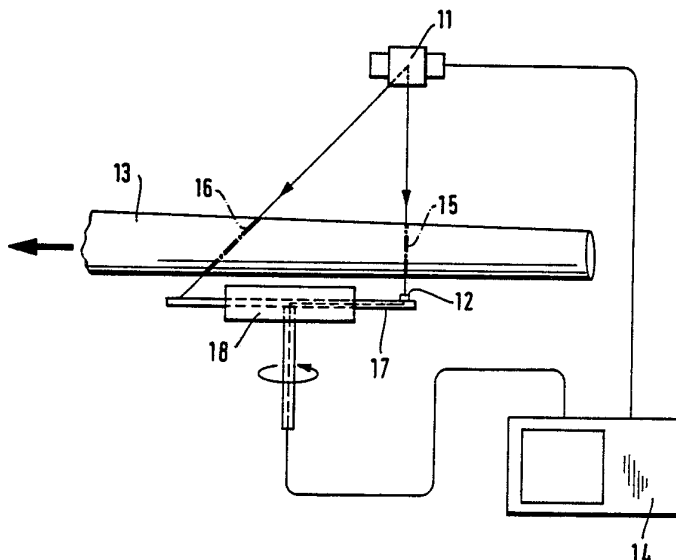




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁵ : G01N 23/02	A1	(11) International Publication Number: WO 92/06367 (43) International Publication Date: 16 April 1992 (16.04.92)
(21) International Application Number: PCT/FI91/00304 (22) International Filing Date: 2 October 1991 (02.10.91) (30) Priority data: 904845 2 October 1990 (02.10.90) FI (71) Applicant (for all designated States except US): PUUMALAINEN CONSULTS OY [FI/FI]; Linnankatu 28, SF-57130 Savonlinna (FI). (72) Inventor; and (75) Inventor/Applicant (for US only) : PUUMALAINEN, Pertti [FI/FI]; Linnankatu 28, SF-57130 Savonlinna (FI). (74) Agent: OUTOKUMPU OY; Patenttiosasto, PL 27, SF-02201 Espoo (FI).		(81) Designated States: AT (European patent), BE (European patent), CA, CH (European patent), DE (European patent), DK (European patent), ES (European patent), FR (European patent), GB (European patent), GR (European patent), IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent), US. Published <i>With international search report.</i> <i>In English translation (filed in Finnish).</i>

(54) Title: IMAGING METHOD FOR DEFINING THE STRUCTURE OF OBJECTS**(57) Abstract**

The invention relates to an imaging method for defining the structure of objects. Current methods and apparatuses are complicated and expensive, and cannot be applied to purposes where a large amount of images is needed in a rapid succession. In the method of the invention, the object (13) under inspection and at least one radiation source (11) and at least one detector (12) are moved in relation to each other, so that the object under inspection passes through the radiation transmitted by the radiation source, and at least one detector is used for measuring the changes in the intensities of radiation absorbed, at least partly, in the object under inspection, as a function of the motion of the said object. Thus, the structural points needed for imaging the structure are defined from at least two directions, and as the passage of radiation in the object at the moment of measurement is always known, the three-dimensional structure of the object is calculated.

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IMAGING METHOD FOR DEFINING THE STRUCTURE OF OBJECTS

The present invention relates to an imaging method for defining the structure of objects, in which method the object under inspection and at least one radiation source are moved, with respect to each other, so that the object travels through the rays emitted from the radiation source.

For about a hundred years, X-ray technique has been utilized and developed in order to reveal the inner structure of objects. In X-ray photography, the details in the inner structure of the object under examination are seen as superimposed absorption differences of X-ray radiation. If the object in question contains several elements with the same absorption coefficient, as is the case for instance with human internal organs in the area of the abdomen, the image will be difficult to interpret, and a specialist is required for analyzing its structure. X-ray technique has developed various methods, for example opaque matter photography, where the desired object is seen better. The most advanced method nowadays is X-ray tomography. Tomography renders a cross-sectional image seen from the direction of inspection, so that different elements are seen in the image separately and in relatively right places. When a desired number of cross-sectional images is made in succession in the lengthwise direction, an accurate three-dimensional image of the target is obtained. Other types of radiation have also been used for creating three-dimensional images of the target; the best known method at present is ultrasonic scanning. In the future, imaging will probably be carried out by using infrared radiation, too. The current devices are complicated, expensive and slow. For instance the tomographs required in the inspection of the human body succeed in shooting one image within several seconds.

Currently images of the internal structures of objects under inspection are required automatically and rapidly. In

these cases, a resolution of even less than one millimeter is not necessary, contrary to the case of an X-ray tomograph designed for the inspection of the human body. A typical application of this type is the scanning of various objects, pieces and materials in order to detect undesirable objects, pieces and/or materials, as well as for defining the internal structure of these materials and objects. In some cases it suffices to define the three-dimensional shape of the object, and the inspection of the internal structure is not necessary.

The object of the invention is to introduce an imaging method for defining the structure of objects, by means of which method there are constructed adequately sharp three-dimensional images for various applications, rapidly and by using equipment which is remarkably simpler and more economical than the equipment used in current tomography technique.

The object of the invention is achieved by means of a method which is characterized by the novel features enlisted in the appended patent claims.

In the method of the invention, at least one detector is used for measuring, from at least three different angles, the changes in the intensity of the rays that are absorbed, at least partly, in the object under inspection; these changes are measured as the function of the motion of the said object. Thus the structural points required for imaging the structure are defined at least from three different directions, and as the passage of the rays through the object is always known at the moment of measurement, the three-dimensional structure of the object can be calculated. The greatest advantage of the invention lies in that for instance in X-ray tomography, the moving of the X-ray tube, or several tubes, can be replaced by one stationary X-ray tube, and the several hundreds of radiation detectors can be

replaced even by one detector only. The equipment is simple and economical as for its production and maintenance costs. Respectively, if the only requirement for the equipment is that it defines the external shape of the object, the employed radiation source can be a light emitting diode or the like, and the detector can be a light-sensitive transistor, in which case the transmitter/receiver pair needed in imaging is very simple and not expensive.

The method of the invention can be applied and used for automatically and rapidly scanning the internal structure of various items. Possible applications are for instance the detection of dangerous materials inside the objects under inspection, e.g. stones and other objects attached to logs when lumber is being sawed or cut to chips. The method also defines the location of defects and knots in the lumber to be sawn, in order to optimize the sawing process. Moreover, the method can be applied to various other purposes, such as for searching explosives or weapons in the suitcases of air travellers. Scanning rates with the method of the invention are high, about 100 - 500 images per second, and the obtained resolution is sufficient for these purposes. In addition to this, the method can be used in the definition of the three-dimensional shape of various objects. As an example, let us mention the definition of the size and shape of pieces cut out of a given material - e.g. the definition of the size and shape of chips in the pulp industry, and the size and shape of crushed aggregate in the mining industry.

In the following the invention is explained in more detail with reference to the appended drawing, where
figure 1A is a side-view illustration of an embodiment of the method of the invention,
figure 1B is a top-view illustration of the embodiment of figure 1A,
figure 1C illustrates the various images, obtained from different directions, of one element in the

embodiment of figure 1B,
figures 2A and 2B illustrate another embodiment of the
method of the invention, seen from the side and
from the top,
figure 3 is a side-view illustration of a third embodiment
of the method of the invention, and
figures 4A and 4B illustrate a fourth embodiment of the
method of the invention, seen from the side and
from the top.

The principle of an imaging method according to the invention is illustrated in figures 1A, 1B and 1C, where the imaging of the internal structure of a log is shown as an example. The radiation source is an X-ray tube transmitting X-ray radiation at a wide scanning angle. The log to be inspected is passed through the conical X-ray beam. Radiation is measured by means of linescan detectors 4, 5, 6, 7 and 8. The detector lines proceed transversally underneath the log. A linescan detector may be composed of several (e.g. 100 - 500) parallel, separate X-ray detectors, or of one long detector, which is sensitive to location, i.e. both detects and defines the location of the detected point in relation to its length. Figure 1C shows the images of one element obtained from different angles, when the X-ray tube has relatively passed over the log during scanning, and the numbers 4, 5, 6, 7 and 8 below refer to the respective line detectors which were used in scanning these directions. The said elements may be for instance 0.5 cm in diameter. The densities of wood elements are defined on the principle that each element is imaged from different angles, and their summed absorptions are always obtained from the respective detector of the linescan detector, along with the time when the log passes through scanning. In principle, at least 2 detector lines are always needed for scanning; the number in the example is 5. The number of detector lines may vary in different applications, and a larger number of detectors generally produces a sharper image. The images are

computed, like in normal tomography, as cross-sectional images of a given plane, for instance of the cross-sectional image 1-6. When all cross-sectional images are processed, we obtain a three-dimensional density image of the log in question, with indication to knots, rot, cracks and often height distribution, too. In addition, the apparatus can be provided with a profile reader for defining the external shape of the log. This is a useful aid in calculation, when constructing sawing images. All elements of the log are imaged from several directions, and therefore the location of knots in the sawn goods produced of the log can also be directly defined.

In the embodiments of figures 2 - 4, the radiation source and the detector form a pair, one of which remains still and the other moves along a circular path, so that the radiation surface under measurement obtains a conical form. The object under inspection passes through this conical surface, in which case the image is normally constructed by means of a computer. In practical applications, it is possible to use either several detectors or several radiation sources. Different modifications can naturally be combined; for example perpendicular imaging is carried out by means of a stationary detector line, and inclined images from both sides are obtained by using a rotating plate.

In the description below, we give three detailed examples of the use of the method:

Example 1.

Figure 2 illustrates a log tomograph comprising a radiation source 11 (X-ray machine) transmitting continuous X-ray radiation, and a rotating plate 17 provided with a radiation detector 12 for measuring the amount of X-ray radiation at any given moment. The object, i.e. log 13, under inspection, is conducted, for example on a conveyor belt, at an even velocity through the tomograph. When the log enters

the conical X-ray beam, the absorption curve of the cross-section is measured on the spot 15, and a cross-sectional density profile is obtained. When the log passes through the second surface 16 of the X-ray beam, lateral density profiles are obtained. From these cross-images, the density distributions in the internal structure of the log can be defined, and on the basis of the said distributions, the location of knots, cracks and rot in the log can be calculated, as was explained in the specification above. In practice, the imaging rate can be for instance 2 m/s, and if the sections are made at 1 cm intervals, the imaging rate is 200 sections per second. If two X-ray detectors are arranged on the circular path (with a phase difference of 90°), the speed of rotation is 6000 rpm, which is achieved with conventional technique. The protective screens seen in figure 2 are provided in order to prevent the detector from being incessantly subjected to radiation. The system can incorporate one or several detectors, and the data is read along a line onto a computer 14, so that only one detector at a time is exposed to radiation. An optional laser profilator, for instance, can be provided in the apparatus in order to define the cross-sectional contour image of the log prior to inspecting the internal structure. This information helps create the cross-sectional image more rapidly and accurately.

Example 2.

Figure 3 illustrates a stone detector. The detection of stone for instance in peat to be burned as fuel, or in a flow of lumber to be chipped, is an important task, but a fully satisfactory method has earlier been lacking. Because the resolution needed here is not nearly as high as in the previous case, the radiation source 21 is a radio isotope source (e.g. 100 mCi Am-241). The detector 22 can now be installed in a stationary fashion to measure the radiation intensity. Density differences in the conveyed material 23 are defined from the absorptions on the perpendicular cone

surface 25 and on the inclined cone surface 26 by means of the computer 24.

Example 3.

Figure 4 illustrates the definition of the size of chip particles. An interesting object of measurement in the pulp industry are the dimensions of chip particles: their length, width and height distribution. Because it is not necessary to observe the internal structure, an ordinary light suffices as the radiation source. In the measuring arrangement of figure 4, the employed sources are light emitting diodes 30, and the detectors are two photomultiplier tubes 31 and 32. The light sources, 20 or more in number, are attached to a rotating plate 36, which in this case is rotated at the speed of about 10,000 rpm. On a transparent conveyor belt 35, the chips 33 are scattered so that they do not fall on top of each other. The belt is conveyed at the pace of for example 1 m/s, so that each light source successively proceeds above the imaging aperture 37, underneath the transparent conveyor belt 35. If the number of light sources is 20, and the speed is 10,000 rpm, the belt is scanned at the intervals of 1/3 of a second. On the basis of the black-out time of the photomultiplier located vertically above, the width of the chip is obtained at the scanning point in question. From the appearance time difference of the edge, which is detected by means of the photomultiplier tube 32 looking from an inclined direction, the height of the chip at the respective scanning point is obtained. On the basis of these readings, the length, width and height of the chip are calculated in a computer.

Other types of variation can also be used in the imaging method, and the velocity of the objects of inspection, as well as the imaging rate, can vary in different applications. In the preferred embodiments described above, the objects of inspection are moved with respect to the radiation source and the detector, but in other embodiments the

radiation source and/or the detector can be moved, while the object under inspection remains in place. In addition to stationary detector arrays, one or several rotatable plates or platforms can be used. In another preferred embodiment, on a rotatable platform there are located radiation detectors for different radiation intensities, in which case more than two inclined sections can be measured.

When using the method of the invention, the employed radiation can be visible light, X-ray radiation, radar, gamma, neutron, infrared or microwave radiation, pulsated magnetic field or other such radiation or combinations thereof, which radiation or radiations interact with the object under inspection. An interesting branch of tomography is neutron tomography, where a large, rotatable plate is provided with a neutron source, and above it there is placed a neutron detector. If the dimensions are 3 - 5 meters, this method can be used for scanning vehicles, containers and the like when searching possible organic materials, such as explosives or drugs.

The invention is not restricted to the preferred embodiments above, but it may vary within the scope of the inventional idea specified in the appended patent claims.

PATENT CLAIMS

1. An imaging method for defining structures of objects, in which method the object under inspection (3; 13; 23; 33) and at least one radiation source (1; 11; 21; 30) and at least one detector (4 - 8; 12; 22; 31, 32) are moved in relation to each other, so that the object under inspection is passed through the radiation transmitted by the radiation source, c h a r a c t e r i z e d in that one or more detectors are used for measuring, from at least three different angles, the changes in the intensity of the rays that are absorbed, at least partly, in the object under inspection - these changes being measured as the function of the motion of the said object; so that the structural points required in order to image the structure are defined from at least three different directions; and as the passage of the radiation through the object is always known at the point of measurement, the three-dimensional structure of the object can be calculated.

2. The imaging method of claim 1, c h a r a c t e r i z e d in that the object (3) under inspection is made to travel in between a stationary X-ray tube (1) and X-ray detectors (4 - 8) arranged transversally in the motional direction of the object of inspection, and that the said X-ray detectors observe the radiation of the X-ray tube from at least three different angles.

3. The imaging method of claim 1, c h a r a c t e r i z e d in that the object under inspection (13; 23; 33) is made to travel at least through one conical imaging surface (15, 16; 25, 26), the said imaging surface being created by at least one radiation source (11; 21; 30) and at least one radiation detector (2; 22; 31, 32), and that at least one of these is moved along a circular path, while the other remains static.

4. The imaging method of claim 3, c h a r a c t e r - i z e d in that a three-dimensional tomography image is created of the object under inspection, and that for processing the image, there are used values obtained from the readings of radiation intensity transmitted by a stationary X-ray tube (11), from at least two divergent sections (15, 16) of the object under inspection, which readings are measured by means of at least one detector (12) arranged on a rotatable platform (17).

5. The imaging method of claim 4, c h a r a c t e r - i z e d in that on a rotatable platform, there are arranged detectors (12) along a circular path, so that the rest of the detectors are located under radiation-protective screens (18) while other detectors measure the sections (15, 16).

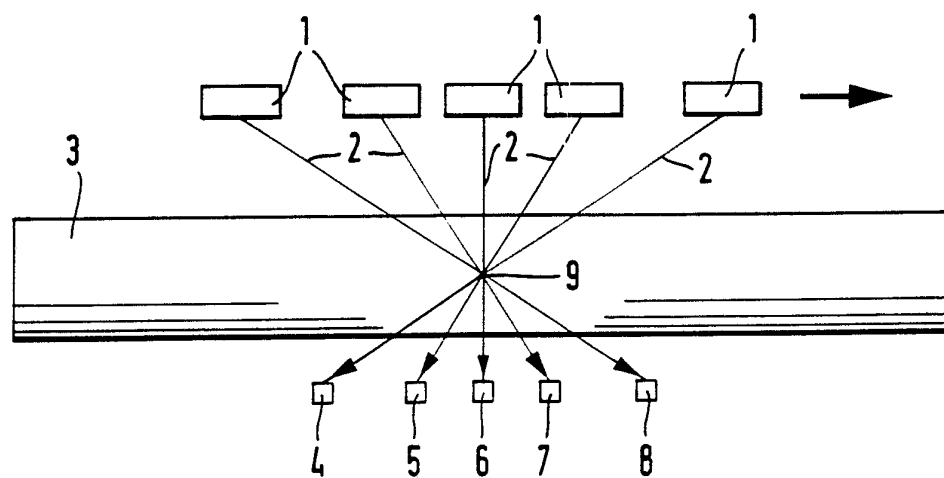
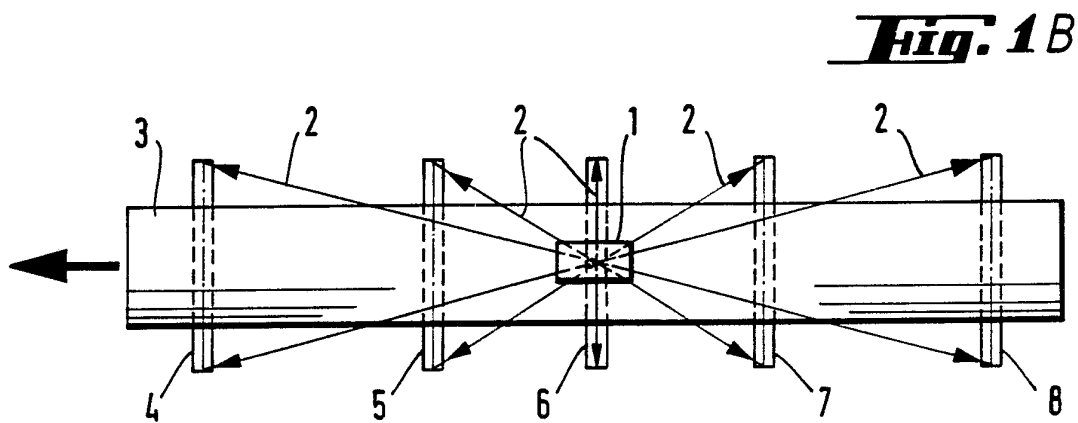
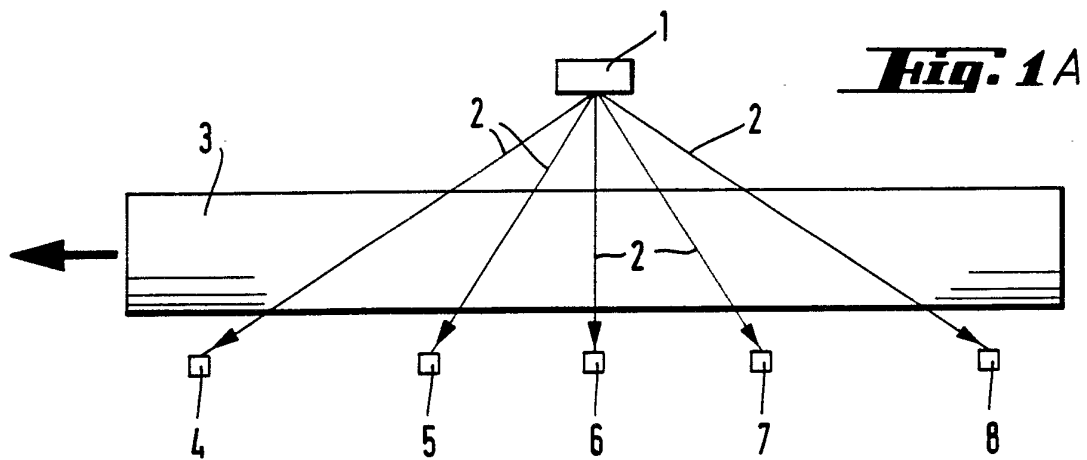
6. The imaging method of claim 3, c h a r a c t e r - i z e d in that items with deviant densities are identified in the material flow (23) by allowing the material pass in between the radiation source (23) composed of a radio isotope arranged in the rotatable plate (27) and a stationary radiation detector (22), and that the said radiation detector measures the radiation in the sections (25, 26).

7. The imaging method of claim 3, c h a r a c t e r - i z e d in that the shape of three-dimensional objects (33) is defined by using light as the employed radiation, which light is emitted by light sources (30) attached to a rotatable platform (36); that the projection parallel to the surface of the object is measured by means of a detector (31) provided vertically above the imaging aperture (37), and that the height is calculated from the black-out time difference between this detector (31) and the detector (32) looking towards the same light source from an inclined angle, so that the final image of the width, length and height is constructed on the basis of the velocity data of these detectors (31, 32) and the transparent belt (35).

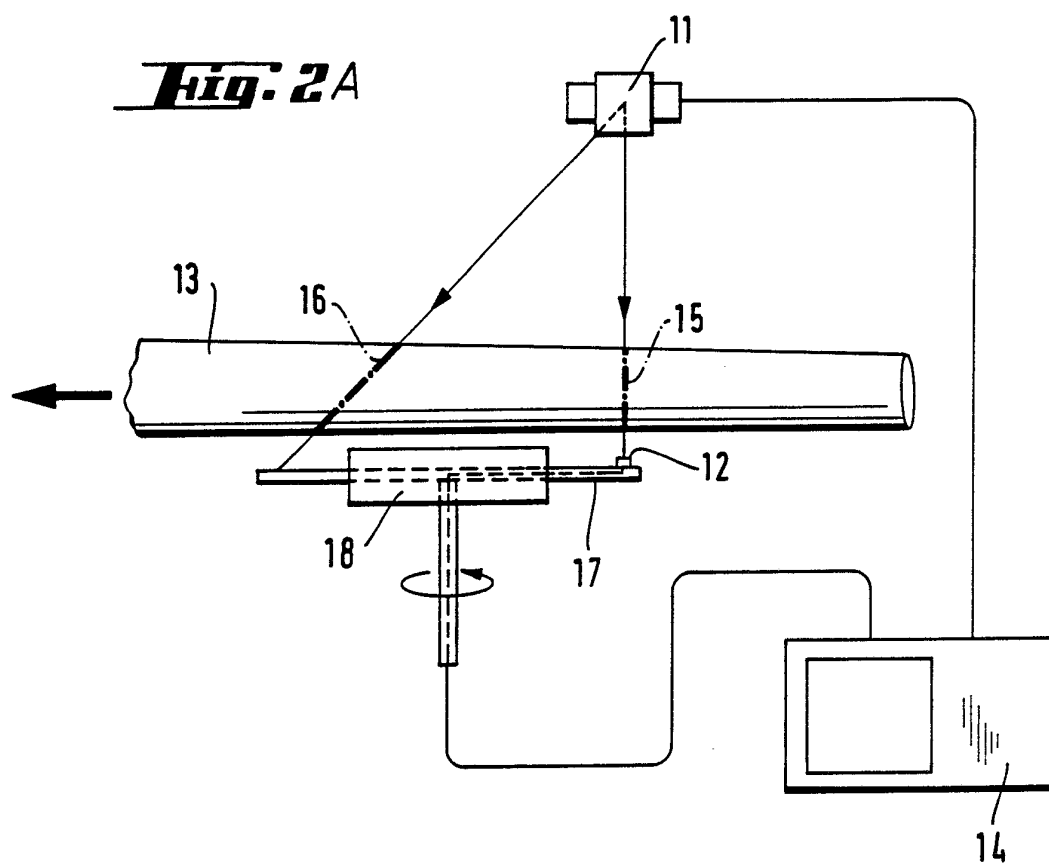
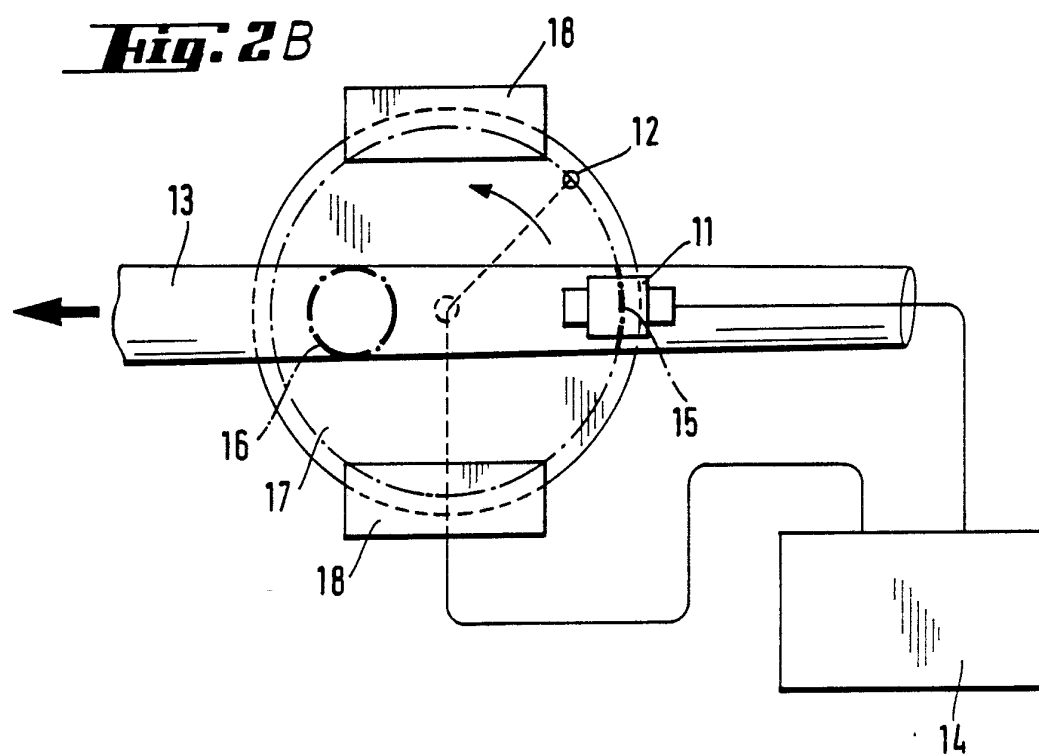
8. The imaging method of any of the preceding claims 3 - 6, characterized in that on a rotatable platform, there are arranged radiation detectors for different radiation intensities, so that more than three inclined sections can be measured for processing the tomography images.

9. The imaging method of claim 1, characterized in that there are simultaneously used both stationary detectors arranged in a line, and a rotatable detector for measuring the required sections.

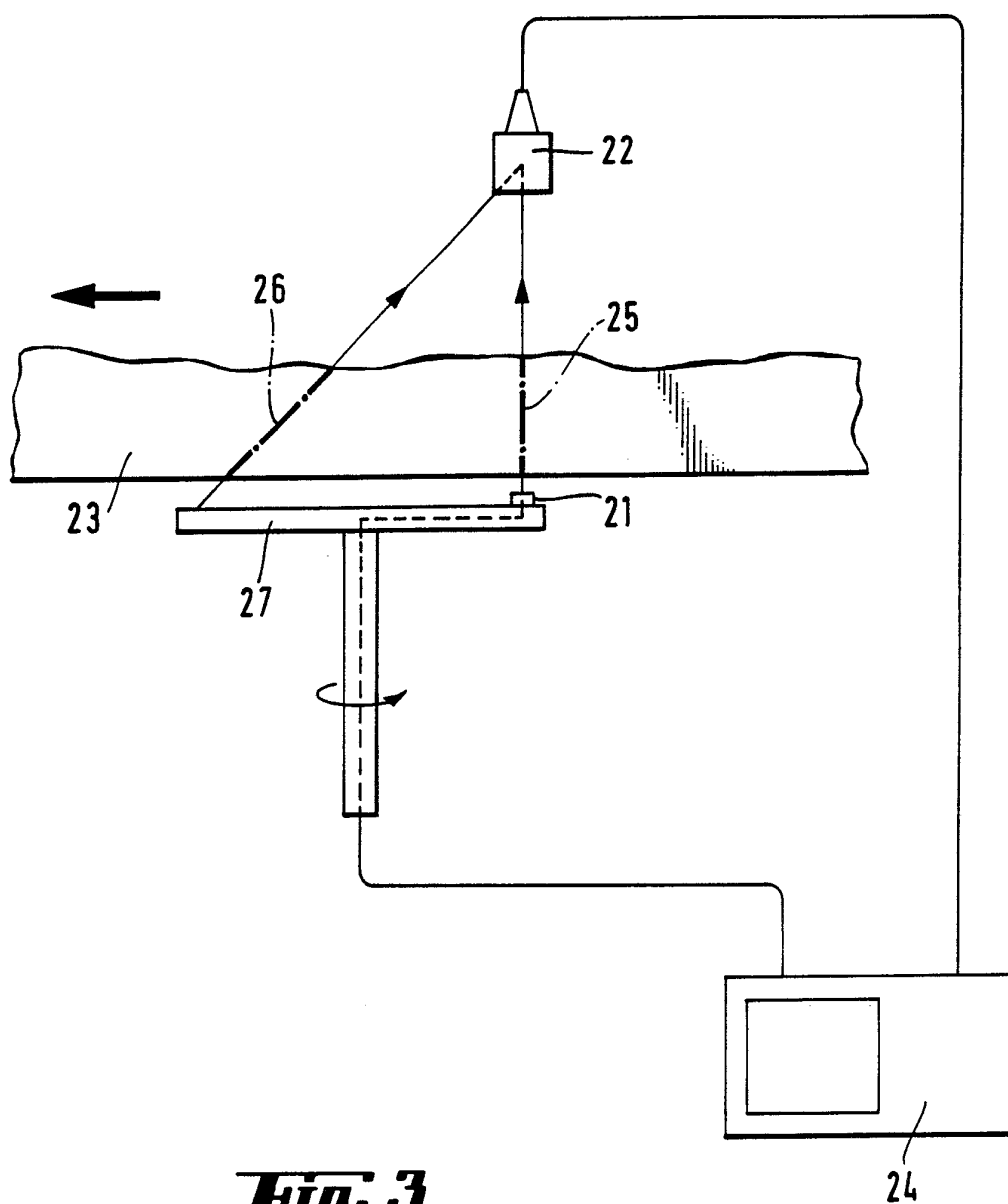
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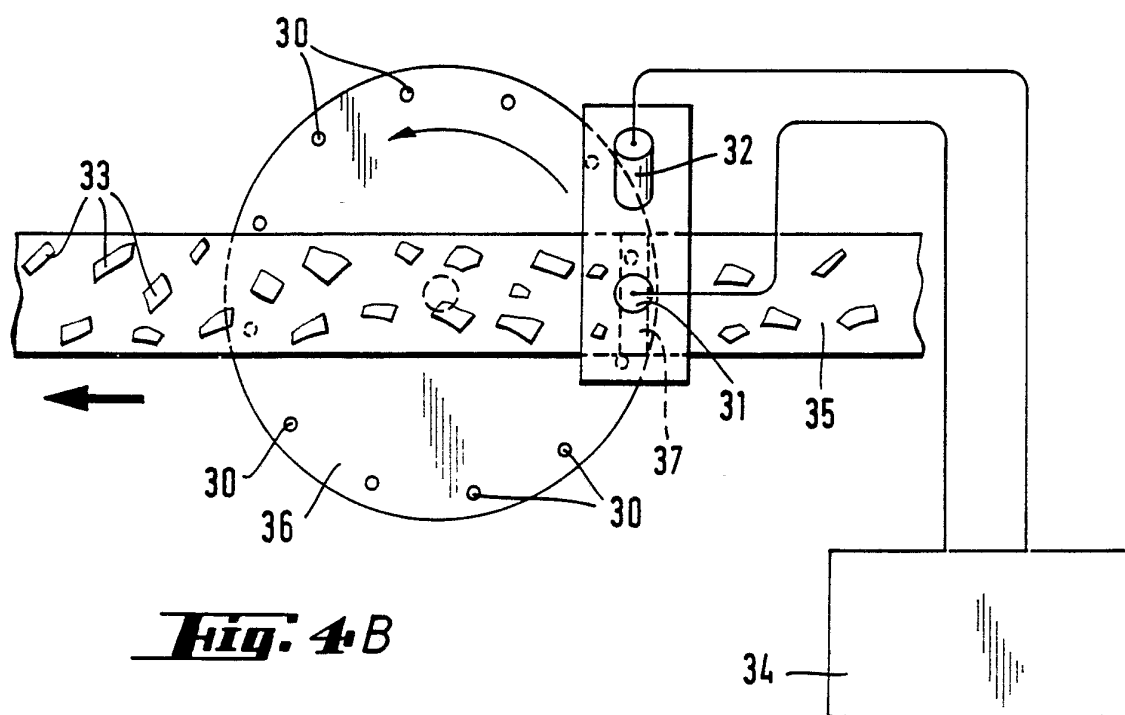
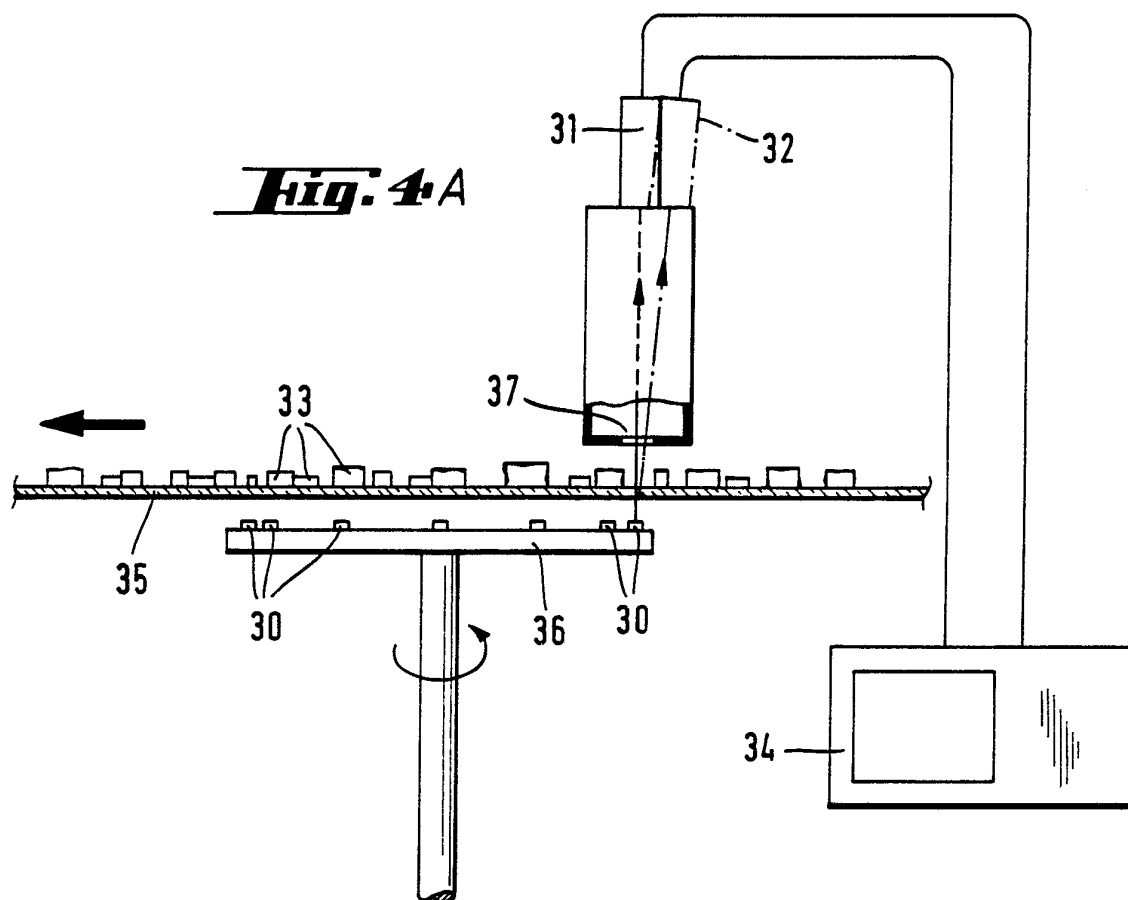
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Fig. 2A**Fig. 2B**

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**Fig. 3**

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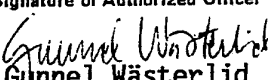


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INTERNATIONAL SEARCH REPORT

International Application No **PCT/FI 91/00304**

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate)		
According to International Patent Classification (IPC) or to both National Classification and IPC IPC5: G 01 N 23/02		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁷		
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IPC5	G 01 N	
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III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹		
Category *	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
X	EP, A2, 0261984 (ROBINSON, MAX) 30 March 1988, see figure 2; claims 1,2	1,2
A	--	3-9
X	US, A, 4064440 (FREDERICK L. RODER) 20 December 1977, see column 2, line 9 - line 34; column 2, line 64 - column 3, line 22; column 5, line 1 - line 42; figure 1	1
A	--	2-9

<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>* Special categories of cited documents:¹⁰</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> </div> <div style="width: 45%;"> <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> </div> </div>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
9th January 1992	1992 -01- 3	
International Searching Authority	Signature of Authorized Officer	
SWEDISH PATENT OFFICE	 Gunnel Wästerlid	

**ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.PCT/FI 91/00304**

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the Swedish Patent Office EDP file on 31/10/91
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A2- 0261984	88-03-30	AU-D- 7922687 JP-A- 63107294	88-03-31 88-05-12
US-A- 4064440	77-12-20	NONE	