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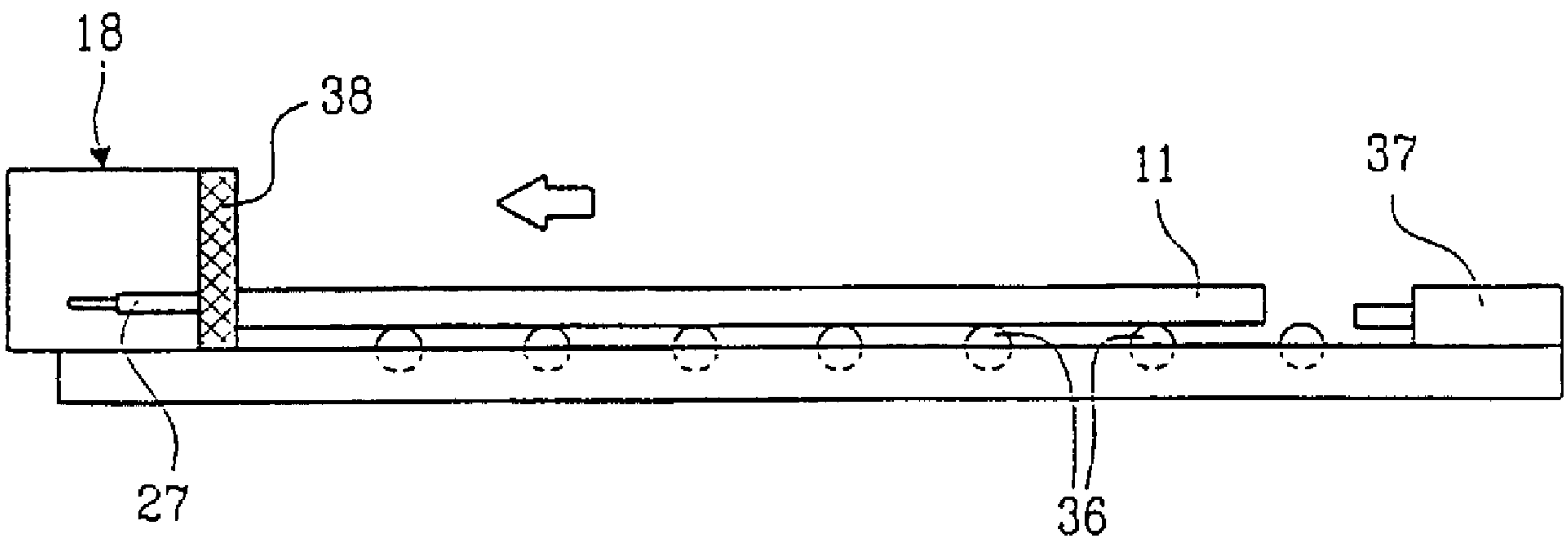

(57) Abrégé/Abstract:
Method and device for nondestructive determination of rigidity, strength and/or structural properties of preferably oblong and/or plate-shaped objects (11), alternatively determination of the geometrical dimensions of the object, through impact excitation and registration of resonance frequencies of natural modes of the object. According to the invention resonance frequency from at least one of the natural modes of the object is used, which resonance frequency is achieved by bringing the object (11) in vibration by means of a stroking body (24, 31, 38), and substantially controlling the initiation of the motion of the stroking body (24, 31, 38) and subsequent physical impact in time and space by motion of the object (11).

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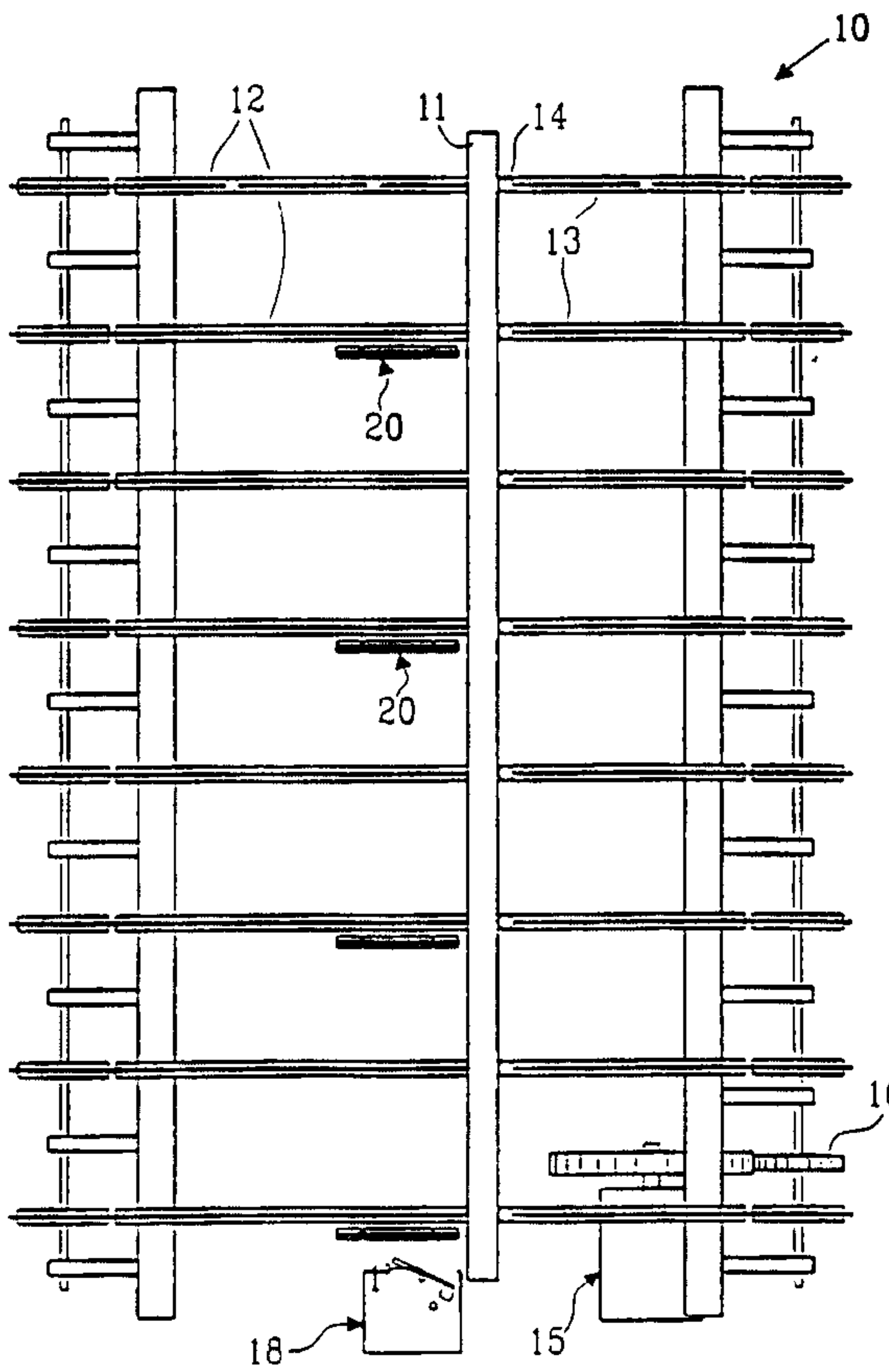
(57) Abstract

Method and device for nondestructive determination of rigidity, strength and/or structural properties of preferably oblong and/or plate-shaped objects (11), alternatively determination of the geometrical dimensions of the object, through impact excitation and registration of resonance frequencies of natural modes of the object. According to the invention resonance frequency from at least one of the natural modes of the object is used, which resonance frequency is achieved by bringing the object (11) in vibration by means of a stroking body (24, 31, 38), and substantially controlling the initiation of the motion of the stroking body (24, 31, 38) and subsequent physical impact in time and space by motion of the object (11).



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METHOD AND ARRANGEMENT FOR NONDESTRUCTIVE CLASSIFICATION

Technical field

The present invention relates to a method and an arrangement for nondestructive determination of rigidity, tensile and/or structural properties of a preferably oblong and/or plate-shaped object, alternatively determination of the geometrical dimensions of the object, through impact excitation and registration of resonance frequencies of natural modes of the object.

The invention also relates to an assembly including an arrangement according to the invention.

Background of the invention

When the constructional wood is mechanically strength sorted, the classification is generally based on evaluations of the coefficient of elasticity of the wood by statical bend load in a pliable direction. This coefficient of elasticity is correlated with the strength of the wood and thereby forms the basis for sorting into strength classes. However, these machines have limited performance and do not have satisfying capacity to characterize high strength wood. The majority of present sorting machines require that the wood be transported longitudinally through the machine, while in most cases it would be advantageous, from the production technique point of view, if the machines could manage to perform classification during the continuous cross convey of the wood.

In the laboratory environment, methods based on the measurement of fundamental resonance frequencies at bending and axial vibration, respectively, have shown to be considerably accurate than present machines when it applies to prediction of the bending strength, “Strength and stiffness prediction of timber using conventional and dynamic methods”, by Mikael Perstorper, First European Colloquiums on Nondestructive Evaluation of Wood, University of Sopron, Hungary, September 21-23, 1994, vol. 2. The problem with this method is that until now adaption to industrial conditions in respect of speed, automation and continuos flow has not been possible, .

Until now, one has merely utilized the fundamental resonance frequency at bending and axial vibration, respectively, for predication of strength properties. By using information from multi-channel modes a more reliable characterisation of the mechanical characteristics of the measured object is obtained.

SE 348 558 describes a nondestructive method that classifies the wood material by exposing the short end of the sample body for a physical hit to generate an energy wave in the sample body. The wave extends in the longitudinal direction. The time for the passage of the energy wave between two sensors is measured and the sample body is classified depending on its coefficient of elasticity, which is determined by the speed of the energy wave and the density of the sample body.

The prior art is also evident through a number of other patent documents. For example US 4,926,691 teaches a method to measure rigidity and the condition of a wooden structure, preferably poles dug in the ground. The first five resonance modes are used, which are measured by an accelerometer or velocity transducer. US 4,446,733 shows a system for inducing compressive stress in rigid objects for endurance tests. The sample object is hold firmly in a holder at a test moment. US 4,399,701 also shows a method for detecting degradation in wood, preferably wooden poles firmly dug in the ground. According to this document, grooves are arranged in the pole for insertion of acoustic transducers in the pole. Two relatively complicated equipments are known through US 5,207,100 and US 5,255,565, which require complicated signal processing. US 2,102,614 describes a method for generating and discrimination of vibrations in an air plain propeller. The propeller is suspended by means of an elastic suspension member and a vibrator is connected to the centre of the propeller.

The Summary of the Invention

An object of the invention is to provide a method for strength classification of a body, such as wood and other wood-based products in a more accurate, fast and effective way. Another object of the present invention is to provide an industrially applicable technical solution for determination of resonance frequencies of a body for purpose of strength sorting. In a preferred embodiment, the invention can be applied to sample objects, which primarily are continuously and transversely transported.

The present invention provides an arrangement for the nondestructive determination of at least one property of an object, the arrangement comprising a conveyer for movably supporting the object, a testing unit, including a movable member and a stroking body, mounted adjacent the conveyer, the conveyer bringing the object into engagement with the movable member and then moving the object out of engagement with the movable member whereby, when the object is out of engagement with the movable body, the stroking body physically impacts the object causing the object to freely vibrate at at least one natural resonant frequency mode thereof, a detector for detecting the vibration of the object resulting from the physical impact thereon by the stroking body, and a computer unit coupled to the detector for processing an output of the detector and determining a property of the object.

The present invention provides a method of nondestructively determining a property of an object, the method comprising the steps of conveying the object to a testing unit, the testing unit including a movable member and a stroking body, engaging the movable member with the object, moving the object out of engagement with the movable member, impacting the object with the stroking body thereby causing the object to freely vibrate at at least one natural resonant frequency mode thereof, detecting the vibration of the object resulting from the impact, and determining a property of the object from the detected vibration.

The present invention provides an arrangement for the nondestructive determination of a property of an object having first and second opposite ends, the arrangement comprising a conveyer for movably supporting the object, a testing unit mounted adjacent the first end of the conveyer, the testing unit including an impact absorbing body, a stroking body mounted adjacent the second end of the object, the stroking body displacing the object on the conveyer to impact the impact absorbing body of the testing unit, whereby the object is caused to freely vibrate at least one natural resonant frequency mode thereof, a detector for detecting the vibration of the object resulting from the physical impact thereon by the stroking body, and a computer unit coupled to the detector for processing an output of the detector and determining the properties of the object.

Experiments have shown that the invention can increase the production capacity, for example when classifying wood, about one hundred objects can be classified during one hour compared to the present forty.

These tasks have been solved by using resonance frequency from at least one of objects natural modes, which resonance frequency is obtained by bringing the object into vibration by means of a stroking body, and essentially controlling the initiation of the movement of the stroking body and following physical impact in time and space through movement of the object. The arrangement according to the invention includes means to bring the object in an essentially free vibration state, a unit for processing collected vibration data and determination of rigidity and/or strength of the object alternatively the geometrical dimension of the object by means of resonance frequencies at least from one of the object's natural modes.

Brief description of the drawings

The invention will be described more detailed with reference to a number of embodiments illustrated in the enclosed drawings.

Fig. 1a-1c are natural modes of axial vibration for a free vibrating object.
Fig. 2 is an example of a corresponding frequency spectrum for vibration, according to fig. 1.
Fig. 3 schematically shows an embodiment of the invention arranged by a typical cross conveyor for wood.
Fig. 4 schematically shows a cross-section through the embodiment according to fig. 3.
Fig. 5-7 schematically shows a part of a testing unit according to the present invention and its operation sequence.
Fig. 8 and 9 show two additional embodiments of the testing unit according to the invention.
Fig. 10 is a schematic view of a part of another arrangement for classification of bodies according to the present invention.
Fig. 11 is an example of a basic function scheme for a control unit for classification of the bodies, according to the present invention.

Fundamental theory

If a prismatic body is brought into vibration, for example through a physical impact in the longitudinal direction of the body, different natural modes are identified having specific resonance frequencies f_n and corresponding vibrations. The resonance frequencies of the natural modes and the vibrations are structural properties. No matter where on the body the measurement is carried out, same resonance frequency for a certain natural mode is obtained. The figures 1a-1c show the vibration for some natural modes with axial vibration for a free vibrating object. The vertical axises indicate motion to left by positive values and motion to right with negative values. Nods are zero points in an oscillation and maximums are called bellies or antinods. Fig. 1a shows the natural mode whose resonance frequency is called the fundamental tone, fig. 1b shows the second natural mode and fig. 1c the third natural mode. The frequency spectrum in fig. 2 shows resonance frequencies f_1 to f_3 belonging to the natural modes shown in fig. 1a-1c. The axial vibration implies expansion and compression of the body. The centrum of the body does not move in the first mode. In the second mode, two nods are obtained where the body does not move and so on. Also, other mods such as flexural and torsional mods occur and can be used.

The resonance frequencies are settled by the geometry of the object, density and elastic characteristics such as coefficient of elasticity E and modulus of shearing G. The resonance frequencies f_{A-n} for different natural modes n for axial vibration for of a free vibrating oblong object can be calculated as:

$$\mathbf{f_{A-n} = (n/2L)\cdot(E/\rho)^{0.5}}$$

where

f_{A-n} = resonance frequency for axial mode No. n (Hz)

n = mode number (-)

L = length (m)

E = coefficient of elasticity (N/m^2)

ρ = density (kg/m^3)

A corresponding relationship is found for flexural vibration and torsional vibration. If the resonance frequencies, density and geometry of the objects are definite, the objects coefficient of elasticity can be decided for different natural modes:

$$E_{A-n} = 4\cdot(f_{A-n}\cdot L)^2\cdot \rho/n^2 \quad \text{(i).}$$

In same way, the geometry and density can be decided if other parameters are known.

Different parts of a body have different extensions during the vibration depending on the natural mode. At free vibrating axial vibration, for the first natural mode the maximum extensions in the centre part are obtained, while the extensions adjacent to the ends become relatively marginal. For the second natural mode, the maximum extensions are obtained in other parts of the object and so on. In the same way, the density of the parts of the object, which moves mainly during the vibration have relatively considerable importance for the resonance frequency than the parts that move a little, i.e. the nods. Consequently, for the first axial mode the coefficient of elasticity of the middle part and the density of the ends decide the resonance frequency of the object. For an inhomogeneous object, in which the coefficient of elasticity varies in the length direction, for example wood, different measured values are obtained for the coefficient of elasticity E_{A-n} depending on the vibration mode. Thus, the differences in the coefficient of elasticity between different modes indicate the degree of inhomogeneity of the object.

The boundary conditions (the reserve conditions) are very important for evaluation of the dynamic characteristics of the object. Well-defined reserve conditions are obtained in laboratory environment, typically by hanging up the object in flexible springs, which simulate a free vibrating condition, so-called free-free suspension. The arrangement can be considered as a free-free suspension, if the vibrating mass of the springs is small in relationship to the mass of the object and if the fundamental resonance frequency of the system of object-spring is substantially lower than the object's lowest resonance frequency. Other types of boundary conditions are free disposition and fixed clamping. The latter apply for a beam in US 5,060,516.

Sorting of wood in respect of strength

The invention is primarily intended for sorting objects in classes for which specific demands on strength σ_{break} and/or coefficient of elasticity E are made. In the present description, an application example of the invention for alternative axial vibration of wood is given, but of course, the principle may be applied on other material and other vibrations.

The primary parameter for strength sorting of wood is bending strength. The criteria for an approved sorting (on safe side) is that maximum of 5 of 100 wood pieces may have a bending strength below a value established for each class. Thereby, predicting the bending strength of the timber is the most important criterion at comparisons between different machine operations is apparent that ability. With a good correlation (r^2) between the output of the machine and the bending strength of the timber, higher share of timber in the higher sorting classes are obtained.

In laboratory environment it has shown that connection between dynamic determined coefficient of elasticity according to the present invention and bending strength is very good ($r^2 \approx 0.75$) compared to conventional static bending sorting machines ($r^2 \approx 0.6$). This is described, for instance in "Strength and stiffness prediction using conventional and dynamic methods" by Mikael Perstorper, First European Colloquiums on Nondestructive Evaluation of Wood, University of Sopron, Hungary, September 21-23 1994, vol. 2.

The method according to invention is primarily carried out by in length direction exposing the wood to be classified for a physical impact, which sets the wood in an axial vibration. The resonance frequencies for two or more natural modes are then detected with a sensor. Corresponding elasticity modules are calculated according to equation **(i)** with knowledge of the density and length of the wood. Thereby, the wood is assumed to rest on supporting means, which simulates a floating condition. The sorting method is based on axial vibration, for instance because the boundary conditions are simpler to control for this mode form.

The mean value for coefficient of elasticities from the natural modes that are analyzed, E_{dyn}, constitutes the primary parameter for predication of bending strength. This mean value formation implies that more representative rate of the global coefficient of elasticity of the wood is obtained compared to usage of the first natural mode. The rigidity of the middle part is entirely critical in the latter case while one in the last case considers the impact of a considerable larger part of the wood.

The difference between the coefficient of elasticity from different natural modes is a measure on the degree of inhomogeneity of the wood and can be part of an independent parameter for an improved predication of the strength. Generally, it is known that low strength wood is more inhomogeneous than high strength wood. Furthermore, the information on an object's degree of inhomogeneity may be of importance for other processes than strength sorting.

The risk for an error in measurement and interference, which could prevent a correct classification is diminished by over-determination of coefficient of elasticity. When generating the mean value a control for reasonableness is carried out whereby some natural mode results can be disregarded. Thereby, a more reliable predication and possibilities of error controlling are obtained.

The classification of the wood is carried out according to an established statistical connection between the mentioned mean value generating coefficient of elasticity E_{dyn} and intended mechanical characteristics such as bending strength σ_{bend}:

$$\sigma_{bend} = A + B \cdot E_{dyn}$$

Alternatively, direct connection between resonance frequency and strength for an object at given length for different natural modes are used. This is tantamount to using a relevant mean value ρ_{mean} for the sorting group instead of measuring density for each entity.

The density can be measured by registering length, width, thickness and weight or by exploiting established contactless technics such as x-ray or microwaves. The length and, in applicable cases, also the thickness and width can be decided with commercially an available laser-based technic.

Detailed description of the embodiments

Figs. 3 and 4 show a first simplified embodiment of an assembly 10, for example in a sawmill, for transportation of the object, in this case timber 11, which is to be classified at a measuring zone for nondestructive classification of the timber. With nondestructive is meant a testing operation that does not influence the characteristics of the object. The assembly 10 for instance includes a number of rails 12 on which endless transport chains 13 are provided having carriers

14. Driving means in form of driving assembly 15 and driving wheel 16 are provided to convey the timber 11 to and past a testing unit 18.

The timber 11 is cross conveyed by means of the conveyor chains 13 with the carriers 14 driving the timber forward continuously. The timber 11 normally rests directly on the chain 13 or slide on the rails 12, for example made of steel sections, in which the chains run, so-called chain supports.

The timber 11, whose one end is preferably clearly sawn in an angle without projecting large chips, is manually or automatically placed on the chains 11. As the timber parts can have different lengths, these are so placed on the chains that the timber ends come in contact with the testing unit lies in same line. When passing by the testing unit 18, the timber is given a physical impact in its length direction by means of a device that is shown in detail in fig. 5. At the impact moment a free vibration condition in respect of the axial vibration is simulated. This is achieved by the timber being brought to rest vertically on a support 20, whose rigidity with regard to the vibrations in longitudinal direction of the timber is low enough and whose co-vibrating mass is low enough.

To simulate a free vibration condition with regard to the axial vibration, the timber 11 can for instance be moved forward resting on the support members, including the conveyer 35 of rubber instead of chains or chain supports, e.g., shown in fig. 4. These conveyers 35 have plain regions 20, levels of which are sufficiently higher than the level of the chains/chain supports, so that vertical bearing is only provided on the conveyer 35. However, the level of this plain region 20 is not so high that the carriers 14 loose contact with the timber. The support members are mounted slightly inclined so that the timber is gradually raised from the chains/chain supports. To guide the timber onto the plain region and downwards again, the conveyer can also be provided with inclined slide bars. The rubber band runs in a loop having wheels 17 in both ends of the conveyer. The rubber band 35 on which the timber rests slides on a surface with very low friction. When the timber 11 is carried up onto the conveyer via the slide bars by means of the carriers 14, the friction between the timber 11 and the rubber band 35 is much higher than between the rubber band and underlying slide surface. Thus, the rubber band is brought to run along the surface. Consequently, the timber does not slide on the rubber band. The surface on which the band run has edges so that the band cannot move laterally more than a few millimeters. Thus, the timber is loaded in its longitudinal direction by the impact mechanism without the rubber band sliding laterally on the smooth track surface.

The testing unit 18, according to figs. 5 - 7 includes an arm 19, which can swing in the vertical plane about an axis 39. When the timber 11 is carried froward, the arm 19 rotated anticlockwise and a spring 21 is stretched in a corresponding degree. When the timber 11 is carried further forward and reaches the position, according to fig. 6, the spring 21 is stretched to maximum. A slide spacer or wheel 23 attached to the arm presses against the end of the timber 22. In the next moment, the timber is moved further forward so that the arm 19 loses contact with the end of the timber 22. Thus the arm is turned back toward its rest position by action of the spring force, according to fig. 7. During this accelerating motion, the end of the timber 22 is encountered by a stroking body 24, attached to the arm 19 via a bar 25. This bar 25 has so low bending strength with regard to the bending in the plane that the bar 25 and its stroking body 24 has a fundamental resonance frequency smaller than a tenth of the lowest resonance frequency of the sample object at axial vibration. Thus the bar 25 and its stroking body 24 do not generate acoustic pressure with frequency components that can disturb the measurements.

A receiving member 26 is positioned so that the arm at impact does not bear on it. Consequently, at the impact, the spring 21 presses the stroking body 24 against the end of the timber 22 so that the bar 25 is bend deformed. The high flexibility of the bar 25 results in that the power impulse from the timber piece at the impact is isolated from the arm 19. Thereby, no troubling acoustic pressure is originated from the vibrations in the arm 19 since the arm does not excite in a considerable extent.

A contactless microphone 27 is arranged for recording the emerged sound waves in the timber 11. The microphone 27 is so provided that it, at the impact moment, is essentially in the middle of the width of the timber piece. The microphone 27 is placed so that it at the impact moment can collect the radiated acoustic pressure from the end of the timber, originating from the resonance vibrations generated by the impact. An alternative embodiment is to detect the vibration of the object with laser-based sensors. Alternatively, a number of microphones can be arranged in series, if the width of the timber varies, whereby the recording from the most correctly positioned microphone can be used.

The microphone is connected to a computer unit (not shown), function of which is described later.

One possible method to achieve the necessary flexibility is shown in fig.8, according to which a more stiff bar 25 via a joint 28 is fastened to the arm 19 and a tension spring 29 provides for the flexibility. The tension spring 29 is biased slightly towards a receiving member 30 to ensure same initial position for the stroking body 24 at each attempt. Yet another embodiment is shown in fig. 9. The cylindrical stroking body 31 is arranged running in a tube 32 with an isolating pressure spring 33 at the bottom. The tube is rigidly attached to the arm 19 via a bar 34.

The mass of the stroking body as well as its geometry and modulus of elasticity with its stop face is in addition fitted to the spring rigidity and dimension of the arm and the bar so that the physical impacts generate/excite vibrations having a frequency content that covers the resonance frequencies to be detected.

Another method to avoid exciting of the arm is to design the receiving member so that impacts are damped.

In the embodiment shown in fig. 10, the timber 11 is displaced on the slide bars 36. Rails 36 are arranged rollable or with surfaces having very low friction, at least at the testing zone, i.e., the area that extends in front of the testing unit 18. A stroking mechanism 37, for example a pneumatic motor or a hydraulic piston is arranged at one side of the conveying rails 36. When the timber 11 passes the mechanism 37, it is detected and a compressed air blow displaces the timber laterally towards a rigid impact absorbing body or end stop 38 arranged close to the microphone 27. The collision of the timber with the end stop 38 generates a controlled impact excitation of the timber piece in axial direction (lengthwise). The frequency content in the impact is such that the two first axial vibration modes can be excited for all timber pieces to be sorted. Just next to the holder-on a microphone 27 is located, which records the acoustic pressure and transfers it to the computer unit. Since the timber length can vary, the stroking mechanism 37 is arranged movable relative to the movement plane of the timber or its impact strength can be varied with regard to the length of the timber so that all timber lengths are given impact with same strength.

The assemblies, for example according to figs. 3, 4 or 10, are assumed to be located in a sawmill or other wood refining industry as part of the process where the timber is cross conveyed, for instance in so-called trimmer. In an assembly according to the present invention a timber piece with varying length of about 2-5 m can be classified in the ongoing process during a time period of just one to two seconds.

Generally, the frequency contents in the impacts are such that the first two axial vibration modes can be excited for all timber pieces intended to be sorted. The reflected sound from the end of the timber, recorded by the microphone 27 contains same frequency content as the impacts gave raise to. The frequencies that coincide with the two lowest axial resonance frequencies of the timber piece will exhibit strong increased acoustic pressure levels in relation to the remaining frequencies. Also, adjacent frequencies will exhibit high amplitudes.

Fig. 11 schematically shows a block diagram for a computer unit, which partly can control the assembly and partly processes the sound received from the microphone. The sound recorded by the microphone 27 is amplified in an amplifier 101 and the analog response signal in a time unit is analogue to the converted 102 and Fourier transformed 103 digitalized "signal" in the frequency plane, whereby an acoustic pressure spectrum 104 is created.

The resonance frequencies in this spectrum can then simply be decided by means of an algorithm scanning 105 the spectrum after corresponding high amplitude values. When the two actual resonance frequencies have been estimated, the values are compared to reasonable values for actual length, which is found stored in a database 106 by the computer unit 100, which manages the measurement and calculation procedure. When said control has been carried out, a mean value 107 for the estimated coefficient of elasticity E_{dyn} according to equation (i) is calculated. By using a statistical connection between the coefficient of elasticity and bending strength the timber piece can be classified 108 according to the strength classes that are valid according to standards or other demands in force.

If the standard is changed the classifying value and/or the interval is simply changed in the computer unit 100, which can operate as a control unit of the sorting machine. When the timber piece has been associated with a strength class, the timber piece is marked for ocular inspection and control 109.

The machine also generates information for guiding each individual timber piece to right "line" in a later working moment.

In connection with the measurement of the resonance frequency, also, the information about mass density and timber length are fetched from the computer unit 100.

The timber length can be determined by means of known commercial laser techniques 110 in close connection to the resonance frequency measurement. The timber piece density can be decided according to one of two alternatives. In the first one, wave technique 111 and laser-based length measurement 112 are used, whereby the mass M and further geometrical dimensions, cross section dimensions T, B are obtained.

The other alternative is carried out by means of microwave technology 113, whereby density (and moisture ratio) is obtained explicitly 114. However, no"complete" mean values for density are obtained, but a mean value based on one or a pair of points along the timber piece. These technics are available on the market.

The density ρ can also be decided by means of microwave technology. Also, this technic gives information about the moisture ratio, which is a significant parameter for coefficient of elasticity. The moisture ratio may otherwise be assigned an assumed value based on the climatic conditions at proceeding storage. The length L and the cross section dimension B and T are intended to be measured by means of laser technique, which today is used in several sawmills. The measured data from such a commercial equipment is transmitted to the computer unit of the sorting machine. Timber length L is obtained by means of laser-based length measuring technique.

The marking is carried out ocularly readable to be used and controlled in later product stages.

The assembly can leave information about the sorting result to the control unit to enable physical separate storing of the timber in different strength classes after each timber unit leaving the sorting machine. Data storage should partly satisfy the different demands as a basis for statistics and partly satisfy the demands directed by the certifying authorities in connection with a reliability control and calibration etc.

The method can be applied on objects of wood of any length and cross-section. When classifying oblong objects the length can preferably be at least 4 times larger than cross-section dimensions. The object can be logs of wood, poles, or blocks such as boards, boarding, glulam beams and laminated wood beams. The method can also be applied to I-beams with a rib and flanges of wood or wood-based material.

Instead of contactless microphones also piezoelectric sensors can be used to.

Additional Applications

The method and the device according to the present invention can in principle be applied to any rigid, preferably prismatic object on which theory of elasticity can be apply, such as brick blocks, concrete panels, cement stabilized haydite elements, elements of steel, plastic, gypsum etc., with a view to determine some of the parameters, such as coefficient of elasticity, dimension or density.

In forgoing description it has been anticipated that analyzes are based on more modes within one and same type of vibration form. Another method to achieve over-determinating of coefficient of elasticity is to study both the axial and flexural modes. By means of the flexural vibration, the coefficient of elasticity can be decided in a similar way as for axial vibration, however, it is required that the cross section geometry of the object is measured exactly.

Usually, the timber has longitudinal, frequently throughout, cracks which originate from timber drying. These cracks, which frequently appear at the ends reduce the capacity to hold against lateral forces on the timber. One can simply say that the shear strength of the timber is low. Existence of these kinds of cracks is consequently important for strength sorting. Presently, these cracks are estimated visually by educated sorters since no machine is yet found for reliable detection.

By deciding the module of shearing (G) from torsional vibration, the existence of cracks can however be decided. These types of cracks also reduce the torsional stiffness of the object. Thus, a remarkable lowering of the evaluated module of shearing of the object is achieved. A low module of shearing from torsional vibration is consequently an indicator of existence of longitudinal cracks.

Moreover, it can be noted that one with the present method can decide the density of the object in weightless state provided that the coefficient of elasticity, geometry and resonance frequency are known.

Also, the geometrical dimensions for different objects, described above, can be decided through the method according to the present invention.

While we have illustrated and described preferred embodiments of the invention, it is obvious that several variations and modifications within the scope of the enclosed claims can occur.

Designation Numeral

10	=	Assembly
11	=	Timber (object)
12	=	Rail
13	=	Chain
14	=	Carrier
15	=	Driving assembly
16	=	Driving wheel
17	=	Wheel
18	=	Testing unit
19	=	Arm
20	=	Support members
21	=	Spring
22	=	The timber end
23	=	Wheel/slide spacer
24	=	Stroking body
25	=	Bar
26	=	Receiving member
27	=	Microphone
28	=	Joint
29	=	Tension spring
30	=	Receiving member
31	=	Stroking body
32	=	Holder
33	=	Pressure spring
34	=	Bar
35	=	Rubber band
36	=	Rail
37	=	Stroking mechanism
38	=	Holder-on
39	=	Axis
100	=	Computer unit
101	=	Amplifier
102	=	A/D-converter
103	=	Unit for Fourier transform
104	=	Processing unit
105	=	Processor unit
106	=	Data collection unit
107	=	Calculating unit
108	=	Classification unit
109	=	Marking
110	=	Measuring unit
111	=	Scale unit
112	=	Measuring unit
113	=	Microwave unit
114	=	Density calculation unit

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. An arrangement for the nondestructive determination of at least one property of an object, the arrangement comprising:

a conveyer for movably supporting the object;

a testing unit, including a movable member with a stroking body, mounted adjacent said conveyer, said conveyer bringing the object into engagement with said movable member and then moving the object out of engagement with said movable member whereby, when the object is out of engagement with said movable body, said stroking body physically impacts the object causing the object to freely vibrate at at least one natural resonant frequency mode thereof;

a detector for detecting the vibration of the object resulting from the physical impact thereon by said stroking body; and

a computer unit coupled to said detector for processing an output of said detector and determining a property of the object.

2. The arrangement according to claim 1, wherein said movable member is an arm rotatably mounted on a pivot and attached to said stroking body, said arm being rotated about said pivot by movement of the object; and

a spring having a fixed first end and a second end, the second end of said spring being attached to said arm, said spring being stretched by the rotation of said arm and released when the object is moved past said arm, whereby said stroking body is driven by the force of said spring to physically impact the object.

3. The arrangement according to claim 2, further comprising a receiving member and a tension spring, said receiving member and said second spring connecting said stroking body to said arm, the tension spring being biased toward said receiving member to maintain constant an initial position of said stroking body.

4. The arrangement according to claim 1, 2 or 3, wherein the conveyer is an endless chain, and which further comprises at least one support member adjacent said chain on which the object rests with no vertical movement as it is impacted by said stroking body.

5. The arrangement according to any one of claims 1 to 4, further comprising a rail having a slide surface; and

a support member including a movable rubber band, said rubber band sliding with relatively low friction on said slide surface prior to said stroking body impacting the object and accelerating when the object comes into contact with said rubber band due to relatively high friction between the object and said band, whereby the object rests on said band without relative motion between the object and said band as the object is impacted by said stroking body.

6. The arrangement according to any one of claims 1 to 5, wherein said detector is at least one of a microphone, laser and piezoelectric sensor.

7. The arrangement according to any one of claims 1 to 6, wherein the output of said detector is analog data, and said computer unit further comprises:

an analog to digital converter for converting the analog data to digital data;

a Fourier transform unit for transforming the digital data onto a frequency plane;

a processing unit for producing a frequency spectrum from an output of said Fourier transform unit;

a measuring unit for determining the length, cross-sectional dimensions and density of the object;

a data storage unit for storing data relating to the object;

a processor unit for algorithm scanning of the frequency spectrum for resonance frequencies, said processor unit receiving outputs of said measuring and data storage units; and

a calculating unit for calculating an estimated coefficient of elasticity of the object from measurements of the resonance frequencies, length and density thereof.

8. The arrangement according to any one of claims 1 to 7, wherein the object is timber, the length of the timber being at least four time larger than its cross-sectional dimensions.

9. The arrangement according to any one of claims 1 to 8, further comprising a cylindrical tube having a closed end for receiving said stroking body and an isolating pressure spring, said isolating pressure spring being interposed between the stroking body and the closed end of said cylindrical tube.

10. A method of nondestructively determining a property of an object, the method comprising the steps of:

conveying the object to a testing unit, said testing unit including a movable member with a stroking body;

engaging said movable member with the object;

moving the object out of engagement with said movable member;

impacting the object with said stroking body thereby causing the object to freely vibrate at at least one natural resonant frequency mode thereof;

detecting the vibration of the object resulting from said impact; and

determining a property of the object from said detected vibration.

11. The method of nondestructively determining a property of an object according to claim 10, wherein said at least one natural resonant frequency mode is from the group consisting of axial and flexural modes.

12. The method of nondestructively determining a property of an object according to claim 10 or 11, wherein a property of the object determined from the detected vibration is a modulus of shearing.

13. The method of nondestructively determining a property of an object according to claim 10, 11 or 12, wherein said at least one natural resonant frequency mode is measured, and wherein an over-determination is effected by comparing the measured at least one resonant frequency mode with a corresponding theoretical value thereof.

14. The method of nondestructively determining a property of an object according to claim 13, wherein the comparison between a measured resonant frequency mode and a theoretical resonant frequency modes is used as a basis for the determination of a property selected from the group consisting of rigidity, associated strength, geometrical variation of rigidity and non-homogeneity of the object, said determinations being carried out by mean value generation.

15. The method of nondestructively determining a property of an object according to claim 13, wherein the comparison between a measured resonant frequency mode and a theoretical resonant frequency mode is used as a basis for excluding erroneous measurements at a large statistical dispersal of an established rigidity rate determined from different resonant frequencies.

16. The method of nondestructively determining a property of an object according to claim 13, wherein the over-determination is carried out by assuming geometrical variation independency for rigidity of the object.

17. The method of nondestructively determining a property of an object according to any one of claims 10 to 16, wherein the vibration of the object is detected by at least one testing device, and said at least one resonant frequency mode is determined by processing in a computer unit.

18. The method of nondestructively determining a property of an object according to any one of claims 10 to 17, wherein said stroking body has a motion, form, mass and rigidity which produces said at least one natural resonant frequency mode in said object when impacting thereon.

19. The method of nondestructively determining a property of an object according to any one of claims 10 to 18, wherein the impact of said stroking body on said object results from at least one of the momentum of said object and the stretching of a spring.

20. The method of nondestructively determining a property of an object according to any one of claims 10 to 19, wherein said object rests during the step of impacting by said stroking body on a support, said support simulating ideal boundary conditions for said at least one natural resonant frequency mode.

21. The method of nondestructively determining a property of an object according to any one of claims 10 to 20, wherein said at least one natural resonant frequency mode is determined by automatic scanning of a frequency spectrum produced through Fourier transformation of a vibration of said object and an acoustic pressure response.

22. The method of nondestructively determining a property of an object according to any one of claims 10 to 21, said object being freely vibrating, of oblong shape and having resonant frequencies, including the further step of calculating

$$f_{A-n} = (n/2L)\cdot(E/\rho)^{0.5}$$

where

f_{A-n} =resonance frequency for axial mode No. n (Hz);

n =mode number (-);

L =length (m);

E =coefficient of elasticity (N/m^2); and

ρ =density (kg/m^3).

23. The method of nondestructively determining a property of an object according to any one of claims 10 to 22, for flexural vibration and torsional vibration, wherein a coefficient of elasticity for said at least one natural resonant frequency mode of said object is

$$E_{A-n} = 4\cdot(f_{A-n} L)^2\cdot\rho /n^2$$

where

f_{A-n} =resonance frequency for axial mode No. n (Hz);

n =mode number (-);

L =length (m);

E =coefficient of elasticity (N/m^2); and

ρ =density (kg/m^3).

24. An arrangement for the nondestructive determination of a property of an object having first and second opposite ends, the arrangement comprising:

a conveyer for movably supporting the object;

a testing unit mounted adjacent the first end of said conveyer, said testing unit including an impact absorbing body;

a stroking body mounted adjacent the second end of said object, said stroking body displacing the object on said conveyer to impact the impact absorbing body of said testing unit, whereby the object is caused to freely vibrate at least one natural resonant frequency mode thereof;

a detector for detecting the vibration of the object resulting from the physical impact thereon by said stroking body; and

a computer unit coupled to said detector for processing an output of said detector and determining the properties of the object.

FIG.1a

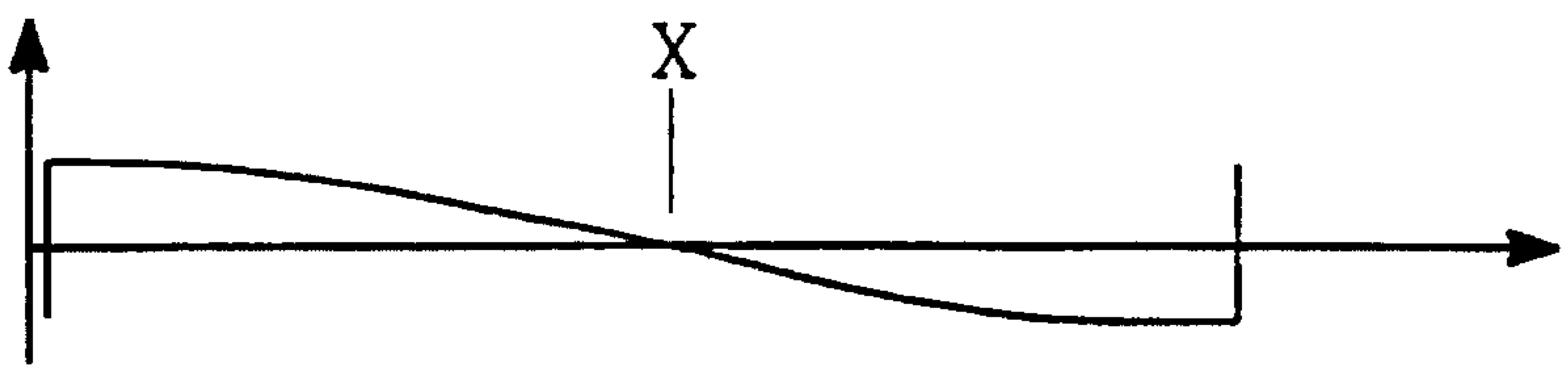


FIG.1b

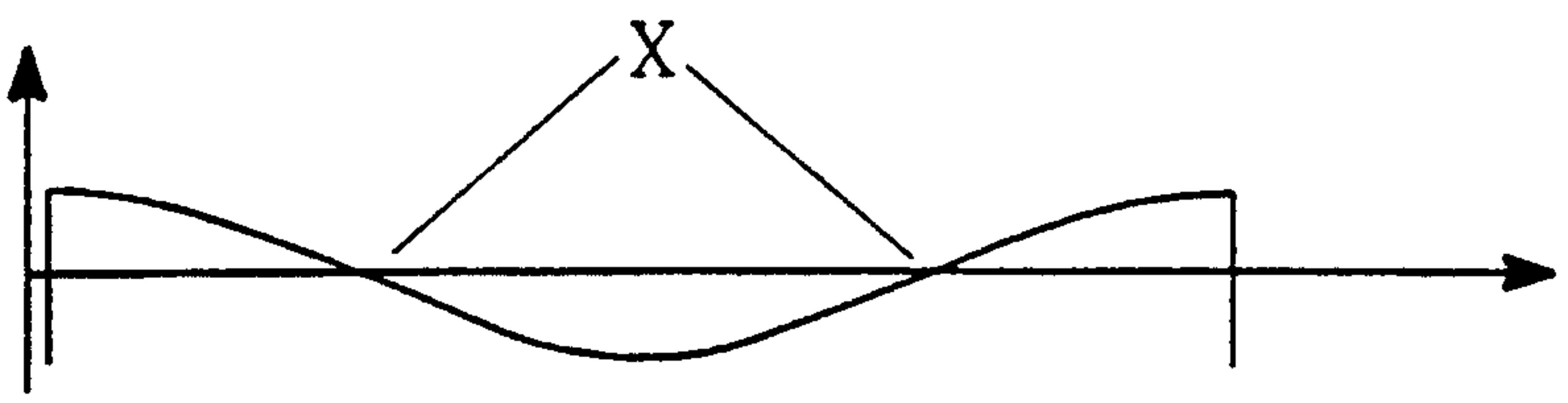


FIG.1c

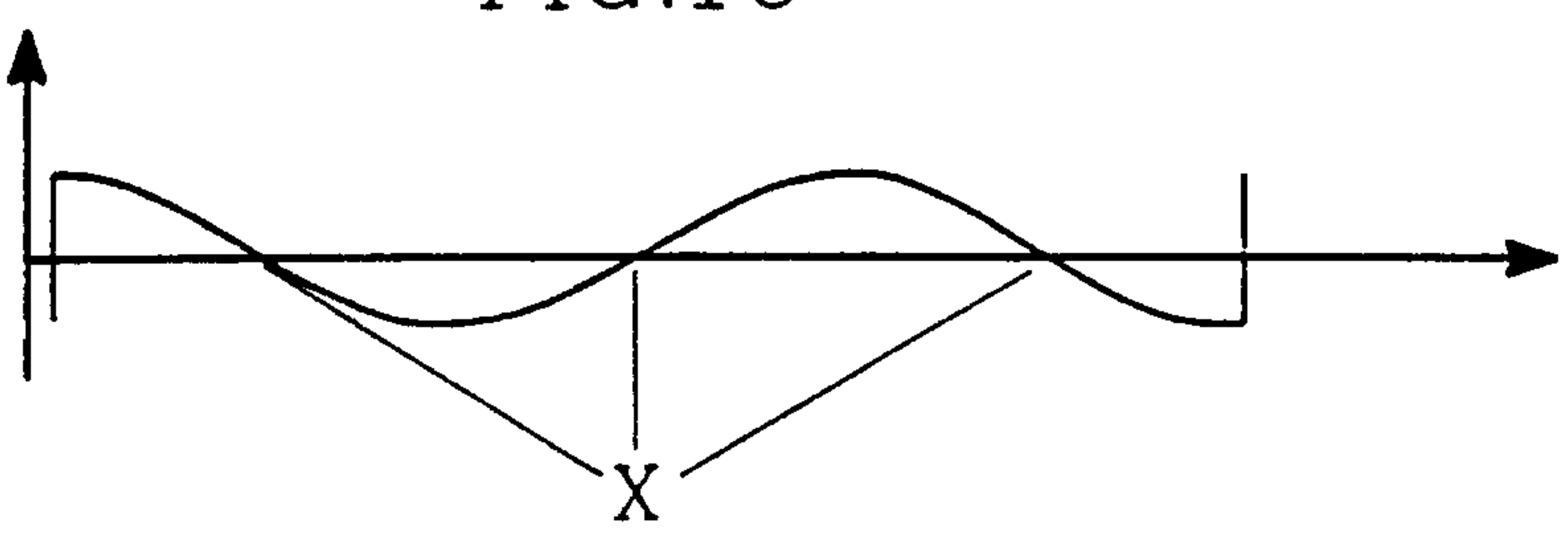


FIG.2

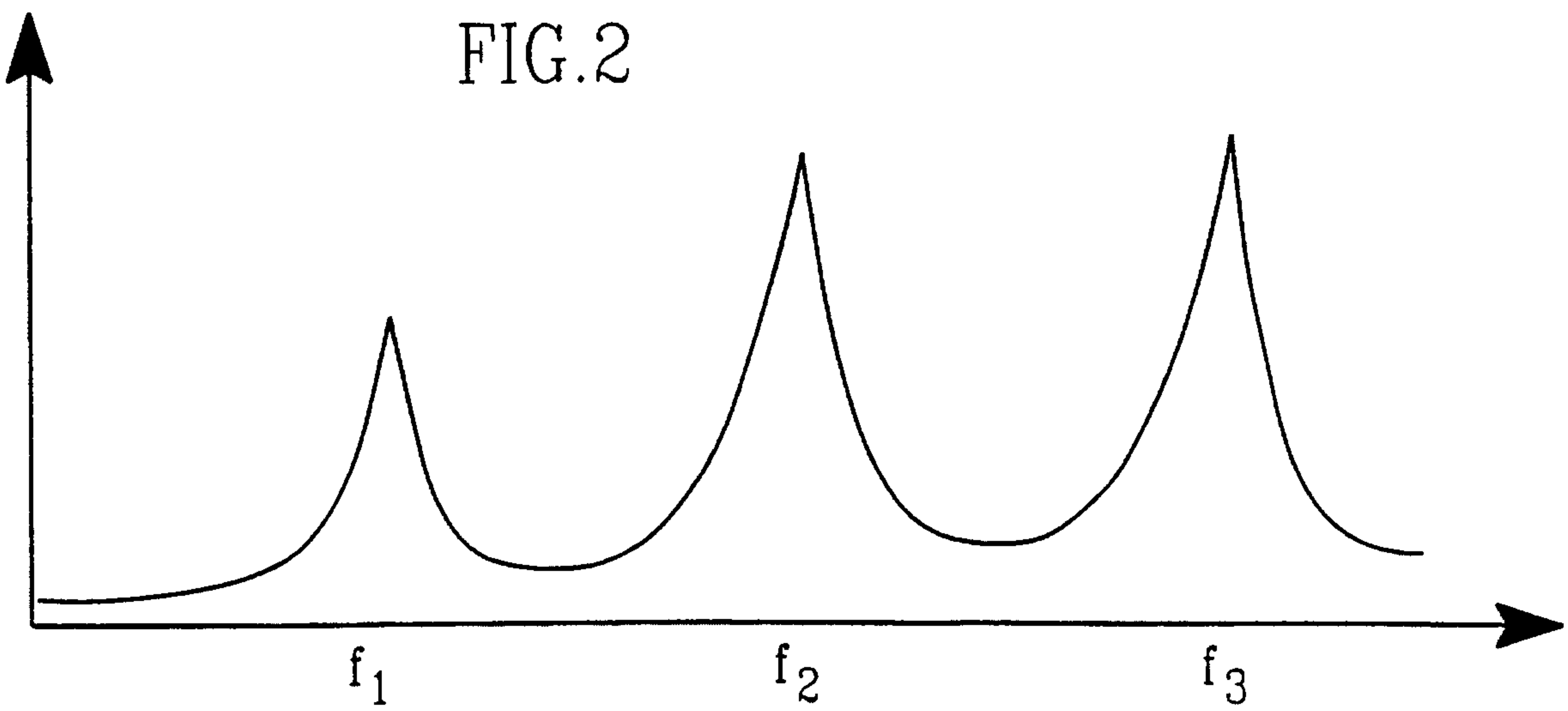


FIG.3

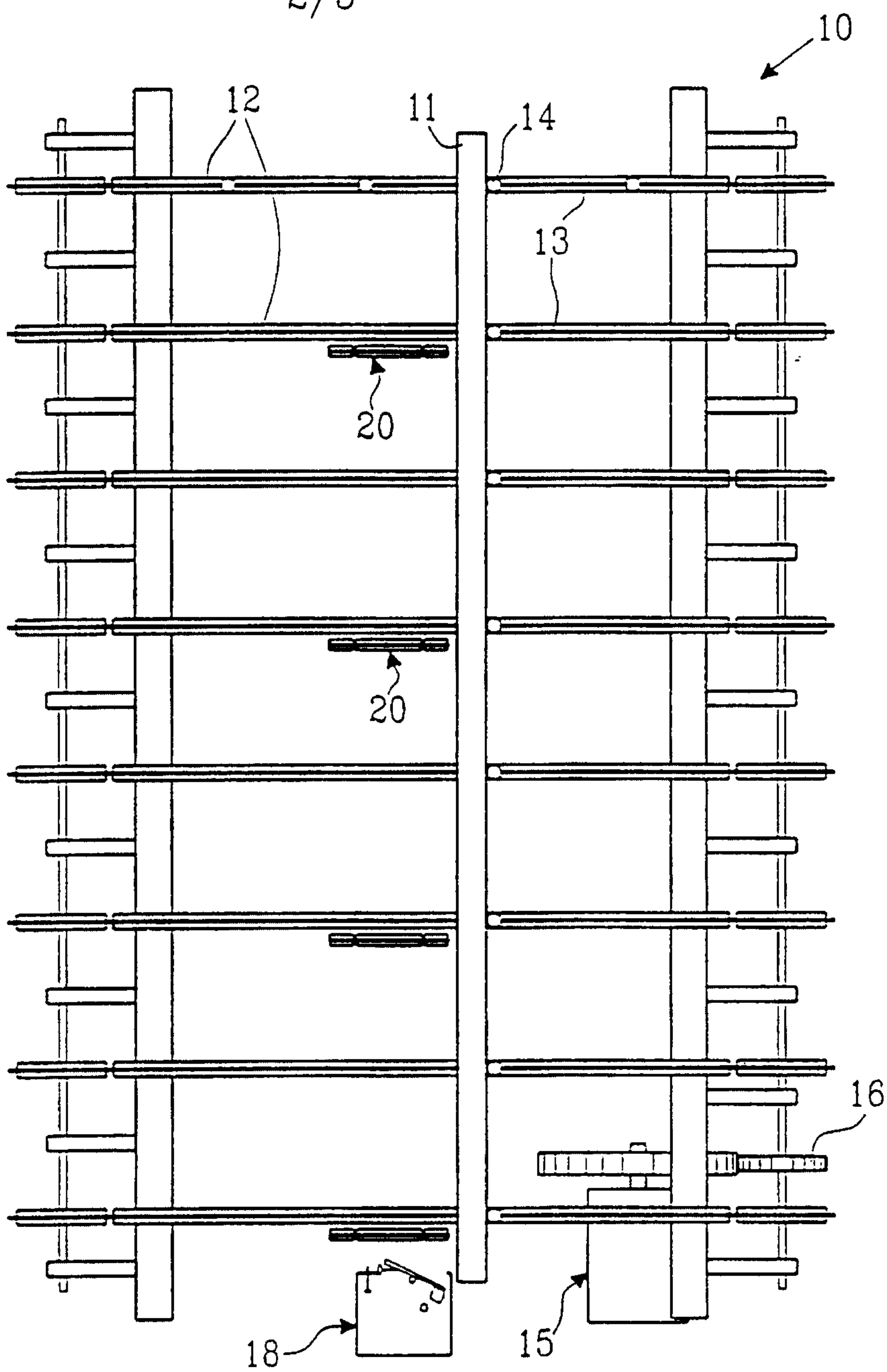


FIG.4

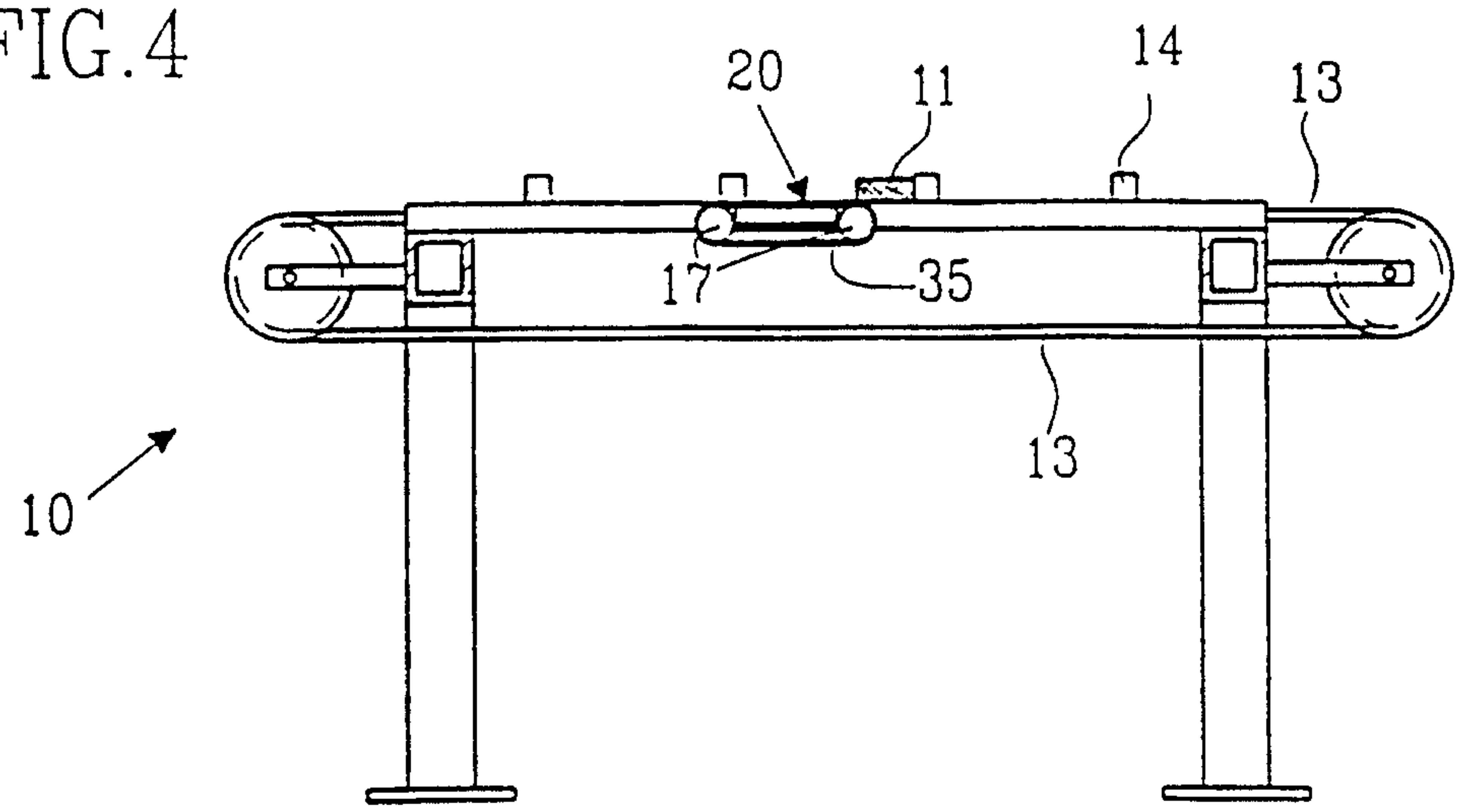


FIG.5

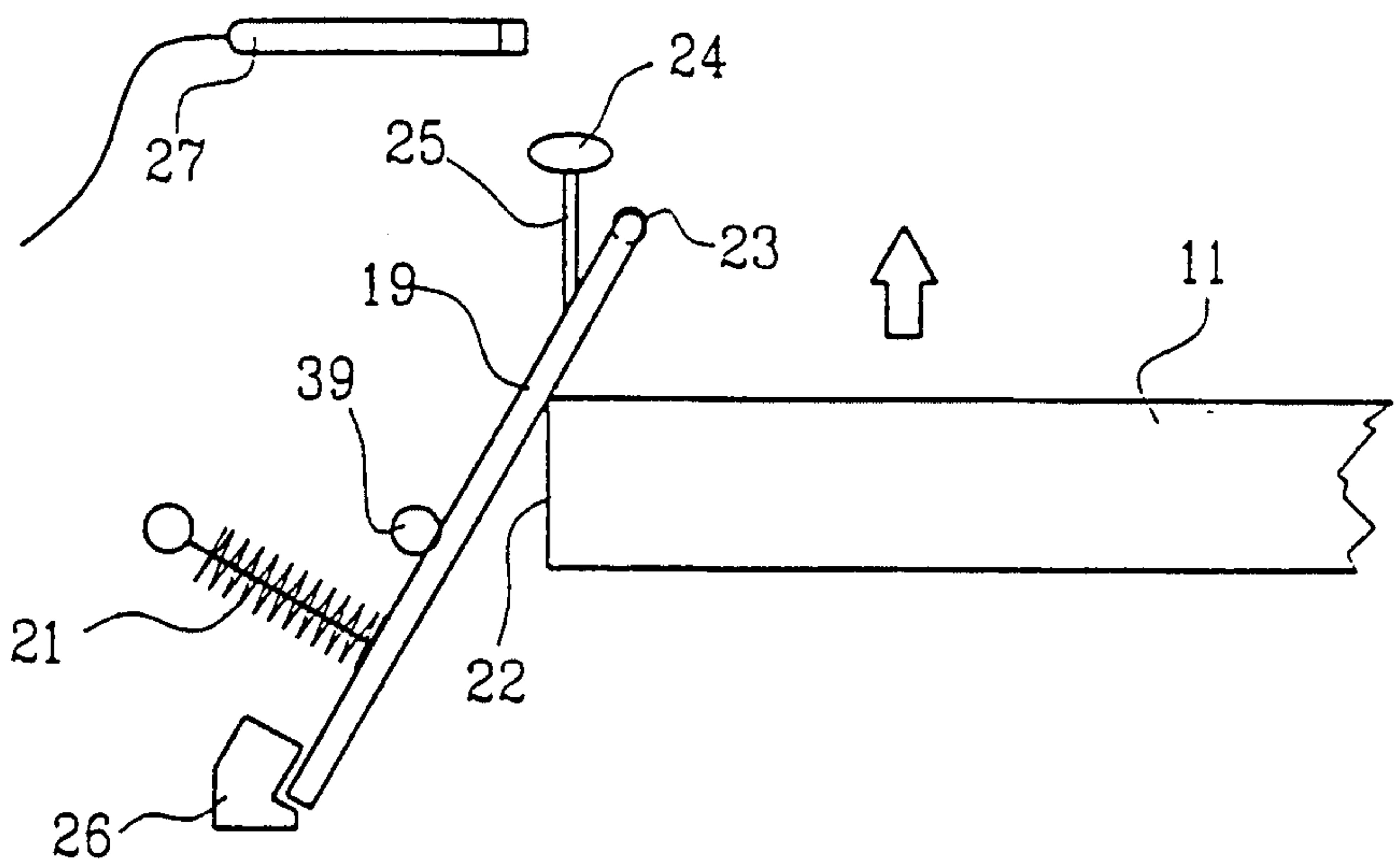


FIG.6

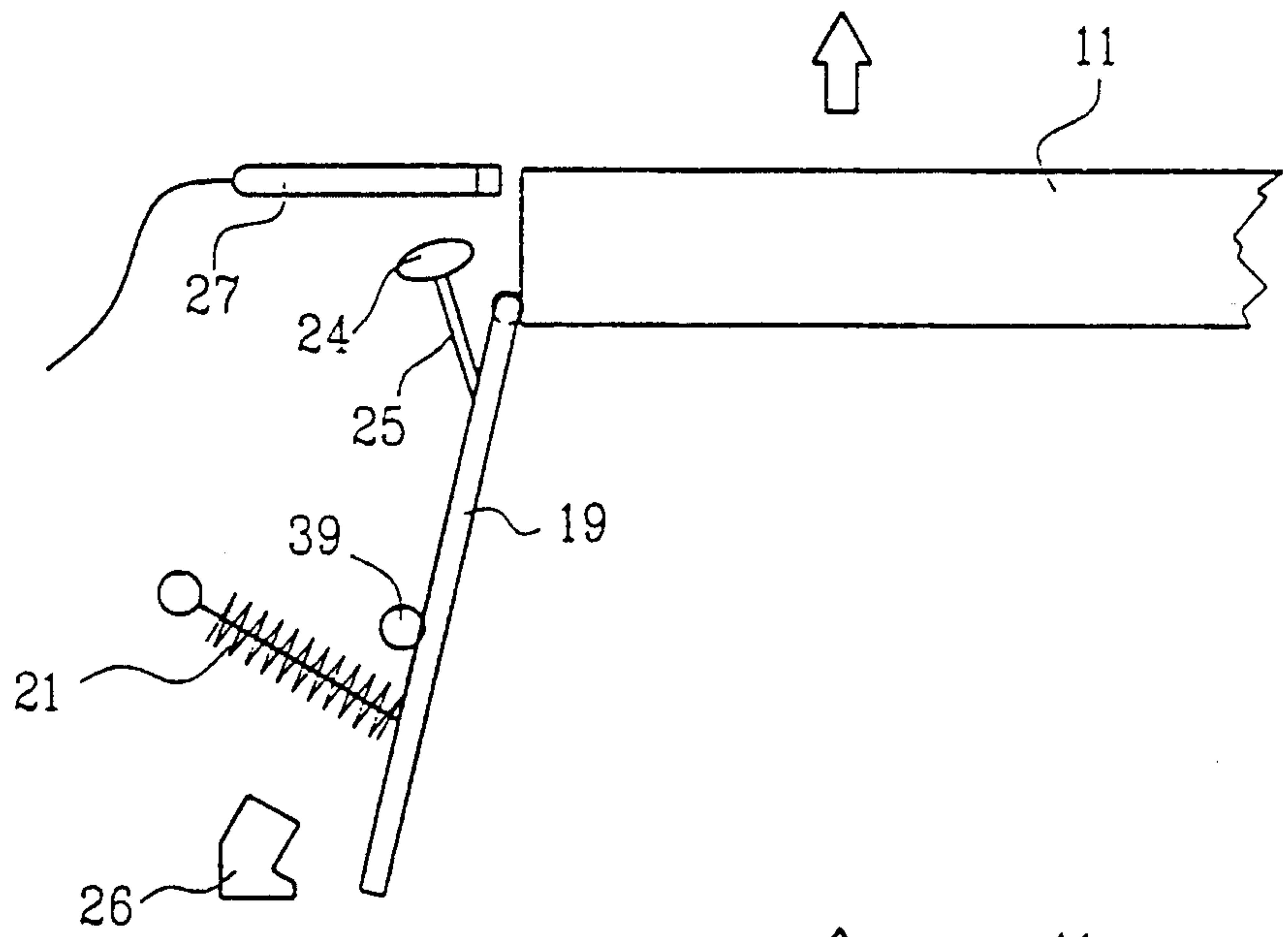


FIG.7

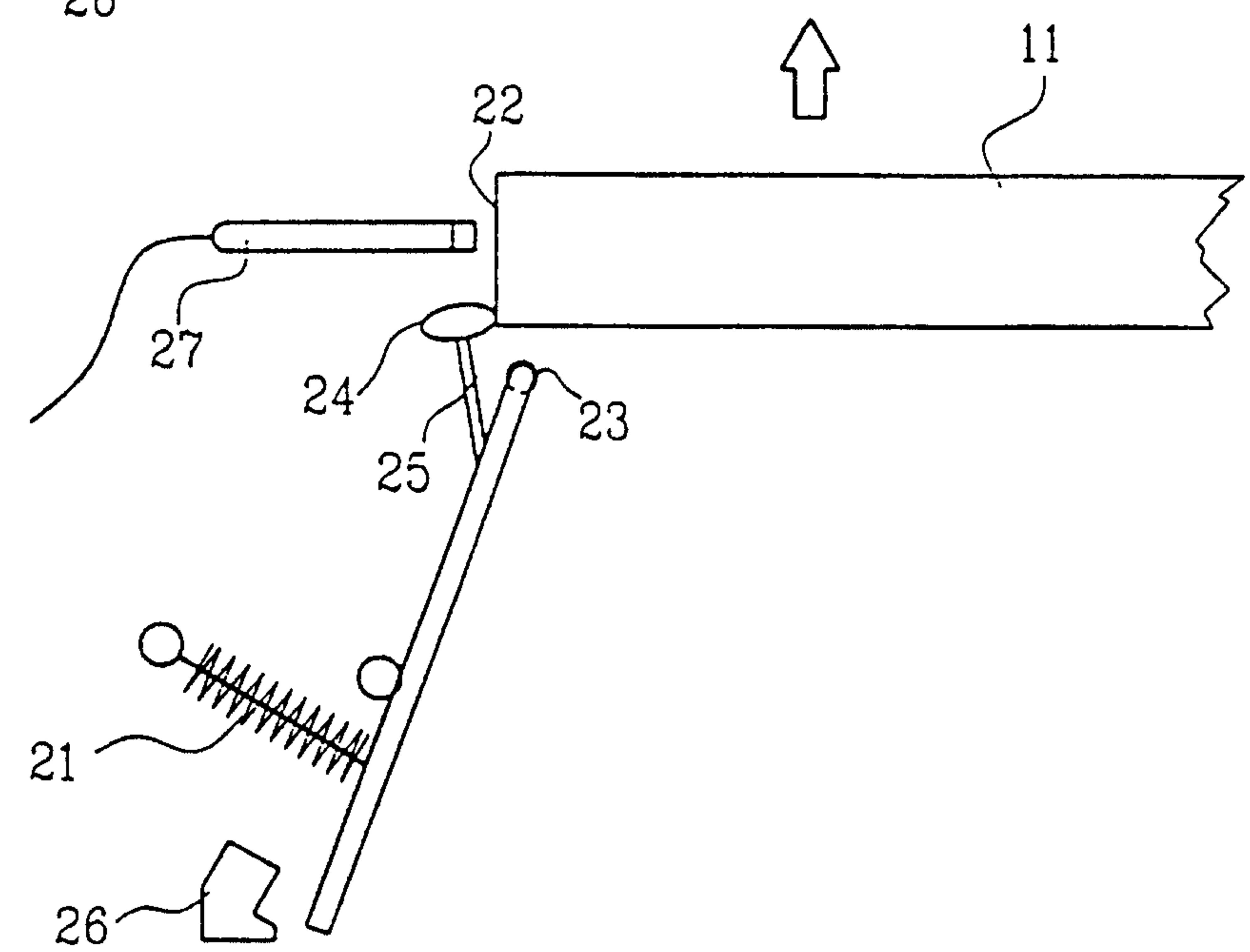


FIG.8

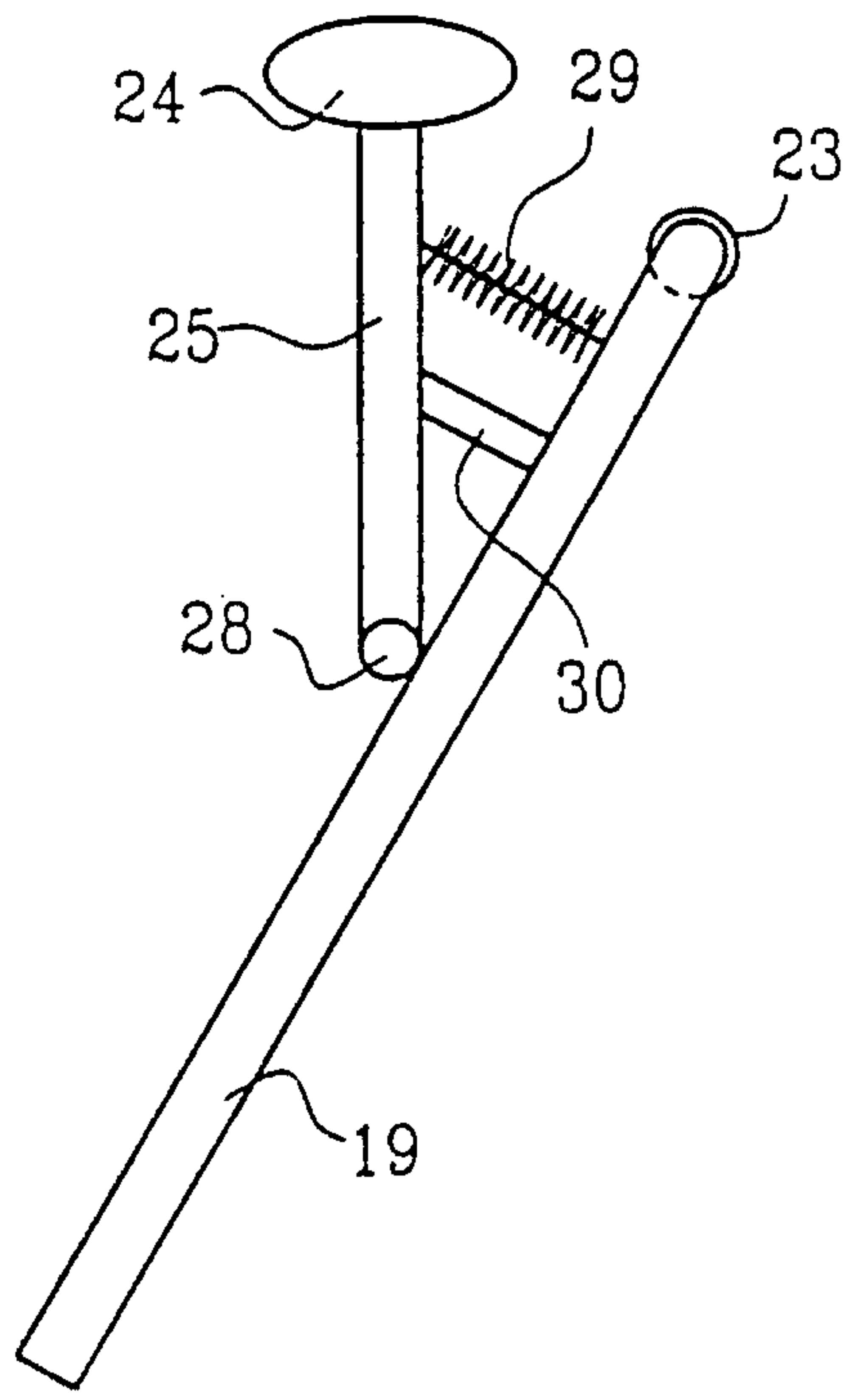


FIG.9

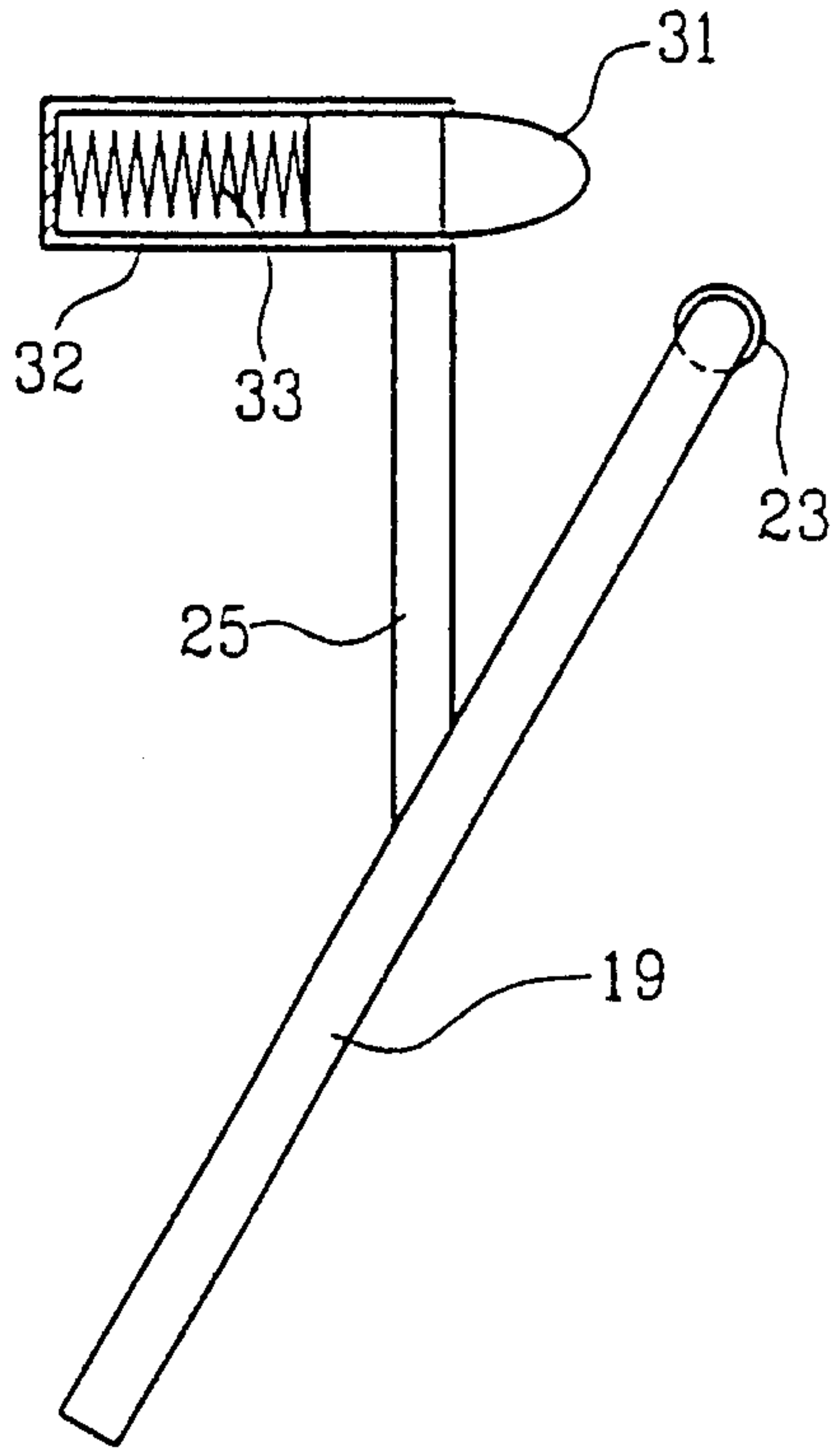


FIG.10

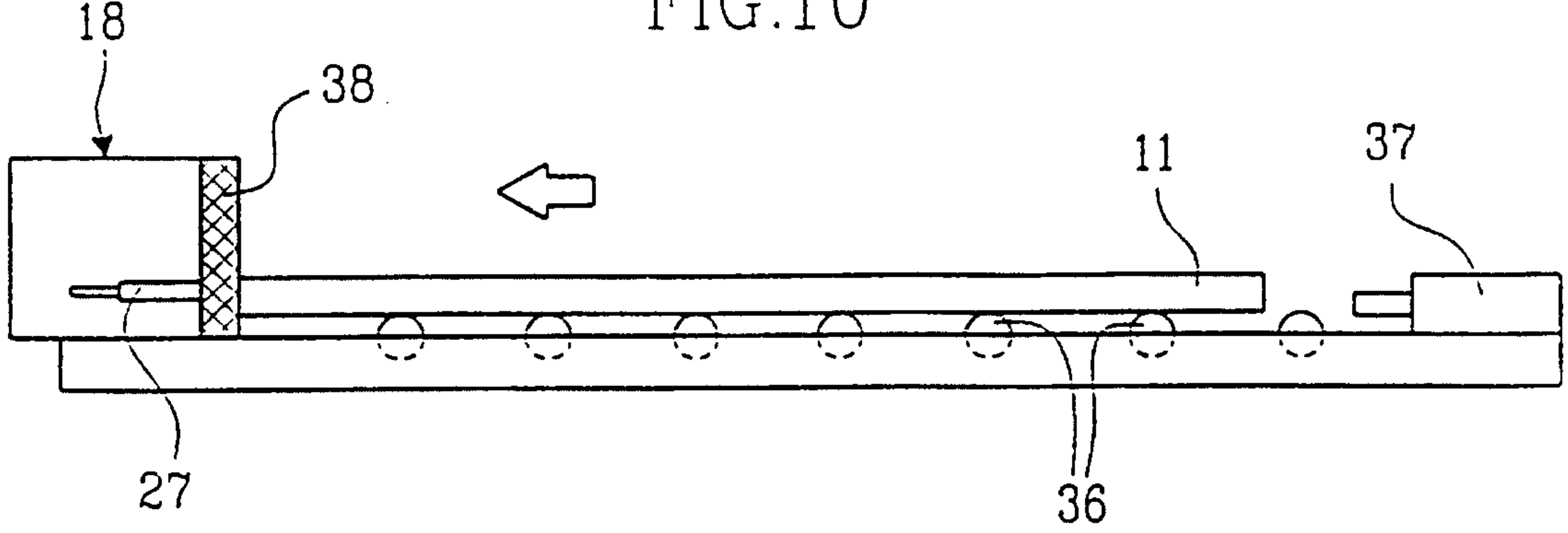
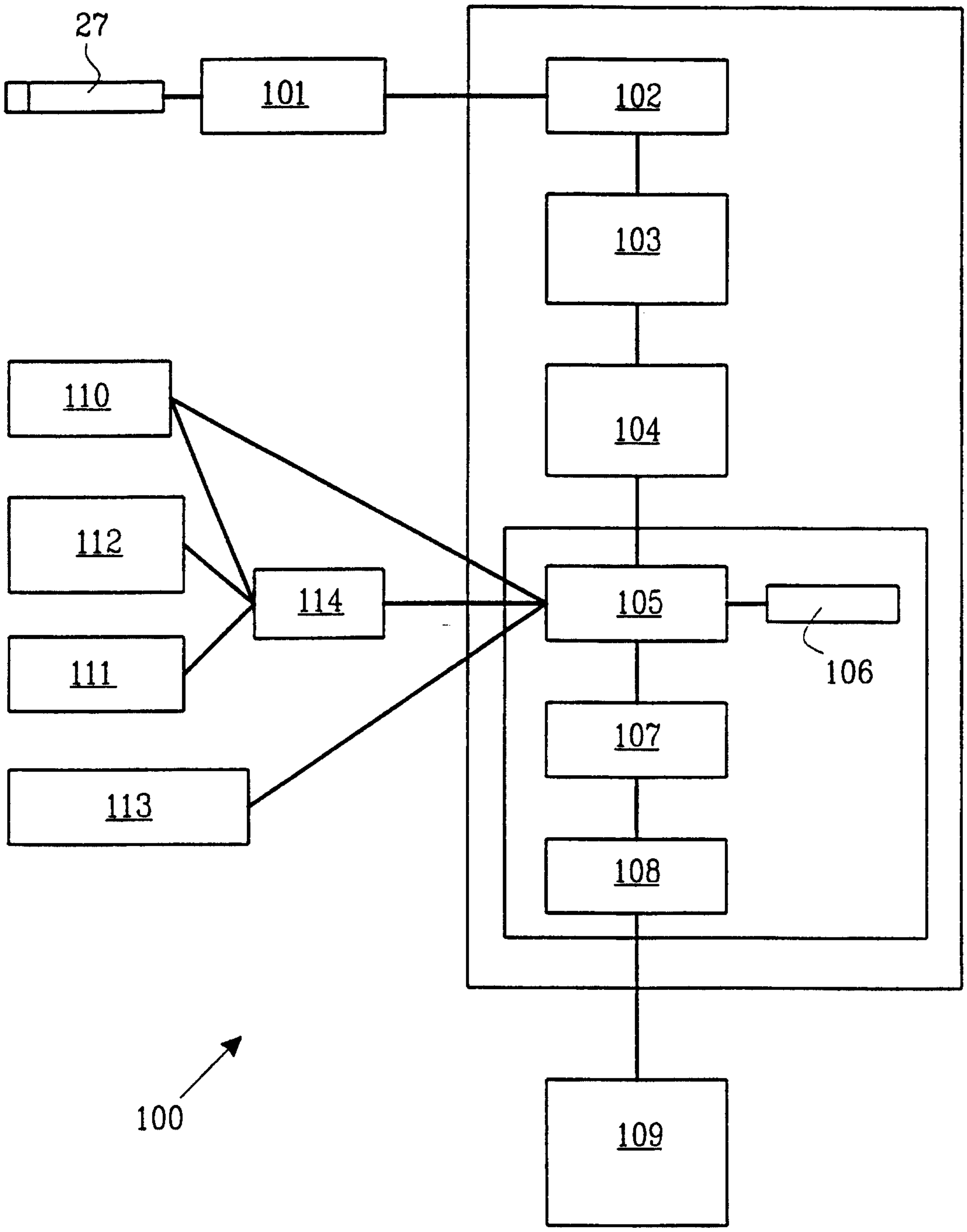
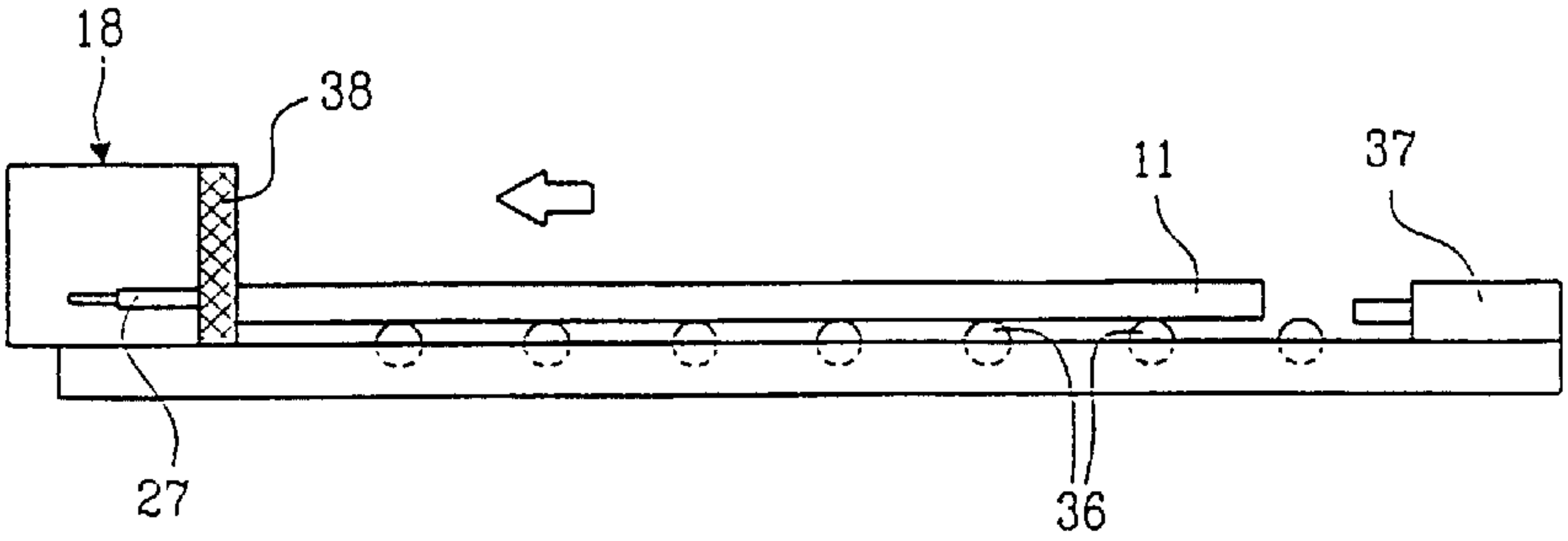


FIG.11





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