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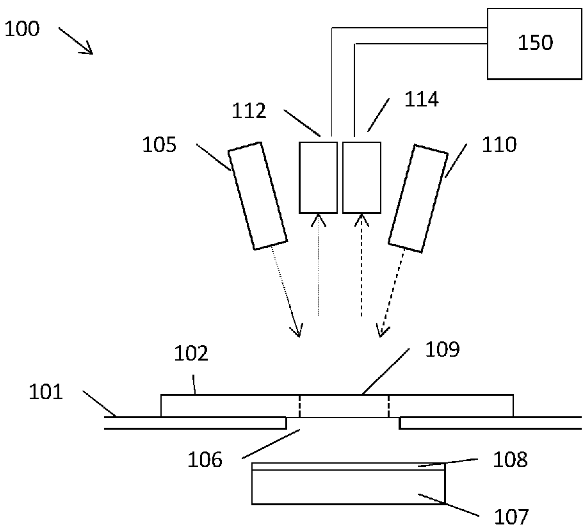

Figure 1

(57) Abstract: Document inspection apparatus is provided for inspecting translucent regions of security documents. A first illumination device provides visible light illumination of the document and a first detector receives the light reflected from features in a translucent region of the document, together with light reflected from a reflection member behind the translucent region. A second illumination device and detector perform a similar function for infra-red light, notably using the same reflection member. The reflectivity properties of the reflection member are engineered to produce contrast in images of the translucent regions obtained using the detectors.

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Document Inspection Apparatus

Field of the Invention

The present invention relates to document inspection apparatus, for example in the inspection of security features upon or within security documents or documents of value, such as banknotes.

Background to the Invention

Document inspection is used in a number of different technical fields to obtain information about different characteristics of documents, particularly documents which are fed along a transport path. These characteristics include the document condition, size and, in the case of security documents, characteristics such as authenticity and denomination. The document inspection or monitoring may be performed for various purposes including authentication and sorting. It may also be performed as part of a quality control procedure to ensure that the documents have been manufactured according to given specification.

In order to ascertain the characteristics of the documents, different information must be obtained from the documents. Typically the documents are fed past a number of different detectors and processing environments to enable each aspect or characteristic to be determined. The accuracy, reliability and resolution of the inspection apparatus used is typically subject to stringent engineering specifications. In addition there is usually a need to perform such inspection at a very high throughput or processing speed. The use of multiple detectors and processing environments has an impact in terms of the cost and space required. For example each type of detector is typically provided with its own dedicated part of an extensive document path. As new types of features are developed in such documents the corresponding detectors required to inspect them are also developed. This results in a corresponding increase in the cost and size of the apparatus. For example a relatively recent development in such documents is the provision of regions of translucent substrate upon which printing inks and metallic foils are applied to produce new aesthetic and security features. There is a need to improve such apparatus to address these issues.

Summary of the Invention

In accordance with the invention we provide document inspection apparatus for inspecting a document when in an inspection region, the document having a first translucent part including a first reflective material and a second translucent part including a metallic reflective material, the apparatus comprising:

a first illumination device arranged to illuminate the inspection region, from a front side, with electromagnetic radiation within a first wavelength range that is a human-visible wavelength range;

a second illumination device arranged to illuminate the inspection region, from the front side, with electromagnetic radiation within a second wavelength range that is an infra-red wavelength range;

a reflection member, located at a rear side of the inspection region with respect to the first and second illumination devices and formed from a material having a first reflectivity with respect to the first wavelength range and a second reflectivity with respect to the second wavelength range;

a first detector arranged to receive any electromagnetic radiation in the first wavelength range that has been reflected from the first translucent part of the document when in the inspection region, and, to receive any electromagnetic radiation in the first wavelength range that has been reflected by the reflection member according to the first reflectivity and transmitted back through the first translucent part;

a second detector arranged to receive any electromagnetic radiation in the second wavelength range that has been reflected from the second translucent part of the document when in the inspection region, and, to receive any electromagnetic radiation in the second wavelength range that has been reflected by the reflection member according to the second reflectivity and transmitted back through the second translucent part;

wherein the first reflectivity of the reflection member is different from the reflectivity of the first reflective material of the first translucent part of the document so as to enable the structure of the first reflective material to be analysed using the first detector; and wherein the second reflectivity of the reflection member is different from the reflectivity of the metallic reflective material of the second translucent part of the document so as to enable the structure of the metallic reflective material to be analysed using the second detector.

The invention makes it possible to use a common inspection region for the provision of reflective infra-red detection and reflective optical detection for the inspection of regions of documents having translucency. This is achieved using an illumination and detection system in combination with a reflection member having carefully designed reflection properties with respect to the infra-red and optical wavelengths of the incident electromagnetic radiation. The use of common features not only saves upon costs by obviating the need for additional dedicated equipment but also allows a more compact apparatus to be produced.

The term “translucent” is used here according to its generally accepted meaning in which light is transmitted but it is not essential that the formation of a clear image is achievable. This term therefore includes transparency in which the formation of a clear image is possible.

When considering a reflection-based geometry it is important to consider whether to detect specularly reflected radiation or diffusely reflected radiation. Whilst the present invention contemplates the use of specular reflection, it is preferable to use diffuse reflection here. Accordingly, one or each of: the first illumination device and first detector, or, second illumination device and second detector, are arranged in a non-specular configuration such that the respective first or second detector receives diffusely reflected light from the respective first or second illumination device. The reflectivity “seen” by the detector in each case is dependent upon the geometry of the system and therefore the first or second reflectivity may be considered as an effective reflectivity in dependence upon the relative arrangement of the respective illumination device and detector.

The difference in intensity between a specular and diffuse reflective arrangement is most extreme when considering metallic reflective materials used on security documents. It is therefore preferred that at least the second reflectivity detected of the metallic material is a diffuse reflectivity and wherein the said second reflectivity is less than that of the reflection member, in the second wavelength range.

The first reflective material may take a number of different forms including a region of opacifying layer on a translucent polymer substrate, or various forms of printing (offset, lithographic, intaglio and so on). In principle the reflection member may have a greater reflectivity than this material although, due to the design requirements of most documents, in practice usually the reflection member will have a lower level of reflectivity than the first reflective material.

The reflection member is preferably arranged so that the electromagnetic radiation in the first wavelength range is partially reflected from the first reflective material and the electromagnetic radiation in the second wavelength range is partially reflected from the metallic reflective material. There is no requirement that such reflectivities in these wavelength ranges be similar, indeed in many cases it may be desirable practically that they differ.

The primary practical objective of the apparatus is to allow the analysis of the structure of the first reflective material and the metallic reflective material. Typically such analysis will be partially automated or fully automated (effectively unsupervised). The structure of the first reflective material may be one or more of two dimensional topography, three dimensional topography, the opacity. Likewise the structure of the metallic reflective material is one or more of two dimensional topography, three dimensional topography, the opacity.

Reflectivity is a property well understood in physics, together with its related property of reflectance in certain structures. In the present discussion is it understood that each material has a specific reflectivity at each wavelength, and that the variability of this reflectivity as a function of wavelength is usually relatively complex. Ordinarily the reflectivity is considered as being specific to that material and therefore the material can be thought of as a semi-infinite body. In practice it is understood that some materials, whilst having a reflectivity, will due to their limited thickness permit the passage of electromagnetic radiation at some wavelengths, making them non-opaque. The reflectivity of the materials discussed here takes a practical meaning in the sense of the amount of radiation reflected from the material that is present, at a given wavelength, as a function of the amount which was incident at that wavelength. In this discussion we prefer to use normalised reflectivities due to the comparative nature of the reflectivites in the invention. Preferably therefore the first reflectivity of the reflection member and the reflectivity of the first reflective material are each normalised reflectivities. Normalised reflectivities are also convenient when considering the effect of the geometry on the reflected intensity. For example the normalised reflectivity of a surface according to normal incident radiation and measured at a first angle (say of 20 degrees) will, for most materials and surface finishes, be effectively different from the reflectivity at a second angle (say 40 degrees). Whilst the reflectivity of the surface itself will be the same in each instance, the angle causes an “effective reflectivity” to be observed by the detector. Since the arrangements discussed herein are primarily diffuse reflectivity arrangements, the reflectivities described herein are, unless otherwise discussed, effective reflectivities.

In practice it is preferred that the first reflectivity of the reflection member is different from the reflectivity of the first reflective material by a normalised value of 0.1 or more in a given arrangement. It is also preferred that, where the second reflectivity of the reflection member and the reflectivity of the metallic reflective material are each normalised reflectivities, then the second reflectivity of the reflection member is different from and typically greater (as is the case for diffuse reflection) than the reflectivity of the metallic reflective material by a normalised value of 0.1 or more.

The present discussion also considers the effect of wavelength bands of illumination and detection, rather than a single wavelength. This is due to the practicalities of real life illumination and detection. For this reason, unless the context otherwise requires it, each reflectivity can be considered to be an average reflectivity of the electromagnetic radiation across the respective range of incident wavelengths in the respective wavelength band. A simple mean average can be used for this. This becomes more important for larger wavelength bands such as “white light” where the actual reflectivity function is likely to be complicated. The averaging causes no problem in practice since it is the difference in effective reflectivities that matters most for producing discernible contrast in any image data to be processed.

Returning to the apparatus itself, whilst the first and second illumination devices may illuminate discrete or overlapping inspection areas, which may be of different sizes, it is convenient to arrange each of the first illumination device and the second illumination device to illuminate a common area of the inspection region, also preferably a common area of the reflection member. This assists in costs reduction and production of a compact apparatus. The wavelength specificity of the detectors can readily prevent any “cross talk” due to simultaneous illumination. In any of the above arrangements it will also be understood that the reflection member may have an area which corresponds to part of or all of the area of the inspection region, as appropriate.

The preferred arrangement with relation to documents in the inspection region which lie within a general document plane, is that the first and second illumination devices are located upon each side of a plane which is orthogonal to the document plane. This orthogonal plane can be thought of as a mirror plane for the positioning of the apparatus. The first and second detectors may be located upon each side of the mirror plane. Typically the detectors and illumination devices lie in a plane which is orthogonal to each of the aforementioned planes. The detectors may be positioned inwards or outwards of the illumination devices with respect to the mirror plane.

The first wavelength range may represent part or all of the human-visible wavelengths of light. These are generally considered to be in the range of about 400 to 700 nm. The intensity of the electromagnetic radiation need not be constant although in practice a near constant illumination across all or substantially all of this visible range results in a white light band of wavelengths which may be preferred to provide general application to different types of documents. The second wavelength range that is the infra-red wavelength range is typically within the near infra-red range, for example between 700 and 1000 nm.

Since it is usually desired to transmit the documents along the transport path at high speed it is preferred to use line scanning rather than image scanning as the preferred type of detectors. Line scanning is helpful for the purposes of illumination because a smaller area requires illuminating which reduces the overall intensity of the illumination needed. For this reason preferably the detectors are line scan cameras.

The apparatus also preferably is provided with a control computer which is adapted to receive signals from the first and second detectors and to perform an analysis upon the signals. The signals are typically in the form of digital data and the computer controller may perform a number of different processing techniques according to the desired application, including comparison with thresholds, comparison with master patterns and other image processing. Generally the analysis includes a comparison between the received signals and expected signals. The analysis also typically includes the detection of the location of one or more edges (particularly those normal to the feed direction) or corners of the document. The control computer is typically further adapted to produce an output signal indicating a resultant condition of the document. In a straightforward example such a signal may take the form of data indicating that a particular analysis test has been passed or failed. As will be understood the signals from the first and second detectors are each used in the analysis of one or each of the first translucent part or second translucent part of the document. These parts generally represent security features or aesthetic features of interest. The first and second translucent parts of the document will be understood to include translucent areas in combination with other reflective material (generally opaque) according to the feature in question. These parts may overlap or effectively may be a single part.

The form of the reflection member is particularly important. Generally it comprises a reflection material. Whilst the reflection material may be formed from one unitary component or constituent material, generally the reflection material comprises a plurality of component materials. Typically one or more of the component materials is selected from the group comprising an infra-red absorbing additive or a printing ink. As an alternative to a coating or printing ink the reflection member may be a polymer substrate into which is incorporated an infra-red absorbing additive and a colourant such as a dye or pigment which would be selected to achieve the correct reflective properties. The printing ink could be applied to the substrate using any known printing process such as lithographic, gravure, flexographic or screen printing.

Typical Infrared absorbers can be:
An infra-red dye,
An infrared organic pigment and
An inorganic infra-red pigment.

Examples of infra-red dyes are:
indolizine dyes,
quinone dyes,
azo dyes,
quinoid dyes,
merocyanine dyes,
cyanine dyes,
squarylium dyes,
croconium dyes,
polymethine dyes,
oxyindolizine dyes,
polymethyl indoliums,
indocyanine green,
bis(aminoaryl)polymethine dyes,
chalcogenopyryloarylidene dyes,
metal thiolate complex dyes,
bis(chalcogenopyrylo)polymethine dyes,
pyrylium dyes,
phthalocyanine dyes,
naphthalocyanine dyes,
metal complex IR dyes,
and combinations thereof.

A preferred infrared dye is:
5-[2,5-bis[2-[1-(1-methylbutyl)benz[cd]indol-2(1H)-ylidene]ethylidene]cyclopentylidene]-1-butyl-3-(2-methoxy-1-methylethyl)-2,4,6 (1H,3H,5H)-pyrimidinetrione.

Suitable inorganic infra-red pigments include:
Transparent IR absorbers from NYACOL Nano Technologies-
NYACOL® SN902
NYACOL® SN902W
NYACOL® SN902SD
NYACOL® SN902
NYACOL® SN903
NYACOL® SN903W
NYACOL® SN903SD
NYACOL® SN903-PM
NYACOL® ITO-EG.

Suitable inorganic infra-red pigments can also be carbon blacks including:
Carbon Black MA8™ (MITSUBISHI CHEMICAL),
Special Black 250, Special Black 350, Special Black 550, Printex™ 25, Printex™ 35, Printex™ 55 and Printex™ 90 from DEGUSSA.
Regal™ 400R and Elftex™ 320 (CABOT Co.).

Typical concentrations of additive are 0.01 to 2.0 g/m^2, more preferably in an amount of 0.1 to 1 g/m^2 in the final coated layer.

It may be preferred to provide the reflection material as a layer upon a support. This is convenient to allow the layer to be replaced as may be necessary if different documents or different detectors or illumination devices are employed. The reflection layer may be opaque. However the reflection layer may be translucent and in this case the reflectivity of the reflection member is a combination of the reflectivity of the layer and the reflectivity of the support. The reflectivity of the support itself may therefore need consideration and selection to achieve the desired cumulative reflectivity properties.

Brief Description of the Drawings

Some examples of the invention are now described with reference to the accompanying drawings, in which:

Figure 1 is a schematic view of a first example apparatus;

Figure 2 shows the features of an example document for inspection;

Figure 3 illustrates the reflectivity properties of the reflection member; and

Figure 4 shows a second example document.

Description of Examples

An example system 100 for use in the quality control of banknote production is now discussed with reference to Figure 1. The system is a high speed banknote inspection system, part of which is shown schematically in Figure 1. The system 100 has a document guide 101 forming part of a transport path. The guide in Figure 1 is generally planar. A banknote 102 is shown positioned upon an upper side of the guide 101. The banknotes are transported along the transport path (including the guide 101) using a number of parallel thin belts. An infra-red (IR) LED emitter 105 is positioned on the upper side of the transport path. The emitter 105 is arranged to have an optical axis passing through an inspection region 106 in the form of a gap in the guide 101. The emitter 105 is positioned a few centimetres upstream of the centre of the inspection region 106 and is therefore angled at about 15 degrees. A white light LED emitter 110, formed from a combination of red, green and blue LED sources, is similarly positioned downstream, in a mirrored fashion with respect to the inspection region and IR emitter 105. The two emitters 105 and 110 are therefore spaced equally from a mirror plane normal to the inspection region and the plane of the guide 101. Beneath the inspection region 106 on the other side of the plane of the guide 101 is positioned a reflection member 107. In practice the separation distance is about 1 mm. This reflection member 107 has an upper surface which is provided with a specialised reflective layer 108. The reflective layer 108 selectively reflects electromagnetic radiation received from each of the IR emitter 105 and white light emitter 110. The upper surface of the reflection member 107 and its layer 108 are arranged in a plane generally parallel with that of the guide 101 and therefore the electromagnetic radiation received from the emitters is generally reflected back through the inspection region 106 in the opposite direction to that in which it is received. In practice the reflection member may form part of the guide 101 and a slit may be positioned above the guide to define the inspection region 106, with the radiation being transmitted to and received from the banknote 102 through the slit. In this case the banknote 102 may physically contact the reflective layer 108 of the guide which is beneficial for the reflection function but may cause deterioration of the surface through wear.

Two detectors, one for each emitter, are located between the emitters 105 and 110. The first detector is an IR line scan detector 112, located on the same side of the mirror plane, and inward of, the IR emitter 105. Likewise an optical line scan detector 114 is positioned inwardly of the white light emitter 110 with respect to the mirror plane. The general path of the infra-red light is shown by the dotted line arrows in Figure 1. A similar path for the optical white light is shown with the dashed line arrows. It will be noted that each detector is positioned upon the same side of the mirror plane as its respective radiation source. The result is that, even when taking into account the finite “width” of the line scan detectors, the radiation received is between 15 and 30 degrees in angle away from the specular reflection geometry. It will be appreciated also that the detector may be positioned upon the other side of the mirror plane either at a small angle to the mirror plane (such as less than 5 degrees) or at an angle significantly higher than 15 degrees (such as greater than 25 degrees) to similarly avoid detecting specularly reflected radiation. The detectors therefore are arranged to detect radiation that has been diffusely reflected.

The banknote 102 is illustrated with a generic translucent region 109 (denoted by dashed lines) sitting above the inspection region 106 in Figure 1. The translucent region is schematically representative of one or more translucent regions within the banknote 102 as now illustrated with reference to Figure 2.

Figure 2 shows a schematic banknote 102 when viewed from above its general plane. The banknote 102 in this case is formed from a polymer substrate 115. As will be understood such polymer substrates have increased in popularity in recent years and are now used for the currency of a number of nations. The substrate for the banknote 102 in the present example is biaxially oriented polypropylene (BOPP). Since this material is translucent, when used as a substrate for a banknote it is typically provided with one or more opacifying layers (with anti-static properties) for example based upon titanium dioxide, giving a resulting appearance similar to a paper substrate. By selective application of the opacifying layer in a region it is possible to generate a “watermark” in the banknote. In such a region there is a modulation in the position dependent translucency of the banknote 102. Such a watermark region 120 is indicated in Figure 2. The outer oval region delimits the opacifying layer (exterior) from a translucent region (interior). Within the translucent region is shown an inner oval and portrait which together can be thought of as a watermark image 121. In Figure 2 the detail of the watermark image 121 represents the presence of opacifying material. The watermark region 120, including the watermark image 121 are a first security feature within the banknote 102.

A second security feature is provided by the foil 125 which takes the form of a rectangular metallic strip generally passing between the long edges of the banknote 102. Within the foil are a number of demetallised regions 126 taking the shapes of letters to spell the word “Twenty Pounds”. The foil overlies a similarly sized rectangular region of the substrate such that, within the boundaries of each demetallised letter, the translucent BOPP material of the substrate 115 is exposed.

Within the system 100 the manufacturing quality of the watermark region 120 is assessed using the optical white light emitter 110 and detector 114. Likewise the manufacturing quality of the foil 125 with demetallised regions 126 is assessed using the IR emitter 105 and detector 112. In each case this assessment must be performed very rapidly whilst the banknotes are in motion along the transport path, for example at a rate of 40 banknotes per second. The position of these features with respect to the leading and trailing edges of the banknotes (these being the “short” edges in the present example) is also monitored by using the detection systems to identify the edges.

With reference to the foil 125, electromagnetic radiation having a wavelength in the range 850 to 950 nm is emitted from the emitter 105 and impinges on the translucent region 109 of the banknote 102 (noting that the translucent region represents the foil 125 with demetallised regions 126 in this instance). The metallic foil, whilst generally being strongly, specularly reflective to incident optical radiation and infra-red radiation, exhibits weak diffuse reflection in each of these wavelength bands. Thus little of the infra-red radiation that is incident on the metallic foil is reflected back to the detector 112 because the detector is not located at the specular reflection angle. The radiation that is incident upon the demetallised regions 126 passes through the letter shaped apertures within the metallic foil and continues, through the substrate material to impinge upon the layer 108 of the reflection member 107. The infra-red radiation that reaches the reflection member 107 is partially reflected back, through the substrate and regions 126 and is detected by the infra-red line scan detector 112. The reflection member 107 diffusely reflects a substantially higher proportion of the incident infra-red radiation than the foil 125 and therefore the infra-red detector sees the foil areas as relatively dark (that is, low intensity radiation) with the surrounding demetallised regions 126 as relatively light (higher intensity).

The line scan detector detects lines of image data and provides corresponding infra-red line data to a computer controller 150 (shown in Figure 1) for analysis. In analysing the quality of the manufacturing process the computer controller 150 generates a composite image from the infra-red line scan data and this may then be compared with an expected image using known techniques. The principal issue under assessment in this case is whether the foil material has been correctly demetallised to accurately reproduce the characters of the “twenty pounds” lettering.

Returning to Figure 2 the white light emitter 110 optically combines the outputs of red, green and blue LEDs to produce white light of an approximately constant spectral power distribution across an optical wavelength range of about 400 to

700 nm. This impinges on the translucent region 109, in this case the region representing the region 120 with watermark image 121. The white regions within Figure 2 that are inside the oval boundary of the region 120 represent the substrate which is absent the opacifying layer. White light radiation passes readily through this region of the substrate material to impinge upon the layer 108 of the reflection member 107. The white light radiation that reaches the reflection member 107 is partially reflected back, through the translucent parts of the region 120 (those absent in the watermark image structure) and is detected by the optical line scan detector 112. In addition, the radiation that impinges upon the watermark image 121 is partially reflected back to the optical line scan detector 112. The reflectivity of the layer 108, on average, across the 400 to 700 nm wavelength band, is less than that of the opacifying material forming the watermark image 121 at least when in the diffusely reflective arrangement described. The optical line scan detector 112 detects lines of image data and provides corresponding optical line data to the computer controller 150 for analysis. Again, as for the infra-red system, a composite image is generated and then analysed to look for printing defects in the application of the watermark image 121. The overall intensity of the radiation (across the wavelength band) is significantly greater than that diffusely reflected from the reflection member 107. As is described below, the reflection member 107 appears red in colour when illuminated with the white light emitter 110 since the reflection member is arranged to more strongly reflect diffusively in the longer wavelength part of the visible wave band.

In each case the quality of the image produced is dependent upon a number of equipment factors such as the resolution and sensitivity of the respective detectors. However, it is most strongly influenced by the contrast provided between, for the infra-red system, the radiation intensity diffusely reflected by the foil in comparison with that from the layer 108 of the reflection member 107 for the demetallised regions 126 and, for the optical system, the radiation intensity diffusely reflected by the opacifying material (watermark image) in comparison with the layer 108 of the reflection member 107 for the translucent regions. It follows that the choice of the layer 108 is extremely important.

The layer 108 can be provided by the use of a translucent polymer substrate (such as clear or coloured polypropylene). This is provided with a two component coating to promote diffuse reflection and minimize specular reflections. Accordingly it has a substantially matt appearance. The first component is an ink having a reflectivity in the optical wavelength range which is less than that of the opacifying layer. Preferably the reflectivity of the ink is less at all wavelengths in the optical wavelength band, in comparison with the opacifying layer. The second component is an infra-red additive in the ink which acts as an infra-red absorber and has a lower reflectivity in the infra-red wavelength range used than that of the opacifying layer. Of course, consideration must be given to any optical response in terms of reflectivity provided by the infra-red additive, together with the infra-red reflectivity response of the ink. As has been discussed, the diffuse reflection intensity provided from the foil is very low. The diffuse reflection in the infra-red wavelength band of the opacifying layer is high. Whilst the infra-red additive is therefore not strictly needed to cause contrast between specular reflection from the foil and from the reflection member in the infra-red wavelength band, it is however useful to provide contrast between the reflectivity of the reflection member 107 and that of the opacifying layer on the banknote substrate in this wavelength band. This difference in reflectivity allows the detector system to distinguish between, on the one hand, regions of unprinted opacifying layer on the banknote, and, on the other hand, regions of translucent BOPP overlying the reflection member 107.

Figures 3 illustrates this concept in more detail. Figure 3 is a graph of normalised reflectivity (ordinate) against wavelength of emitted light (abscissa). For the normalised reflectivity a value of 0 represents absolutely no radiation is reflected, whereas a value of 1 represents total reflection of the radiation at the given wavelength (which would require specular reflection). The band 301 represents the incident radiation wavelength band from the optical white light emitter 110. The band 302 represents the infra-red radiation band from the infra-red emitter 105. Notably the infra-red band is considerably narrower in wavelength than the optical band.

The curve 303 represents the reflectivity of the base ink component when applied to the reflection layer 108 and at the given system geometry. It can be seen that the greatest reflectivity is found in the longer wavelengths of the visible spectrum, such as between 600 and 700 nm. This means that the ink, when irradiated with white light (that is having a generally constant spectral power distribution) will have a generally red appearance as mentioned earlier. It will be recalled that the ink in the layer 108 also contains an infra-red additive in the form of an infra-red absorber and the corresponding reflectivity curve of this is illustrated at 304. Here it can be seen that the reflectivity of this additive is lowest in the infra-red part of the spectrum (that is, the absorption is highest in this part of the spectrum).

In Figure 3 the arrow that intersects the ordinate axis at V1 indicates the average reflectivity value of the curve 303 in the wavelength band 301. The arrow that intersects the ordinate axis at I1 indicates the average reflectivity value of the curve 304 in the wavelength band 302. However it is noted that the two components are not entirely independent and in particular the ink has some reflectivity in the infra-red wavelength band 302. The infra-red additives similarly have a small but finite reflectivity in the wavelength band 301. The effect of these additional reflectivities is to slightly increase the overall reflectivity in the optical wavelength band 301 of the layer 108 due to the contribution from the curve 304. For the infra-red wavelength band 302 the effect is to, again, increase the reflectivity due to the contribution from the curve 303 in the band 302. The average value V1 is therefore increased to V2 and that of I1 is increased to I2.

Notably the relative quantities of the two different components are different. The ink represents the majority of the total composition (for example by weight), whereas the additive represents the minority component. These relative quantities of course affect the contribution to the reflectivity of the layer 108 on the basis of simple additive summation.

The effectiveness of the layer 108 in providing the desired contrast in the images produced by the computer controller 150 is dependent upon the difference between the value I2 and the diffuse reflectivity of the foil in the infra-red band.

Similarly the effectiveness of the layer 108 in providing the contrast for the optical white light image is dependent upon the difference between the value V2 and the reflectivity of the opacifying layer of the watermark image. The diffuse reflectivity of the foil is illustrated at Fdiff on the ordinate axis, and that of the opacifying layer is illustrated at O. As expected the diffuse reflectivity of the foil is very low in comparison with the diffuse reflectivity of the opacifying layer. In each case in the present example the difference, which represents a measure of contrast, is a normalised reflectivity value of about 0.15 to 0.3. Theoretically, it is preferred that this difference is maximised in each case, although in practice this is moderated by the need to ensure that the dynamic range of the detector in question is capable of handling significantly different intensity levels with a view to providing high quality line scan data. It is recommended that a normalised diffuse reflectivity difference of at least 0.1 is used in each case.

The actual values which are achievable are dependent upon the specific emitters, detectors and the type of feature being inspected. The interaction between the two components in question is of course important in this selection. Various infra-red additives may be used. These are available within the industry for other purposes, particularly as print additives. Similarly the inks may be selected from various printing inks, including those used to print banknotes and other security documents.

The above discussion is in terms of reflectivity and therefore assumes a value based for example on a semi-infinite instance of the component. However, in the case of printing inks and additives to these, unless very thick layers are used, there is generally a degree of density or transparency to consider. Thus in practice the reflectivity of the substrate forming the reflection member 107 should also be considered when assessing the combined spectral response. This may be advantageous for controlling the desired total reflectivity since it adds a third degree of control freedom. For example a coloured substrate of polypropylene may be considered as effectively a third component to be treated in a similar manner to the first and second components using the methodology of Figure 3.

It will be understood that the reflectivity of a material in practice is angle dependent and is therefore dependent upon the illumination angle and the detector geometry with respect to the angle of specular reflection. It is also dependent upon the extent to which the reflected light is diffused rather than specularly reflected. This may also be a function of angle. The reflectivities considered in the present discussion are therefore understood to be dependent upon the illumination and detection geometry of the apparatus, together with the extent to which each surface in question acts as, at one extreme, a perfect diffuse reflector, or a perfect specular reflector, and in particular where upon the continuum of intervening values each material is positioned. For the purposes of designing appropriate apparatus, any foil region acting as a security element can be thought of approximately as a specular reflector and the opacifying layers on a banknote, together with the reflection layer of the reflection member can each be thought of as perfect diffuse reflectors (having a matt surface), in each case when observed under geometrically normal incidence and detection.

The reflectivities of the various elements in the wavelength bands in question ultimately enable a sufficient level of contrast in the image data to be obtained. This enables each of the watermark image and the foil region to be distinguished from the translucent background. It is however also advantageous to ensure that the watermark image and the foil region each exhibit sufficient contrast with respect to the general areas of the banknote 102. These areas are also covered with the opacifying layer in the present example. In a banknote formed from a paper substrate (and therefore no opacifying layer) the visual appearance is similar to that of an opacifying layer on a BOPP substrate. In the case of white light illumination and infra-red illumination, the possibility of detecting the edge of the banknote is dependent upon the contrast that is achievable between the reflection layer and the banknote substrate. In the case of a broad band of white light the different reflectivities at wavelengths within the band can be used to provide the contrast. This can be thought of simply as colour contrast. However, for a narrow band, particularly the infra-red band, this is not to readily achieved. In the present case, the opacifying layer has a strong reflectivity in the infra-red and it is desired to distinguish this from the response of the reflection layer. A colour contrast will not be effective in a narrow wavelength band. The solution is provided by the infra-red absorbing additive which ensures the reflective layer reflects with a lower intensity in comparison with the opacifying layer of the banknote. Accordingly the reflection layer is dark in the infra-red image data and the opacifying layer is light. This difference provides the contrast needed to locate the edge of the banknote against the reflection member background in the image.

A second example banknote 402 is shown in Figure 4. In this case the banknote is formed from a paper substrate 415 of the type well known in the art. This is provided with a square through-thickness aperture 430 within the substrate. This aperture is overlayed with a layer of polymer material as an optic 440 which typically would be a polypropylene film or a polyester film. The optic 440 seals the aperture and is present as a band across the banknote 402. The layer of polymeric material comprises a metallic region such as a vapour deposited aluminium layer located where the optic overlies the aperture 430 (for example containing an optically variable element) in the form of a star 450. In addition three arrows are overprinted using offset printing across the substrate 415 and optic 440, including across the region of the aperture 430. In this case the combination of the optic 440 and aperture 430 provide a common transparent area.

Automated inspection of the structure of the printed arrows overlying the aperture can be performed by the use of the optical emitter and detector described in association with Figure 1. Automated inspection of the structure of the star 450 may be performed using the infra-red emitter and detector arrangement also described in association with Figure 1. In the present case some modifications may be made to the system. For example if the banknote 402 is generally printed with blue or green inks (including the arrows) then, in a similar manner to the previous example, a broadband white light emitter may be used. However, it may be advantageous to narrow the emission band to shorter wavelengths of the visible spectrum (for example <550 nm). Accordingly the component used to form the ink of the reflection member may be replaced to provide enhanced contrast for the detector 114. An analogous effect could be produced using a light filter, positioned upon the optical path between the light emitter and detector. Whilst two components have been discussed for use in forming the reflection layer 108, it is conceivable that a single component may fortuitously provide the desired spectral response, or, more likely, three or more components may be used.

Whilst the discussion above has focused upon the detection of diffuse reflected light in the optical and infra-red bands, it will be understood that, in principle, the emitter-detector pairs may be configured in a specular reflection arrangement. In this case a metallic foil (or metallic ink or other equivalent) would produce a very high intensity reflection. The more “matt” nature of each of the opacifying layer of a polymer banknote (or the general surface of a paper banknote) and the reflection member would provide the necessary mutual contrast to perform edge detection by distinguishing the banknote substrate from the reflection member since in each case much of the intensity would be diffusely reflected away from the detectors. Appropriate use of detectors in terms of dynamic range capability would be needed to achieve this arrangement in practice.

In each of the examples the data from the detectors relating to the two different wavelength bands are primarily used to interrogate specific features in corresponding security elements. Thus the infra-red system is used for foil (or other metallic component) inspection whilst the optical system is used to inspect the watermark image. Edge detection for locating the edges of the document is used for each system. Such edge detection may be used to ensure that the security features are correctly located, to identify a region of interest on the document for analysis, or to simply provide basic information regarding the general positioning of a document. It is also contemplated that the data from one or each of the detectors may be combined in respect of the analysis of a particular security element so as to improve the quality or speed of the analysis.

CLAIMS

1. Document inspection apparatus for inspecting a document when in an inspection region, the document having a first translucent part including a first reflective material and a second translucent part including a metallic reflective material, the apparatus comprising:

a first illumination device arranged to illuminate the inspection region, from a front side, with electromagnetic radiation within a first wavelength range that is a human-visible wavelength range;

a second illumination device arranged to illuminate the inspection region, from the front side, with electromagnetic radiation within a second wavelength range that is an infra-red wavelength range;

a reflection member, located at a rear side of the inspection region with respect to the first and second illumination devices and formed from a material having a first reflectivity with respect to the first wavelength range and a second reflectivity with respect to the second wavelength range;

a first detector arranged to receive any electromagnetic radiation in the first wavelength range that has been reflected from the first translucent part of the document when in the inspection region, and, to receive any electromagnetic radiation in the first wavelength range that has been reflected by the reflection member according to the first reflectivity and transmitted back through the first translucent part;

a second detector arranged to receive any electromagnetic radiation in the second wavelength range that has been reflected from the second translucent part of the document when in the inspection region, and, to receive any electromagnetic radiation in the second wavelength range that has been reflected by the reflection member according to the second reflectivity and transmitted back through the second translucent part;

wherein the first reflectivity of the reflection member is different from the reflectivity of the first reflective material of the first translucent part of the document so as to enable the structure of the first reflective material to be analysed using the first detector; and wherein the second reflectivity of the reflection member is different from the reflectivity of the metallic reflective material of the second translucent part of the document so as to enable the structure of the metallic reflective material to be analysed using the second detector.

2. Apparatus according to claim 1, wherein one or each of: the first illumination device and first detector, or, second illumination device and second detector, are arranged in a non-specular configuration such that the respective first or second detector receives diffusely reflected light from the respective first or second illumination device.

3. Apparatus according to claim 1 or claim 2, wherein the first or second reflectivity is an effective reflectivity in dependence upon the relative arrangement of the respective illumination device and detector.

4. Apparatus according to any of the preceding claims, wherein the second reflectivity of the metallic material is a diffuse reflectivity and wherein the said second reflectivity is less than that of the reflection member, in the second wavelength range.

5. Apparatus according to any of the preceding claims, wherein the first reflectivity of the reflection member is less than the reflectivity of the first reflective material.

6. Apparatus according to any of the preceding claims, wherein the electromagnetic radiation in the first wavelength range is partially reflected from the first reflective material and wherein the electromagnetic radiation in the second wavelength range is partially reflected from the metallic reflective material.

7. Apparatus according to any of the preceding claims, wherein the structure of the first reflective material is one or more of two dimensional topography, three dimensional topography, the opacity.

8. Apparatus according to any of the preceding claims, wherein the structure of the metallic reflective material is one or more of two dimensional topography, three dimensional topography, the opacity.

9. Apparatus according to any of the preceding claims, wherein the first reflectivity of the reflection member and the reflectivity of the first reflective material are each normalised reflectivities, and wherein the first reflectivity of the reflection member is different from the reflectivity of the first reflective material by a normalised value of 0.1 or more.

10. Apparatus according to any of the preceding claims, wherein the second reflectivity of the reflection member and the reflectivity of the metallic reflective material are each normalised reflectivities, and wherein the second reflectivity of the reflection member is different from the reflectivity of the metallic reflective material by a normalised value of 0.1 or more.

11. Apparatus according to any of the preceding claims, wherein each reflectivity is an average reflectivity of the electromagnetic radiation across the respective range of incident wavelengths in the respective wavelength band.

12. Apparatus according to any of the preceding claims, wherein each of the first illumination device and the second illumination device is arranged to illuminate a common area of the inspection region.

13. Apparatus according to any of the preceding claims, wherein each of the first illumination device and the second illumination device is arranged to illuminate a common area of the reflection member.

14. Apparatus according to any of the preceding claims, wherein the first wavelength range represents a white light band of wavelengths.

15. Apparatus according to any of the preceding claims, wherein the documents in the inspection region lie within a general document plane and wherein the first and second illumination devices are located upon each side of a plane which is orthogonal to the document plane.

16. Apparatus according to any of the preceding claims, wherein the documents in the inspection region lie within a general document plane and wherein the first and second detectors are located upon each side of a plane which is orthogonal to the document plane.

17. Apparatus according to any of the preceding claims wherein one of each of the first and second detectors is a line scan camera.

18. Apparatus according to any of the preceding claims, further comprising a control computer adapted to receive signals from the first and second detectors and to perform an analysis upon the signals.

19. Apparatus according to claim 18, wherein the analysis includes a comparison between the received signals and expected signals, and wherein the control computer is further adapted to produce an output signal indicating a resultant condition of the document.

20. Apparatus according to claim 18 or claim 19, wherein the signals from the first and second detectors are each used in the analysis of one or each of the first translucent part or second translucent part of the document.

21. Apparatus according to any of claims 18 to 20, wherein the analysis further includes identifying an edge or corner of the document.

22. Apparatus according to any of the preceding claims, wherein the reflection member comprises a reflection material and wherein the reflection material comprises a plurality of component materials.

23. Apparatus according to claim 22, wherein one or more of the component materials is selected from the group comprising an infra-red absorbing additive, or a printing ink.

24. Apparatus according to claim 22 or claim 23, wherein the reflection material is provided as a layer upon a support.

25. Apparatus according to claim 24, wherein the reflection layer is translucent and wherein the reflectivity of the reflection member is a combination of the reflectivity of the layer and the reflectivity of the support.

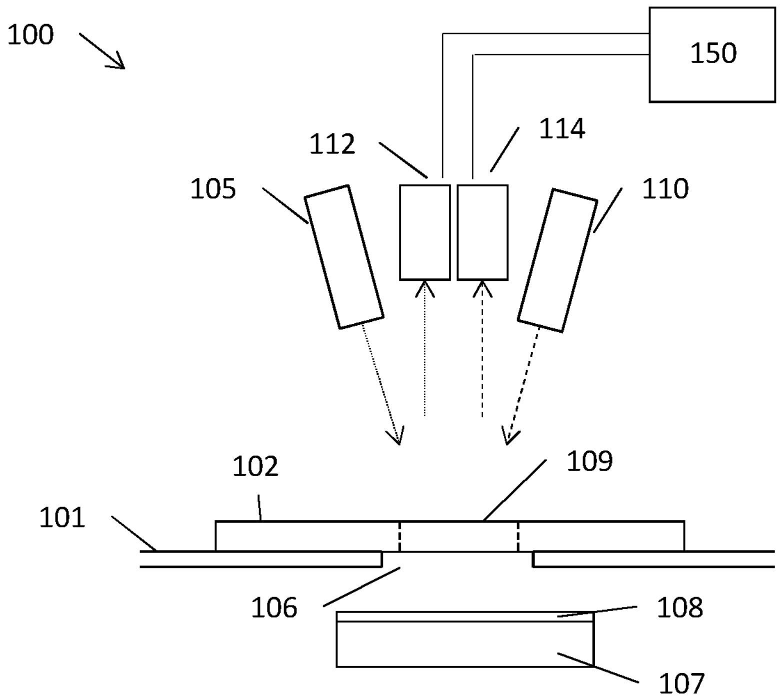

Figure 1

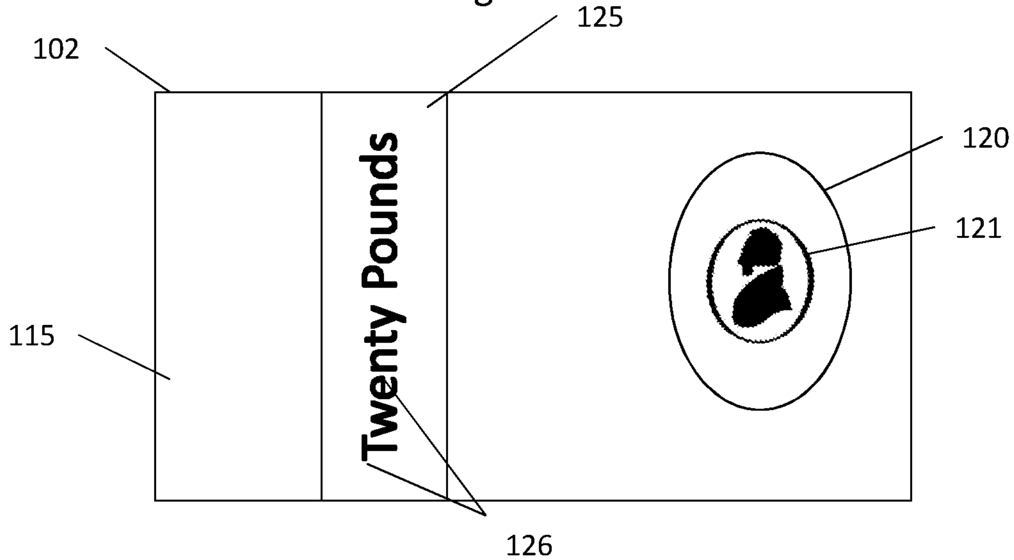

Figure 2

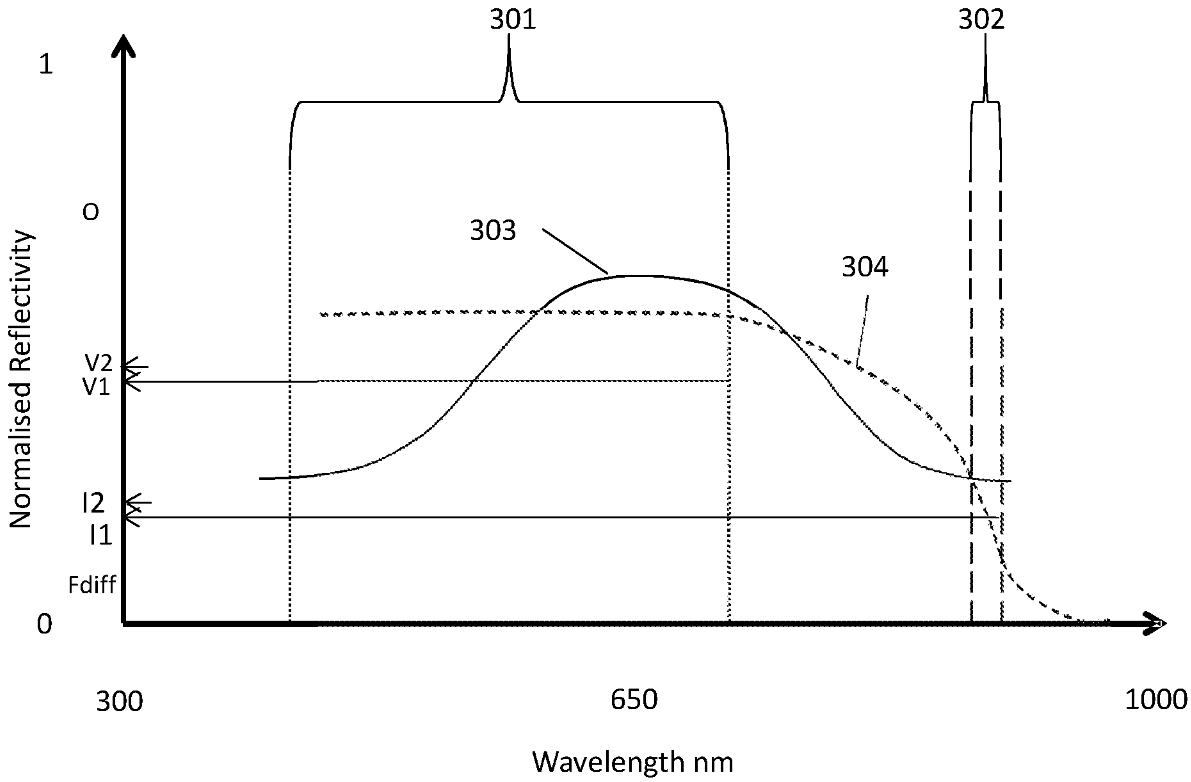

Figure 3

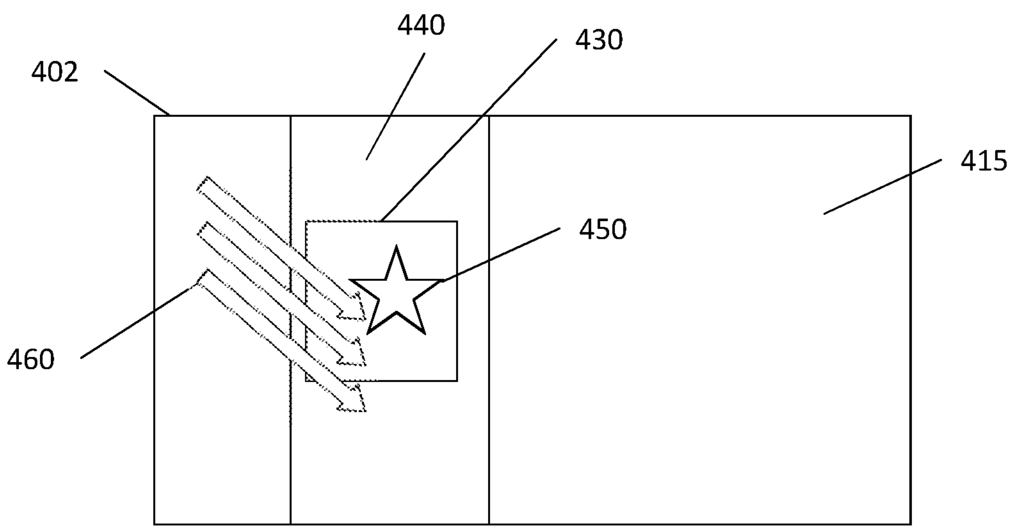

Figure 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2017/051312

A. CLASSIFICATION OF SUBJECT MATTER
INV. G07D7/1205
ADD.

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)
G07D B42D

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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2014/161026 A1 (INNOVIA SECURITY PTY LTD [AU]) 9 October 2014 (2014-10-09) abstract; figure 6 page 1, line 10 - page 3, line 19 page 5, line 24 - line 33 page 7, line 1 - line 12 page 8, line 1 page 8, line 26 - line 30 page 10, lines 1-3 page 10, line 23 - page 11, line 2 page 12, line 4 - line 14 -----	1-25
A	GB 2 355 522 A (INNOVATIVE TECHNOLOGY LTD [GB]) 25 April 2001 (2001-04-25) the whole document -----	1-25
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"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)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"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

"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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 August 2017	09/08/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Lindholm, Anna-Maria

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Form PCT/ISA/210 (second sheet) (April 2005)

International application No
PCT/GB2017/051312

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	WO 2004/036508 A2 (CUMMINS ALLISON CORP) 29 April 2004 (2004-04-29) page 1, line 20 - line 27 page 3, line 8 - line 9 page 8, line 4 - line 18 page 9, line 1 - line 2	1-25
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2017/051312

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