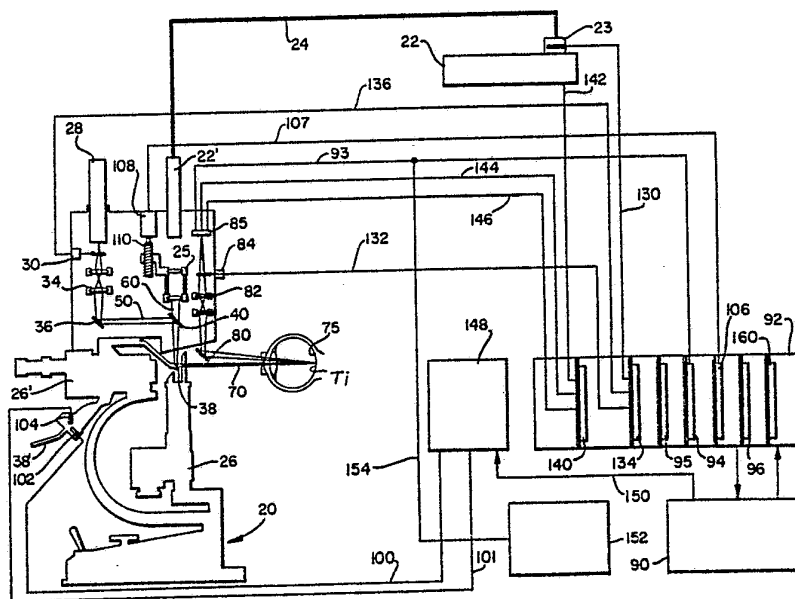




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(54) Title: PROCESS AND APPARATUS FOR CONTROLLING THE PHOTOCOAGULATION OF BIOLOGICAL TISSUE



(57) Abstract

A process and apparatus for controlling the photocoagulation of biological tissue (75) in which two lasers (22 and 28) supply laser beams via slit lamp (26) into an area (75) to be irradiated. The reflected luminance is directed to a photodiode array (85) which sends signals to a control means (90) which then in turn controls the two lasers (22 and 28).

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**PROCESS AND APPARATUS FOR CONTROLLING THE
PHOTOCOAGULATION OF BIOLOGICAL TISSUE**

The present invention relates to a process for controlling the coagulation of biological tissue and improvements in apparatus for controlling the coagulation of tissue of the type disclosed in German Application P30 24 169.1-35; in Documenta Ophthalmologica Proceedings Series 36 - "Laser Treatment and Photo-
5 coagulation of the Eye," Proceeding of the International Symposium Munich, F.R.G. September 1982; and GSF-Bericht BPT 5, published by Gesellschaft Fur Strahlen-und
10 Umweltforschung, Munich, West Germany, "Time Dependence of the Retina-Reaction during and after Laser coagulation with Various Coagulation Parameters." The method and apparatus are, for example, used in ophthalmology for the treatment of retinal diseases. However, the method
15 may be used in processes wherein a change in reflectance of a surface results from treatment of the surface and the underlying material on which the surface is formed.

In the known process and the associated apparatus,
20 the area or part of said area which is to undergo photocoagulation is imaged in the form of an intermediate image by means of an optical device. The light flux passing through a diaphragm installed in the intermediate image is proportional to the luminance
25 prevailing in the diaphragm field and is supplied to a detector. This makes it possible to measure the



average luminance prevailing in the complete area illuminated by the measuring radiation and imaged in the intermediate image, as well as its time change during the coagulation process. Typically, the time
5 behaviour of the luminance has a certain "latent period", during which the luminance is initially constant, this being followed by a second phase in which the luminance increases linearly with time. Information is obtained from the length of the latent period and
10 the size of the growth rate in the linear luminance increase phase, which enables forecasts to be made regarding the further course of the coagulation action. This makes it possible to influence the total coagulation action obtained during the actual irradiation,
15 in that the exposure parameters are adapted in a planned manner during irradiation.

However, the known process can only be performed with satisfactory results, if either the absorption characteristics of the irradiated objects are known
20 and/or are the same for all the irradiated areas, or if the intensity distribution of the coagulation irradiation at the location of the action is known and/or is constant for all the irradiations. Recent research has shown that conclusions can only be drawn
25 on the energy quantities deposited in the absorption coatings when at least one of these prerequisites regarding the measurement of the latent period and the constant luminance growth rate at the start of the luminance change is known. Only then is it
30 possible to forecast the further course of the irradiation action, which can be controlled by varying the irradiation parameters. The known process also assumes that the irradiation action and the extension of the coagulation zone can be adequately monitored,
35 in that the luminance prevailing in the complete area

imaged in the diaphragm in the intermediate image plane is measured. However, such an integral measurement, which supplies a mean value, cannot distinguish whether a narrowly defined partial area within the measured area has become brighter, i.e. the luminance has locally increased, or whether, in said area, the partial area in which an increased luminance exists has spread. This means that with the known process, a local coagulation, acting in the depth of the tissue, cannot be distinguished from a radial expansion or a radial extension of the coagulation zone of the surface of the tissue and both are in fact evaluated as the same reaction.

Under the normal conditions prevailing in the photocoagulation of biological tissue, for example in the case of retina treatment with intense light, neither are the absorption characteristics, which can vary widely, known or obtainable by measurement, or is it possible to reliably adjust and control the intensity distribution of the coagulation radiation at the point of action, because it is often considerably impaired by fine irregularities in transmitting and imaging media. In addition, both the intensity distribution and the absorption and consequently the effectiveness of the irradiation, can be greatly impaired by inhomogeneities, such as differences in the tissue structure or the nature of the tissue, or also portions of adjacent, already coagulated areas within the area irradiated with the intense light source. The imaging and transmission conditions for the intense light irradiation also locally vary in different ways with the increase in the light scattering in the coagulated area during the coagulation process. These local differences cannot be individually determined with the integral measurement of the



luminance, which merely supplies a mean value for the total surface area illuminated by the measuring beam. Moreover, incorrect measurement of the luminance caused by reflections of the measuring beam on other surfaces of the measuring system, i.e. the illuminating and measuring optics are only detected if made apparent by considerable divergences from the customary values.

Thus, the problem of the invention is to provide a process making it possible to determine local differences within the area to be measured and more particularly making it possible during the coagulation process to distinguish whether the luminance has locally increased in a partial area or whether said partial area has increased in size with increased luminance.

The invention is based on the finding that the increase in the luminance during the coagulation of biological tissue is a measure of the size of the volume of the coagulated tissue, in accordance with the relation:

$$R = p V$$

in which R is the luminance increase in the coagulated area and V the volume of the coagulated tissue, while p is a coefficient, which is dependent on the nature of the tissue and can be experimentally determined. The measurement of the local distribution of the luminance in the coagulation area makes it possible to precisely establish which volume has been assumed by the coagulated area. This evaluation can take place during irradiation and it is then possible to reliably control the intense light source and its imaging optics and consequently the coagulation action.

The process according to the invention makes it possible to determine irregularities in the intense light irradiation and/or measuring radiation, which



are for example due to reflections and/or limitations to the radiation in the optical system. These irregularities can be detected by means of the pattern of the local luminance distribution. In particular, the process according to the invention advantageously makes it possible to determine the depth of the coagulation action in a given partial area if its surface is known and the ratio of the luminance to the size of the tissue volume re-emitting the light is known on the basis of experimental investigation.

The process according to the invention also has the advantage that it can detect irregularities in the spatial extension of the coagulation zone, which can be taken into consideration during the control.

The performance of the process according to the invention leads to the following advantages:

1. With the formation of the quotients of the luminances in the partial areas, it is possible to determine the relative luminance distribution and consequently also the relative size of the local irregularities, which in turn make it possible to discriminate inhomogeneities of the object and interferences in the irradiating and measuring optics.
2. On the basis of this information and using the regulating member 19 and the sighting unit, it is possible to correct the distribution in which the intense light source and/or measuring radiation source is imaged on the measured area, while also making it possible to select the target area.
3. By subtracting the relative luminance changes in the partial areas and/or partial area groups, it is possible to determine relative divergences with respect to the symmetrical coagulation action.
4. By subtracting the relative luminances, time interval of the latent periods and the time gradients of the



luminance changes in the partial areas and/or partial area groups, it is possible to determine the spatial gradients of the coagulation action.

5 5. By forming the quotients of the luminances, time interval of the latent periods and the time gradients of the luminance changes in the partial areas and/or partial area groups, it is possible to determine relative divergences with respect to the symmetrical spread of the coagulation action.

10 6. By comparing the measured local luminances, and the magnitudes determined therefrom with predetermined values, it is possible to fix limits for the coagulation action which, if exceeded, can have undesired effects.

15 7. By combining the partial areas into partial area groups, it is possible to reduce the quantity of data to be processed and consequently the measurement and control of the expected coagulation action can be adapted as regards time and space.

20 8. Time adaptation of the measurement and control of the expected coagulation action is made possible by the variable selectable scanning rates of the luminances.

25 9. The use of solid-state image sensors involves employing known technology, which is particularly suitable for performing the process according to the invention when combined with laser treatment apparatus and a precise computerized control circuit.

30 10. By measuring the luminance in the transmission, it is possible to measure and control the coagulation action with increased sensitivity with respect to its extension in the depth of the tissue.

DESCRIPTION OF DRAWING

The invention is described in greater detail hereinafter relative to a preferred embodiment of the invention illustrated in the attached drawings, wherein:

35



FIG. 1 is a diagrammatic view of the apparatus;
FIG. 2 is an enlarged elevational view of an
array of photodiodes or an arrangement of individual
light detectors;

5 FIG. 3 is a graph diagrammatically indicating
the spatial intensity distribution of the intense
light of a first laser reflected from an area and a
second laser reflected from the area measuring radiation,
as can be determined by means of detectors arranged
10 along a diameter of the detector surface to indicate
the light intensity across the irradiated surface;

FIG. 4 a diagram in which the luminance increase
within the individual partial area groups is plotted
during an irradiation with a constant intensity dis-
15 tribution up to 1000 ms and relative to time; and

FIG. 5 a block circuit diagram of the evaluation
and control circuit.

Numeral references are employed to designate
like parts throughout the various figures of the draw-
20 ing.

DESCRIPTION OF A PREFERRED EMBODIMENT

Referring to FIG. 1 of the drawing, the numeral
20 generally designates apparatus which may be employed
for accomplishing the process described herein. The
25 apparatus includes an argon laser 22 connected through
a flexible fiberoptic cable 24 and a connector tube
22' connectable to a slit lamp 26 and microscope 26'
of a type which are commercially available from Coherent
Medical Group of Palo Alto, California, and is referred
30 to as Innova 910 ophthalmic photocoagulator and multi-
purpose laser system.

The argon laser 22 produces the treatment beam
of light of approximately 4.0 watts of blue-green
argon light having a wave length of 488 and 514
35 nanometers (nm) or 1.5 watts of green-only argon light

with green-only option having a wave length of 514 nm. The lens structure is adjustable to provide spot sizes ranging from 50 to 2,000 microns. A control module permits adjustment of power levels and adjustment of the spot size. Since argon lasers and slit lamps for use as a photocoagulator are well known to persons skilled in the art, further description of this aspect of the apparatus is not deemed necessary. An early form of a similar laser photocoagulator is disclosed in U.S. Patent No. 3,720,213.

The slit lamp 26 is preferably of the type commercially available from Carl Zeiss, Inc. of New York City, New York, and distributed as a "Slit Lamp 30 SL-M" which is conventionally used by ophthalmologists for examination and treatment of eyes.

The exposure time of the argon laser 22 is controlled by a shutter controller 23, as will be hereinafter more fully explained, which is provided as a component of the argon laser 22 but controlled by a computer circuit.

A helium-neon laser 28 preferably has a power output of 0.5 mW and forms a beam having a wave length of 632 nm to function as a pilot laser. A suitable laser is commercially available from Newport Corporation of Fountain Valley, California and is distributed under the trademark Spectra-Physics HeNe Laser Model Sp-155A. An electronic shutter 30 is mounted to selectively interrupt the light beam measuring radiation emitted from the pilot laser 28. A suitable shutter is available from Newport Corporation and is generally referred to as a Model 884 Electronic Shutter featuring a 6mm diameter open aperture, black teflon-coated plates rated at up to one watt and one millisecond minimum open time.



A mounting system including a lens holder 32 is employed for supporting a lens system 34 and mirror 36 and a beam splitter 40 as illustrated in Figure 1 of the drawing for combining the beam 50 of the helium-
5 neon laser with the beam 60 of the argon laser to form a combined beam 70 which is directed into the eye by a mirror 38 on the slit lamp 26. The combined beam 70 impinges against tissue such as the retina in the posterior aspect of the eye or other tissue. The
10 mirror 38 is manually controlled by a joy stick 38' or remotely controlled by horizontal and vertical actuators 102 and 104 as will be hereinafter more fully explained.

Light from the combined beam 70 from lasers 22
15 and 28 is reflected from surface 75 in the eye and delivered by a mirror 80 through a lens system 82 and a filter 84 to a two dimensional photodiode array 85. Each photodiode in array 85 generates electrical signals related to the light intensity reflected from a corre-
20 sponding portion of the area on surface 75. A suitable photodiode array is available from Reticon Corporation of Sunnyvale, California, which is a subsidiary of EG&G, Inc. of Wellesley, Massachusetts. The photodiode array is distributed as EG&G Reticon RA100 x 100A and
25 is a two-dimensional self-scanned optical sensor array which has 10,000 diodes arranged in a 100 x 100 matrix. Diode spacing is on sixty micron centers in either dimension. Scanning is by means of two shift registers, one running at a sample rate and the other at a line
30 rate. The maximum sample rate is 10 MHz. The individual diodes are packaged in a twenty-four pin dual-in-line package with a ground and polished window covering the mask-defined active area.

A MOS dynamic shift register sequentially selects
35 the diode rows while two bucket brigades select the



diodes from each column. Each position of the shift register selects two diode rows through two multiplexing gates, one for the odd and the other for selecting the even. This property of odd and even selection gives the array an added feature by providing the user the choice of selecting the odd and even fields.

Together the shift register and the bucket brigade process the signal. The shift register selects rows by a clock. The transfer gates parallel transfer the selected diode in each column into the bucket brigade. One bucket brigade obtains information from odd and the other bucket brigade the information from even diode columns. Each bucket brigade then shifts that information sequentially to the output.

The system hereinbefore described is controlled by a computer 90 which processes data received from the photodiode array 85 and controls the lasers 23 and 28.

A suitable computer 90 for controlling the apparatus is a Hewlett Packard, Model 26S computer, product number HP9826S equipped with a multi-programmer main frame 92 (Hewlett Packard Model 6944A) and plug-in cards to provide the required control functions.

Analog-to-digital converter card 94 (Hewlett Packard 69759A) measures bipolar DC voltages and return the digitized value to the controller to indicate the magnitude and sign of the measured voltage on cable 93 connected to the photodetector array 85. Up to 100,000 readings per second can be transferred from the A/D converter 94 to a Hewlett Packard 69791A memory card 95 (via the external data outputs). Each reading can be initiated by program commands or by an external trigger signal.

A timer/pacer card 96 (Hewlett Packard Product No. 69736A) provides an output which is a programmable



pulse from one microsecond to 18 hours in duration. In the normal mode, the output is a single pulse that can be used as a programmable delay. This card controls and triggers the other cards in the system.

5 A stepping motor controller card 106 (Hewlett Packard Product No. 69735A) delivers current through cable 107 to energize stepping motor 108 to rotate a screw 110 for adjusting the spacing between the lenses of the laser focusing lens system 25 in the argon
10 laser 22.

 A relay output card 134 (Hewlett Packard Product No. 69730A) is connected through line 130 to shutter 23 of the argon laser 22 and through lines 132 and 136 to filter 84 and shutter 30. This circuit operates
15 as a flip-flop such that when shutter 30 is open to pass the light beam from the HeNe laser 28, the filter 84 is in position to pass only light having a wave length of 632 nm. When shutter 30 is closed, the filter 84 is moved to an inactive position to pass
20 reflected light from the argon beam.

 A digital output card 140, having sixteen separate channels, is connected through cable 142 to control power of the laser 22 and through cables 144 and 146 to the photodiode array 85.

25 A remote control module and interface 148 (Newport Corporation 855C Programmable Controller) is connected to the computer 90 by a cable 150 and delivers pulses through cables 100 and 101, respectively, to actuators 102 and 104 for moving the joy stick controller 38'.
30

 A video monitor 152 is connected through cable 154 to cable 93 to display the output of the photodiode array 85. This output provides for visual observation of the tissue in surface 75 in the eye.



An interrupt card 160 is controlled by a suitable software program to initiate the digital output functions which are controlled by output cards 140 and 134.

5 The manufacturer's descriptions and specifications of the various computer and laser devices referred to above are incorporated herein by reference for all purposes.

10 Firstly, the irradiation optics of the argon laser intense light source 22, as well as the photodiode detector device 85 and the helium-neon laser 28 for measuring the local luminance distribution is aligned by adjusting the patient and rotating the microscope with the area in which coagulation is to take place.

15 Thus, this area is also imaged in the plane, in which is located the detector elements d_i in the photodiode array 85 corresponding to the center of the irradiated surface area as illustrated in FIG. 2. The local luminance distribution, which still does not have an

20 effective intensity within this area due to the irradiation with the intense light source is measured by interrogating each of the photodiode detectors d_i in the array 85 which, by means of the selection circuit element according to the block diagram of FIG. 5, are

25 connected via a data bus with the various evaluation circuits. By the formation of the quotients R_i/R_j of the luminances R_i in the individual partial areas T_i represented by each photodiode light detector element by the largest luminance R_j in the partial area T_j ,

30 the relative luminance distribution and consequently the relative local intensity distribution of the coagulation radiation are determined. Then, the relative local luminance distribution of the measuring radiation is determined in the same way. FIG. 3 shows

35 a cross-section of the luminance distributions of the

sub-threshold intense light radiation K of the argon laser 22 and the measuring radiation M of the helium-neon laser 28.

On the basis of each of these measured local
5 distributions, a check is made by comparing the known
distributions whether and to what extent irregularities
are present. Their divergence from the predetermined
distribution patterns are recognized by forming dif-
ferences $R_i - R_j$ of the luminances R_i, R_j in the adjacent
10 partial areas T_i, T_j with equal distances from the
partial area with the maximum luminance. On the basis
of the size and location of the irregularity in the
distribution pattern, conclusions can be drawn regard-
ing their cause as an inhomogeneity in the tissue
15 and/or interference in the irradiation and imaging
optics.

On the basis of these luminance distributions of
the measuring radiation, the field illuminated by
said measuring radiation is combined into $m=10$ partial
20 area groups G_i of photodiodes d_i of array 85 by corre-
sponding linking of individual adjacent detector elements.
These represent half-ring surfaces of equal area with
the same number of diodes in each half-ring area,
which are concentric to the partial area with the
25 maximum luminance and with increasing distance from
said center, and are in each case displaced by 90°
(of FIG. 2). A check is made beforehand by comparing
the luminance distributions of the intense light
irradiation and the measuring radiation to establish
30 whether the area illuminated by the latter also covers
in the intended manner the area irradiated by the
intense light source. The luminance R_l prevailing in
the partial area groups G_i is then retained as values
 R_{oi} at the start of coagulation irradiation and before

coagulation is started with a preselected and now effective irradiation intensity.

During the following coagulation irradiation, the relative luminance R_i/R_{oi} is measured at regular intervals in the individual partial area groups G_i .
5 The number of measuring times, at the end of which the relative luminance R_i/R_{oi} in the partial area group G_i is greater than 0.1 for the first time, is the latent period D_i (of FIG. 4). After the latent
10 period D_j in another area group G_j has been determined, by subtracting the latent periods D_i-D_j of the luminance change in adjacent partial area groups G_i, G_j within the different radii (of FIG. 2, e.g. $i=4, j=2$), it is possible to determine the speed of the radial
15 extension of the coagulation zone. By forming the quotients D_i/D_j of the latent periods of partial area groups G_i, G_j within the same radii (of FIG. 2, e.g. $i=3, j=4$), it is possible to determine the relative difference in the radial propagation rate in different
20 directions. The luminance in the individual partial area groups then increases firstly with a rising and then with a falling increment rate S_i (FIG. 4). For example, S_5 in FIG. 4 indicates the slope or rate of change of the relative intensity of light reflected
25 to a specific group of photodiodes in the array 85. This is determined as the gradient of the luminance change. The number of measuring time intervals up to the time when the increment rate S_i in the partial area group G_i decreases again for the first time,
30 represents time "tsi." The interval between this time and the end of the latent period is dependent both on the irradiation intensity prevailing in this partial area group, the energy which has taken place there and the size of said partial area group.

Conclusions can be drawn regarding the ratio of the local coagulation action to its radial extension on the basis of experimental investigations based on the differences of the gradients of the luminance change in the partial area groups at different distances from the irradiation center. The relative difference in the coagulation action in the case of the asymmetrical formation of the coagulation zone can be established by forming the quotients of the gradients of the luminance change in two partial areas and at the same distance from the irradiation center. By subtracting the gradients of adjacent partial area groups at different distances from the center, on the basis of the 90° displacement, it is possible to further define the direction of the irregular spread. On the basis of experimental investigations, it is possible to forecast the further course of the luminance change and consequently also the spatial spread of the coagulation zone from the size of the latent period D_i and the gradients of the luminance change S_i at time " t_{si} ," as well as the time interval $t_{si}-D_i$ (FIG. 5). As soon as the saturation value of the luminance change is reached within any one of the partial area groups, this value marks the complete coagulation of the tissue volume, whose surface is represented within this partial area group.

On the basis of this information, which can be determined at a very early stage of the coagulation action on subdividing the detector area into correspondingly small concentric surfaces around the radiation center, the further course of the coagulation spread can be regulated by a planned change to the radiation intensity and/or the radiation time and/or the diameter of the area irradiated by the intense light source.



At the end of the coagulation and while constantly measuring the luminance distribution in a predetermined direction, the irradiation and measuring optics can be moved by using the actuators 102 and 104 so far
5 out of the previous irradiation field that it is possible to measure a distribution pattern, which is not impaired any more than intended by projecting in of the previous coagulation zone. This permits rapid coagulation in reliable uniform intervals, as is frequently
10 required in practice.

FIG. 5 diagrammatically shows a block logic circuit diagram of the evaluation and control circuit. It compresses a timer 1 and a selection circuit 2 for selecting and interrogating detectors D_i . The outputs
15 of the timer and the selection circuit are connected across a data line with the individual circuits 3-16 and logic circuit 17, which determine the aforementioned quantities, e.g. the relative luminance, its time and spatial gradient, etc. The outputs of circuit 3-16
20 are connected to the inputs of a logic circuit. From the data fed in, the logic circuit determines control data for the regulating units 18, 19 connected thereto, which in turn act on the intense light source 22, as well as its imaging optics and the sighting unit.

25 The mathematical calculations described above and outlined in the logic diagram illustrated in FIG. 5 are accomplished by the software program in the computer 90. Having described the details of the cards in the computer circuit, further description of the manipulation
30 of the data in the memory of the computer is not deemed necessary.



Having described my invention, I claim:

1. Process for controlling the photocoagulation of biological tissue in which, for starting coagulation, an intense light source is imaged on the area to be coagulated by means of an irradiation optics, which
5 is measured by a measuring radiation on the luminance caused by the biological tissue and the irradiation optics and luminance measuring device are aligned with a sighting unit, characterized in that the
10 luminance is measured in partial areas of the zone covering the area irradiated by the intense light source and the region around it, and that according to the spatial distribution and/or the time develop-
ment of the measured values for the individual partial areas, the irradiation is controlled by means of a
15 first regulating member (18) acting on the intense light source and/or the irradiation optics, and/or controls a selection of the irradiation area with a second regulating member acting on the sighting unit.



2. Process according to Claim 1, characterized in that for controlling the irradiation and/or for selecting the irradiated area, one or more of the following derived quantities are determined and their values are fed into the regulating members:
- 5 (a) quotient R_i/R_{oi} , in which R_i is the momentarily measured luminance and R_{oi} is the luminance in the with partial area T_i measured at the start of the irradiation,
- (b) the difference $R_i - R_j$ of the luminance R_i , R_j of
10 two partial areas T_i , T_j ,
- (c) the quotient R_i/R_j ,
- (d) the difference $R_i/R_{oi} - R_j/R_{oj}$ from the quotients,
- (e) time interval of the latent periods D_i of the
luminance changes (of FIG. 3),
- 15 (f) the difference $D_i - D_j$ of the delay times D_i , D_j ,
- (g) the quotient D_i/D_j ,
- (h) the time gradient S_i of the luminance,
- (i) the difference $S_i - S_j$ of the gradients S_i , S_j ,
- (k) the quotient S_i/S_j ,
- 20 (l) the spatial gradient Z of the luminance.



3. Process according to Claims 1 or 2, characterized in that the individual partial areas T_i of n partial areas are combined in predetermined manner and/or in accordance with the test results to give a
5 number m of partial area groups G_i (in which $1 \leq i \leq m$ and $2 \leq m \leq (n-1)$), that the quantities given in Claim 2 for the partial area groups are determined and the control of the irradiation and/or the selection of
10 the irradiation area is carried out on the basis of the test results for the partial area groups.

4. Process according to Claims 1 or 2, characterized in that the determined values of the luminance of the partial areas and/or the partial area groups and the quantities derived therefrom are compared
5 with predetermined values and that the control of the irradiation and/or the selection of the irradiation area is carried out on the basis of the comparison results.



5 5. Process according to Claim 4, characterized in that the combination of the partial areas T_i to partial area groups was carried out on the basis of the measured luminances of the partial areas and/or the quantities derived therefrom.

5 6. Process according to Claim 4, characterized in that the combination of the partial areas to partial area groups take place in such a way that the surface contents of the partial area groups are predetermined and/or are of the same size, and/or that they are located along lines of identical intensity within the intensity distribution of the intense light irradiation or the measuring radiation.

7. Process according to one of the Claims 1 to 6, characterized in that a measuring beam source differing from the intense light source is used for measuring the luminances.



8. Process according to one of the Claims 1 to 7, characterized in that the intense light radiation and measuring radiation are alternately used for measuring the luminances in the partial areas or partial area groups and the quantities derived therefrom in a predetermined manner and/or in a manner determined by the measured values, and that the test results obtained with the intense light source and the test results obtained with the measuring beam source are evaluated and compared with the comparison result is supplied to a regulating member.

9. Process according to one of the Claims 1 to 8, characterized in that the luminance is measured in transmission through the biological tissue.

10. Process according to one of the Claims 1 to 9, characterized in that the light of the intense light source is used for measuring the luminance.

11. Process according to one of the Claims 1 to 10, characterized in that the area to be measured is imaged on an array of photodetectors and that the individual photodetectors are interrogated for measuring the luminance.

12. Process according to one of the Claims 1 to 10, characterized in that the area to be measured is imaged on a photodetector and that the individual partial areas are successively scanned by a measuring beam for measuring the luminance.



13. Apparatus for performing the process according to one of the Claims 1 to 10 with an intense light source and a regulating device for controlling the irradiation with the intense light source and a regulating device for controlling the sighting unit for aligning the irradiation optics, characterized in that the zone illuminated by the intense light source and/or a measuring beam source is imaged on an array of photodetectors in such a way that a photodetector d_i is associated with each partial area T_i of said zone.



14. Apparatus according to Claim 13, characterized in that the outputs of the photodetectors d_i are led to one or more evaluation circuits (3-17).

15. Apparatus according to Claims 13 or 14, characterized in that the photodetectors are photodiodes and/or phototransistors.

16. Apparatus according to Claims 13 to 15, characterized in that linking elements are provided which enable the individual photodetectors d_i to be combined in groups.

17. Apparatus according to Claims 13 to 16, characterized in that the zone to be measured is imaged on an individual photodetector and that a measuring beam deflecting device is provided, so that in time
5 sequence the measuring beam illuminates predetermined partial regions of the irradiated area and its surrounding region.



18. Apparatus to control the extent of treatment of a surface by treatment apparatus comprising: a light source; means to direct light from the light source to the surface to be treated by the treatment apparatus; an array of photodiodes; means to direct light reflected from each of a plurality of discrete portions of the surface to corresponding photodiodes in the array; and control means associated with the array of photodiodes and the treatment apparatus to terminate treatment of the surface when the reflectance of any of the discrete portions of the surface changes a predetermined amount relative to the reflectance of the surface prior to treatment.



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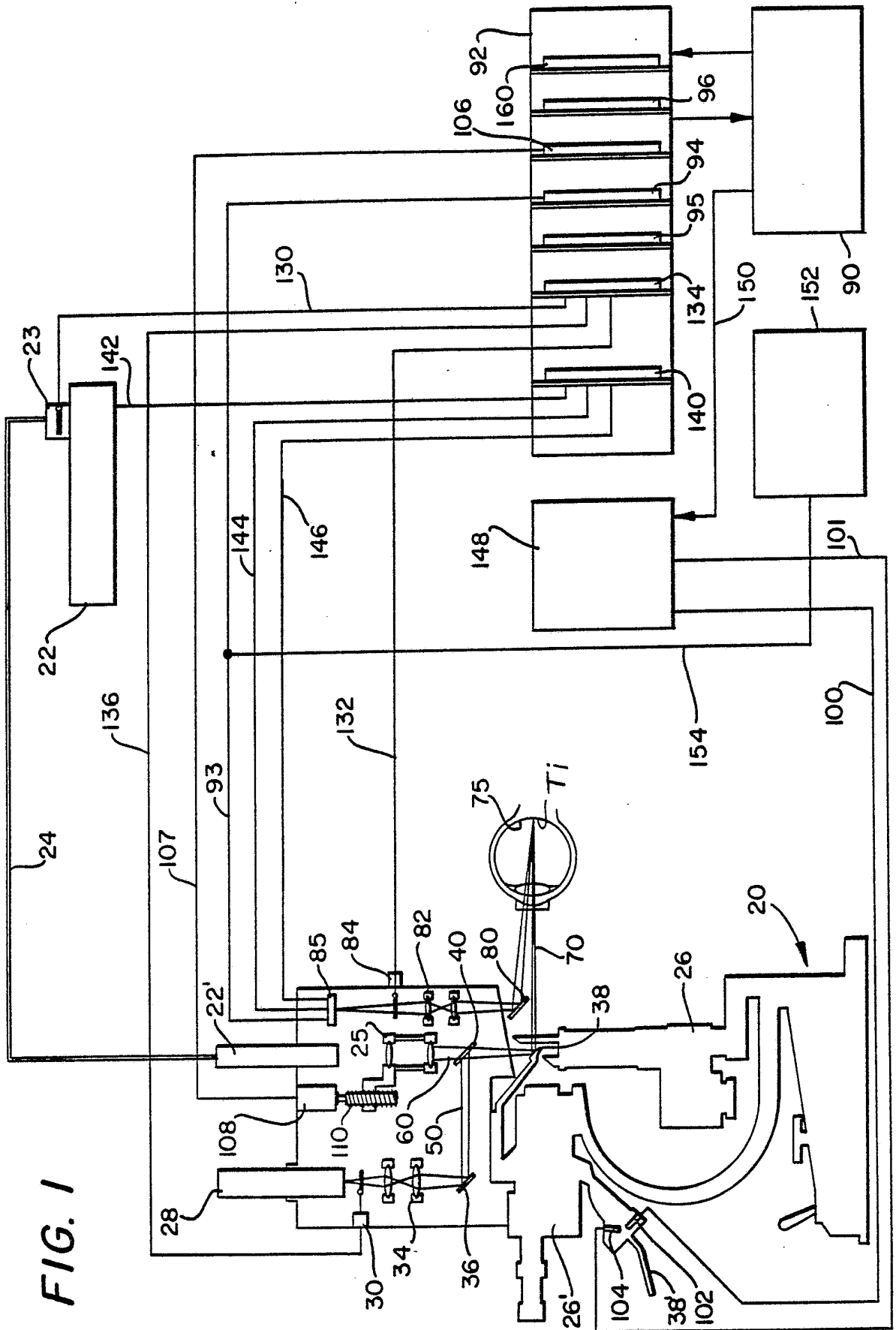


FIG. 1

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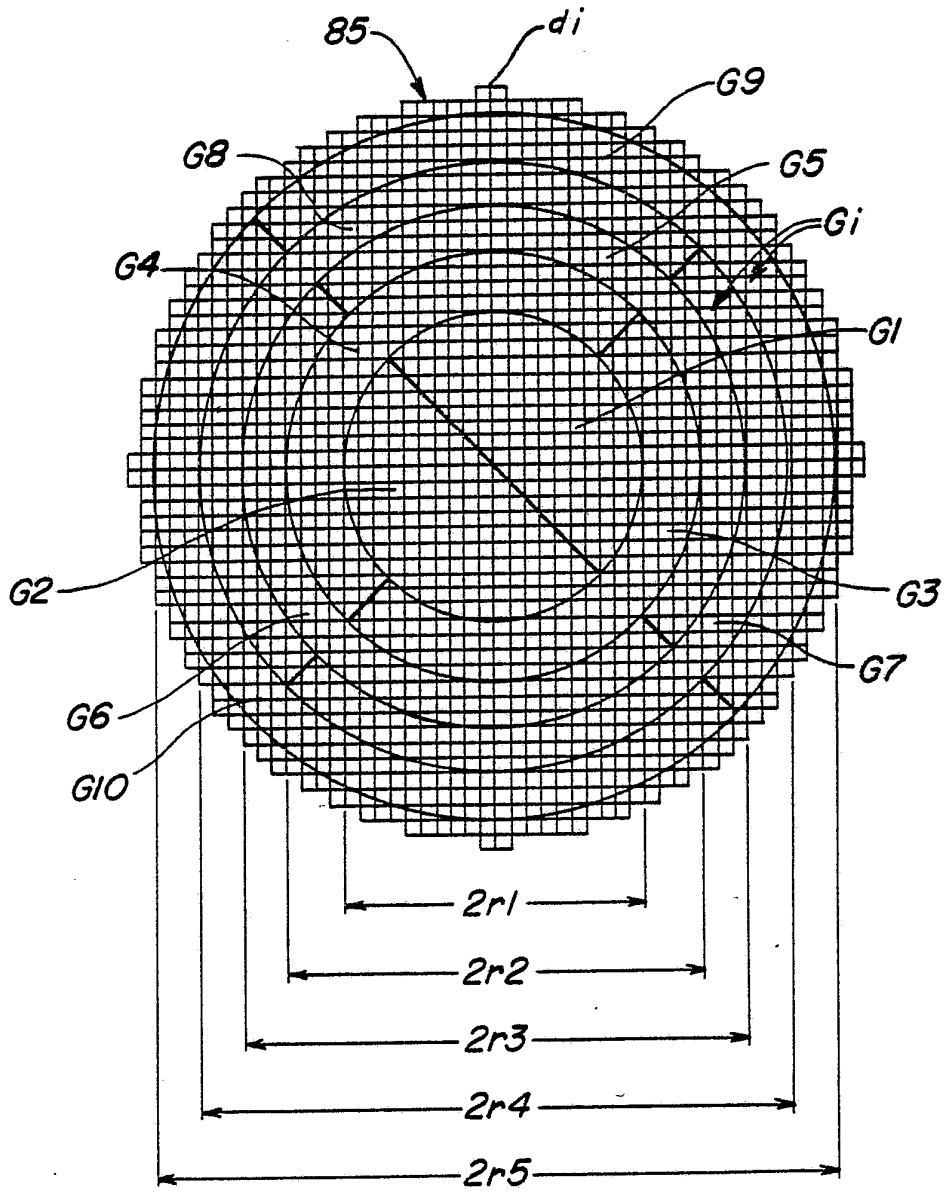


FIG. 2



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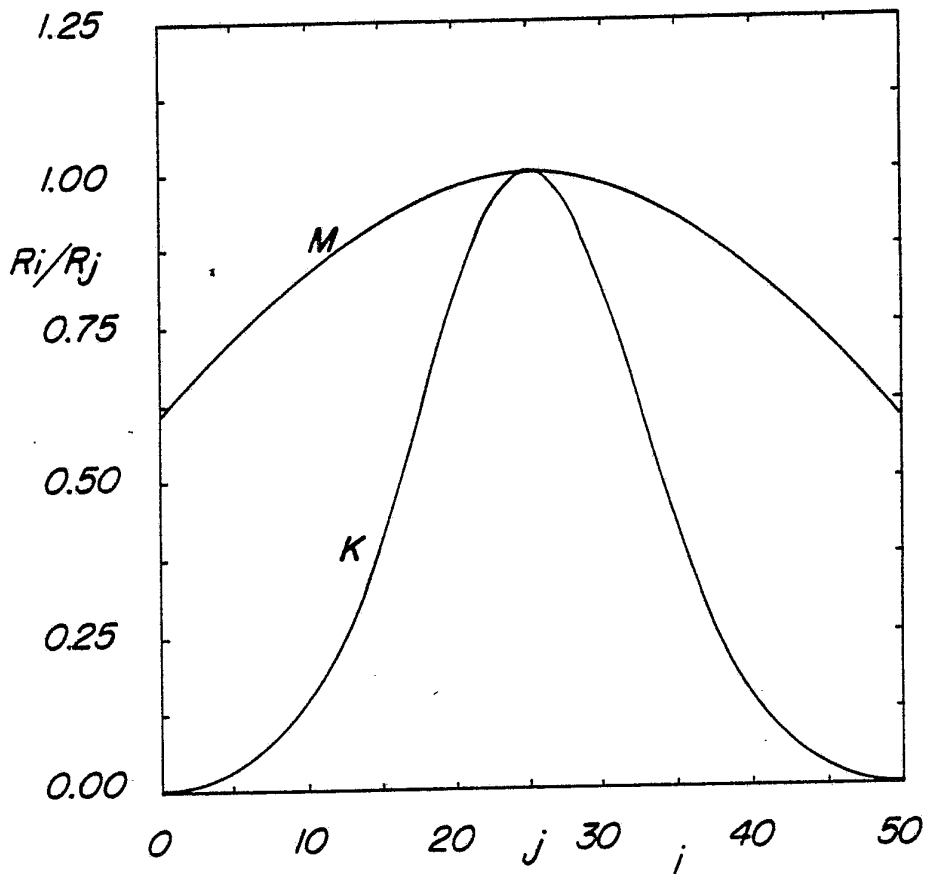


FIG. 3



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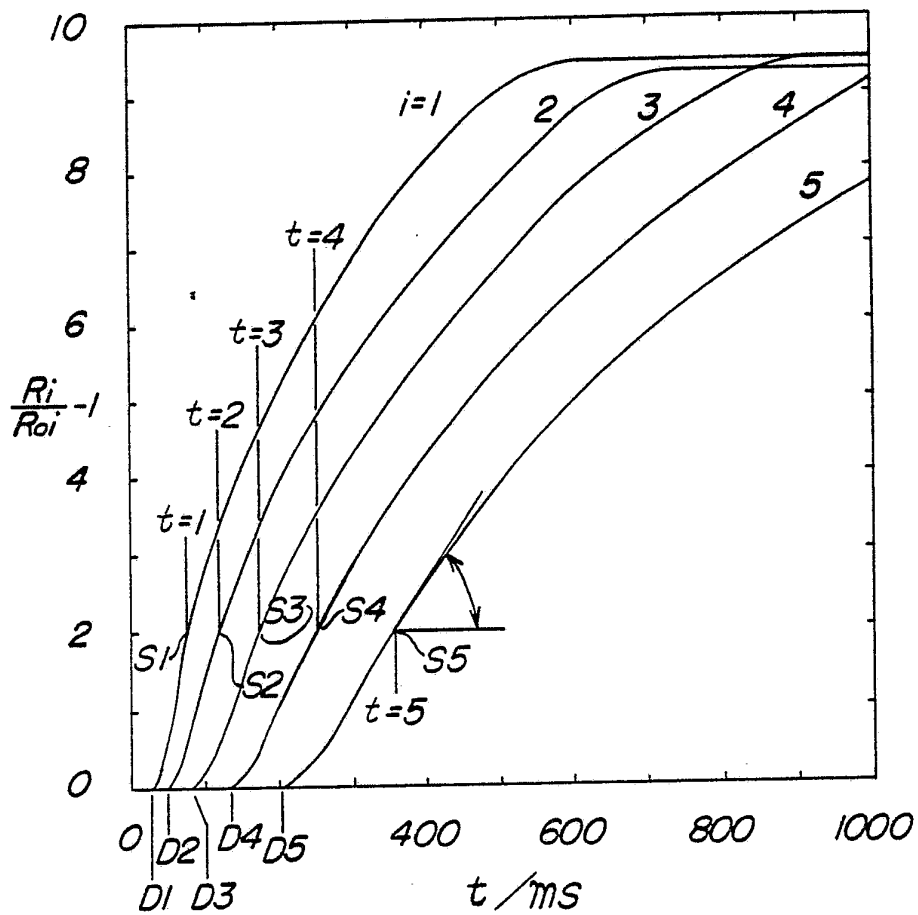


FIG. 4



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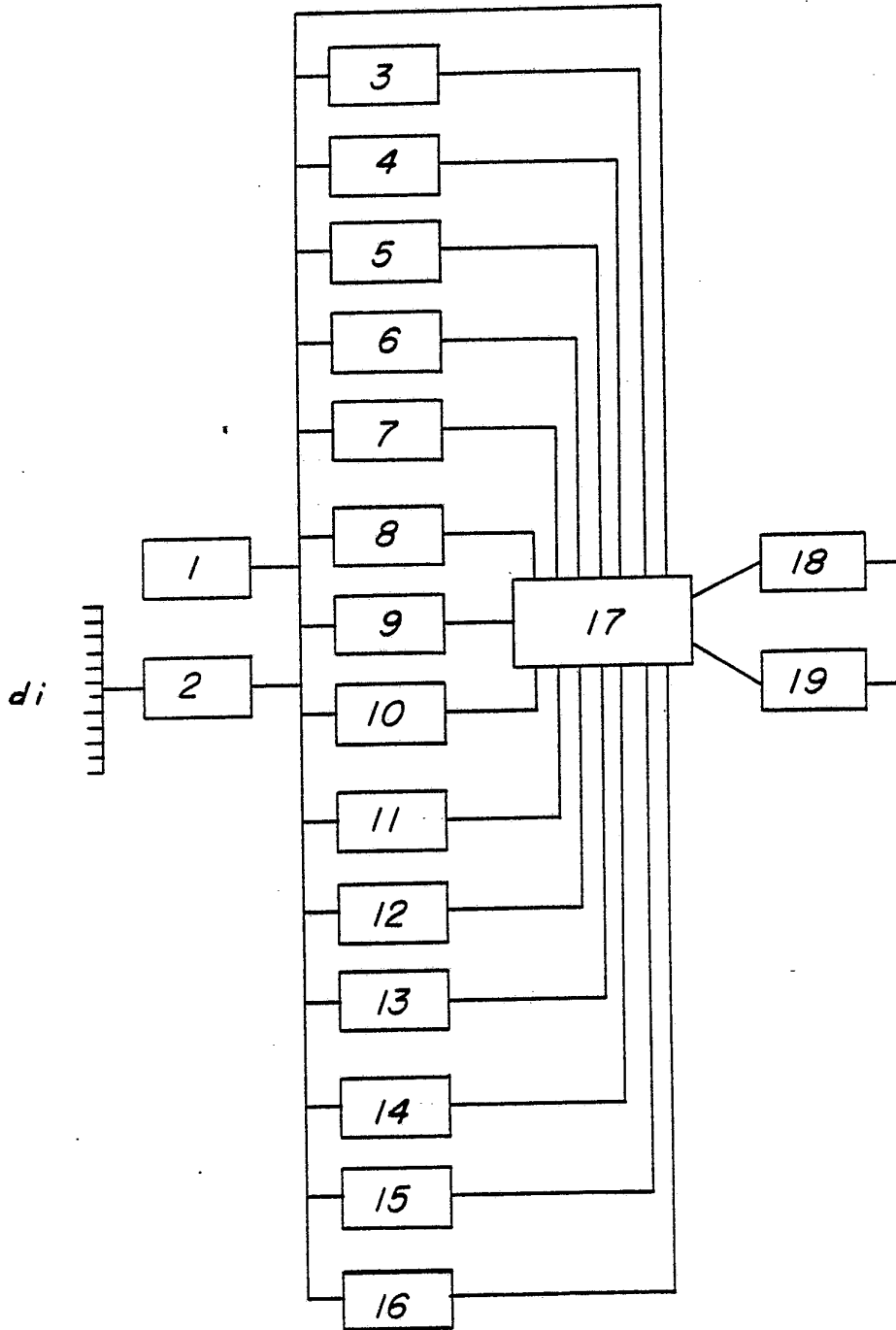



FIG. 5



INTERNATIONAL SEARCH REPORT

International Application No PCT/US84/00295

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ³		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int Cl	A61N	5/06
US Cl	128/395	
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁴		
Classification System	Classification Symbols	
US	128/303.1, 395-398, 645-649, 745 219/121LB, 121LX	604/20, 294 351/200, 210
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁵		
III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹⁴		
Category *	Citation of Document, ¹⁶ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸
Y	US, A, 3,689,159 05 September 1972 TANIGUCHI	1-3, 7-18
Y	US, A, 4,249,825 10 February 1981 SHAPIRO et al	1-3, 5, 6, 8-18
Y	US, A, 4,350,163 21 September 1982 FORD et al	1-3, 5, 6, 8-18
Y	US, A, 3,720,213 13 March 1973 HOBART et al	1-3, 5, 6, 8-18
Y	US, A, 3,181,351 04 May 1965 STAUFFER	1-3, 5, 6, 8-18
Y	US, A, 4,149,787 17 April 1979 KOBAYASHI et al	1-3, 5, 6, 8-18
Y	US, A, 4,154,330 15 May 1979 CONNOLLY et al	1-3, 5, 6, 8-18
Y	SU, A, 555-576 26 October 1977 ISAK	1-3, 5, 6, 8-18
<p>* Special categories of cited documents: ¹⁵</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&" document member of the same patent family</p>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search ²	Date of Mailing of this International Search Report ²	
12 April 1984	16 MAY 1984	
International Searching Authority ¹	Signature of Authorized Officer ²⁰	
ISA/US		

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

Y	SU, A, 251860	15 July 1970 AVETISOV et al	1-3, 5, 6, 8-18
Y	DE, A, 2,202,120	26 July 1973 EISFELD	1-3, 5, 6, 8-18
Y	EP, P, 75-912	April 1983 HITA	1-3, 5, 6, 8-18
Y	DE, A, 2,620,846	24 November 1977 ISAK	1-3, 5, 6, 8-18
Y	US, A, 4,289,373	15 September 1981 REMY et al	18

V. OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE ¹⁰

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. Claim numbers, because they relate to subject matter ¹² not required to be searched by this Authority, namely:

2. Claim numbers, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out ¹³, specifically:

VI. OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING ¹¹

This International Searching Authority found multiple inventions in this international application as follows:

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

- The additional search fees were accompanied by applicant's protest.
 No protest accompanied the payment of additional search fees.

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, ¹⁶ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No ¹⁸
Y	US, A, 4,164,689 14 August 1979 VITAL et al	18
Y	US, A, 4,091,814 30 May 1978 TOGO	18