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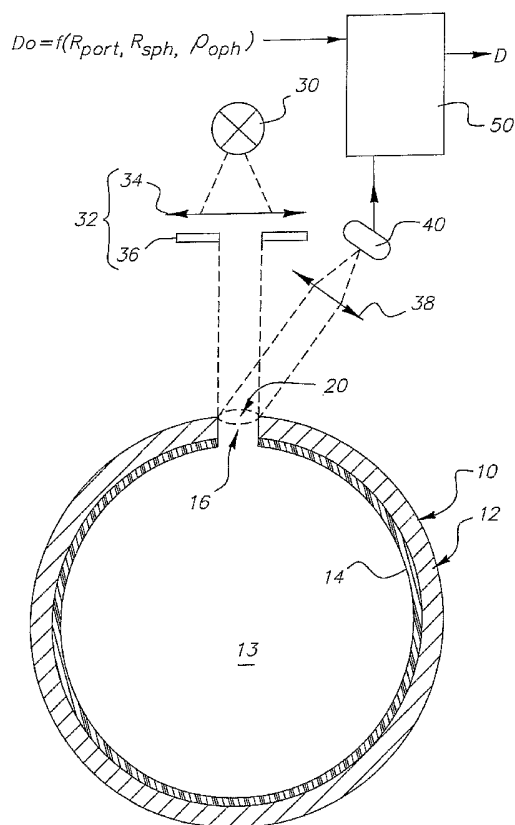
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(54) Title: OPTICAL DENSITY STANDARD AND CALIBRATION METHOD OF A REFLECTION OPTICAL DENSITOMETER



(57) Abstract: The invention relates to an optical density standard for calibrating reflection optical densitometers. The density standard comprises a more or less spherical chamber (10) with a wall (12) provided with a single aperture (16). The aperture (16) is used as the standard's proof surface. Application to photography.



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**OPTICAL DENSITY STANDARD AND CALIBRATION METHOD OF A
REFLECTION OPTICAL DENSITOMETER**

FIELD OF THE INVENTION

The present invention relates to an optical density standard and a
5 calibration method of a reflection optical densitometer using the density standard.

Optical density is one of the essential measurements that enable the
recording of an image on a photographic support to be characterized. For example,
a photographic film can be characterized by a sensitometric curve that links the
light energies capable of printing the film with the optical densities of the
10 resulting film, after development for each energy. The sensitometry curve can be
established using an optical densitometer.

The invention has applications for calibrating optical densitometers,
and more especially reflection optical densitometers. Its implementation extends to
all optical density measuring fields, and especially to that of photography.

15 **BACKGROUND OF THE INVENTION**

An optical densitometer is a measuring instrument for the optical
density of a proof surface. Essentially it comprises a light source and a detector.
The light source is designed to emit a measuring light towards the target. The
measuring light coming from the source is called the incident light. Usually it is
20 directed to the target so as to correspond to a lighting cone with a set aperture.
Under the effect of the lighting, the target returns all or part of the light. This is
collected and directed to the detector. The detector is capable of converting the
received measuring light into an electrical signal. The density of the target is
calculated according to this signal. Optical density is expressed as the decimal
25 logarithm of a ratio of the light returned by the target to the incident measuring
light. In practice, the detector's signal is matched with a reference signal.

Essentially there are two types of optical densitometers according to
whether the measuring light coming from the target has or not crossed the latter.
When the light, collected and directed to the detector is light that has crossed the
30 target, the densitometer is qualified as a "transmission densitometer". When the
light, collected and directed to the detector is light that has been reflected by the

target, the densitometer is qualified as a "reflection densitometer". More precisely, it is the latter type of densitometer that the invention addresses.

Standards accurately set the lighting conditions of the target by the densitometer source and the collection conditions of the light coming from the target. For a reflection densitometer, the lighting is produced, for instance, in a 5° equivalent cone and the light coming from the target is collected in a 45° equivalent cone.

Like any measuring instrument, densitometers have to be calibrated. Calibration is performed using "standards targets" whose density is known. Now, except for barium sulfate targets whose density is fixed by convention at $D = 0$ (100 percent reflection) we do not know how to make materials whose density is known a priori and with sufficient accuracy to envisage their use as target standards. Thus, we do not know how to make a target whose density would be, for instance $D = 2$ (1 percent reflection), with sufficient accuracy.

Standard targets thus have to be previously measured themselves with another densitometer used as reference.

Thus there is a difficulty in guaranteeing the universality of density measurements. The value of density standards is not established intrinsically. Knowing them stems from an optical density measurement.

Another difficulty, partly linked to the previous one, is that the uncertainty of the values of the optical density standards increases strongly with density. Indeed, high optical densities mean low measuring light coming from the target, i.e. a weak measuring signal. As the measurement noise is more or less constant, it happens that the signal to measurement noise ratio deteriorates strongly for densities greater than 2.

The existing uncertainty in establishing the values of the optical density standards similarly affects the accuracy of the densitometers adjusted using these standards.

The calibration difficulties of optical densitometers are a constraint, especially when different processing of photographic supports occurs in places that are geographically remote and where different densitometers are used.

SUMMARY OF THE INVENTION

The purpose of the present invention is to propose density standards, and a calibration method not having the difficulties mentioned above.

One aim in particular is to propose optical density standards whose density value can be established without using a reference optical densitometer.

One aim again is to propose such optical density standards whose density value can be established with great accuracy and with an uncertainty much less than that of the densitometers.

Another aim is also to propose density standards whose value is known with an uncertainty that deteriorates very little for high density values.

To achieve these aims, the invention relates more precisely to an optical density standard comprising a more or less spherical chamber with a wall provided with a single aperture, the aperture defining a proof surface.

It is considered that the chamber is more or less spherical in so far as a deviation in relation to a perfect sphere has negligible effect on the standard's density value.

In a way the chamber constitutes an integration cavity. The more or less spherical character of the cavity ensures good integration uniformity of the measurement light. Similarly, for integration uniformity purposes, the cavity wall preferably has an interior surface whose reflectance is more or less uniform.

It is considered that the reflectance is more or less uniform in so far as any reflectance deviations are sufficiently low to be ignored in calculating the standard's density value. For instance, the reflectant is uniform to near 0.5 percent.

When the standard is used for adjusting a densitometer, the single aperture in the cavity wall receives the incident light, coming from the densitometer and re-emits a measuring light towards the densitometer.

As will be shown later in the description, the optical density of a standard according to the invention mainly depends on the cavity dimension, the aperture dimension and the reflectance of the wall's interior surface. These three parameters can easily be measured and do not require the use of a densitometer. The reflectance of the wall's interior surface depends on the material used to make

the wall or its interior coating. This is noted ρ and is measured by a spectrophotometer. The spectrophotometer differs from the densitometer in that it enables spectral transmission or reflection measurements to be made, i.e. linked to a wavelength. However, the densitometer makes a transmission or reflection measurement in a standardized wavelength area.

While this characteristic is not essential, the cavity's interior surface is preferably neutral, i.e. its reflectance is more or less independent from the light's wavelength. In other words, the surface is preferably white or gray.

The shape of the aperture making the proof surface is not determining. Preferably, it is circular and has a diameter less than tenth of the sphere's diameter. The aperture's circular character increases the standard's uniformity and facilitates the measurement of its dimension.

The invention also relates to a calibration method of a reflection type optical densitometer. The method comprises:

- the supply of a standard as described above, with a wall whose interior surface has reflectance ρ_{sph} ,

- the calculation of a value D so that

$$D = \log_{10}(1/\tau)$$

$$\text{with } \tau = (\rho_{sph} \cdot A) / (1 - \rho_{sph}(1 - A))$$

where ρ_{sph} is the reflectance of the cavity's interior surface and A the ratio of the proof surface area to the cavity's interior surface area,

- the measurement of an optical density by pointing the densitometer at the standard's proof surface, and
- the adjustment of the densitometer to a density value of D .

In the case of a cavity whose interior surface is uniform the reflectance value ρ_{sph} is obtained by a simple measurement. If this is not the case, ρ_{sph} is an integration value such that:

$$\rho_{sph} = \int_{sphere} \rho$$

where ρ is the local reflectance measurement at every point of the sphere's interior surface.

Similarly the density value D can be obtained with a cavity whether neutral or not. If the cavity's interior surface is not neutral, the density value,
5 expressed between the wavelength limits λ_1 and λ_2 will be such that:

$$D = \int_{\lambda_1}^{\lambda_2} D_{\lambda} d\lambda$$

with $D = -\log_{10}(\tau_{\lambda})$

and $\tau_{\lambda} = (\rho_{sph\lambda} \cdot A) / (1 - \rho_{sph\lambda}(1 - A))$

The index λ here means the wavelength dependence of the parameters.

10 Other characteristics and advantages of the invention will appear in the following description, with reference to the figures in the appended drawings. This description is given purely as an illustration and is not limiting.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1, is a diagrammatic cross-section of an optical density
15 standard according to the invention. It also represents, in summary, the main parts of a densitometer.

Figure 2 is a graphic showing, for a particular example of optical density standard according to the invention, the compared evolution of the optical density and uncertainty for the optical density.

20 DETAILED DESCRIPTION OF MODES OF IMPLEMENTING THE INVENTION

Figure 1 shows a density standard according to the invention. It should be noted that the various parts of this figure are not represented to a uniform scale for clarity purposes.

25 The density standard essentially comprises a chamber 10, which defines a more or less spherical cavity 13, with a rigid wall 12. The wall 12 is made of a material such as metal, for instance. It has an interior coating 14 whose function is to provide its interior surface with a set reflectance.

In the example illustrated here, the coating 14 is a more or less
30 uniform and continuous coating of barium sulfate $BaSO_4$. This material has the

advantage of being neutral and having a known reflectance. By convention it is 100 percent. Nevertheless, other materials can be selected. The coating's neutrality is kept, for instance with mixtures of barium and carbon sulfate. The coating can also be based on Teflon or a mixture of Teflon and carbon.

5 As Figure 1 shows, the chamber 10 has a small aperture 16 crossing the wall 12 and the wall's coating 14. In the illustrated example, the aperture is circular and has a radius noted as R_{port} . It defines a proof surface 20. The radius R_{port} is selected less than the radius R_{sph} of the spherical cavity, and preferably much less than the latter.

10 In the case of a sphere according to Figure 1, i.e. with a circular aperture, and an interior wall with more or less uniform reflectance ρ_{sph} , the optical density value of the proof surface defined by the aperture can be calculated simply from the aperture radius 16, the interior radius of the spherical cavity and the wall's internal reflectance. The aperture and cavity radii are used to calculate
15 the areas of these parts. The formulas linking the optical density to the reflectant and to the ratio of the areas are those given above.

Taking the uncertainties for the aperture radius 16, the cavity radius and for the reflectance to be $U_{R_{sph}}$, $U_{R_{port}}$ and $U_{\rho_{sph}}$ respectively, the uncertainty U_τ for the value τ , and thus the uncertainty for the density value, has the following
20 form:

$$U_\tau = 2 \sqrt{\left(\frac{A}{[(A-1)\rho_{sph} + 1]^2} \right)^2 \cdot U_{\rho_{sph}}^2 + \left(\frac{-\rho_{sph}(\rho_{sph} - 1)}{[(A-1)\rho_{sph} + 1]^2} \right)^2 \left[\left(\frac{1}{2} \cdot \frac{R_{port}}{R_{sph}^2} \right)^2 \cdot U_{R_{port}}^2 + \left(-\frac{1}{2} \cdot \frac{R_{port}^2}{R_{sph}^3} \right)^2 \cdot U_{R_{sph}}^2 \right]}$$

$$U_D = \left(-\frac{1}{\ln(10) \cdot \tau} \right) \cdot U_\tau$$

Figure 2 is a graphic drawn up for a density standard according to the invention whose cavity has a diameter 120 mm and whose aperture has a diameter 6 mm. The uncertainties for the diameters in question are 2.5 μm . The uncertainty for the reflectance ρ_{sph} is 0.5 percent for reflectance values between 0.05 and 0.99.

5 On the abscissa the graph gives the reflectance values ρ_{sph} of the cavity's interior surface. On the left-hand ordinate, it gives the uncertainty U_D for the standard's optical density value, expressed as a percentage. On the right-hand ordinate, it gives the optical density value D . Curves relating to the density and its uncertainty, expressed according to ρ_{sph} are identified with the references D and
10 U_D .

Figure 2 shows that the uncertainty for the density is less than about 0.5 percent for density values between 0 and 4 and less than 0.1 percent for densities between 0 and 3.5. Also it may be observed that for a wide range of density the uncertainty is almost constant and thus does not depend on the density
15 value.

When the reflectance of the spherical chamber's coating becomes very low, the uncertainty for the optical density value increases. Essentially this is due to the low quantity of light available to take the measurements. As shown above, the optical density standard is preferably made with a chamber whose
20 reflectance is between 0.05 and 0.99.

For comparison, an uncertainty measured directly with a densitometer would be several percent for an optical density between 2.5 and 4.

Returning to Figure 1, a calibration method for a reflection optical densitometer should now be examined.

25 Only the parts of a densitometer, necessary for the correct understanding of the method are shown in Figure 1. Essentially one may note a measuring light source 30, projection means 32 of the measuring light onto the standard, light collection means 38, and a detector 40. The projection means are symbolized by a lens 34 linked to a diaphragm 36, to set a lighting cone. The
30 collection means are symbolized by a single lens. The detector 40 receives light coming from the optical density standard and delivers an electrical signal. The

signal is directed to a computer 50 where it is converted into an optical density value noted D . This value takes account of the lighting conditions created by the source 30.

5 The densitometer, or more accurately the computer 50 can be adjusted, so that the optical density measured D equals a value D_0 calculated according to the equations given above for a standard with given dimensions and reflectance.

This adjustment can be refined using several standards of different value.

10 It follows therefore, that density standards can be advantageously used for calibrating reflection densitometers whose structure differs from that shown in the figure.

Density standards according to the invention and according to Figure 1 can be made at a relatively low cost and have optical density values that
15 can be determined without the use of another densitometer. Thus they facilitate obtaining uniform measurements.

CLAIMS

1. An optical density standard comprising substantially spherical chamber (10) with a wall (12) provided with a single aperture (16), the aperture defining a proof surface.
2. A standard according to Claim 1, wherein the wall (12) has an interior surface with substantially uniform reflectance.
3. A standard according to Claim 1, wherein the reflectance is between 0.05 and 0.99.
4. A standard according to Claim 1, wherein the aperture (16) is circular, and has a diameter less than a tenth of the sphere's diameter.
5. A standard according to Claim 1, wherein the wall has a neutral interior surface.
6. A standard according to Claim 1, wherein the wall (12) has a coating (14).
7. A calibration method of a reflection type optical densitometer, comprising
 - the supply of a standard according to Claim 1, whose wall (12) has an interior surface with reflectance ρ_{sph} .
 - the calculation of a value D so that

$$D = \log_{10}(1/\tau)$$
 with $\tau = (\rho_{sph} \cdot A) / (1 - \rho_{sph}(1 - A))$
 where A is the ratio of the area of the proof surface to the area of the cavity's interior surface,
 - the measurement of an optical density by pointing the densitometer at the proof surface, and

- the adjustment of the densitometer to a density value of D .

8. The use of a substantially spherical chamber with a wall
provided with a single aperture as density standard, the aperture defining a proof
5 surface.

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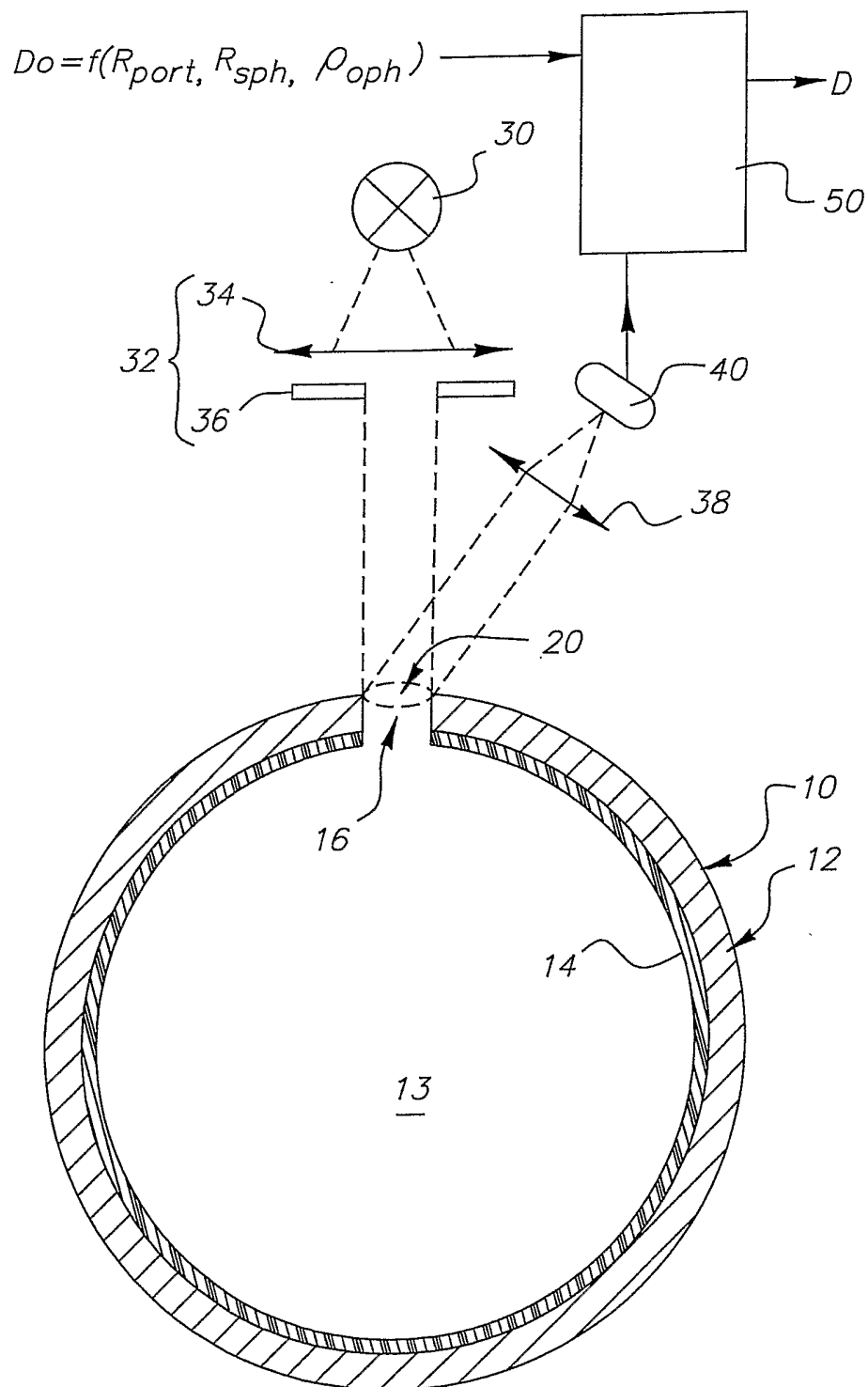


FIG. 1

2/2

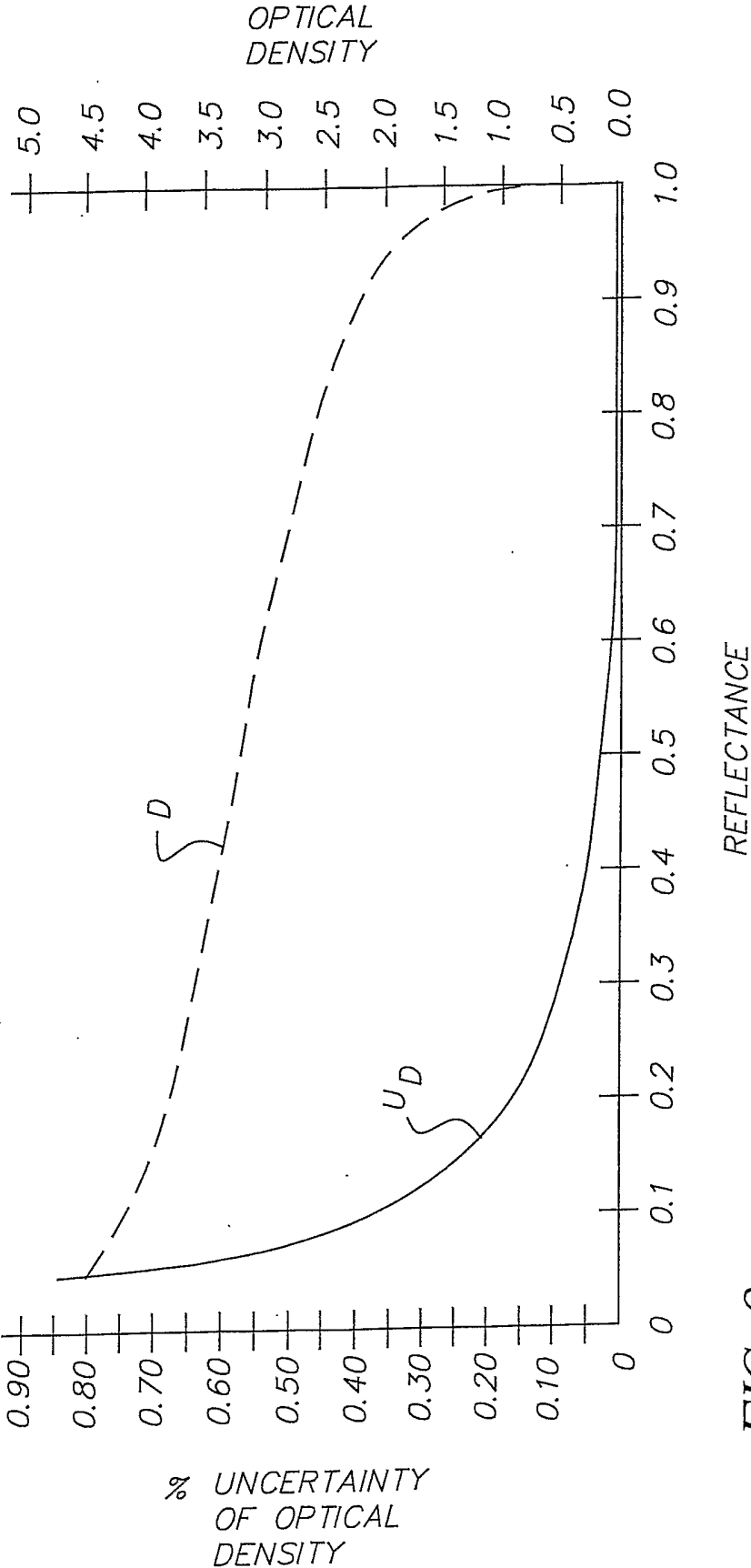


FIG. 2

INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP2004/008619

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 G01N21/47

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 717 504 A (HERNICZ RALPH S) 5 January 1988 (1988-01-05)	1-6,8
Y	abstract; examples 1,2 column 2, line 6 - line 30 -----	7
Y	US 4 566 798 A (HAAS DANIEL D) 28 January 1986 (1986-01-28) abstract column 1, line 38 - column 3, line 56 column 6, line 45 - column 10, line 38 -----	7
X	GB 1 211 302 A (EASTMAN KODAK CO.) 4 November 1970 (1970-11-04) page 2, column 1, line 11 - line 20; claims 10,12 ----- -/--	1,8



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

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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

X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP2004/008619

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 3 832 070 A (COX J) 27 August 1974 (1974-08-27) abstract; figures 1,2 -----	1-8
A	US 4 035 085 A (SEINER JEROME A) 12 July 1977 (1977-07-12) abstract; figures 1,2 column 1, line 63 - column 2, line 44 -----	1-8
A	PATENT ABSTRACTS OF JAPAN vol. 015, no. 322 (P-1239), 16 August 1991 (1991-08-16) & JP 03 118445 A (ANRITSU CORP), 21 May 1991 (1991-05-21) abstract -----	1-8

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/EP2004/008619

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 4717504	A	05-01-1988	AU 556078 B2	23-10-1986
			AU 4918785 A	19-06-1986
			CA 1272340 A1	31-07-1990
			DE 3582407 D1	08-05-1991
			EP 0184097 A2	11-06-1986
			ES 8800432 A1	01-01-1988
			JP 1641881 C	18-02-1992
			JP 3006458 B	30-01-1991
			JP 61134645 A	21-06-1986
US 4566798	A	28-01-1986	CA 1210955 A1	09-09-1986
			DE 3481547 D1	12-04-1990
			EP 0145283 A2	19-06-1985
			JP 1710941 C	11-11-1992
			JP 3071064 B	11-11-1991
			JP 60119442 A	26-06-1985
GB 1211302	A	04-11-1970	DE 1622100 A1	04-02-1971
			FR 1563018 A	11-04-1969
			US 3512895 A	19-05-1970
US 3832070	A	27-08-1974	NONE	
US 4035085	A	12-07-1977	US 3956201 A	11-05-1976
JP 03118445	A	21-05-1991	JP 2534137 B2	11-09-1996