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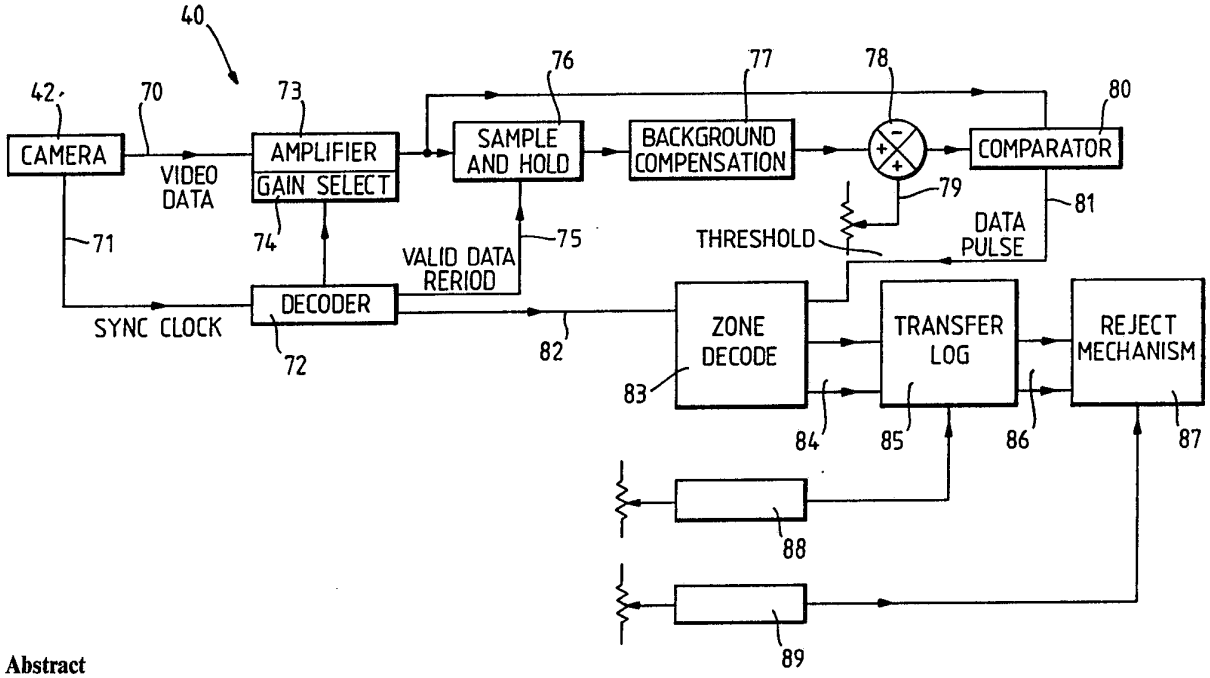

(57) Abstract

Apparatus for detecting unacceptable material in a stream of particulate material includes means (20) to illuminate the stream of material, scanning detector means (16) arranged to receive light reflected from the particles of material in the stream and to distinguish the level of light reflected from an unacceptable particle from the level from acceptable particles to produce an electrical output signal indicative of the position across the stream of that unacceptable particle. A light reflective background plate (36) is disposed behind the stream from the detector means, and means (20) are provided to illuminate that background plate with light in a colour range corresponding to the color of the acceptable particles of material in the stream.

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OPTICAL GRADING APPARATUS

This invention relates to apparatus for detecting unacceptable particles in a stream of particulate material such as tobacco, Kellog's Rice Krispies etc. as described in U.S. Patent No. 3782544.

An optical grading system (such as that described in US 4651144, Figure 1) may typically consist of a conveyor feed system by which the material is transported. The material cascades from the feed conveyor to a take-off conveyor. The material as it cascades from one conveyor to the next passes over a reference back plate and is illuminated by a light source. The light source may be a pair of metal halide lamps or a fluorescent lamp operating at a high frequency or by other known methods of illumination.

The illuminated material and reference plate are optically scanned by a solid state camera and the video signal processed by an electronic control system.

The known optical apparatus may consist of a single line photo-diode array where the number of elements is determined by the resolution required. The scan time or integration time of the camera can be adjusted but for fast response is set at 1 millisecond so that small particles can be detected as they cascade past the scanning area.

The video-signal is smoothed and amplified before being fed to a computer circuit which determines when a particle

must be rejected. The output from the computer is fed to a logic circuit which activates the appropriate solenoid (from 1 to 64 zones) to reject the particle of material as it transfers to the take-off conveyor.

The background plate is used as a reference standard against which the colour of the product is compared. The colour of the reference is used as a divide between the product that is to be accepted and the product to be rejected.

There are three modes of grading which can be initiated.

The first mode is to reject all material that is darker than the background reference. The acceptable product will transfer to the take-off conveyor and the reject product will be transferred to the reject bin/conveyor.

The second mode is to reject all product lighter than the background reference.

In the third mode of operation all product which is lighter or darker than the background reference will be rejected.

An object of the invention is to provide an optical scanning apparatus in which the level of detection of unacceptable material is heightened.

A further object is to provide apparatus which can reject material which is lighter, darker or a combination of lighter and darker material compared with a reference background.

A further object of the invention is to provide electronic or optical means to compensate for the non-linear i.e. saucer shape or "smile" characteristic over the field of view of the detector.

For optimum detection the optical detector should be most sensitive at wavelengths which maximise the difference between acceptable and reject product material. The use of painted metals or other materials do not have the required specific or repeatable optical characteristics.

According to the invention there is provided an apparatus for detecting unacceptable material in a stream of particulate material, including means to illuminate the stream of material, scanning detector means arranged to receive light reflected from the particles of material in the stream and to distinguish the level of light reflected from an unacceptable particle from the level from acceptable particles to produce an electrical output signal indicative of the position across the stream of that unacceptable particle, comprising a light reflective background plate disposed behind the stream from the detector means, and means to illuminate that background plate with light in a colour range corresponding to the colour of the acceptable particles of material in the stream.

The invention will now be described by way of example with reference to the accompanying drawings in which:

FIGURE 1 is a schematic side view of the grading system,

FIGURE 2 is a perspective view of the background plate used in the present invention,

FIGURE 3 shows characteristics of spectral response from acceptable and unacceptable products;

FIGURE 4 is a characteristic of a video signal having high and low level spikes including rejected material, and

FIGURE 5 is a schematic block diagram of the electric/electronic circuit for controlling rejects means in response to detection of unacceptable material.

In a similar manner to the apparatus described in U.S. Patent No. 4657144 there is provided a conveyor 12 for delivering a stream of tobacco 11 containing unacceptable material such as foil, wrappings, labels, paper and/or string or may be for delivering a cereal product containing the occasional burnt or otherwise objectionable particle. The conveyor 12 is preferably a vibrating inclined conveyor which vibrates the tobacco in a direction as shown by the arrow in FIG. 1. Conveyor 12 ends above another conveyor 13, which can be an ordinary conveyor belt, and is spaced vertically above conveyor 13 a sufficient distance to accommodate the remainder of the apparatus described below. As the stream 11 reaches the end of conveyor 12, it drops under the influence of gravity in a cascade 14 to conveyor 13. Because conveyor 12 is inclined, the stream does not have so great a horizontal velocity when it falls, so that

cascade 14 does not have any significant front-to-back horizontal spread.

The cascade 14 is illuminated by light source 15 which is preferably a pair of high-temperature lamps 20, such as metal halide or other high-intensity discharge lamps, which emit an increased percentage of their output at the desired spectrum compared to ordinary incandescent lamps. The illuminated area of cascade 14 is scanned by an optical detector 16 having a matrix of electro-optical detectors which is preferably a line-scan camera 21 having a lens 22 and a filter 23. Detector 16 is preferably kept in a housing 24, having an aperture 25 opposite the lens 22 and the filter 23. The scanning area is 1 meter wide by about 1 mm deep and is divided into 64 zones. The camera has a 2048 pixel matrix with a 28mm lens.

Arranged beneath the delivery end of the conveyor 12 and behind the cascade 14 i.e. remote from the light source 20, there is mounted a background plate assembly 36.

The background plate assembly 36 is of a sandwich construction with a clear polycarbonate (e.g. LEXAN, Trade Mark) front 37 which is sandblasted to reduce specular reflection. The middle section 38 is a filter film with fixed optical characteristics to match the product to be treated. The rear background plate 39 is of a flat white material (e.g. PERPLAS, Trade Mark) to give a uniform reflection of all light impinging on it.

The light passes through the filter 38 and is reflected back through the filter. The colour of the background plate as seen from the back behind the material by the detector 16 is now the same as or similar to the colour of the product at the chosen wavelength .

The filter 38 is thus selected so that the colour of the acceptable product is at a reference level or background colour and therefore undetectable by the optical system 16. The signals detected from unacceptable material can be above or below the reference. There are three options which can be selected; to reject objects darker than the reference, lighter than the reference or a combination of both.

To illustrate this invention by way of a specific example in the grading of Kellog's Rice Krispies, the spectral response of the product both good and poor and that of the selected filter is shown in FIGURE 3.

The characteristic of a high quality Rice Krispie or cornflake is shown as curve A, whilst a pale example is shown as curve B. By selecting a filter 23 having a wavelength range (see curve C) compatible with the portion of the curves where they diverge, say in the region of 550-650 Å small changes can be detected. This contrasts with a black background where this would result in large dynamic changes in the signal which would not necessarily represent an unacceptable particle. With the use of a broader filter spectrum, extending over the whole range (from 400 - 670 Å

in Figure 3) no difference would be observed between good and bad products.

The background plate as described enables high and low amplitude changes to be detected.

The video signals with background reference, acceptable product and reject product are represented in Fig. 4. The video signal is fed to control electronics 40 (described in greater detail below) where it is amplified, smoothed and fed to a comparator which is set to reject all material darker, lighter, or with lighter and darker than a desired level.

When detector 16 detects foreign material, the control electronics 40 sends a signal to the appropriate one or more solenoid valves 26, all as described below. Valve 26 is connected at 27 to a source of high pressure fluid which is preferably air at approximately 80 psi, although other gases, such as steam, or liquids, such as water, can be used. A deflection bar 28 is situated below detector 16 adjacent cascade 14. The bar 28 is hollow, and is divided internally into chambers 28 having holes 29 for directing air against cascade 14. Each chamber 28 is supplied by one of the valves 26 through tubes 19. When one of valves 26 opens in response to a signal, a blast of air A is directed by the deflection bar 28 against that portion of cascade 14 in which the unacceptable material was detected to force that portion 17 of the tobacco with the unacceptable

material to fall into a receptacle 18.

The control electronics 40 will now be described: The scanning device 42 is arranged to provide a video signal on the line 70, corresponding to the light intensity reflected from the material in a single line scan across the cascade 14. The scanning device 42 also pzovides a synchronisation pulse on the line 71 to coincide with the commencement of the video signal line on the line 70. The sync pulse is passed to a decoder 72 which embodies a counter arranged to divide the time interval of the video line into a series of elements, in this embodiment 64, to divide the width of the cascade 14 in effect into 64 bands or strips. The counter is started by the sync pulse on line 71. The video signal is passed to an amplifier 73 the gain of which is controlled by control means 74, in dependence from the count from the counter in the decoder 72, indicative of the instantaneous position across the cascade that is represented by that instant in the video signal. By this means the response of the scanning device may be corrected to make it substantially linear despite the effects of uneven illumination of the individual sensors of the scanning device 42 and of scanning geometry, which would otherwise tend to make the scanning device more sensitive at the centre of the cascade than at the sides.

The decoder 72 provides an output on the line 75 during the scan time of the video signal on the line 70 to activate

a sampling means 76 which stores the content of the video signal passed to it from the amplifier 73. An averaging device 77 produces a background compensation signal from averaging the video signal stored in the sample device 76, and a signal representative of the average output of the scanning device 42 is passed to a summing amplifier indicated at 78, together with a pre-set value for a detection threshold which is set on the line 79. The output of the summing amplifier 78, and of the amplifier 73, are passed to a comparator 80, so that when the video signal from the scanning device 42 exceeds a pre-set threshold above the background output, the comparator 80 gives an output signal on the line 81.

Thus when foreign matter is detected by the scanning device, by giving a video output markedly different from the background level, a matter detected signal occurs on the line 81. The count from the counter in the decoder 72 is also passed on the a line 82 to a band or strip decoding means 83, in conjunction with the unacceptable matter detected signal on the line 81, so that a corresponding signal occurs on an appropriate one of a series of parallel outputs 84, which corresponds to the band or strip across the cascade at which the unacceptable matter was detected.

The outputs 84 are each connected to a respective one of the series parallel shift registers indicated by the block 85. These shift registers are each clocked to carry any

input signal along their logical length, in synchronism with the speed of the material; so that an output occurs, on one of the series of parallel lines 86, at an instant corresponding to the arrival of detected unacceptable matter at the ejection stage.

The output lines 86 are connected through driver circuits in the block 87 to the solenoids to control the valves 26, so that the appropriate one is energised to eject the detected unacceptable matter. Pre-set means indicated at 88 may be used to alter the starting point in any of the shift registers of the block 85, to adjust the operation delay of the valves 26 (e.g. 10 to 500 μs) when setting up the machine in use. Similar means 89 may be provided for controlling the length of time (e.g. 20-100 ms.) that the valves 26 are operated thus to control the length of air blast during rejection of a particle.

In an alternative embodiment, the effects of uneven illumination of the individual sensors of the scanning device may be compensated by providing a series of filters between the light source and the cascade, the filters being selected to produce a uniform video signal across the scan width. The filters may be neutral or of wavelengths compatible with the product.

Instead of providing a filter of a wavelength compatible with the wavelength of the filter of the scanning device it is possible to provide lamps which give the desired

wavelength range. The filter of the camera may in this case be omitted. In such an alternative, the background plate may take the form of a coating on a substrate or may be a mirror.

Preferably a single white light source is provided which serves to illuminate both the cascade and the background plate. However, separate sources may be used to illuminate respectively the cascade material and the background plate.

In the prefered example the wavelength extends beyond each end of the visible wavelength i.e. from 0.3 to 1.2 microns but any suitable range may be selected.

CLAIMS

1. Apparatus for detecting unacceptable material in a stream of particulate material, including means (20) to illuminate the stream of material, scanning detector means (16) arranged to receive light reflected from the particles of material in the stream and to distinguish the level of light reflected from an unacceptable particle from the level from acceptable particles to produce an electrical output signal indicative of the position across the stream of that unacceptable particle, comprising a light reflective background plate (36) disposed behind the stream from the detector means, and means (20) to illuminate that background plate with light in a colour range corresponding to the colour of the acceptable particles of material in the stream.

2. Apparatus as claimed in claim 1, wherein said background plate includes filter means (12) for limiting the reflected light to a wavelength compatible with the wavelength range of said detecting means.

3. Apparatus as claimed in claim 1 or 2, wherein said detecting means (16) has an optimum wavelength response in the range of wavelength wherein the difference between the reflectivity of unacceptable material and the reflectivity of acceptable material is negative.

4. Apparatus as claimed in claims 1, 2 or 3, wherein the background plate (36) comprises an assembly having a rear

layer (39) of white opaque plastics material, a front layer (37) of clear plastics material with a frosted or sandblasted front surface, and a filter film (38) sandwiched between said front and rear layers.

5. Apparatus as claimed in claim 1, wherein the means (20) to illuminate the stream of material provides a light beam having a wavelength range compatible with the wavelength range of the detecting means.

6. Apparatus as claimed in claim 5, wherein filter means determining said wavelength is provided in the light path from said illuminating means to said stream.

7. Apparatus as claimed in any one of claims 1 - 6, wherein said scanning detector means includes control means (40) for comparing the light reflected from said illuminated particulate matter containing unacceptable material with the light reflected from the background plate (36) for generating said signal when said reflected light indicates the presence of unacceptable material.

8. Apparatus as claimed in claim 7, wherein said control means include a signal amplifier (73), and a comparator (80) which is settable to give an output reject signal in the event that material is darker, lighter or both lighter and darker than a desired level.

9. Apparatus as claimed in claim 7 or 8, including deflecting means adapted to direct a blast of fluid under pressure at a portion of said stream of particulate matter

when said control means determines that unacceptable material is present in said portion of said stream of particulate matter, said blast of fluid deflecting said unacceptable material from said stream.

10. Apparatus as claimed in any one of claims 1 to 9,including first conveying means (12) for delivering a stream of particulate matter containing unacceptable material to said apparatus; second conveying means (13) located below and spaced vertically from said first conveying means for conveying said stream of particulate matter is transferred from said first conveying means to said second conveying means by falling therebetween under the influence of gravity in a turbulent cascade; said illuminating means serving to illuminate said turbulent cascade of particulate matter while it is falling between said first and second conveying means; said background plate (36) being arranged beneath the delivery end of the conveyor means (12) and behind the region of the cascade remote from the illuminating means (20).

11. Apparatus as claimed in any one of claim 1 - 10, wherein the means (2) to illuminate the stream of material and the means to illuminate the background plate (36) comprise a common light source (20).

Fig.1.

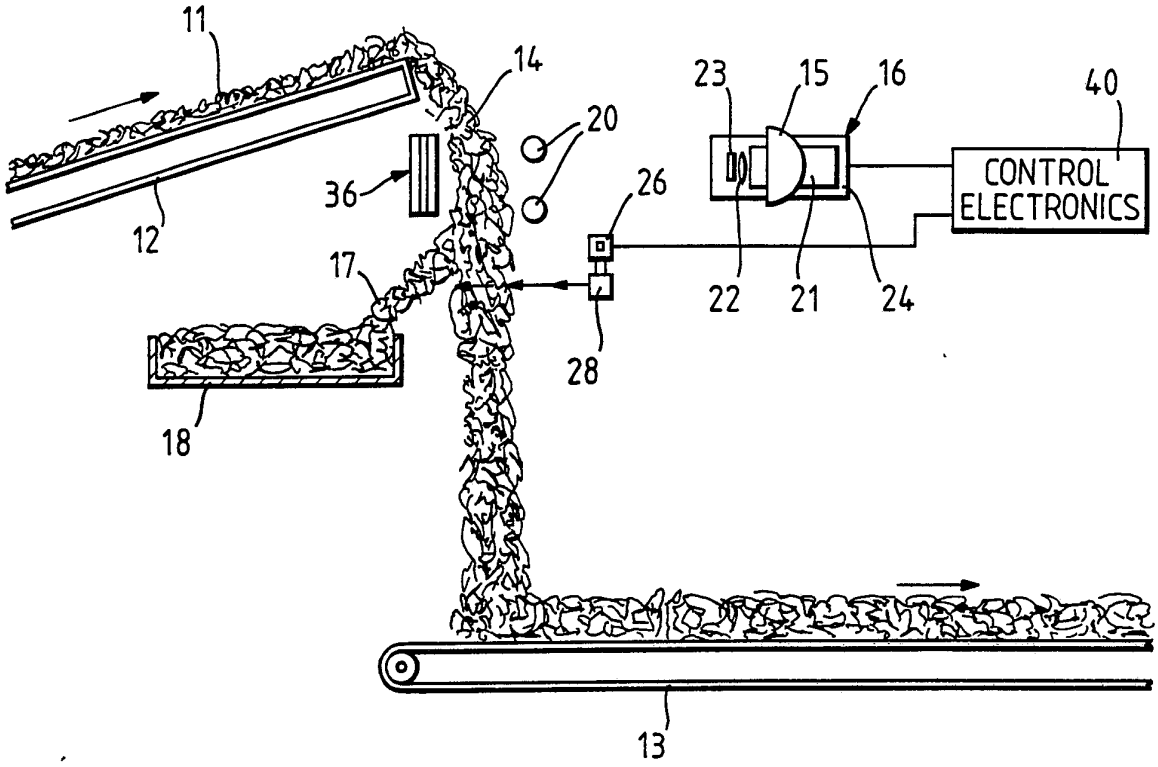

11
14
20
23
15
16
40
CONTROL ELECTRONICS
36
26
12
17
22
21
24
28
18
13

Fig.2.

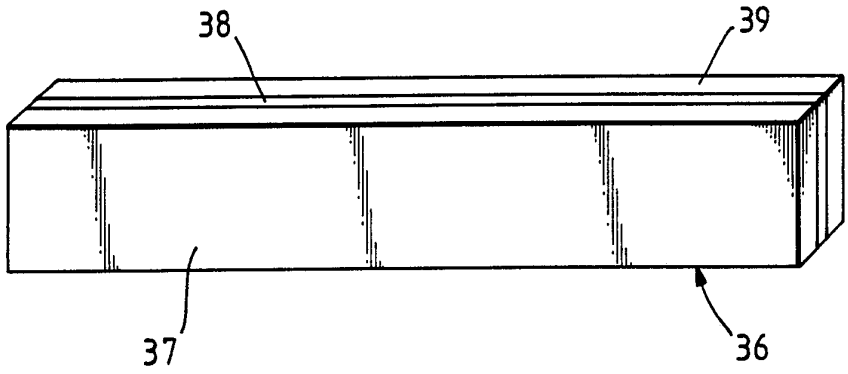

38
39
37
36

Fig.3.

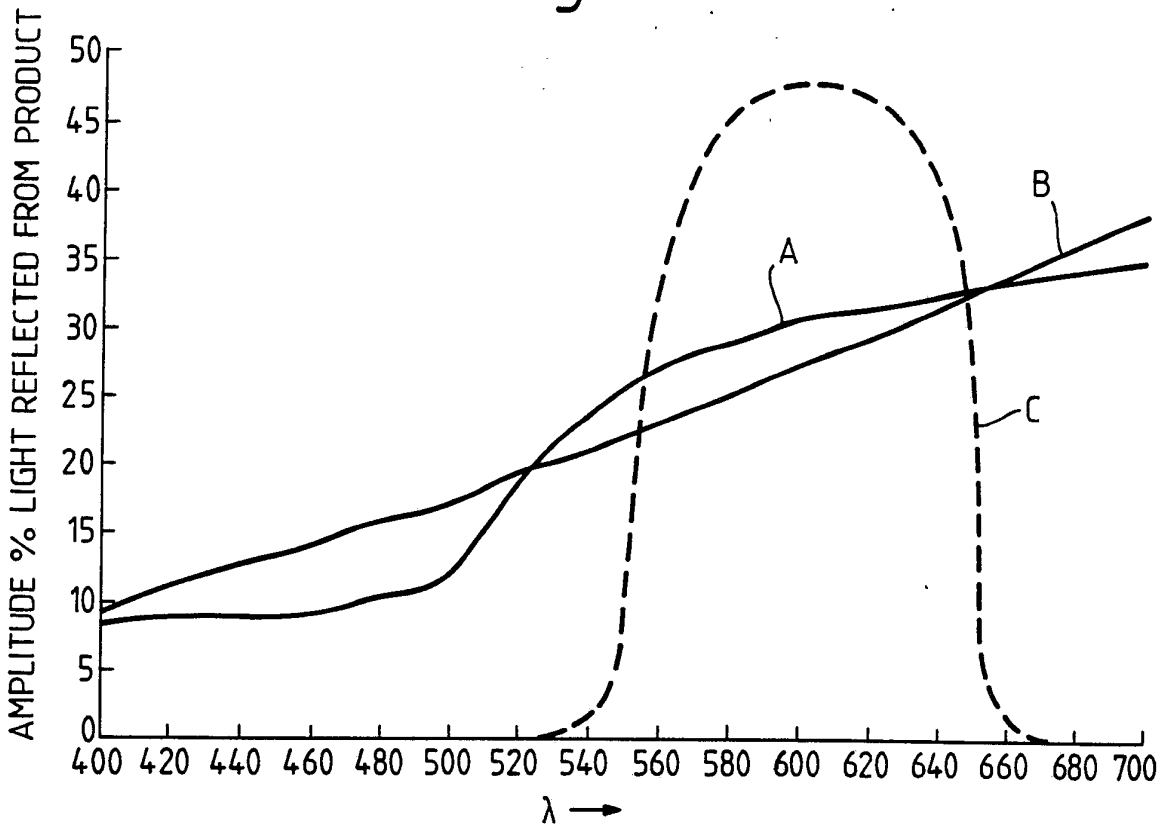
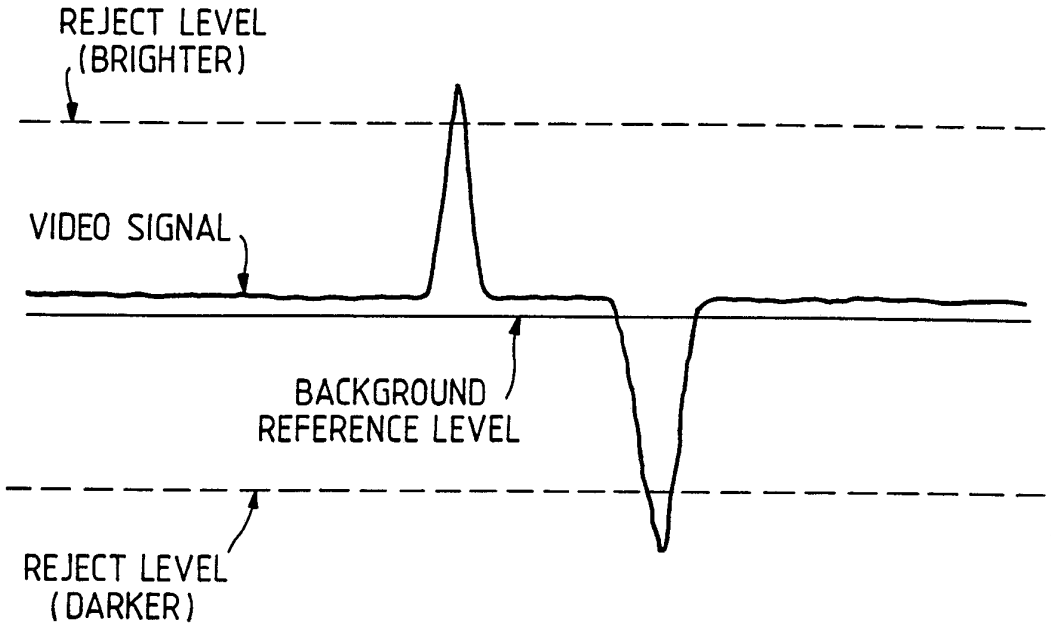

AMPLITUDE % LIGHT REFLECTED FROM PRODUCT
50
45
40
35
30
25
20
15
10
5
0
400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700
λ
A
B
C

Fig.4.


REJECT LEVEL
(BRIGHTER)
VIDEO SIGNAL
BACKGROUND
REFERENCE LEVEL
REJECT LEVEL
(DARKER)

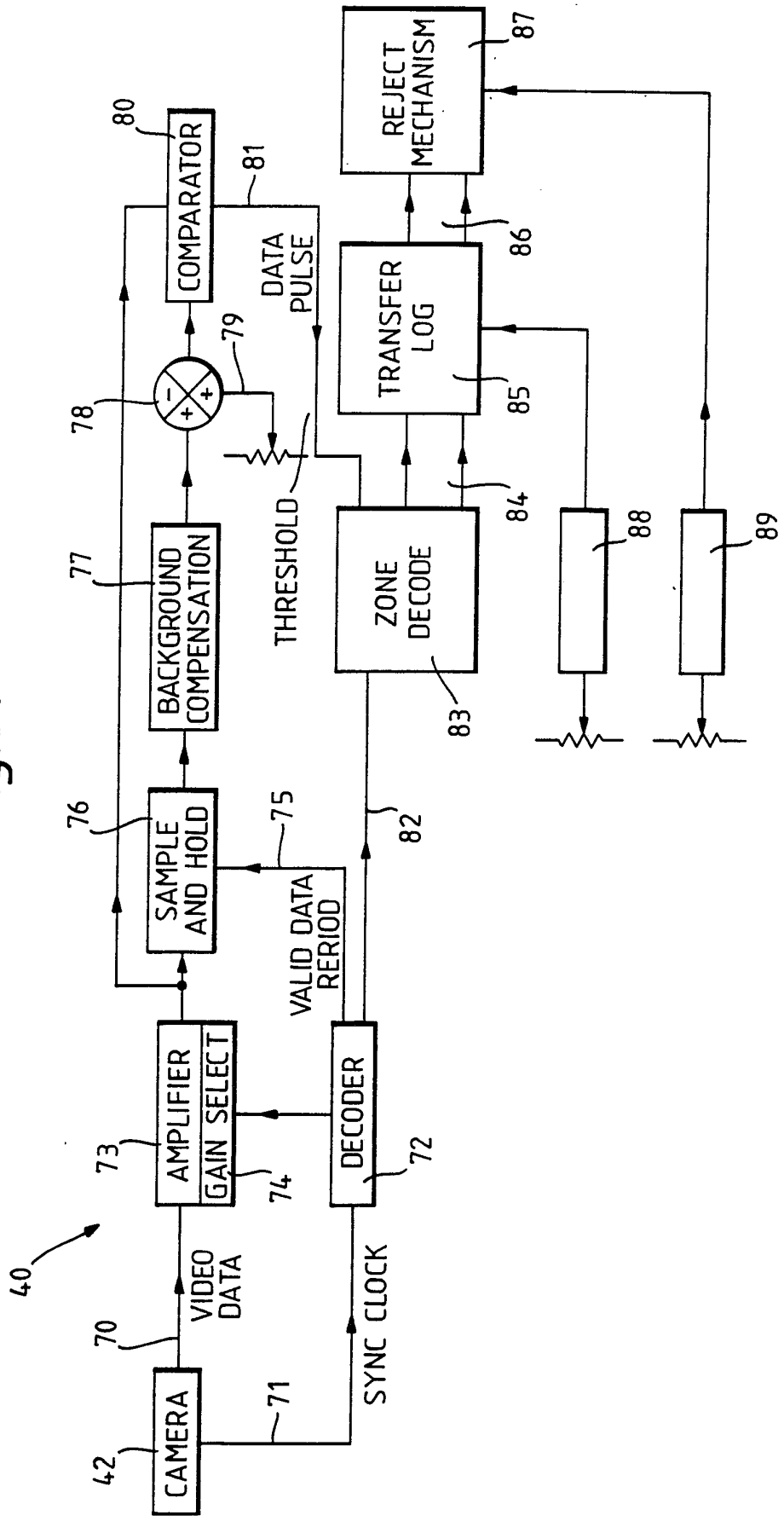

REJECT MECHANISM
87
80
COMPARATOR
81
DATA PULSE
86
TRANSFER LOG
85
79
78
THRESHOLD
84
ZONE DECODE
83
88
89
77
BACKGROUND COMPENSATION
76
SAMPLE AND HOLD
75
82
VALID DATA REPIOD
AMPLIFIER
GAIN SELECT
73
74
DECODER
72
40
VIDEO DATA
70
SYNC CLOCK
71
CAMERA
42

Fig. 5.

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 89/01489

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 B07C5/342

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	B07C

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
X	US,A,3066797 (H.FRAENKEL) 04 December 1962 see column 1, line 9 - column 3, line 75; figures 1-9	1-2, 5-9, 11
Y		10
X	EP,A,146299 (GUNSON'S SORTEX) 26 June 1985 see page 1, line 1 - page 4, line 26; figures 1-4	1, 5, 7-9
X	GB,A,2180062 (DELTA TECHNOLOGY) 18 March 1987 see page 1, line 121 - page 3, line 9; claims 14-23; figures 1-2	1, 7
Y	EP,A,193308 (PHILIP MORRIS) 03 September 1986 see page 3, line 8 - page 4, line 14; figures 1-5	10
A		1

-/--

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"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
18 APRIL 1990	13. 05. 90
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	GYSEN L.A.D.

Form PCT/ISA/210 (second sheet) (January 1985)

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	US,A,4634881 (BILLION) 06 January 1987 see column 4, lines 32 - 63; figure 6 ---	1, 7
A	US,A,3782544 (PERKINS,III) 01 January 1974 (cited in the application) ---	

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. PCT/GB 89/01489

SA 33129

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 European Patent Office EDP file on 18/04/90
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A-3066797		None	
EP-A-146299	26-06-85	GB-A,B 2151018	10-07-85
		DE-A- 3473572	29-09-88
		US-A- 4699273	13-10-87
GB-A-2180062	18-03-87	US-A- 4697709	06-10-87
		JP-A- 62057683	13-03-87
EP-A-193308	03-09-86	US-A- 4657144	14-04-87
		AU-B- 591097	30-11-89
		AU-A- 5407686	28-08-86
		CA-A- 1243752	25-10-88
		JP-A- 61195333	29-08-86
US-A-4634881	06-01-87	US-A- 4723659	09-02-88
US-A-3782544	01-01-74	None	