Nov. 25, 1969 D. E. LORENZI 3,480,855

IMAGE DISSECTOR SYSTEM HAVING PATTERN ROTATION MEANS

Filed April 10, 1967 3 Sheets-Sheet 1

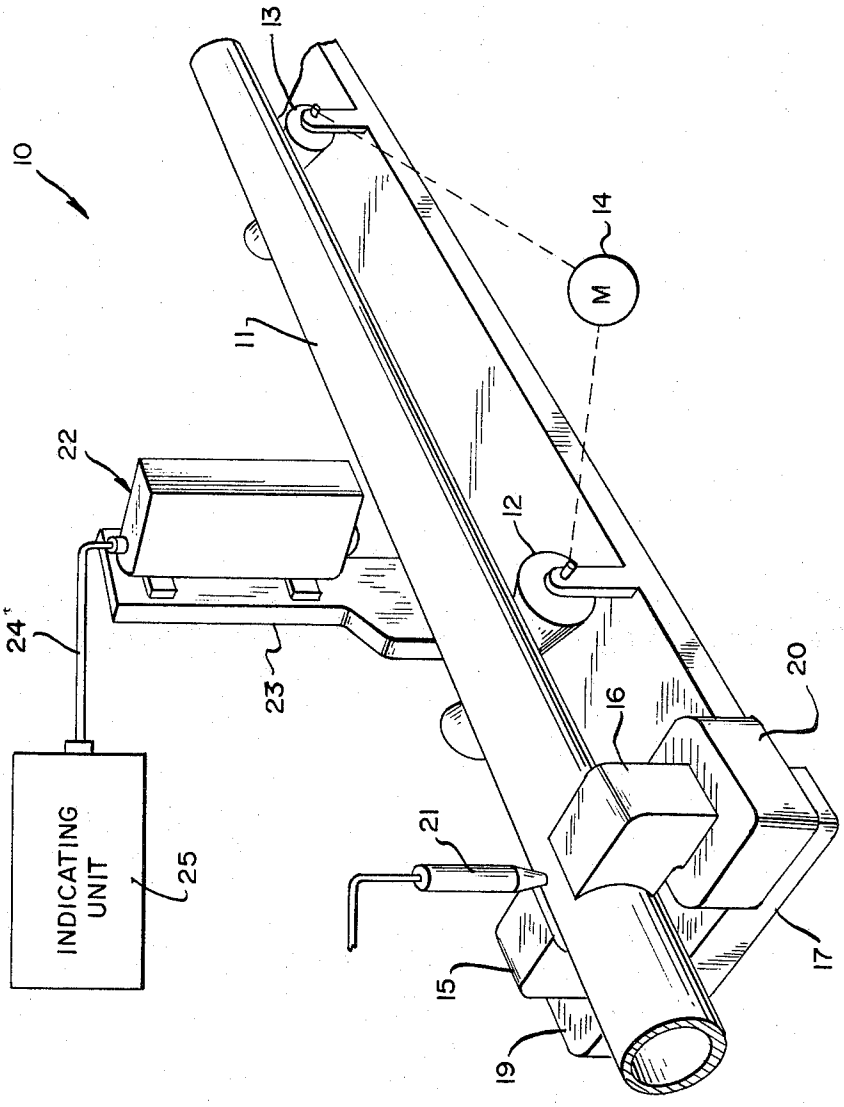


FIG. 1

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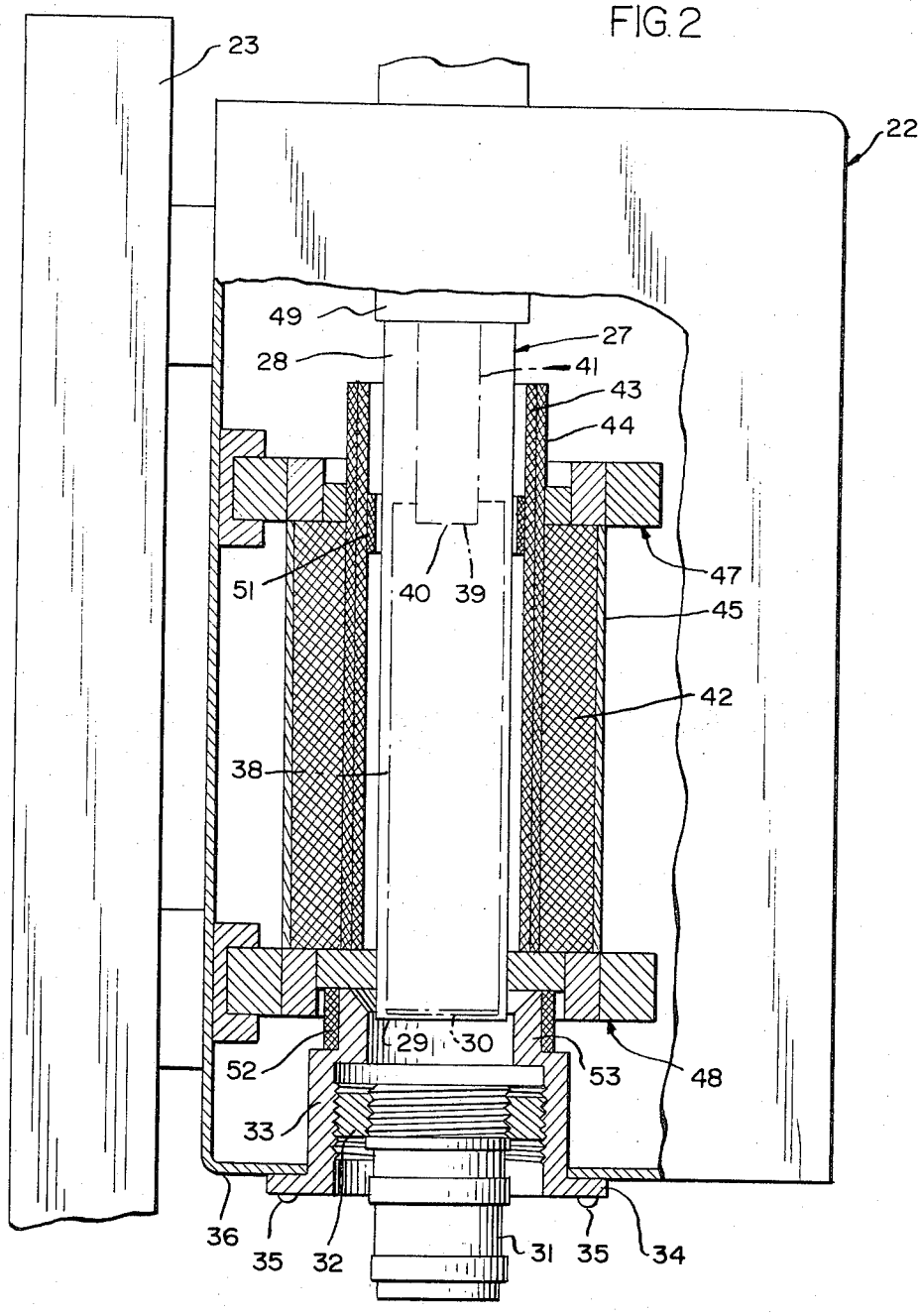
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IMAGE DISSECTOR SYSTEM HAVING PATTERN ROTATION MEANS

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FIG. 2



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FIG.3

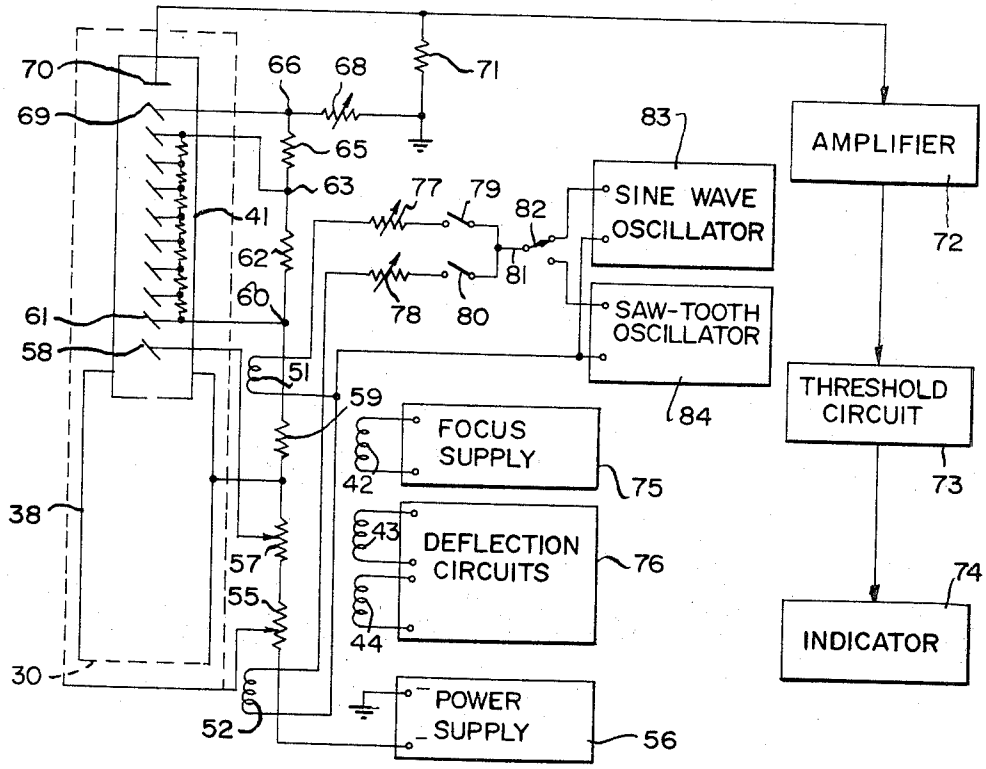


FIG.4

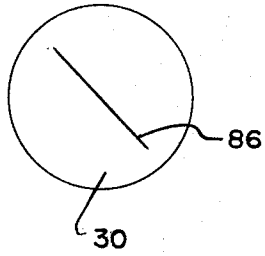


FIG.5

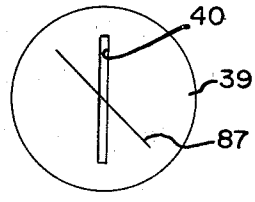
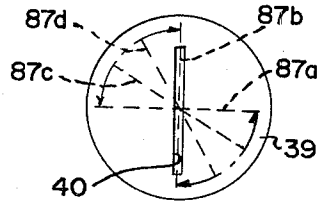


FIG.6



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IMAGE DISSECTOR SYSTEM HAVING PATTERN ROTATION MEANS

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U.S. Cl. 324—38 16 Claims

ABSTRACT OF THE DISCLOSURE

Image dissector system illustrated in use in sensing flaw indications produced on the surface of a part by application of magnetic particles to the surface while magnetizing the part. The system can be used in other applications. An image of the part surface is focused on a photocathode which emits electrons in a pattern corresponding to the image to travel to an aperture in a plane spaced from the cathode plane, an output electrical signal being produced in response to electrons passed through the aperture. During travel from the cathode to the aperture plane, the electron pattern is controllably rotated which may be accomplished magnetically through a coil located either in the cathode plane or the aperture plane, to produce a magnetic field extending radially with respect to the axis of rotation of the pattern. The aperture is preferably a narrow slit extending radially with respect to the axis of rotation and the electron pattern is preferably oscillated about the axis of rotation. The arrangement achieves a high degree of sensitivity to indications while accommodating wide variations in the orientation of the indications.

This invention relates to an image dissector system and more particularly to an image dissector system which has a high degree of sensitivity to indications while accommodating wide variations in the relative location of the indications. The system of this invention is relatively simple and yet is highly effective and reliable in operation.

Image dissector systems have heretofore been proposed in which an image dissector tube is provided having a photocathode and an aperture in spaced planes, with an electrical signal being produced in response to electrons passed through the aperture, a high degree of sensitivity being obtained through the use of an electron multiplier responsive to the electrons passed through the aperture. With an image focused on the photocathode, a pattern of electrons is developed which drifts from the cathode to the aperture plane, and suitable focusing means such as a coil encircling the tube, may be used for causing the electrons to assume the same pattern at the aperture plane as they assumed when emitted from the photocathode. With an aperture in the form of a narrow slit, a high degree of sensitivity can be obtained to narrow elongated portions of the image focused on the photocathode.

It has been found, however, that in practice such image dissector systems are not always satisfactory in that they require precise positioning of the image dissector tube with respect to the indications to be detected, while such indications do not always have exactly the same orientation. As a result, indications may be missed which it would be desirable to detect, and the reliability and usefulness of the systems has been impaired.

In accordance with this invention, rotation means are provided for controllably rotating the electron pattern arriving at the aperture plane relative to the image, so as to permit maximum sensitivity to an area of the image corresponding to the aperture.

Preferably and in accordance with a specific feature of the invention, the rotation means comprises means for

developing a magnetic field in the image dissector tube extending radially with respect to an axis of rotation generally parallel to the direction of travel of electrons from the cathode to the aperture plane. With this feature, the rotation can be effected without physically rotating the dissector tube.

According to a further specific feature of the invention, the magnetic field is developed by means of a coil having an axis generally parallel to the direction of travel of electrons from the cathode to the aperture plane. The coil is preferably located generally in alignment with either the plane of the photocathode or with the aperture plane, so as to develop the magnetic field in the region between the photocathode and the aperture plane, extending generally radially outwardly with respect to the axis of the coil.

According to a further feature of the invention, means are provided for oscillating the electron pattern relative to the aperture through a certain arcuate distance, to permit detection of indications oriented within a certain range of angles. Preferably, the oscillating means may comprise means for applying an oscillatory current to the magnetic field developing means. The oscillatory current may have a sinusoidal form or may have some other form such as a sawtooth form.

According to still another feature of the invention, the aperture is a narrow slit which permits response to narrow elongated indications.

The system has a wide variety of applications, but according to still another feature of the invention, it is applied to a magnetic particle inspection system wherein magnetic particles are applied to the surface of a test object during or after magnetization of the object, to develop indications in response to flaws within the object. The system is particularly advantageous in combination with a magnetic particle inspection system in that the flaw indications can be readily detected within a wide range of orientations, while the system discriminates against variables which it is not desired to detect.

This invention contemplates other objects, features and advantages which will become more fully apparent from the following detailed description taken in conjunction with the accompanying drawings which illustrate a preferred embodiment and in which:

FIGURE 1 is a diagrammatic perspective view of magnetic particle inspection apparatus incorporating an image dissector system constructed in accordance with the principles of this invention;

FIGURE 2 is a side elevational view, partly in cross-section, illustrating the construction of an image dissector unit of the system shown in FIGURE 1;

FIGURE 3 is a circuit diagram of the image dissector system; and

FIGURES 4, 5 and 6 are views illustrating diagrammatically the relationship between image patterns and an aperture in the system, for explaining the operation thereof.

Referring to the drawings, reference numeral **10** generally designates magnetic particle inspection apparatus incorporating an image dissector system constructed according to the principles of the invention.

In the illustrated magnetic particle inspection apparatus **10**, a pipe **11** is supported by rollers **12** and **13**, which may be driven by a motor **14** as diagrammatically illustrated. The pipe **11** passes between pole pieces **15** and **16** of a magnetic yoke structure **17** on which coils **19** and **20** are provided, connected to a source of direct current (not shown) so as to develop magnetic flux passing transversely through the pipe **11**, which may have a welded seam extending longitudinally along the upper side thereof. Magnetic particles may be applied to the pipe

during or after magnetization thereof by means of a suitable noxzzle **21**, the magnetic particles being carried in a suitable liquid. The magnetic particles are attracted and localized over any cracks or other flaws in the seam portion of the pipe **11**. The image dissector system is provided for detecting such indications.

The image dissector system comprises a sensing unit **22** which is supported by suitable support **23** over the pipe **11** and which is connected through a cable **24** to an indicating unit **25**.

The construction of the sensing unit **22** is shown in FIGURE 2. The unit comprises an image dissector tube **27** having a cylindrical glass envelope **28** with a generally planar end wall **29** behind which a photocathode **30** is disposed. The image from an upper surface portion of the pipe **11** is focused on the cathode **30** by means of lenses within a lens mount **31** which is threaded into a rotatable support ring **32** the support ring **32** being threaded in a fixed support ring **33** having an annular flange portion **34** secured by suitable screws **35** to a housing **36** of the unit **22**. By rotation of the lens mount **31** and the support ring **32**, the distance from the lenses to the photocathode **30** may be adjusted to obtain a sharp focus of an image from the upper surface of the pipe **11**.

The focusing of the image on the photocathode **30** causes the emission of electrons from the cathode **30** in a pattern corresponding to the image. The electrons drift upwardly within a drift-tube section **38** of the tube **27** and impinge upon a wall **39** having an aperture **40** therein, the aperture **40** being preferably in the form of a narrow slit intersecting the axis of the image dissector tube **27**. Electrons passing through the aperture **40** are applied to an image-multiplier section **41** which develops an output electrical signal proportional to the instantaneous value of the electron current through the aperture **40**.

To keep the electron in a pattern corresponding to the electron pattern emitted from the photocathode **30**, a focusing coil **42** is provided around the tube **27** and having its axis aligned with that the tube **27**. Horizontal and vertical deflection coils **43** and **44** are provided for control of the deflection of the pattern in directions transverse to each other and transverse to the axis of the tube **27**. A shield **45** is disposed around the focusing coil **42** and suitable support and clamp ring assemblies **47** and **48** are provided for supporting the coils from a wall of the housing **36**. Terminals at the upper end of the tube **27** are inserted in a suitable socket **49** for connection to electronic circuitry as hereinafter described.

According to this invention, means are provided for controllably rotating the pattern of electrons arriving at the plane of the aperture **40** relative to the aperture. In particular, a pair of coils **51** and **52** are provided either or both of which may be used. The coil **51** surrounds the tube **27** and is mounted inside the deflection coil **43** generally in the aperture plane. The coil **52** is wound on a reduced-diameter portion **53** of the fixed support ring **33** and surrounds the lower end portion of the tube **27** so as to be generally in the plane of the photocathode **30**. When a current is passed through either of the coils **51** or **52**, a magnetic field is developed which extends through the region between the cathode plane and the aperture plane and which extends radially outwardly from the axis of the coils. When the electron pattern is passed through a field so developed, it is rotated to a certain extent dependent upon the speed of travel of the electrons and the intensity of the field. Thus electrons moving along the axis of the coils are not deflected but electrons moving along a line spaced from the axis are deflected through an angular distance proportional to the distance from the axis while keeping the same substantial distance from the axis. Accordingly, the entire electron pattern is rotated through an angular distance proportional to the intensity of the magnetic field. It should be noted that it is important that the coil be located generally in either the cathode plane or the aperture plane to develop a magnetic field which will perform the rotation operation. If a coil were located mid-way between the cathode and aperture planes, the fields produced from opposite ends of the coil would neutralize each other by effecting rotation of the image first in one direction and then in the opposite direction.

FIGURE 3 illustrates the circuitry of the system. The photocathode **30** is connected to the movable contact of a potentiometer **55** having one terminal connected to the negative terminal of a power supply **56**, the positive terminal of the supply **56** being connected to ground. The other terminal of potentiometer **55** is connected to one terminal of a potentiometer **57** having a movable contact connected to a first dynode **58** of the electron multiplier section **41**. The other terminal of potentiometer **57** is connected to the drift tube **38** and through a resistor **59** to a circuit point **60** which is connected to a second dynode **61** and also through a resistor **62** to a circuit point **63** which is connected to a ninth dynode **64**. The third through eighth dynodes are interconnected with each other and to the second and ninth dynodes through an internal resistance voltage divider. Circuit point **63** is connected through a resistor **65** to a tenth dynode **67** and through an adjustable resistor **68** to ground. An anode **70** is connected through a load resistor **71** to ground and is also connected to the input of an amplifier **72** having an output connected through a threshold circuit **73** to an indicator **74** which may be in the form of a suitable meter, an indicating light, an audible device, a recorder, or any other type of indicator.

The focusing coil **42** is connected to a focus supply **75** while the deflection coils **43** and **44** are connected to a suitable deflection circuit **76**.

The image rotator coils **51** and **52** are connected through adjustable resistors **77** and **78** and through switches **79** and **80** to a line **81** which is connected through a selector switch **82** either to the output of a sine wave oscillator **83** or a sawtooth oscillator **84** the other output terminals of the oscillators **83** and **84** being connected to terminals of both coils **51** and **52**. With this arrangement, either a sine wave signal or a sawtooth signal may be applied to either or both of the coils **51** and **52**, and the amplitude of the current applied through the coils may be adjusted by adjustment of the resistors **77** and **78**. It will be understood that both coils are not always necessary, and a system can be provided using only one of the coils.

FIGURE 4 illustrates diagrammatically the orientation of the image **86** of a flaw indication on the photocathode **30**, and FIGURE 5 illustrates the corresponding electron image **87** produced at the plane of the aperture **40** from the image **86**, without any rotation. It will be observed that only a small portion of the electron image **87** crosses the aperture **40** and therefore the electrical output of the dissector tube would be quite low. FIGURE 6 illustrates how the electron image may be rotated through a certain arcuate range through application of oscillatory current to one or both of the rotator coils **51** or **52**. Dotted line **87***a* illustrates the position of the electron image when the oscillatory current has a maximum value in one direction while dotted line **87***b* illustrates the position of the electron image with current having a maximum value in the reverse direction. Dotted lines **87***c* and **87***d* illustrate the positions of the electron image with lesser currents applied. It will be observed that when the image is in the position as indicated by dotted line **87***d*, the image is aligned with the aperture **40** and a maximum indication is obtained, while low indications are obtained with the electron image in the position as indicated by dotted lines **87***a*, **87***c* and **87***d*.

Thus in the illustration of FIGURES 4–6, the system will produce a large output indication even with the image of an indication in a position displaced approximately 45 degrees from that at which a maximum indication would

be obtained without rotation of the image. It will be apparent that a maximum indication would also be obtained with the image rotated 45 degrees in the opposite direction and that with any image orientation within a 90 degree range, a maximum indication can be obtained. It should further be noted that the image can be rotated through a greater range through application of higher currents to the image rotator coil or coils.

An additional advantage of the system is that a very narrow aperture can be used to improve the resolution capabilities of the system. Thus a slit may be used which without the image rotation would reduce the output signal by 50% with a departure from alignment with the slit of only 1 degree. The invention assures parallelism by rotating the electron-optical image within the camera tube at a predetermined rate through an arc symmetrical about the center of the camera's aperture.

It should further be noted that scanning signals can be applied to the deflection coils **43** and **44** during application of the rotation signal, thus permitting scanning of a substantial area of the surface of the part under inspection.

I claim as my invention:

1. In an image dissector system, an image dissector tube including means defining an aperture in an aperture plane, a photocathode in a cathode plane in spaced relation to said aperture plane, and means for producing an electrical signal in response to electrons passing through said aperture, image forming means for forming an image to be dissected, lens means for focusing said image on said photocathode to cause emission of electrons and travel of electrons from said cathode plane to said aperture plane in an electron pattern corresponding to said image, and rotation means for controllably rotating said electron pattern arriving at said aperture plane relative to said aperture about a central axis of rotation generally parallel to the direction of travel of electrons from said cathode plane to said aperture plane.

2. In an image dissector system as defined in claim **1**, said rotation means comprising means for developing a magnetic field in said image dissector tube extending radially with respect to said central axis of rotation.

3. In an image dissector system as defined in claim **2**, said magnetic field developing means comprising a coil having an axis generally aligned with said central axis of rotation.

4. In an image dissector system as defined in claim **3**, said coil being located generally in alignment with one of said planes.

5. In an image dissector system as defined in claim **4**, said coil being located generally in alignment with said aperture plane.

6. In an image dissector system as defined in claim **4**, said coil being located generally in alignment with said cathode plane.

7. In an image dissector system as defined in claim **2**, means for applying an oscillatory current to said magnetic field developing means to oscillate said pattern.

8. In an image dissector system as defined in claim **7**, said oscillatory current having a generally sinusoidal form.

9. In an image dissector system as defined in claim **7**, said oscillatory current having a generally sawtooth form.

10. In an image dissector system as defined in claim **1**, said aperture being in the form of a narrow slit extending generally radially relative to said central axis of rotation.

11. In an image dissector system as defined in claim **1**, said rotation means including means for oscillating said electron pattern through a certain arcuate distance.

12. In an image dissector system as defined in claim **1**, said image forming means comprising means for supporting a test object with a surface thereof opposite said lens means to cause focusing of an image of said surface on said photocathode.

13. In an image dissector system as defined in claim **12**, means for effecting relative movement between said test object and said image dissector tube to effect scanning of said surface.

14. In an image dissector system as defined in claim **12**, means for applying a magnetic field to said test object, and means for applying magnetic particles to said test object to develop flaw indications on said surface thereof.

15. In an image dissector system as defined in claim **1**, deflection means for deflecting said electron pattern in at least one direction transverse to the axis of rotation of said pattern.

16. In an image dissector system as defined in claim **1**, said rotation means comprising a coil located generally in alignment with one of said planes and having an axis generally aligned with said central axis of rotation and means for applying an oscillatory current to said coil to rotate said electron pattern about said central axis of rotation, said aperture being in the form of a narrow slit extending generally radially relative to said axis.

References Cited

UNITED STATES PATENTS

2,135,149	11/1938	Rutherford	315—11 X
2,632,864	3/1953	Hunter	315—24
3,073,212	1/1963	Dunsheath et al.	324—38 X
3,329,856	7/1967	Foote	315—11
3,295,010	12/1966	Clayton	315—11

ALFRED E. SMITH, Primary Examiner

U.S. Cl. X.R.

178—7.2; 315—18, 23