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Gill et al.

[11] **3,776,315**

[45] **Dec. 4, 1973**

[54] **PENDULUM LIGHT SENSOR**

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[73] Assignee: **Westinghouse Air Brake Company,** Peoria, Ill.

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[52] **U.S. Cl.** **172/4.5,** 33/366, 250/231, 37/DIG. 20

[51] **Int. Cl.** **E02f 3/76**

[58] **Field of Search** 33/366, 378, 396; 37/DIG. 20; 172/4.5; 180/41; 280/6; 356/250; 350/266, 269; 250/231

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[57] **ABSTRACT**

A pendulum light sensor mounted on the cutting tool of a surface finishing machine for automatically adjusting the angle of the cutting tool upon the raising and lowering of same to effect a deeper or shallower cut; said sensor incorporating a liquid chamber within which is disposed a bubble housing having a switch control arm attached thereto for opening and closing a photoelectric cell switch within the housing upon rotatable movement of said cutting tool. The photoelectric cell switch is in circuit with an elevator mechanism for raising and lowering the cutting tool to maintain the angle of the cutting tool at a predetermined attitude above the ground surface at all times.

13 Claims, 5 Drawing Figures

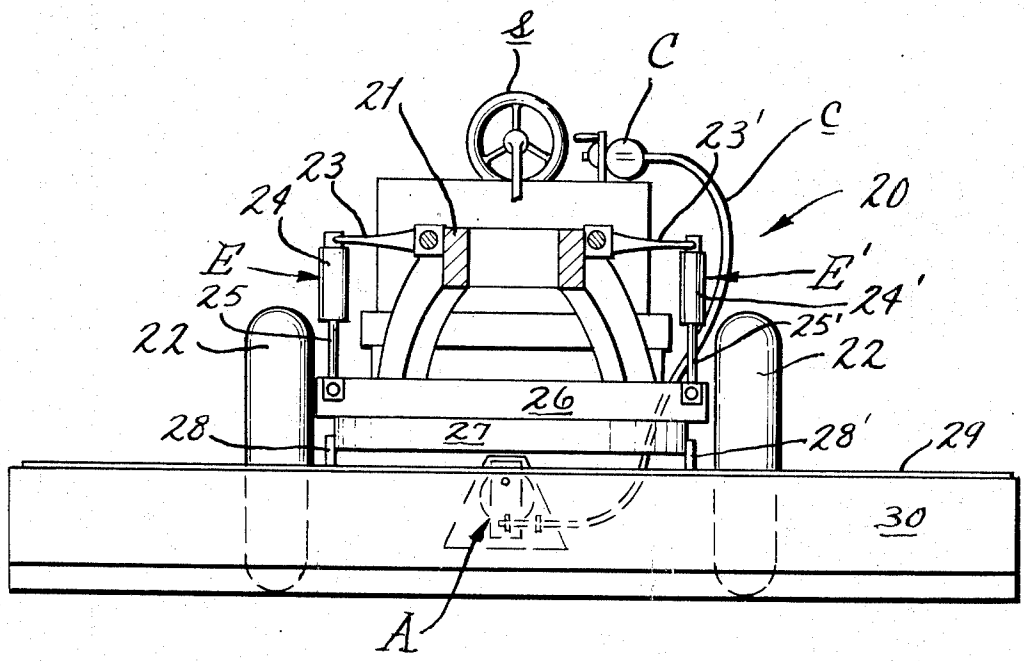


FIG. 1

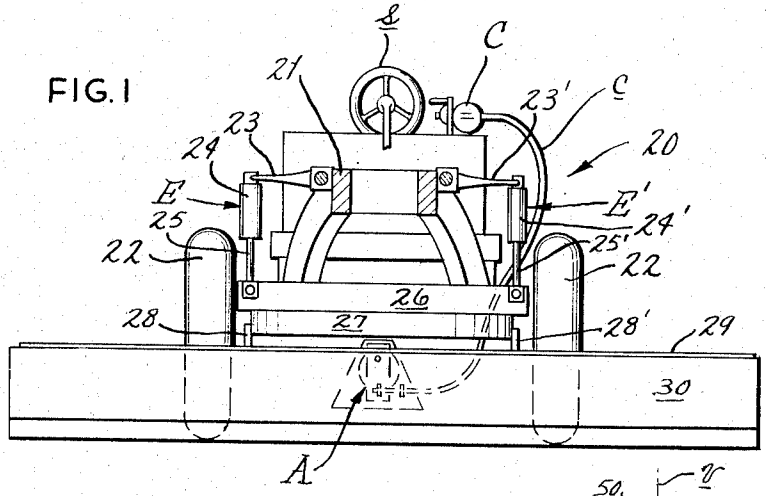


FIG. 3

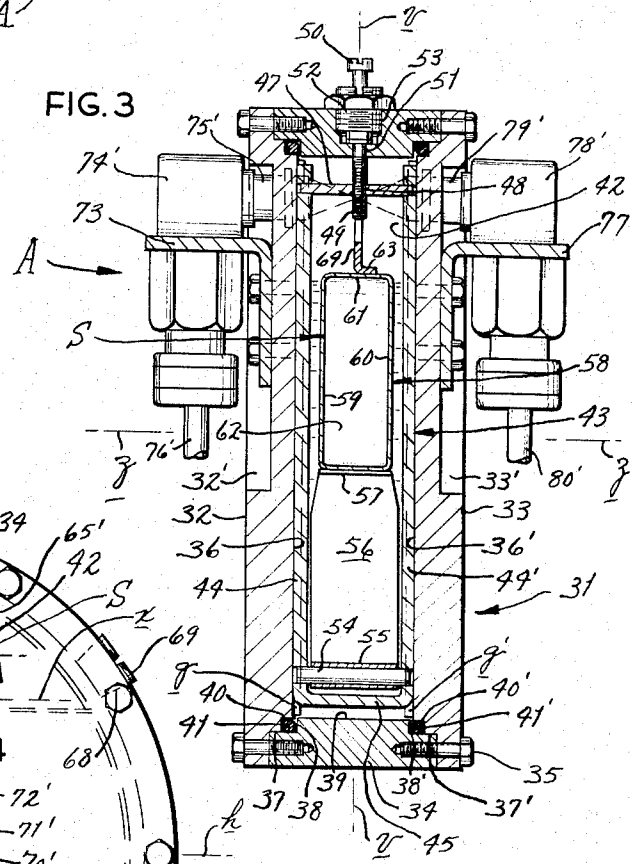


FIG. 2

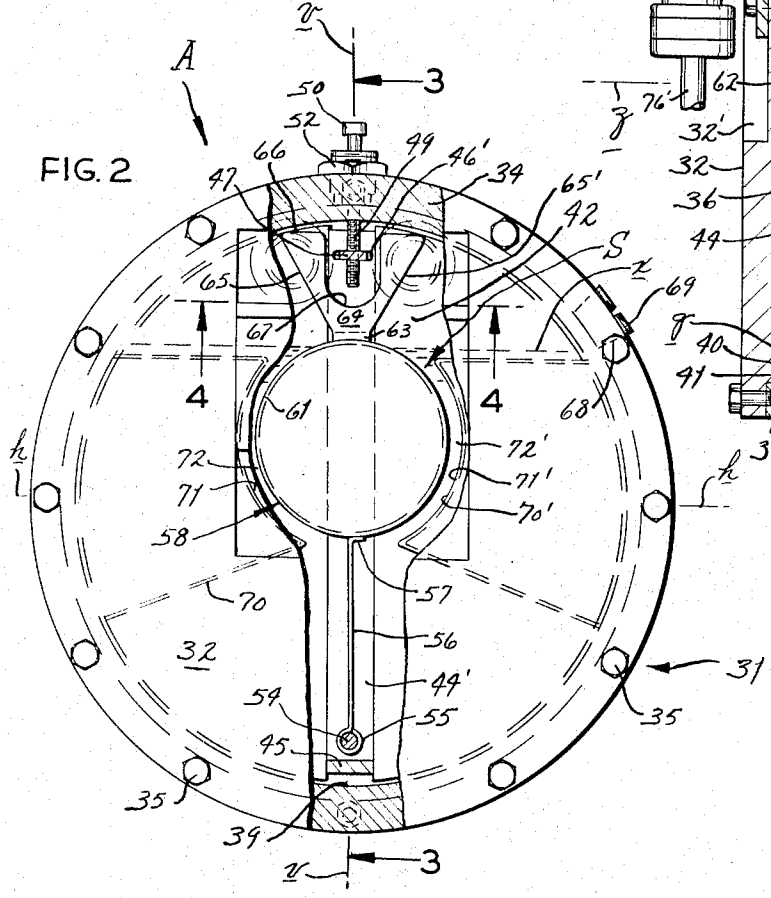


FIG. 4

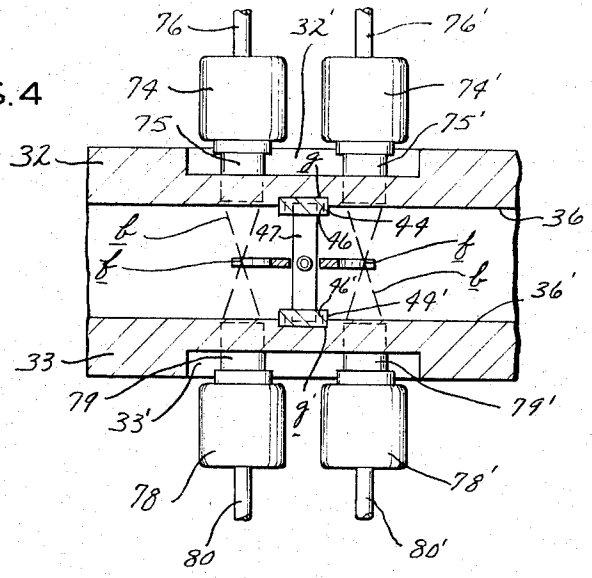
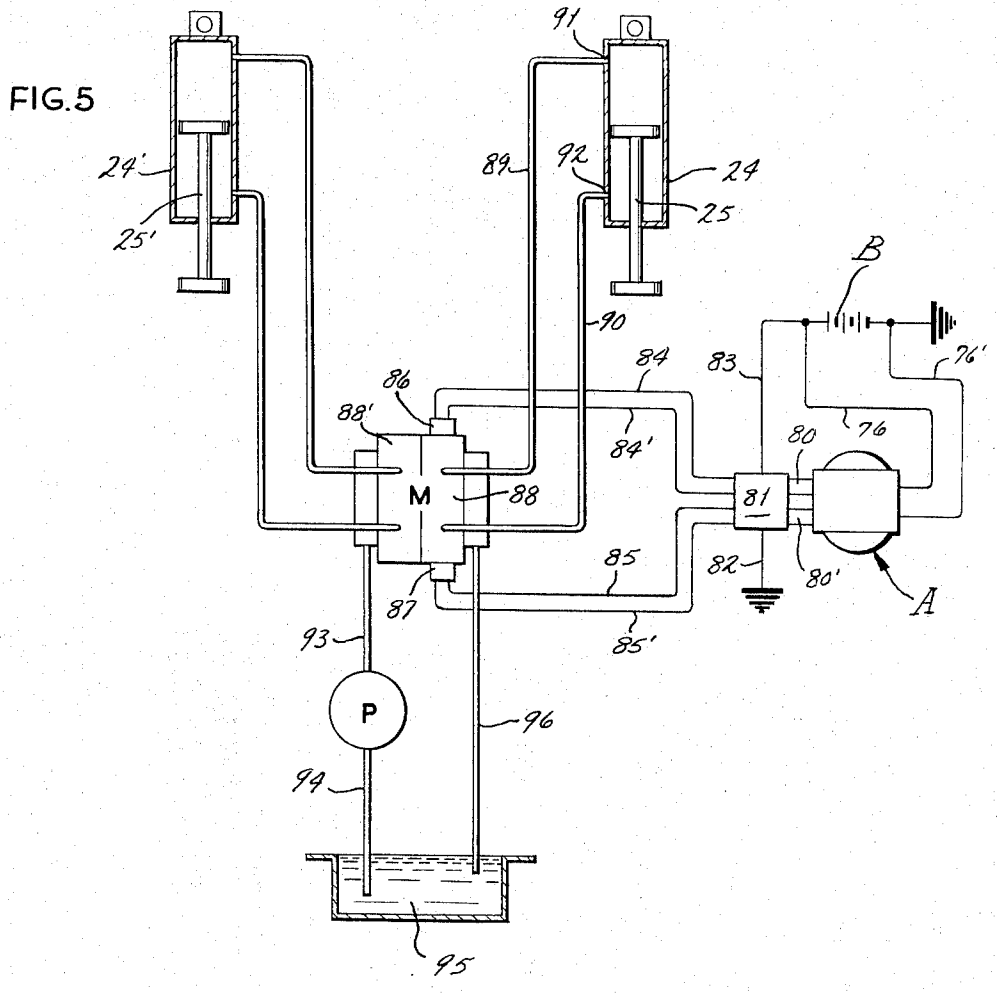

76
32'
76'
74
74'
75
75'
32
36
47
46
44
36'
46'
44'
33
79
33'
79'
78
78'
80
80'

FIG. 5


91
24'
25'
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92
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25
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83
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86
88'
84'
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76
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85
82
80'
A
87
85'
93
P
96
94
95

PENDULUM LIGHT SENSOR

BACKGROUND AND SUMMARY OF THE INVENTION

The present invention relates in general to surface finishing equipment and more particularly, to a pendulum light sensor for automatically adjusting the angle of a cutting tool therefor.

Heretofore, the prior art surface finishing equipment employed pendulum weights for sensing deviations from the horizon. Such weights were in operative engagement with hydraulic valves, electro micro switches, linear variable differential transformers, electric potentiometers, and the like, to produce a signal for actuating electric solenoid valves, which in turn adjusted the cutting edge of the blade to the correct position as noted by the pendulum deviation. All of the prior art pendulum sensors required work output either at the switch or at the signal producer thereby requiring a most sensitive instrument since the friction and other forces acting thereon would result in inefficient operation. Therefore, such prior art apparatuses were necessarily extremely delicate, costly in manufacture and required extensive care and maintenance.

By the present invention, the above disadvantages have been alleviated by using a pendulum light sensor incorporating an incapsulated air bubble whice floats within a liquid chamber having a flag arm attached thereto which is positioned between photoelectric cells connected in circuit with an electrohydraulic valve. The flag arm is interposed between light projecting means and the photoelectric cells so that circuit is closed upon swingable movement of the flag arm thereby requiring virtually no friction or resistance during movement of the flag arm. Since the apparatus of the present invention has few moving parts a simple maintenance is achieved while being economical in manufacture and durable in usage. Said pendulum light sensor may be utilized over relatively long periods of time without adjustment while being capable of precision adjustment within 0.005 inch. Moreover, the flag arm of the present invention is adjustable so that different tolerances may be readily obtained depending upon the particular specifications of the job. Importantly, the position sensing apparatus of the present invention is a relatively simple construction and may be easily incorporated within existing surface finishing equipment so as to avoid costly modification and installation.

The liquid level within the apparatus may also be adjusted to float the incapsulated bubble with the greatest liquid displacement thereby creating a force to cancel the friction at the pivot point thereof. Thus, the apparatus of the present invention performs with a minimum of friction thereby enhancing its sensitivity as the work done by the bubble and the flag arm is such that they move relatively without friction between the light switches and with the pivot point of friction being cancelled by the bubble force action.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a vertical transverse section taken through a surface finishing vehicle illustrating a pendulum light sensor constructed in accordance with and embodying the present invention.

FIG. **2** is a front elevational view.

FIG. **3** is a vertical section taken on the line **3—3** of FIG. **2.**

FIG. **4** is a horizontal section taken substantially on the line **4—4** of FIG. **2.**

FIG. **5** is an electro-hydraulic shcematic diagram.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings wherein like reference characters designate like corresponding parts, there is shown in FIG. **1** a surface finishing vehicle **20,** such as a grader or the like, comprising a frame **21** which is supported above ground in the customary fashion by a plurality of wheels **22.** Fixed to the forward portion of the frame **21** on each side thereof is an elevator mechanism E,E′, such as the customary lift device **23,23′**, respectively, each being operatively engaged to a hydraulic ram **24,24′**, respectively, having an extensible and retractable piston **25,25′**, of the double-acting type, fixed at its outer end portion to the draw bar **26.** Mounted to the underside of draw bar **26** is the conventional circle **27** having fixed thereto, in diametrically opposed portions, an arcuate support leg **28,28′**, which in turn is connected to the mold board **29** having an elongate cutting blade **30** secured thereto. Although the hydraulic rams **24,24′** constitute the preferred embodiment of the present invention for raising and lowering the cutting blade **30** to the associated structure, it will be understood that a hydraulic motor and worm gear system may be readily substituted for the hydraulic ram **24,24′** to raise and lower the blade **30** by rotation.

Fixed to the rearward face of the mold board **29,** there is a pendulum light sensor A having a verticle axis *v—v* coextensive with the transverse axis of the cutting blade; a horizontal axis *h—h* in parallel relationship with the longitudinal axis of the cutting blade **30**; and a depth axis *z—z* (FIG. **3**) in parrallel relationship to the path of travel of vehicle **20.** The pendulum light sensor A is presented at the desired angle through a cable *c* which extends upwardly for suitable attachment to a hand crank control C located in the region adjacent the steering wheel *s* of the vehicle **20.** As will be further described hereinbelow, the pendulum light sensor A is connected in circuit with said hydraulic ram **24** for effecting the raising and lowering of the piston **25** to adjust the slope angle of the cutting blade **30.** The other hydraulic ram **24′** is connected in circuit with a position sensing apparatus (not shown) which is adapted to ride along the customary reference string (not shown) as is shown and described in detail in my co-pending application entitled POSITION SENSING APPARATUS, Ser. No. 160,741, filed July 8, 1971.

For purposes of description, the terms "upwardly" and "downwardly" will denote direction relative to the vertical axis *v—v* of the pendulum light sensor A; the terms "inwardly" and "outwardly" will denote direction relative to the horizontal axis *h—h* thereof; and the terms "forwardly" and "rearwardly" will denote direction relative to the depth axis *z—z* (FIG. **3**).

Said pendulum light sensor A comprises a body **31** of cylindrical configuration having a forward wall **32,** a rearward wall **33** and an intervening peripheral side wall **34,** the latter being secured, as by bolts **35,** to the forward and rearward walls, **32, 33.** Formed within said forward and rearward walls **32, 33** are enlarged recesses **32′, 33′**, respectively, located eccentrically upwardly of said depth axis *z—z* and terminating spacedly forwardly of the interior faces **36,36′**, respectively, of

the forward and rearward walls **32,33.** Each interior face **36,36'** incorporates a peripheral end wall **37,37'**, respectively, which is received within an annular recess **38,38'**, respectively, machined within the inner face **39** of said side wall **34** in the region immediately adjacent said forward and rearward walls **32** and **33.** Each end wall **37,37'** of the respective interior face **36,36'** is formed with a peripheral notch **40,40'**, which accommodates a sealing gasket **41,41'**, respectively, such as an O-ring or the like, to seal the adjoining peripheral margins between the inner face **39** of said sidewall **34** and the related interior face **36,36'.** As best observed in FIG. **3,** the inner face **39** of side wall **34** and the opposed interior faces **36,36'** cooperate to define a chamber **42.**

Received within the chamber **42** is a U-shaped support frame **43** having a pair of spaced-apart flanges **44,44'** presented in flatwise, but slideable, engagement within guideways *g,g'* machined in the associated interior face **36,36'**, and joined at their lower end portions by a web **45** spacedly from the inner face **39.** The upper, or web-remote, end portions of each flange **44,44'** is formed with an elongate, horizontally disposed slot **46,46'**, respectively, within which is received the related end portion *s* of a bar **47.** The vertical dimention of the bar **47** is substantially the same as that of said slots **46,46'**, while the horizontal dimention of the bar **47** is slightly less than that of said slots **46,46'** for permitting restricted lateral movement. Intermediate the flanges **44,44'**, said bar **47** is tapped with an opening **48** for threadedly receiving the shank **49** of an adjustment screw **50** which projects upwardly through an opening **51** in side wall **34** and through an internally shouldered bore (not shown) within a cap nut **52** being trapped within a counter bore **53** in the side wall **34.** The internally shouldered bore of the cap nut **52** serves as a bearing for the adjustment screw **50.** Thus, it will be observed that said U-shaped support frame **43** is suspended within the chamber **42** by the bar **47** and the adjustment screw **50.** Therefore, by selective rotation of the adjustment screw **50,** the bar **47,** and hence the U-shaped support frame **43,** may be vertically raised and lowered within the guideways *g—g'* in chamber **42.**

Spacedly upwardly of the web **45** of the frame **43** there is provided aligned aperatures (not shown) for receiving the end portions of a pivot pin **54.** Provided surroundingly of the pivot pin **54** in the region between the flanges **44,44'**, there is a sleeve **55** which is integrally formed within an upwardly extending, relatively thin mounting plate **56** being of slightly less width than the distance between the flanges **44,44'.** The sleeve remote end of the mounting plate **56** is fabricated with a flange **57** to which is fixed the lower portion of a bubble housing **58** being of cylindrical configuration having a front wall **59,** and a rear wall **60** and a peripheral side wall **61** therebetween. The said walls **59, 60** and **61** define with their inner faces an air chamber **62** for purposes to be presently described.

Mounted to the side wall **61** in diametrically opposed relationship with the flange **57** of the mounting plate **56** is a skirt **63** of a flag arm **64** having outwardly diverging side margins **65,65'** projecting outwardly and upwardly from said skit **63** and terminating into an end margin **66.** Said flag arm **64** is of flat-plate construction having a U-shaped cut-out **67** provided intermediate the side margins **65,65'** and opening through the end margin **66.** The bar **47** passes through the cut-out **67.**

The flag arm **64,** the bubble housing **58** and the mounting plate **56** constitute a pendulum bubble unit S, or sensor control means, the operation of which will be described in detail hereinbelow.

The chamber **42** is filled with dampening liquid; such as water, mineral oils, silicones, or any other liquid having suitable viscosity and temperature characteristics to properly dampen the bubble housing **58** in the peculiar ambient conditions, to a predetermined level *x* (FIG. **2**) within which the bubble housing **58** is substantially immersed. In the region of liquid level *x* the side wall **34** is formed with an internally threaded opening **68** for accommodating a closure plug **69,** Accordingly, the liquid level within the chamber **42** may be conveniently controlled and maintained through the opening **68.**

Mounted to the inner face **39** of the side wall **34,** in the region of the bubble housing **58,** are a pair of opposed dampeners **70,70'**, each of which project radially inwardly and terminate into an arcuate wall **71,71'**, respectively, being formed on a slightly greater radius than the side wall **61** of the bubble housing **58** to develop a spacing **72,72'**, respectively, therebetween. Said dampeners **70,70'** assure against untoward movement of liquid within the chamber **42** which would adversely affect the operation of the bubble housing **58,** and hence the sensor control unit S.

Since the bubble housing **58** is immersed in liquid, it will move responsive to the axial movement or tilting about the vertical axis *v—v* of the pendulum body **31.** Therefore, anytime the cutting blade **30** undergoes an angle change relative to the horizontal, the sensor control unit S will swing away from the plane containing the vertical axis *v—v* for purposes to be now described.

Fixed to the exterior side of said interior face **36,** in the zone of the recess **32',** as by angle brackets **73,** are a pair of spaced-apart light source heads **74,74'** located on opposite sides of said U-shaped support frame **43,** as best seen in FIG. **4.** Each light source head **74,74'** incorporates a cylindrical body **75,75'** projecting through a suitable opening in the interior face **36** for communication within chamber **42.** Each light source head **74,74'** projects a beam of light *b,* indicated in phantom lines in FIG. **4,** into the chamber **42;** the cylindrical body **75,75'** being adjustably mounted so that the focal point *f* of a light beam *b* is positioned in planar alignment with the vertical axis *v—v* of body **31.** Said light source heads **74,74'** are in circuit through leads **76,76'**, respectively, to a convenient source of power, such as a vehicle battery B, for supplying a continuous source of power thereto so that a light beam *b* is projected at all times during operation.

Mounted on the exterior side of the interior face **36'** in the zone of opening **33'**, as by brackets **77,** there are a pair of sensing heads or receivers **78,78'** each having a cylindrical body **79,79'** positioned within a suitable opening in the interior face **36'** in axial alignment with the opposed cylindrical bodies **75,75'**, respectively, of the light source heads **74,74'**, respectively. Each of said sensing receivers **78,78'** are adapted to receive the light beam *b* projected by the axially aligned light source heads **77,77'**, respectively, for closing a circuit; each sensing receiver **78,78'** being connected by leads **80,80'**, respectively, to an amplifier **81** (FIG. **5**), one side of which is connected to ground by a lead **82,** the other side to the battery B by a lead **83.** It will be observed that when the sensor control unit S is in a normal position, the side margins **65,65'** of the flag arm **64**

block each light beam *b* for maintaining the sensing receivers **78,78'** in a circuit opened position. The flag arm **64** is positioned within chamber **42** so that it is in planar alignment with the focal point *f* of the light beam *b*. (FIG. **4**).

Depending on which direction the flag arm **64** is swung responsive to the movement of the bubble housing **58** within the fluid chamber **42,** one of said side margins **65,65'** will swing out of blocking engagement with the related light beam *b* for permitting transmittal of same to the axially aligned sensing receiver **78** or **78'** for closing the circuit. The signals emitted by the sensing receivers **78** or **78'** are transmitted to the amplifier **81** for enhancing the emitted signal. The amplifier **81** is connected by the leads **84,84'** and the leads **85,85'** to electric solenoids **86, 87,** respectively, which solenoids **86, 87,** are positioned on opposed ends of a spool valve **88** incorporated within a master valve M. The master valve M also incorporates a spool valve **88'** for operative connection to a position sensing apparatus (not shown) and the ram **24'** for effecting the raising and lowering of same, as previously described in my copending application Ser. No. 160,741, filed July 8, 1971, and therefore will not be described.

Said spool valve **88** is in communication with the hydraulic ram **24** by conduits **89, 90** which are connected to ports **91, 92,** respectively, located adjacent the opposed end portions of said hydraulic ram **24.** Additionally, the master valve M is connected by a conduit **93** to the discharge side of a pump P, the intake side of which is connected by a conduit **94** to a reservoir **95** of hydraulic fluid, said reservoir **95** also being connected to the master valve M by a return line **96.** Therefore, by selective energization of solenoids **86** and **87** through the signals emitted by the sensing receivers **78** or **78'** respectively, the hydraulic ram **24** will effect a raising and lowering of said cutting blade **30** in accordance with slope requirements.

In operation, with the cutting blade **30** being presented at its desired cutting angle through manipulation of the hand crank C, the flag arm **64** is vertically adjusted through the adjustment screw **50** to the desired position in accordance with the design tolerances. If the angle of the cutting blade **30** is increased, as in a situation when the opposite end portion of the cutting blade **30** lowers, the flag arm **64** will be moved out of blocking relationship with the sensing receiver **78** for closing a circuit thereto through leads **84,84'** to the solenoid **86** for energizing same which establishes communication between the conduits **93** and **89** for supplying hydraulic fluid from reservoir **95** to the hydraulic ram **24.** Upon entering the hydraulic ram **24** through the port **91,** the fluid will push piston **25** downwardly for lowering the cutting blade **30** until the flag arm **64** again blocks the light beam *b*. The fluid within the hydraulic ram **24** on the downward side of piston **25** will pass through the port **92** for return through conduit **90,** master valve M, and return line **96** to the reservoir **95.** Similarly, when the flag arm **64** is swung in the other direction, upon the decrease of the cutting blade angle through the raising of the opposite end portion of the cutting blade **30,** the circuit is completed to the sensor receiver **78'** for emitting a signal through the leads **85,85'** for energizing the solenoid **87** wherein fluid from the reservoir **95** will be pumped through conduits **93** and **90** for raising the piston **25** and hence the cutting blade **30.** The fluid within the hydraulic ram **24** on its upward side will be returned through conduits **89,** master valve M and the return line **96** to the reservoir **95.** Thus, it will be observed that as the flag arm **64** swings within the chamber **42** through the movement of bubble housing **58,** the circuits will be opened and closed through the sensing receivers **78,78'** for alternatively energizing the solenoids **86, 87** respectively, which selectively control the supply of fluid to the hydraulic ram **24** to energize the piston **25** for elevating and lowering the cutting blade **30** and thereby maintain the proper cutting angle of the cutting blade **30.**

Through the adjustment screw **50,** the flag arm **64** may be adjusted vertically within chamber **42** so that the side margins **65,65'** may be positioned at the focal point *f* of both light beams *b*. With the flag arm **64** so centered accuracy to 0.005 inch of the flag arm **64** may result in an adjustment of the cutting angle of the blade **30.** Since the work accomplished by the flag arm **64** passing through light beam *b* is a relatively frictionless operation, the pendulum light sensor A offers a more reliable sensing instrument than heretofore thought possible. Additionally, the accuracy of the flag arm **64** may be increased or decreased depending on job conditions by merely turning the adjustment screw **50** so as to move the margins **65** and **65'** either closer to the focal point *f* or further away.

Having thus described our invention, what we claim and desire to obtain by Letters Patent is:

1. A pendulum sensing apparatus comprising:

A body;

Means defining a chamber in said body, said chamber containing a dampening fluid;

Sensor means including:

Light projecting means mounted to said body for transmitting beams of light within said chamber; and

A pair of parallel, spaced-apart sensing receivers mounted within said body and adapted to receive said beams of light for energizing same;

A pendulum member having end portions presented within said chamber;

Support means slideably mounted within said body;

Means pivotally mounting one end portion of said pendulum member to said support means, the other end portion of said pendulum member being free;

Said pendulum member having a bubble housing located between said end portions, said bubble housing being floatatable within said dampening fluid and being sensitive to the shifting movement thereof;

The free end portion of said pendulum member constituting a flag arm carried by said bubble housing, said flag arm having side margins projecting divergingly outwardly from said bubble housing so that the width of said flag arm increases as the distance from said bubble housing increases;

Said flag arm being normally presented between said light projecting means and said sensing receivers for interrupting said beams of light to maintain said sensing receivers in circuit-opened condition, the width of said flag arm in the region adjacent said bubble housing being greater than the distance between the centers of said sensing receivers;

Adjustment means connected to said support means for moving said support means relative to said body to alter the relative position between the width of

said flag arm and the plane containing the centers of said sensor means.

2. A pendulum sensing apparatus as defined in claim **1** and further characterized by:

Said support means comprising a frame;

Means defining guideways formed within said body;

Said frame having a pair of spaced-apart flanges slideably received within said guideways, and a web connecting said flanges;

Said adjustment means operatively connected to said support frame.

3. A pendulum member as defined in claim **2** and further characterized by:

Said body having first and second parallel spaced-apart walls and an intervening side wall, said walls constituting said means for defining a chamber;

Said guideways being formed within said first and second walls;

A pair of opposed dampener members mounted to said side wall in the region of said bubble housing, each dampener member extending inwardly of said chamber having an arcuate end wall positioned spacedly from said bubble housing.

4. A pendulum sensing apparatus as defined in claim **2** and further characterized by:

Said support flanges having slots formed in the web-remote end portion thereof;

Said adjustment means comprising a cross bar having end portions received within said slots;

An adjustment member operatively connected to said cross member and projecting outwardly of said body.

5. A pendulum sensing apparatus as defined in claim **4** and further characterized by:

Said flag arm having a cut-out interposed between said side margins;

Said cross member extending through said cut-out for limiting the extent of swingable movement of said pendulum member.

6. A pendulum sensing apparatus as defined in claim **4** and further characterized by:

Said cross member having a tapped opening;

Said adjustment member comprising an adjustment screw having a threaded portion engaged within said tapped opening.

7. An apparatus for maintaining a cutting implement at a predetermined attitude relative to a work surface comprising in combination:

A body carried by said cutting implement;

Means defining a chamber within said body;

Fluid means received within said chamber;

A pendulum arm swingably mounted within said chamber;

Incapsulated bubble means, carried by said pendulum arm and immersed within said fluid means, for swinging said pendulum arm upon shifting movement of said fluid means responsive to a change in attitude of said cutting implement;

Elevator means operatively connected to one end portion of said cutting implement for raising and lowering same to maintain the predetermined attitude;

Light projecting means for transmitting beams of light within said chamber;

Sensor means including a pair of light sensing receivers adapted for energization upon receiving a beam of light, said light sensing receivers being located within said body having centers in axial alignment with said beams of light;

Means operatively connecting said light sensing receivers and said elevator means for effecting actuation of said elevator means responsive to the energization of said sensing receivers;

Sensor control means for effecting energization of said sensing receivers responsive to the swingable movement of said pendulum arm, said sensor control means comprising a flag arm connected to said incapsulated bubble means and interposed between said light projecting means and said sensor means for blocking said beams of light to maintain said light sensing receivers in deenergized condition;

Said flag arm having side margins projecting divergingly outwardly from said incapsulated bubble means, the distance between said side margins in the region adjacent said incapsulated bubble means being greater than the distance between the centers of said light sensing receivers;

Means for moving said flag arm in a plane normal to the plane containing the centers of said light sensing receivers to adjust the sensitivity of said sensor control means.

8. An apparatus as defined in claim **7** and further characterized by:

Said means for moving said flag arm including:

A support frame having a pair of parallel flanges carrying said pendulum arm;

Means defining guideways within said body for receiving the flanges of said support frame; and

Adjustment means operatively connected to said support frame for slideably moving same within said guideways.

9. An apparatus as defined in claim **8** and further characterized by:

Said adjustment means comprising:

A cross member having end portions supporting said support frame; and,

An adjustment member operatively connected to said cross member and projecting outwardly of said body.

10. An apparatus as defined in claim **9** and further characterized by:

Said flared end portion having a cut-out interposed between said diverging margins;

Said cross member extending through said cut-out for limiting the extent of swingable movement of said pendulum arm.

11. A surface finishing vehicle of the type used for moving earth comprising:

A mobile frame adapted for travel over ground;

A cutting blade adjustably supported from said mobile frame and preset at a predetermined angle relative to the ground;

An elevator mechanism operatively connected to one end portion of said cutting blade for adjusting the angle of same;

A pendulum sensor apparatus comprising a body centrally mounted on said cutting blade;

Means defining a chamber within said body;

A dampening fluid received within said chamber;

A pendulum member rockably mounted within said chamber and including a sensor control arm and an incapsulated bubble;

Said incapsulated bubble being immersed in said dampening fluid and adapted to swing said pendulum member upon shifting movement of said dampening fluid in accordance with a change in attitude of said cutting blade;

Sensor means within said chamber comprising first and second light sensing receivers arranged in parallel, spaced-apart relationship;

Light projecting means within said chamber disposed in opposed, registering relationship with said first and second light sensing receivers;

Means operatively connecting said sensor means to said elevator mechanism for selectively raising and lowering said one end portion of the cutting blade to maintain same at the desired attitude;

Said sensor control arm having an end portion positioned for normally interrupting said light projecting means to maintain said sensor means in circuit-opened condition, said sensor control arm being adapted for energizing said sensor means responsive to the rockable movement of said pendulum member;

Said sensor control arm end portion being flared having outwardly diverging margins, the distance between said diverging margins being greater than the distance between the centers of said light sensing receivers;

Means for longitudinally moving said pendulum member to selectively adjust the distance between said diverging margins relative to the plane containing the centers of said first and second light sensitive receivers.

12. A surface finishing vehicle as defined in claim **11** and further characterized by:

Said means for longitudinally moving said pendulum member including:

A support frame having side members carrying said pendulum member for rockable movement therebetween;

Means defining guideways within said body for accommodating said side members;

A transverse member having end portions supporting the related side member of said support frame; and

Adjustment means operatively connected to said transverse member for slideably moving said side members within said guideways.

13. A surface finishing machine as defined in claim **12** and further characterized by:

Said sensor control arm having a cut-out located between said diverging margins;

Said transverse member passing through said cut-out for restricting the rockable movement of said pendulum member.

* * * * *