Process Units for Electrophotographic Machines

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1. Introduction

Electrophotographic machines, which are represented by copy machine (PPCs), fax equipment and printers, are expected to continue to develop into the future as important image output equipment that provides high image quality, high speed and low noise operation. Recent trends of electrophotographic machines include miniaturization, lowering of price, and shifts from analog to digital, from single function to complex function, and from monochromatic to color machines. The processing parts of these machines, the heart of the machines, will become standardized in order to enhance users' convenience and to facilitate the exchange of wear-and-tear parts.

Fuji Electric, as a manufacturer of photoconductors, has developed and manufactured selenium photoconductors and organic photoconductors (OPC), and recently is promoting the development and manufacture of process peripheral equipment aiming to add value to the products and to offer proposals for processes to our customers.

In this paper, an overview of our activities concerning process units is introduced.

2. Overview of Products

2.1 Composition of process unit

As shown in Fig. 1, in an electrophotographic machine, a process unit contains a photoconductor and integrates some or all electrophotographic processes, such as electrostatic charging, development and cleaning. This kind of process unit facilitates miniaturization of the equipment and stabilization of image quality and further eliminates the necessity of maintenance by service personal.

2.2 Types and characteristics of process units

There are several types of process units as shown in Fig. 2, and each of which is utilized in accordance with the characteristics of the type of electrophotographic machine.

The all-in-one unit integrates all processes including the photoconductor, electrostatic charger, developer, toner, etc. This type of unit is supplied filled with toner. So, when the toner is used up, the entire unit, that is, all of the process should be exchanged. Accordingly, although handling is very easy, printing costs generally tend to be high because the life of the unit is determined by the amount of toner filled in the unit.

The separate unit has two types, the two-block separate type and the three-block separate type. The former contains a photoconductor, charger and cleaner in one unit (drum unit) and developer and toner in another unit. For this type of unit, when toner is used up, the entire unit can be refreshed simply by exchang-

Fig.1 A schematic of printer
(Source: basic and application of electrophotographic technology, corona, 1988)

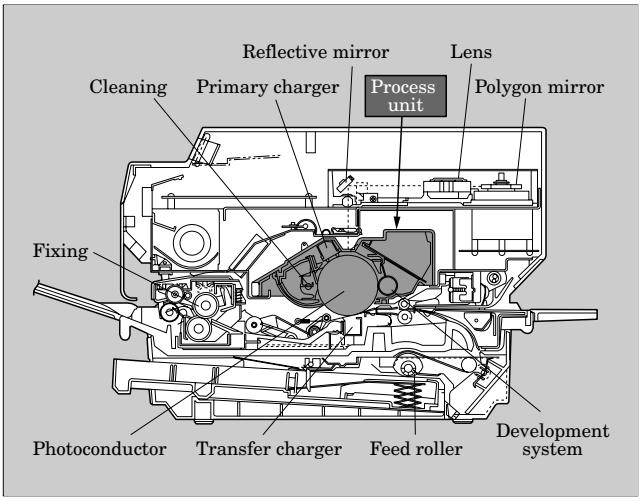
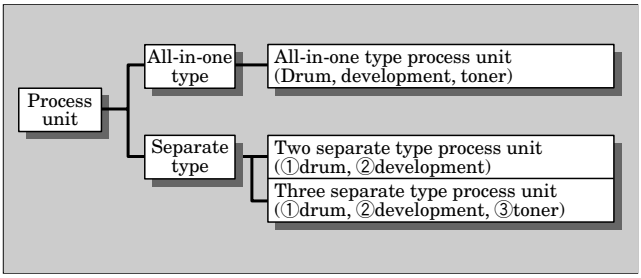


Fig.2 A system of process unit



ing the development unit, while the drum unit having a longer life can remain unchanged. Accordingly, this type has an advantage of lower running cost compared to the all-in-one type.

In the latter type, the toner container is separated from the development unit. This type of machine has an advantage in that each component unit can be exchanged according to the life of each individual process, but also has a disadvantage of less easy handling compared to the other two types. This type of unit is the least wasteful and has the lowest running cost.

3. Market Trends

The North American and European markets for electrophotographic machines such as PPCs, facsimile machines and printers occupy about 80 % of the global market. Figures 3 and 4 show the predicted changes in market scale for process units for electrophotographic machines in these two regions. Although electrophotographic machines compete with ink jet printers in the field of low-speed machines, they are expected to grow steadily in the fields of medium- and high-speed machines because of their advantages of high-speed and high resolution.

Further, the predicted market scale for each type of process unit in Japan is shown in Figs. 5 and 6. Also, the same steady growth is expected in Japan as in foreign markets. For 2001, all-in-one units occupy about 80 % of the market in terms of monetary amount and about 70 % in terms of quantity. However, the percentage occupied by the separate units, with separate drum unit and development unit, is estimated to increase in the future.

For this enlarging market, countermeasures for the global environment are required. All the manufacturers are requested to contribute to strengthening recycling measures and to conserve the earth's resources. In the past, used units were treated and disposed of as industrial waste. However in recent years, each manufacturer is starting to collect used units and to recycle some of them. In the future, collection and recycling will increase and a unit design suitable for recycling will become required.

4. Activities of Fuji Electric

4.1 History of process unit business

As a manufacturer of photoconductors, Fuji Electric has developed various types of selenium photoconductors and OPCs for many years. Our research

Fig.3 The market scale prediction of process units (quantity)

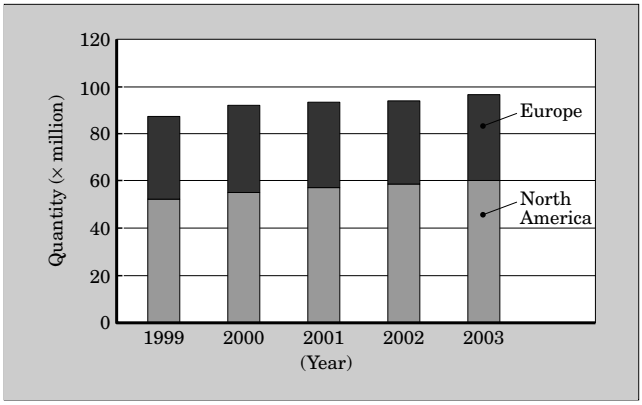


Fig.4 The market scale prediction of process units (the sales)

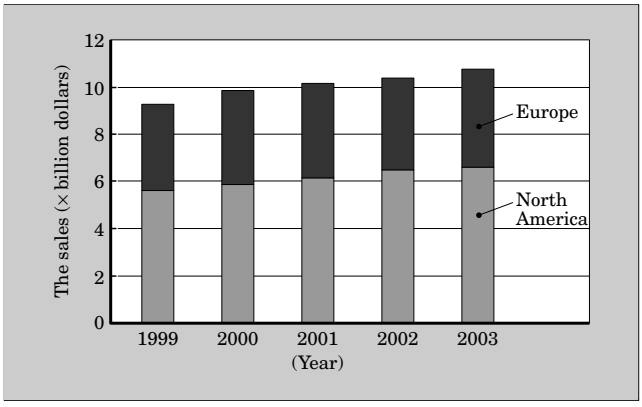


Fig.5 Japanese market scale prediction of process unit (quantity)
(Source: reproducts sweeping over Japanese cartridge market, data supply, 2001)

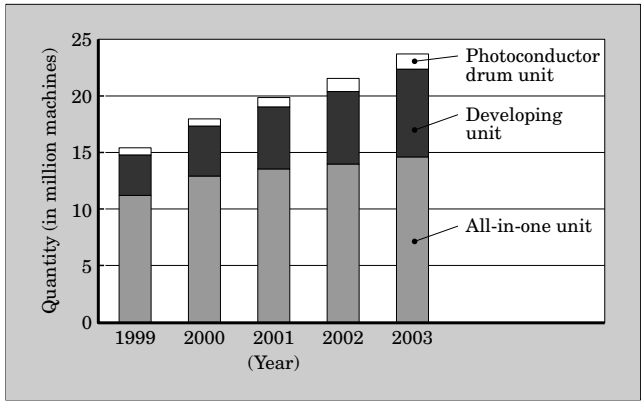
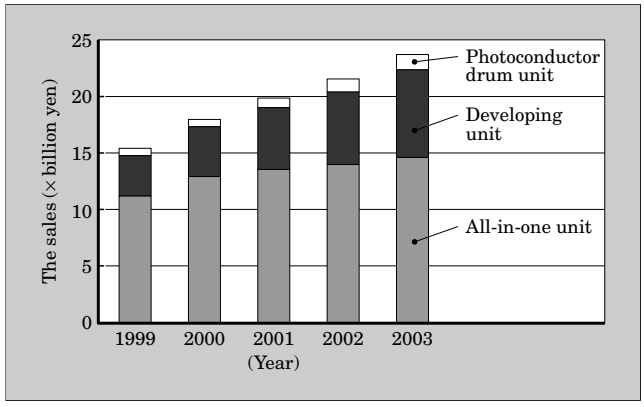


Fig.6 The market scale prediction of process units (the sales)



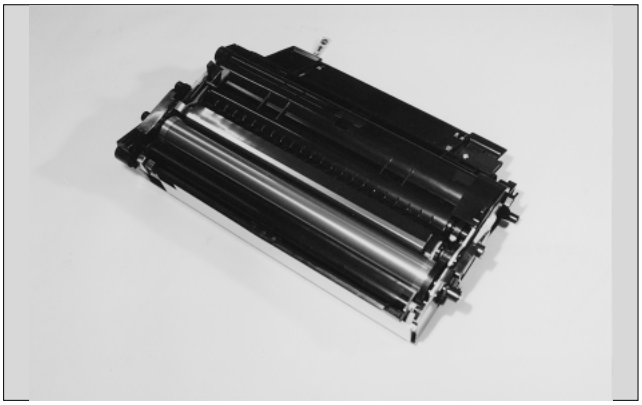
efforts have sought to discover the optimal photoconductor that functions most suitably for each type of electrophotographic process in various types of machines. We have also endeavored to develop the most stable process. As a result, our products have been adopted by many machine manufacturers. Our technology to match our products to customers' processes is highly appreciated by our customers. And at present, we produce not only photoconductors but also process units equipped with photoconductors as well as toner units.

Table 1 History of process unit product development

Year	Status
1986	Starting up production of drum unit for PPC at Fuji Electric, Matsumoto factory (using Selenium photoconductor drum for copy machine)
1987	Starting up production of drum unit for PPC at Hong Kong Fujidenki Co., Ltd. (using Selenium photoconductor drum for copy machine)
1990	Starting up production of drum unit for PPC at Hong Kong Fujidenki Co., Ltd. (using positive charging type OPC drum for copy machine)
1995	For processing unit production, Fusui Electric Co. Ltd. was founded in Guangzhou, China. (Fig. 7)
1996	Starting up production of three divided type process unit for A4 size printer at Fusui Electric Co. Ltd. (using negative charging type OPC drum for printer)
1997	Starting up production of three divided type process unit for A3 size printer at Fusui Electric Co. Ltd. (using negative charging type OPC drum for printer)
1998	Starting up production of two divided type process unit for A4 size printer at Fusui Electric Co. Ltd. (using negative charging type OPC drum for printer) Starting up production of toner unit for copy machine
1999	Starting up production of toner unit for color printer

Fig.7 Fusui Electric Co. Ltd. in Guangzhou, China (process unit production center)

Fig.8 An example of mass-produced process unit



Further, in order to increase our production of process units, we are working to develop and commercialize the process units. Fuji Electric's activities concerning electrophotographic process units up to now are shown in Table 1.

Fuji Electric continues to develop products under a fully integrated system in which development design is performed at our Matsumoto Factory and production is performed at Fusui Electric Co. Ltd. in Guangzhou, China. Figure 8 shows an example of our products.

4.2 Development of positive charging type process unit

Nowadays manufacturers of electrophotographic machines are competing with one another in trying to reduce the price of their products (that is, the reduction of initial costs and running costs for users) and to improve printing speed and image quality. Realization of these goals such as low price, long life and high performance are also required for photoconductors. Accordingly, Fuji Electric started to develop positive charging type OPCs upon realizing that they are more advantageous in principle compared to conventional negative charging type OPCs. Fuji Electric fully leveraged its own capabilities to develop organic materials, made full use of product development capabilities (application development capabilities) that had been cultivated through development of selenium photoconductors, and applied its OPC mass production technology. As a result, we have succeeded in developing and commercializing a positive charging type OPC capable of providing higher speed and higher resolution than a conventional negative charging type OPC and in reducing the price of the machine.

However, the positive charging type OPC had a

Fig.9 An example of Fuji developing process unit (positive charging type)

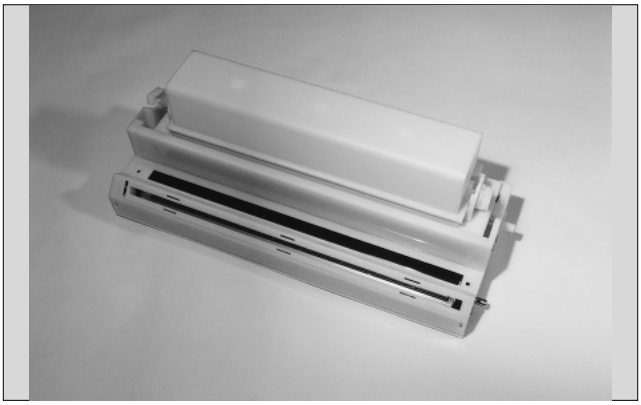


Fig.10 A transition of drum surface potential in negative charging process

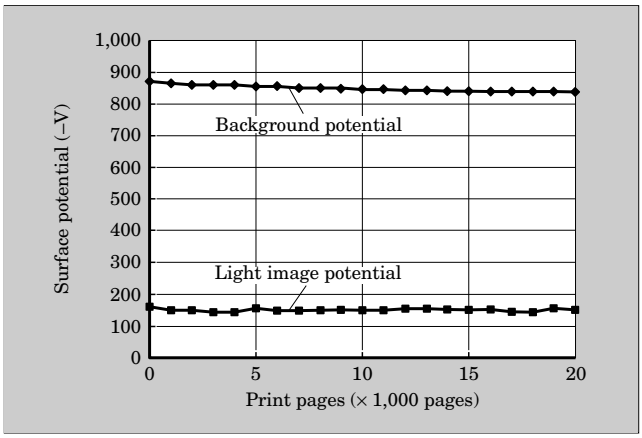


Fig.11 A transition of drum surface potential in positive charging process

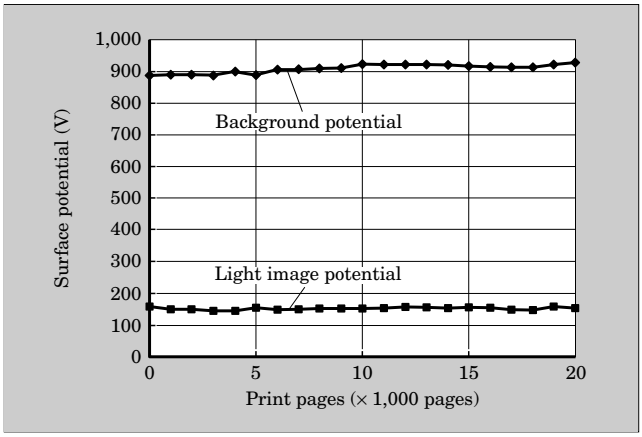


Fig.12 A transition of image density in negative charging process

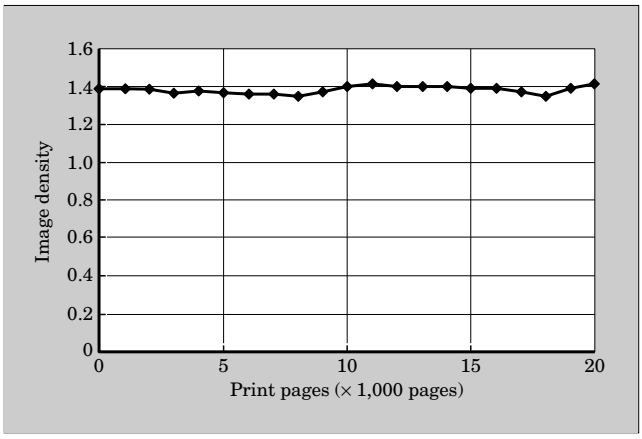


Fig.13 A transition of image density in positive charging process

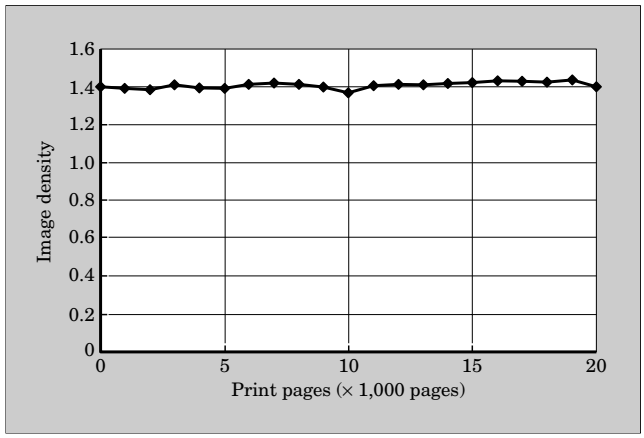


Fig.14 Tone property in negative charging process

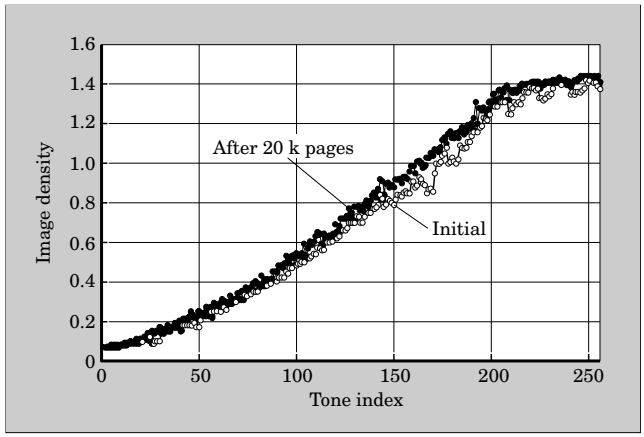
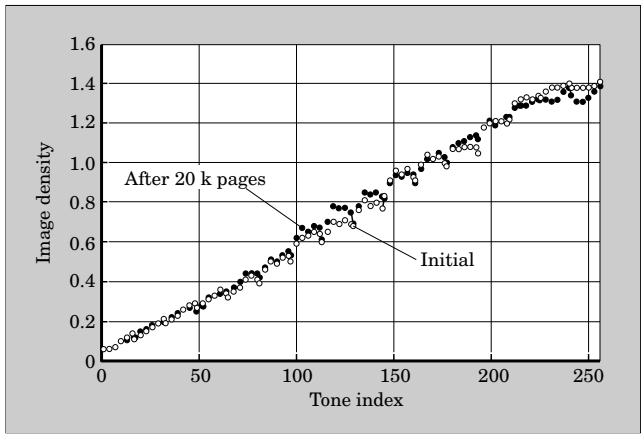


Fig.15 Tone property in positive charging process



problem in that it required a process different from that of the traditional negative charging type OPC, and adoption of the positive charging type process (positive charging type OPC) was difficult even though its superiority to the negative charging type OPC had been recognized. Fuji Electric considered it necessary to overcome this limitation in order to enlarge the application range of this advantageous photoconductor and we therefore developed a positive charging type process unit as shown in Fig. 9. Through the process development for this photoconductor, we aim to be able to propose optimum processes to our customers and ultimately to develop, design and produce process units that include photoconductors.

4.3 Results of comparative experiment of positive charging type and conventional type units

Characteristics of the original negative charging type process applied to a commercial printer and those of the positive charging process unit of Fuji Electric applied to a commercial printer which was modified to the positive charge process were researched, and the results are given in Figs. 10 to 15. Figures 10 and 11 show the change of drum surface potential for negative and positive charging processes while running under the environmental conditions of normal temperature and humidity, respectively. Also the positive charging process exhibits stable potential characteristics, the same as those of the negative charging process.

Figures 12 and 13 show the change of image density for negative and positive charging processes while running under the environmental conditions of normal temperature and humidity, respectively. Moreover, the positive charging process exhibits stable image density, the same as that of the negative charging process.

Figures 14 and 15 show the tone property of negative and positive charging processes while running under the environmental conditions of normal temperature and humidity, respectively. Tone property of the positive charging process is better and more stable than that of the negative charging process. Thus, the positive charging type process is recognized as having higher resolution and better stability. This suggests that this process will exhibit superiority not only in monochromatic high-resolution machines but also in color machines.

5. Conclusion

Regarding the electrophotographic machine, it is forecast that the trends toward digital, complex and color machines will continue to progress, accompanied with lower prices. Corresponding to such trends, lower price, longer life and higher performance are also required of the process unit, which is the heart of the machine. Further, easiness of recycling is also required for the sake of environmental protection. Fuji Electric intends to continue to develop process units corresponding to these requirements, centered about the positive charging type OPC, and further intends to promote actively the unit recycling business.