Aug. 29, 1967 S. K. HILAL 3,339,076

DUAL DIFFERENTIAL DENSITOMETER

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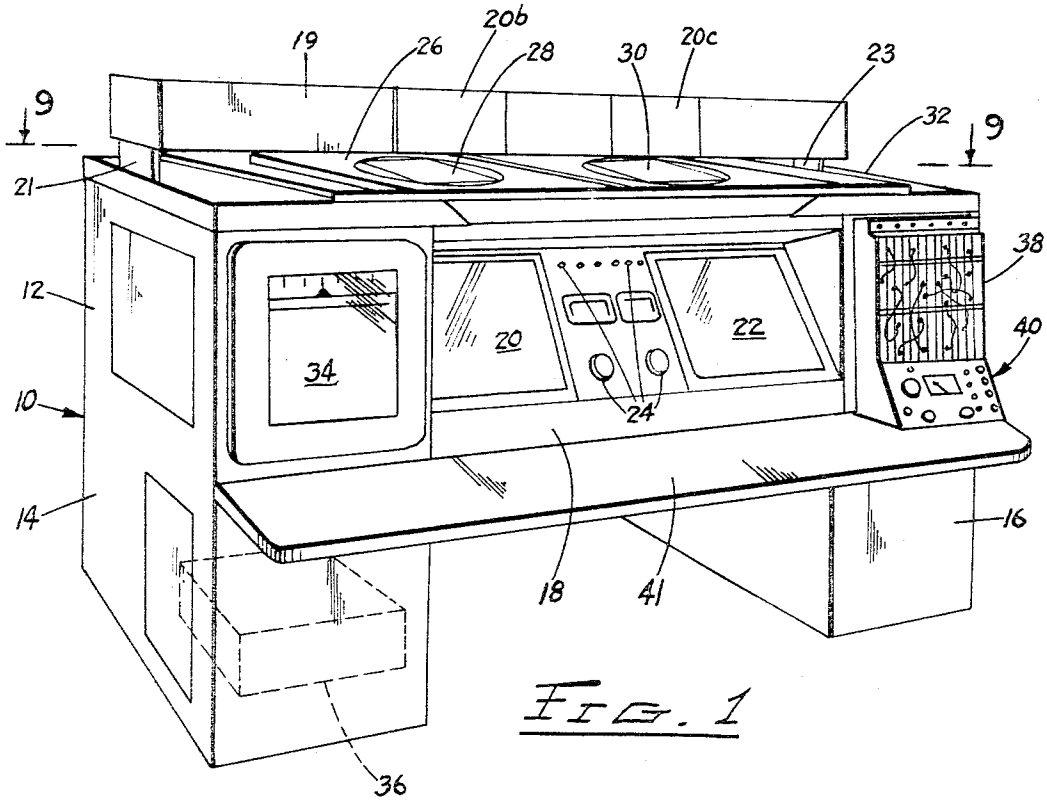


FIG. 1

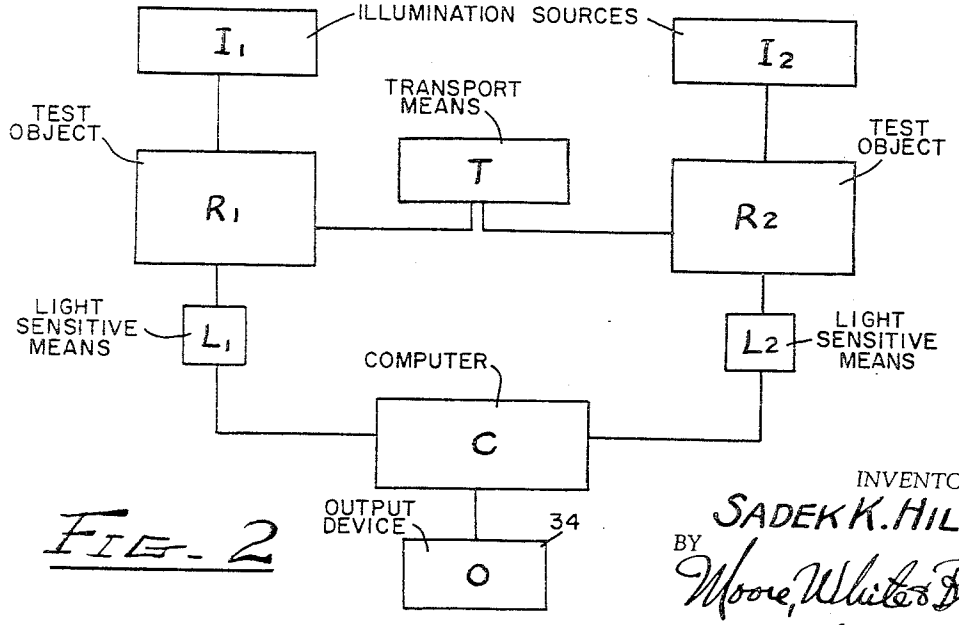


FIG. 2

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DUAL DIFFERENTIAL DENSITOMETER

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FIG. 3

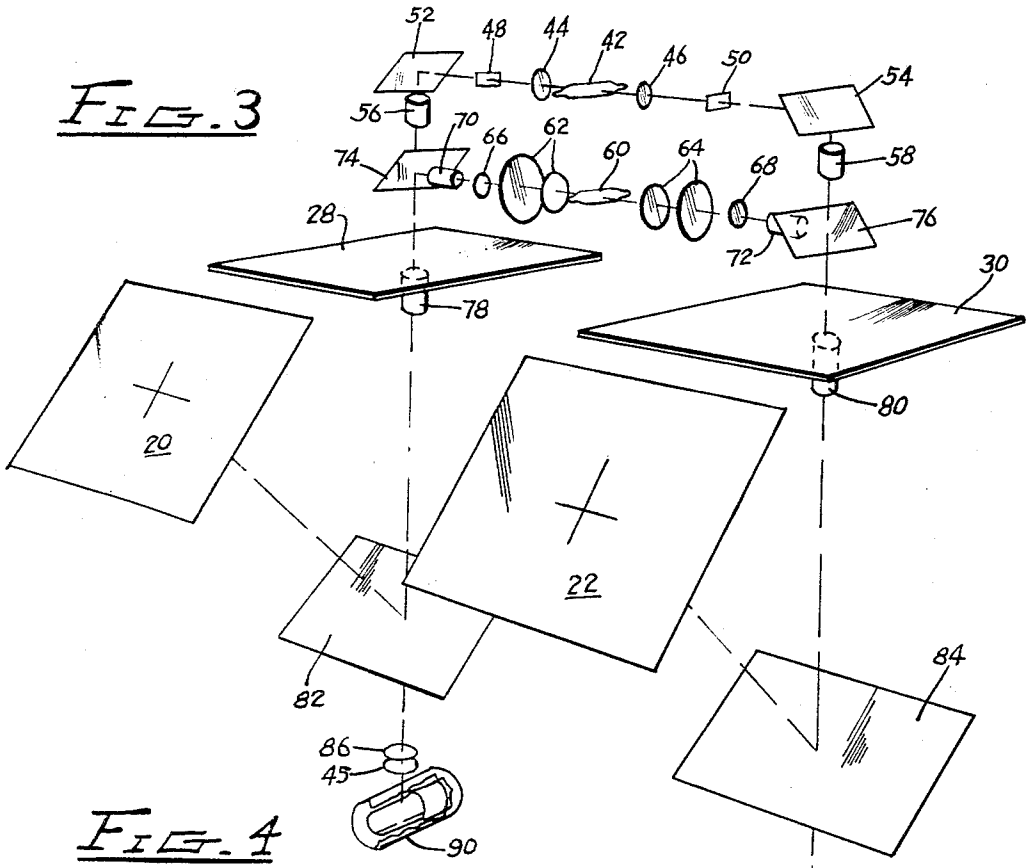
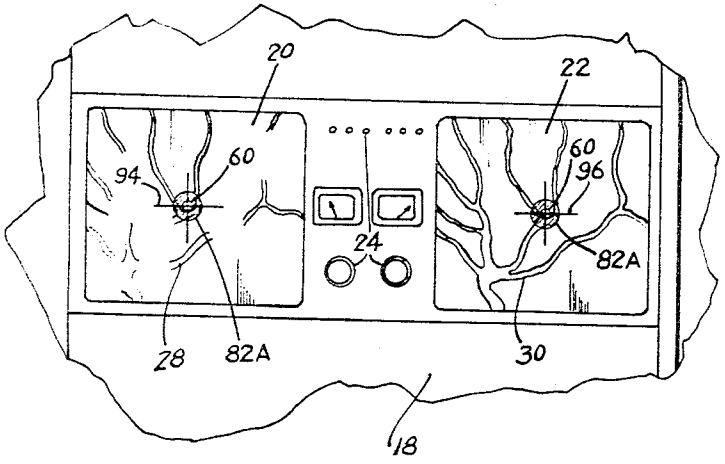


FIG. 4



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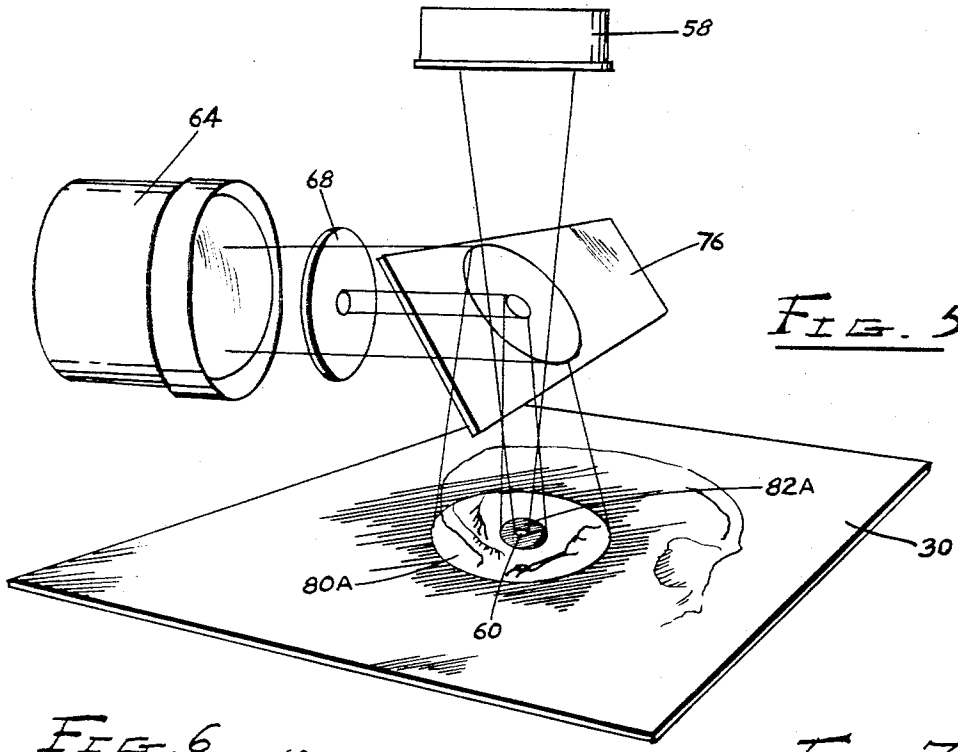


FIG. 5

FIG. 6

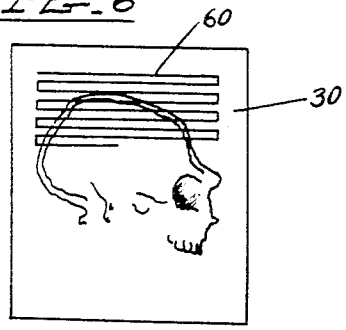
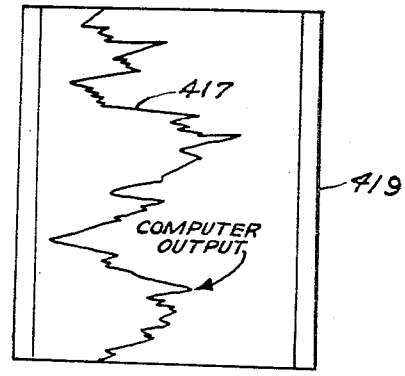


FIG. 7



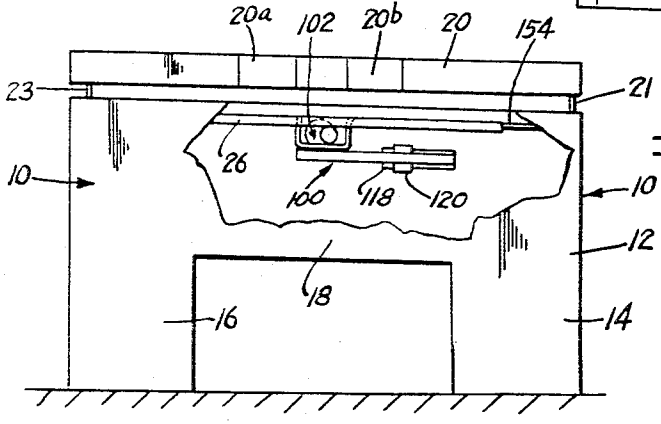


FIG. 8

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Aug. 29, 1967 S. K. HILAL 3,339,076

DUAL DIFFERENTIAL DENSITOMETER

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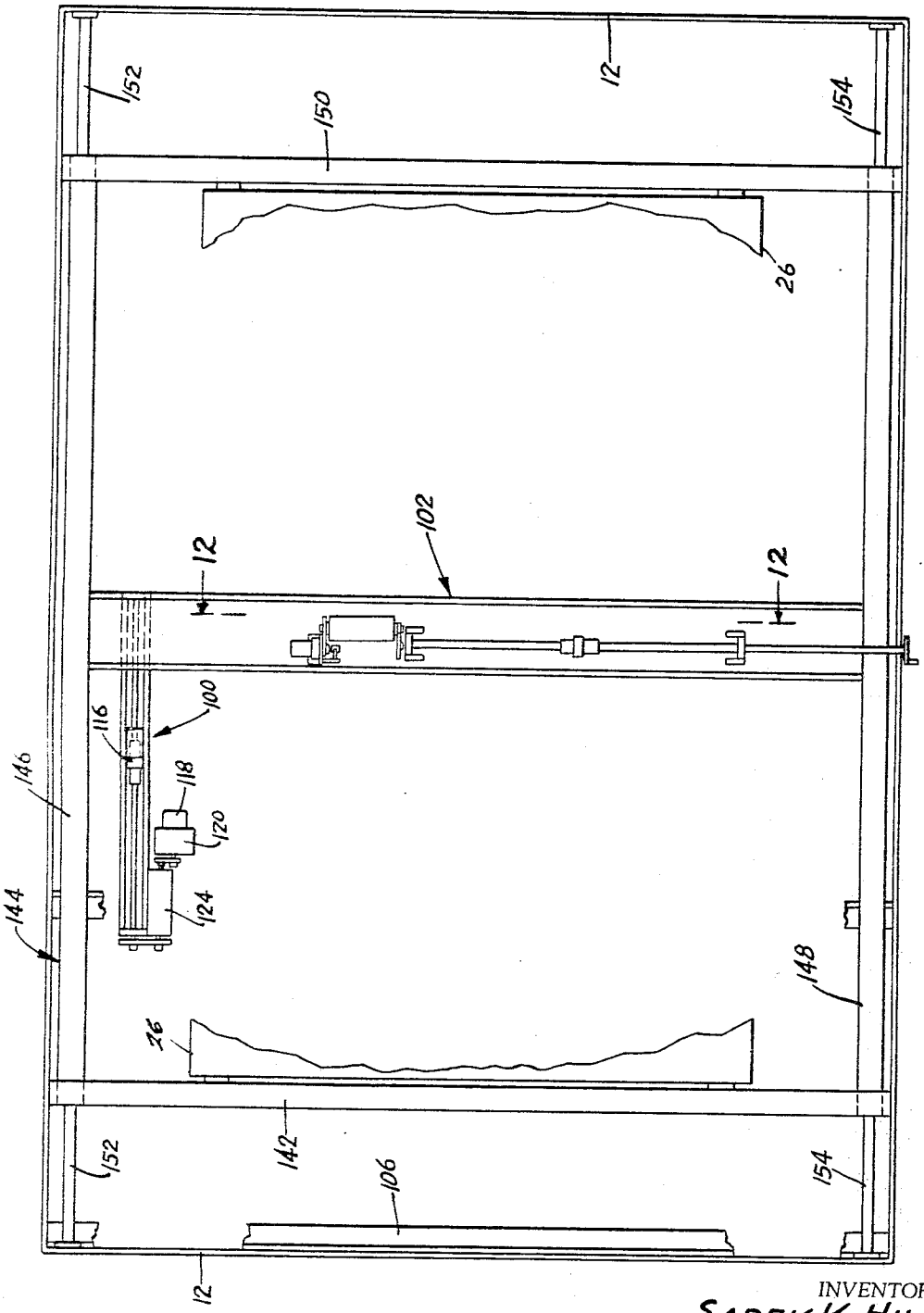


FIG. 9

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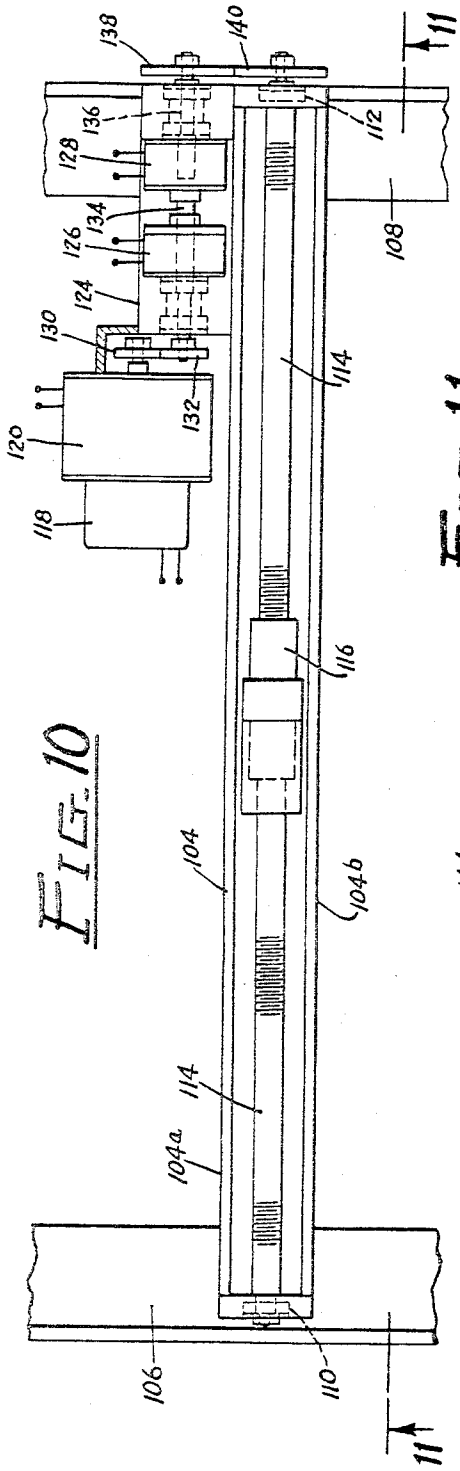


FIG. 10

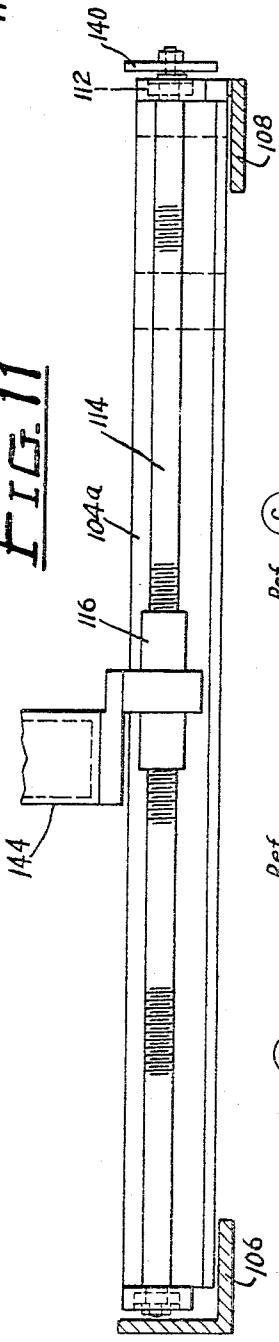


FIG. 11

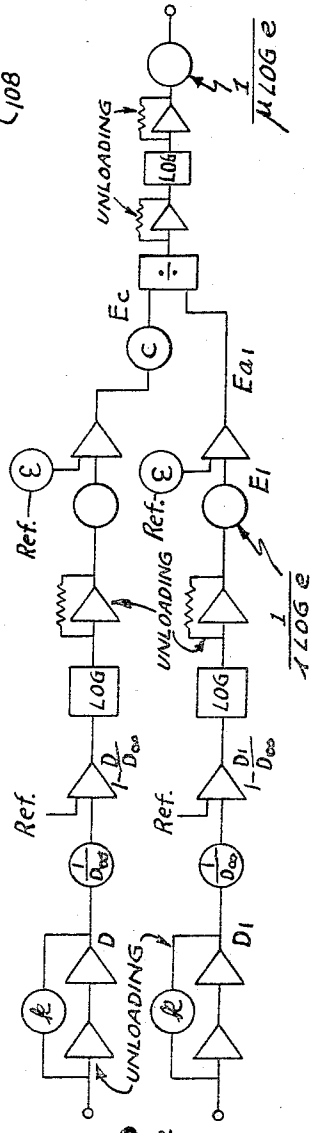


FIG. 22

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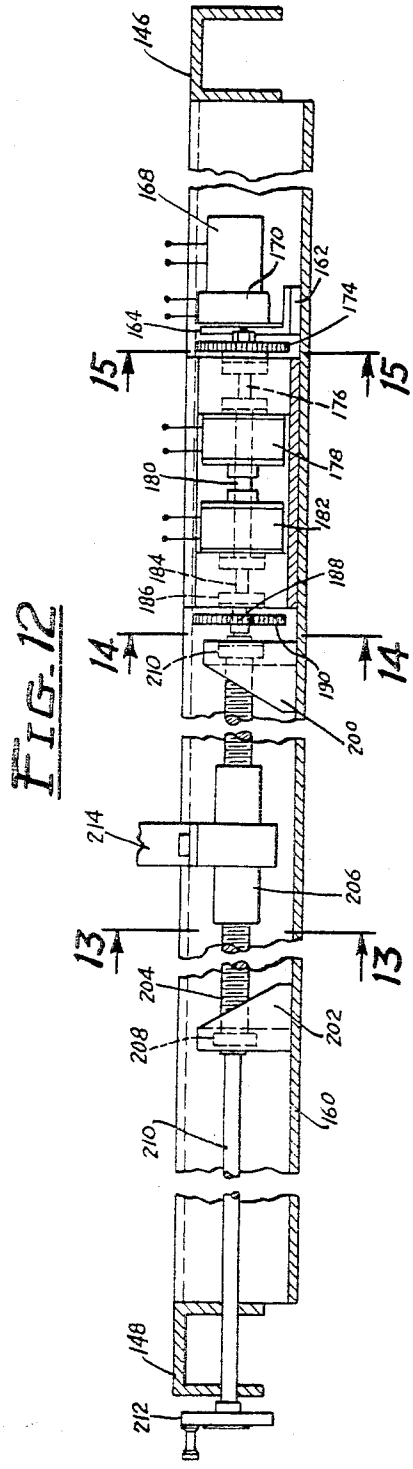


FIG. 12

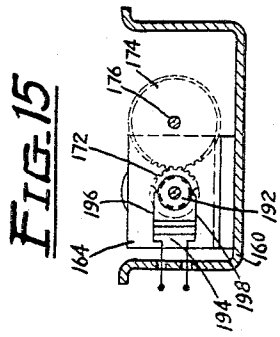


FIG. 15

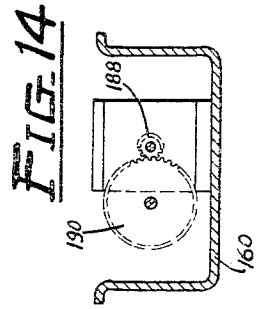


FIG. 14

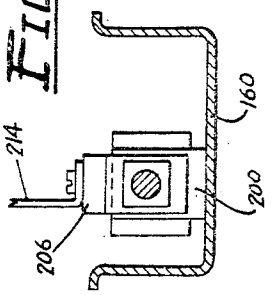


FIG. 13

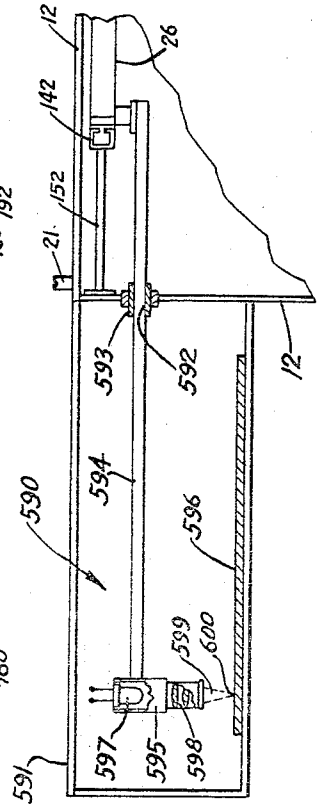


FIG. 21

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DUAL DIFFERENTIAL DENSITOMETER

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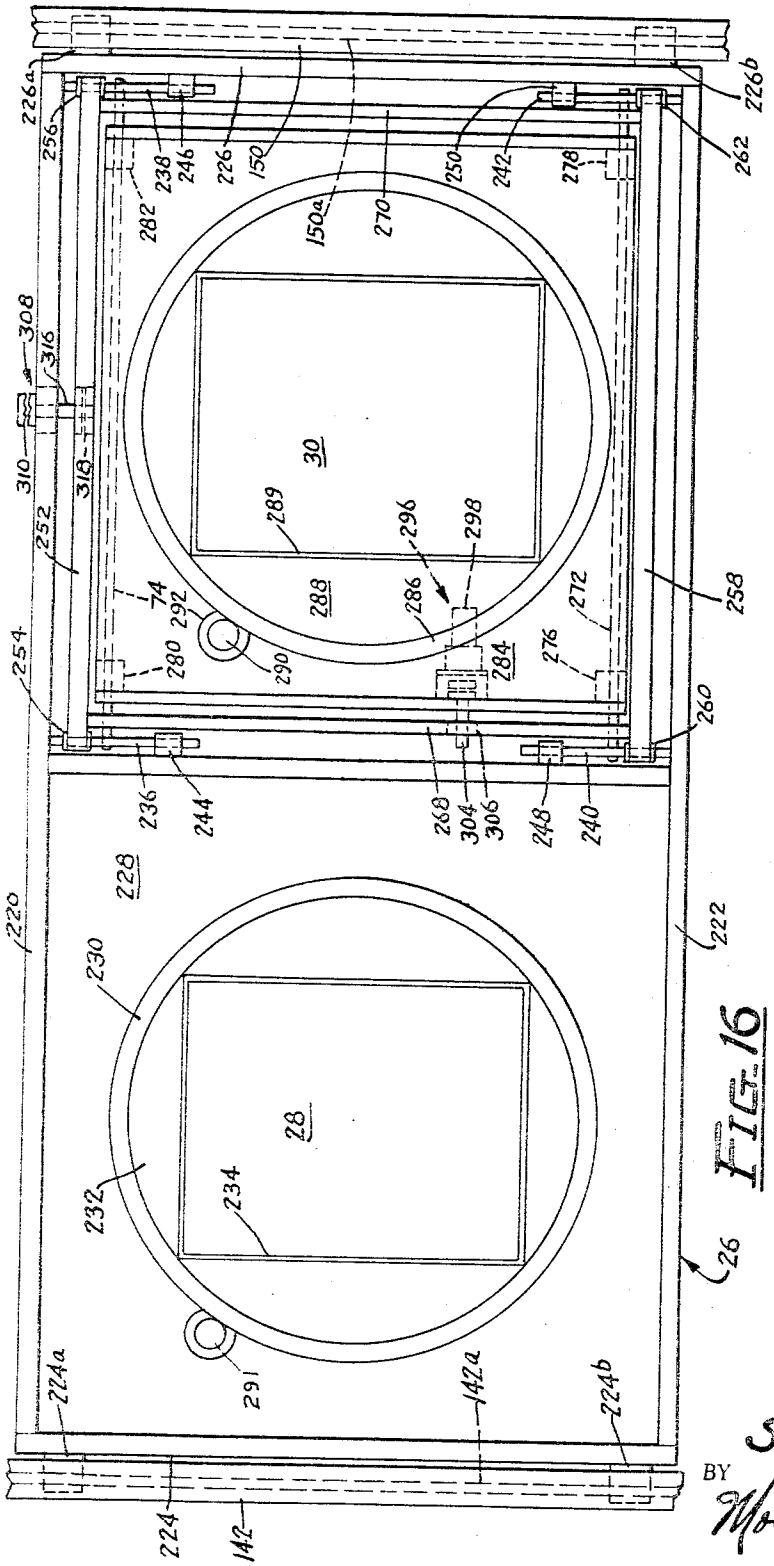


FIG. 16

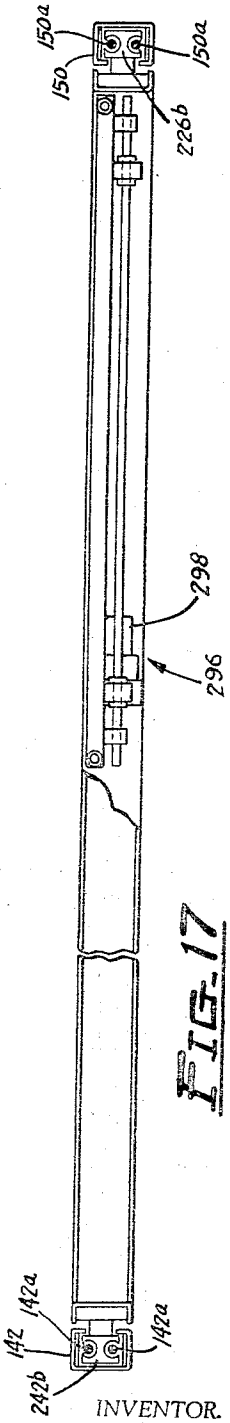


FIG. 17

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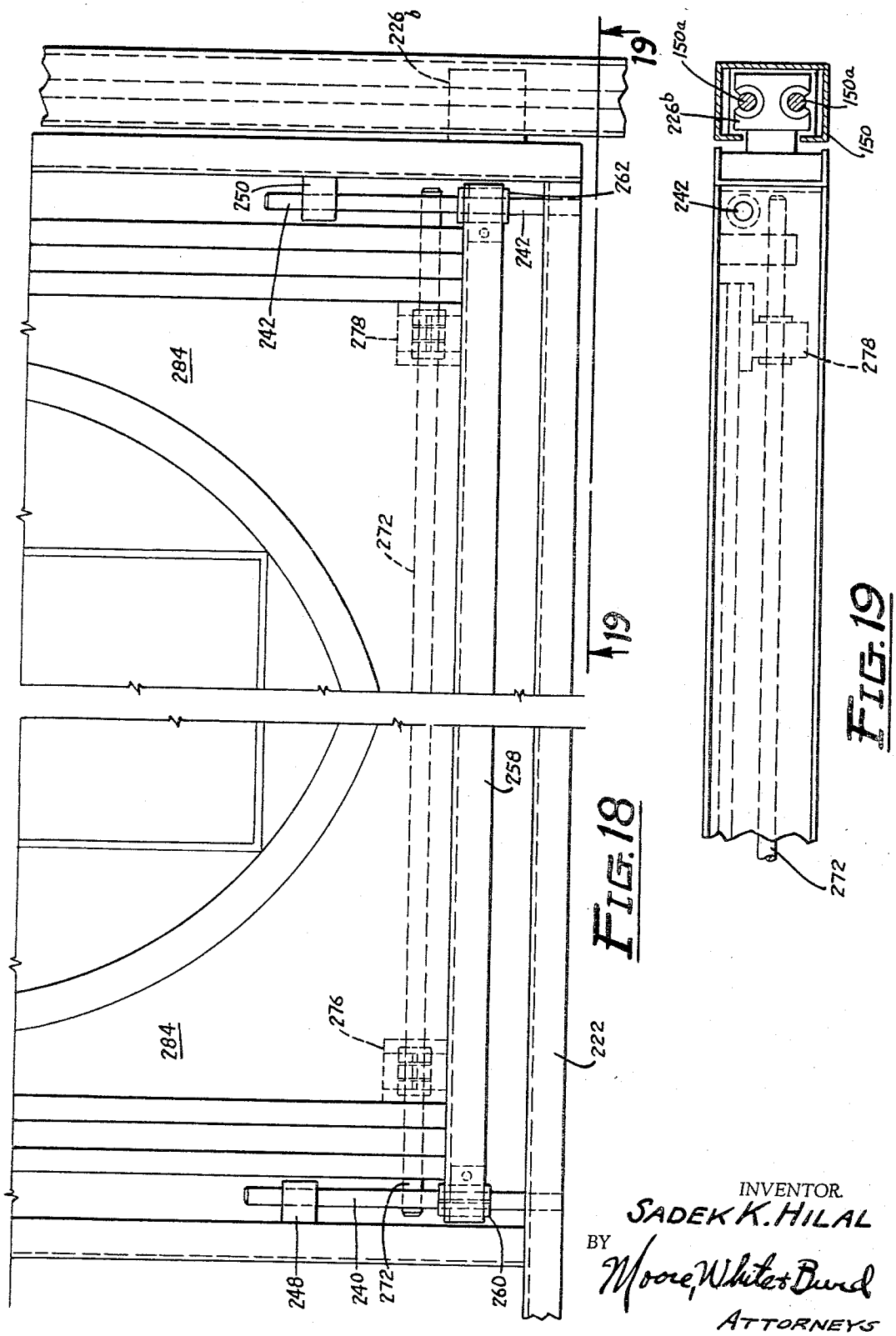


FIG. 19

FIG. 18

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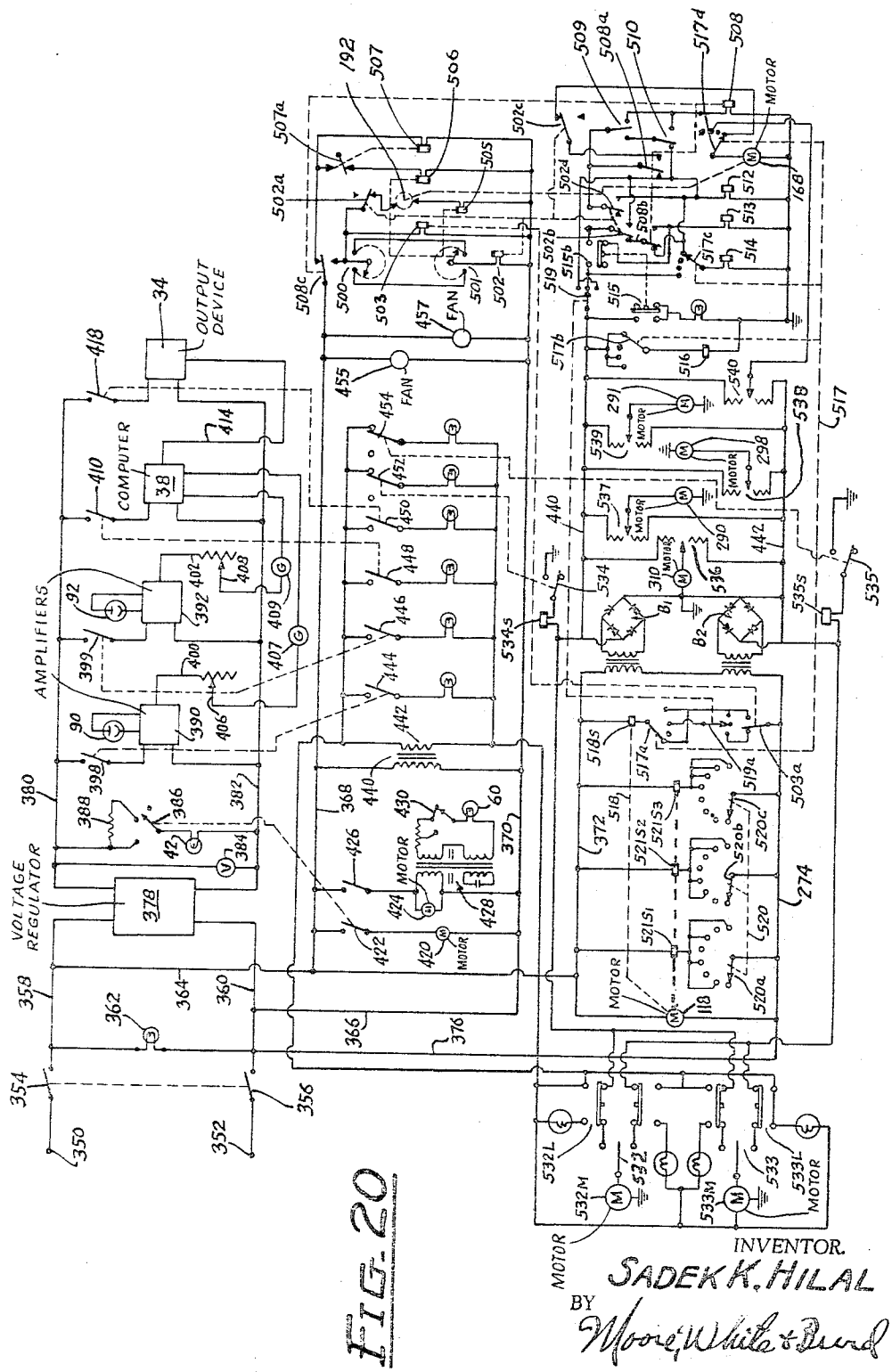


FIG. 20

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United States Patent Office 3,339,076 Patented Aug. 29, 1967

3,339,076

DUAL DIFFERENTIAL DENSITOMETER

Sadek Kamil Hilal, Fort Lee, N.J., assignor to The Regents of the University of Minnesota, Minneapolis, Minn., a corporation of Minnesota

Filed Jan. 13, 1964, Ser. No. 337,473
32 Claims. (Cl. 250—220)

The present invention relates to scanning devices and more particularly to a device for scanning and comparing corresponding portions of a plurality of test objects simultaneously. The present invention is particularly useful in the scanning of medical radiographic films for the purpose of simultaneously measuring, comparing and recording the density of a plurality of exposed films taken of similar subjects.

A number of devices have been previously proposed for evaluating test objects such as photographs. These prior devices have however been unsatisfactory in various respects and are to some extent ineffective in operation. Thus, while some of the prior devices of the type described are relatively expensive, they do not provide the required resolution, speed of operation, nor are they suitable for use in comparing medical radiographic films such as angiograms.

In view of these and other deficiencies of the prior art, it is thus one object of the present invention to provide an improved scanning device which can be used for simultaneously comparing the densities of medical X-ray films.

Another object of the present invention is the provision of a device in which can be inserted a plurality of medical X-ray films, one being taken before the injection of a radio opaque material and the other subsequent to the injection of the material and including a provision for scanning each film and simultaneously and continuously sensing, processing, comparing and recording the resultant electrical signal to display the same in either graph form or on a photographic film.

Yet another object of the present invention is the provision of an improved apparatus for simultaneously scanning multiple test objects such as medical radiographic films, creating a continuous variable impulse proportional to the optical density of each of the films and for simultaneously comparing the signals thus produced as the test objects are moved linearly relative to the scanning means.

Yet another object of the present invention is the provision of an improved scanning apparatus for simultaneously transporting multiple photographic or radiographic films of a relatively large size in the same direction and at the same speed relative to multiple scanning devices positioned at a preset spacing and including a means for positioning the test objects relative to one another whereby the same relative position on each test object can be brought into accurate alignment with the corresponding scanning device.

A more specific object of the present invention is the provision of a scanning device including a carriage adapted to support multiple test objects, a means for illuminating the test objects and projecting at least a portion of the image of each test object onto a viewing screen and a further means for moving at least one of the test objects on the carriage whereby the same relative position on each of the test objects can be placed in alignment with respect to the scanning devices by observation of the projection screens.

A still further object of the present invention is the provision of an improved scanning apparatus including a carriage for supporting multiple test objects, a first optical means for illuminating only a relatively small area of each test object, a second optical means for illuminating a relatively large portion of the test object and a means for preventing light from the second optical means from striking the area illuminated by the first optical means.

A further objective of the present invention is the provision of an apparatus for simultaneously scanning corresponding portions of multiple films and including a readout means or providing a continuous record of the difference between the density of each of the films.

A still further objective of the present invention is the provision of an improved scanning apparatus including a carriage having a film mounting plate thereon which is movable from front-to-back of the apparatus, from side-to-side and is rotatable about a vertical axis normal to its center.

To the accomplishment of the foregoing and related objectives the invention provides briefly a supporting framework upon which is mounted a carriage adapted to hold a plurality and preferably two test objects R_1 and R_2 (FIGURE 2) such as medical radiographic or photographic films. The term "photographic film" as used herein is intended to refer either to film used with light or with Roentgen rays. Positioned in spaced relationship above each of the carriages and located at the same relative position with respect to each of the film holders in an illuminating means I_1 and I_2 including a provision for concentrating a relatively strong beam of light in a selected area upon each of the films. The carriage also includes an adjustment means for changing the position of at least one of the film holders. Specifically, the adjustment means allows the film holder to be moved laterally from front-to-back of the machine or rotated about a vertical axis extending normal to its center. In this manner, the same relative location on each film can be illuminated and scanned simultaneously.

Positioned beneath each of the film holders and in alignment with each of the illuminating means is a light sensing means L_1 and L_2 such as a photomultiplier tube. The output of each of the photomultiplier tubes is passed through a separate amplifier of a suitable known construction and the output of each amplifier is sent to a computer C also of known construction which is programmed so as to compute a resultant signal which varies as the ratio between the intensity of the signals. The resultant signal is in turn read out on a recording device such as an oscillograph O. A transport system T is provided including a drive means operatively connected to the carriage for moving the carriage laterally at a predetermined and selected rate of speed and for a distance which is substantially the same as the width of the film to be scanned. The transport system includes a second drive means to move the film a short distance horizontally at right angles to the direction of its lateral movement. The first drive means is reversed so as to transport the carriage back toward the side of the apparatus at which it was originally located.

To enable an operator to quickly and easily adjust the relative position of the film on the carriage so that the same portion of each film will be scanned simultaneously, a second optical system is employed for illuminating a relatively large area of each of the films surrounding the area which is illuminated for scanning purposes. A beam splitting means is provided for reflecting a portion of the light passing toward each photomultiplier tube onto a projection screen. In this way, the illuminated portion of each film can be observed by the operator.

In the preferred form of optical system employed for illuminating the test objects, a single lamp is employed to provide illumination for each of the test objects. The optical system includes in addition to the light source an adjustable slit or other opening, a means for focusing the light beam, a beam splitter such as a half silvered mirror,

and a projection lens means for focusing the light beam on the radiograph. One such focusing device is provided on each side of the lamp.

Mechanical motion which is essential for scanning an area of the film is preferably provided by suitable electric drive motors which are operatively connected to a pair of ball screw drive devices of known construction, each positioned at right angles to one another. One of the drives is adapted to provide movement of the carriage from front-to-back of the apparatus and a second is provided to allow side-to-side movement. The carriage is preferably of sufficient size to accept a pair of medical radiographs each measuring 14 x 17 inches or thereabouts. Each of the radiographs is mounted between two glass plates positioned upon metal frames. The frames are each mounted so as to allow 360° of rotation about a vertical axis. A positioning means such as an electric motor is provided to rotate the frame of at least one of the holders. One of the frames is independently movable and selectively adjustable from side-to-side and from the front to the back of the apparatus.

Refer now to a detailed description of a preferred embodiment of the invention and to the drawings wherein:

FIGURE 1 is a perspective view of the apparatus according to the present invention;

FIGURE 2 is a block diagram showing the flow of information in the present invention;

FIGURE 3 is a diagrammatic perspective view of the optical system in accordance with the present invention;

FIGURE 4 is a front elevation of the viewing screens showing the appearance of the screens after the test objects have been adjusted to appear in the same relative position;

FIGURE 5 is a diagrammatic perspective view on an enlarged scale of the illumination provided for the test objects in accordance with the invention;

FIGURE 6 is a diagrammatic plan view showing the path taken by the scanning beam as a test object is moved relative to the scanning head;

FIGURE 7 is a portion of a strip chart showing the record of the signal obtained;

FIGURE 8 is a rear elevational view of the apparatus on a reduced scale partly broken away;

FIGURE 9 is a horizontal sectional view taken on line **9—9** of FIGURE 1;

FIGURE 10 is an enlarged plan view of the horizontal carriage drive mechanism;

FIGURE 11 is a vertical sectional view taken on line **11—11** of FIGURE 10;

FIGURE 12 is a vertical sectional view taken on line **12—12** of FIGURE 9;

FIGURE 13 is a transverse vertical sectional view taken on line **13—13** of FIGURE 12;

FIGURE 14 is a transverse sectional view taken on line **14—14** of FIGURE 12;

FIGURE 15 is a vertical transverse sectional view taken on line **15—15** of FIGURE 12;

FIGURE 16 is a plan view of the film support carriage;

FIGURE 17 is an end elevational view of the film support carriage partly broken away;

FIGURE 18 is a partial enlarged plan view of the lower half of the right one-half of the film support carriage;

FIGURE 19 is a transverse sectional view taken on line **19—19** of FIGURE 18;

FIGURE 20 is a schematic wiring diagram of the power supply information transmission and motor control circuits in accordance with the invention;

FIGURE 21 is a vertical sectional view of a modified form of read out mechanism in accordance with the invention; and

FIGURE 22 is a schematic diagram representing the flow of information as it travels through the computer to the recording mechanism.

Refer now to the figures which show by way of example a preferred form of practicing the present invention. As can be clearly seen in FIGURE 1, the apparatus indicated generally at **10** is mounted within a case **12** which is composed of four major components, a left housing **14** including amplifier and recorders, a right housing **16** including the signal analyzing means, a center housing **18** including scanning and projection devices and a control panel and a top housing **19** within which is mounted the illuminating means.

The center section of the casing **12** includes left and right viewing screens **20** and **22**, controls indicated generally at **24** and at the upper end a test object support carriage **26** upon which a pair of test objects such as radiographic films **28** and **30** are mounted. The carriage **26** is itself mounted for lateral movement as well as movement along a horizontal path extending from the front to the back of the apparatus **10**. The construction of the carriage will be fully described hereinbelow.

The recording means in the left hand casing **14** preferably comprises a recording oscillograph of strip chart recorder **34** of a suitable known construction. Beneath the strip chart **34** is mounted an electrical signal amplifying means **36** for amplifying the signals which are to be compared.

The signal analyzing means within the right enclosure **16** preferably comprises an analog computer **38**. The analog computer **38** can be of any well-known suitable type and will ordinarily be provided with its own controls indicated generally at **40**.

Extending the entire length of the housing **12** along the front thereof is a work table **41** upon which records and other materials can be placed during the time the machine is in operation. The machine casing **14** is preferably large enough so that at least two operators can be seated at the work table **41** in position to observe the viewing screens **20** and **22** while the machine is in operation. The upper housing **19** is supported by vertically disposed end plates **21** and **23** which are connected at their lower ends to the upward end of the housing **12**. Housing **19** is provided with a pair of removable access panels **20***b* and **20***c* which permit the optic components described hereinbelow to be serviced and adjusted. The flow of information through the apparatus can be best understood by again referring to FIGURE 2, in which the illumination sources I_1 and I_2 are presented to the test objects such as radiographic films R_1 and R_2 respectively. The radiographic film R_1 is somewhat different from that at R_2 and in accordance with a preferred form of practicing the invention, R_2 is a radiographic film of the same patient but after the injection of the radio opaque stain. The difference between the two radiographs will thus be the difference in film density which has resulted from the action of the stain.

The illumination from I_1 passes through R_1 and is received by a suitable light sensitive means such as the photomultiplier tube L_1 while the illumination passing through R_2 is sensed by the illumination sensitive means L_2. The output of each of the illumination sensing devices is then amplified and sent to an analyzing or comparing means such as a computer C. The computer C can be used for comparing the signals in different ways but is preferably employed for computing the difference between the two signals and in that manner providing an output signal which varies as a function of the amount of the staining material sensed at any given location of the radiograph which is being scanned. The output of the computer C is then fed to the output device **34**. The transport means or drive T is operatively connected to the radiographs R_1 and R_2 for moving both the radiographs R_1 and R_2 at the same direction and speed relative to the illumination means I_1 and I_2 and the light sensitive means L_1 and L_2. During operation of the transport means T, the same relative positions on each of the radiographs R_1 and R_2 can be simultaneously scanned.

A number of important results can be obtained through the use of my invention. The signal produced at the read-

out device can be used to accurately represent a visible change which has taken place in any part of the patent's body. Moreover, the amount of opaque material which has been deposited or present at the instant that the radiograph is taken can be recorded quantitatively.

While the information obtained in this way has a variety of uses, it can be employed for example in the early diagnosis of symptoms such as those which are present before a stroke. This invention does however has a variety of other uses and can in fact be employed whenever it is desired to compare test objects such as photographs. It can be used for example in comparing aerial photographs, microphotographs, spectrographic plates, meteorological photographs and for other purposes.

Refer now to FIGURES 3, 4 and 5 which illustrate the preferred optical projection system employed in accordance with the present invention. As can be best seen in FIGURE 3, a first light source such as a line lamp **42** is provided for the purpose of illuminating both of the radiographs **28** and **30**. The radiograph **28** is for example one which was taken previous to the injection of a radio opaque stain while the plate **30** is one which was taken subsequently to the use of the staining material. The lamp **42** can be of any suitable well-known type such as a 200 watt incandescent lamp having a condensed filament.

As clearly seen in FIGURE 3, the light from the lamp **42** passes through a pair of condenser lenses which serve to focus light upon the radiographs **28** and **30** respectively. The light which passes through the condensers **44** and **46** next passes through reticles **48** and **50** respectively, which enable the amount of illumination presented to the radiographs **28** and **30** to be controlled. The reticles **48** and **50** each preferably contain a number of openings which can be selected as desired.

The light passing outwardly through the reticles **48** and **50** then strikes reflective means such as inclined mirrors **52** and **54** respectively, which reflect the light downwardly toward the radiographs. The light beams then pass through projection lenses **56** and **58** which serve to focus the light exactly upon the films **28** and **30** as shown best at **60** in FIGURE 5. The lamp **42**, condensers **44** and **46**, reticles **48** and **50** and mirrors **52** and **54** are all placed in optical alignment within the optic housing **19**. Since any convenient supporting device can be used for holding these components within housing **19**, no detailed description of the support is provided herein. Illumination striking the radiographs **28** and **30** at each of the respective illuminated spots **60** will of course pass through the film to an extent which is dependent upon the density of the film at that point. The light which passes through the film at each of the illuminated spots **60** will be picked up by one of the photomultiplier tube and transmitted to the computer as described hereinbelow.

Positioned within the housing **19** beneath the bulb **42** is a second illuminating means such as an incandescent bulb **60** having a relatively large area filament as for example ½ inch x ½ inch. The light emanating from the lamp **60** passes outwardly through condensing lenses **62** at the left and **64** at the right. The beams passing from the condensing lens **62** is directed through an obscurancy spot reticle **66** and the rays passing from the condenser **64** strike an obscurancy spot reticle **68**. The rays then pass through projection lenses **70** and **72** respectively, which focus the beam as a hollow cone of light upon the films **28** and **30**. To this end, the light passing out of the projection lenses **70** and **72** strikes inclined beam splitting means such as a dichroic material or half silvered mirrors **74** and **76** each of which is positioned to direct a beam downwardly in alignment and concentric with the beams projected from the lamp **42**. The projection lenses **72** have been omitted from FIGURE 5 for clarity of illustration.

As can be seen in FIGURES 3 and 5, the light passing through condensers **62** and **64**, spot reticles **66** and **68** will illuminate a relatively wide area **80A** of each radiograph. The center of the area **80A** will however be blacked out at **82A** by the image of the darkened area at the center of the spot reticle **68**. Positioned concentrically within the darkened spot **82A** is the illuminated spot **60** produced by the light focused on the radiograph from the lamp **42**. The light emanating from the illuminated spots **60** of each radiograph passes downwardly through suitable projection lenses **78** and **80** respectively. The projection lenses **78** and **80** direct convergent beams to come to a focus at the screens **20** and **22** after reflection from beam splitters **82** and **84**. Portions of the beam which pass through the mirrors **82** and **84** pass through condensing lenses **86** and **88** respectively which concentrate the light emanating from the spot **60** onto suitable light sensing means such as photomultiplier tubes **90** and **92**. Mounted between the lens **86** and tube **90** is a motor operated shutter **45** and between lens **88** and tube **92** is a shutter **47**. A portion of the light will be reflected upwardly from the mirrors **82** and **84** respectively and will fall upon suitable viewing means such as ground glass projection screens **20** and **22**. Projection screens **20** and **22** are each preferably provided with cross-hairs **94** and **96** which assist in placing the corresponding parts of the images of each of the radiographs in alignment with the illuminating means as will be described fully hereinbelow.

The various parts of the optical system employed for illuminating the test objects have been described in general terms since the detailed construction of each of the condensers will be readily apparent to those skilled in the art. The specific form of condensers, projection lenses and reticles employed can be selected in accordance with the specific requirements of the particular application for which the machine is to be employed. It should be understood that the various condensing lenses, projection lenses and reticles should be mounted for adjustment along the optic axis so that the images can be properly focused. When it is desired to focus the images of the radiographs more precisely on the screens **20** and **22**, the projection lenses **78** and **80** respectively should be moved as required. In order to focus the scanning illumination of the lamp **42** more precisely upon the films **28** and **30**, the projection lenses **56** and **58** should be moved appropriately. The focusing of the lenses **56** and **58** is preferably motorized as will be explained hereinbelow.

Refer now to FIGURE 9 which shows a preferred form of film support carriage and drive mechanism. In accordance with the present invention, the carriage **26** which is used to support the test objects is driven laterally by first drive means indicated generally at **100** to provide a scanning motion and is driven along an axis extending from the front to the back of the apparatus by means of a second drive system indicated generally at **102** to provide a rack motion. A control for actuating the drive means **100** and **102** sequentially will be described in more detail hereinbelow.

The lateral drive mechanism **100** as best seen in FIGURES 8, 9, 10 and 11 includes an elongated laterally extending support bracket **104** including spaced members **104***a* and **104***b* connected between the spaced horizontal supports **106** and **108** which are affixed rigidly to the framework of the apparatus. Journalled for rotation upon suitable bearings **110** and **112** at each end of support **104** is an elongated and threaded drive member such as a ball screw **114** upon which is mounted a threaded traveler **116** of a suitable known construction. When the screw **114** is rotated in one direction the traveler **116** will travel towards one end thereof for example toward the left in FIGURE 10. When the screw **114** is rotated in the opposite direction, the traveler **116** will, of course, move in the opposite direction.

Rigidly affixed to the support **104** at the right end thereof as seen in FIGURES 10 and 11 is a power means including an electric motor **118** and an electrically operated speed controlling and reversing transmission **120** of a suitable known construction, the latter being mounted by means of a bracket **122** to a housing **124** which is itself affixed to the support **104**. As shown in FIGURE 10, the housing **124** includes an axially spaced brake and

clutch means such as an electrically operated clutch **126** and brake **128** electrically operated. The output of the transmission **120** is coupled by means of spur gears **130** and **132** to the clutch **126** and the latter through a shaft **134** to the clutch **128**. The output of the clutch **128** is transmitted by means of a shaft **136** to a gear **138** which is positioned to mate with a similar gear **140** rigidly affixed to the end of the ball screw **114**. Thus, during operation the driving force of the motor **118** is transmitted through the electrically operated transmission **120** through gears **130** and **132**, clutch **126**, brake **128**, gears **138** and **140** to the screw **114**.

In order to rapidly reverse the direction of rotation of the screw **114**, the brake **126** is applied while the clutch **128** is simultaneously disengaged. The transmission **120** is then operated to reverse the direction of rotation of the output gear **130** at which time the brake **126** is released and the clutch **128** is reengaged. In this way the screw **128** and traveler **116** can quickly reverse its direction of movement.

As best seen in FIGURE 11, the traveler **116** is rigidly connected to a rectangular carriage support frame **144**. The carriage support frame **144**, best seen in FIGURE 9, includes a pair of laterally extending and horizontally disposed elongated members **146** and **148** between which are connected a pair of cross-members **142** and member **150**. The carriage supporting frame **144** is itself slidably supported for lateral movement within the apparatus upon suitable guides **152** and **154** of any suitable known construction extending between the side walls of the housing **12**.

The second carriage drive means or racking drive will now be described. Rigidly connected between the lateral supports **146** and **148** is a support composed of a channel **160**. Rigidly mounted on the bottom of the channel **160** is a support bracket **162** (FIGURE 12) having an upwardly extending portion **164** to which is secured a combination drive motor **168** and electrically operated speed control and reversing transmission **170**. Connected to the output of the transmission **170** is a pinion gear **172** which mates with a gear **174** itself connected to a shaft **176** to which is secured an electrically operated clutch **178**. The clutch **178** includes an output shaft **180** which is connected to an electrically operated brake **182** of a suitable known construction. The output shaft **184** of the brake **182** is supported rotatably within the bearing **186** and is provided with a pinion gear **188** which mates with a gear **190**.

As shown in FIGURE 15, there is affixed to the output shaft of the transmission **170** adjacent the gear **172** a commutator **192** which includes a plurality of circumferentially spaced and electrically connected conducting segments separated by nonconductive spacers of a suitable insulator material. Suitably supported upon the bracket **194** affixed to the channel **160** are a pair of vertically spaced brushes **196** and **198** whose free ends are held in contact with the commutator **192** through the resiliency of the material from which the brushes are formed. The operation of the commutator **192** will be described hereinbelow.

As seen in FIGURES 9, 12 and 13, a pair of longitudinally spaced brackets **200** and **202** are affixed to the lower portion of the channel **160**. Rotatably mounted between the brackets **200** and **202** is a longitudinally extending drive member such as a ball screw **204** upon which is threaded a traveler **206**. The ends of the screw **204** are journalled for rotation within suitable bearings **208** and **210** within the brackets **200** and **202**. Extending axially from the end of the screw **204** within the bearing **208** is a shaft **210** which projects through the support **148** and has rigidly secured to the free end thereof a hand crank **212** which will enable an operator to manually change the position of the traveler **206** should it be desired.

Rigidly secured to the upward end of the traveler **206** is an upwardly extending arm **214** which is affixed to the lower surface of the carriage **26**. It will thus be understood that during the operation, when the motor **168** is actuated, movement will be imparted to the screw **204** and traveler **214** through the clutch **178** and brake **182** so as to transport the carriage **26** in a horizontal plane along a path extending between the front and rear of the apparatus **10** i.e., at right angles to the motion imparted to the carriage by the drive **100**. The controls for operating the motor **168**, transmission **170**, clutch **178**, brake **182** will all be described in more detail hereinbelow.

Refer now to FIGURES 16 through 19 which illustrate a preferred form of carriage to be employed in the present invention. The carriage **26** includes a peripheral frame comprising elongated members **220**, **222**, **224** and **226** which are rigidly connected together at their ends in any suitable manner as by welding. Extending laterally from the support members **224** and **226** respectively are two pairs of horizontally spaced slide blocks **224***a* and *b* and **226***a* and *b*. The slide blocks are mounted for longitudinal sliding movement upon vertically spaced slide rods **142***a* and **150***a*, respectively. In this manner, the carriage **26** will be able to slide freely along an axis extending between the front and rear of the apparatus and in horizontal plane. Mounted upon the members **220**, **222** and **224** in a horizontal plane is a plate **228**. In the center of the plate **228** is a circular opening **230** in which a circular plate **232** is mounted. At the center of the plate **232** is a rectangular opening **234** within which is mounted a test object such as the radiograph **28**. The edge of the opening **234** is preferably provided with a recess around the edge thereof which will enable a plate of glass (not shown) to be placed both above and below the film **28**. Should it be desired to turn the film **28** about a vertical axis, the plate **232** can be rotated as required within the opening **230**.

Referring now to the right-hand side of the carriage, it will be seen that a pair of slide rods **236** and **238** extend centrally from the support **220**. Similar slide rods **240** and **242** extend centrally from the support **222**. The inward ends of the rods **236–242** are rigidly mounted within suitable brackets **244–250**. Mounted upon the rods **236** and **238** is an elongated support **252** provided at each end with bearings **254** and **256** which are adapted to slide longitudinally of the rods **236** and **238** respectively. A similar elongated support **258** is mounted for sliding movement upon the rods **240** and **242** respectively by the provision of bearings **260** and **262** as best seen in FIGURE 18.

Rigidly connected between the members **252** and **258** are a pair of parallel elongated supports **268** and **270**. Extending transversely of the apparatus between the members **268** and **270** are a pair of parallel and horizontally spaced slide rods **272** and **274**. Slidably mounted upon the rods **272** and **274**, respectively, are two pairs of spaced apart slide bearings **276**, **278**, **280** and **282**. Rigidly connected to the bearings **276–282** is a test object support plate **284** having a circular opening **286** at the center thereof within which is mounted a plate **288**. A suitable shoulder is provided in the opening **286** to support the plate **288**. Within the opening between plate **288** and the shoulder is provided a friction reducing material such as a ring of Teflon.

At the center of the plate **288** is a rectangular opening **289** which also is provided with a suitable recess shoulder for supporting a test object such as the radiographic film **30**. A rectangular sheet of glass (not shown) is preferably positioned both above and below the film **30**.

Referring now particularly to FIGURE 16 it will be seen that a reversible electric motor **290** is affixed to the upper surface of the plate **284**. At the lower end of the motor **290** is provided a circular drive member **292** such as a friction wheel which is forced into contact with the periphery of plate **88**.

When the motor 290 is operated, the wheel 292 will cause the plate 288 to turn either in a counterclockwise or clockwise direction about a vertical axis depending upon the direction of rotation of the motor 290. The control for the motor 290 will be described fully hereinbelow.

Operatively connected between the member 268 and the plate 284 is a lateral positioning adjustment drive indicated generally at 296. The drive 296 includes a motor 298 mounted rigidly upon the plate 284. Secured to the shaft of the motor 298 is a drive member such as a screw 304 which passes through a threaded member 306 itself rigidly secured to member 268 in any suitable manner. It should be apparent that during operation of motor 298, the screw 304 will force the plate 284 to move laterally either toward the left or right depending upon the direction of rotation of the motor 298.

A similar adjustment drive means indicated at 308 is provided for adjusting the position of the plate 284 and in a horizontal plane extending from the front to rear of the apparatus. A drive motor 310 is affixed to the support 220 and includes a threaded shaft or screw 316 which is threaded through a member 318 secured within the support 258. When the motor 310 turns in one direction, the screw 316 will force the member and plate 284 toward the rear of the apparatus or turn the top of FIGURE 16 while rotation in the opposite direction will move the plate 284 toward the front of the apparatus or toward the bottom of FIGURE 16.

Refer now particularly to FIGURE 20 which shows a preferred power supply and control system in accordance with the present invention. As can be seen, electric power such as commercially available 115 volt 60 cycle power is supplied to a pair of terminals 350 and 352 to a suitable double pole single throw switch including contact elements 354 and 356 for supplying power to lines 358 and 360. A suitable power-on indicator bulb 362 is wired across the lines 358 and 360. Another pair of lines 364 and 366 are connected to the line 358 and 360, respectively, to supply current to lines 368 and 370. Another pair of supply lines 372 and 374 are connected across the lines 358 and 360 by means of conductors 364 and 376.

Connected across the lines 358 and 360 is the input of a voltage regulator 378 of known construction to supply constant voltage for the amplifiers, computer and recording devices to be described hereinbelow. The output of the voltage regulator 378 is connected to lines 380 and 382.

Connected across the lines 380 and 382 is a volt meter 384 which will enable an operator to observe the output of the voltage regulator 378. Also connected across the lines 380 and 382 is the scan illumination lamp 42. Connected in series with the lamp 42 is a suitable switch 386 having off, bright and dim positions, current being supplied to the latter through a resistance 388.

Also connected between conductors 380 and 382 are a pair of amplifiers 390 and 392. The photomultiplier tube 90 is connected to the input of the amplifier 390 while the photomultiplier tube 92 is connected to the input of amplifier 392. Power supplied to the amplifiers through switches 398 and 399 which are mechanically linked with switches 444 and 446 respectively which are in turn wired in series with suitable indicator lamps. The output of the amplifiers passes through lines 400 and 402 to calibration resistors 406 and 408 respectively, each of which is connected to the input of the computer 38. Connected to the resistors 406 and 408 are current measuring devices such as galvanometers 407 and 409. The scale of each galvanometer is calibrated to indicate directly the density of the test object.

The computer 38 is supplied power from lines 380 and 382 through an on-off switch 410. A pilot light is provided in series with a switch 448 which is mechanically linked with switch 410. The output of the computer 38 is connected by means of a conductor 414 to a suitable recording device such as a strip chart recorder or oscillograph 34. Power is supplied to the recorder 34 through line 380, line 382 and a switch 418 which is linked with a switch 450 wired in series with a suitable pilot light. During operation, the oscillograph 34 will produce a visible record 417 of the computer output upon a sheet of paper 419 (FIGURE 7).

Connected across the lines 386 and 370 is the motor 420 of a blower (not shown) which is used for cooling the lamp 42. A switch 422 is connected in series with the motor 420 to control supply of power thereto. The switch 422 is preferably linked to the switch 386 so that the blower will always be turned on when lamp 42 is operating.

Also connected across the lines 370 and 368 is a blower motor 424 connected to operate a blower (not shown) for supplying cooling air to the background or field lamp 60. In series with the motor 424 is an on-off switch 426. Operatively connected to the motor 424 through a voltage regulator 428 of suitable known construction is the field lamp 60. Current to the field lamp 60 can be adjusted by means of a switch 430 having bright and dim positions.

Connected across the lines 368 and 370 is a step-down transformer 440 having an output winding 442 across which is connected four switches 444, 446, 448 and 450. Another pair of switches designated 452 and 454 are also wired across the secondary winding 442 of the transformer 440 and in series with suitable pilot lamps.

The switches 452 and 454 are mechanically linked respectively with manually operated shutter switches 534 and 535. The switch 534 is connected in series with a shutter solenoid 534*s* which is wired between a bridge rectifier B_1 and ground. The shutter switch 535 is connected in series with a shutter solenoid 535*s* between a second bridge rectifier B_2 and ground. The shutter solenoids 534*s* and 535*s* are operatively connected to the shutters 45 and 47 respectively as seen in FIGURE 3, which serve to permit the illumination provided for scanning to be interrupted without actually turning off and on the lamp 42 thereby prolonging the life of the lamp.

Also connected in parallel across the lines 368, 370 are housing fans 455 and 457 for maintaining the interior of housing 12 at a permissible temperature.

Connected together in parallel relationship are a pair of switches composed of a rack increment switch 500 and a stepping switch 501. The contact arm of switch 500 is selectively adjustable and will determine the final position of the contact arm of switch 501 as described hereinbelow. The contact arm of the switch 501 is connected in series with a solenoid 502 which is wired to the line 370. Contact arm of the switch 500 is connected to one contact of a switch 508*c* and the contact arm of the latter is wired to the conductor 368. The other contact of the switch 508*c* is wired to a solenoid 507 having a contact 507*a* which is itself wired between one side of the coil 507 and a reset coil 506. The other side of reset coil 506 is connected to the line 370. The reset coil 506 is connected mechanically to the contact arm of stepping switch 501. Also connected to the arm of the stepping switch 501 is a stepping coil 505 which is wired between the line 370 and the segmented commutator 192. If desired, a time delay means (not shown) of a suitable known construction can be wired to the solenoid 507 to introduce a time delay for direct current solenoids used in the sequence transfer of the reset coil 506.

The commutator 192 is itself in contact with the brushes 196 and 198 which are connected respectively with a switch contact 502*a* and the stepping coil 505. The switch 502*a* is in turn wired to the contact arm of the rack increment switch 500.

Wired between the contact arm of rack increment switch 500 and the conductor 370 is a solenoid 503 having a contact 503*a*, one teminal of which is wired to a contact of a scan switch 519*a* and to a contact of a reversing solenoid switch 517*a*. The contact arm of the solenoid switch 517*a* is in turn wired to a reversing solenoid 518*s* which

is mechanically linked with the reversing transmission **120** of the carriage scan drive.

Three additional solenoids **521**s_1, **521**s_2 and **521**s_3 are each mechanically connected to the transmission of the carriage scan motor **118** for regulating the speed thereof. Between the respective solenoids **521**s_1–**521**s_3 and line **274** are connected three mechanically linked scan speed selector switches **520***a*–**520***c*.

While the beam from the lamp **42** can be focused upon the respective films in any convenient way, the focusing operation is preferably performed by means of reversible motors **532M** and **533M** (FIGURE 20) which are operatively connected to the projection lenses **56** and **58** respectively. The motor **532M** is connected between the secondary of the transformer **440** and a two-way switch **532**. The motor **533M** is connected between secondary of transformer **440** and a two-way switch **533**. The switches **532** and **533** are in turn wired to limit switches **532L** and **533L**, the latter being wired to suitable pilot lamps which function to indicate when the limiting position of the projection lenses has been reached. The contact elements of the switches **532L** and **533L** are mechanically connected to the projection lenses **56** and **58** respectively.

Connected across the output of the power supplies B_1 and B_2 respectively are lines **440** and **442**. Wired across these lines are four motors **290**, **291**, **298** and **310**. These motors have wired to them a plurality of two-way manually operated motor control switches designated **537**, **539**, **538** and **536** respectively. The motor **310** adjusts the position of the plate **30** along an axis extending from the front to the rear of the apparatus. The motor **298** adjusts the position of plate **30** laterally, the motor **290** adjusts the position of the plate **30** about a vertical axis and the motor **291** adjusts the position of the plate **28** about a vertical axis. The motor **298** adjusts the position of plate **30** laterally. By moving any of the contact arms of switches **236**–**240** in alternate directions, the motors can be moved in opposite directions until the position of the plate **30** is adjusted properly with respect to the position of the plate **28**. The operation can be observed by examining the viewing screens **20** and **22**.

Wired in series with a switch contact **517***b* is a carriage rack clutch solenoid **516**. Connected in parallel with the switch contact **517***b* is an alternate action push button switch contact **515** which can be set to cause the carriage scan motor **118** to operate continuously. A suitable pilot light is connected in series with the switch contact **515**. The switch contact **515** is mechanically linked to a contact **515***b* having terminals wired to the line **440** and to the contact **502***b* and **502***d* of a switch operated by solenoid **502**. The solenoid **502** also includes contacts **502***c* which are wired between the contact **508***a* and a carriage rack control switch **517***d*. The contacts **508***a*, **508***b* and **508***c* are operated by a solenoid **508** which is wired between ground and one contact of a scan limit switch **509** which is secured to the carriage **26** so as to be actuated when the carriage reaches the right end of the housing.

Three solenoids **512**, **513** and **514** are connected between ground and contact **517***c*, contact of **508***b* and the contact of a limit switch **510** which is connected to carriage **26** so as to be actuated when the carriage reaches the left end of the housing **12**. The solenoids **512**–**514** operate the carriage scanning clutch **126**, the carriage scanning brake **128** and the carriage rack brake **182**. The operation of the carriage drive mechanism and scanning mechanism as well as the shutter operating mechanism and focusing mechanism will now be described as the carriage is moved through a complete cycle of operation.

When the master switch terminals **354** and **356** are closed, the following steps take place. The carriage scan motor **118** is energized. The reset coil **506** of the stepping switch **501** is simultaneously energized through relay coil **507** and contacts **507***a*. A reset pulse is applied to **506** before the switching action of contact **507***a*. The carriage rack clutch solenoid **516** is energized, engaging the carriage to the rack motor **168**. The carriage scan brake **118** is energized through the contact of the continuous scan switch **515***b*.

The operator begins the step-scan operation by depressing the continuous scan switch **515** with the switch **517***d* in the proper position for operating the rack motor **168**. Switch **515** lights the pilot lamp wired thereto. Contact **515***b* switches to the position for de-energizing the carriage scan brake **513**, energizing the carriage scan clutch **512** and energizing the carriage rack brake **514**.

The carriage which is now clutched to the scan motor **118**, is driven laterally until it actuates the carriage scan limit switch **509** assuming a left to right movement of the carriage. The carriage scan clutch **126** remains energized through contact **508***a* until switch **509** makes positive contact in the deflected position. Relay **508** then becomes energized, de-energizing the carriage scan clutch solenoid **512** through contacts **508***a*, de-energizing the carriage rack brake **514**, and energizing the carriage scan brake solenoid **513** through contact **508***b*. Simultaneously contact **508***c* switches, deenergizing relay **507**. The reset coil **506** of the stepping switch remains passive because contact **508***c* is in contact with its lower terminal as seen in FIGURE 20. The carriage rack motor **168** is energized.

The relay coil **503**, an impulse reversing type, now reverses the disengaged carriage scan motor by energizing the reversing solenoid **518S** through the switching action of contact **503***a*.

The segmented commutator **192**, fastened to the shaft of the carriage rack motor **168**, turns as the carriage racks, transmitting pulses to the stepping coil **505**. This coil imparts switching action to the arm of **501** until it reaches the contact to which the arm of the rack increment switch **500** has been preset. At this point relay **502** will become energized, removing voltage from the commutator circuit by the switching of contact **502***a*, energizing the carriage scan clutch through contact **502***b* and de-energizing the rack motor **168** as contact **502***c* switches. The carriage rack brake is maintained through the switching of contact **502***d*.

The carriage racking is stopped and reverse scanning motion begins. The carriage scan limit switch **509** returns to its normal position as the carriage reverse scans. Relay **508** de-energizes with contact **508***b* returning to the position illustrated. Contact **508***a* also returns to the position illustrated. Contact **508***c* returns to the position illustrated, pulsing the reset coil **506** momentarily until relay **507** is energized thereby removing the pulse voltage as contact **507***a* opens.

The stepping arm of **501** is now returned to the starting position. Relay **502** becomes de-energized, returning contact **502***a* to the original position, contact **502***c* to the original position, and contact **502***b* to the original position thereby maintaining voltage to the carriage rack brake solenoid **514**. The carriage continues to reverse scan until the left scan limit switch **510** is actuated, at which time the sequence repeats. The action is stopped with the operator again depressing the continuous scan switch **515**.

Refer now to FIGURE 22 which illustrates in diagrammatic form proceeding from left to right, the flow of information through the computer, and in which the upper flow line of FIGURE 22 indicates information received from the photomultiplier tube **90** and the lower flow line indicates information received from the photomultiplier tube **92**.

While various mathematical operations can be performed, as will be apparent to those skilled in the art, the following equations illustrate one example of the operations which can be performed upon signals produced by a pair of radiographic films.

The following equations may be solved by the computer:

1. $D=D_\infty(1-e-\lambda E)$

2. $E=\frac{-1}{\lambda \log e}\log\left(1-\frac{D}{D_\infty}\right)$

3. $D_1-D_\infty(1-e\lambda E_1)$

4. $E_1=\frac{-1}{\lambda \log e}\log\left(1-\frac{D}{D_\infty}\right)$

5. $Ea=E-\epsilon$

6. $Ec=Ea\times C$

7. $Ea_1=E_1-\epsilon$

8. $\frac{EC}{Ea_1}=AF$

9. $AF-e-\mu I$

10. Log $Af=-\mu I \log e$

11. $I=-\frac{\log AF}{\mu \log e}$

Definition of terms used above is:

D=Density of X-ray as received from amplifiers
D_∞=Denstiy of film where "E" energy goes to infinity
Ea=The exposure corrected for error induced by initial fogging of X-ray
E_1=Energy of X-ray where no radio opaque material is injected
ϵ=Exposure factor due to film fogging
Ec=Corrected exposure due to any difference in exposure time between films **28** and **30**
C=Correction factor
AF=Attenuation factor of X-ray beam
$\mu\lambda$=Constants
I=Quantity of radio opaque material in mg./cm.^{2}
E=Exposure of film

The computation of these equations is shown diagrammatically in FIGURE 22. An unloading means of known construction is applied to each of the incoming signals in any convenient and well-known manner so that the load on the computer at a given instant will not alter the signal presented to it from the respective photomultiplier tubes. From D and D_1 is computed the value of E and E_1 as shown in Equations 1, 2, 3 and 4. The computer is programmed such that $D\infty$ and λ represent constants. Equations 1 and 2 represent the solution of E for the upper flow line of FIGURE 2 and Equations 3 and 4 represent the solutions of E_1 for the lower flow line of FIGURE 2.

With Equations 5 and 7, Ea and Ea_1 is determined by subtracting ϵ an exposure factor which is a function of the pre-exposure condition of fogging of the film. Next, in Equation 6 correction is made for the error due to the slight difference in the exposure of each of the films being scanned. In Equation 8 a comparison is made between the signals received from the two channels. The ratio between these two signals, AF, is a function of the amount of opaque material which is present at any given location in the patient whose X-ray is being scanned.

Finally, in Equations 9, 10 and 11 is calculated the quantity of opaque material causing the measured AF. To determine the solution of Equations 9–11, the standard quantity of absorption resulting from a given amount of staining material is previously calculated and by applying this constant to the signal which is received, the amount of stain present at any given location in the patient's body can be calculated quantitatively.

While one set of computations which can be performed by the computer **38** has been set forth by way of example, many other variations will be apparent once the principles of the invention are understood. The computer **38** can, for example, be programmed to increase or decrease the contrast of photographic information either generally or of a selected pattern in the photograph.

Refer now to FIGURE 21 which illustrates an alternative read-out or recording means **590**. The recording

means **590** comprises a generally rectangular and light tight enclosure or housing **591** positioned at one side of the housing **12** adjacent the carriage **26**. In the side wall of the housing **12** is provided an elongated opening **592** within which is mounted for sliding movement along a horizontal path extending from front to rear of the apparatus a bushing **593**. Within bushing **593** is mounted for lateral sliding movement an elongated rod **594** connected at one end to the carriage **26** and at the other end to a read-out head **595** which is adapted to produce visible markings on a suitable matrix **596**. Matrix **596** can, for example, comprise an unexposed section of photographic film.

In the specific form of the invention illustrated in FIGURE 21, the read-out head **595** includes a lamp **597** connected to the output of the computer **38** and optically aligned with a lens **598** for projecting a beam **599** to a focal point **600** at the surface of the matrix **596** so as to trace the same pattern on the film **596** as the carriage **26** traces with respect to the scanning beams produced by the lamp **42**. The lamp **597** can be constructed in the same manner as those used for producing a motion picture sound track. If desired, all or a part of the motion of head **597** can in the alternative be imparted through electrical servosystems.

Since the signal provided to the lamp **597** will vary as the difference between the signals received from first and second photomultiplier tubes **90** and **92**, the resulting exposure of the film **596** will represent the difference in the exposure of the plates **28** and **30** or in other words the radio opaque only and will not be confused by the information which the exposed plates contain in common, viz., the image of tissue and bone material.

While various forms of recorders can be provided for recording the output of the computer, a Leeds & Northrup Strip Chart Recorder Model Speedomax G can conveniently be employed. The computer employed for comparing the signals received by each of the photomultipliers can be of any suitable well-known type but preferably comprise an analog computer such as an Electronic Associates Incorporated model TR10.

It is apparent that many modifications and variations of this invention as hereinbefore set forth may be made without departing from the spirit and scope thereof. The specific embodiments described are given by way of example only and the invention is limited only by the terms of the appended claims.

I claim:

1. A scanning apparatus for comparing a plurality of test objects comprising in combination a means for illuminating each of the test objects, a drive means operatively connected to each of the test objects for moving the same in the same relative direction and speed with respect to the illuminating means and separate light sensing means for receiving the illumination emanating from the illuminated portions of the respective test objects.

2. A scanning apparatus for comparing a plurality of test objects comprising in combination a means for illuminating each of the test objects, a drive means operatively connected to each of the test objects for moving the same in the same relative direction and speed with respect to the illuminating means and separate light sensing means for receiving the illumination emanating from the illuminated portions of the respective test objects and means for projecting the image of the illuminated section of each test object for observation by an operator.

3. The apparatus according to claim **2** wherein the drive means operatively connected to the test objects comprises a carriage, a first motive power means for driving the carriage laterally and a second motive power means for driving the carriage in a horizontal plane at a right angle to the movement produced by the first drive means and a control means for coordinating the operation of the first and second drive means.

4. The apparatus according to claim **2** wherein one of

the test objects is adjustably mounted upon the carriage for movement in all directions in the plane of the carriage and for rotation about the axis normal to the surface of the test object.

5. The apparatus according to claim 2 wherein said projection means comprises a projection screen optically aligned with each of the test objects for displaying an image thereof.

6. A densitometer comprising in combination a means for supporting a pair of test objects, means for illuminating the test objects, separate light sensing means for receiving illumination emanating from the illuminated portion of each of the test objects, means for translating the test objects in the same direction and speed relative to the light sensing means, light sensing means operatively connected to the analyzing means for comparing the signals received by each of the light sensing means and a read-out head means including a means for producing visible markings thereon which will vary in accordance with the changes in the output of the analyzing means, and a drive means for the read-out head which will move the read-out head in a direction and speed corresponding to that of the carriage.

7. The apparatus according to claim 6 wherein the read-out means comprises a lamp means wired to the analyzer and an optical projecting means for focusing the light produced by the lamp onto a light sensitive recording medium.

8. A scanning apparatus comprising in combination, a carriage adapted to receive a pair of laterally spaced apart photographic films, illuminating means mounted upon one side of each of the films and a transport means connected to the carriage for moving the carriage laterally in alternate directions to provide a scanning motion and for moving the carriage at right angles to the path of scanning movement a pair of separate, light sensitive current control devices on the opposite side of the carriage from the illuminating means, an analyzer operatively connected to each of the light sensitive current control means for comparing the signals received from each said control means, a light sensitive recording means and a read-out means connected to the carriage for movement therewith in a two dimensional plane, said read-out means including a lamp means operatively connected to the analyzer and a means for directing the light produced by said lamp onto said light sensitive recording means.

9. The apparatus according to claim 8 wherein the light sensitive recording means is a photographic film.

10. The apparatus according to claim 8 wherein the read-out means is rigidly connected to said carriage.

11. A scanning apparatus for comparing first and second test objects simultaneously, comprising in combination a supporting framework, a carriage mounted upon said framework for movement along a set of mutually perpendicular axes, holders mounted upon the carriage for receiving said first and second test objects, a transport means connected between the framework and the carriage, said transport means comprising a scanning drive means including a first drive motor, reversing means operatively connected to the motor, a clutch connected to said motor and an elongated driving means connected to the output of said clutch, a traveler connected to said driving member and a brake operatively connected to the driving member, a second drive motor, reversing means operatively connected to the second motor, a second clutch connected to said second drive motor and an elongated driving member connected to the output of the clutch, a second traveler connected to the second driving member for movement upon an axis at right angles to the movement of the first traveler and a second brake means connected to the second driving member.

12. The apparatus according to claim 11 wherein said first and second elongated driving members comprise threaded rods and said first and second travelers comprise members provided with threaded openings therein threaded upon said rods.

13. The apparatus according to claim 11 wherein all of said reversing clutch and brake means are electrically operated and conductively connected to a control means including means for operating said first motor in a first direction with said first clutch engaged and said first brake disengaged until the carriage has reached one side of said supporting framework, means for then disengaging said first clutch and applying said first brake and simultaneously operating said second motor for relatively short time with the second clutch engaged and the second brake disengaged, and a means for then disengaging said second clutch and applying said second brake while simultaneously operating said first reversing means, connecting said first clutch and disengaging said first brake whereby said carriage will travel to the original side of said framework.

14. A scanning apparatus comprising in combination, a supporting framework, a pair of parallel laterally spaced apart first guides mounted upon the framework, a carriage support frame slidably mounted upon the guides for movement along a first path, said carriage support frame including a second pair of parallel guides mounted at right angles to said first guides, a carriage mounted upon the second pair of guides, said carriage including a first stage mounted upon one side thereof and a second stage on the other side, each of said stages adapted to receive a test object therein, a transport system including a first drive means operatively connected between the supporting framework and the carriage support frame for moving the frame along a first path in alternate directions, a second drive means operatively connected between said carriage support frame and said carriage for moving the carriage along a path extending perpendicular to the first path upon said carriage support frame, and a control means for operating said first drive means so as to move the carriage support frame in alternate directions and for intermittently operating the second drive means in the same direction to move the carriage relative to the support frame between motion of the first drive means in alternate directions.

15. The apparatus according to claim 14 wherein the first and second drive means each comprise drive motors, motor reversing transmissions and a ball screw drive connected to each transmission.

16. A scanning apparatus comprising in combination, a supporting framework, first and second illuminating lamps, a carriage adapted to support a pair of spaced apart test objects, projection means for projecting a beam from each of said lamps on each of said test objects with the beam from one of said lamps on each of said test objects being projected as a hollow cone and the beam from the other of said lamps on each of said test objects being projected upon a small area of each test object at the center of the hollow cone.

17. The apparatus according to claim 16 wherein first and second viewing screens are positioned each in optical alignment with one of said respective test objects whereby an image of each test object can be projected upon one of said viewing screens.

18. A scanning apparatus comprising in combination, a supporting framework, a film support carriage mounted upon the framework for movement of a pair of films in mutually perpendicular directions, a transport means connected to the carriage for driving the same to produce scanning and racking movement thereof, an illuminating means mounted on one side of the carriage for projecting a pair of beams for illuminating a pair of spaced apart photographic films mounted upon the carriage, viewing screens mounted upon the supporting framework, means for projecting an image of each of the films onto one of the viewing screens, a pair of light sensing means each in optical alignment with one of the beams from said illuminating means for receiving an amount of light proportional to the density of each of said films, analyzing means operatively connected to the light sens-

ing means for comparing the signals received by the light sensing means, a read-out means connected to the analyzer, a stage on said carriage, an adjustable mounting means on said carriage whereby the position of the film on said stage can be adjusted along mutually perpendicular axes with respect to the other of said films and means for rotating at least one of said films about an axis extending normal to the surface thereof.

19. A scanning device comprising in combination, a supporting framework, illuminating means to provide illumination at spaced apart locations, a carriage mounted for sliding movement along mutually perpendicular axes upon said framework, said carriage being adapted to support a pair of spaced apart test films, a transport means operatively connected to the carriage for moving the same along said mutually perpendicular axes and a supporting stage member mounted upon the carriage for sliding movement along mutually perpendicular axes for adjusting the position of one of said films relative to the other of the films whereby corresponding portions of each of the films can be illuminated by said illuminating means and a separate light sensing means optically aligned with each of the illuminating means for receiving illumination transmitted through each of the films, analyzing means connected to each of the light sensing means for continuously computing the difference in density between each of the films and read-out means connected to the analyzing means.

20. A scanning apparatus for comparing photographic films comprising in combination a supporting framework, a carriage slidably mounted upon the framework for movement along a predetermined scanning path, a transport means connected between the framework and the carriage for moving the carriage at selected speeds and directions upon said path, a pair of stages upon said carriage, one of said stages being mounted upon said carriage for adjustment within a plane parallel to the plane of movement of the carriage, selectively operable adjustment means connected between the carriage and the movable stage for changing the position therebetween, a rotatable member in the center of at least one of said stages for supporting one of said films for rotation about a vertical axis, an adjustment means connected between the circular member and the framework for rotating said circular member about an axis extending normal to the surface of the film, viewing means optically aligned with each of the films for observing the position of each film, illuminating means for projecting first and second conical beams of light focused upon a relatively small area of each of said films, first and second light sensitive circuit control means positioned in optical alignment with the first and second beams of light respectively on the other side of the carriage from the illuminating means and adapted to receive illumination passing through the portion of each film upon which each of said beams is focused, and a computing means including means for comparing the signal provided by each of the light sensitive means and means for modifying each signal by the application of at least one constant value thereto.

21. A scanning apparatus having a carriage adapted to support a pair of films for movement relative to a fixed illumination source and a pair of light sensing means, first and second drive motors for moving the carriage along perpendicular axes, a first and second clutch connected to each motor, a reversible transmission connected to each motor and a brake connected to each motor, control means conductively connected to said transmission drive motors and to said first and second clutch and said brakes and including means for operating the first motor in a first direction with the first clutch engaged until the carriage has described a scanning movement, thereafter applying the brake of the first motor and reversing said first transmission while simultaneously engaging said second clutch and releasing the brake of the second motor and means for then reengaging said first clutch and means for releasing said corresponding brake until the carriage has returned to the side of the apparatus at which it was originally located and said control means being adapted to repeat this operation until both of said films have been scanned throughout their entire area.

22. A scanning apparatus for simultaneously scanning a pair of medical radiographic films comprising in combination a supporting framework, first and second light sensitive scanning means positioned in spaced relationship from said films and at the same relative spacing as the spacing between corresponding parts of each of said films and a transport means operatively connected between the scanning means and the films for imparting relative movement between the framework and the scanning means and an analyzer connected to receive signals from the scanning means for finding the ratio between the signals and a read-out means connected to the analyzer for providing a visual image of the signal produced by the analyzer.

23. A scanning apparatus comprising in combination a supporting framework, a means on the framework for holding at least a pair of test objects, a first illuminating means for distributing light over a relatively large area of each of the test objects, a second illuminating means for directing illumination upon a relatively restricted area of each of the test objects, an obscurancy means for preventing the light from the first illuminating means from striking the area of each of the test objects illuminated by the second illuminating means, a light sensing means positioned in optical alignment with the portions of each of the test objects illuminated by the second illuminating means and a drive means for imparting relative movement between the light sensing means and the test objects.

24. A scanning apparatus comprising in combination a supporting framework, a carriage mounted upon said framework for movement of at least a pair of test objects in mutually perpendicular directions, a drive means mounted upon the framework and operatively connected between the carriage and the framework for imparting a scanning movement to the carriage, a first lamp mounted in spaced relationship with the carriage, a condenser lens means in optical alignment with the first lamp for projecting the light from said first lamp as a conical beam upon said carriage, a second lamp mounted upon said framework, a beam splitter mounted in optical alignment with said second lamp and positioned to direct the light of said second lamp onto the carriage concentric to the beam from said first lamp, and an obscurancy reticle positioned between said second lamp and the beam splitter of the second lamp for eliminating a portion of the beam produced by the second lamp in the area surrounding the beam produced by said first lamp, and light sensing means positioned on the opposite side of the carriage from the first and second lamps and in optical alignment with the beam produced by the first lamp.

25. The apparatus according to claim 24 wherein a drive motor is connected to each such condenser lens means for adjusting the position thereof so as to control the focusing of the light of said first lamp with respect to the carriage.

26. The apparatus according ot claim 25 wherein a viewing screen is positioned upon said apparatus, a projection lens is mounted between the carriage and the viewing screen for projecting an image upon the viewing screen, and a beam splitting means is mounted upon said apparatus in optical alignment with each of the test objects for deflecting the image thereof onto said viewing screen.

27. The apparatus according to claim 26 wherein the viewing screen comprises a sheet of a translucent material.

28. A scanning apparatus comprising in combination, a supporting framework, first and second illuminating

lamps, a carriage adapted to support a pair of spaced apart test objects, projection means for projecting a beam from each of said lamps on each of said test objects with the beam from one of said lamps on each of said test objects being projected as a hollow cone and the beam from the other of said lamps on each of said test objects being projected upon a small area of each test object at the center of the hollow cone, and motorized focusing means connected to the illuminating lamps for adjusting the focus of said illuminating lamps upon each of said test objects.

29. The apparatus according to claim **28** wherein a means is provided upon the carriage for adjusting the position of the test objects relative to one another whereby the same relative parts of each of the test objects can be brought into alignment with the corresponding scanning means.

30. A scanning apparatus comprising in combination, a supporting framework; a film support carriage mounted upon the framework for movement of a pair of films in mutually perpendicular directions; a transport means connected to the carriage for driving the same to produce scanning and racking movement thereof; a first illuminating means mounted on one side of the carriage for projecting a pair of beams for illuminating a pair of spaced apart photographic films mounted upon the carriage; a second illuminating means mounted on the same side of the carriage for projecting a pair of beams for supplying light to the area surrounding the portion of each of said films illuminated by said illuminating means; viewing screens mounted upon the supporting framework; means for projecting an image of each of the films onto one of the viewing screens; a pair of light sensing means each in optical alignment with one of the beams from said illuminating means for receiving an amount of light proportional to the density of each of said films; analyzing means operatively connected to the light sensing means for comparing the signals received by the light sensing means; a read-out means connected to the analyzer; a stage on said carriage; and an adjustable mounting means on said carriage whereby the position of the film on said stage can be adjusted along mutually perpendicular axes with respect to the other of said films comprising first, second and third electric motor means connected to said stage, said first motor being adapted to move said stage along a first axis parallel with the plane of movement of the carriage, said second motor being adapted to move the stage along an axis at right angles to the first axis and said third motor being adapted to rotate said stage about an axis normal to the surface of said film.

31. In a densitometer of the type for comparing a plurality of test objects and including a support means for supporting a plurality of test objects and a screen positioned in optical alignment with each of said test objects, each such screen including a reference point permanently affixed thereto, the improvement comprising a selectively operable adjustment means for at least one of said test objects for changing the position of said one test object relative to the other test object whereby the test objects can be aligned by visual inspection of said screens.

32. The apparatus according to claim **31** wherein a magnifying means is positioned in optical alignment between each test object and each screen for projecting a magnified image of each test object on each respective screen whereby magnified images of the test objects can be observed during the operation of said selectively operable adjustment means.

References Cited

UNITED STATES PATENTS

2,912,761	11/1959	Woodward et al.	88—14
2,931,904	4/1960	Fine	88—14
2,964,643	12/1960	Hobrough	250—220
2,989,890	6/1961	Dressler	88—14
3,049,046	8/1962	Patnode	88—14
3,071,762	1/1963	Morgan	250—219
3,145,303	8/1964	Hobrough	250—220
3,244,893	4/1966	Miller et al.	250—220
3,246,560	4/1966	Birnbaum et al.	88—14

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,339,076 August 29, 1967

Sadek Kamil Hilal

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 5, line 9, for "has" read -- have --; line 51, for "tube" read -- tubes --; column 9, line 38, for "line" read -- lines --; column 15, lines 15 and 16, for "light sensing means operatively connected to the analyzing means" read -- analyzing means operatively connected to the light sensing means --.

Signed and sealed this 3rd day of September 1968.

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents