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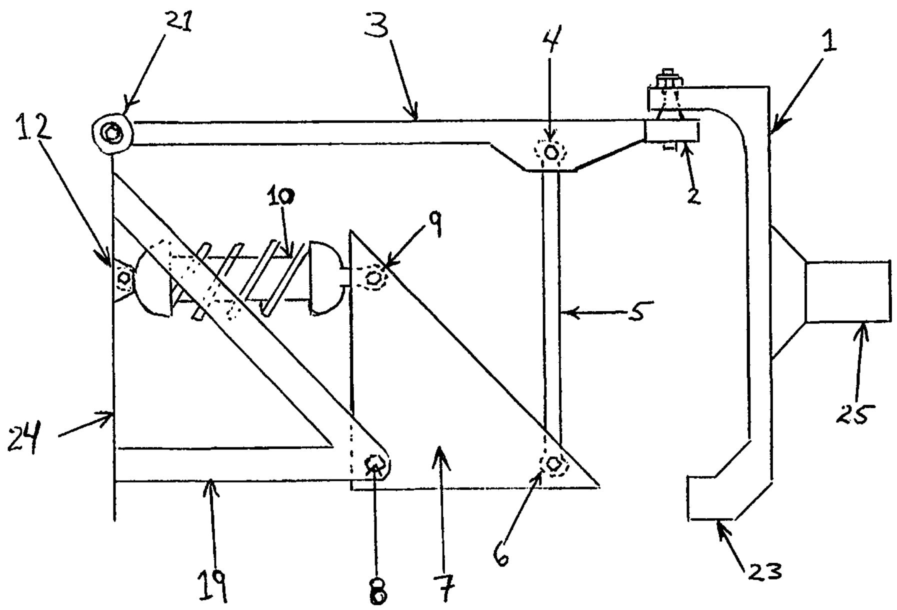
(54) Title: VEHICLE SUSPENSION



(57) Abstract

The vehicle suspension system enables an improved linear relationship between a vehicle wheel's jounce and rebound travel and a spring's compression and extension by the positioning of an outboard bell crank (7) in a vertically oriented plane perpendicular to the longitudinal axis of a vehicle chassis (24). The bell crank (7) is pivotally connected by a vertical link member (5) to the outer end of an upper control arm (3). Wheel movement is linearly transferred directly from the bell crank (7) to a spring assembly (10). Alternatively, a horizontal link member may be used to transfer wheel movement to the spring assembly.

VEHICLE SUSPENSION

DESCRIPTION

This invention involves the placement of an outrigger (outboard) primary lever (bell crank [#7]) in a vertically oriented plane, further oriented perpendicularly to the longitudinal axis (center line) of a vehicle chassis and positioned below the axle line adjacent to the inside of the vehicle wheel(s), skid or track. The primary lever (#7) is articulately connected (#4 and #6) by a vertically oriented link member (pull rod [#5]) running from the primary lever to the outer end of the upper hinged (#21) control arm (#3) (A-arm/wishbone/locating arm) close to the wheel assembly (#4). This relationship enables the wheel assembly's vertical distance traveled, and force generated, to be linearly transferred via the upright (#1), then the articulated joint (#2), into the upper control arm (#3), then into the vertical link member (#5) feeding the primary lever, which transfers the force and travel into a horizontally oriented, articulately connected link member (#11) from the primary lever (outrigger bell crank) to a chassis-mounted (#18) springing (coil spring/shock, pneumatic, electro-hydrolic or the like) assembly (#17) [see Drawing number 3]...or alternatively, directly from the primary lever (#7) into the chassis-mounted (#12) springing assembly (#10) without the use of a horizontal link member [see Drawing number 2].

The invention's attribute of accomplishing an improved linear relationship for a vehicle's jounce and rebound travel to springing compression and extension is obtained by the novel positioning and structure (#19) for the pivot of the primary lever (bell crank) far outward from the chassis center line—thus the outrigger nomenclature. By such placement, there is a more accurate relationship of vertical wheel travel at the end of the vertical link member (pull rod [#5]) than if the link member were at 45 degrees of angle. Since the primary lever (outrigger bell crank [#7]) is positioned in a vertical plane, the force and amount of travel of the wheel assembly and its upright (#1) is relayed via the articulated joint (#2) into the upper control arm (#3), and then to the primary lever by the vertical link member (pull rod [#5]), can then be transmitted in a horizontal path by the opposing side of the primary lever. As stated, the force and amount of travel can then either be transmitted directly into a horizontally oriented springing assembly (#10)...or be further transmitted toward the chassis center line by a horizontally oriented link member (#11). When a horizontally oriented link member transmits the travel and force amounts deeper into the chassis to a secondary lever (inboard bell crank [#14]), it is then possible to mount the springing system (#17) at most any angle desirable. The secondary lever (#14) enables such options as placing the springing assembly (#17) in front, behind, above or below the axle line while still maintaining the accuracy of the linear relationship established by the outrigger bell crank (#7).

While it is possible to slightly angle the relationship of the primary lever (outrigger bell crank) to other than near perpendicular to the chassis's longitudinal axis, such an orientation may not be one of the many packaging variations afforded the automotive engineer. However, on the occasion of desiring to direct the load path and distance traveled of the mass of the hub and wheel assembly to a location on the chassis that is not located immediately lateral from the subject mass, the outrigger bell crank will still perform it's functions efficiently.

The articulated vertical link member (pull rod), which connects the upper control arm (for the top portion of the wheel assembly's upright) to the primary lever, the primary lever itself (outrigger bell crank), and the horizontally oriented link member (also articulated) along with the secondary lever (inboard bell crank), which then relates to the springing system, are all components for the basis of this new and useful vehicle suspension system.

Although one of the described methods of operation for this suspension system does not require use of the horizontal link member or the secondary lever (inboard bell crank), these are still vital elements of the invention. Depending on an engineer's objectives, one method may be more suitable than another.

While vehicle suspension systems have evolved from the leaf spring solid beam axle method of carrying the rolling wheels (by which a vehicle moves upon the road or over rough terrain) to independently sprung wheels, which provide a smoother ride for passenger or cargo, this invention enables a further improvement to prior systems.

Rather than having either a single leaf spring positioned laterally—or two leaf springs mounted longitudinally—to the vehicle chassis for solid beam axles, the most commonly used suspension system today is coil springs encircling shock absorbers arranged with independently attached wheels. With this method, a bump in the road or rough terrain will primarily affect only one wheel rather than directly affecting the other wheel, as is the case at the other end of a solid beam axle.

The independent method of wheel attachment is usually by hinged control arms (often called A-arms or wishbones, due to their shape), or by a single hinged arm and a sliding strut of the McPherson type. The independent method of wheel attachment is fitted between the chassis and the individual assemblies.

The wheel assembly is attached to an upright (#1), which has a spindle (stub axle [#25]) that carries the bearings around which the wheel rotates. This invention is applicable for steered or non-steered wheels, as well as for driven or non-driven wheels. The disk or drum of a braking device for a wheel rotates with the wheel assembly, while the caliper for disk brake or the backing plate and shoes of a drum brake would be fixedly attached to the upright. In the instance of steering requirements, a steered wheel would have a steering arm as part of the upright.

For clarity of explanation, the drawings 1|4 and 2|4 do not show the hinged (#22) lower control arm (#20) attachment (#23) to the bottom of the upright (#1). The drawings of this invention for a vehicle suspension system have been made clearly to focus on showing the principle of the new method of suspension, no matter whether the application would be for front, rear, mid-axle, and no matter whether the wheel be steered/non-steered or driven/non-driven. This invention is also applicable to tracks and skids.

Heretofore, the coil spring/shock absorber or other springing devices, were most often attached directly to the lower of the hinged control arms at a distance of at least halfway out from the chassis. Sometimes further out, closer to the wheel assembly. While one end of the coil spring/shock absorber unit would be attached to the lower control arm, the other end of the coil/shock unit (or strut) would be attached directly to the chassis at a location higher than the wheel assembly and inboard (toward chassis center line). The inboard inclination of the coil spring/shock absorber assembly would often be in the 40 to 45 degree from vertical range. Some racing vehicles had more extreme inclinations in the 50 to 60 degree range for their coil spring/shock unit or for the push/pull rod leading to the springing device.

As a wheel rolls over a bump, [or the outer wheel(s) during cornering], it rises in relation to the chassis, and thus the spring/shock absorber assembly is compressed. However, as the wheel assembly rises in a near vertical fashion, the coil spring/shock absorber combination are being compressed at angles from anywhere in the range of 40 to 60 degrees from vertical. This angularity results in the lack of a true direct relationship, since the springing unit does not travel in compression the same actual distance that the wheel travels. Part of the spring's true force is spent acting sideways rather than vertically, resulting in a reduction of the spring force applied opposition to the vertical movement of the wheel. The ratio of spring pressure to wheel travel changes throughout the wheel's range of travel.

When installed at an angle, a spring will need to be of a higher rating (resistance to compression) since it is not acting in direct relationship to the vertical (near vertical) travel of the wheel. Obviously, the closer a spring and/or shock absorber, or the linkage, is mounted to the wheel assembly, the more efficient it will be. However, if the shock/spring unit is inclined, there will not be a linear relationship of compression to travel. If the spring/shock unit is mounted further out on the lower control arm, it may be necessary for an even greater inclination, which would then require an even greater spring rate, resulting in a harsher ride for passenger or cargo.

It is important for the realization of the benefits of this novel solution to also realize the heretofore position of the coil spring/shock absorber in the inclined attitude, or the use of a nearer to vertical suspension strut (McPherson style), has necessitated the location of approximately half of either springing system's physical hardware above the axle line, and more often than not, above the upper control arm (A-arm/wishbone) as well.

The required use of space above the axle line and above the upper control arm for placement of the coil/shock, strut, air suspension, hydrolic, electro-mechanical or other suspension systems within the confines of the body (coachwork) exterior, restricts the stylist's freedom to design exterior surfaces to no lower than the highest point of the suspension assembly.

If it were possible to lower the height of the suspension assembly, stylists would be free to reduce the height of the exterior surface in that area, and therefore not only create new designs, but when applied to the forward or leading edge surfaces of a vehicle, reduce the frontal area and decrease drag (wind resistance). Such a reduction of frontal area would achieve the economy of increased fuel mileage, the capability of higher top speed with the same of amount of propulsive power or maintain the same top speed with less propulsive energy.

The invention provides a new method of vehicular suspension, whereby the attributes of fuel efficiency, greater design freedom, reduction of frontal area, lower center of gravity, increased safety due to improved handling and a more linear relationship of spring pressure to wheel travel are accomplished with the outboard primary lever (outrigger bell crank [#7]) and the associated linkages (#5 and #11).

The invention introduces a practical arrangement by which the springing apparatus can be completely part of the sprung mass of the chassis (#24), thereby reducing unsprung weight. Previously, one half of the weight of the coil spring/shock or McPherson style strut attached to the control arm was unsprung weight. Unsprung weight reduction adds to safety and is an improvement in the quality of the ride for passenger or cargo. The ability of any driven or non-driven to maintain contact with the ground's surface is enhanced when it weighs less. A reduced mass is easier to control and the wheel will require a reduced spring weight, therefore leading to a more supple ride. The lighter a wheel is—the more time it will spend in contact with the road—therefore improving vehicle control and safety.

It has been said that a one pound reduction of unsprung weight relates equally to a reduction of fifteen pounds of vehicle sprung mass when evaluating the quality of a vehicle's comfort and handling.

The invention's primary lever (outrigger bell crank [#7]), though far outboard mounted, is chassis mounted via the structure holding its pivot (#19), and while the structure is sprung weight, the primary lever would be classified as 50% sprung weight. The secondary lever (bell crank [#14]) is inboard chassis mounted, as are its associated shock/coil (#17) or other springing device(s), thusly classifying these elements in the fully sprung weight category.

Although not found during the inventor's patent search for prior art, and therefore apparently not patented, the inventor recognizes that for such vehicles as racing cars, the location of coil springs and shock absorbers, pneumatic, hydrolic or other springing devices has commonly been sprung weight within the chassis for many years. The method by which such racing cars operate the coil spring/shock absorber/swaybar or other springing systems is by a singular push-rod or pull-rod running from the A-arm/wishbone/control arm (in the area of its attachment to the wheel assembly's upright) upwardly for a push-rod or downwardly for a pull-rod, directly to the chassis-mounted springing device. However, the angle of the push- or pull-rod is far more extreme than the 40 or 45 degree coil/shock/strut installation of production car assemblies, which run from the hinged A-arm/wishbone/control arm to the chassis. In order for the racing cars to compensate for the extreme (25 to 30 degrees from horizontal range) angle of the push- or pull-rod, the suspension spring pressure is multiplied by a factor in the range of three. For such racing cars, the section of the inboard, chassis-mounted bell crank, which is connected to the chassis-mounted springing device, is approximately three times longer from the pivot point than is the opposing side, which is connected to the push- or pull-rod. An extremely stiff ride is the result, but with racing cars, that is desirable and acceptable. Since a passenger or cargo carrying vehicle requires a softer, more compliant ride for the chassis, the extreme stiffness of the racing vehicle is unacceptable.

The invention's innovative solution of an outrigger bell crank (#7) makes possible a sure a more direct relationship of vertical (near vertical) wheel travel and force to the compression travel of the springing system (coil spring, torsion bar, electro-hydraulic, pneumatic, et. al. [#17 or #10]), thereby affording the capability for a softer, more compliant ride with independent suspension. The outrigger bell crank application makes it possible for the use of a one-to-one ratio lever so that the true vertical (near vertical) travel of the wheel assembly can be fully and comfortably transferred to the chassis-mounted springing system (#10 or #17). The upward travel and force of the independent wheel assembly is converted to an equal (negating stiction) horizontal travel and force via the primary lever alone (into the springing device [#10]), or transmitted further by the horizontal link member (#11) to the secondary lever (#14), and then into the springing device (#17). The outrigger bell crank system can even assist in hardware placement for solid beam axles.

If there is a desire for adjustment of the handling characteristics or capability of carrying cargo, the invention is not restricted to a one-to-one ratio for either the outrigger bell crank (#7) or the inboard bell crank (#14). Adjustment can be further accomplished by such means as either changing the spring rate, using different distances from the pivot (#8 or #15) for the attachment point(s) of either link member (#5 or #11) to the bell crank(s), or rather than a 90 degree relationship for a certain ratio, the mounting points (#6, #9, #13, #16) for the link members can be more acute or obtuse from their respective pivot points.

BRIEF DESCRIPTION OF THE DRAWINGS

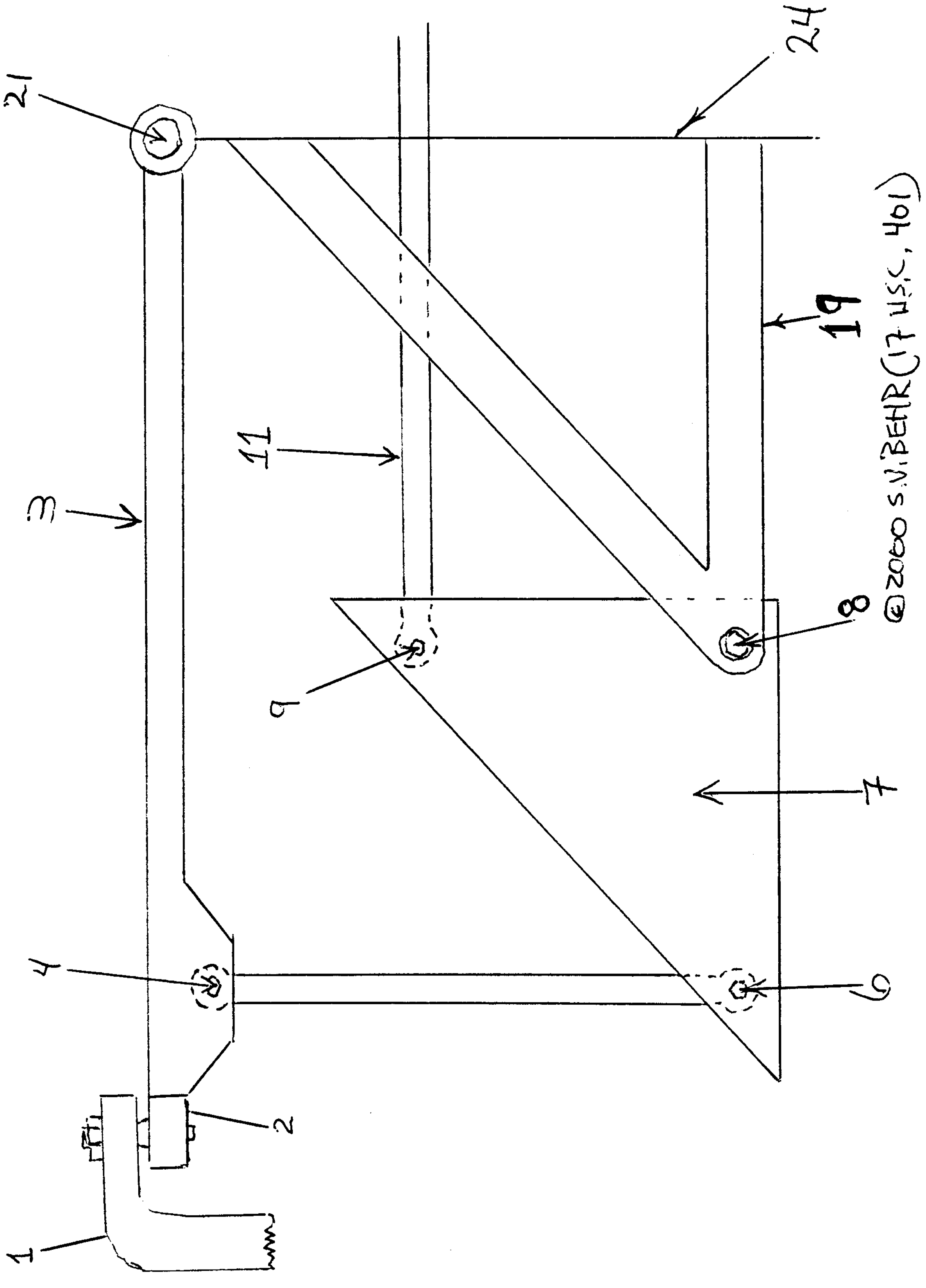
Drawing 2|4 and Drawing 4|4 show the outrigger primary lever connected directly to a coil over/shock absorber springing device. Figure 4|4 is the arial view. Figure 2|4 is the view from ground level. The horizontal link member is not used in either drawing.

Drawing 1|4 and Drawing 3|4 show the outrigger primary lever in the embodiment where the horizontal link member (#11) is utilized. Drawing 1|4 is the view from ground level depicting the horizontal link member entering the interior of the chassis. Drawing 3|4 is the arial view showing the horizontal link member connected to the secondary inboard lever that actuates the coil over/shock absorber springing device.

CLAIMS

1. Improved linear relationship of vehicle wheel/skid/track travel and force to the compression and rebound of the springing system.
2. Reduction of unsprung weight improves vehicle control, comfort and safety.
3. Reduced frontal area improves aerodynamics by lowering coefficient of drag factor thereby increasing fuel economy and/or top speed.
4. Increased control and safety due to the improved relationship of vehicle mass to vehicle contact patches because of the lower and wider locations of the chassis suspension input points (outrigger bell cranks).
5. Efficient packaging of vehicle components due to increased opportunities to place suspension springing units most anywhere relative to axle line.
6. Improvement of polar moment and/or achieving a lower center of gravity due to the options of placement of vehicle springing devices (spring/shock units).
7. More chassis adjustment and suspension tuning options are available to accommodate passenger, cargo load or vehicle use variations, than by other suspensions where changing the spring rate is the only method to alter vehicle characteristics.
8. Elimination of the inherently increased loads to the control arms when extremely angled push- or pull-rods are utilized.
9. Increased lateral force (cornering performance) is generated by tires due to the effect of chassis weight transfer acting in a vertically downward path rather than the angular path of other suspension systems. That is to say...with the utilization of the outrigger bell crank and the vertical pull-rod, there is more downward vertical force being

applied to the tire, forcing it into the ground for the benefit of lateral (cornering) force than would otherwise be applied with an inclined coil/shock at 45 degrees or by a similarly (or greater) inclined push- or pull-rod system.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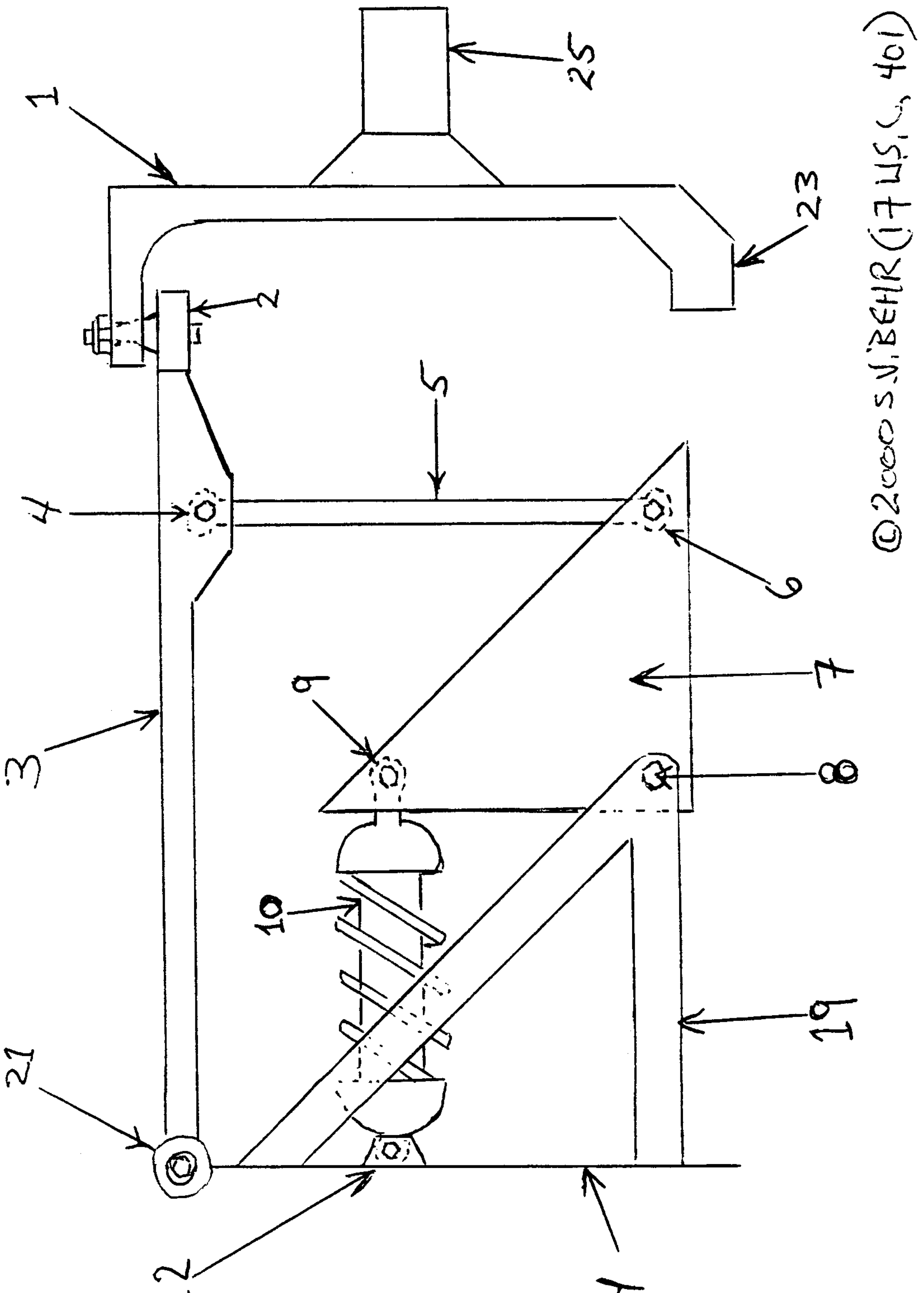
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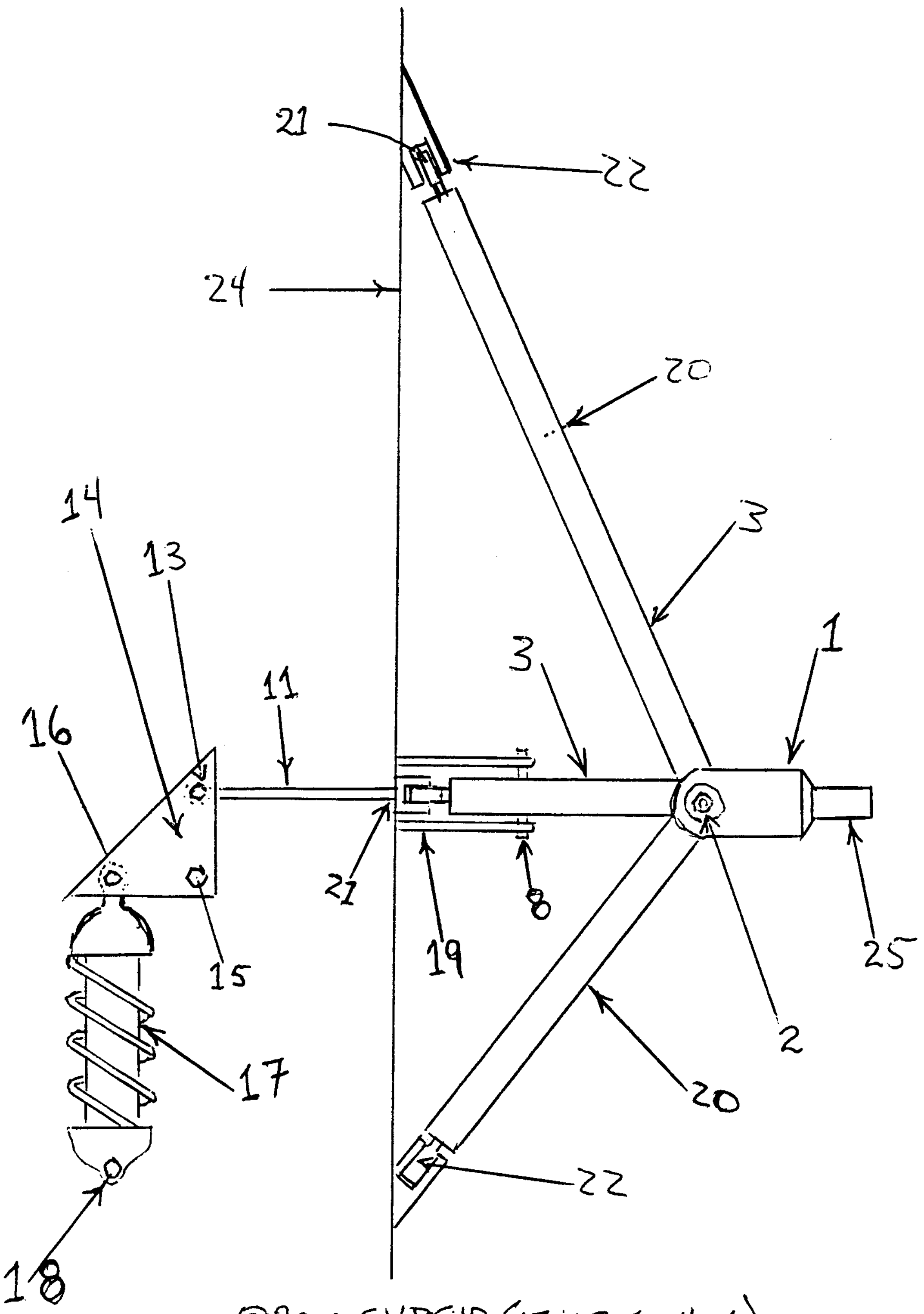
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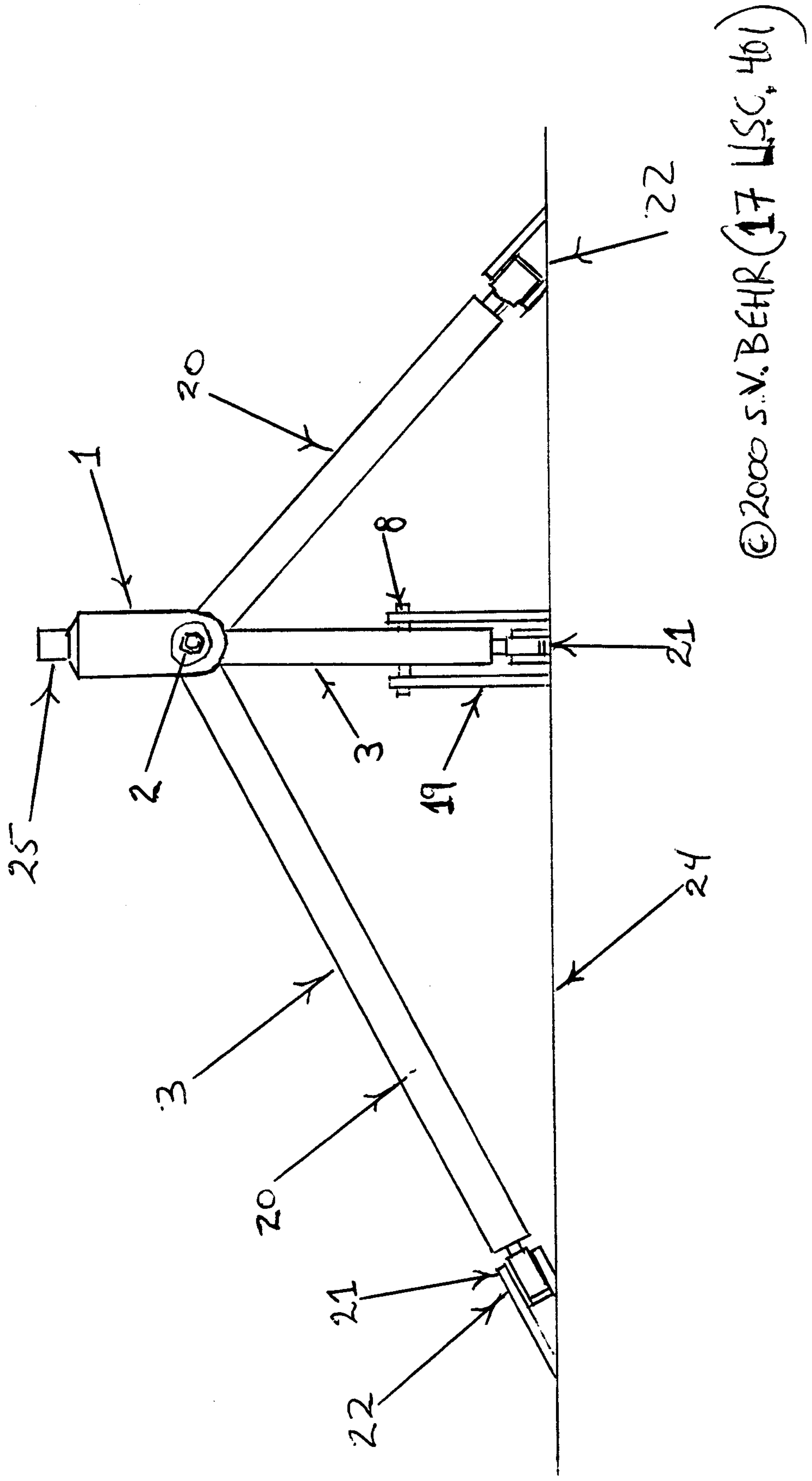
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/00112

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :B60G 3/20; 11/16
US CL :280/124.135, 124.141; 267/254
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 280/124.134, 124.135, 124.136, 124.138, 124.139, 124.141, 124.143, 124.15, 124.179; 267/248, 254

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,881,752 A (TANAKA) 21 NOVEMBER 1989 (21.11.89), see entire document.	1-9
X	US 5,431,429 A (LEE) 11 JULY 1995 (11.07.95), see entire document.	1-9
A	US 4,927,169 A (SCADUTO) 22 MAY 1990 (22.05.90).	1
A	US 1,612,421 A (DE RAM) 28 DECEMBER 1926 (28.12.26).	1

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
15 MARCH 2000	25 APR 2000

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