendicular to the directional arrows **100**, there is room for some movement in that direction which imparts some dampening in the down aisle direction. It will be appreciated that similar modifications could work equally well in other combinations and types of storage rack vibration isolators. It will be understood that some features depicted in FIG 39 have not been discussed because they are common to previously described embodiments. It will be understood that generally these features are similar in form or function across the embodiments.

FIG. 40 depicts storage rack vibration isolators **20w** attached to cross brace **90w**. The fixed base pad **94w** has been modified into a U-shaped trough in which the storage rack vibration isolators **20w** are housed. The modified fixed base pad **94w** also serves as a structure that restricts the movement of the storage rack vibration isolator **20w** to one substantially horizontal direction parallel to the modified fixed base pad **94w** in the direction depicted by the directional arrows **100**. While the restriction element substantially restricts movement perpendicular to the directional arrows **100**, there is room for some movement in that direction which imparts some additional dampening in the down aisle direction. It will be appreciated that similar modifications would work equally well in other combinations of storage rack vibration isolator types and numbers. It will be understood that some features depicted in FIG 40 have not been discussed because they are common to previously described embodiments. It will be understood that generally these features are similar in form or function across the embodiments.

FIG. 41 depicts a modification of the restriction element **95v** of Fig. 39. The restriction element **95x** is further bent over the storage rack vibration isolator **20x** to provide additional support against substantial vertical movement of the storage rack vibration isolator **20x**. At the same time, the restriction element is sized to not interfere with the movement of the storage rack vibration isolator in the direction indication by directional arrows **100**. The end of the restriction element **95x** could be coated with an elastomer or other shock absorbing material, such as rubber, etc., to help absorb the vertical impact of the vibration isolator **20x** during seismic events. While the restriction element substantially restricts movement perpendicular to the directional arrows **100**, there is room for some movement in that direction which imparts some additional dampening in the down aisle direction. Similarly there is also some room for movement of the storage rack vibration isolator in the vertical direction, which imparts some dampening in the vertical direction. It will be understood that some features depicted in FIG 41 have not been discussed because they are common to previously described embodiments. It will be understood that generally these features are similar in form or function across the embodiments.

FIG. 42 depicts another embodiment incorporating a structure that restricts the movement of the storage rack vibration isolators **20y**. In this embodiment, the fixed base pad **94y** extends under and between the columns **38** of the storage rack. Two storage rack vibration isolators **90y** are attached to the cross brace **90y** at the attachment members **46y** as described earlier. However, in this embodiment, the first mounting plate **22y** is a flange that creates a slot in which the restriction element **97y** can fit into. The first mounting plate **22y** has an elastomer coating **98y** to help absorb the vertical impact of the vibration isolator **20y** during seismic events. The elastomer coating **98y** could be any shock absorbing material such as rubber, etc. During seismic events, the restriction element **97y** serves to substantially restrict the horizontal movement of the storage rack vibration isolator **20y** to one horizontal directional parallel to the fixed base pad **94y** in the direction depicted by the directional arrows **100,** as well as to

substantially restrict vertical movement of the storage rack vibration isolator **20y.** While the restriction element substantially restricts movement perpendicular to the directional arrows **100**, there is room for some movement in that direction which imparts some additional dampening in the down aisle direction. Similarly there is also some room for movement of the storage rack vibration isolator in the vertical direction, which imparts some dampening in the vertical direction. It will be understood that some features depicted in FIG 42 have not been discussed because they are common to previously described embodiments. It will be understood that generally these features are similar in form or function across the embodiments.

FIG. 43 depicts an embodiment in which the storage rack vibration isolators **20z** are attached to the bottom of the columns **38** of the storage rack system. In this embodiment two first mounting plates **22z** and two second mounting plate **24z** are perpendicular to the floor with the elastomeric component extending between them. In this embodiment, the elastomeric component comprises a single elastomeric member **26z** on either side of the column **38**. Each first mounting plate **22z** is attached to a sliding base plate **92z** that extends under the column **38**. The sliding base plate **92z** rests on a fixed base plate **94z** to which each second mounting plate **24z** is attached. A layer of low friction bearing material may be interposed between the fixed base plate **94z** and the sliding base plate **92z**.

The structure and orientation of the two second mounting plates **24z** serves to-restrict the horizontal movement of the storage rack vibration isolator **20z** to substantially one horizontal directional parallel to the two second mounting plates **24z** in the direction depicted by the directional arrows **100**. Nevertheless, the nature of elastomeric component allows from some compression in the direction perpendicular to the directional arrows **100** therefore some dampening is provided in that direction.

The embodiment depicted in FIG 43 is depicted with the storage rack vibration isolated located under and adjacent to the columns of the storage rack system. However, other configurations of this type of storage rack vibration isolator are possible. FIG 44 depicts one

such variation. In this embodiment, each storage rack vibration isolator **20za** comprises two sets of elastomeric components on either side of a cross brace **90za** that is welded between two storage rack columns **38**. The first mounting plate **22za** of each elastomeric component is bolted to the cross brace **90za**. The second mounting plate **24za** of each elastomeric component is attached to a fixed base pad **94za** at the perpendicular brace element **96za**. The fixed base plate **94za** extends across and under each column **38**. The columns **38** of the storage rack system are welded to sliding base pads **92za** that rest on the fixed base pad **94za**. The fixed base pad **94za** is itself coupled to the floor. A layer of low friction bearing material **99za** is interposed between the sliding base pad **92za** and the fixed base pad **94za**. The fixed base pad **94za** is sized to cover the area that the storage rack may move in a seismic event. In this embodiment each elastomeric component comprises three elastomeric members **26za** with two intermediate plates **70za**. The structure and orientation of the elastomeric components serves to substantially restrict the horizontal movement of the storage rack vibration isolator **20za** to substantially one horizontal directional in the direction depicted by the directional arrows **100**. Nevertheless, the nature of elastomeric component allows from some compression in the direction perpendicular to the directional arrows **100** therefore some dampening is provided in that direction.

FIG. 45 depicts an embodiment of storage rack vibration isolators **20zb** with an elastomeric component coupled to one side of cross brace **90zb** and a steel block **98zb** on the opposite side of the cross brace **90zb**. An elastomeric bumper **101zb** is attached to the steel block **98zb** on the side adjacent the cross brace **90zb** to absorb the impact of the cross brace **90zb** against the steel block **98zb** during seismic events. The structure and orientation of the elastomeric components and the steel block **98zb** serves to restrict the horizontal movement of the storage rack vibration isolator **20za** to substantially one horizontal directional in the direction depicted by the directional arrows **100**. Here again, the nature of elastomeric component allows

from some compression in the direction perpendicular to the directional arrows **100** therefore some dampening is provided in that direction.

FIG. 46 depicts another embodiment with storage rack vibration isolators **20zc** on either side of cross brace **90zc**. The second mounting plates **24zc** of the storage rack vibration isolators **20zc** are mounted on a fixed base plate **94zc** having a vertical component **96zc** that serves to restrict the horizontal movement of the storage rack vibration isolator **20zc** to substantially one horizontal directional in the direction depicted by the directional arrows **100**. The first mounting plate (not shown) of the storage rack vibration isolator **20zc** is coupled to a top plate **102zc** that is welded to the cross brace **90zc**. While movement perpendicular to the directional arrows **100** is substantially restricted in this embodiment, there is room for some movement in that direction which imparts some dampening in the down aisle direction.

The storage rack vibration isolators do not have to be attached to the storage rack system at the top of the isolators as has been described above. FIG. 47 depicts a seismic vibration system in which the columns **38** are welded to the top of a sliding base pad **92zd** that extends between and under the two columns **38** such that the storage rack vibration isolators **20zd** are also attached to the sliding base pad **92zd**. The sliding base pad **92zd** is formed into a U-shaped trough to provide additional protection to the storage rack vibration isolators **20zd** from side impacts. The sliding base pad **92zd** sits on top of a fixed base pad **94zd**. A restriction element **97zd** is placed over and coupled to the storage rack vibration isolators **20zd** with plate screws **62zd**. The restriction element is welded to the fixed base pad **94zd** thereby connecting the storage rack vibration isolator **20zd** to the floor.

During seismic events, while the restriction element **97zd** remains fixed, the sliding base pad **92zd** with the storage rack vibration isolators **20zd** slides through the tunnel created by the restriction element **97zd** and the fixed base pad **94zd**. The sliding base pad **92zd** projects over the end of the fixed base pad **94zd** to about the extent of the movement of storage rack system during each vibration cycle while supporting the columns **38** mounted on it. The protrusion of the

sliding base pad **92zd** into the aisle prior to an earthquake can be minimized by minimizing or eliminating the extension of the sliding base pad **92zd**, the fixed base pad **94zd**, and the low friction bearing material **99zd** beyond the outside end of the column **38.** The structure of the restriction element **97zd** serves to restrict the horizontal movement of the storage rack vibration isolator **20zd** to substantially one horizontal directional parallel to the fixed base pad **94zd** in the direction depicted by the directional arrows **100,** as well as to substantially restrict vertical movement of the storage rack vibration isolator **20zd**. As with other embodiments, the potential energy stored in the elastomeric members **26zd** biases them to return the storage rack system to substantially its original position at the end of a seismic event. In between the sliding base pad **92zd** and the fixed base pad **94zd** is a layer of bearing material **99zd** having a low coefficient of friction that helps the sliding base pad **91zd** to slide over the fixed base pad **94zd**.

All of the embodiments disclosed above can be applied to a storage rack system comprising a plurality of columns not just one or two columns. Indeed, as has been discussed above, to ensure adequate protection for the storage rack system against seismic events, the design characteristics of the storage rack system must be taken into account. Existing storage rack systems can be retrofitted with storage rack vibration isolator units to ensure the entire storage rack system is adequately protected during seismic events. Storage rack systems could also be designed with the storage rack vibration isolators installed during their construction. FIGS. 48 through 50 depict storage rack vibration isolators attached to various storage rack systems and illustrate the application of the storage rack vibration isolators to complete storage rack systems. Other configurations and designs of storage rack systems could work just as well.

FIG. 48 depicts a storage rack system with storage rack vibration isolators **20ze** attached to the lower ends of each column and to the floor. FIG. 49 depicts a six-column storage rack system with the storage rack vibration isolators **20zf** attached between the columns of a storage rack system **38**. Storage rack vibration isolators **20zf** are attached to cross braces **90zf** between pairs of columns **38**. Each column in the system is welded to a sliding

base pad **92zf** and position over a fixed base pad **94zf** on which the column may slide. FIG. 50 depicts a storage rack system with eight columns with storage rack vibration isolators **20zg** installed between the columns **38**. In this case the storage rack vibration isolators **20zg** are an embodiment described above, which include structures that mechanically restricted to movement in substantially one horizontal direction corresponding to the cross-aisle direction of the storage rack system, i.e. the direction in which the storage rack is stiffer. It will be appreciated that the particular embodiments of storage rack vibration isolators depicted in FIGS. 48 through 50 are shown by way of example and any of the embodiments, or combination of embodiments, of storage rack vibration isolators previously described would work equally well.

As has been discussed, because the storage rack system is less flexible in the cross-aisle direction than in the down-aisle direction, the elastomers must be selected to at least lower the natural frequency of the whole storage rack system in at least the cross-aisle direction. It has been calculated that for storage rack systems with a design maximum load capacity of about 40,000 lbs comprising of three rows of two columns each in the less flexible cross-aisle direction, a storage rack vibration isolator system that has a total shear stiffness of about 1,600 lbs/in for the entire storage rack system and allows the columns to move about five inches in both directions from their resting positions for a total of about ten inches of peak-to-peak distance would reduce the natural frequency of the storage rack to about 0.6 Hz in the cross-aisle direction.

Seismic testing has been successfully conducted on this type of storage rack system having a 40,000 lb. load distributed on two bays three and four levels high typical of a warehouse retail store configuration. The storage rack system comprised three rows of columns having two columns each in the less flexible, cross-aisle direction. Two storage rack vibration isolators were installed between each row of two columns in the less flexible cross-aisle direction in the configuration shown in FIGS. 42 and 47. The tests were conducted in accordance with the AC-156 *Accepted Criteria For Seismic Qualification by Shake-Table Testing of Nonstructural*

Components and Systems of ICC Evaluation Services to achieve performance levels as outlined in the Federal Emergency Management Agency's FEMA 460 *Seismic Considerations for Steel Storage Racks Located in Areas Accessible to the Public*. The storage rack systems mounted on the shake tables were subjected to amplitudes corresponding to up to 200% of the AC-156 qualification levels. Each of the six storage rack vibration isolators had a static shear stiffness of about 270 lbs/in. for a total of 1,600 lbs/in and the ends of the elastomers moved under shear sufficiently to allow the columns to move about five inches in each direction from their resting positions for a total of about ten inches of peak-to-peak distance. This storage rack systems did not suffer any significant damage and the loads did not fall off the racks. The number of columns of the storage rack system does not limit the number of storage rack vibration isolator units that can be used. Additional storage rack vibration isolator units could be installed between the columns to achieve appropriate results if there is room for them.

It has been determined that elastomeric components made of butyl rubber (ASTM D2000 4AA 415 A13 Z1) with a stiffness of about 40 durometer and a loss factor of about ~~0.4~~ 0.3 are suitable for use in storage rack systems with design maximum loads of up to about 10,000 lbs per upright frame. Elastomeric components made of butyl rubber with a stiffness of about 40 durometer could be used for storage rack systems with maximum design loads of up to about 20,000 lbs. per upright frame. Additional damping could be provided to limit the larger travel requirements of the softer elastomers. It has been determined that elastomeric components made of butyl rubber (ASTM D2000 4AA 615 A13 Z1) with a stiffness of about 60 durometer and a loss factor of about 0.45 are suitable for use in storage rack systems with maximum design loads of between about 10,000 lbs. and about 20,000 lbs. per upright frame. Additional testing should be conducted to determine optimal characteristics for the elastomeric components for various designs of storage racks with various design load ranges. If softer materials are used for applications across the range of maximum design loads of storage rack systems, additional damping may be incorporated into the elastomeric component. This could

be achieved by including deformable lead cores, polymeric yielding devices, metallic yielding devices, or other devices into the elastomeric components. Other secondary damping elements, such as hydraulic shock absorbers, could be added in parallel with the isolation damper.

This invention has been described with reference to several preferred embodiments. Many modifications and alterations will occur to others upon reading and understanding the preceding specification. It is intended that the invention be construed as including all such alterations and modifications in so far as they come within the scope of the appended claims or the equivalents of these claims.

What is claimed:

1. A storage rack vibration isolator for a storage rack system installed on a floor comprising:

a first mounting plate connectable to the storage rack system;

a second mounting plate connectable to the floor; and

an elastomeric component extending between said first and second mounting plates and operatively attached to said first and second mounting plates so that during seismic events said first and second mounting plates remain attached to said elastomeric component as said elastomeric component is placed in shear while said first and second mounting plates are able to move in planes substantially parallel to each other, said elastomeric component comprising at least one elastomeric member, said at least one elastomeric member made of material that is capable of absorbing and dissipating the energy of ground movement imparted to the storage rack system during seismic events while said material enables the storage rack system to move a sufficient distance relative to the floor to lower the natural frequency of the storage rack system in at least one horizontal direction.

2. The storage rack vibration isolator of claim 1 in which the elastomeric component is chosen to reduce the natural frequency of the storage rack system in the at least one horizontal direction to about 0.9 Hz or less.

3. The storage rack vibration isolator of claim 1 in which the elastomeric component is chosen to reduce the natural frequency of the storage rack system in the at least one horizontal direction to about 0.5 Hz or less.

4. The storage rack vibration isolator of claim 1 in which said elastomeric component further comprises:

at least two elastomeric members; and

at least one intermediate plate positioned between every two said at least two elastomeric members.

5. The storage rack vibration isolator of claim 1 in which said at least one elastomeric member is made of a material from the group consisting of polyisoprene, polyisoprene blend, butyl rubber, acryl rubber, polyurethane, flurorubber, polysulfide rubber, ethylene-propylene rubber (EPR and EPDM), Hypalon, chlorinated polyethylene, ethylene-vinyl acetate rubber, epichlorohydrin rubber, chloroprene rubber, and silicone.

6. The storage rack vibration isolator of claim 1 in which said at least one elastomeric member is made of a material that has a damping loss factor greater than about 0.1.

7. A storage rack vibration isolator for a storage rack system installed on a floor comprising:

a first mounting plate connectable to the storage rack system;

a second mounting plate connectable to the floor;

an elastomeric component extending between said first and second mounting plates and operatively attached to said first and second mounting plates so that during seismic events said first and second mounting plates remain attached to said elastomeric component as said elastomeric component is placed in shear while said first and second mounting plates are able to move in planes substantially parallel to each other, said elastomeric component comprising at least one elastomeric member, said at least one elastomeric member made of material that is capable of absorbing and dissipating the energy of ground movement imparted to the storage rack system during seismic events while said material enables the storage rack system to move a sufficient distance relative to the floor to lower the natural frequency of the storage rack system in at least one horizontal direction; and

a structure that restricts the movement of said elastomeric component to substantially the at least one horizontal direction.

8. The storage rack vibration isolator of claim 7 in which said structure that restricts the movement of said elastomeric component to substantially the at least one horizontal direction allows a limited amount of movement in another horizontal direction.

9. The storage rack vibration isolator of claim 7 which includes a structure that substantially restricts the movement of said elastomeric component in a vertical direction.

10. The storage rack vibration isolator of claim 7 which includes a structure that substantially restricts the movement of said elastomeric component in a vertical direction so as to allow a limited amount of movement in the vertical direction.

11. The storage rack vibration isolator of claim 7 in which said elastomeric component is configured to function primarily in the at least one horizontal direction.

12. The storage rack vibration isolator of claim 7 further comprising:

said elastomeric component configured to function primarily in the at least one horizontal direction; and

a structure that substantially restricts the movement of said elastomeric component in a vertical direction.

13. The storage rack vibration isolator of claim 7 in which the elastomeric component is chosen to reduce the natural frequency of the storage rack system in the at least the one horizontal direction to about 0.9 Hz or less.

14. The storage rack vibration isolator of claim 7 in which the elastomeric component is chosen to reduce the natural frequency of the storage rack system in the at least the one horizontal direction to about 0.5 Hz or less.

15. The storage rack vibration isolator of claim 7 in which said elastomeric component further comprises:

at least two elastomeric members; and

at least one intermediate plate positioned between every two said at least two elastomeric members.

16. The storage rack vibration isolator of claim 7 in which said at least one elastomeric member is made of a material from the group consisting of polyisoprene, polyisoprene blend, butyl rubber, acryl rubber, polyurethane, flurorubber, polysulfide rubber, ethylene-propylene rubber (EPR and EPDM), Hypalon, chlorinated polyethylene, ethylene-vinyl acetate rubber, epichlorohydrin rubber, chloroprene rubber, and silicone.

17. The storage rack vibration isolator of claim 7 in which said at least one elastomeric member is made of a material that has a damping loss factor greater than about 0.1.

18. A storage rack system installed on a floor comprising:

a plurality of columns having lower ends that are moveable with respect to the floor;

at least one storage rack vibration isolator; and

said at least one storage rack vibration isolator comprising a first mounting plate connected to said storage rack system, a second mounting plate connected to the floor, and an elastomeric component extending between said first and second mounting plates and operatively attached to said first and second mounting plates so that during seismic events said first and second mounting plates remain attached to said elastomeric component as the elastomeric component is placed in shear while said first and second mounting plates are able to move in planes substantially parallel to each other, said elastomeric component comprising at least one elastomeric member made of material that is capable of absorbing and dissipating the energy of ground movement imparted to the storage rack system during seismic events while said plurality of columns moves with respect to the floor while said material enables the storage rack system to move a sufficient distance relative to the floor to lower the natural frequency of the storage rack system in at least one horizontal direction.

19. The storage rack system of claim 18 further comprising said at least one storage rack vibration isolator mounted between the lower end of at least one of said columns and the floor.

20. The storage rack system of claim 18 further comprising said at least one storage rack vibration isolator mounted between the lower end of each said column and the floor.

21. The storage rack system of claim 18 further comprising said at least one storage rack vibration isolator mounted adjacent the lower end of at least one of said columns and the floor.

22. The storage rack system of claim 18 further comprising said at least one storage rack vibration isolator mounted adjacent the lower end of each said column and the floor.

23. The storage rack system of claim 18 in which the elastomeric component is chosen to reduce the natural frequency of the storage rack system in the at least one horizontal direction to about 0.9 Hz or less.

24. The storage rack system of claim 18 in which the elastomeric component is chosen to reduce the natural frequency of the storage rack system in the at least one horizontal direction to about 0.5 Hz or less.

25. The storage rack system of claim 18 in which said elastomeric component further comprises:

at least two elastomeric members; and

at least one intermediate plate positioned between every two said at least two elastomeric members.

26. The storage rack system of claim 18 in which said at least one elastomeric member is made of a material from the group consisting of polyisoprene, polyisoprene blend, butyl rubber, acryl rubber, polyurethane, flurorubber, polysulfide rubber, ethylene-propylene rubber (EPR and EPDM), Hypalon, chlorinated polyethylene, ethylene-vinyl acetate rubber, epichlorohydrin rubber, chloroprene rubber, and silicone.

27. The storage rack system of claim 18 in which said at least one elastomeric member is made of a material that has a damping loss factor greater than about 0.1.

28. A storage rack system installed on a floor comprising:

a plurality of columns having lower ends that are moveable with respect to the floor;

at least one storage rack vibration isolator;

said at least one storage rack vibration isolator comprising a first mounting plate connected to said storage rack system, a second mounting plate connected to the floor, and an elastomeric component extending between said first and second mounting plates and operatively attached to said first and second mounting plates so that during seismic events said first and second mounting plates remain attached to said elastomeric component as the elastomeric component is placed in shear while said first and second mounting plates are able to move in planes substantially parallel to each other, said elastomeric component comprising at least one elastomeric member made of material that is capable of absorbing and dissipating the energy of ground movement imparted to the storage rack system during seismic events while said plurality of columns moves with respect to the floor while said material enables the storage rack system to move a sufficient distance relative to the floor to lower the natural frequency of the storage rack system in at least one horizontal direction; and

a structure that restricts the movement of said elastomeric component to substantially the at least one horizontal direction.

29. The storage rack system of claim 28 in which said structure that restricts the movement of said elastomeric component to substantially at least one horizontal direction allows a limited amount of movement in another horizontal direction.

30. The storage rack system of claim 28 in which said at least one storage rack vibration isolator includes a structure that substantially restricts the movement of said elastomeric component in a vertical direction.

31. The storage rack system of claim 30 in which said structure that substantially limits the movement of said elastomeric component in a vertical direction allows a limited amount of movement in the vertical direction.

32. The storage rack system of claim 28 in which said elastomeric component of said at least one storage rack vibration isolator is configured to function primarily in the at least one horizontal direction.

33. The storage rack system of claim 28 further comprising:

said elastomeric component of said at least one storage rack vibration isolator is configured to function primarily in the at least one horizontal direction; and

said at least one storage rack vibration isolator includes a structure that substantially restricts the movement of said elastomeric component in a vertical direction.

34. The storage rack system of claim 28 further comprising said at least one storage rack vibration isolator mounted between the lower end of at least one of said columns and the floor.

35. The storage rack system of claim 28 further comprising said at least one storage rack vibration isolator mounted between the lower end of each said column and the floor.

36. The storage rack system of claim 28 further comprising said at least one storage rack vibration isolator mounted adjacent the lower end of at least one of said columns and the floor.

37. The storage rack system of claim 28 further comprising said at least one storage rack vibration isolator mounted adjacent the lower end of each said column and the floor.

38. The storage rack system of claim 28 in which the elastomeric component is chosen to reduce the natural frequency of the storage rack system in the at least one horizontal direction to about 0.9 Hz or less.

39. The storage rack system of claim 28 in which the elastomeric component is chosen to reduce the natural frequency of the storage rack system in the at least one horizontal direction to about 0.5 Hz or less.

40. The storage rack system of claim 28 in which said elastomeric component further comprises:

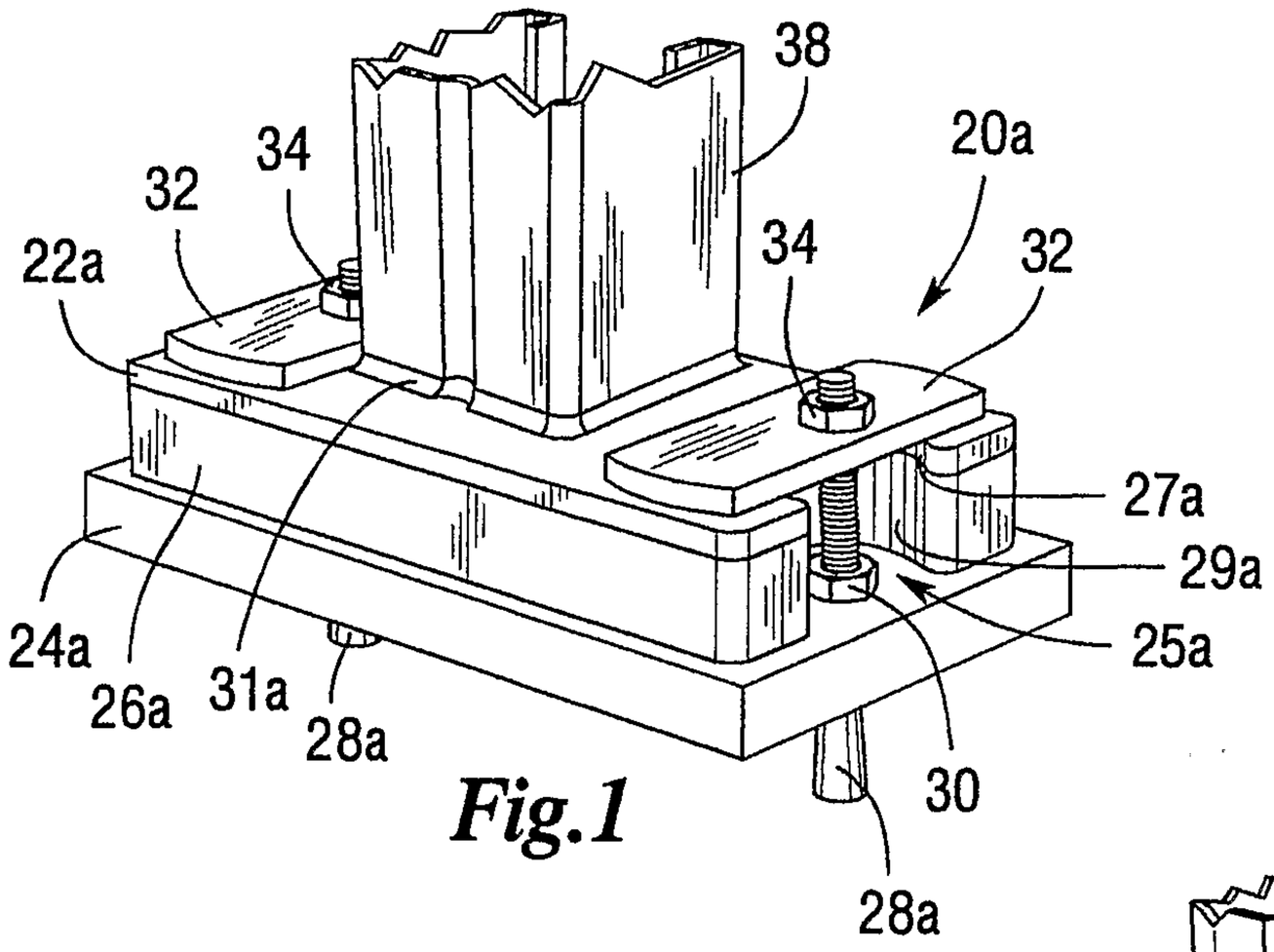
at least two elastomeric members; and

at least one intermediate plate positioned between every two said at least two elastomeric members.

41. The storage rack system of claim 28 in which said at least one elastomeric member is made of a material from the group consisting of polyisoprene, polyisoprene blend, butyl rubber, acryl rubber, polyurethane, flurorubber, polysulfide rubber, ethylene-propylene rubber (EPR and EPDM), Hypalon, chlorinated polyethylene, ethylene-vinyl acetate rubber, epichlorohydrin rubber, chloroprene rubber, and silicone.

42. The storage rack system of claim 28 in which said at least one elastomeric member is made of a material that has a damping loss factor greater than about 0.1.

43. The storage rack system of claim 28 which includes at least one storage rack vibration isolator mounted adjacent the lower end of at least one of said columns.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28a

Fig.1

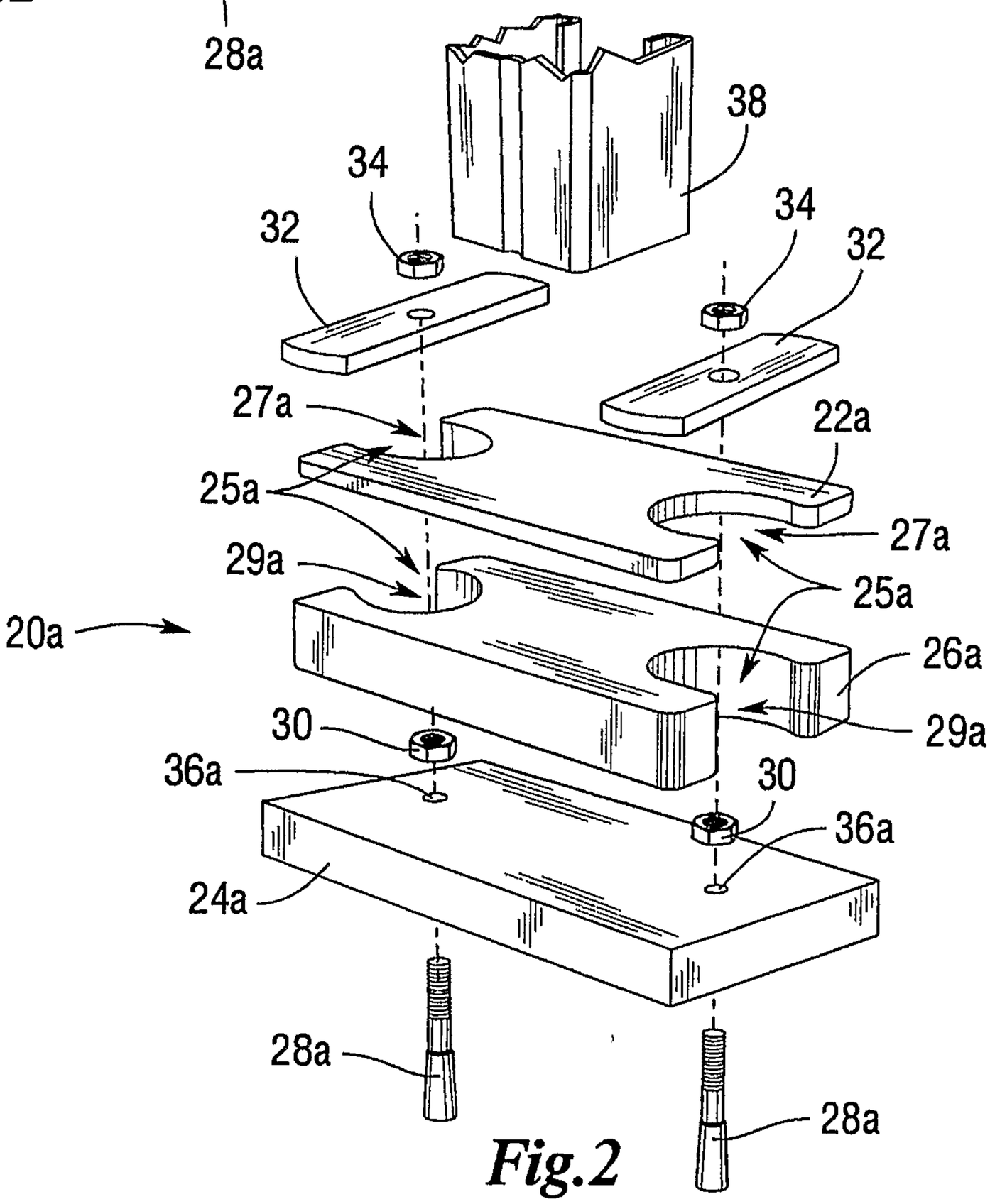
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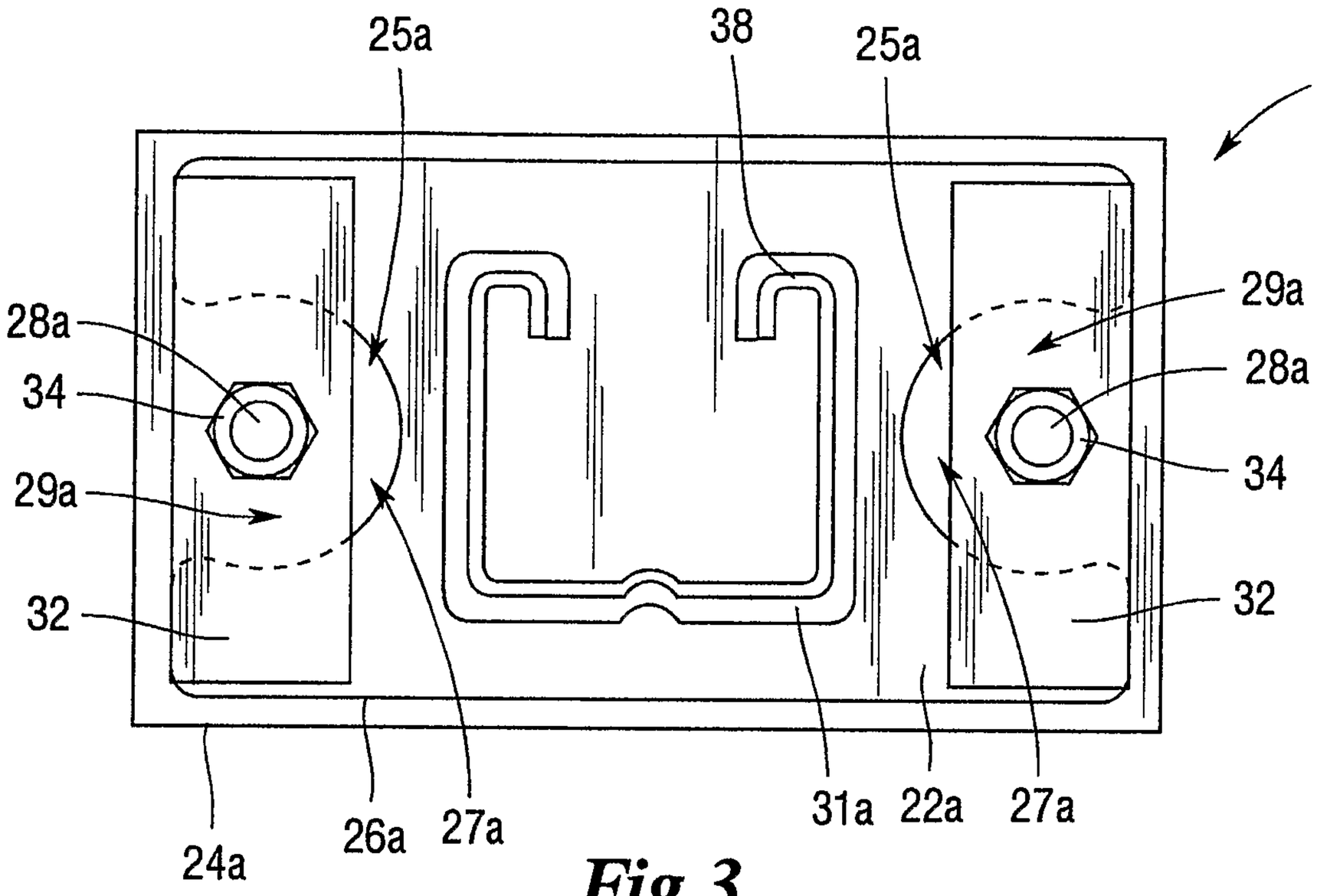
Fig.2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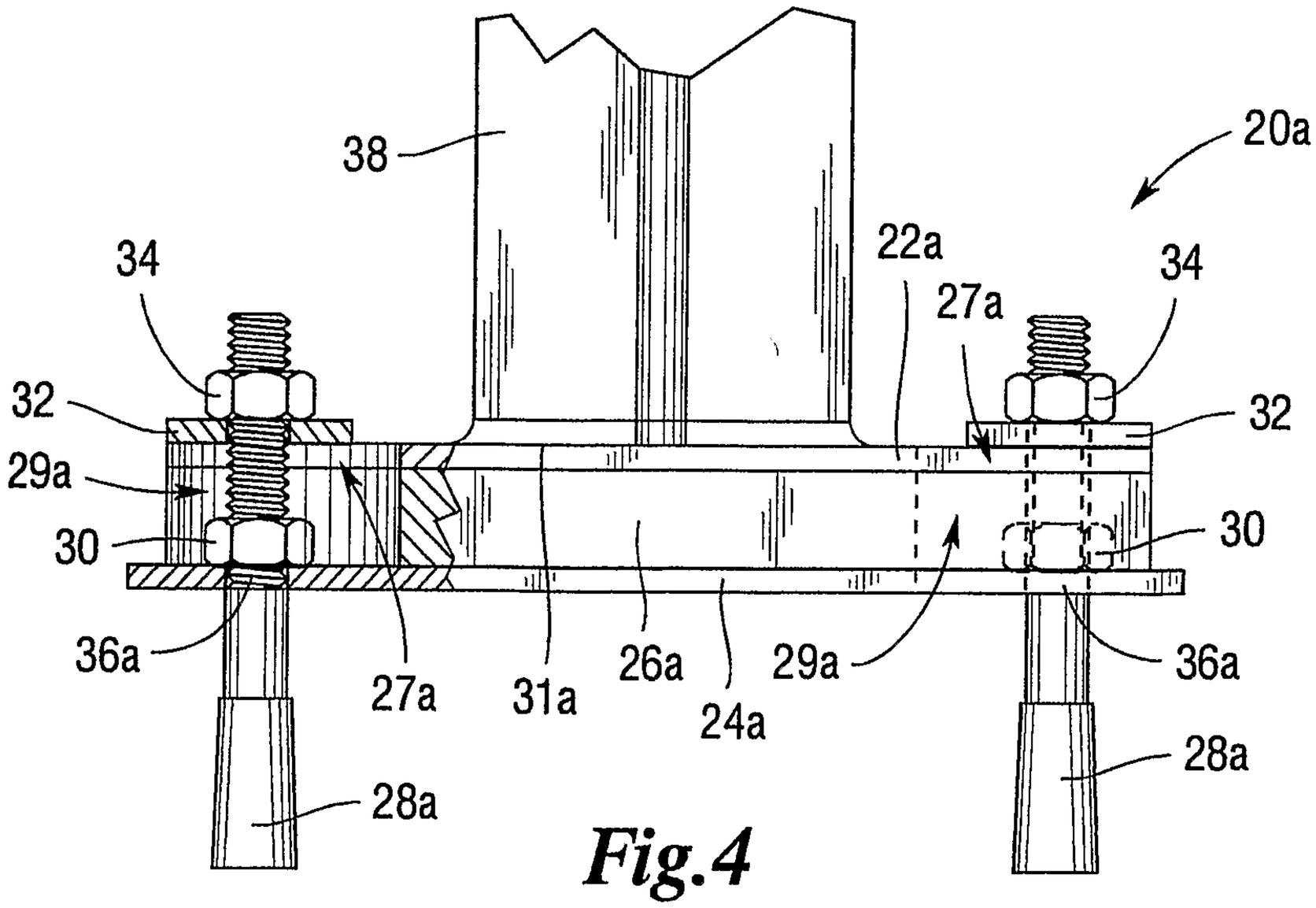
27a

Fig.3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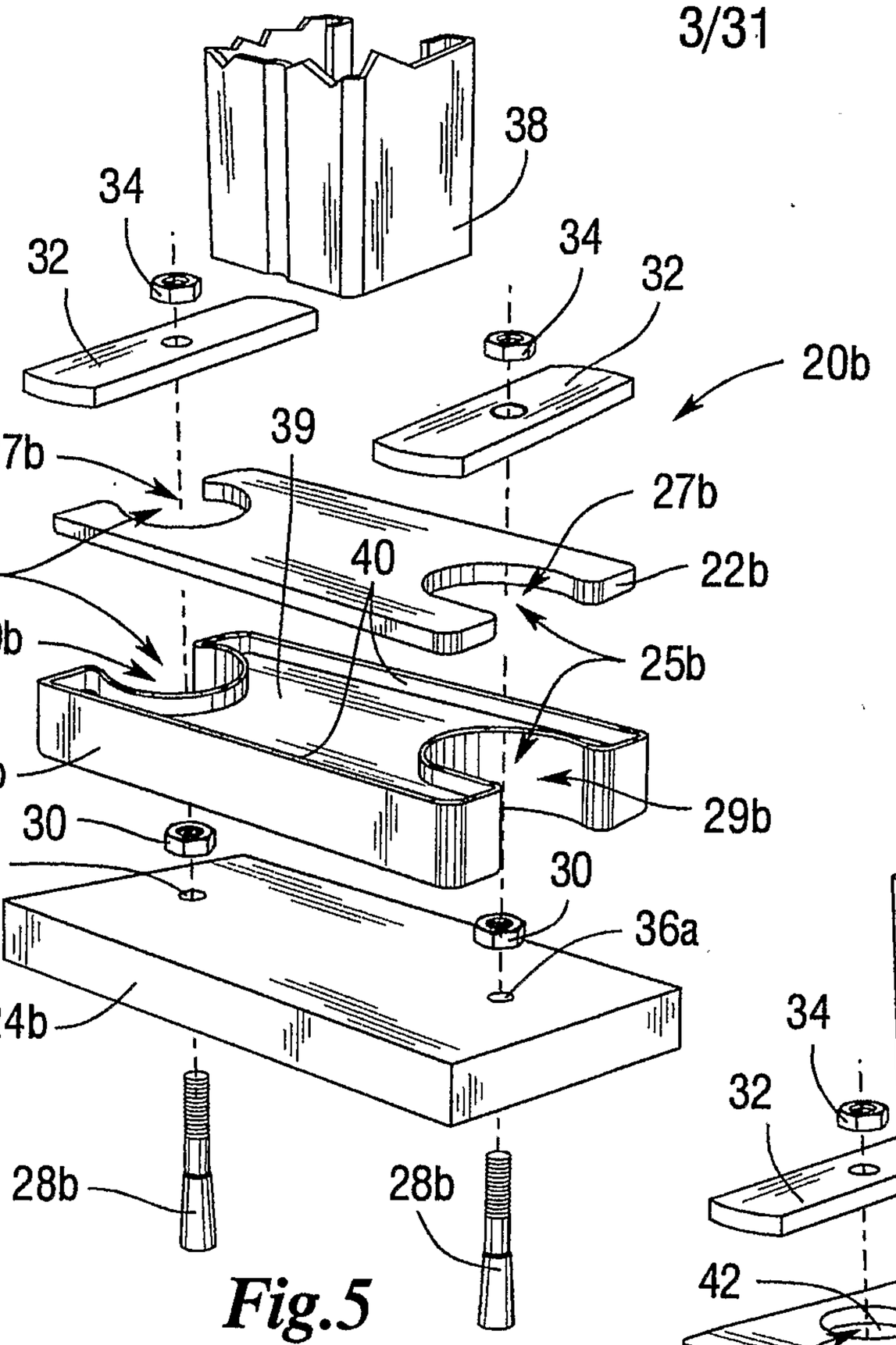
28a
28a

Fig.4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34
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32
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39
27b
27b
25b
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25b
26b
29b
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28b
28b

Fig.5

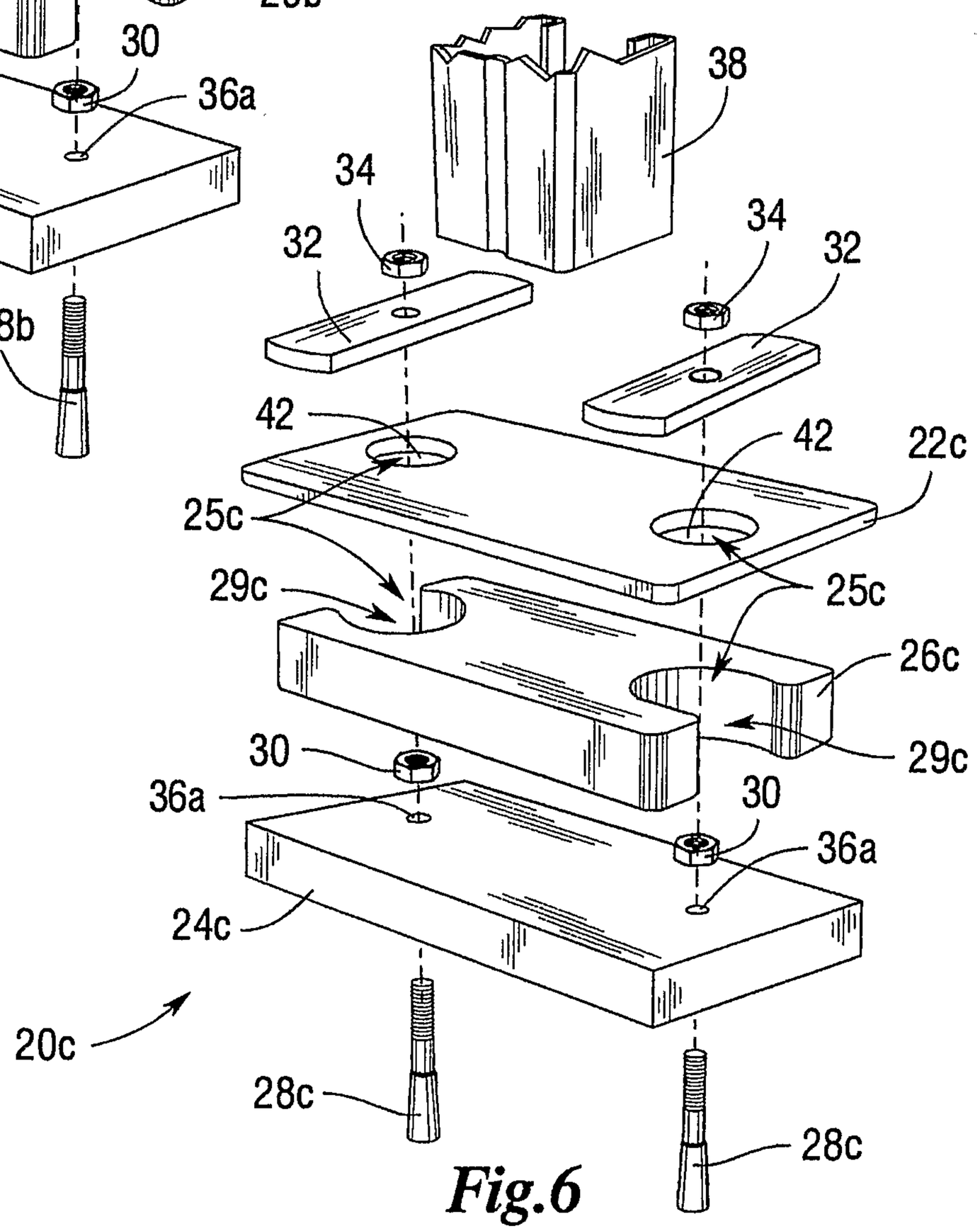
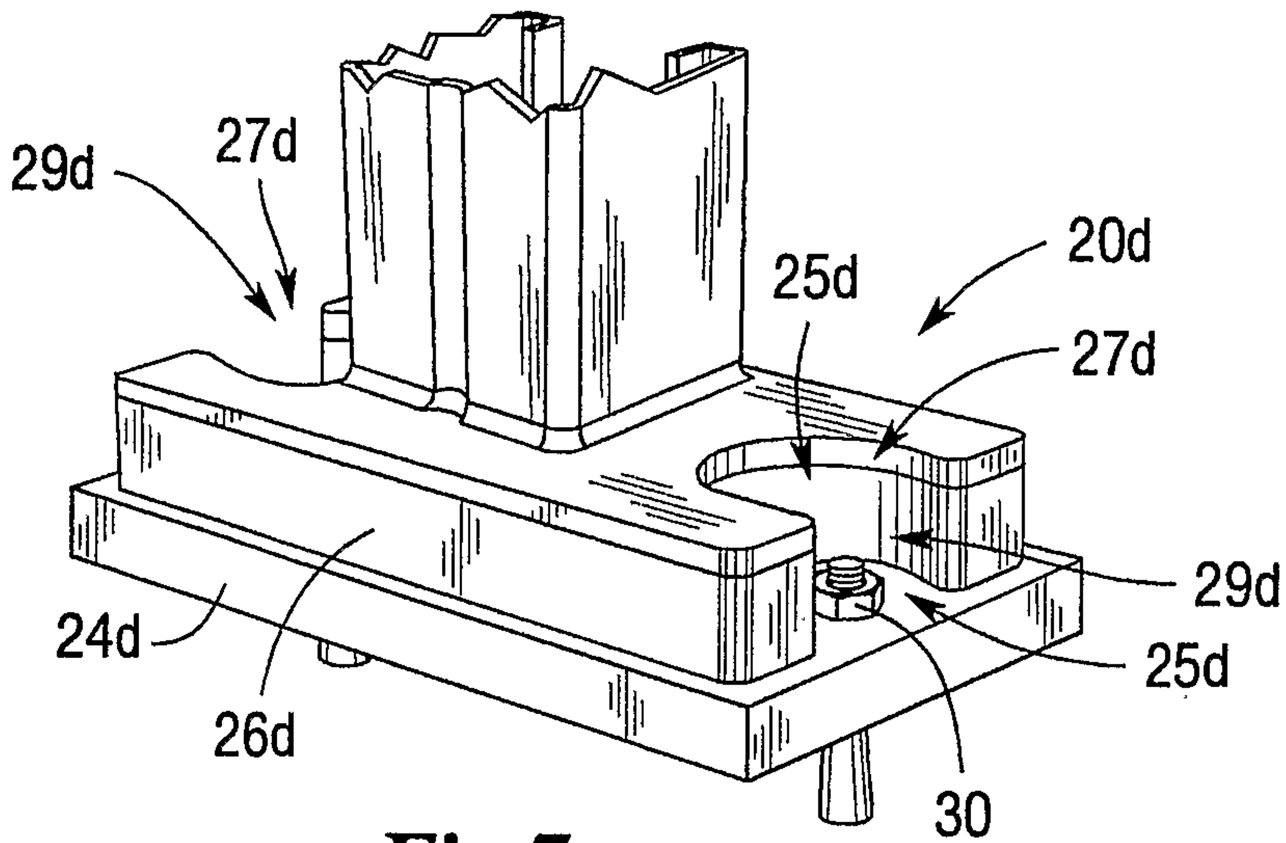

38
34
32
34
32
42
42
22c
25c
25c
29c
26c
29c
30
36a
30
36a
24c
20c
28c
28c

Fig.6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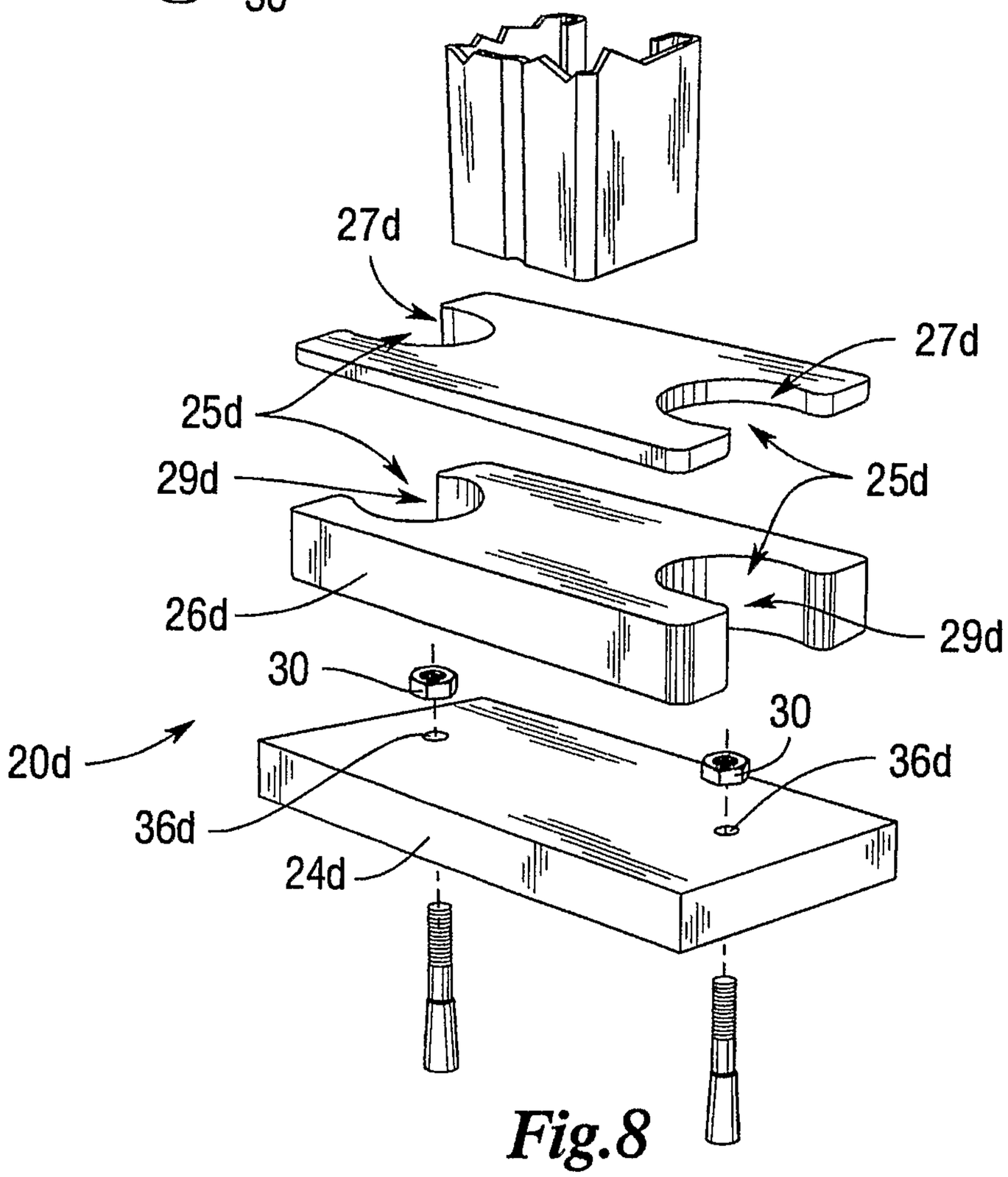
29d
25d
24d
26d
30

Fig.7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25d
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29d
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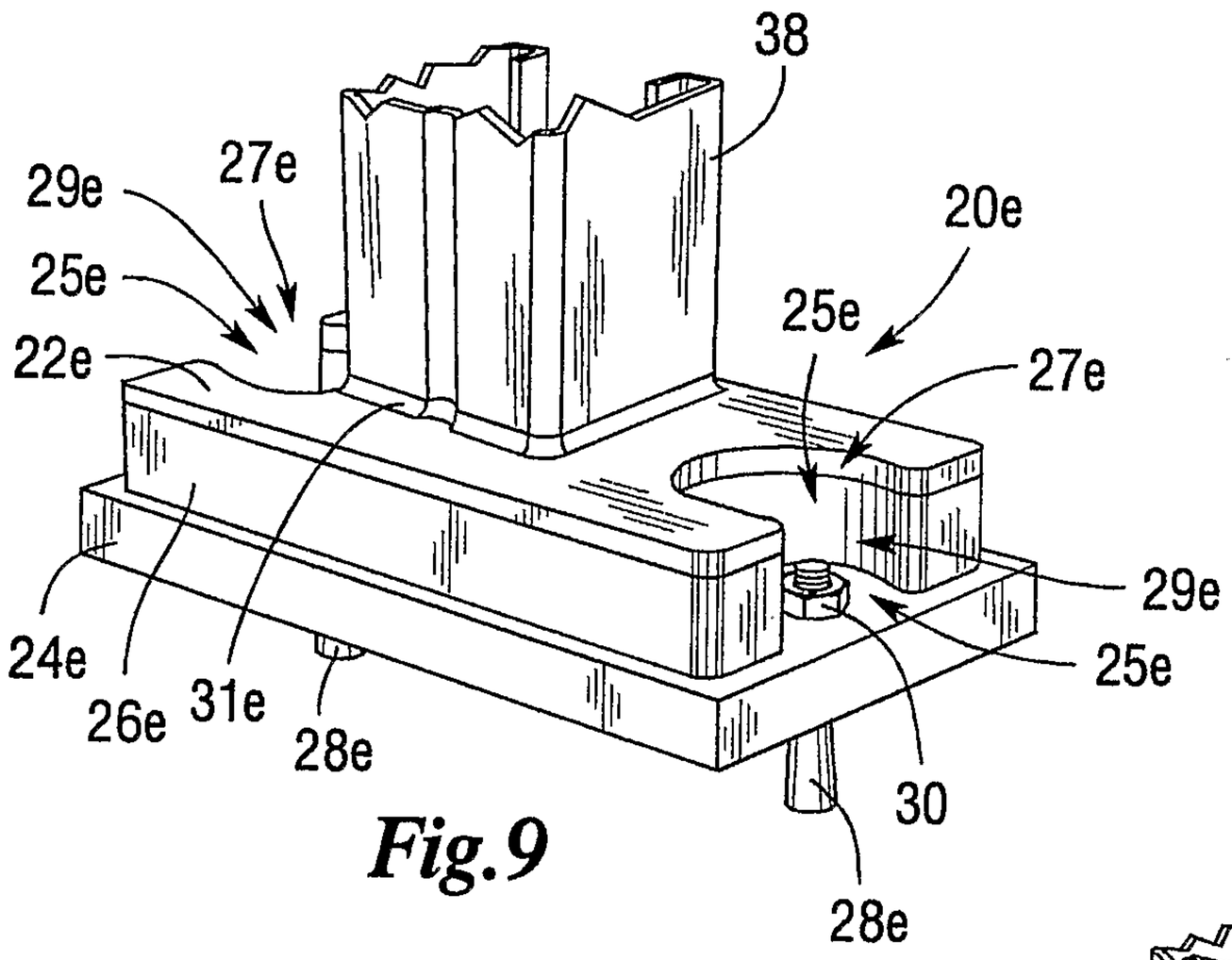
30
20d
36d
36d
24d

Fig.8


38
29e
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25e
24e
26e
31e
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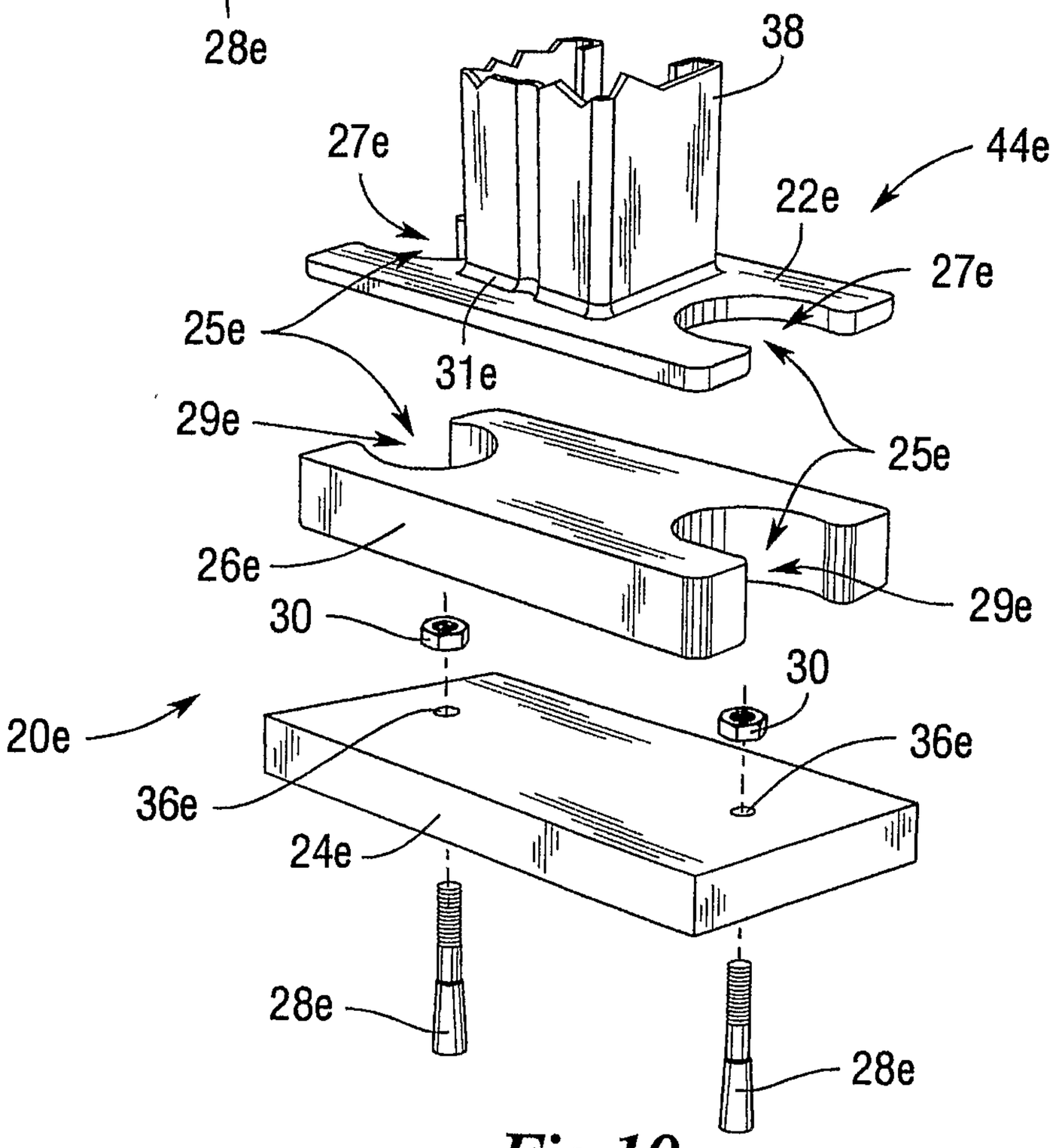
30
28e

Fig.9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22e
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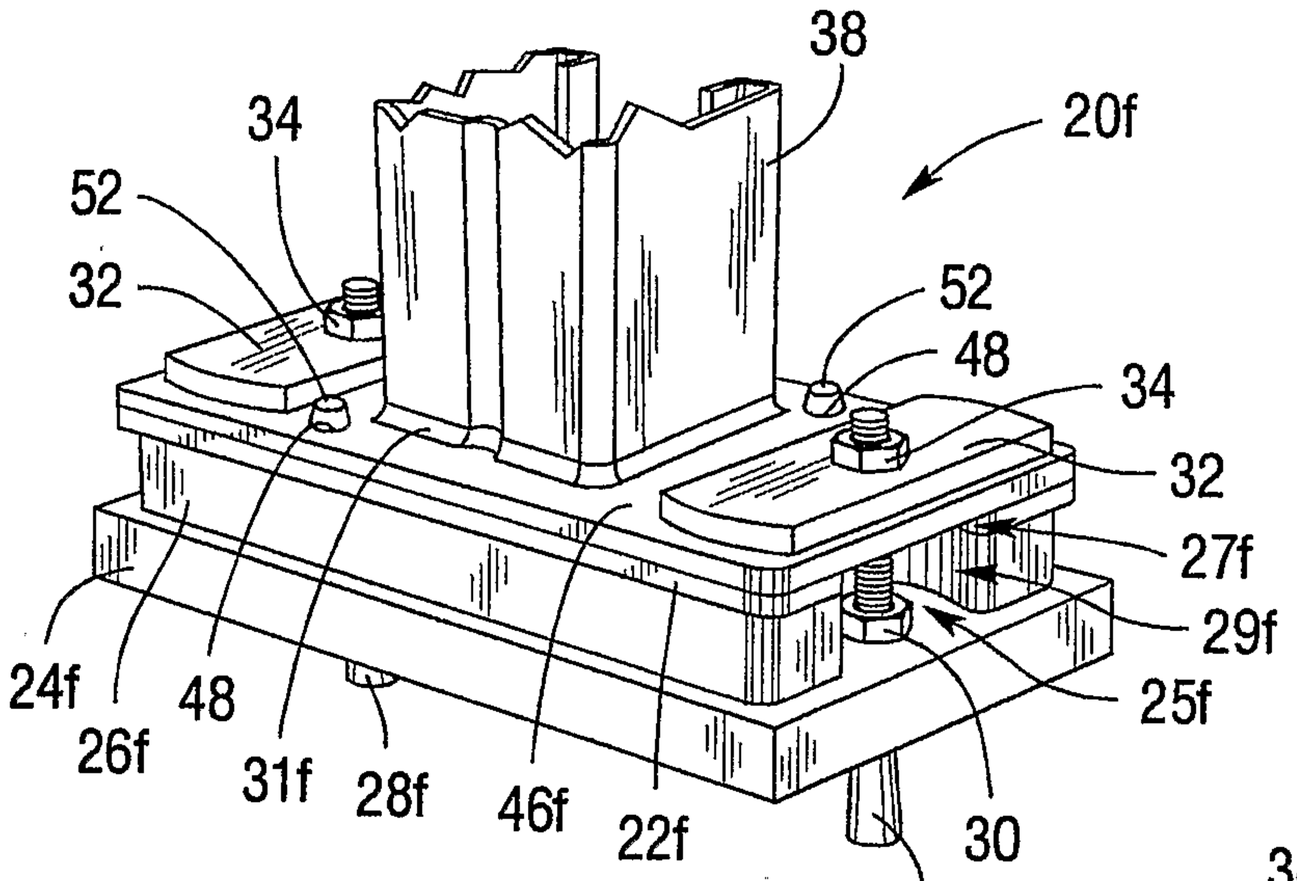
28e
28e

Fig.10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34
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29f
24f
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31f
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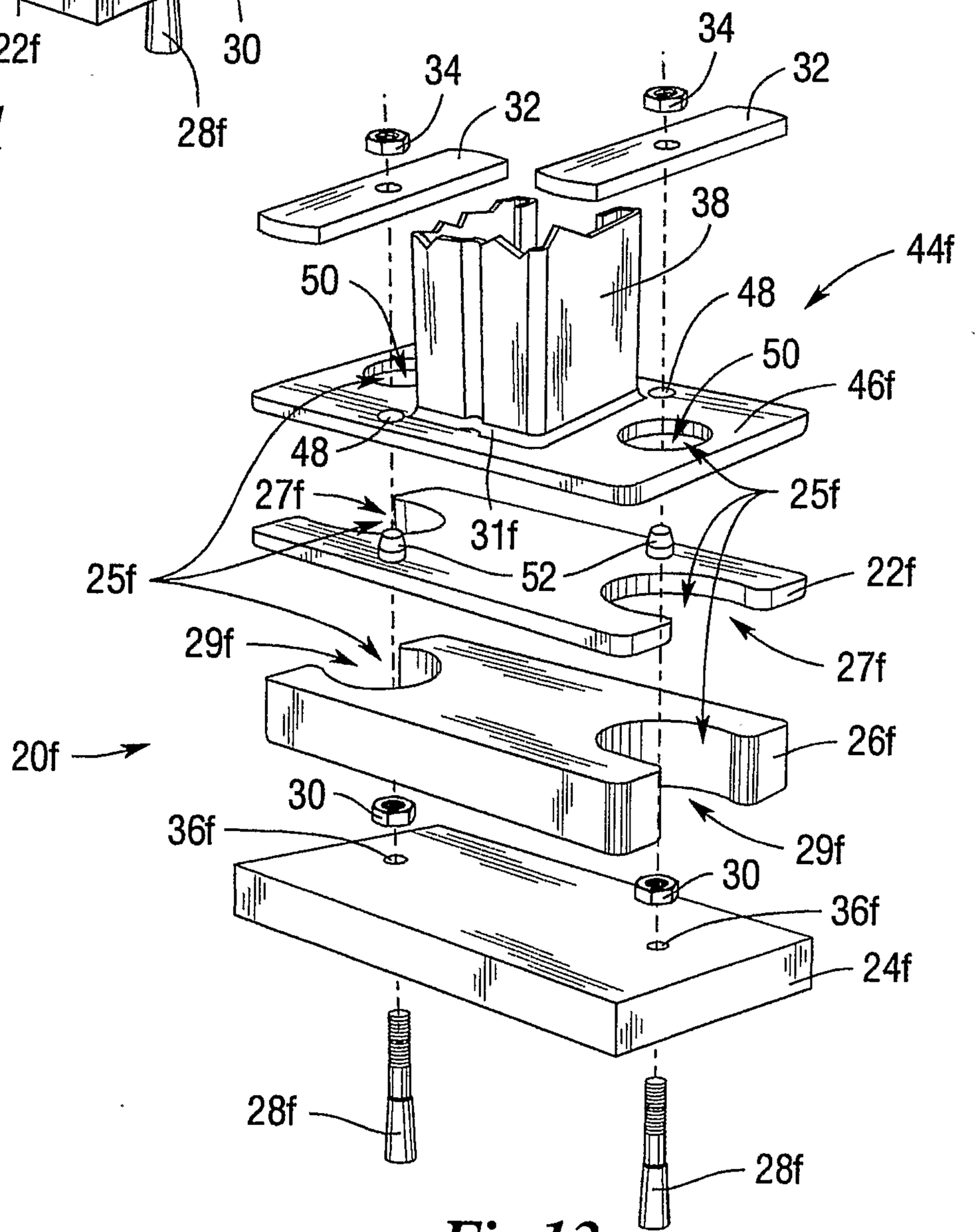
46f
22f
25f
30
28f

Fig.11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44f
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46f
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25f
27f
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20f
26f
30
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29f
30
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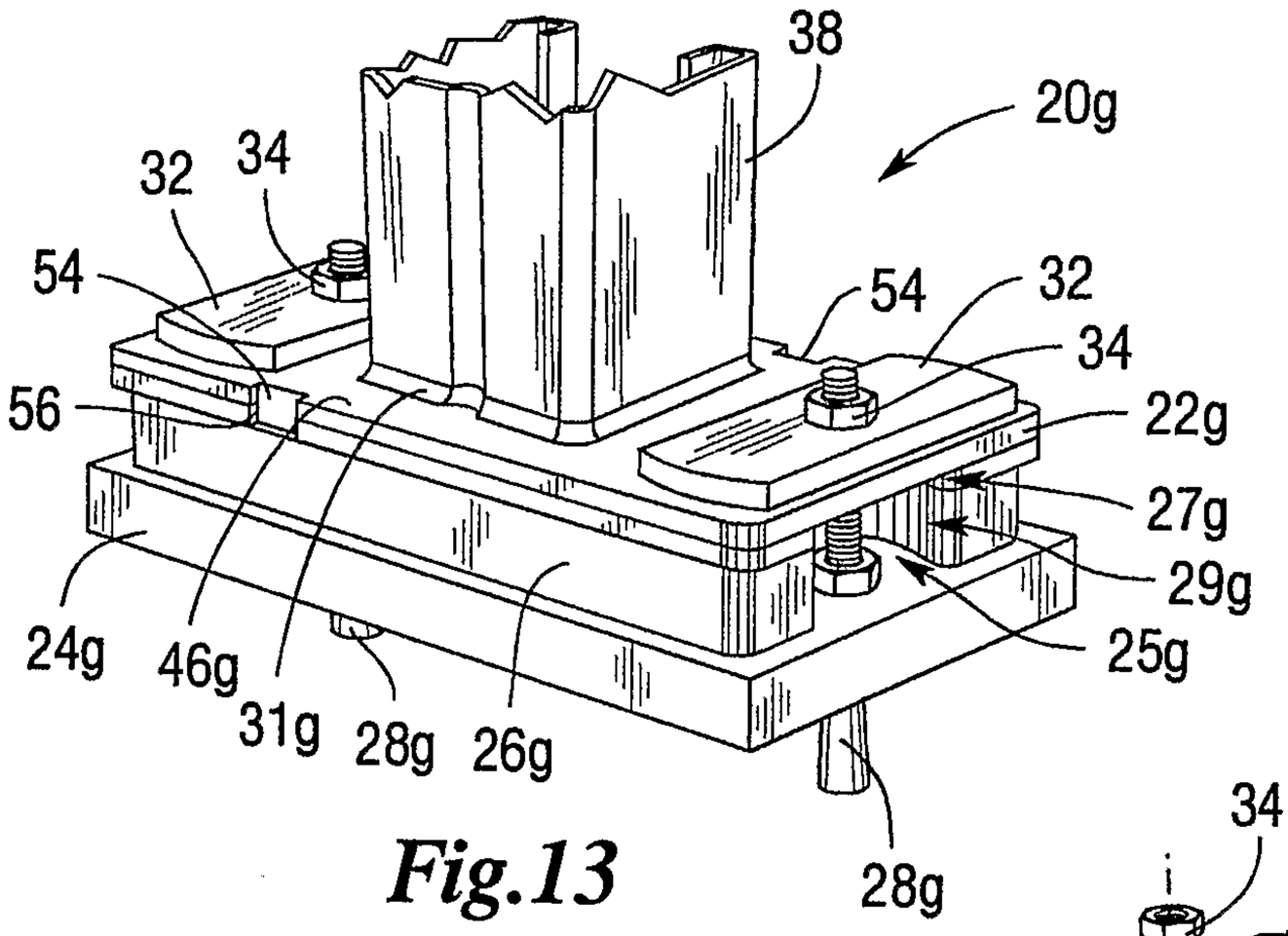
24f
28f
28f

Fig.12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20g
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54
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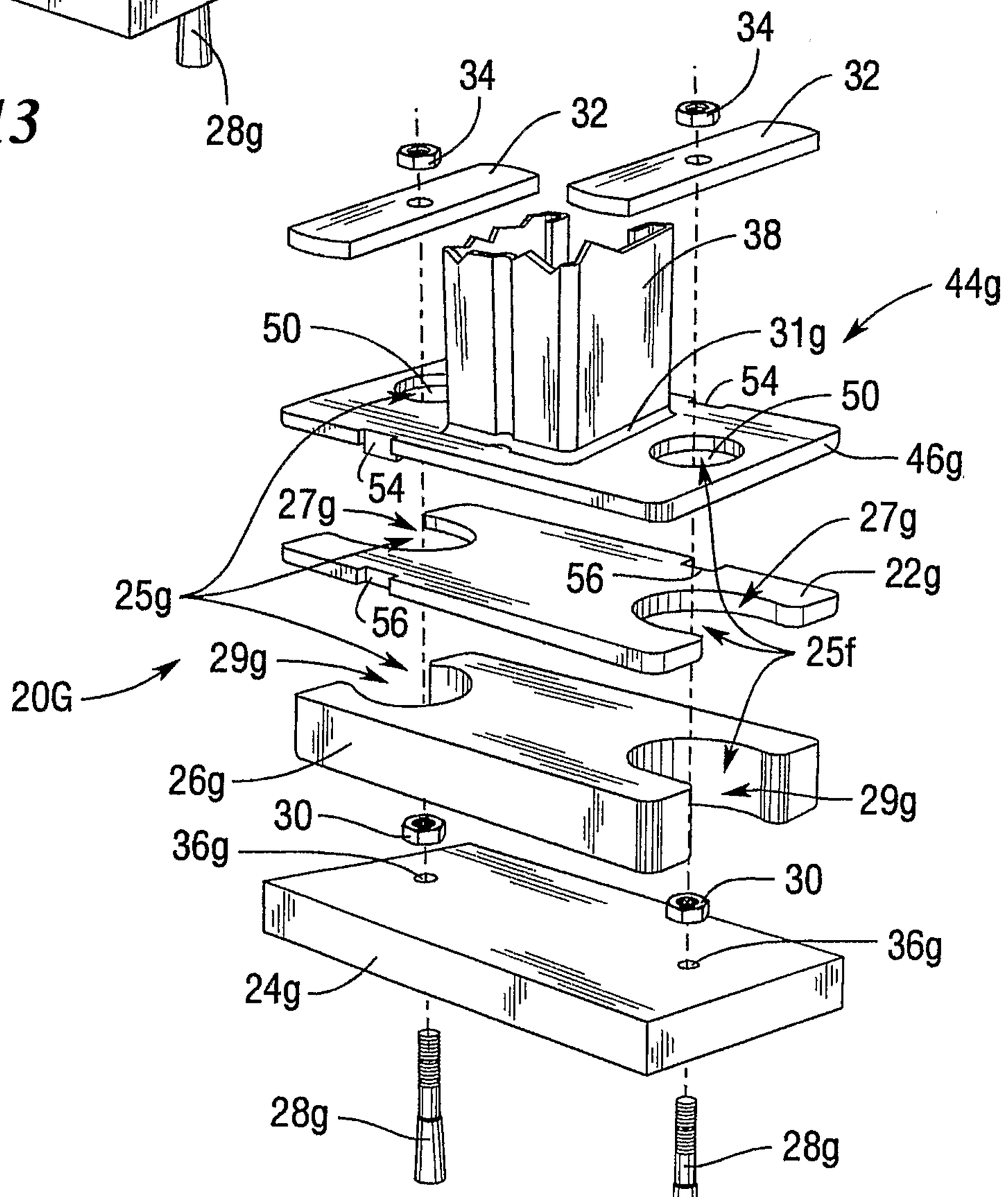
56
22g
27g
29g
24g
46g
31g
28g
26g
25g
28g

Fig.13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34
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44g
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31g
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46g
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27g
27g
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25f
20G
29g
26g
29g
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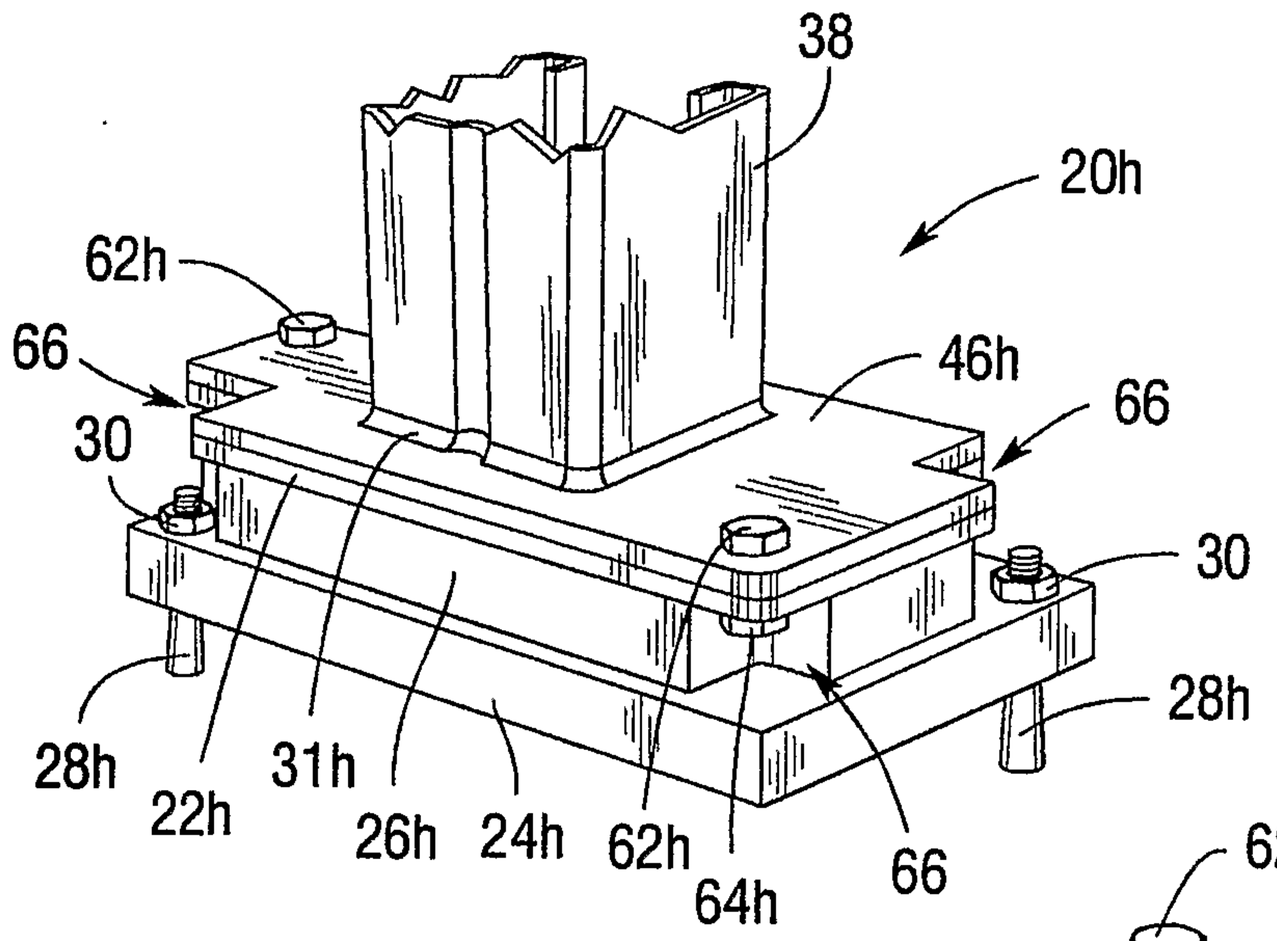
36g
30
36g
24g
28g
28g

Fig.14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20h
62h
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46h
66
30
30
28h
28h
22h
31h
26h
24h
62h
64h
66

Fig.15

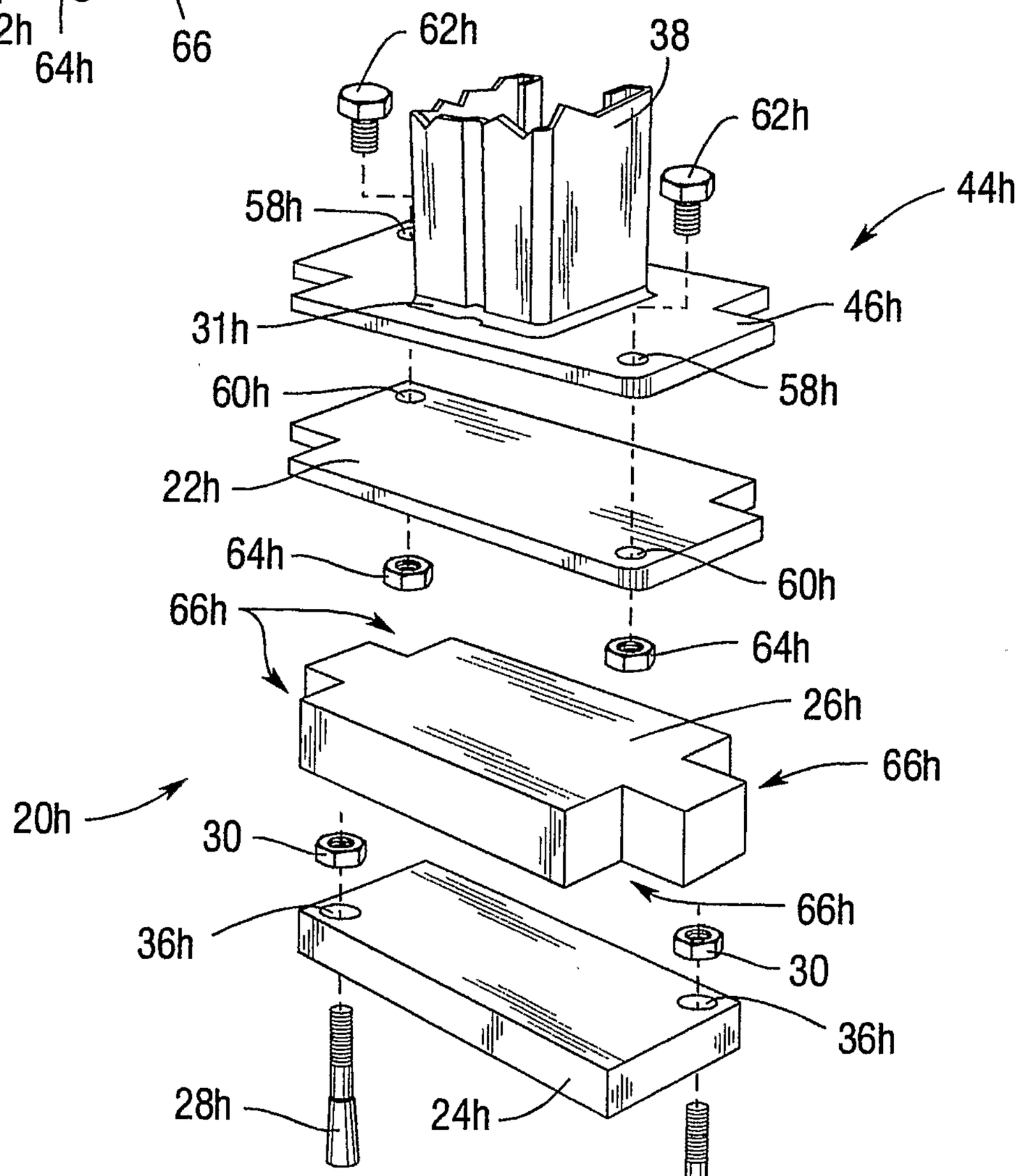

62h
38
62h
58h
44h
31h
46h
60h
58h
22h
64h
60h
66h
64h
26h
66h
20h
30
66h
36h
30
36h
28h
24h
28h

Fig.16

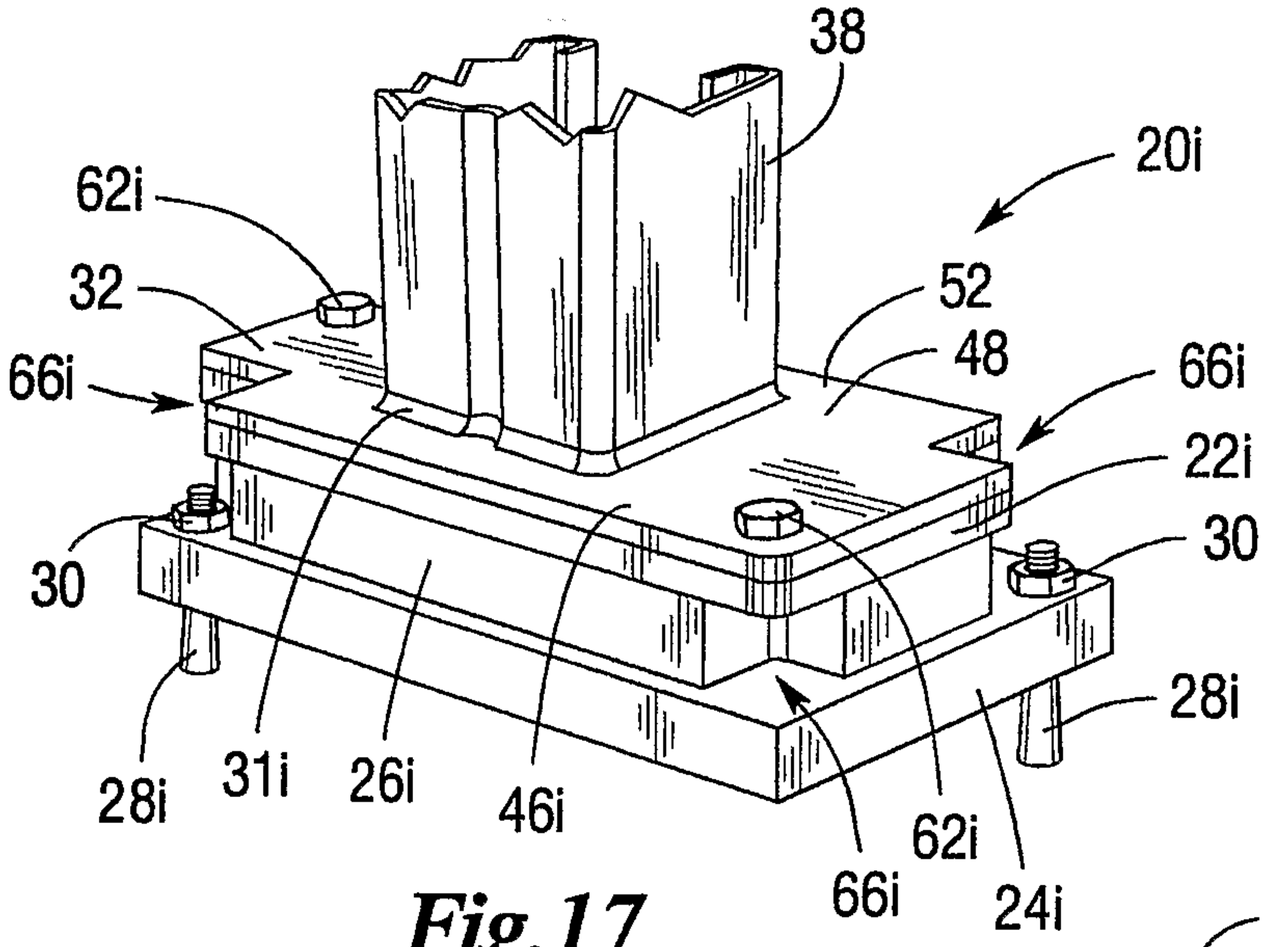
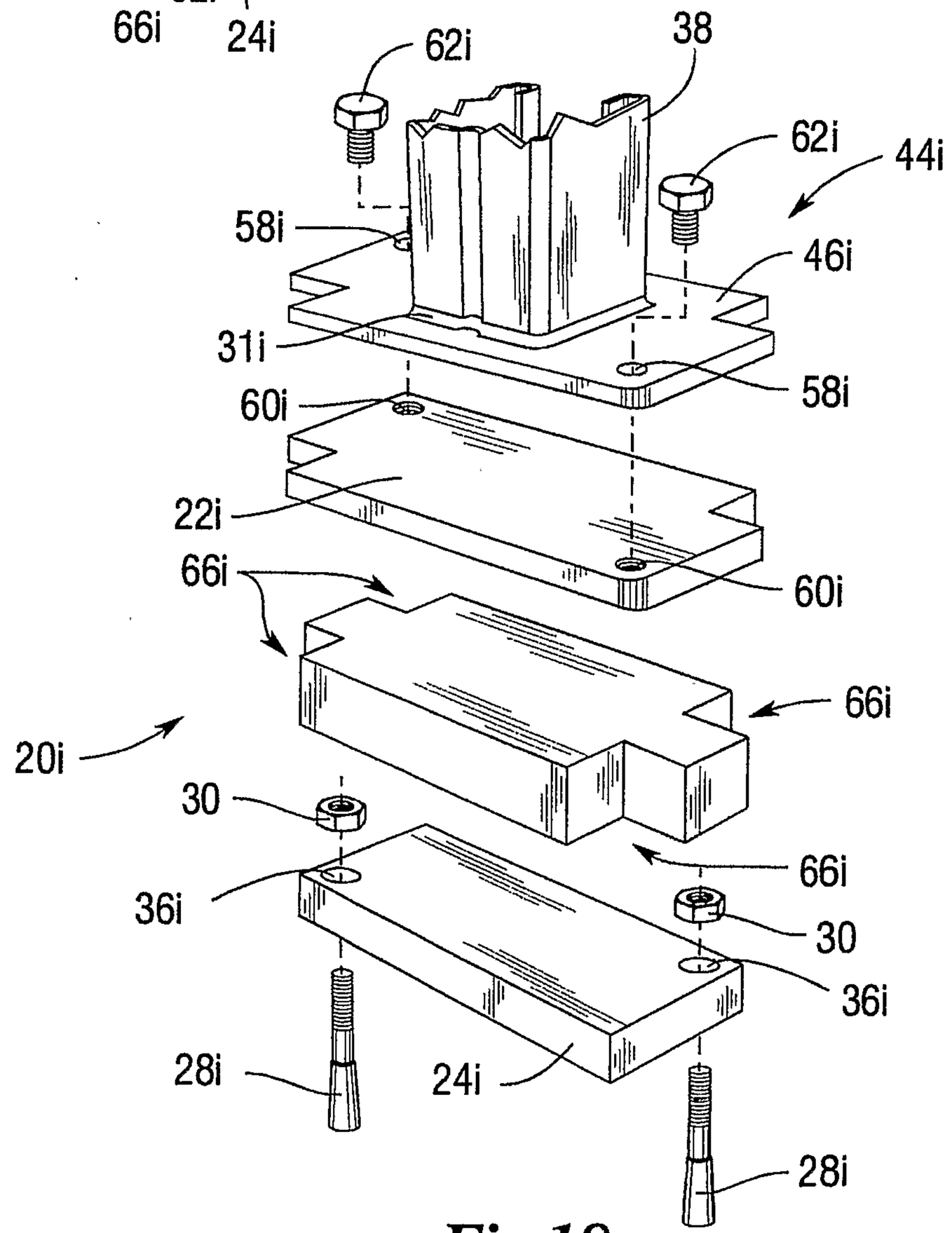

38
62i
20i
32
52
48
66i
66i
22i
30
30
28i
28i
31i
26i
46i
62i
66i
24i

Fig.17


62i
38
62i
44i
58i
46i
31i
58i
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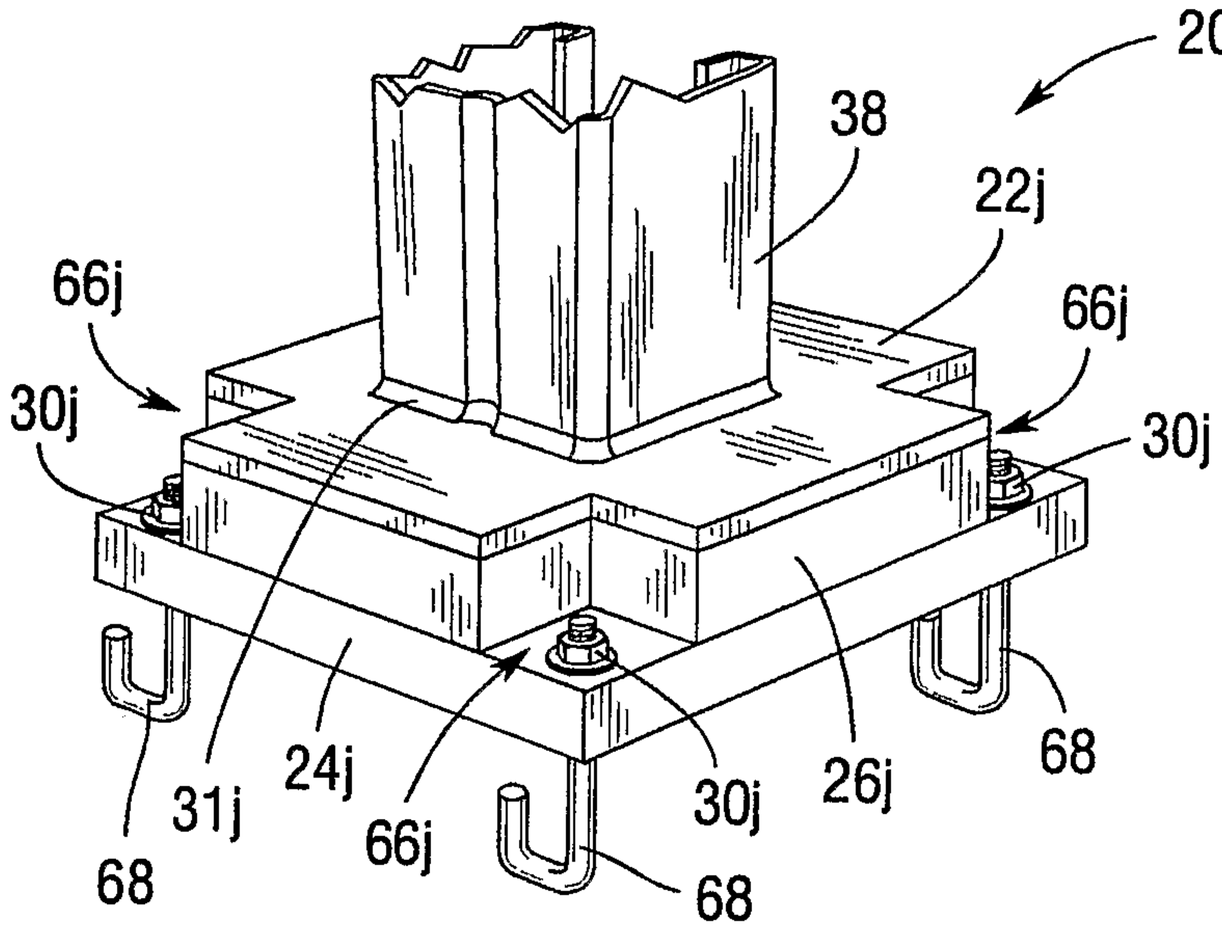
22i
60i
66i
66i
20i
30
66i
36i
30
36i
28i
24i
28i

Fig.18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22j
66j
66j
30j
30j
68
31j
24j
66j
30j
26j
68
68

Fig.19

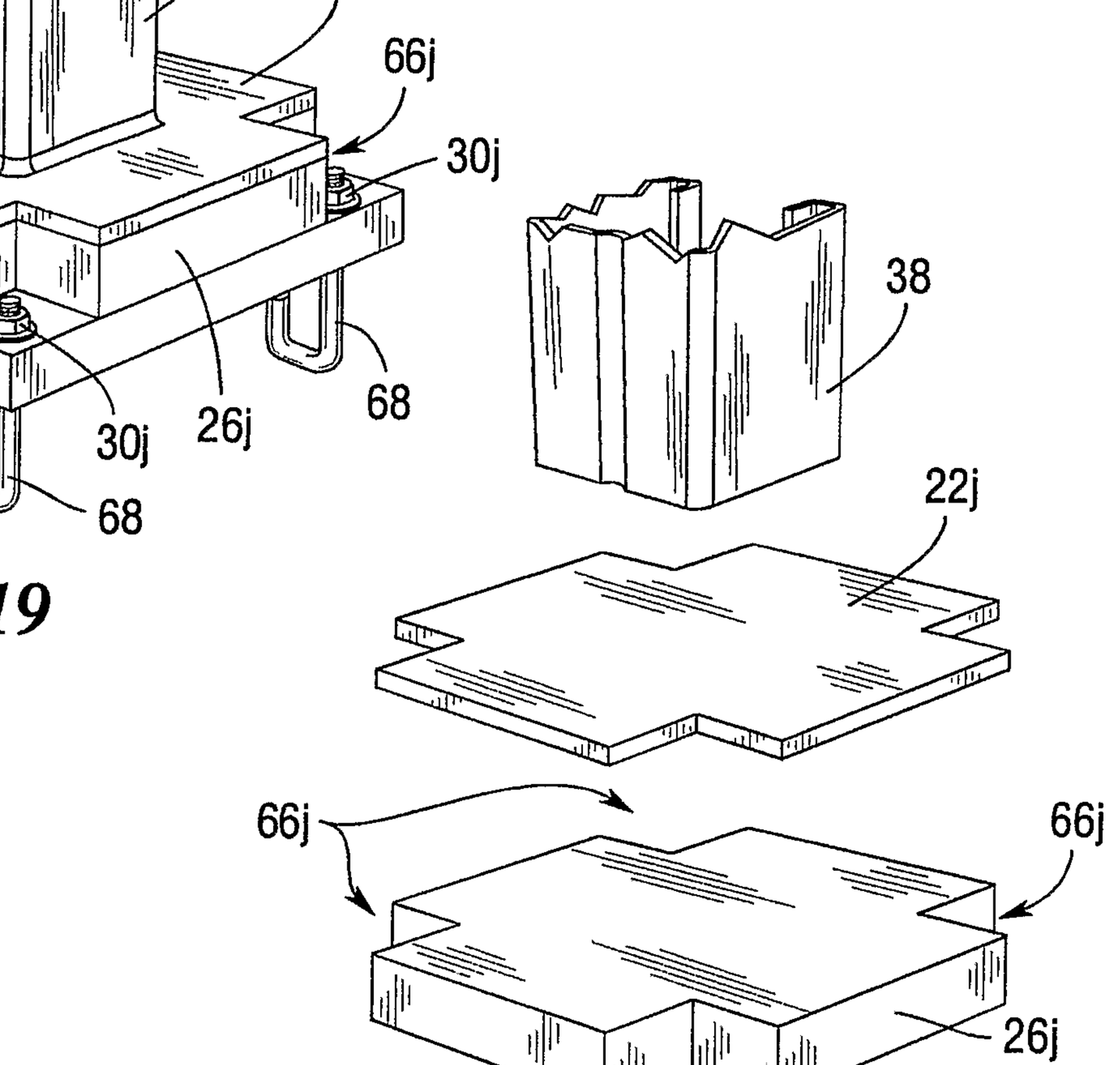
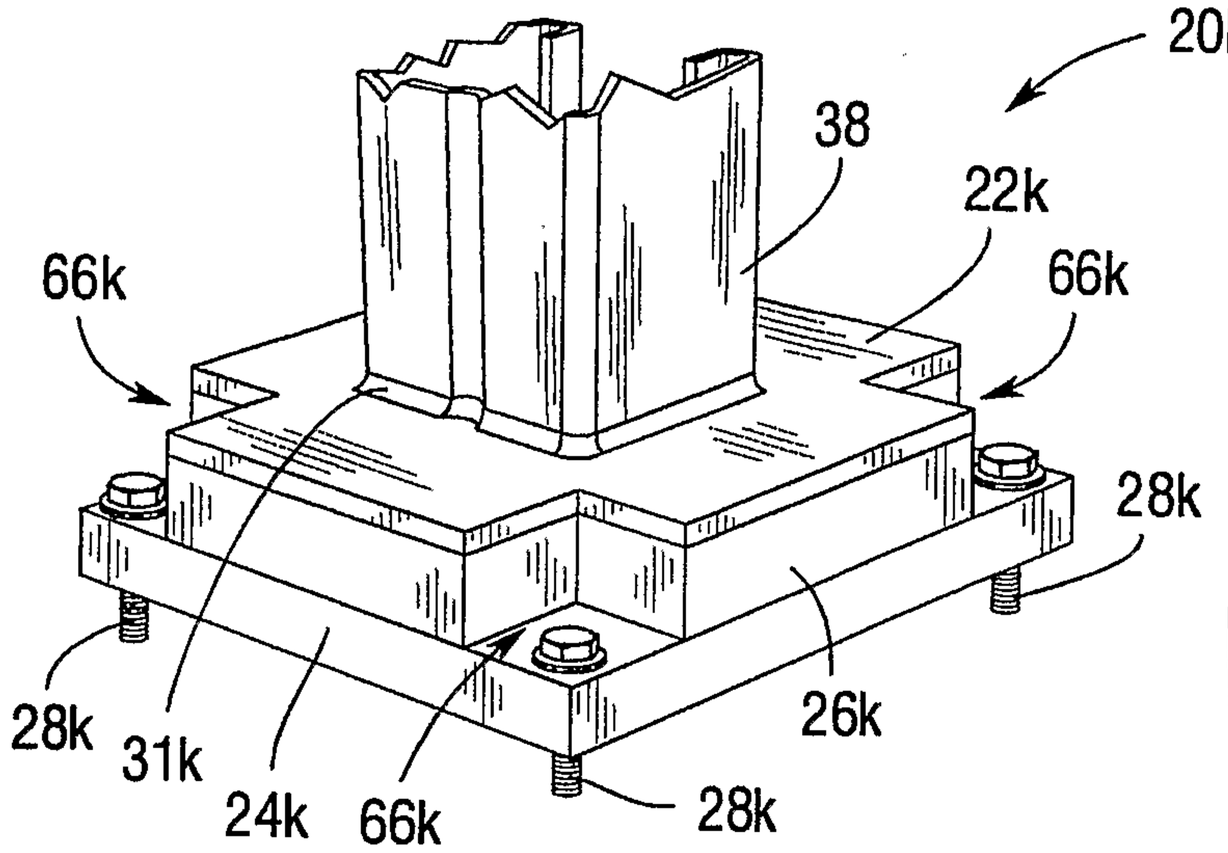

38
22j
66j
66j
26j
66j
20j
30j
30j
36j
36j
30j
36j
36j
68
24j
68
68

Fig.20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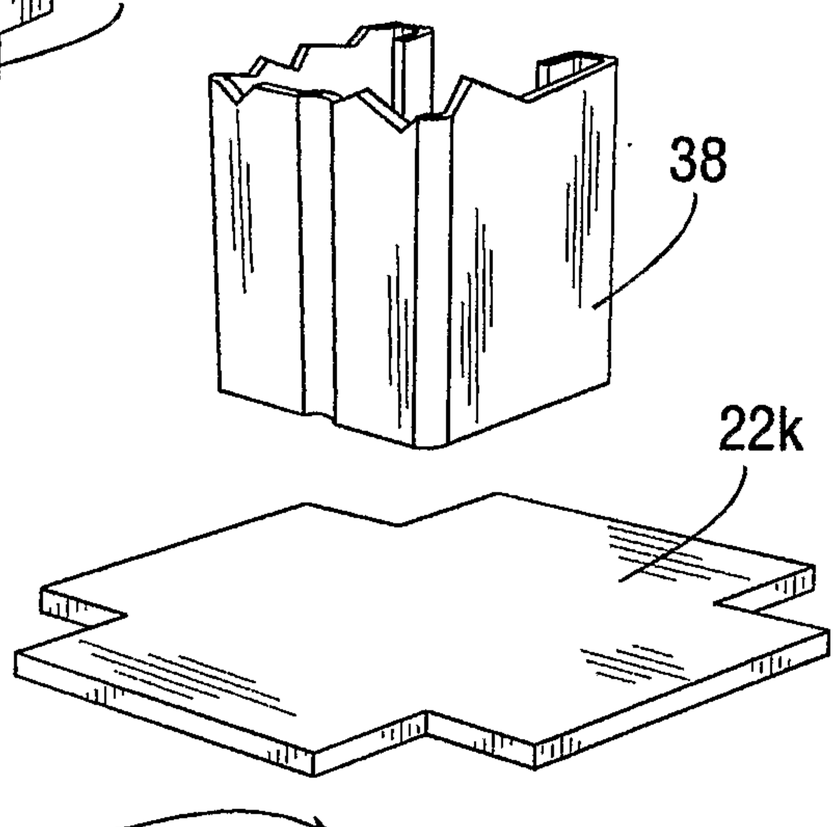
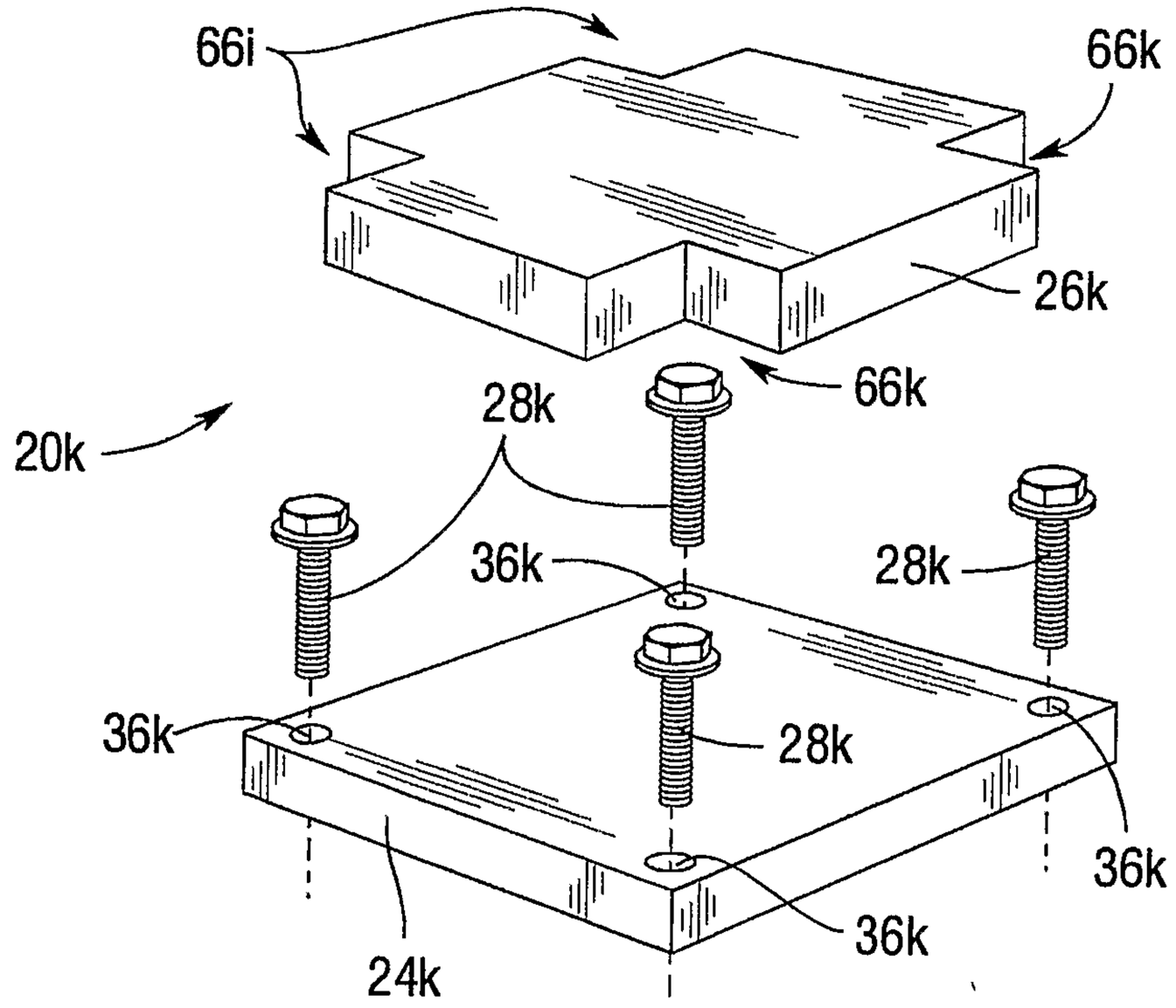
38
22k
66k
66k
28k
28k
31k
24k
66k
26k
28k

Fig.21


38
22k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66k
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28k
36k
28k
36k
28k
36k
24k
36k

Fig.22

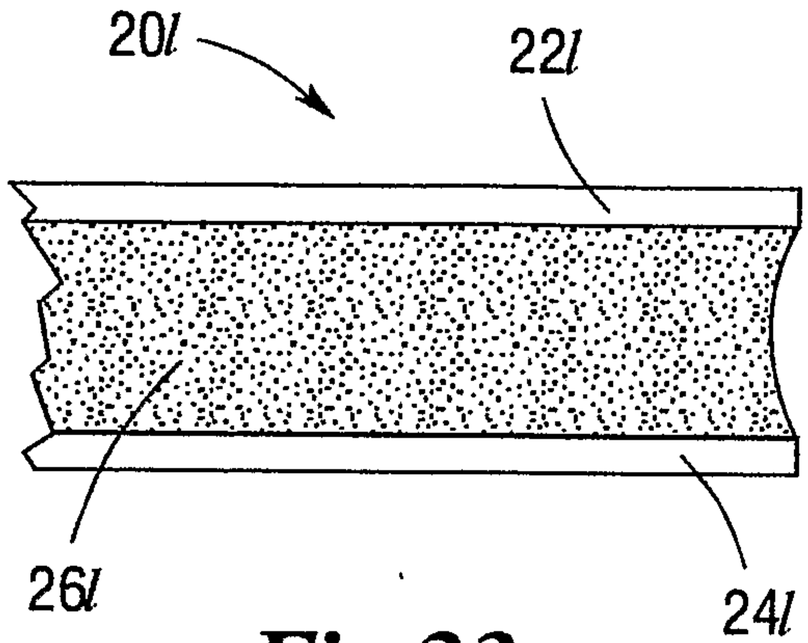
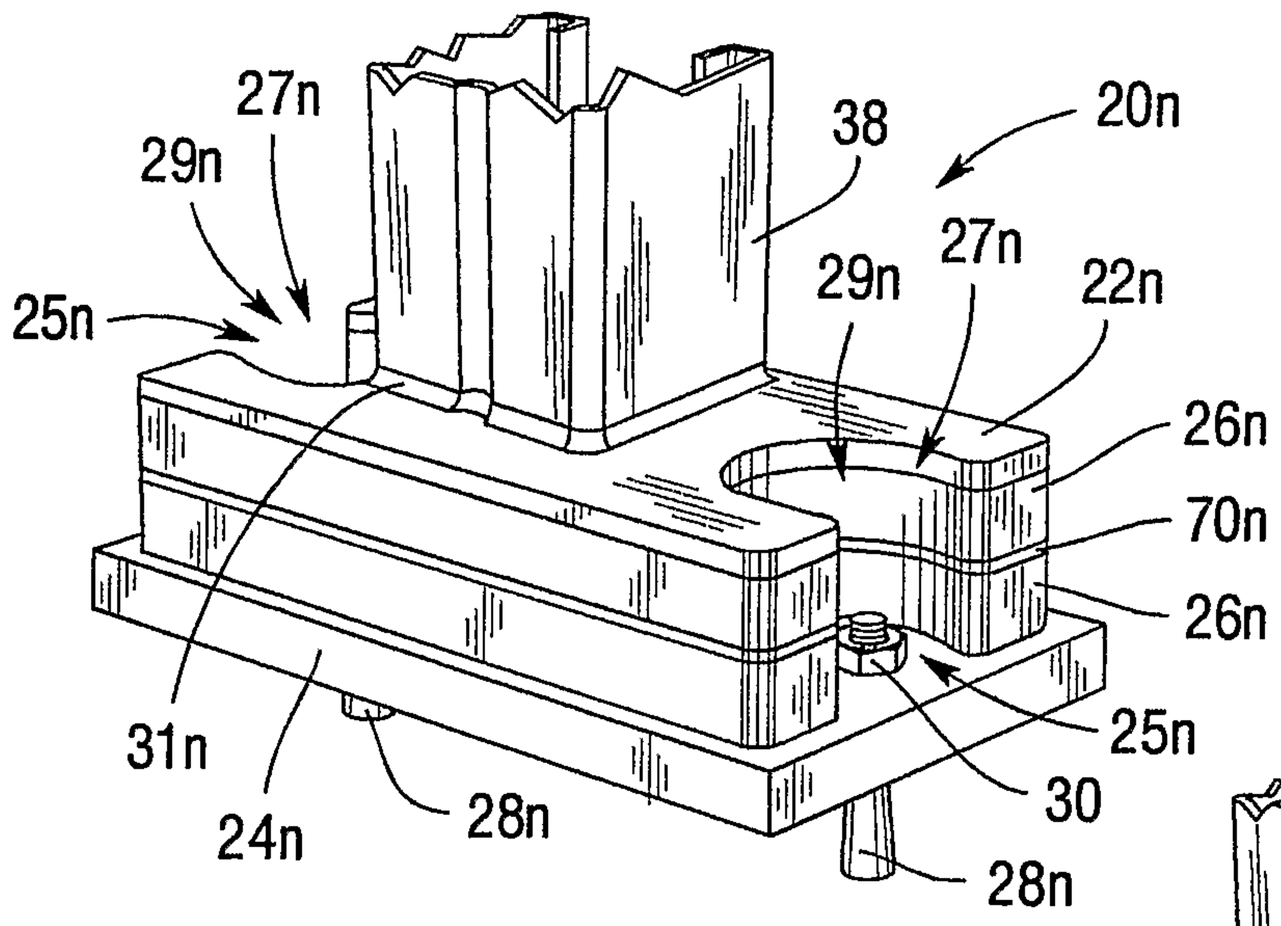


Fig.23

Fig.24


27n
29n
25n
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20n
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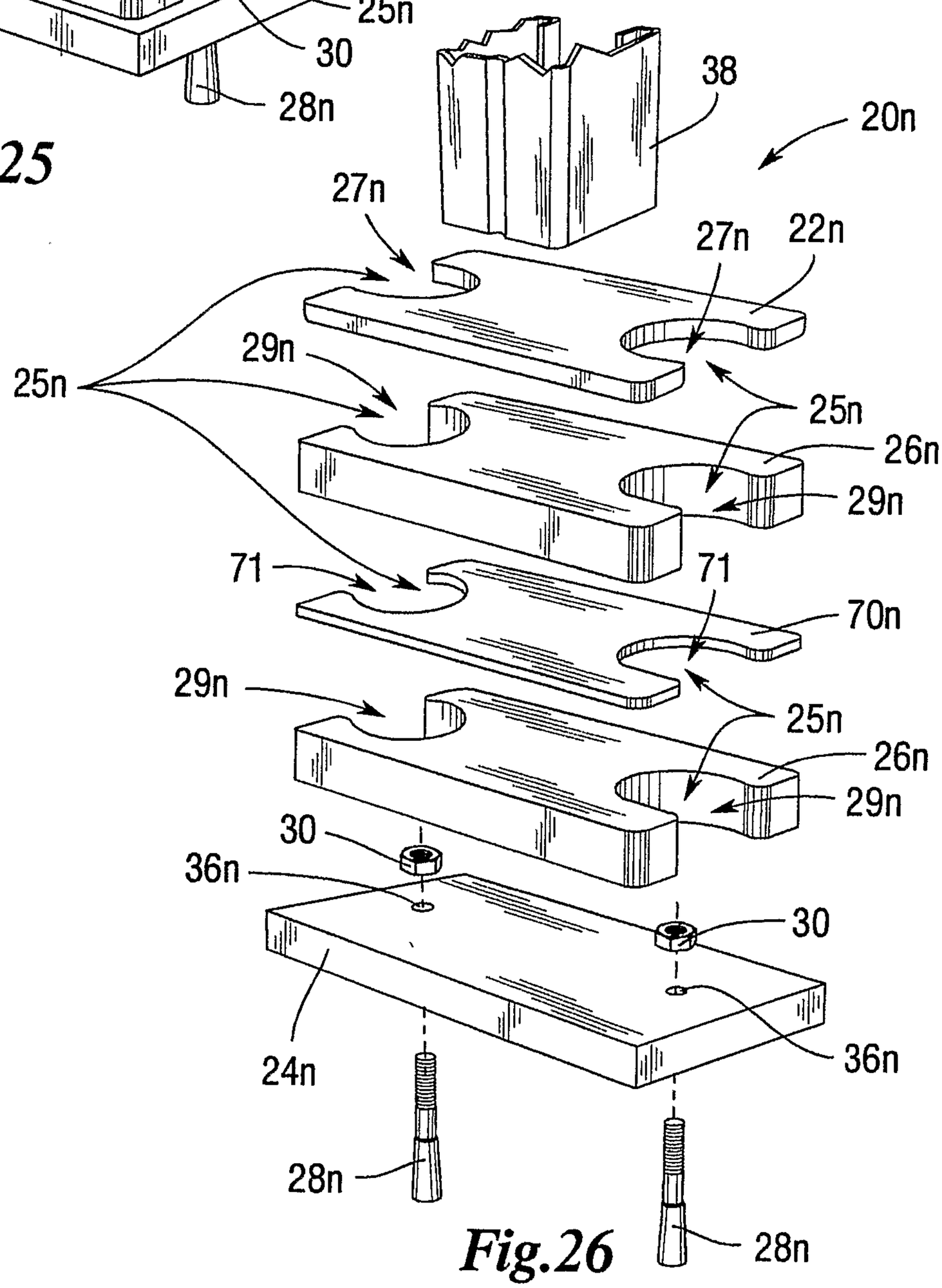
27n
22n
26n
70n
26n
25n
31n
24n
28n
30
28n

Fig.25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20n
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27n
22n
29n
25n
25n
26n
29n
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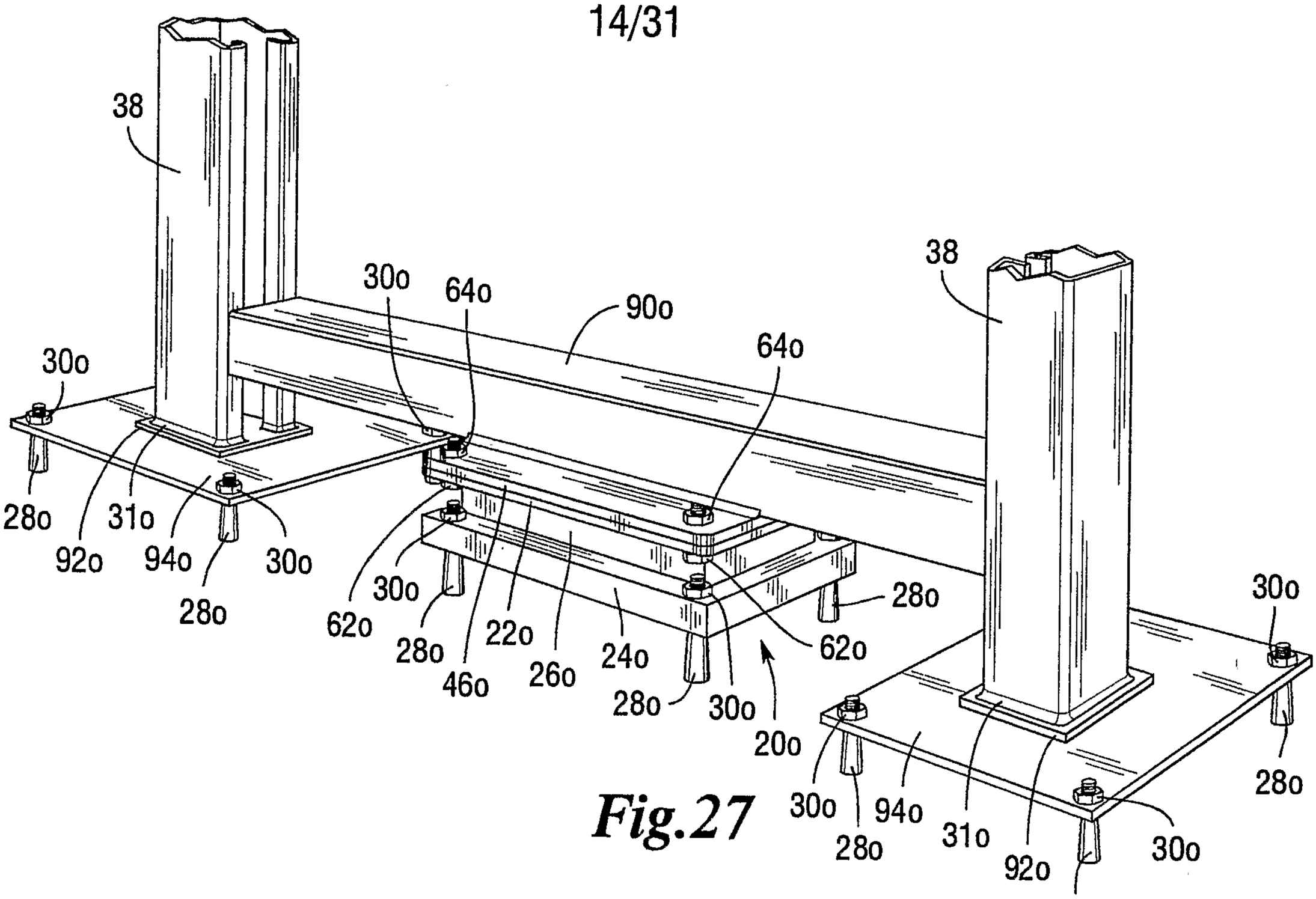
29n
25n
26n
29n
30
36n
30
24n
36n
28n
28n

Fig.26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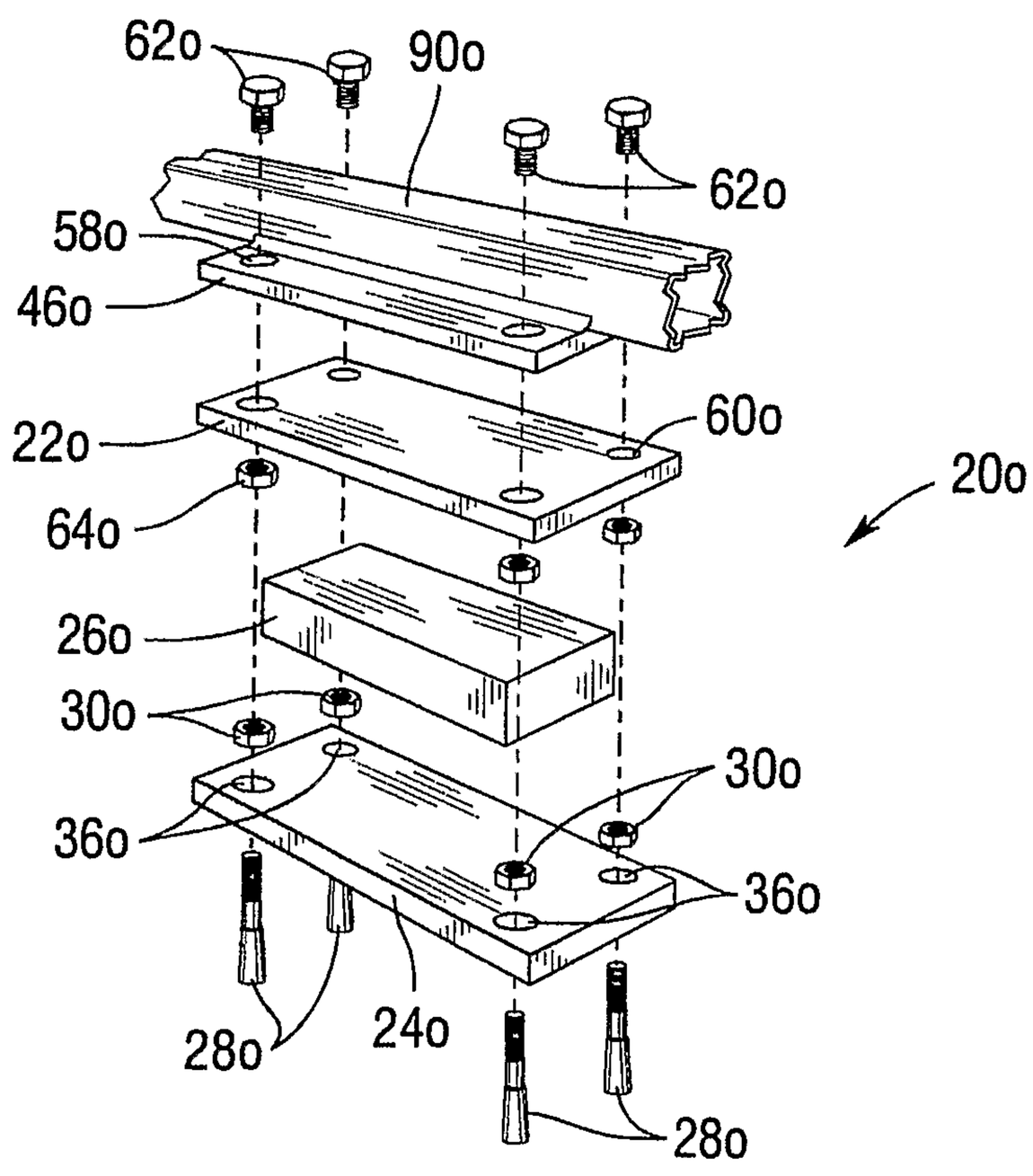
90o
64o
30o
28o
92o
31o
94o
30o
28o
62o
30o
28o
46o
22o
26o
24o
28o
30o
20o
62o
28o
38
30o
28o
30o
94o
28o
31o
92o
30o
28o

Fig.27


62o
90o
62o
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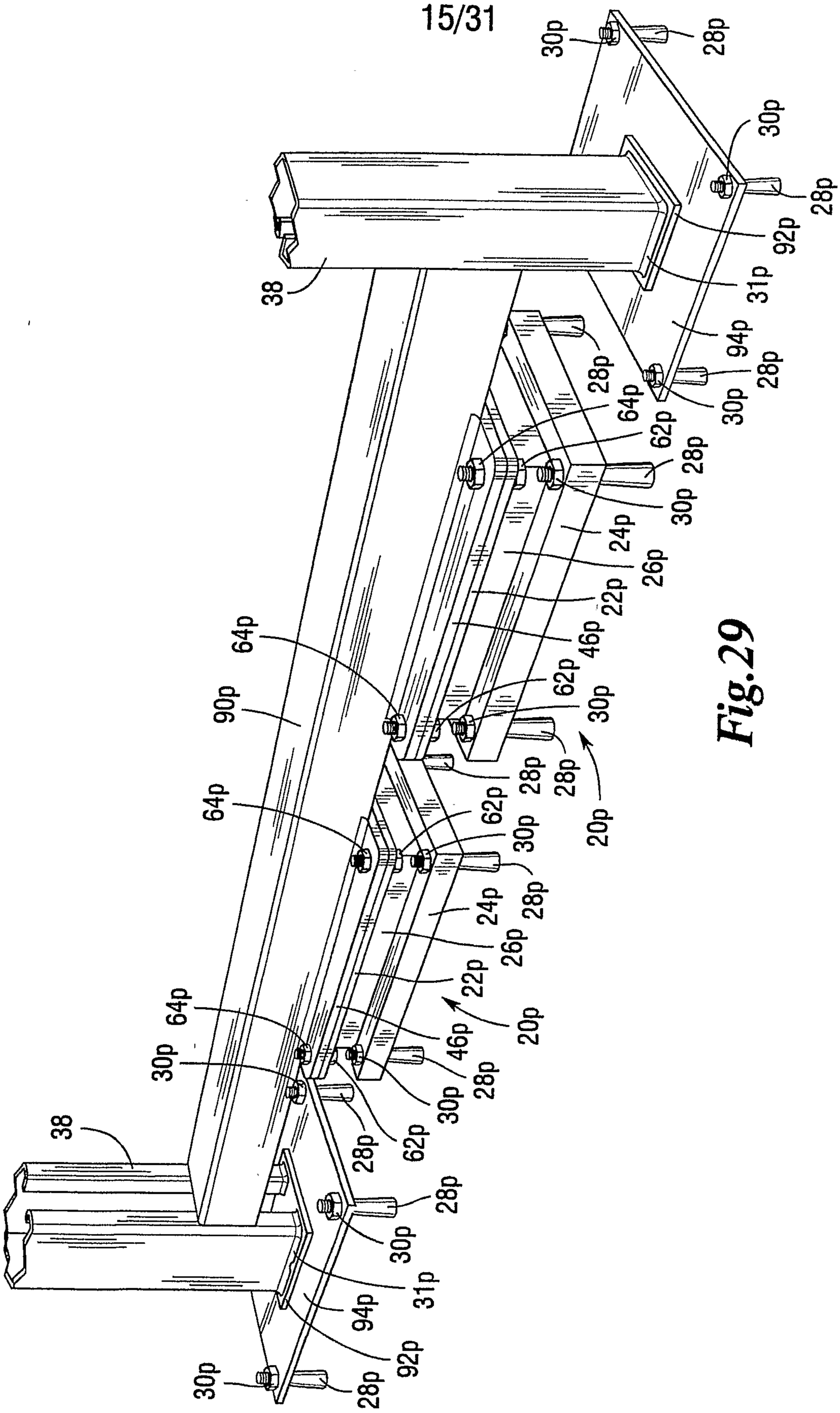
46o
22o
60o
64o
20o
26o
30o
30o
36o
36o
28o
24o
28o

Fig.28


30p
28p
30p
28p
92p
31p
94p
28p
30p
38
28p
64p
62p
28p
30p
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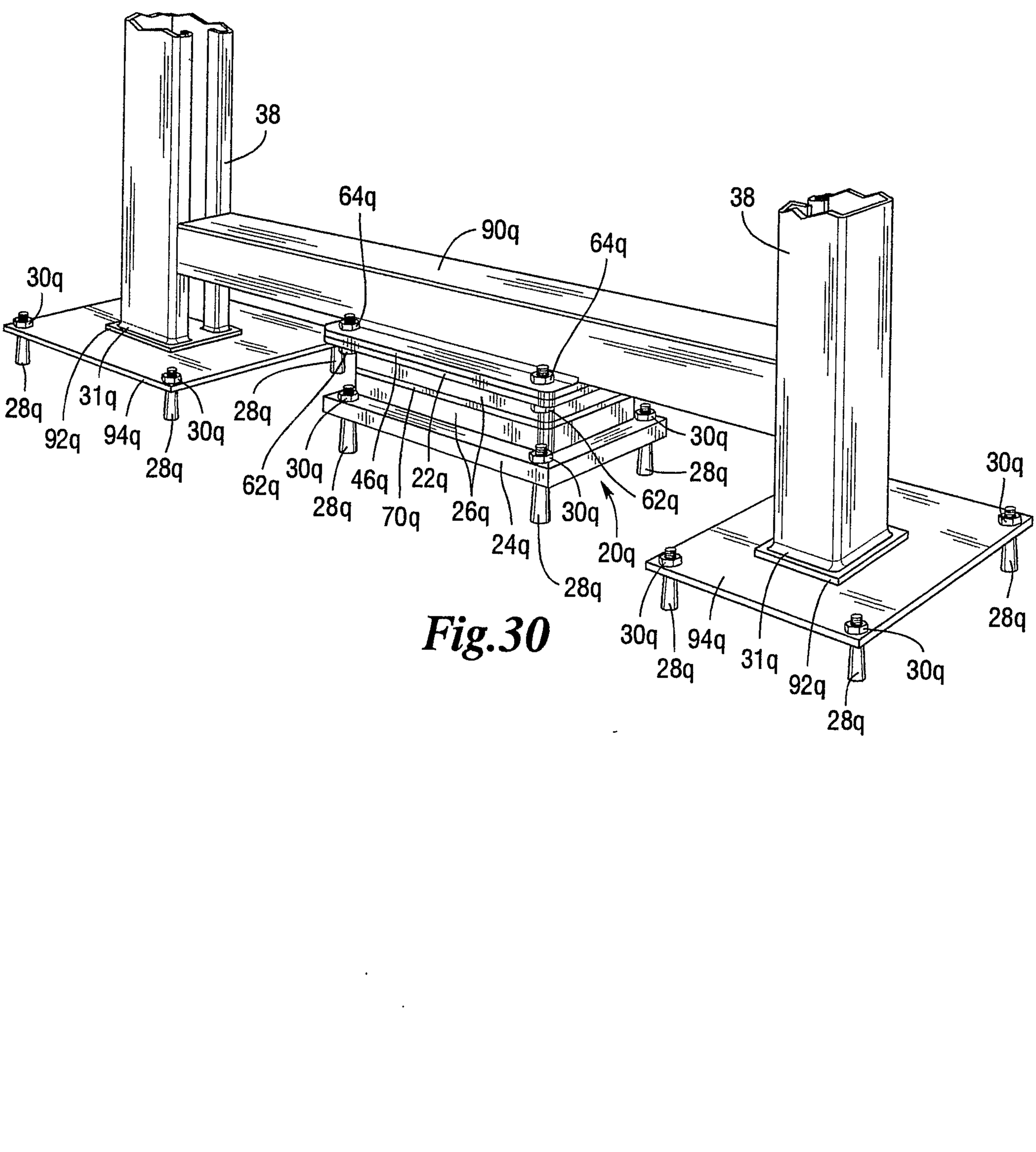
26p
22p
46p
64p
90p
62p
30p
28p
28p
20p
64p
62p
30p
24p
28p
26p
22p
30p
64p
46p
20p
28p
30p
38
28p
62p
30p
94p
31p
92p
28p

Fig.29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64q
90q
64q
38
30q
28q
92q
31q
94q
30q
28q
28q
62q
30q
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46q
70q
22q
26q
24q
28q
30q
20q
62q
30q
28q
30q
94q
28q
31q
92q
28q
30q
28q

Fig.30

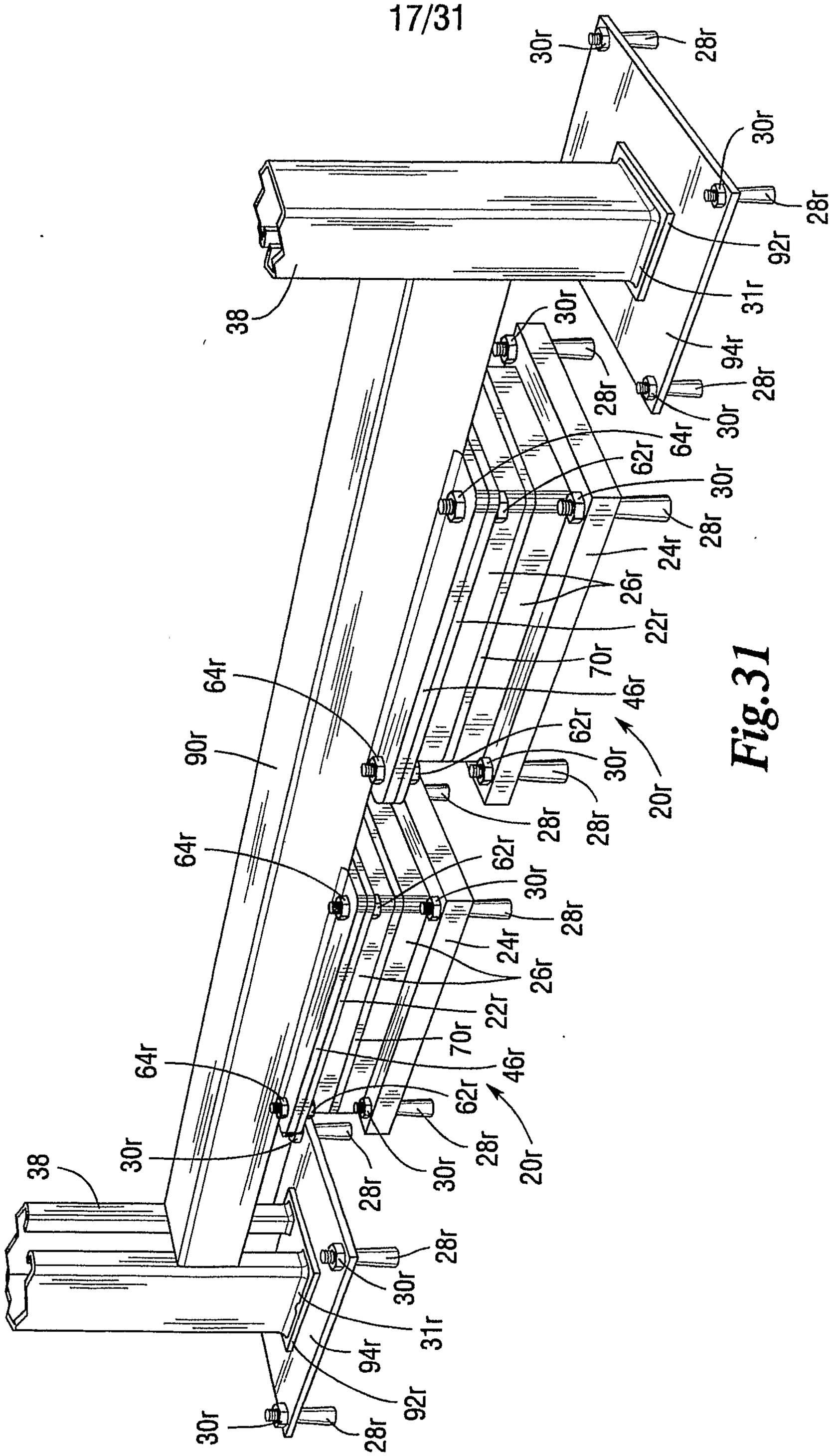

30r
28r
30r
28r
92r
31r
38
30r
28r
94r
28r
30r
64r
62r
30r
28r
24r
26r
22r
70r
46r
62r
30r
20r
28r
28r
64r
90r
64r
62r
30r
28r
24r
26r
22r
70r
64r
46r
62r
28r
20r
38
30r
28r
30r
28r
94r
31r
92r
30r
28r

Fig.31

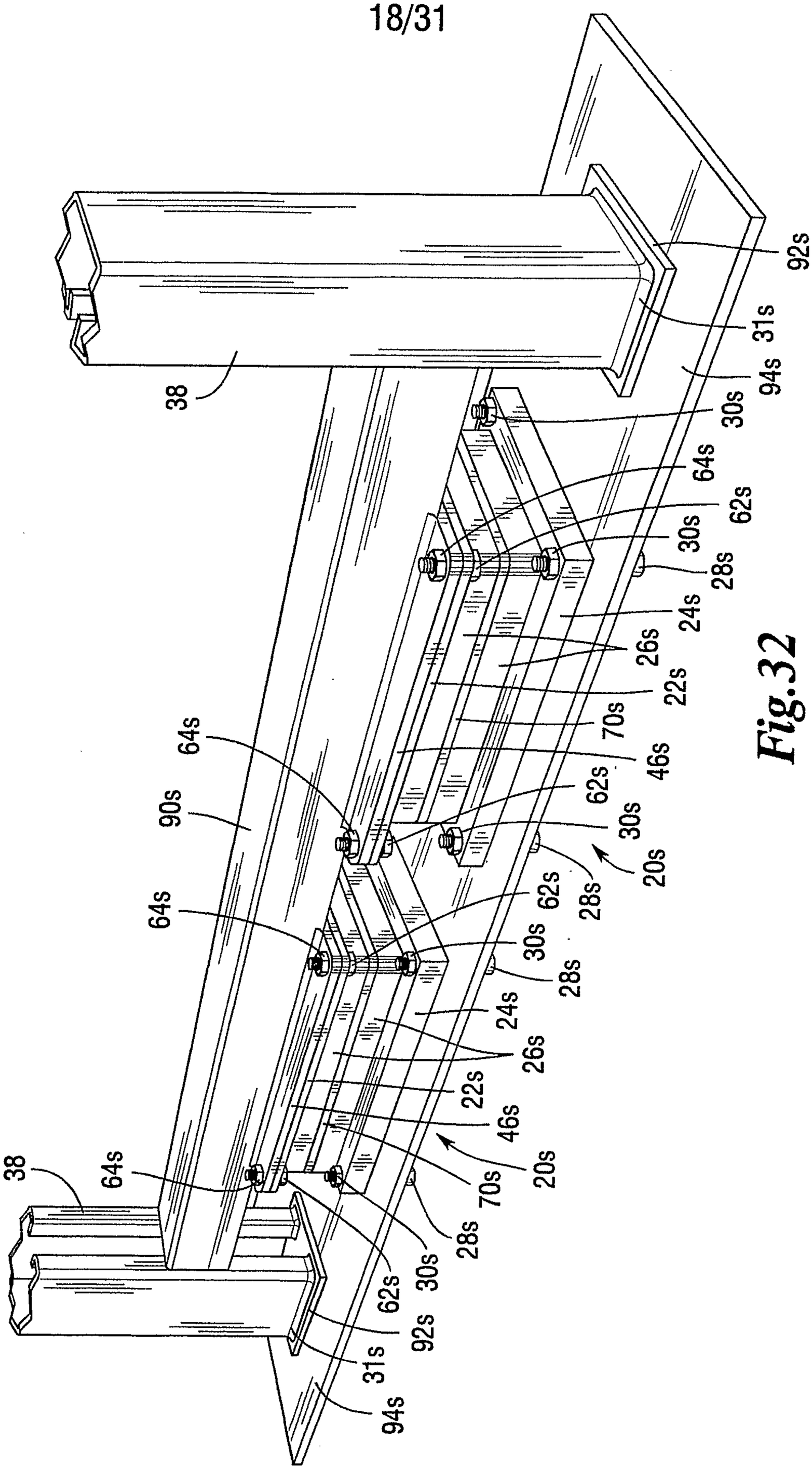


Fig.32

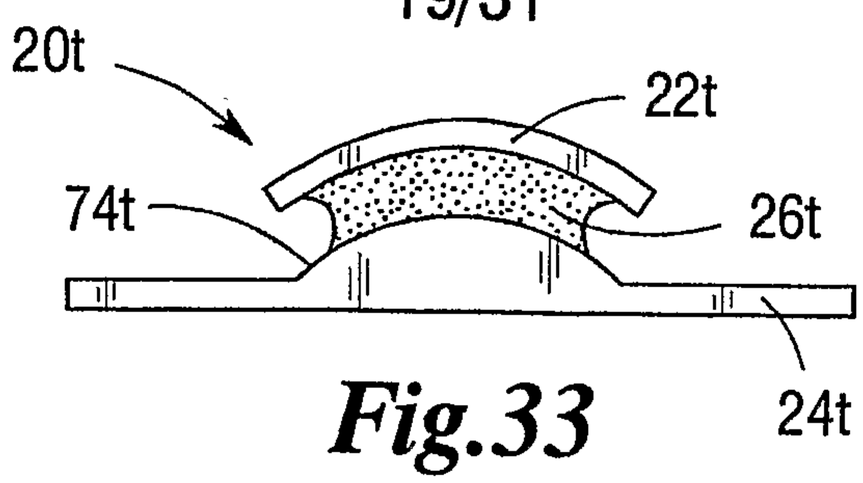


Fig.33

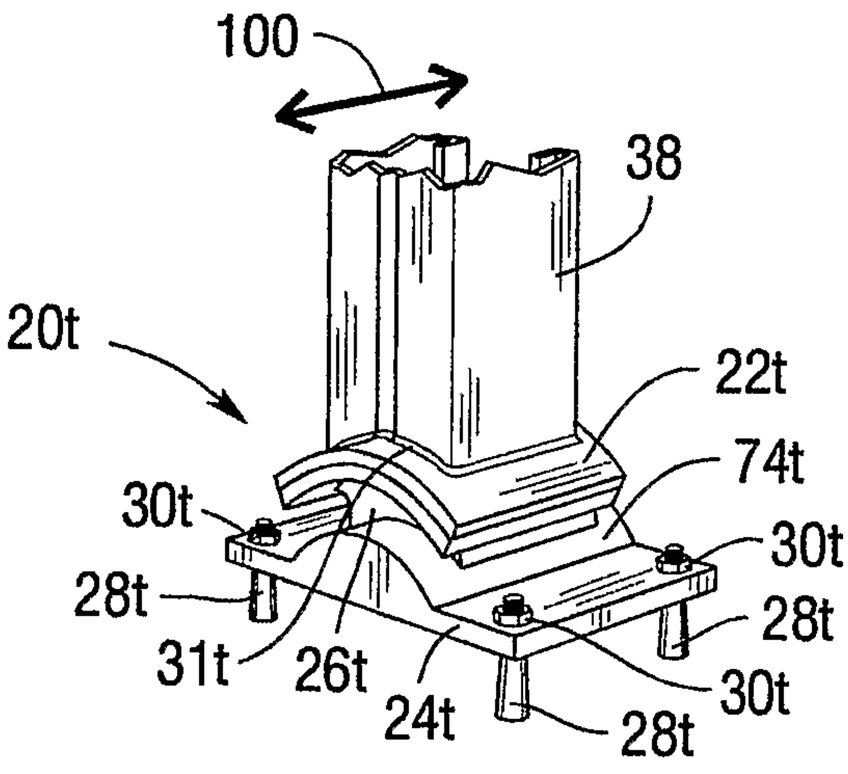


Fig.34

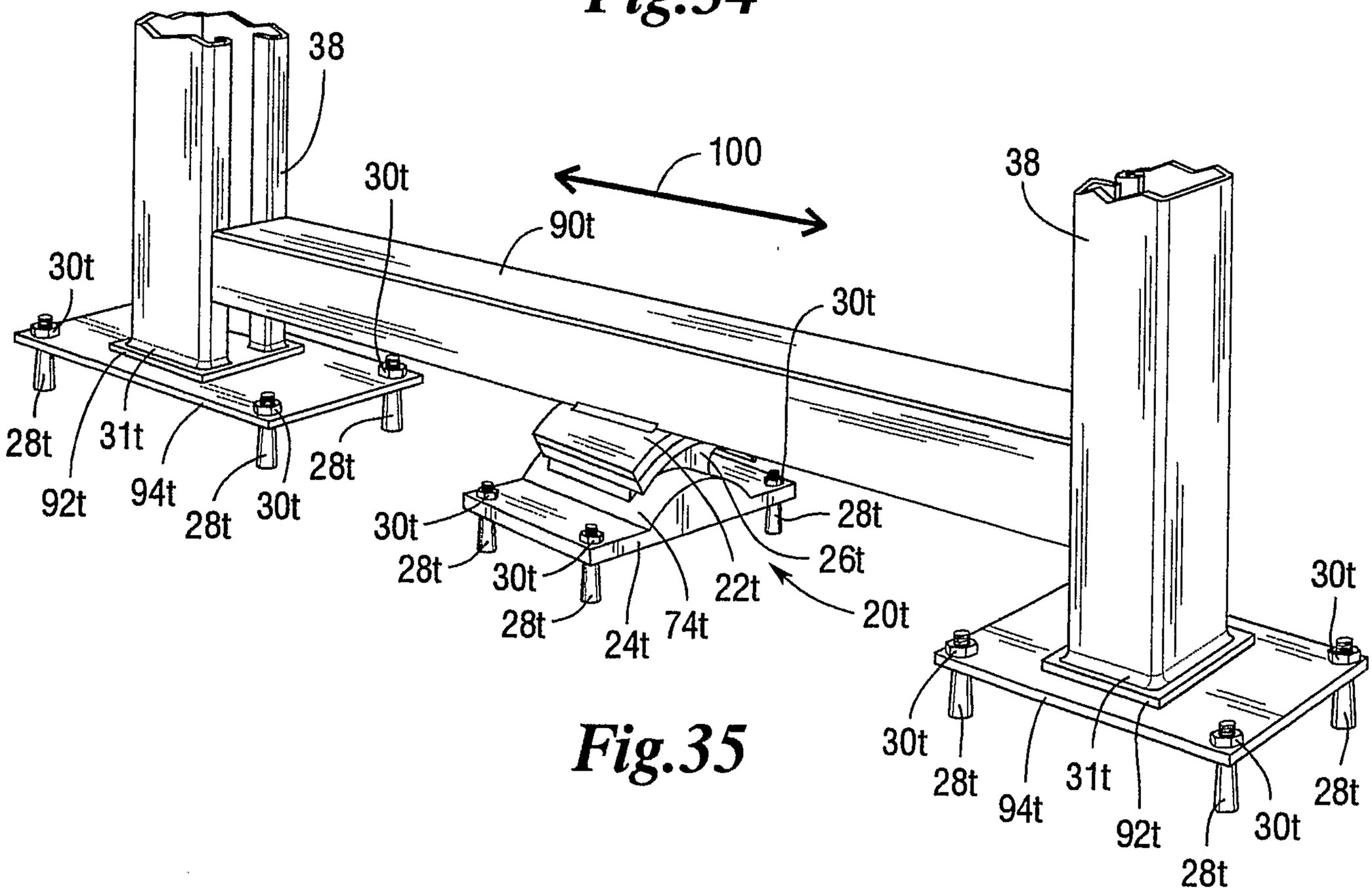


Fig.35

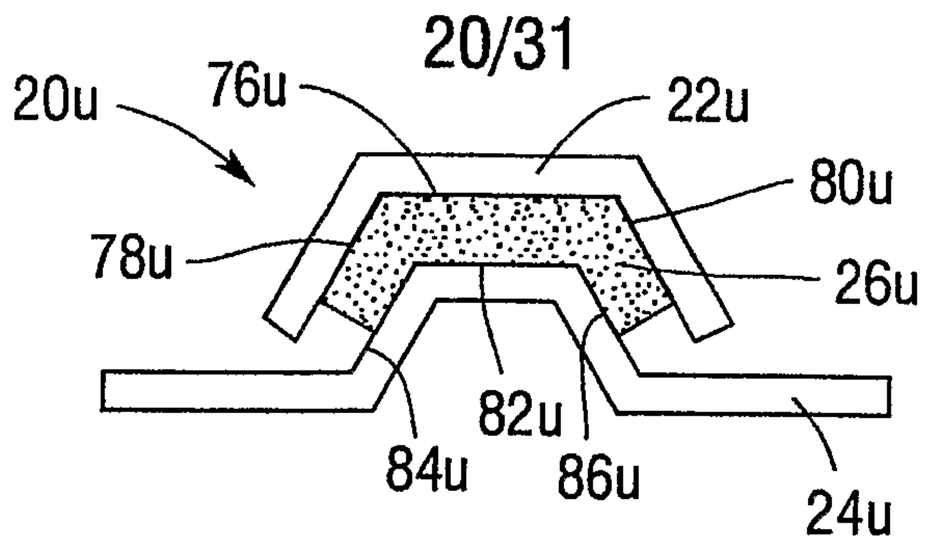


Fig.36

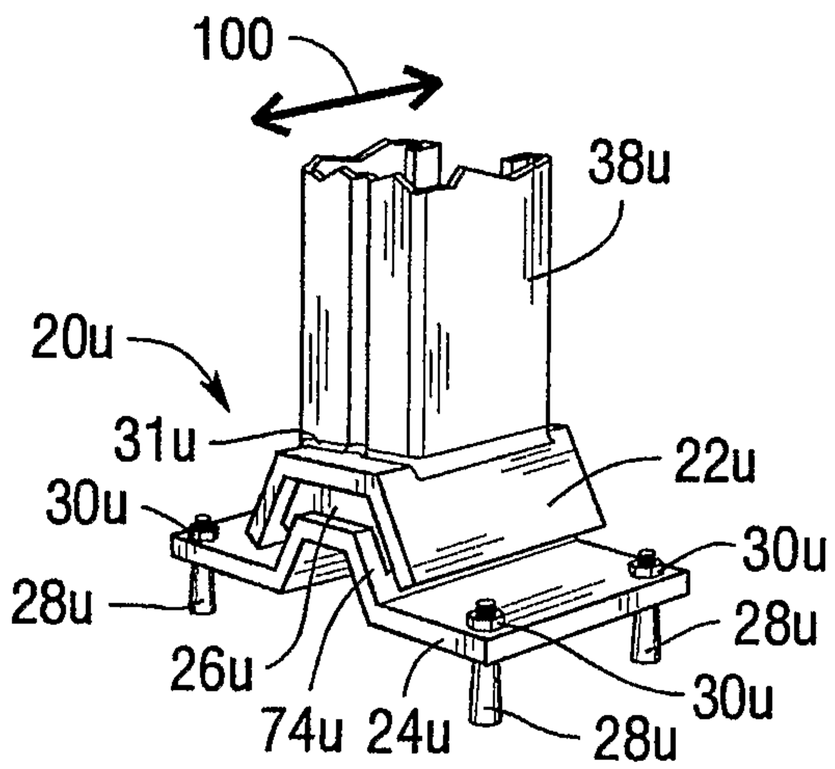


Fig.37

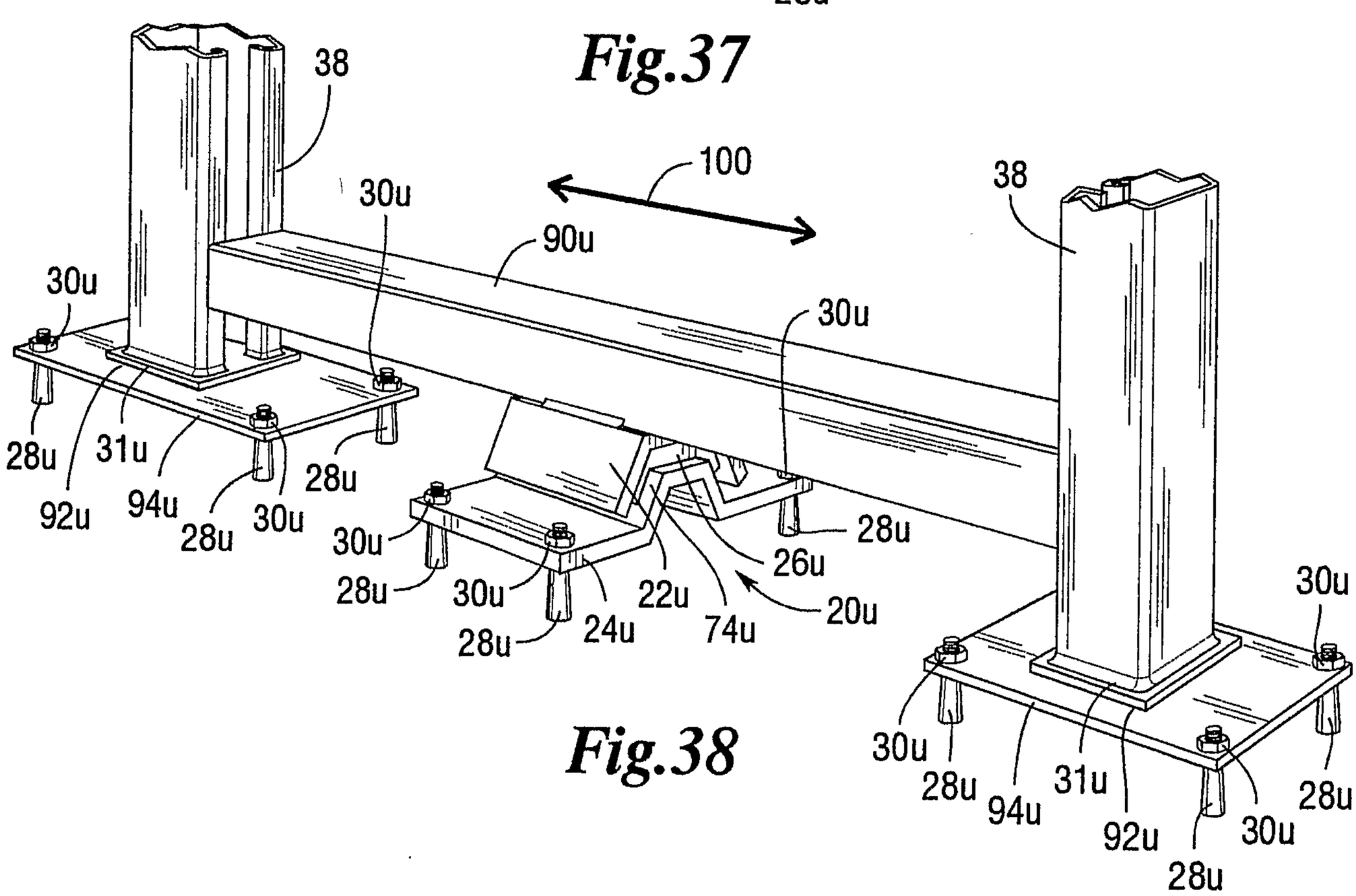


Fig.38

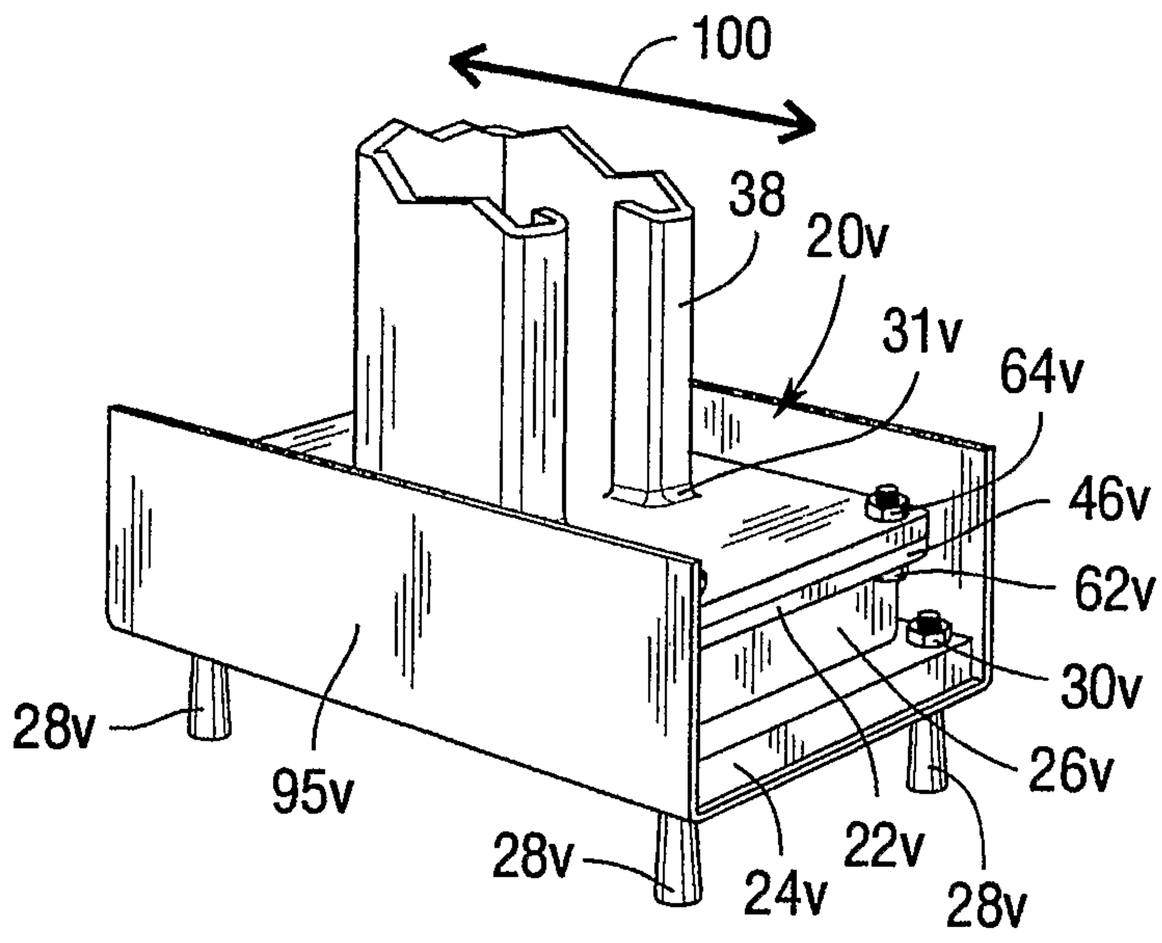

100
38
20v
31v
64v
46v
62v
30v
26v
22v
24v
28v
28v
95v
28v
28v

Fig.39

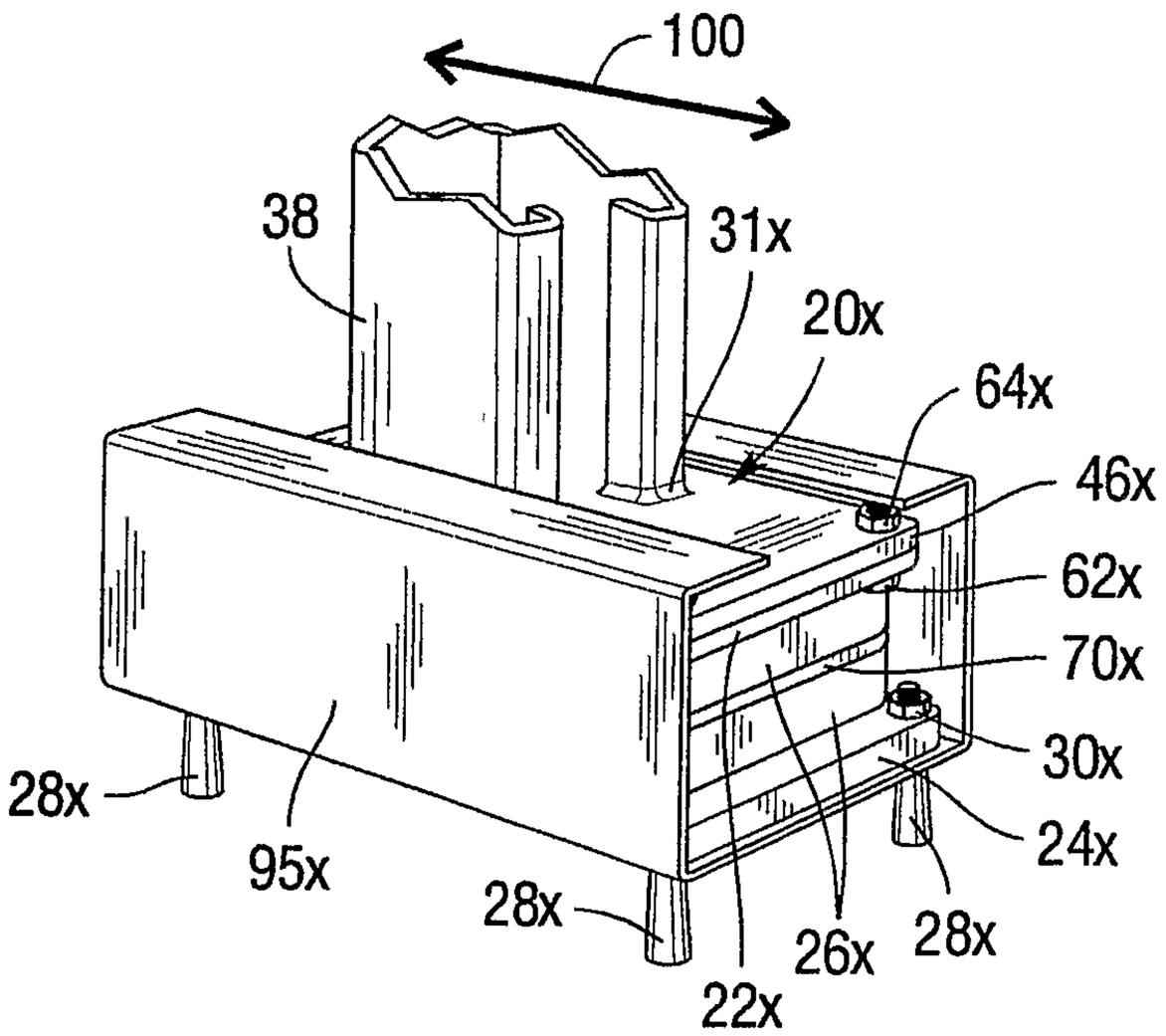

100
38
31x
20x
64x
46x
62x
70x
30x
24x
28x
95x
28x
26x
28x
22x

Fig.41

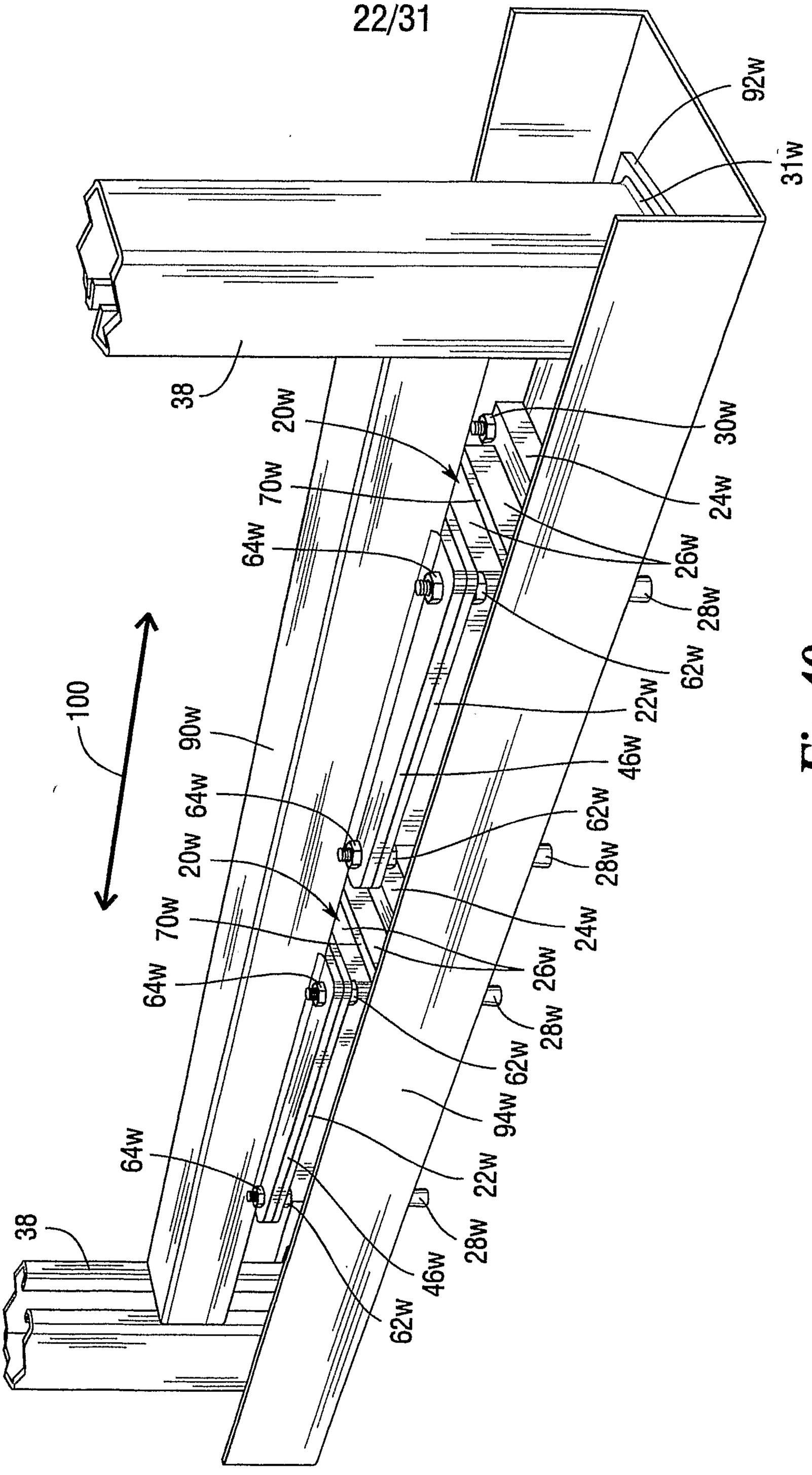


Fig.40

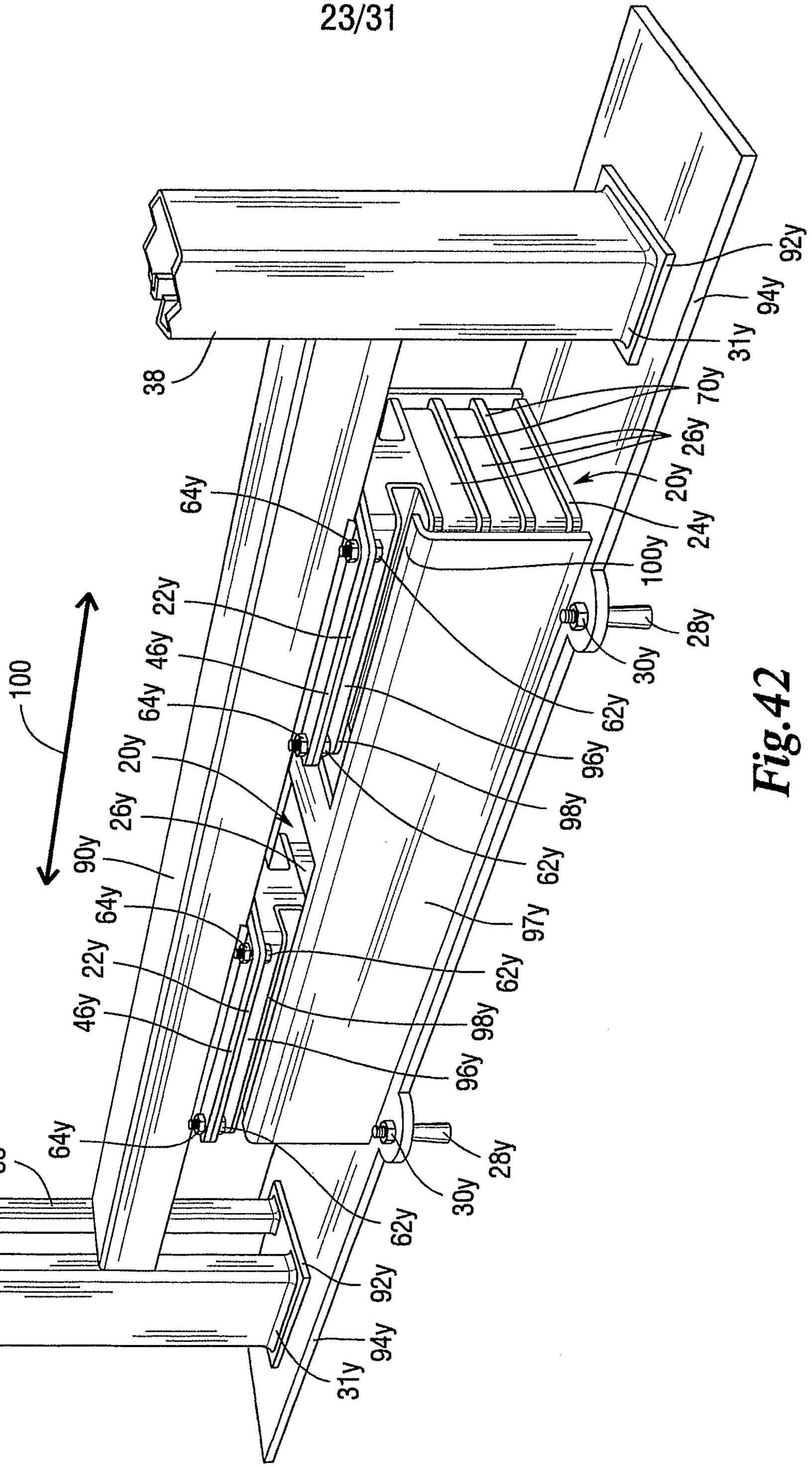

100
38
64y
22y
46y
20y
26y
90y
96y
98y
62y
97y
28y
30y
31y
94y
92y
70y

Fig.42

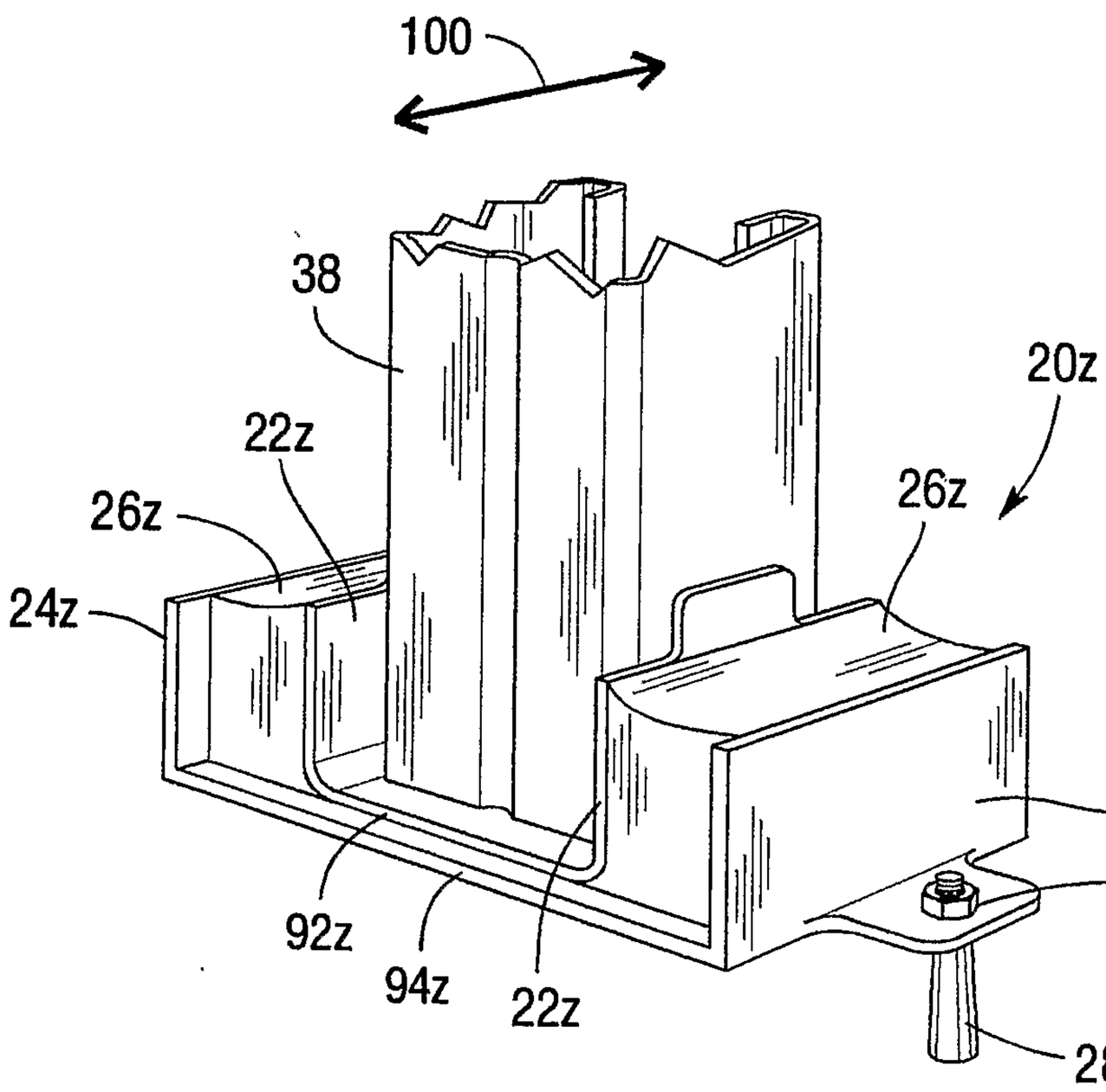


Fig.43

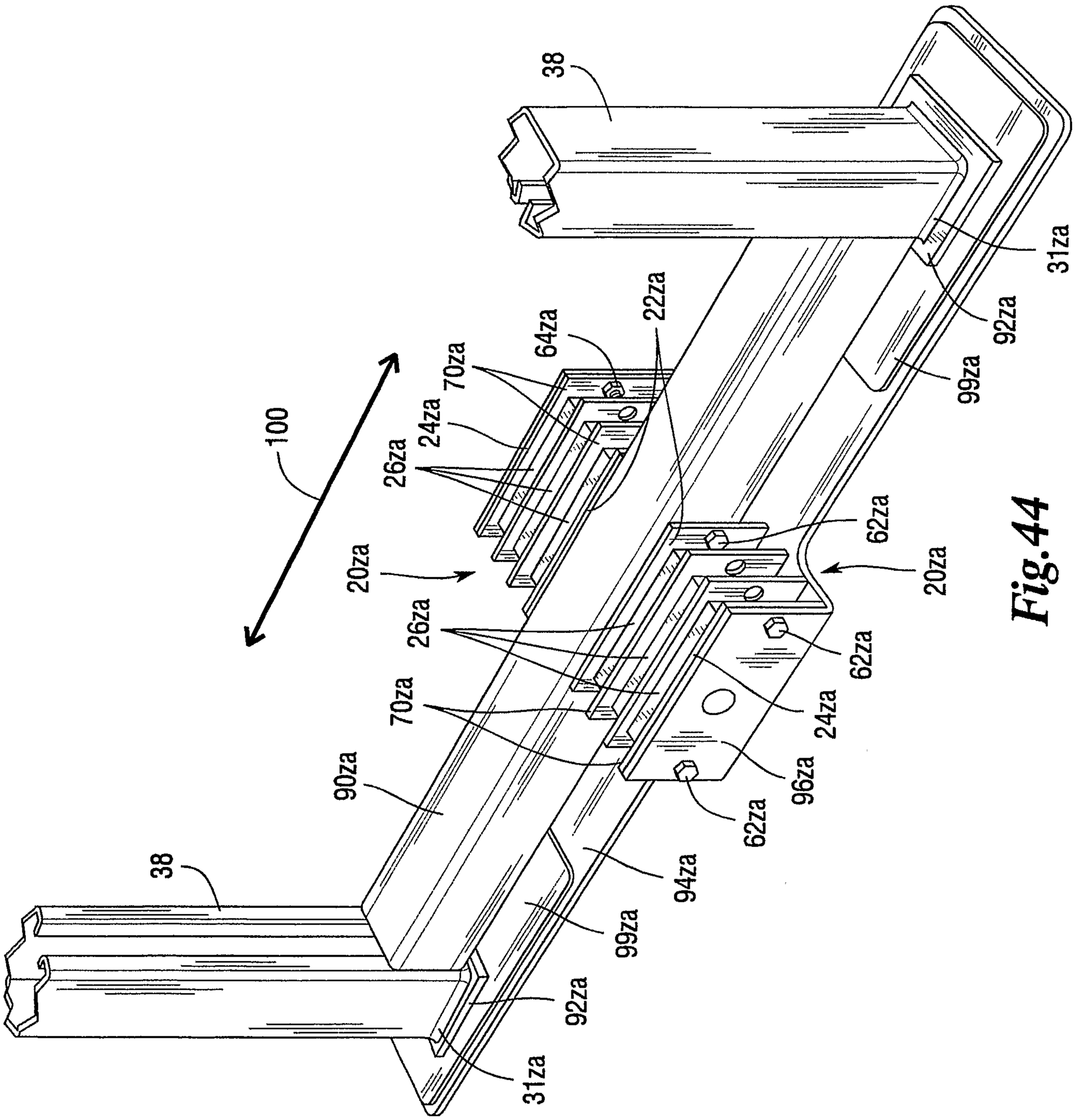

100
20za
26za
24za
70za
64za
22za
38
31za
92za
99za
62za
96za
94za
90za

Fig.44

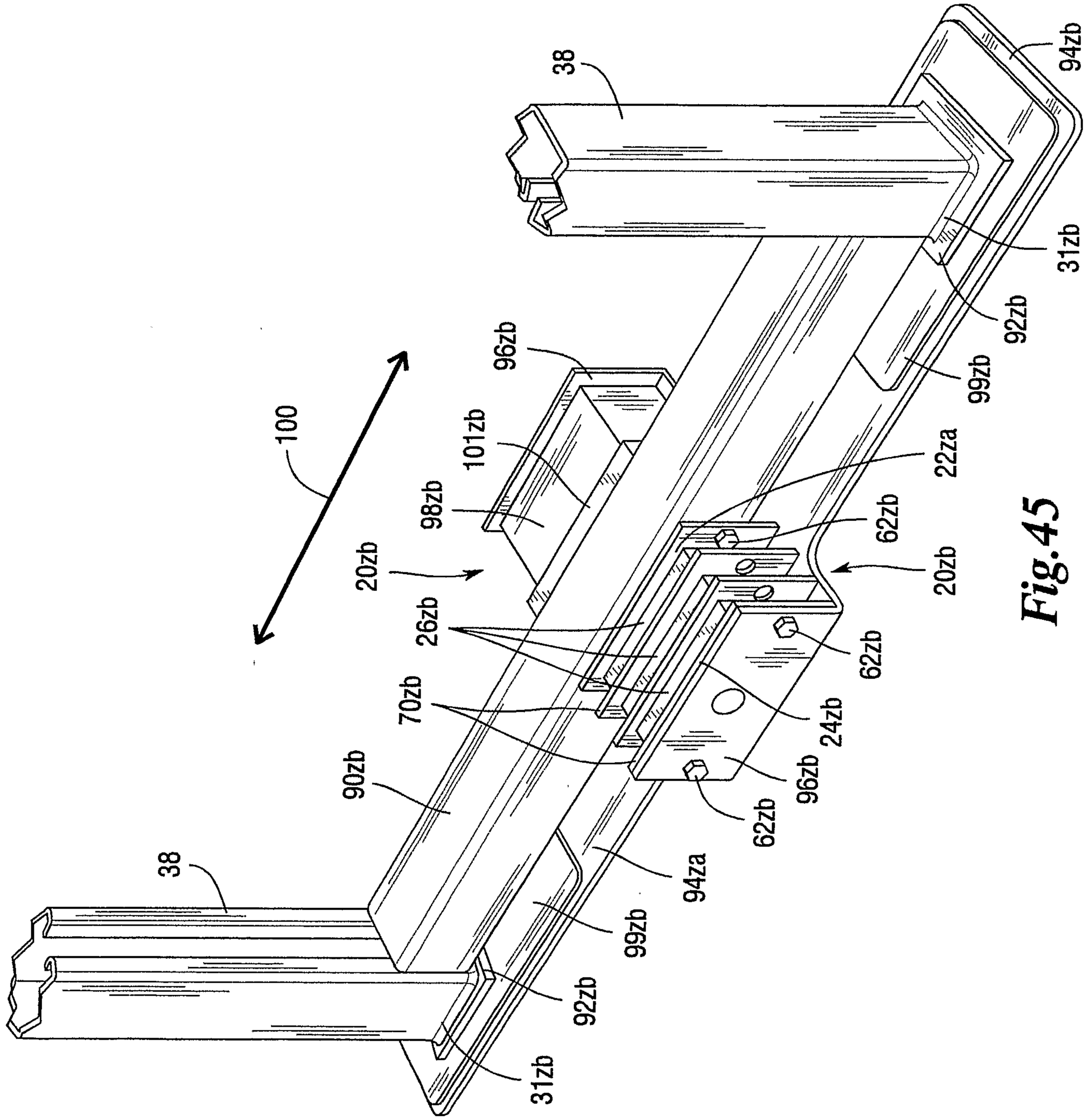
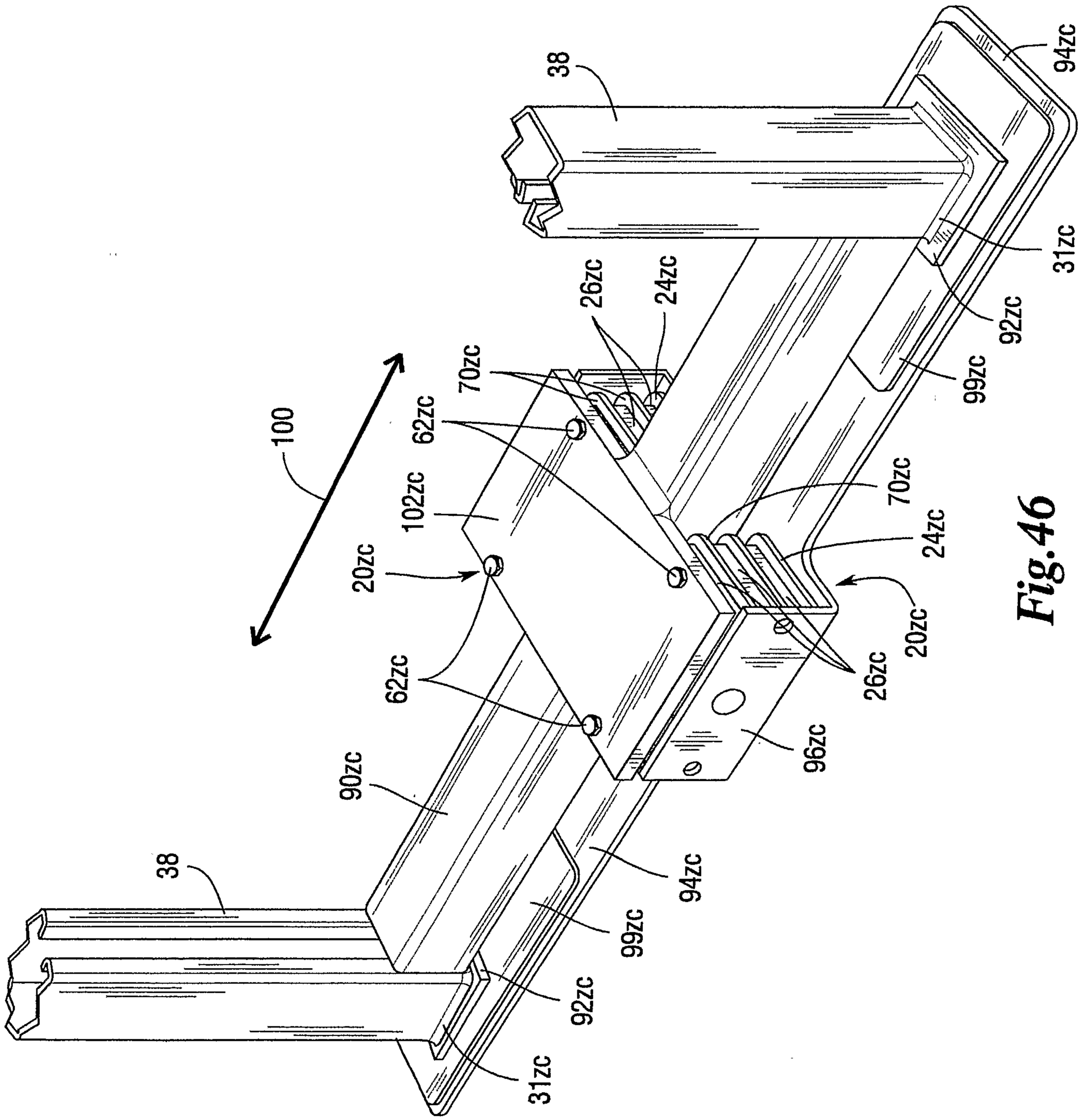

100
20zb
26zb
70zb
90zb
38
92zb
99zb
94za
62zb
24zb
96zb
98zb
101zb
22za
31zb
94zb

Fig. 45


100
38
94zc
31zc
26zc
24zc
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99zc
70zc
62zc
102zc
20zc
90zc
96zc

Fig.46

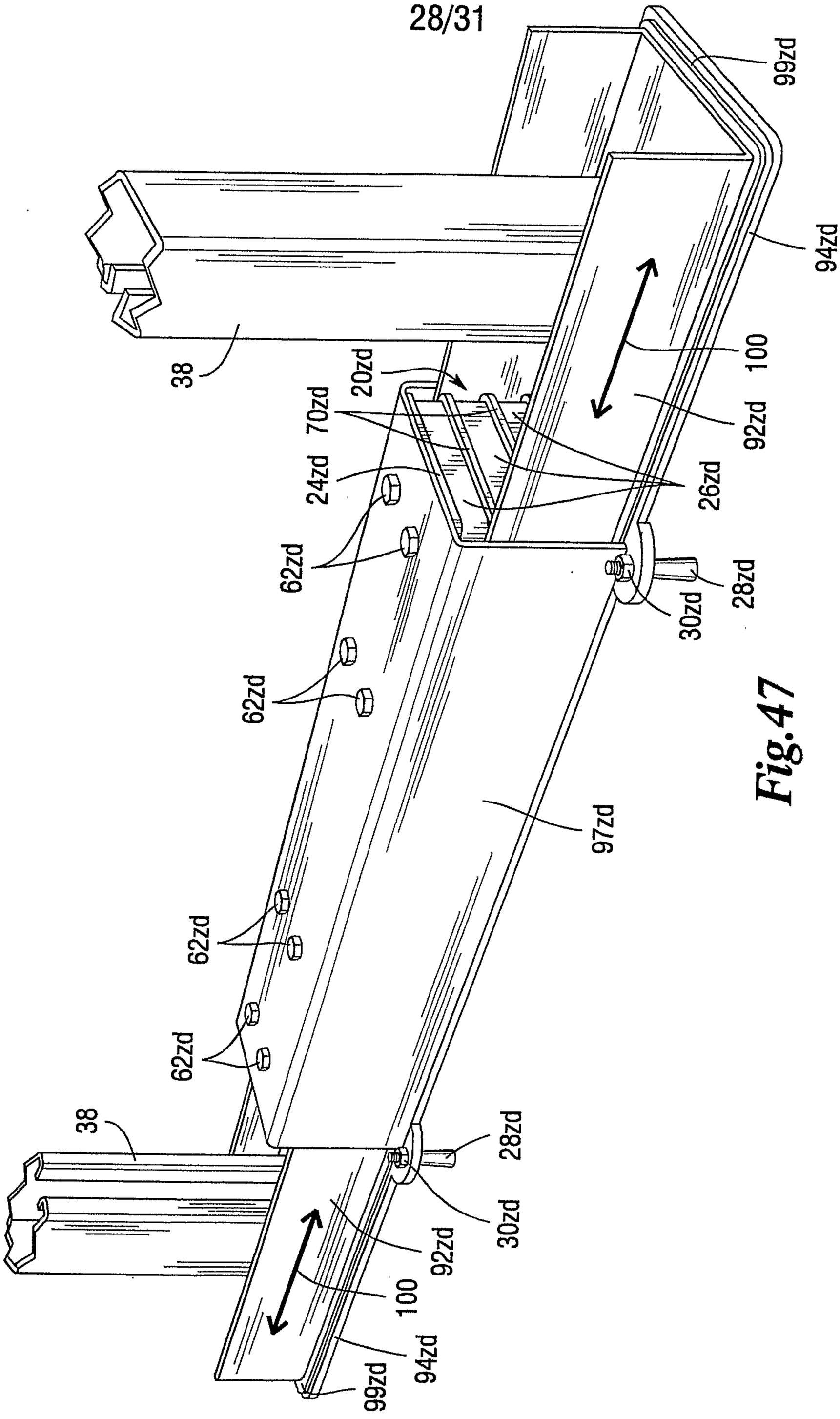


Fig.47

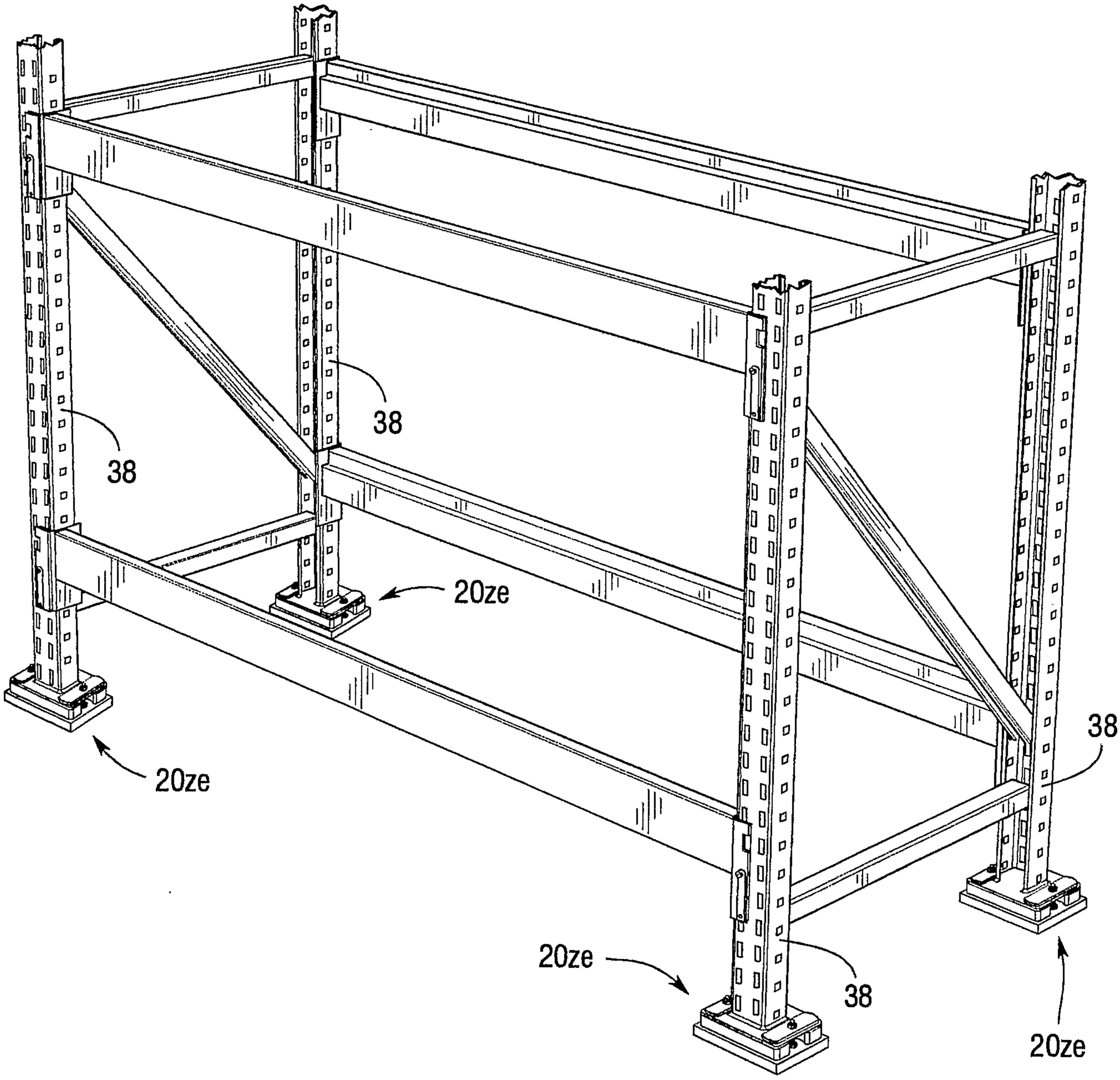
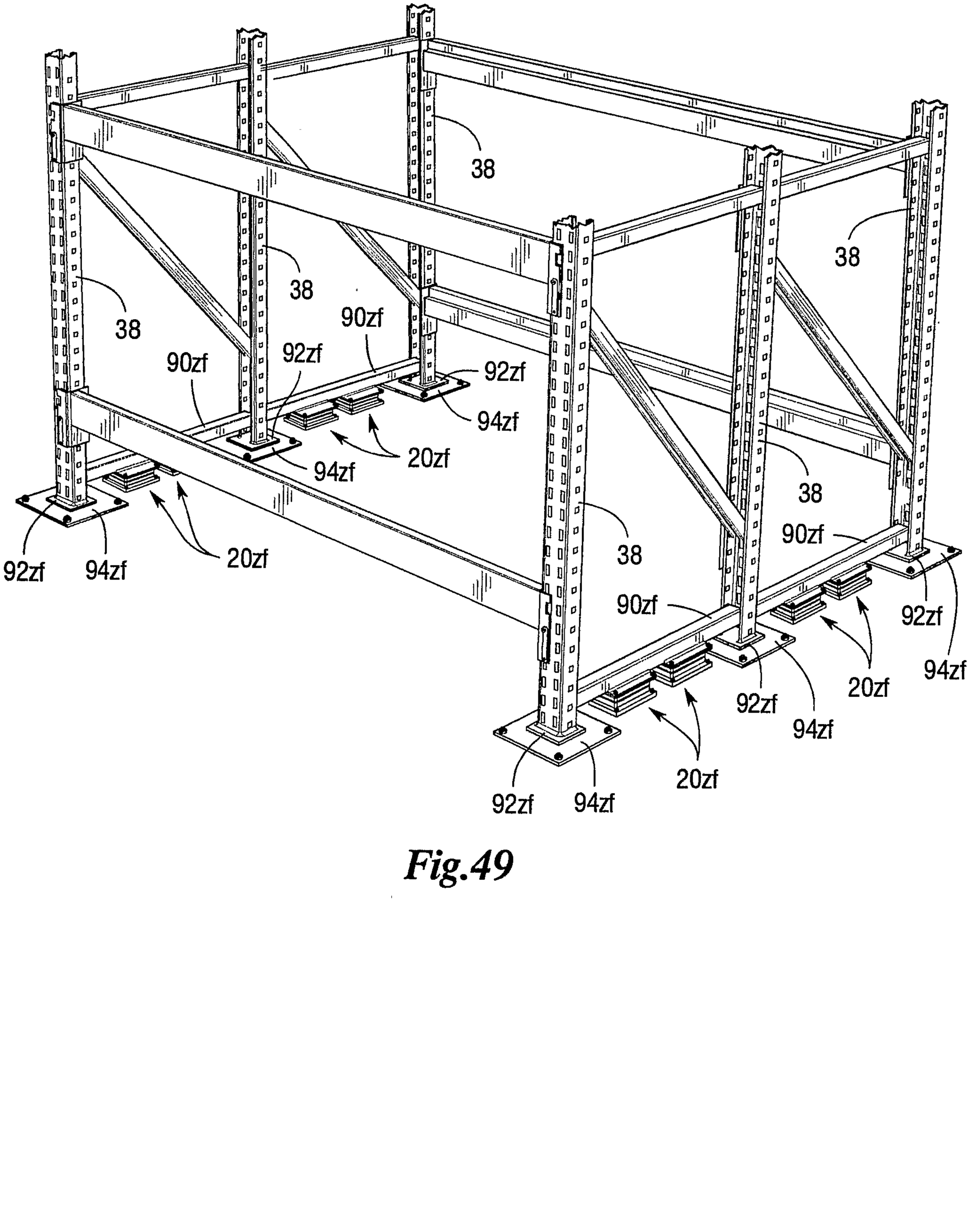


Fig.48


38
38
38
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92zf
90zf
92zf
94zf
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94zf

Fig.49

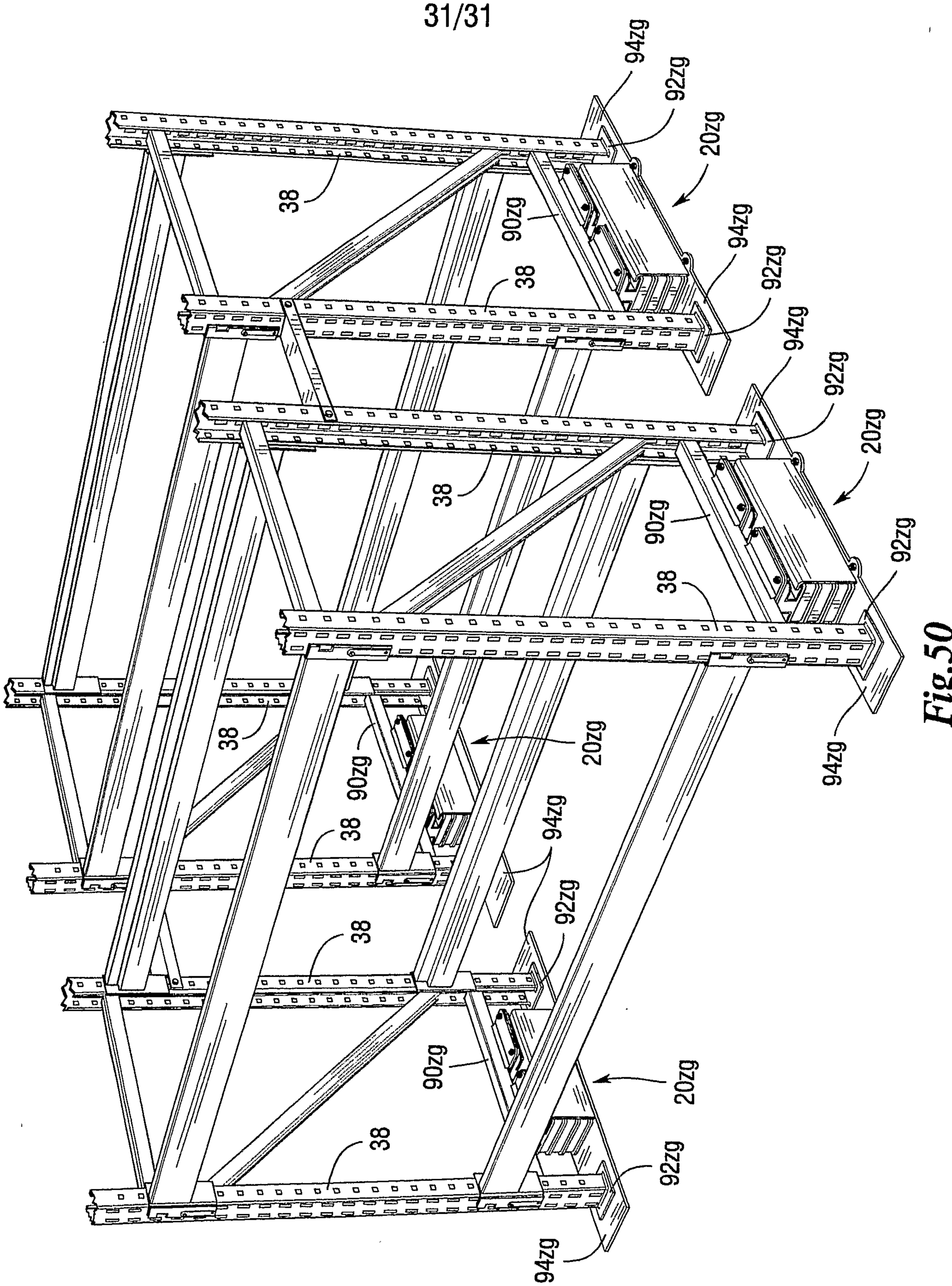

Fig.50