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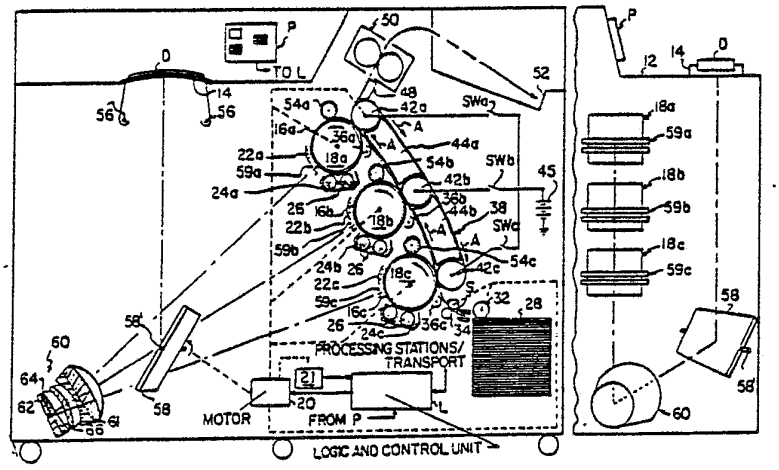
(54) Title: COLOR ELECTROPHOTOGRAPHIC COPIER WITH CATADIOPTRIC LENS

(57) Abstract

Optical mechanisms for exposure of the photoconductive member(s) in prior art color copiers are complex. The complexity arises, in part, from the need to space the elements of the optical mechanisms and accurately align the elements in their relative positions to insure projection of the respective light images toward desired spaced locations. This complexity problem is eliminated by using a simplified optical arrangement for an electrophotographic copier for making multicolor reproductions of a multicolor original document. The copier includes at least one charged photoconductive member (18a) which is exposed by primary color separation images of an original document (D) to form corresponding latent image charge patterns. The primary color separation images are projected onto the photoconductive member (18a) by the simplified optical arrangement which has a catadioptric-type lens assembly (60) optically located between the original document (D) and the photoconductive member (18a). The lens assembly includes a refractive lens (61) and a plurality of dichroic mirrors (62, 64, 66) each being tilted with respect to the others and each being spectrally reflective to a different primary color. Polychromatic light emanating from the copier's exposure platen (14) passes through the refractive component (61) of the lens assembly, strikes the dichroic mirrors (62, 65, 66) and becomes color separated. The color separated light then passes back through the refractive lens (61) to form color separated images at discrete spacial locations on the photoconductive member (18a).



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COLOR ELECTROPHOTOGRAPHIC COPIER WITH CATADIOPTRIC LENS

This invention relates generally to electrophotographic copiers, and more particularly to an electrophotographic copier for making multicolor reproductions of a multicolor original document.

In making multicolor reproductions with an electrophotographic copier, typically a light image of a multicolor original document is projected through primary color filters (red, green, and blue) to form color separation images. The color separation images expose a moving electrostatically charged photoconductive member. Exposure may take place sequentially by illuminating the document three times, and projecting the light images respectively through the color filters, or simultaneously by illuminating the document once and dividing the light image into color separation images such as by beam splitters or dichroic mirrors. Exposure forms latent image charge patterns in spaced areas on a photoconductive member corresponding to the color separation images. The latent image charge patterns are respectively developed with complimentary colored toner material (e.g., cyan, magenta, and yellow). The developed images are then transferred to a receiver sheet in registered superimposed relationship to form a multicolor reproduction of the multicolor original.

In an alternative color copier configuration, separate electrostatically charged photoconductive members are exposed by respective color separation images to form the latent image charge patterns. Of course, with plural photoconductive members, there is a duplication of certain of the copier mechanisms (e.g., photoconductive members,

chargers, cleaning apparatus). However, steps of the copying process can be carried out in parallel. This results in an equal number of copies being reproduced per unit time (with respect to apparatus having one photoconductive member) at relatively reduced photoconductive member and receiver sheet transport velocities.

Optical mechanisms for exposure of the photoconductive member(s) in prior art color copiers are complex (see, for example, U.S. Patent No. 3,690,756 issued September 12, 1972 in the name of Smith, and U.S. Patent No. 3,841,751 issued October 15, 1974 in the name of Draugelis et al). The complexity arises, in part, from the need to space the elements of the optical mechanisms and accurately align the elements in their relative positions to insure projection of the respective light images toward desired spaced locations.

This invention is directed to a simplified optical arrangement for use in an electrophotographic copier for making multicolor reproductions of a multicolor original document. The copier includes at least one charged photoconductive member which is exposed by primary color separation images of an original document to form corresponding latent image charge patterns. The primary color separation images are projected onto the photoconductive member by the simplified optical arrangement which comprises a catadioptric-type lens assembly optically located between the original document and the photoconductive member. The lens assembly comprises a refractive lens and a plurality of dichroic mirrors which are optically aligned on a common optical axis. Each mirror has a spectral reflectance and transmittance which differs from the others, and each mirror is tilted with respect to the other

mirrors. The refractive lens serves both to direct polychromatic light emanating from the copier's exposure platen toward the dichroic mirrors and to project color-separated light, as reflected by the dichroic mirrors, toward the photoconductive recording element(s) to form thereon distinct, color separated images at spacially separated locations.

The invention, and its objects and advantages, will become more apparent in the detailed description of the preferred embodiment presented below.

In the detailed description of the preferred embodiment of the invention presented below, reference is made to the accompanying drawings in which:

Fig. 1 is a schematic side elevational view, in cross-section, of a color electrophotographic copier including the optical arrangement according to this invention;

Fig. 2 is an end elevational view of the copier of Fig. 1, with portions removed to faciitate viewing, taken from the left of Fig. 1.

Referring now to the drawings, a color electrophotographic copier is schematically shown having a housing 12 including a transparent platen 14 for supporting an original document to be copied. The copier of the preferred embodiment includes a plurality of photoconductive members 16a, 16b, 16c, although other arrangement of photoconductive members could also be employed without departing from the scope of this invention (e.g., one photoconductive member having a plurality of spaced image receiving areas). The photoconductive members are formed of photoconductive material, sensitive to light in the primary color range (red, green, blue), fixed to conductive support material,

such as described, for example, in U.S. Patent No. 3,615,414 issued October 26, 1971 in the name of Light. Of course the photoconductive material of the members could be individually tailored to be respectively sensitive to substantially one primary color. The members are respectively mounted on equal diameter, rotatable drums 18a, 18b, 18c supported in the housing. An electrical grounding path is provided for members through the drums. The drums are driven in a counterclockwise direction (when viewed in the direction of Fig. 1) by a motor 20.

The motor 20 is controlled by a copier logic and control unit L, which also controls the activation of the various processing stations and transport elements of the copier in response to timing signals produced by the motor. Such timing signals are produced by a timing signal generator 21 such as described, for example, in U.S. Patent No. 3,790,270 issued February 5, 1974 in the name of Donohue. The logic and control unit includes, for example, an Intel 8080 microprocessor available from Intel Corporation of Sacramento, California. The unit L is operatively coupled to an operator programmable input and display panel P so as to receive input signals, such as the number of desired copies and a start copy cycle, produced by the panel.

When an original document is to be reproduced, the operator places the document (e.g., document D), information side down, on the transparent platen 14, and programs the panel P. On receiving the start copy cycle signal, the logic and control unit L turns on the motor 20 to rotate the drums 18a, 18b, and 18c and activates the timing generator 21 to initiate control of the processing stations. Particularly, D.C. or biased A.C. chargers 22a, 22b,

22c, located respectively in juxtaposition with the photoconductive members, are selectively turned on to electrostatically charge the respective members uniformally prior to exposure as they rotate past the chargers. The rotating members are then respectively exposed to primary color separation light images in the manner to be explained below. The members become conductive in the areas struck by light, leaving latent image charge patterns corresponding respectively to the primary color separation light images.

Developing stations 24a, 24b, 24c are supported in the housing 12 in juxtaposition with respective photoconductive members 16a, 16b, 16c. The developing stations are, for example, of the magnetic brush type disclosed in U.S. Patent No. 3,543,720 issued December 1, 1970 in the names of Drexler et al. Such developing stations contain triboelectrically charged carrier particles and marking particles respectively complimentary to primary colors (i.e., cyan, magenta, and yellow). Specifically, if member 16a is to be exposed to a blue color separation image, the particles in station 24a are yellow. Then member 16b would be exposed to a green color separation image and the particles in station 24b would be magenta; and member 16c would be exposed to a red color separation image and the particles in station 24c would be cyan. The marking particles, are for example, of the type shown in U.S. Patent No. 3,893,935, issued July 8, 1975 in the names of Jadwin et al. Magnetic brushes 26 bring the complimentary colored marking particles into contact with the respective photoconductive members. The latent image charge patterns on the members attract the marking particles so that

the images are respectively developed to form complimentary color separation images.

At a preselected time in the copy cycle, as determined by the logic and control unit L, a receiver sheet (e.g., sheet S) is fed from the top of a stack of cut sheets 28. A sheet feed mechanism, such as a rotary vacuum feeder 32 driven by motor 20 removes the top sheet from the stack and delivers such sheet to a registration mechanism 34, such as shown in U.S. Patent No. 4,019,732 issued April 26, 1977 in the name of Hunt, Jr. et al. The registration mechanism, which is also driven by motor 20, is controlled by the unit L to align the sheet relative to the developed image on the moving photoconductive member 16c. Thus when the sheet is transported from the mechanism 34 into contact with such member the sheet is accurately registered with the developed image for transfer of the image to the sheet.

A transport 38 feeds the sheet successively past the drums 18c, 18b and 18a. The transport 38 includes a perforated belt 40 of dielectric material such as polypropylene, for example. The belt is entrained over conductive transfer rollers 42a, 42b, and 42c and vacuum plenums 44a, 44b. Rotation of the transfer rollers, induced by a drive mechanism, such as motor 20, causes the belt to traverse a closed loop path in the direction of arrows A at a speed substantially equal to the peripheral speed of the drums. The plenums 44a, 44b respectively have ported walls in juxtaposition with the run of the belt 40 facing the drums. Vacuum in the plenums is effective through the ported walls and the belt perforations to tack the sheet to the belt for movement therewith. As the sheet is transported along the portion of the path adjacent to the photo-

conductive members, it is brought into contact with member 16c, then member 16b and finally member 16a.

The transfer rollers 42a, 42b and 42c, which are for example of the type shown in U.S. Patent No. 2,807,233 issued September 24, 1957 in the name of Fitch, are coupled to a potential source 45 through respective switches SWa, SWb, SWc. The logic and control unit L respectively closes switches SWa, SWb, SWc to electrically connect the transfer rollers to the potential source in response to the contact of the receiver sheet with the respective photoconductive members. Of course, the transfer rollers could be respectively connected to independent potential sources tailored to optimize transfer for differing electrical characteristics of respective colored toner particles. The transfer rollers charge the receiver sheet to a level greater than that attracting the marking particles (forming the developed images) to the photoconductive members. The particles are therefore attracted from the respective photoconductive members to the receiver sheet, in image wise patterns, during respective contact with such members in the nips between the members and respective transfer rollers. Transfer of the images is facilitated by substantially neutralizing the attractive forces on the marking particles with charge from coronas 36a, 36b, 36c respectively associated with the drums 18a, 18b, 18c immediately upstream of the respective transfer nips.

The spacing of the drums 18a, 18b, 18c and their circumference are selected such that the nips of transfer rollers 42a, 42b and 42c and respective photoconductive members 16a, 16b, and 16c are separated by a distance equal to an exposure area plus the spacing between the trail edge of an expo-

sure area and the lead edge of the next area to be exposed, in the direction of rotation of the drum. Therefore, when a receiver sheet is registered in the nip between roller 42c and member 16c relative to an image on member 16c, movement of such sheet by transport 38 brings the sheet to the subsequent nips in accurate timed relation relative to arrival of images on members 16b and 16a in the respective nips. Thus the transferred images are in accurate superimposed register.

After transfer at the nip between drum 18a and roller 42a, the sheet is delivered to a vacuum transport 48 which, in turn, delivers the sheet to a fuser apparatus 50. The fuser 50 includes a pair of pressure rollers at least one of which is heated, to permanently fix the registered transferred images to the sheet; see for example U.S. Patent No. 4,199,626 issued April 22, 1980 in the name of Stryjewski et al. After fusing, the sheet is delivered to a copy output tray 52 for operator retrieval. Meanwhile, subsequent to transfer, the photoconductive members are rotated in contact with respective rotating fur brushes 54a, 54b, 54c to clean the members of any residual marking particles. The brushes are substantially surrounded with respective vacuum housings (not shown) to remove the particles for transport to a storage container, see for example, U.S. Patent No. 3,780,391 issued December 25, 1973 in the name of Leenhouts. Further rotation of the drums then brings a cleaned portion of the photoconductive members to the area of the respective chargers 22a, 22b, 22c where the members are ready to be recharged in preparation for a repeat of the copy cycle.

In order to obtain the color separation light images of the document D on the platen 14,

such document is illuminated for example by flouresc-ent lamps 56 controlled by the unit L in response to the start of the copy cycle. A mirror 58 is rotatably supported on a pivot 58' in the path of the light image reflected from the document. The platen 14 lies on a portion of a cylinder having a longitudinal axis perpendicular to the plane of Fig. 1 intersecting the pivot 58' at its midpoint so that the distances between any element of the platen and the axis are equal to maintain the reflected light image of the document on the platen in focus. The mirror 58 is rotated about its support pivot 58' in a counter-clockwise direction (as viewed in Fig. 1), such as by motor 20, at a synchronous speed with respect to the rotation of the drums 18a, 18b, 18c, to scan the document from right to left. Specifically, the scanning speed at the document plane (from right to left) is substantially equal to the peripheral speed of the photoconductive members to prevent smearing of the reflected images projected onto the members. At the end of the document scan, the lamps are turned off and the mirror is relatively rapidly rotated in a clockwise direction to return the mirror to the position for the next scan. The return is accomplished, for example, during the time at which an interframe portion of the photoconductive members passes through the exposure area. Of course, other scanning arrangements could be employed in accordance with this invention.

The reflected light image is projected from the mirror 58 to a catadioptric-type lens assembly 60. The lens assembly 60 comprises a compound refractive component 61 and a plurality of dichroic mirrors 62, 64, and 66, spectrally reflective respectively to the primary colors for separating

the reflected light image into primary color separation images. Catadioptric lenses of this general type, but without the color separating elements, are commercially available from Carl Zeiss, Oberkocken, West Germany. Such lenses are known as a medial lenses, and the refractive element is one-half of a symmetrical lens such as a Triplet or double Gauss. According to the invention, however, the plane mirror of such lenses is replaced with a plurality of dichroic mirrors that are relatively tilted at angles selected so that the color separation images are projected to exposure areas of respective photoconductive members 16a, 16b, 16c through respective slit apertures 59a, 59b, and 59c. Specifically, if member 16a is to receive a blue color separation image, mirror 66 reflects a blue color separation image; then member 16b would receive a green color separation image reflected from mirror 64 and member 16c would receive a red color separation image reflected from mirror 62. The platen 14 and mirror 58 are disposed forwardly in the housing 12 (see Fig. 2) with respect to the lens assembly 60 and the photoconductive members. Further, the mirror 58 and the lens assembly 60 are disposed in parallel angular relationship to the plane of Fig. 1 to provide a folded optical path between the platen and the photoconductive members (see Fig. 2) so that the mirror does not interfere with the images projected from the lens assembly to the members. Any keystoning effect caused by the angular relationship could be compensated for, if necessary, by tilted field lenses. The color separation images of the document are faithfully transmitted to accurately expose the members to respectively form corresponding latent image charge patterns. It should be noted that if the photoconductive members are formed

of strips of material on the drums spliced transverse to the direction of rotation, the logic and control unit L times the rotation of the respective drums such that the splices do not fall within the image receiving areas.

In operation of the described copier, three scanning cycles are required to make a single full color reproduction on a receiver sheet. Although drums 18a, 18b, and 18c are continuously rotated during the scanning cycles, only charger 22c is turned on during the first scanning cycle so that a latent image is formed and developed only on photoconductive member 16c. The logic and control unit L actuates the feeder 32 in timed relation to the first scanning cycle so that a receiver sheet is fed in register (by registration mechanism 34) into the transfer nip between member 16c and transfer roller 42c to be aligned with the developed image on member 16c. In the next scanning cycle, only charger 22b is turned on so that a latent image is formed and developed only on photoconductive member 16b. Because the distance between transfer nips is equal to an exposure area plus the spacing between exposure areas (interframe area), the developed image on member 16b and the transported receiver sheet arrive at the transfer nip in register (i.e., with the developed image in registration with the previously transferred image on the receiver sheet) so that transfer in such nip occurs in superimposed register. Similarly during the third scanning cycle, only charger 22a is turned on so that a latent image is formed and developed only on member 16a; and the developed image and the transported receiver sheet arrive at the transfer nip in register. Thus when the document has been scanned three times and the color separation images

developed on the respective photoconductive members, the developed images reach their respective transfer nips in proper timed relation with arrival of the receiver sheet such that transfer of the images to the sheet occurs in superimposed register. If multiple reproductions of one original document are to be made, more than one charger is turned on by the logic and control unit L during all scanning cycles except the first and last cycle, and a receiver sheet is fed from supply 28 for each cycle except the last two. Accordingly the number of scanning cycles required to make the desired number of reproductions is equal to the number of reproductions to be made plus two (see Table).

TABLE

A. Number of Reproductions to be Made: one

Scan No.	1	2	3
charger 22a	off	off	on
charger 22b	off	on	off
charger 22c	on	off	off
sheet feed	yes	no	no

B. Number of Reproductions to be Made: two

Scan No.	1	2	3	4
charger 22a	off	off	on	on
charger 22b	off	on	on	off
charger 22c	on	on	off	off
sheet feed	yes	yes	no	no

C. Number of Reproductions to be Made : three

Scan No.	1	2	3	4	5
charger 22a	off	off	on	on	on
charger 22b	off	on	on	on	off
charger 22c	on	on	on	off	off
sheet feed	yes	yes	yes	no	no

D. Number of Reproductions to be Made : n

Scan No.	: 1	2	3 ... n	n+1	n+2
charger 22a	: off	off	on...on	on	on
charger 22b	: off	on	on...on	on	off
charger 22c	: on	on	on...on	off	off
sheet feed	: yes	yes	yes..yes	no	no

As can be appreciated from the above Table, the productivity of the electrophotographic copier 10 of this configuration is very high. That is, multiple full color reproductions are produced at a rate equal to that of a conventional monochrome copier plus the time to make two additional reproductions.

The invention has been described in detail with particular reference to a preferred embodiment thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

We Claim:

1. In an electrophotographic copier for making multicolor reproductions of a multicolor original document, said copier including a photoconductive recording element and an optical system for projecting color separated images of the original document onto the recording element at spaced locations, the improvement wherein said optical system includes a catadioptric-type lens comprising a refractive lens and a plurality of dichroic mirrors which are optically aligned with said lens on a common optical axis, each of said mirrors being tilted with respect to the others and having a different spectral reflectance, said mirrors being adapted to color separate multicolor light directed thereto by said lens and to reflect such color separated light back through said lens, whereby said color separated images are projected on said recording element.

FIG. 2

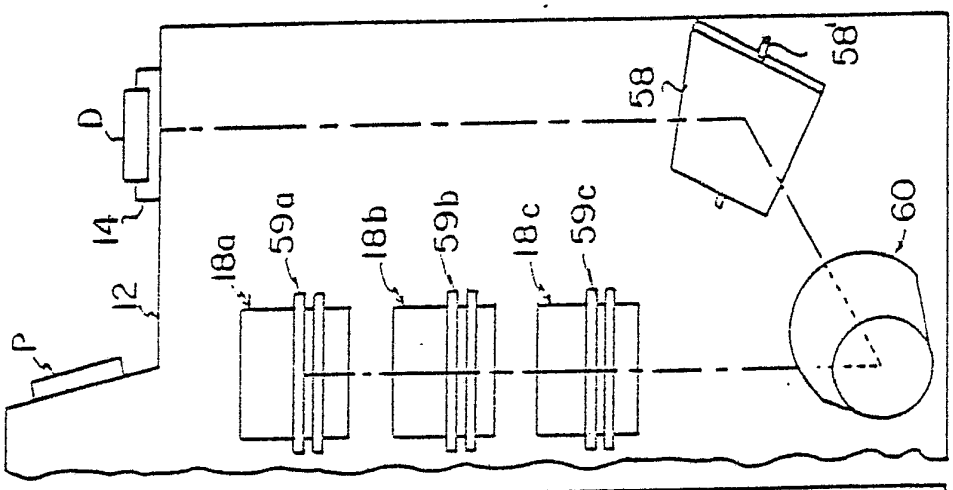
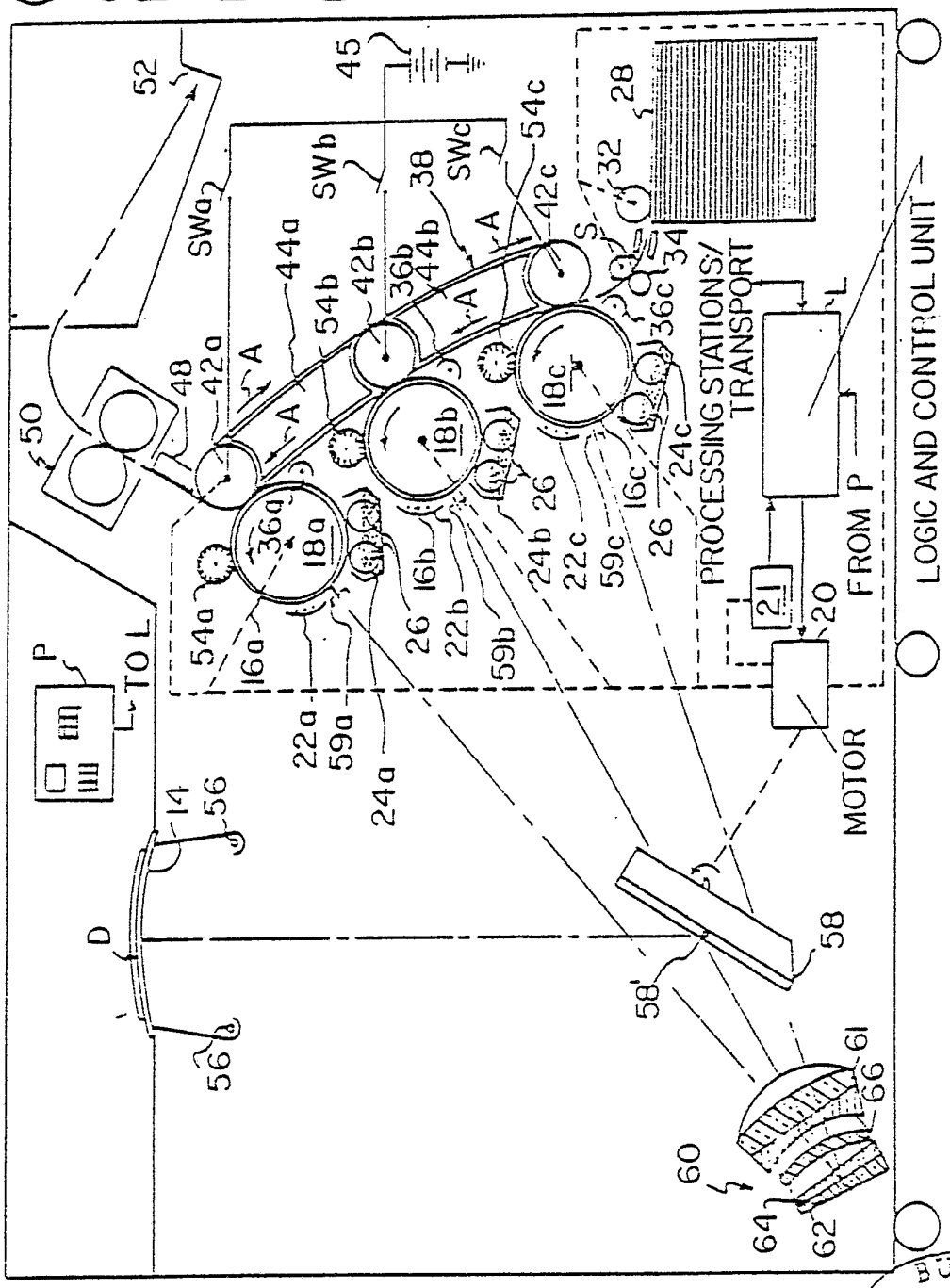


FIG. 1



INTERNATIONAL SEARCH REPORT

International Application No PCT/US82/00042

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC [3]

G03G 15/01; G02B 5/20, 13/24

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
US	350/166, 397, 398, 439; 355/3R, 4,32,35

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [15] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
A	US, A, 2,742,837 Published 24 Apr. 1956 Streiffert (see Fig. 2 and col. 2, line 63 through column 3 line 60)	1
A	US, A, 3,085,468, published 16 APR. 1963, Hehn (see Fig. 3 and col. 3, lines 18-44)	1
A	US, A, 3,690,756, Published 12 Sept. 1972 Smith (see Fig. 4, and col. 7, line 60 through column 9, line 30)	1
A	US, A, 4,080,053, Published 21 March 1978 Friday (see Fig. 2 and col. 3, line 17 through col. 5, line 18)	1

* Special categories of cited documents: [16]

"A" document defining the general state of the art

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

"L" document cited for special reason other than those referred to in the other categories

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

"P" document published prior to the international filing date but on or after the priority date claimed

"T" later document published on or 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

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
26 April 1982	04 MAY 1982
International Searching Authority [1]	**Signature of Authorized Officer [20]**
ISA/US	FRED L. BRAUN PRIMARY EXAMINER

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

A	US,A, 4159,166, Published 26 June 1979 Kasahara et al (See Figs. 3 and 5 and col. 3 line 6 through column 5, line 44)	1
A	US, A, 4,229,095, Published 21 Oct. 1980, Mir (see Fig. 1 and column 6, line 67 through col. 7, line 47)	1

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [10]

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

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

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

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [11]

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

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

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

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

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.