350-6.4 SR
XR 3,614,448
SEARCH ROOM

United States Patent SUBSTITUTE FOR MISSING XR

[11] 3,614,448

[72] Inventors Kenneth Victor DiProse;
Arthur Stuart Forbes, both of Bath, Somerset, England

[21] Appl. No. 843,051
[22] Filed July 18, 1969
[45] Patented Oct. 19, 1971

[73] Assignee Hancock & Co., (Engineers) Limited
Slough, Buckinghamshire, England

[32] Priority Feb. 21, 1969
[33] Great Britain
[31] 9429/69

[54] SCANNING SYSTEM FOR FOLLOWING AN OUTLINE
5 Claims, 5 Drawing Figs.

[52] U.S. Cl. 250/202, 250/236
[51] Int. Cl. G05b 1/00
[50] Field of Search 250/202, 236; 310/93, 95

[56] References Cited
UNITED STATES PATENTS

2,933,668	4/1960	Brouwer	250/202 X
3,099,748	7/1963	Weiss	250/236 X
3,207,950	9/1965	Smith	310/95
3,275,743	9/1966	Conant	250/227 X
3,350,156	10/1967	Adams	250/236 X
3,404,280	10/1968	Diprose	250/236 X

Primary Examiner—James W. Lawrence
Assistant Examiner—D. C. Nelms
Attorney—Berman, Davidson and Berman

ABSTRACT: Method and apparatus for scanning an outline on a substrate in which a beam of light is passed through a semireflecting surface and thence through a rotating prism having an odd number of reflecting surfaces, the emergent beam is focused on the substrate so as to cross and recross the outline in a circular path, light reflected from the substrate is passed back along the path of the beam to the semireflecting surface and light reflected from this surface is detected to produce line-crossing signals.

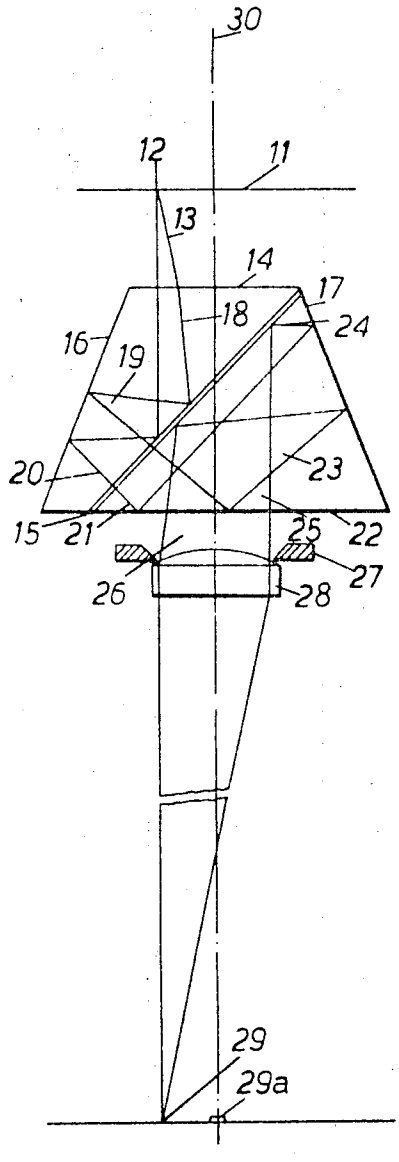


FIG.1

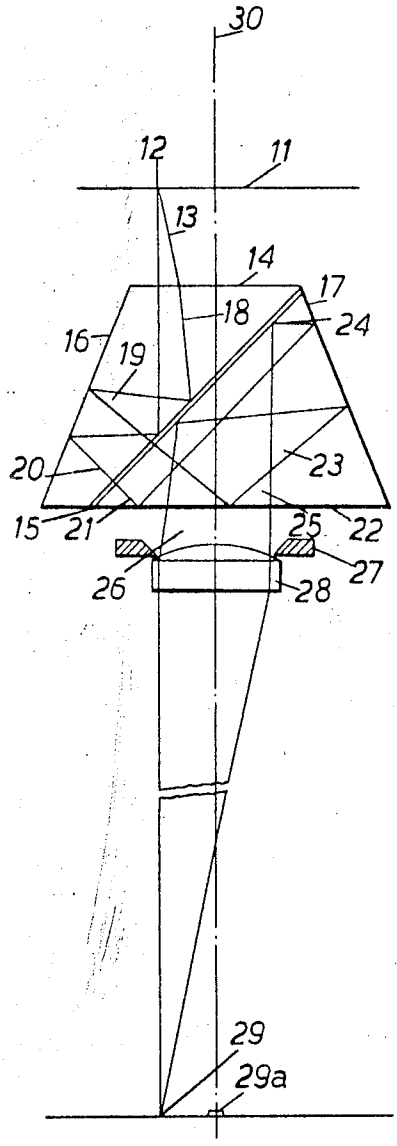
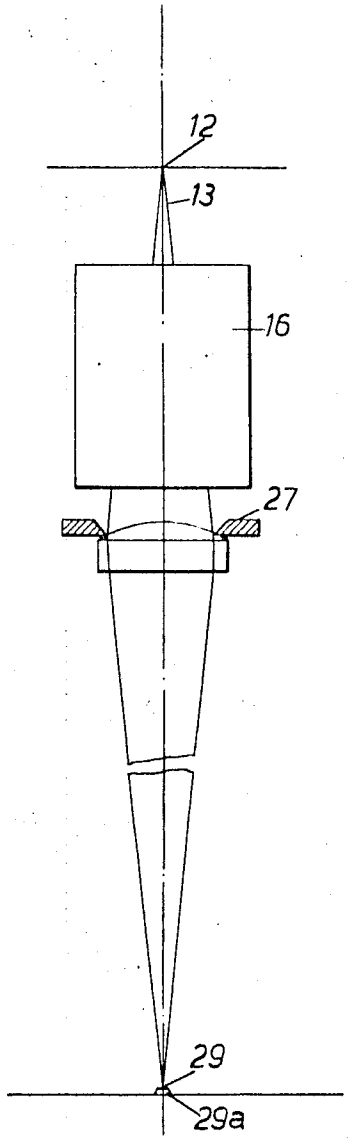
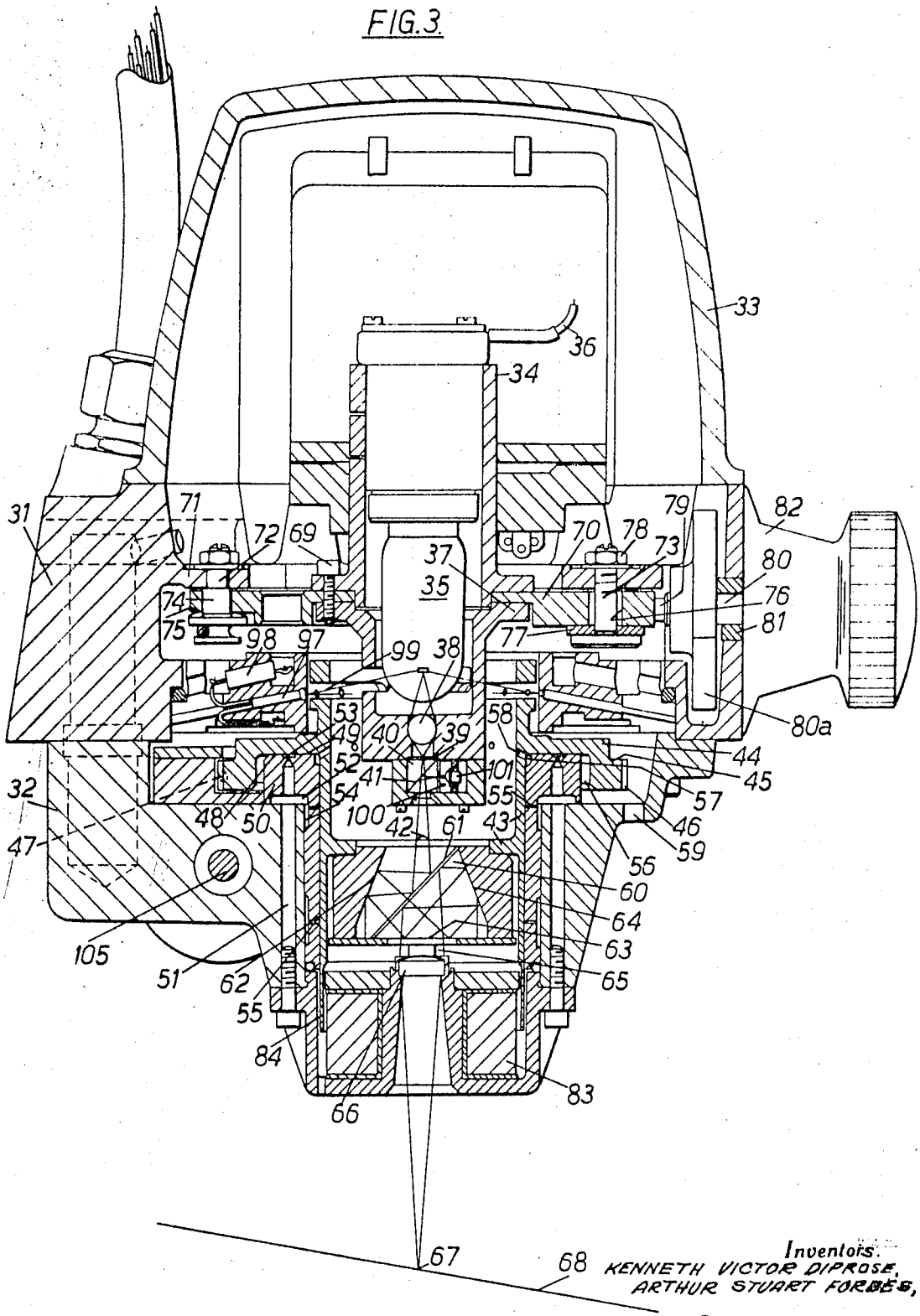


FIG.2



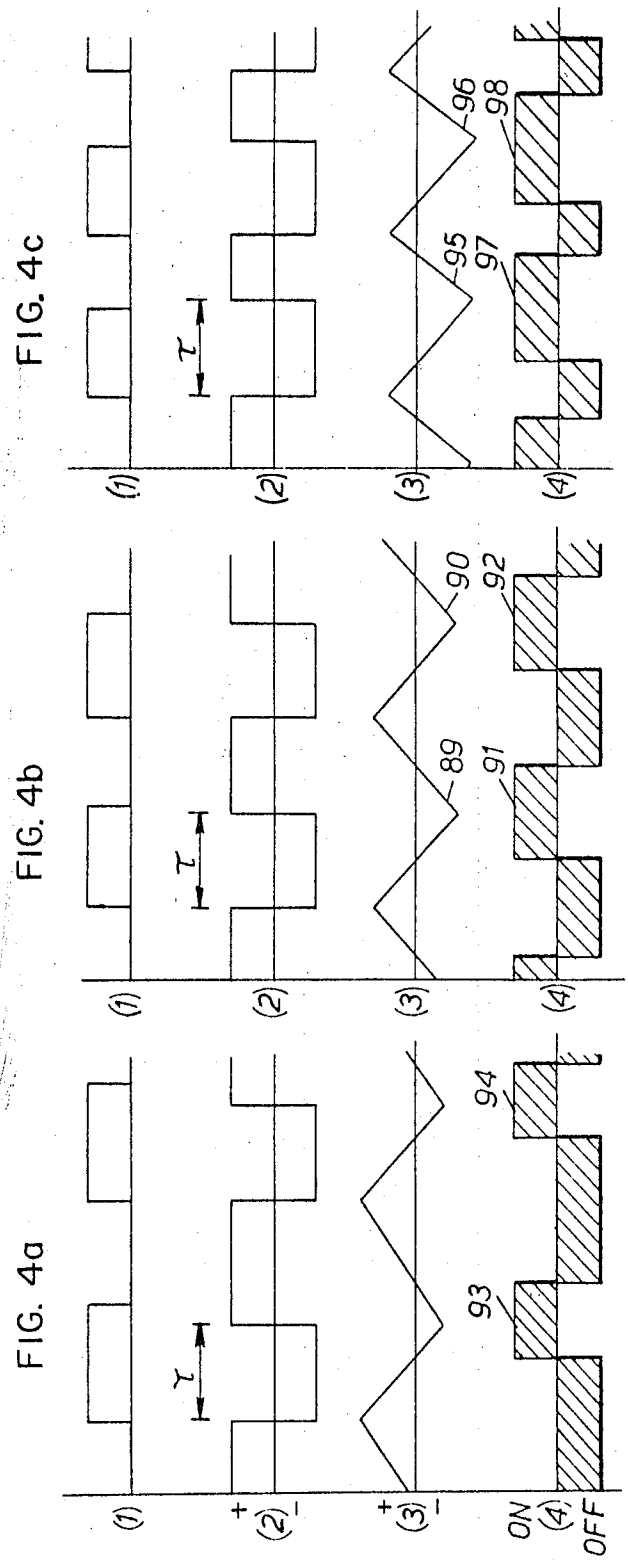
Inventors,
KENNETH VICTOR DIPROSE,
ARTHUR STUART FORBES,
By
Berman, Davidson & Berman Attorneys

FIG.3.



Inventors:
KENNETH VICTOR DIPROSE,
ARTHUR STUART FORBES,

By
Berman, Davidson & Berman Attorneys.



Inventors:
KENNETH VICTOR DIPROSE,
ARTHUR STUART FORBES,
By
Berman, Davidson & Berman, Attorneys.

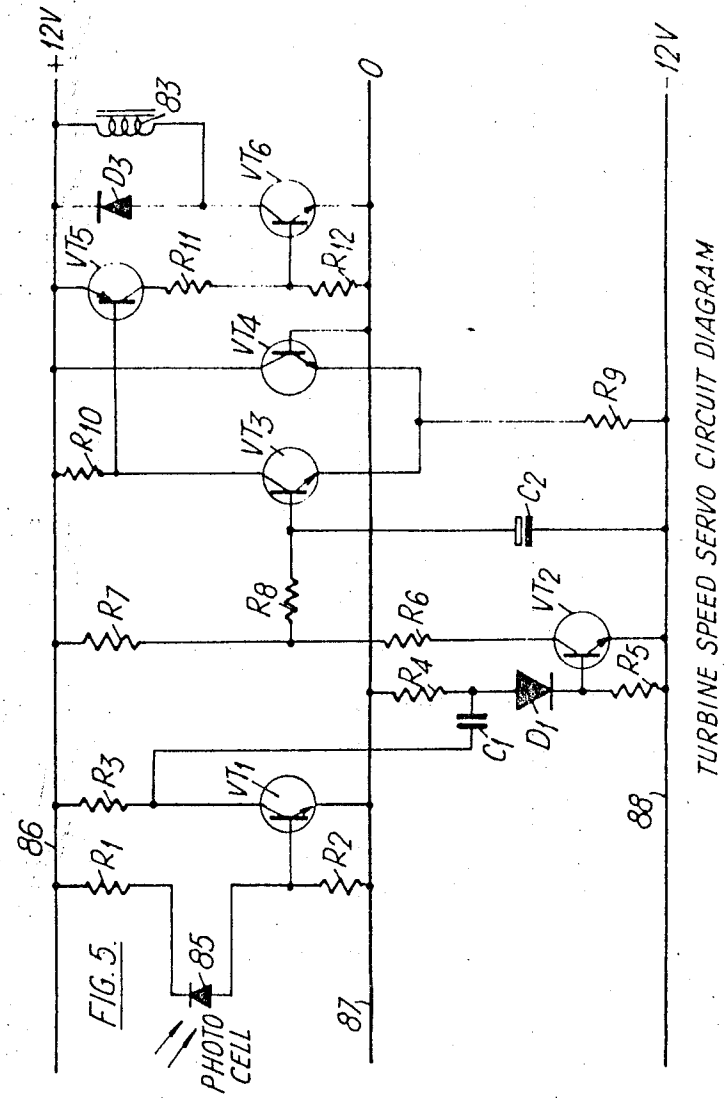


FIG. 5.

Inventors,
KENNETH VICTOR DIPROSE,
ARTHUR STUART FORBES,

By
Berman, Davidson & Berman, Attorneys

SCANNING SYSTEM FOR FOLLOWING AN OUTLINE

This invention relates generally to line-following system, and more particularly to an improved scanning system for a line follower head.

Automatic photoelectric line-following systems are employed for any industrial purposes and in the usual arrangement an outline is carried on a substrate, such as a sheet of drawing paper, and is automatically followed by the line follower head which control the operation of a machine set to carry out a particular operation of work, usually the production of a shape corresponding to the outline in a workpiece.

An example is found in the automatic cutting of steel plated to desired shapes in an oxygen jet cutting machine and the invention will be described in relation thereto. In such machines a support is provided for the steel plate which forms the workpiece and an oxygen jet cutting burner is so mounted that it may move in all directions in a horizontal plane above the workpiece. The substrate carrying the outline is placed on a table associated with the machine and the line follower head is set to follow the outline. In doing so it moves the oxygen jet cutting torch in a precisely similar path and thereby cuts a workpiece having the same shape as the outline from the steel plate.

To enable the line follower head to follow the outline a scanning system is provided and various methods of scanning have been devised. In one method a small spot of light is vibrated across the outline, which is of a dark color on a white background, and the amount of light reflected from each side of the outline is directed to a photoelectric element or elements. If the direction in which the line follower head is instantaneously moving corresponds precisely with the direction of the portion of the outline being followed then the amount of light "seen" by the photoelectric system on the two sides of the outline is identical and the line follower head continues along its set path. If, however, the outline deviates the amount of light "seen" on the two sides of the outline differs and the change is detected by the photoelectric system, which produces a steering signal to cause the line follower head to change course in order to follow the deviation of the outline.

Various methods of driving the line follower head and the cutting torch have been devised. In one method the outline is stationary and a small motor in the line follower head drives a toothed wheel which bites into the surface of the substrate to move the line follower head and the steering signal is caused to steer this wheel. In other systems the line follower head is stationary and a table carrying the substrate and the oxygen jet cutter are moved together.

In many cases a coordinate drive is employed. This uses two motors arranged to drive the line follower head and the cutting torch in directions which are mutually at right angles and the steering signal is "processed" in such a way as to provide two separate signals for application to the respective motors so that they run at different speeds and/or in different directions in order to cause the line follower head to move in the desired direction to follow the outline, carrying the cutting torch with it.

In another method of scanning which is basically an inversion of that described above a small area of the outline below the line follower head is floodlit and an optical system causes a tiny spot of the illuminated field to be forced on the photoelectric system. This tiny "field of view" is vibrated across the outline so that the photoelectric system alternately "looks" at opposite sides of the outline and thereby detects any deviation thereof.

A third known system of scanning is to rotate a small spot of light in a circular path which crosses a portion of the outline being scanned, signals being derived from the crossing points of the light spot over the outline which are used to steer the follower head. Obviously an inversion of this arrangement may be devised by causing a small field of view to scan a circular path over an illuminated area of the substrate.

The first method described above has the advantage that the scanning pattern can be clearly seen by an operator of the machine as a bright line crossing a portion of the outline and this considerably facilitates the initial setting up and operation of the machine. However it has the disadvantage that variations in ambient lighting affect the system. On the other hand the second method is far less affected by ambient light but the floodlit area over a part of the outline gives little assistance to the operator in initially setting the machine and usually has to be supplemented by some form of artificial index for setting purposes. The principal object of the invention is to provide a scanning system in which a prism which is dynamically balanced with respect to a rotational axis is driven at high speed by an air turbine in order to produce a rotational scan, a square wave characteristic is a desired frequency s generated, the rotation of the turbine is monitored to derive a control signal at each rotation of the turbine, and electronic circuitry is provided to vary the brake load applied by an electrodynamic brake to control the speed of the turbine so that it is synchronized with the said desired frequency.

In one aspect the invention consists of a method of scanning and outline comprising the steps of producing a beam of light, passing the beam of light through a semireflecting surface, rotating a prism having an odd number of reflecting surfaces, passing the beam of light from the semireflecting surface through the prism, focusing the emergent beam from the prism to a point on a substrate so as to cross and recross the outline. passing light from the substrate back along the path of the beam to the semireflecting surface, and detecting light reflected by the semireflecting surface in order to produce line-crossing signals.

In another aspect the invention consists of an apparatus for scanning an outline on a substrate comprising means to produce a beam of light, a semireflecting surface through which the beam is passed, an air turbine, a prism having an odd number of reflecting surfaces mounted in the turbine rotor, the beam from the semireflecting element being passed through the prism, a lens to focus the beam to a point at the surface of the substrate, light from the substrate being passed back along the path of the beam, and a photosensitive element to detect light passed back and reflected by the semireflecting surface.

Preferably speed control means are provided to maintain the speed of the turbine substantially constant. The speed control means may comprise an electrodynamic brake to apply a variable brake load to the turbine rotor.

To promote a full appreciation of the invention a description of one embodiment thereof will be given by way of example with reference to the accompanying drawing in which:

FIG. 1 is a diagram showing the path of a spot of light through a rotating member which produces the scanning cycle;

FIG. 2 is a diagram similar to FIG. 1 but taken at right angles to that of FIG. 1;

FIG. 3 is a vertical section through a practical form of line follower head embodying the invention;

FIG. 4 is a series of diagrams showing the signals produced in operation; and

FIG. 5 is a circuit diagram of a servo mechanism.

Referring to FIG. 1, an aperture plate 11 is formed with an aperture in the form of a pinhole at 12 through which light from a source (not shown) emerges as a beam 13. The beam 13 strikes the upper face 14 of a Pechan Schmidt prism. This prism has an air-spaced junction at 15 and the two sloping faces, respectively 16 and 17, are silvered to form reflecting surfaces. The beam 13, having entered the prism follows a path 18 until it reaches the junction 15 where it is reflected at 19 to the silvered surface 16 and is then reflected at 20 back to the junction. The axis of the beam being normal to the surface of the junction 15, most of the beam passes through it, as indicated at 21, and strikes the lower face 22 of the prism where it is reflected to form a beam 23 which strikes the silvered surface 17 and is again reflected as a beam 24. The beam 24 strikes the junction 15 at an angle and is reflected as a beam 25 which, striking the lower surface 22 at an angle ap-

proaching a right angle, mainly passes through it at 26. The beam 26 passes through an aperture 27 to a lens 28 and is focused to a point on a substrate 29 bearing an outline indicated at 29a.

The pinhole 12 is offset from the optical axis 30 and it will be noted that the beam is reflected five times i.e., an odd number of times. Hence, if the prism is rotated about the optical axis 30, with respect to which it is symmetrically positioned, the point 29 will follow a circular path with the optical axis 30 as its center and the point 29 will make to revolutions for each revolution of the prism.

Since the top and bottom faces 14 and 22 are normal to the optical axis the length of the path through the prism remains constant as the prism rotates and in consequence the prism may be used with nonparallel light without introducing astigmatism. It also has the advantage that when correctly mounted it is dynamically balanced about the optical axis (which is also the axis of rotation) and it may therefore be rotated at high speed without introducing undesirable effects due to unbalance.

In conventional line follower heads it is usual to vibrate or drive the scanning spot (be it a spot of light or a field of view) at mains frequency, that is to say 50or 60cycles per second, and a time duration of one-half cycle is, of course, required to detect any change in the direction of the outline and to start the process which produces a steering signal. With a balanced rotating member such as the Pechan Schmidt prism when used as described above it is possible to operate at a higher speed and to provide a line following head in which the scanning arrangement is driven at 6,000r.p.m. for example. This speed may be achieved in a very simple manner by using an air turbine drive and using air-lubricated bearings. This gives a scanning rate of 200cycles per second, bearing in mind that the scanning spot makes two revolutions for each revolution of the prism.

In using a line follower head it is necessary to allow for the material which the cutter, be it an oxygen jet cutter or a milling cutter, inevitably removes in shaping the surface which is to be shaped. If the axis of an oxygen jet flame or milling cutter were to describe a path corresponding precisely to the outline then the resulting workpiece would be smaller than the outline by one-half width of the cut made by the cutter. It is usual to compensate for this by offsetting the axis of the line follower head with respect to the outline. The offset is often called a kerf allowance.

A practical embodiment of the invention is shown in FIG. 3, which presents a vertical section of a line follower head. IT comprises an upper body element 31 which is joined to a lower body element 32 and a cover 33 fixed to the top of the upper body element. Within the body is a lamphouse 34 which contains 35 connected to a power supply by a cable 36. The lower part of the lamp 35 is contained within a housing 37 and the lower part of the housing 37 contains a spherical lens 38 through which a beam of light from the filament or its equivalent, in the lamp 35 is projected. The light passes through an aperture in an aperture plate 39 into an element 40 which may take one of several forms. It may be in the form of a half-silvered mirror which will pass one-half of the light beam and reflect the other half to the left on the drawing or it could be a mirror having a central hole in the silvering through which the beam may pass, to be reflected when the beam passes in the opposite direction, but it is preferably a Swann block made up of two prisms cemented together at a face 41 which will also allow one-half of the light to pass through and reflect the other half to the left on the drawing. The beam of light then passes to a rotatable member 43, which in fact constitutes a turbine rotor. The rotor 43 is in the form of a sleeve having an inwardly directed flange which supports a Pechan Schmidt prism and has an outwardly directed flange 44 with an outer ring 45 formed upon it, the outer ring 45 having gear teeth 46 cut around its periphery. The gear teeth provide a simple method of providing the blades of an elementary type of air turbine. The turbine is a very small one and because of features to be described later only a very small amount of power is required to drive it so that a comparatively ineffecient design is adequate. Air to drive the turbine is supplied through one or more apertures one of which is indicated in dotted lines 47. A slide valve 105 is provided to enable the turbine to be controlled and reversed. The ability to reverse the turbine makes it possible to follow the outline in either direction or to retrace a part of the outline in the opposite direction. It is, of course, necessary that the line follower be so arranged that where a kerf allowance is being made, the line follower will take account of it by making the kerf allowance on the opposite side of the outline when working backwards.

The flange portion 44 is provided with a lower face 48 rests upon a stationary face 49 of a ring-shaped member 50. Air under pressure which is supplied to the turbine nozzle 47 is also supplied to a duct 51 which communicates with a recess 52. A shallow groove 53 is machined in the face of the ring 50 and the air pressure applied through the duct 51 supports the weight of the rotor 43 and provide almost frictionless rotation. Air is also supplied from the recess 52 along a reduced diameter portion 54 and from this air is admitted through small passages 55 to a journal bearing in which the outer diameter of the rotor 4 3 is journaled. In order to reduce the friction as much as possible and to ensure that if the air supply is cut off while the turbine is running at full speed there will be no damage to the bearings, the member 50 may conveniently be coated with P.T.F.E. (polytetrafluoroethylene) and the surface 48 of the flange 44, or the whole of the member 43, may be anodized, the member being , of course, made of aluminum Air which escapes from the thrust and journal bearings wither passes through a clearance 56 into the housing or collects in a recess 57 in the member 50 and then passes through channels 58 into the internal part of the housing. In either case the air may escape to the atmosphere through an escape hole 59.

The rotatable member 43 contains the Pechan Schmidt prism 60. The beam of light is reflected by the junction 61 in the prism, is again reflected by a sloping silvered surface 62, again reflected by a lower surface 63 of the prism, and again reflected by the second sloping silvered surface 64 of the prism, being then finally directed downwards by reflection from the junction to emerge as a beam 65 which passes through a lens 66 by which it is sharply focused to a point 67 at the surface 68 of the substrate containing the outline.

Since as will appear later, the scanning spot and the field of view of the photoelement are coincident, it is a matter of choice whether or not the line follower head is set perpendicularly to the surface of the substrate 68, which is normally horizontal, but for convenience in drawing and description the line follower head is shown vertical and the substrate 68 is shown tilted at an angle of about 10°.

In order that the offset or kerf allowance of the line follower head may be adjusted a lamphouse 34 and the lower housing 37 are fixed by screws 69 to a plate 70 which is mounted against an internal projecting ring 71 in the upper housing member by means of bolts 72 and 73. The bolt 72 has an enlarged portion 74 which shoulders against the ring portion 71 in the housing and the sliding plate 70 is kept in contact by a resilient member 75. A clearance hole 76 is provided for the shank of the bolt 73 and the head is provided with a pad 77 upon which the plate 70 may swing. To provide for adjustment of the height of the pad 77 the hole in the ring portion 71 is tapped and the nut 78 forms a locknut. The swinging of the plate 70 is controlled by a pin 79 fixed to the plate 70. This pin is acted on by a cam 80aon the end of a shaft 80 passing through a bearing bush 81 in the wall of the upper housing 31 and having secured to its outer end a calibrated scale 82 which is integral with an adjusting knob for rotating the shaft 80 and the scale 82.

The line follower head which is being described is arranged to provide two signals for application to two motors which respectively drive the line follower head and the cutting tool in direction parallel to to mutually perpendicular coordinates in order to follow the outline. This in itself is a well known form

of drive and the method of generating the two signals is disclosed in our British Pat No. 1,096,798to the specification of thick reference may be made to obtain full details. Accordingly the description given herein need only be sufficient to enable the present invention to be fully understood.

Included in the circuitry associated with the line follower head is a device for generating a square wave which may be in the form of a monostable multivibrator. This is set so that once triggered the multivibrator remains in its "set" position for a period equal to the time of one-half revolution of the rotor 43. It is triggered by means of a photocell which at each revolution, receives a flash of light from the lamp 35 so that the square wave is locked in phase to the rotation of the rotor 43. The multivibrator remains in its "set" condition for one-half of a revolution then switches over to its "reset" condition for the remainder of the revolution. Two further signals are generated by photoelectric means employing a number of photosensitive elements of which one is indicated by reference 97. Each of these photoelements is connected in series with a resistor such as the resistor 98. The rotor 43 contains a slot 99 having a circumferential length such that at least half the photoelements 97 are illuminated at any one time. The photoelements act purely as switches which are "on" when illuminated and "off" hen obscured by the rotor 43. With a conventional scanning arrangement the photoelements are equally spaced in a ring around the lamp 35 but where the Pechan Schmidt prism is used the scanning spot rotates at double the rotor of a different arrangement of the photoelements is made. The resistors photoelements are so chosen as to their values that if a constant direct voltage were waveform there conductances are in the required ratios to produce a voltage which approximates to a sine wave as the shutter rotates. This is the criterion to be met, however the photoelements are arranged. The photoelements are connected in groups to form four quadrants so that with the said constant direct voltage applied they will produce two approximately sinusoidal waves which are phase displaced by 90° of rotor rotation with respect to each other.

However, the photoelements and their resistors are not connected to a constant DC supply, but the square waveform from the multivibrator is applied to them so that the change of the multivibrator from its "set" to its "reset" position and vice versa has the effect of inverting one-half of each wave. Hence the output consists of two repetitive waveforms each having a fundamental frequency equal to twice the speed of rotation of the rotor 43. The combined effect is that each waveform varies so that its mean DC value is a maximum when the direction of the portion of the outline being instantly followed lies parallel to the associated coordinate and ranges down to zero when the direction of the portion of the outline being followed is perpendicular to the associated coordinate. A differential amplifier is provided for each waveform and the amplifier provides the power to drive the respective coordinate motor.

In operation light from the lamp 35 passes through the spherical lens 38 and the aperture in the plate 39 to the rotating prism. As described earlier the rotation of the prism causes the beam 54 emerging therefrom to follow a circular path so that the point of light 67 striking the substrate 68 also moves in a circular path which crosses the outline twice in each revolution. Light reflected from the substrate travels back through the lens 66 and through the prism. following precisely the it path as the beam of light until it reaches the semireflecting surface 41 at which half the light returning from the substrate is reflected through an aperture in an aperture plate 100 to a photosensitive element 101. It is the crossing signal developed by the photoelement 101 which (after amplification of necessary) is used spot. trigger the multivibrator.

From the above description it will be evident that the square wave generated by the multivibrator varies in phase with respect to the rotation of the rotor 43 in dependence upon the direction of the outline whereas the timing of the two repetitive waveforms generated by the ring of photoelements 97 is locked to the rotation of the scanning spot. Accordingly the modification of the two repetitive waveforms varies in dependence upon the direction of the outline and this in turn varies the voltages applied to the two coordinate drive motors.

It was pointed out above that the multivibrator or flip-flop is so arranged that having been triggered into the "set" condition it remains set for one-half the direction of one revolution of the rotor 43 and then returns to the "reset" condition for the remaining half-revolution. This condition can only be maintained if the rotor 43 is running at a substantially constant speed. If a synchronous AC electric motor is used this is comparatively easy to arrange but where the drive is by means of a high-speed turbine as mentioned earlier it is necessary to control the speed of the turbine so that it is substantially constant.

The speed control for the turbine is arranged by including an electrodynamic or eddy current brake having a fixed winding 83 (FIGS. 3 and 5) placed in a housing attached to the lower body element 32 which induces eddy currents in a sleeve 84 formed at the lower end of the rotor 43. The turbine is arranged to run at a normal speed of 6,000 r.p.m. to provide a scanning or line crossing frequency of 200 line crossings per second and the eddy current brake is arranged to produce a braking torque at this speed approximately equal to twice the accelerating torque of the turbine. Consequently, when the brake is at half power the net accelerating torque is zero, and the speed remains constant.

The servocontrol is so arranged that when the speed falls to 5,925 r.p.m. the eddy current brake is off. Between 5,925 and 6,075 r.p.m. the brake receives a series of electrical impulses whose duration varies with the speed and at 6,075 r.p.m. the brake is on continuously.

The operation of the servo device is illustrated by a series of diagrams shown in FIG. 4 and the actual circuit is shown in FIG. 5. A photocell (not shown) is used to trigger a monostable multivibrator or its equivalent by receiving a flash of light at each revolution of the scanning device. The photocell 85 is connected between two resistors R_1 and R_2 which in turn are connected between a 12 volt positive line 86 and an earth or ground line 87. The junction of the photocell and R_2 is connected to the base of a NPN transistor VT_1 whose emitter is connected to the earth line 87. The collector of VT_1 is connected through a resistor R_3 to the positive line 86 and the junction of VT_1 collector and R_3 is connected to one side of a capacitor C_1, the other side of which is connected to the junction of a resistor R_4 and the anode of diode D_1, whose cathode is connected via a resistor R_5 to a 12 volt negative line 88.

The changes in current caused by the flashes of light on the photocell 85 cause pulses of current in VT_1 and the voltage changes at its collector are applied to C_1, and the output of C_1 is applied to the diode D_1. The pulses appearing at the junction of the cathode of D_1 and R_5 are applied to the base of an NPN transistor VT_3 having its emitter connected to the 12 volt negative line 88 and having its collector connected to resistors R_6 and R_7 in series, the junction of these resistors being connected through a further resistor R_8 to one side of a high value capacitor C_2 and the base of a pair of NPN transistors VT_3 and VT_4, which form the monostable circuit. The emitters of VT_3 and VT_4 are connected together through a common resistor R_9 and to the 12 volt negative line 88. The collector of VT_3 is connected through a resistor R_{10} to the positive line 86 while the collector of VT_4 is connected directly to this line. The junction of the collector of VT_3 and R_{10} is connected to the base of PNP transistor VT_5 which acts as an amplifier. This has its emitter connected to the positive line 86 and its collector connected via two resistors R_{11} and R_{12} in series to the earth line 87, the junction of these two resistors being connected to the base of a further transistor VT_6 which has its emitter connected to the earth line 87, and its collector connected to the brake winding 83. The brake winding 83 has a diode D_2 connected in parallel with it, the polarity of D_2 being such that it will pass current when VT_6 is cut off and the field of the winding 83 collapses. This prevents the development of transient high voltages in the brake coil.

The operation of the circuit may be understood by reference to FIG. 4 which is divided into three sections (*a*) (*b*) and (*c*) showing the conditions respectively when the turbine is running slow (that is below 6,000 r.p.m.), the conditions when the turbine is running at its correct speed, and the conditions when the turbine is running fast.

Referring first to FIG. 4 (*b*) the waveform shown at 4 (*b*)(1) represents the current flow trough the photocell as it is alternately switched on and off by the rotation of the rotor. FIG. 4 (*b*)(2) is the waveform of the monostable circuit the period τ representing the fixed "on" period on the monostable circuit once it has been triggered. The output of the monostable circuit is smoothed and its waveform is shown in FIG. 4 (*b*)(3), the transistor VT_6 being conductive during the period while the output is below the zero line, that is to say, during the portions 89 and 90 of the waveform. Hence, as shown in FIG. 4 (*b*)(4), the brake is energized for one-half of the total time in any given period and the power of the turbine is sufficient to keep it running at the correct speed with this amount of braking. If for any reason the turbine should run slow then the condition shown in the curves of FIG. 4 (*a*) obtain. FIG. 4 (*a*)(1) shows the waveform of the photocell current, the "on" period being equal to the "off" period, but both periods being longer. The "on" period of the monostable circuit remains unchanged and is again represented by the letter τ but the "off" periods are correspondingly longer. This results in a larger portion of the output wave of the monostable circuit being above the zero line as shown in FIG. 4 (*a*)(3) so that there are correspondingly longer "off" periods and shorter "on" periods for the brake, ad shown in FIG. 4(*a*)(4), the "on" periods being indicated at 93 and 94.

When the turbine is running fast (above 6,000 r.p.m.) as shown in the curves of FIG. 4 (*c*) the respective "on" periods for the photocell are shown at FIG. 4 (*c*)(1) and are shorter in view of the higher speed. On the other hand the "on" periods for the monostable circuit shown at 4 (*c*)(2) remain as before and are equal to τ so that the "off" periods are correspondingly shortened. This produces the effect in the smoothed output of the monostable circuit shown at 4 (*c*)(3) in which the portions 95 and 96 are lengthened so that the "on" periods for the brake shown at FIG. 4 (*c*)(4) are longer than the "off" periods, as indicated at 97 and 98.

We claim:

1. A method of scanning an outline comprising the steps of producing a beam of light, passing the beam through a semireflecting element, rotating at high speed a prism having an odd number of reflecting surfaces and which is dynamically balanced about its axis of rotation, passing the beam of light from the semireflecting element through the prism to produce a beam which rotates about the said axis, focusing the emergent beam from the prism to a point on a substrate bearing an outline so as to produce a point of light which continuously follows a circular path to cross and recross the outline during each circular cycle, passing light from the substrate back along the path of the beam to the semireflecting element, detecting light reflected by the semireflecting element to produce line-crossing signals, using the said line-crossing signals to trigger a monostable multivibrator to produce a square wave characteristic of a desired frequency, monitoring the rotation of the prism to produce a control signal at each revolution, and using the control signals to vary an electrodynamic braking load applied to the rotation of the prism in order to maintain the speed thereof in synchronism with the said desired frequency.

2 Apparatus for scanning an outline on a substrate comprising means to produce a beam of light, a semireflecting element through which the beam is passed, an air turbine, an electrodynamic brake co apply load to retard the speed of the turbine, a prism having an odd number of reflecting surfaces and which is dynamically balanced, he said prism being mounted in the turbine rotor, the beam from the semireflecting element being passed through the prism, a lens to focus the emergent beam to a point on the substrate to produce a rotating scan which crosses and recrosses the outline at each revolution, light from the substrate being passed back along the path of the beam to the semireflecting element, a monostable multivibrator which, when triggered, will produce a square wave characteristic of a desired frequency, means to derive a control signal at each rotation of the turbine, and circuitry to vary the brake load applied to the turbine to maintain its speed in synchronism with the said desired frequency.

3. Apparatus as claimed in claim 2 in which the mounting for the turbine rotor comprises air bearings.

4. Apparatus as claimed in claim 3 in which the portion of the turbine rotor which constitutes journal and end location surfaces is made of aluminum and anodized.

5. Apparatus as claimed in claim 3 in which the journal and end location bearings of the turbine rotor are lined with PTFE (polytetrafluoroethylene).