United States Patent [19]

Gull

[11] **3,715,591**

[45] **Feb. 6, 1973**

[54] **OPTICAL SCANNING EQUIPMENT**

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[73] Assignee: **Hawker Siddeley Dynamics Limited,** Hertfordshire, England

[22] Filed: **Dec. 3, 1971**

[21] Appl. No.: **204,463**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 811,698, March 27, 1969.

[30] **Foreign Application Priority Data**

April 1, 1968 Great Britain........................5,299/68

[52] **U.S. Cl.**............................**250/83.3 H,** 250/65 R
[51] **Int. Cl.**..**G01t 1/16**
[58] **Field of Search**........250/65 T, 83.3 H, 83.3 HP, 250/65 R

[56] **References Cited**

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Primary Examiner—James W. Lawrence
Assistant Examiner—Harold A. Dixon
Attorney—Arthur E. Dowell, Jr. et al.

[57] **ABSTRACT**

An aerial infra-red line-scanning system is provided in which rotation of a scanning rotor not only scans the terrain below the aerial vehicle and reflects the scanning beam on to an infra-red detection cell but also traverses a plurality of recording beams widthwise in succession across a film record transported close to the rotor in a direction parallel to the rotor axis. The recording beams are modulated in accordance with the signal output of the IR cell. The film is constrained, in the region where it is scanned by the recording beams, to a widthwise curvature centered on the axis of the rotor.

11 Claims, 11 Drawing Figures

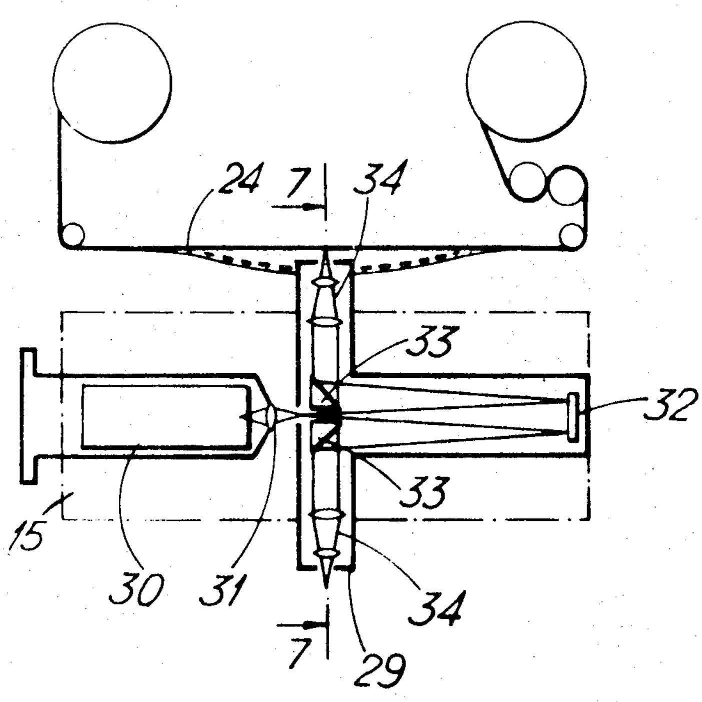


Fig. 1.

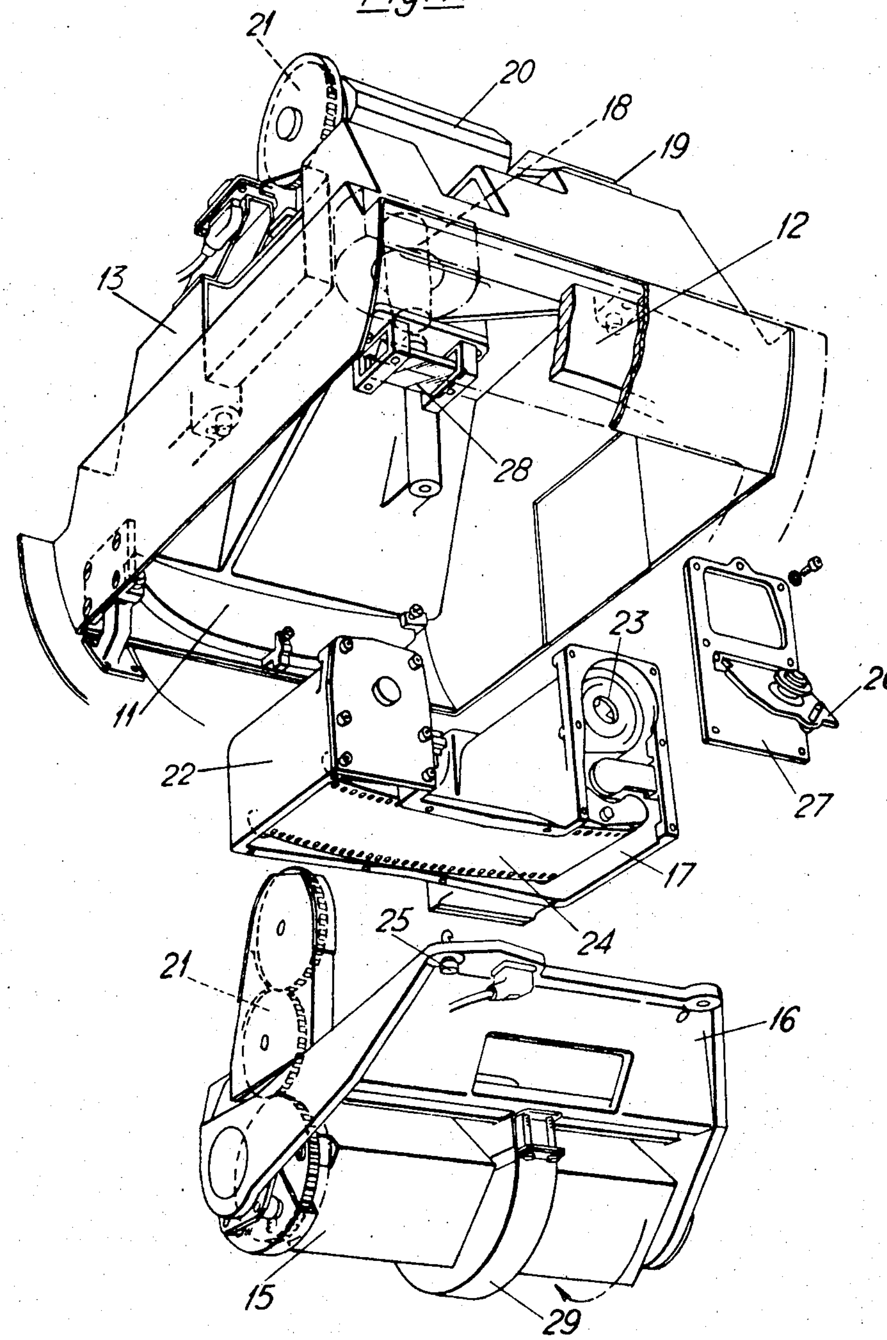


Fig. 2.

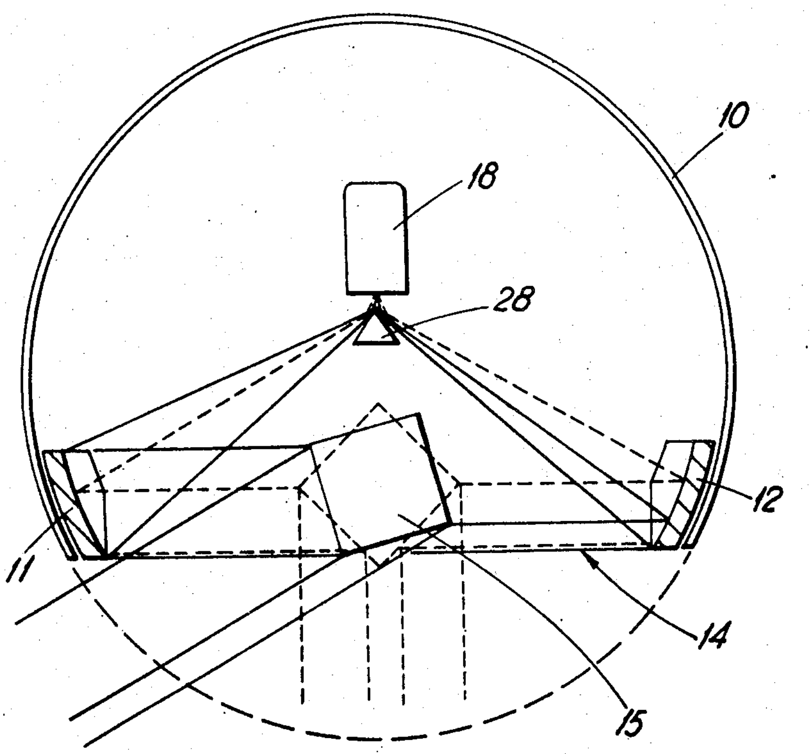


Fig. 3.

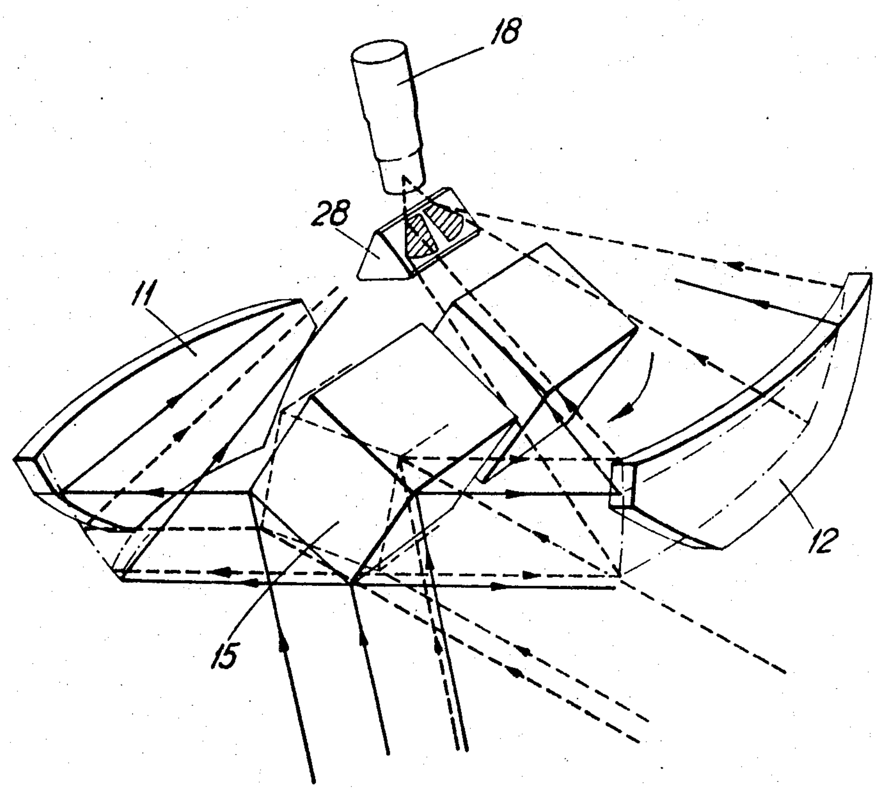


Fig. 4.

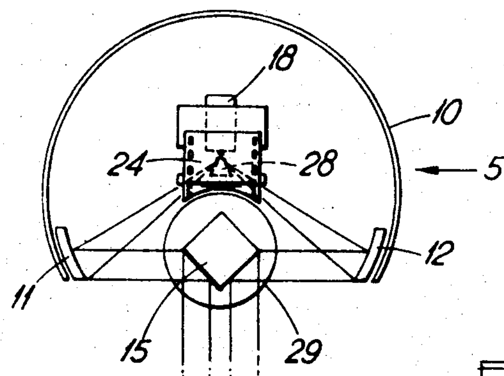


Fig. 5.

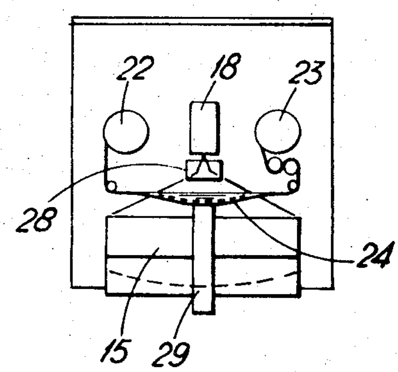


Fig. 6.

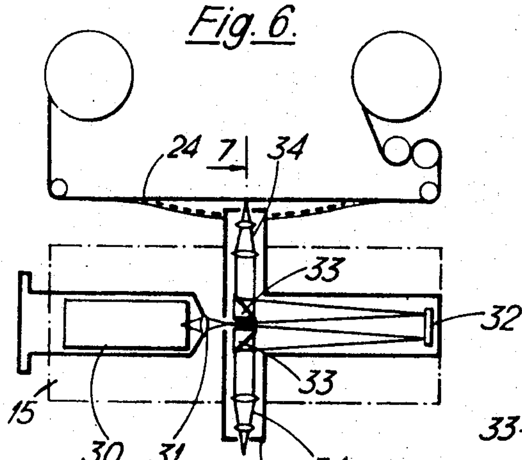
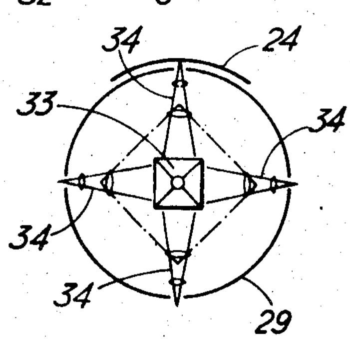


Fig. 7.



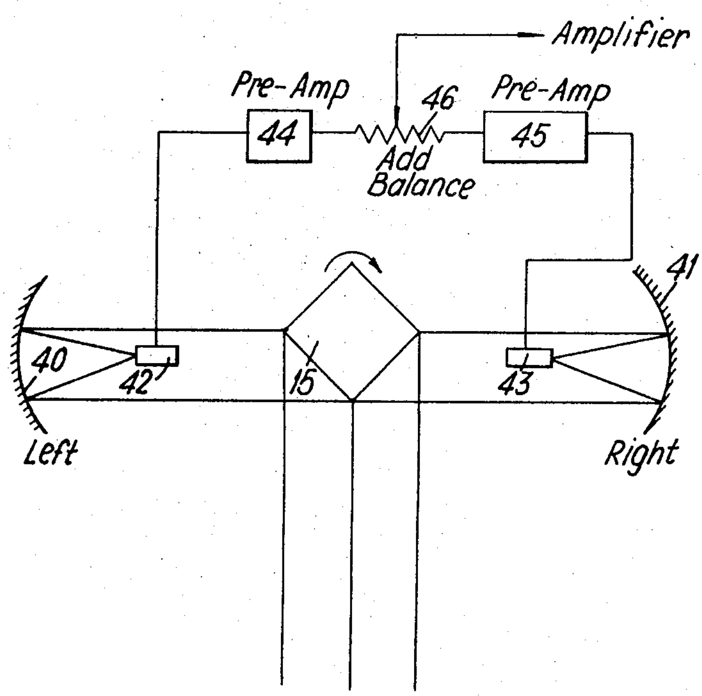

Amplifier
Pre-Amp
44
46
Pre-Amp
45
Add
Balance
41
40
42
15
43
Left
Right

Fig. 8.

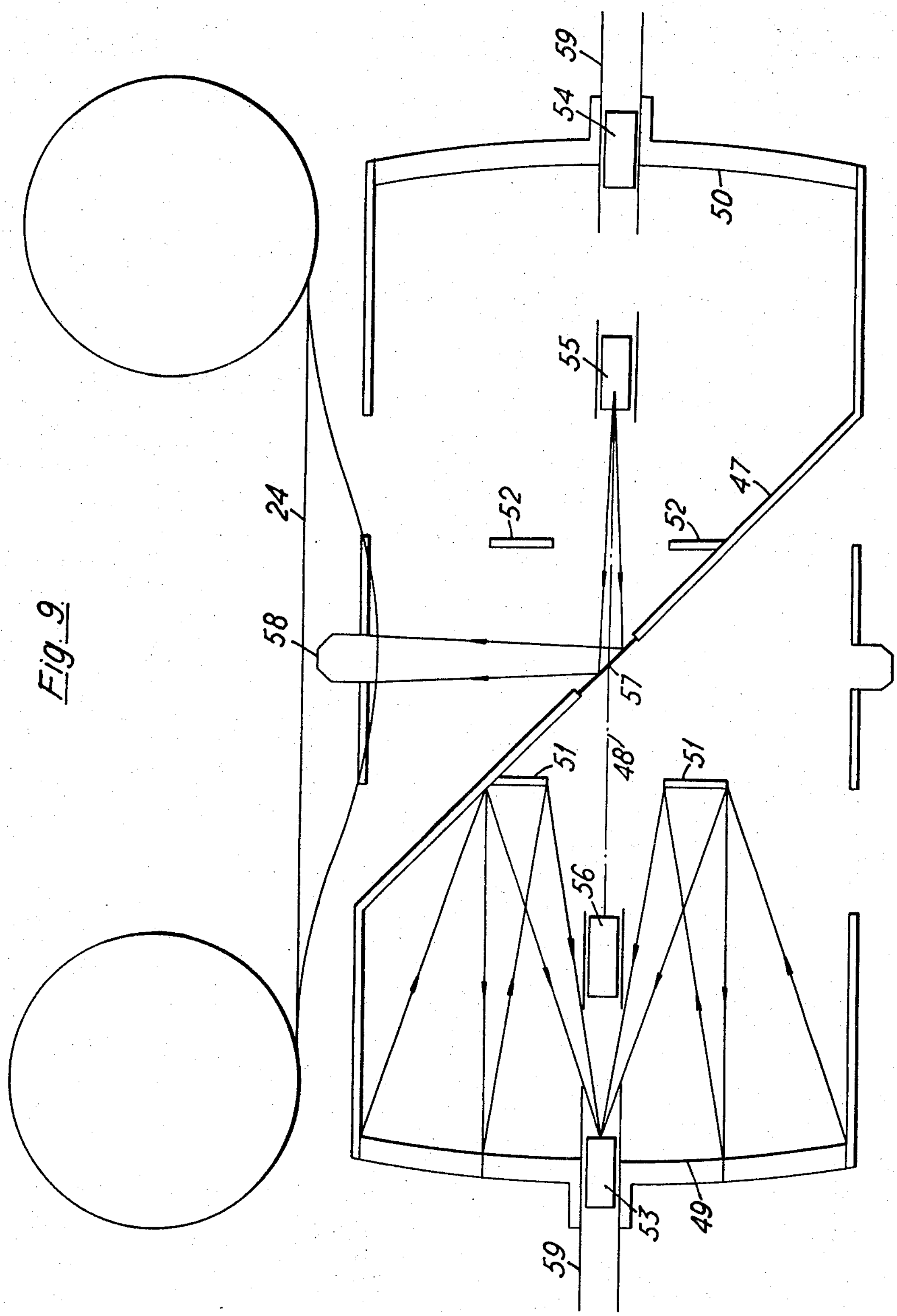


Fig. 9

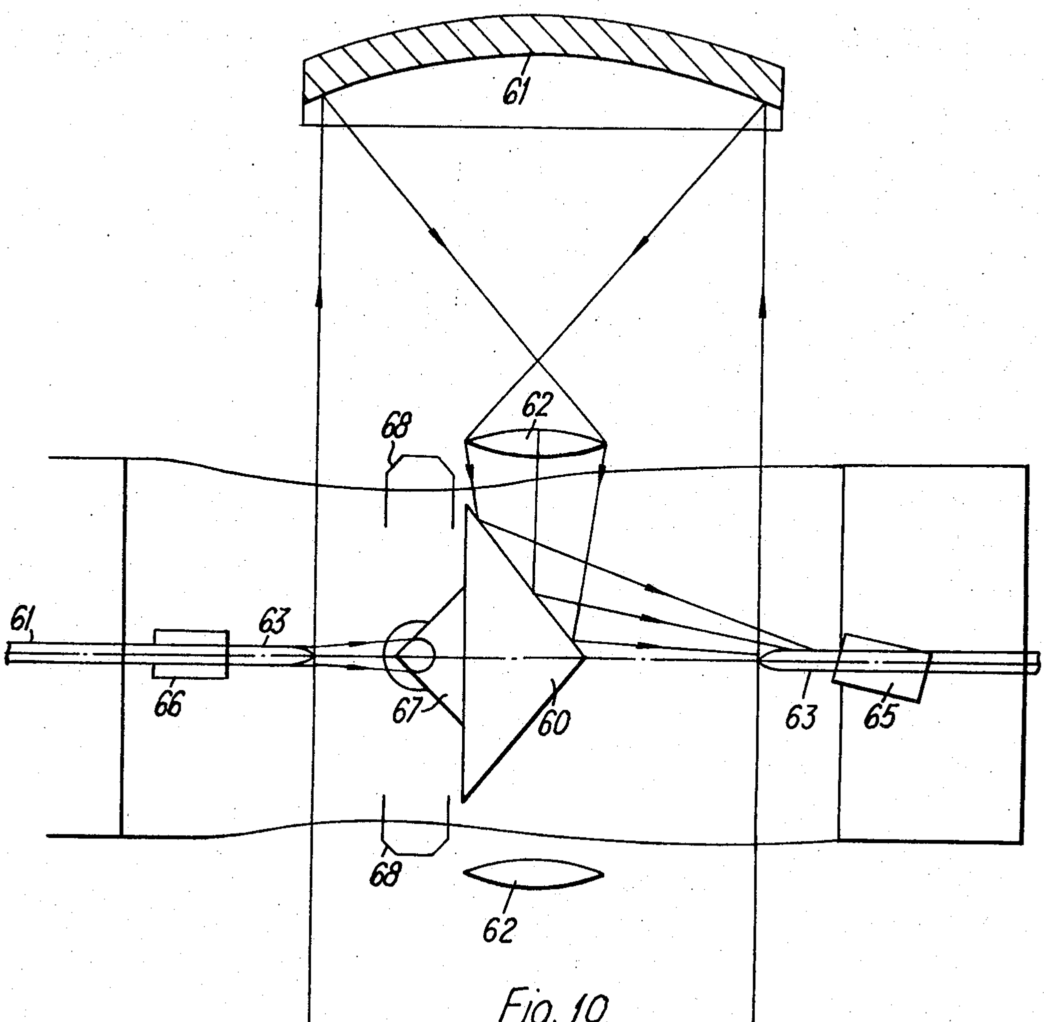
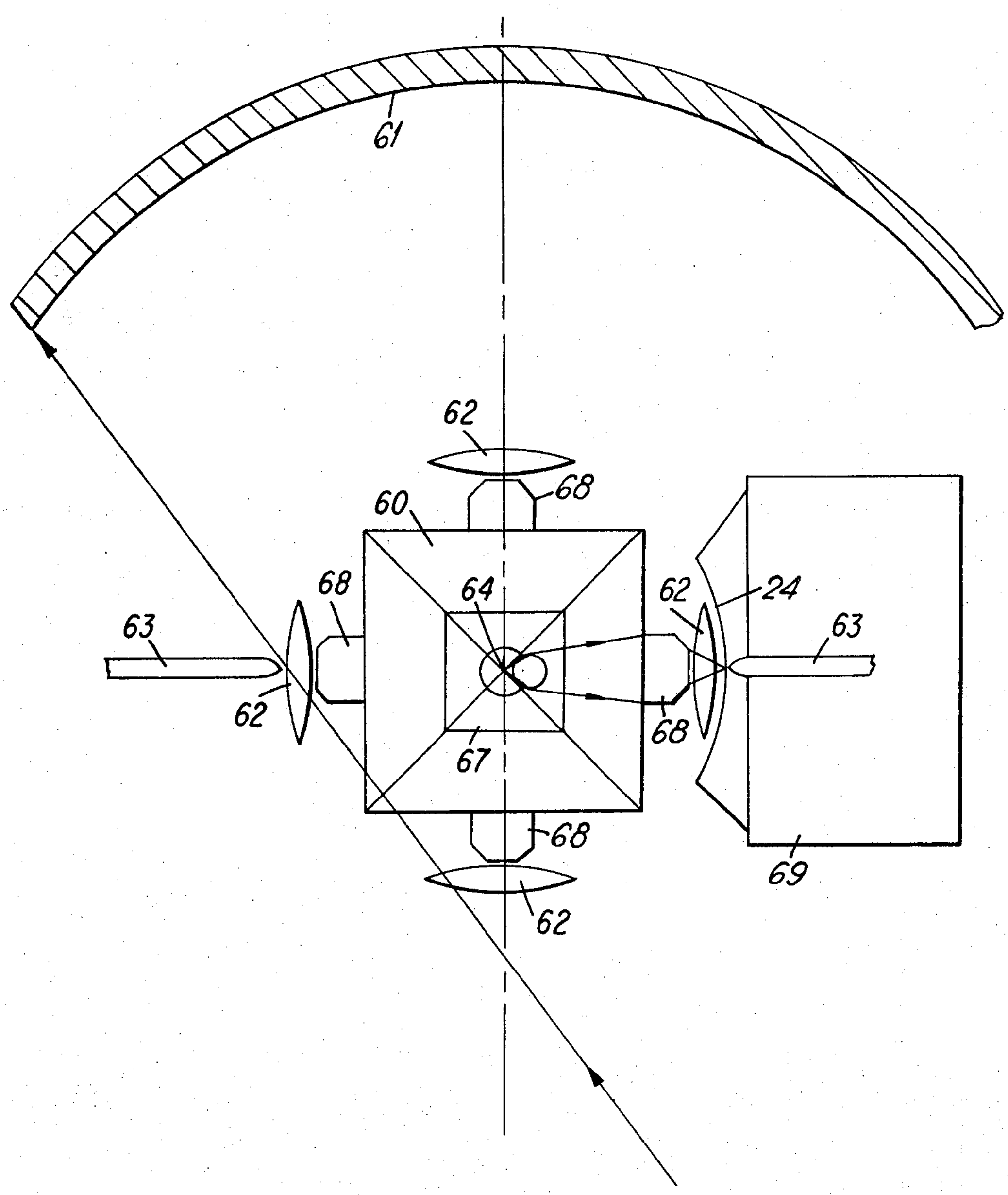


Fig. 10

Fig. 11.



OPTICAL SCANNING EQUIPMENT

The present application is a continuation-in-part of my application Ser. No. 811,698 filed Mar. 27, 1969.

This invention relates to scanning equipment for viewing or illuminating a scene over a wide angle, especially in connection with obtaining a photographic record of a terrestrial scene. A primary field of application of the invention lies in photographing the landscape passing beneath an airborne or similar vehicle, particularly to obtain a "thermal" picture of the infra red part of the spectrum.

It is an object of the invention to achieve scanning equipment for this type of duty which is unusually compact and uses fewer components than systems available hitherto, and for which the driving power required is kept advantageously low.

For infra-red linescan systems which record directly on to film via recording optics that scan a light spot widthwise across the film in synchronization with the infra-red scanner, the angular across-track coverage is dependent on the length of arc traversed by the spot, and hence also on the curvature of the film. For a given film curvature there is a minimum distance between the take-up and supply film spools which allows the film to be curved without tearing. It is this distance which to a large extent determines the size of the recording system.

In a modern airborne reconnaissance linescan system, which will typically scan an angle of 90° or more, the infra-red scanning and detection system is comparable in size with the recorder system. In order to reduce the overall size of the equipment to a minimum it is essential to closely integrate the two systems. The total size is then governed by the distance between film spools determined by the criterion given above.

According to the present invention, there is provided a scanning and recording system to be carried by a vehicle, comprising a scanning rotor mounted to rotate about an axis parallel to the direction of motion of said vehicle and having a plurality of reflecting faces, detection means receiving beams reflected from said plurality of reflecting faces and giving a signal output that varies in accordance with beam strength falling thereon, record medium transport means transporting a record medium band along a path extending parallel to said axis of rotation and close to said rotor, recording beam projection means mounted on said rotor to rotate therewith and projecting at least one recording beam radially with respect to said axis of rotation which recording beam passes repeatedly widthwise across said record medium band transported close to said rotor as said rotor rotates, means modulating said recording beam in accordance with variations in the signal output of said detection means, and means constraining said record medium band, in the region of its travel where it is scanned by said recording medium beam, to a widthwise curvature centered on said axis of rotation.

Preferably, for optical scanning, the rotor is of square cross-section with four mirror faces. In the infra red case the detection means will normally be an infra red sensitive electrical cell. All the picture information can be detected by a sensitive surface or surfaces of a single cell if the beams from the rotor faces are focused by collector mirrors having mirror faces which are parts of a paraboloid and an optical element such as a ridge mirror is employed to reflect on to the detector cell beams approaching it on either side from the two collector mirrors.

The arrangement gives space immediately above or alongside the scanning rotor (assuming the field of scan is below the scanner) for further equipment in the system and especially for transport of the record medium. To produce a photographic record in the infra red case the signal output of the detector cell may be employed to modulate a source of white light projected as a focused recording beam for writing on ordinary photographic film.

The same rotor is employed not only to perform the line scan in the viewing optical system but also to provide the line scan for producing the photographic record. If the rotating optical system is a multiple arrangement projecting the recording beam along a number, say four, of equiangularly-spaced radial paths each radial beam or light pencil will pass in succession across the film so writing successive lines thereon as the film travels. By situating the modulated source of white light, e.g. a glow lamp, on the axis of the scanning rotor, at or near one end of the rotor, an exceptionally compact assembly is achieved wherein all the recording optics are carried in or around the rotor.

By way of example, several embodiments of the invention will now be described with reference to the accompanying drawings, which show equipment to be housed in an airborne vehicle, i.e., a drone, for taking an infra red photographic record of the terrain below. In the drawings:

FIG. **1** is an exploded pictorial view of one embodiment,

FIG. **2** is a diagram of the scanning optics seen along the axis of the rotor of the embodiment of FIG. **1**,

FIG. **3** is a pictorial diagram illustrating the operation of the scanning optics of the embodiment of FIG. **1**,

FIG. **4** is a diagram of a film recorder seen in the same direction as that in FIG. **2**,

FIG. **5** shows the film recorder in the direction of the arrow **5** of FIG. **4**,

FIG. **6** is a diagram of the recorder optics seen from the same viewpoint as that in FIG. **5**,

FIG. **7** shows the recorder optics on the line **7**—**7** of FIG. **6**,

FIG. **8** shows diagrammatically an alternative optical system seen looking along the rotor axis,

FIG. **9** is a diagram of another embodiment seen at right angles to the rotor axis,

FIG. **10** is a diagram of yet a further embodiment seen at right angles to the rotor axis, and

FIG. **11** is a view of the embodiment of FIG. **10** along rotor axis.

Referring firstly to FIGS. **1** to **7**, the equipment is designed as a self-contained unit to fit into a drone camera compartment **10** which takes the form generally of a horizontal cylinder. The line scan device consists of a main frame **13** of light alloy supporting two split parabaloid collector mirrors **11**, **12** disposed at either side of an aperture **14** cut into the lower half of the drone skin and structure. Between the two mirrors **11**, **12** spins an optically polished square scanner **15**, rotating at 7,500 rev/min. about a horizontal fore and aft axis to scan the field of view across the terrain beneath the drone through the aperture **14**.

Immediately above and attached to the scanner mounting **16** is a film transport holder **17** and film drive mechanism. Above this, centrally mounted on top of the main frame **13** is the infra red detector **18**, electronics pack **19**, and a DC motor **20** that drives the scanner rotor through a train of gears **21** at the forward end of the structure. The film transport comprises a supply compartment **22** for an unused film cassette at the front end of a compartment **23** for an exposed film cassette at the rear, the film **24** (70mm) travelling substantially horizontally from front to rear between the two. Quick access to the used film cassette is obtained by removing the scanner mounting **16** and film transport **17** in one piece, by loosening four quick-release bolts **25**, leaving the remainder of the line scan in situ, and opening a hatch **26** in an end plate **27** of the compartment **23**. The choice of the four-sided mirror results from the fact that this configuration gives a reasonably optimum collecting area, consistent with a modest power to drive the rotor and furthermore enables a reasonably constant aperture to be presented during the effective scan.

From this arrangement, the largest collecting aperture can be obtained for the drone space and power available. Since power absorbed in windage losses is approximately proportional to the fifth power of the rotor diameter and directly proportional to length it is important to obtain the desired aperture area using a rotor which can be long and have a small diameter, rather than vice versa. The scanner should therefore be designed, firstly, to occupy the maximum length of aperture available in the drone skin and then to have the largest possible diameter within the limit set by the power available to drive it. A system with a square mirror can operate at atmospheric pressure, without the need for a sealed window to enable a lower pressure to be used to reduce windage.

The fixed optical components collect the radiation reflected from the scanning rotor and focus it on to the infra red detector. These surfaces are all reflecting to avoid transmission losses which would occur if lenses were used. The split paraboloid collector mirrors **11**, **12** are used to gather radiation from each side of the rotor **15** and to focus it on to the detector **18** via a small reflecting ridge mirror **28**. The split collectors allow the optical system to have minimum height, and provide space between and above them for the photographic recording equipment. As the materials most transmissive of infra red radiation are opaque to visible radiation reflextive optics have the further advantage that optical alignment can be more easily performed. This is because:

a. materials reflective to I.R. radiation have reasonably high reflectivity at visible wavelengths,

b. the optical power is independent of wavelength. Visual inspection can thus be used instead of electro-optic conversion of I.R. to visible radiation or to an electrical signal proportional to focused intensity and the visible image is identical with the image which will be produced with I.R. radiation except to diffraction limiting effects and scattering from surface imperfections which are both wavelength dependent.

The paraboloid surfaces of the collector mirrors give a resolution better than 1 milliradian about the scanner axis. These mirrors can be made in glass from a single paraboloid and coated with a special gold-contain reflecting surface coating to provide durability and high reflecting properties out to 14 microns wavelength. Such surfaces will not be susceptible to deterioration with time and a salt laden atmosphere, and can be cleaned by hand without fear of damage. Instead of glass, a suitable compression moulded plastic, or a thin plastic coating on an aluminum or honeycomb rigid substrate, may be employed giving savings in production cost and in weight of the system.

The optical system is auto-collimating with the scanner rotor removed so that it can be focused without the need for an external collimated light source.

The varying signal produced by the infra red detector **18**, due to the incoming radiation falling thereon, is used through the medium of a converter unit to modulate white light which then writes upon the photographic film. For this purpose, the square scanner rotor **15** is hollow with an enlargement mid-way along its length constituting a housing **29** for recorder optics. Into one end of the hollow rotor there projects a stationary glow tube **30** the light output of which is modulated in accordance with the signal output of the infra red detector **28**. This light is focused into a beam by a lens **31** and passes axially through the rotor to be reflected back at the far end by a mirror **32**.

The rotating housing **29** contains a central assembly of mirrors or prisms **33** that reflect the return beam from the mirror **32** out radially along four paths spaced at 90° angles. In each of these radial paths there is a lens system **34** for focusing the respective beam on to the film **24** above the scanner rotor. The four beams so focused traverse the width of the film in succession as the scanner rotates and thereby "write" four successive lines of the film record. To maintain correct focus, the film is constrained by a curved guide so that, in the region of its travel where the lines of the record are written on it, it is curved widthwise about the axis of the scanner rotor. The speed of the scanner rotor is constant while the film transport speed can be varied to suit the speed of the vehicle.

The whole of the detecting and recording assembly thus forms a particularly compact assembly.

Referring now to FIG. **8**, this shows an alternative optical system. The square scanning rotor **15** is, in this case, flanked by two focusing collector mirrors **40**, **41** which reflect energy collected from the scanner faces on to two IR detector cells **42**, **43**, respectively, which detector cells are situated between the mirrors and the scanning rotor approximately on the same horizontal level as the rotor axis. As the system scans, the recovered IR energy varies from a maximum on the cell **43** and a minimum on the cell **42** to a minimum on cell **43** and a maximum on the cell **42**. At the vertical position of the scanning beam the energy is equally divided between the two detector cells. To ensure a constant IR conversion gain at all across-track angles the outputs of cells **42** and **43** are added, after amplification by amplifiers **44**, **45**, and a balance potentiometer **46** is preset to compensate for production differences in detector efficiency and amplifier gain.

The mirrors **40** and **41** are sections of a parabola of sufficient length to collect energy from the full length of the rotor which will have a length to width ratio of typically 4 : 1.

FIG. **9** shows diagrammatically another embodiment. The scanner in this system is a double-sided plane mirror **47**, rotating about a horizontal axis **48** at 45° to the mirror face. Radiation reflected from the mirror **47** is collected by parabolic mirror segments **49**, **50** disposed on the axis **48** at opposite sides of the mirror **47** and is focused via plane mirrors **51**, **52** on to detector cells **53**, **54**. The video signal from each detector cell is used to modulate the output of a light source **55** or **56**, disposed at the opposite side of the mirror **47**, the light from which is reflected by a mirror surface **57** on the IR scanning mirror **47** to a microscope objective **58**. The image from this objective is scanned across the moving film **24**, constrained in an arc about the scanner rotational axis as in FIG. **7**. The scanning mirror **47** is made double-sided, and the system symmetrical, in order to give two scans per revolution. The detector cells and light sources are housed in a tube **59** along the scanner axis **48** such that the remainder of the system rotates about them.

FIGS. **10** and **11** show a system using a four-sided pyramid mirror scanner **60**. This scans the radiation received by a fixed spherical collector mirror **61**, disposed above the rotor, via four rotating infra red transfer lenses **62**, one corresponding to each face of the scanner mirror **60**. A circular field stop **63** is disposed about the scanner axis **64** to control the selection of the area of mirror **61** from which radiation is reflected onto the detector cell **65** so that no unique axis exists. The possibility of extra-axial aberrations is thereby avoided. The radiation from the faces of the scanner **60** is directed to a detector cell **65**, the video signal from which is used to modulate a light source **66** disposed on the scanner axis. Light from the source **66** is directed via a second rotary four-sided pyramid mirror **67**, mounted back to back with the scanner **60**, to each of four microscope objectives **68** positioned adjacent to the infra red lenses **62**. The film record transport **69** is positioned to one side of the scanner and the film **24** is exposed, over an arc equal to the arc scanned by the detector, to the beam from each objective in turn.

In all these systems the detector cell is not limited to a single infra red-sensitive element but can be multielement, the recorders then having a corresponding number of individually modulated light sources.

What I claim is:

1. A scanning and recording system to be carried by a vehicle, comprising a scanning rotor mounted to rotate about an axis parallel to the direction of motion of said vehicle and having a plurality of reflecting faces, detection means receiving beams reflected from said plurality of reflecting faces and giving a signal output that varies in accordance with beam strength falling thereon, record medium transport means transporting a record medium band along a path extending parallel to said axis of rotation and close to said rotor, recording beam projection means mounted on said rotor to rotate therewith and projecting at least one recording beam radially with respect to said axis of rotation which recording beam passes repeatedly widthwise across said record medium band transported close to said rotor as said rotor rotates, means modulating said recording beam in accordance with variations in the signal output of said detection means, and means constraining said record medium band, in the region of its travel where it is scanned by said recording beam, to a widthwise curvature centered on said axis of rotation.

2. A system according to claim **1**, wherein the scanning is optical scanning and said detection means is at least one infra red sensitive cell.

3. A system according to claim **1**, wherein said rotor is generally of square cross-section with four equiangularly-disposed mirror faces.

4. A system according to claim **1**, wherein the rotor comprises a double-sided plane mirror set in a plane at 45° to the axis of rotation, and focusing mirrors disposed at opposite sides of said plane mirror and centered on the rotor axis to collect and focus the beams from said plane mirror on to said detection means.

5. A system according to claim **1**, wherein the rotor comprises a four-sided pyramidal mirror which reflects on to said detection means the radiation from a fixed spherical collector mirror.

6. A system according to claim **1**, disposed in an aerial vehicle for scanning the terrestrial scene below and mounted in an open compartment at ambient atmospheric pressure.

7. A system according to claim **1**, wherein said recording beam projection means comprises multiple optical focusing systems projecting said recording beam along a plurality of equiangularly-spaced radial paths, whereby plural radial beams pass in succession across said record medium band so recording successive lines thereon as said record medium band travels.

8. A system according to claim **7**, wherein a light source modulated in accordance with said detector means signal output is disposed on the axis of said rotor, and said recording beam projection beams further comprises central reflecting optical means within said rotor, the light from said modulated light source passing axially within the rotor and being reflected to said multiple optical systems by said central reflecting optical means.

9. A system according to claim **1**, further comprising twin fixed focusing reflectors situated one on either side of said rotor, to reflect beams from the faces thereof on to said detection means.

10. A system according to claim **9**, wherein said fixed focusing reflectors are mirrors with their reflecting faces forming parts of a paraboloid and disposed to reflect beams from said rotor faces upward in two mutually converging beams, and a ridge mirror is situated and oriented to reflect on to said detection means beams approaching it on either side from said two fixed paraboloid mirrors.

11. A system according to claim **10**, wherein said record medium band is transported between said mutually converging beans, and between said detection means and said rotor.

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