Developments in Rapid-Copying Machines

By PETER SCOTT [1]

A FEW weeks ago I received a circular from the photoservice of a local university that began like this: "Gentlemen, we stand ready to assist you with all your reproduction problems." I have never dared to offer counsel in an equally liberal manner.

The purpose of this brief paper is to compare and to evaluate quick-copying devices and to provide an answer to the often recurring question: which of the many copying devices offered commercially is most useful to the librarian, the archivist, the scholar? I think that a discussion of such equipment calls for an initial comparison of this type of equipment with the more established processes of photoprinting and photostating. Photostating has been used in libraries and archives since about 1900. The process yields full-size legible copy of excellent permanency. Objections to the process are: the copy is not available immediately, the equipment takes up a great deal of space, it is expensive, and it produces a negative copy that must in turn be photostated in order to give a positive. Prices charged for a negative plus a positive copy average about 75 cents.

Since microfilm and microcard require the use of optical apparatus to read them, I am going to leave them out of this discussion. I do, however, want to mention microfilm as an intermediate step in producing an enlarged paper print. The photoprint, which is an enlargement on photographic paper from a microfilm negative, is qualitatively equal to the positive photostat, but it can be produced much more cheaply. Other previously mentioned objections to the photostat apply to the photoprint also — that the copy is not available instantly and that the equipment is space-consuming.

Microfilm can also be used to make enlarged paper copies by means of an electro-magnetic process such as Xerography or the Electrofax, which I shall discuss later. All methods requiring microfilm as a first step are necessarily slow and will remain slow

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until current experiments in the production of dry microfilm are successful.

The photoprint and photostat are still the heart of photoduplication in most libraries today, and it would not do to leave this point unstated. Where, then, does the rapid-copying machine fit into the library?

There is first of all the small library, where the volume of copying does not justify the setting up of photoprinting or photostating facilities. Here these machines serve as a fairly good substitute.

In the larger library or archival establishment, which has a photoduplicating service, quick-copying machines are normally provided for two reasons. First, they offer the user an opportunity to obtain his copy on the spot, within a few minutes. Second, the user can operate the machine himself and thus, by providing his own labor, pay for materials only and save the labor cost included in the price of a photoprint or photostat.

It is my opinion, from observation of several rapid-copying machines at M. I. T., that in library application the cost per print made on one of the rapid-copying machines — including labor, materials, and depreciation — is as high as, and, in some cases, higher than the cost of a photoprint or photostat. It must be mentioned here, however, that most library photoduplication services have a minimum charge of about $1.00 per order, and that means that the user of the self-service, rapid-copying machine effects a genuine saving when the article he wants to copy is only one to three pages long.

If you, the librarian or archivist, decide to buy a quick-copying machine either because your establishment is small and has no other duplicating service or because you are a divisional librarian and believe that an instant copying device in your branch of the library would be a useful supplement to your main photoduplicating department, then you take one step toward the market, and immediately you are involved in a fabulous world of strange names. Here are only some of them: Transcopy, Verifax, Stenafax, Xerox, Photronic Reproducer, Instant Copier, Photorapid, Ozalid, Electronic Messenger, Intrafax, Deskfax, Heccokwik, Exact Photocopy, Electrofax, Duomatic, Dristat, Duplomat Ultra, Cormac, Copymaster, Copease, Contoura, Bruning, and Apeco. The resemblance to Alice in Wonderland increases as you read the manufacturers' prospectuses. As a phototechnologist, I am delighted that there are so many different machines, involving as they do many different technical processes. As a staff member of a large library, however, I must

confess that I find not a single one of these machines altogether satisfactory.

To choose one of these machines for your library, you will want to find answers to these questions:

1. How legible is the reproduction?
2. How permanent is the copy?
3. Does the machine produce a positive or a negative image?
4. Does it copy from books as well as from loose sheets?
5. Does it copy from opaque originals? Does it copy from sheets printed on both sides?
6. Does it reproduce originals of all colors?
7. What is the maximum size of the original that the machine will copy?
8. Does it allow for any choice of copy paper with respect to weight, color, rag content, etc.?
9. How much space does the equipment take up? Is it portable?
10. How long does it take to make a copy, and how much skill is required to operate the machine? How many different steps are involved? Do chemical solutions have to be prepared?
11. How much does the equipment cost and how sturdy is it?
12. How much servicing does it require?
13. What is the cost of making one copy, and is it possible to make additional copies of the same original at less cost?

These are thirteen questions you should ask, and your choice of a machine will depend on the relative importance you attach to each question for your particular requirement. Not one of the machines now available is sufficiently outstanding in every respect to be recommended in preference to all others.

Our first step towards a practical understanding and evaluation of copying devices is to divide them into classes on the basis of the technical process involved. We find that there are five major processes: the electro-magnetic process, the Diazo process, the thermography process, the diffusion-transfer and gelatin-transfer process, and the facsimile process.

The first or electromagnetic process, is represented by Xerography and Electrofax. Xerox is a camera designed to copy from loose pages or thin leaflets. It copies the original on a special metal plate that has previously received a positive electric charge. This plate is the essential element of the process; light rays reflected from the white parts of the original document destroy the positive charge in the corresponding parts of the plate, leaving a positive charge only in those areas of the plate that correspond to the lettering of the

original. A brownish-black powder is then dusted over the plate surface. The powder has a negative electric charge, and therefore adheres to the positively charged part of the plate. We now have a reverse copy of our original in the form of powder particles loosely attached to the plate. A further step transfers the powder to an ordinary piece of paper by means of heat. This process is completely dry and very clean. The cost of materials is about 5½¢ per page. The disadvantages of the process are that the equipment is bulky and very expensive ($1,000 to $2,000 annual rent), that it will not copy from books, that many colors are not reproduced, and that it requires a fairly skilled operator.

For these reasons we must reject the use of Xerox for producing single copies. There are, however, two useful applications of Xerography in the library. Each combines Xerography with another medium of duplicating.

In combination with an offset press, it enables us to reduce printing costs. A xerographically produced offset plate is considerably cheaper than a photographically made plate. The Xerox offset master is usable for short runs of 3,000 to 4,000 copies. The resulting print is only a little less well defined than material printed from photographically produced plates. This application has led to the use of Xerox-Offset in several universities and libraries for the reproduction of catalog cards. The University of Chicago asserts that it can in this manner produce catalog cards more cheaply than it can buy them from the Library of Congress. Needless to say, your volume of printing must be considerable to justify the high cost of the equipment.

The second and very important application of Xerox is in combination with microfilm. The Xerox continuous enlarger produces normal-size enlargements from microfilm in a matter of minutes. These enlargements are cheaper than those produced by standard photographic enlarging and should last as long as the paper stock on which they are printed. The enlarger rents for about $1,600 per month, and that is, of course, prohibitive for all but the largest libraries. Microfilm enlargements may be obtained from commercial houses, however, at the rate of about 10¢ for an 8½″ x 11″ enlargement, a very reasonable price. A more serious disadvantage is the fact that the enlarger does not adequately compensate for different kinds of writing and print on one microfilm. If, for instance, your microfilm contains a series of handwritten documents, you may find that some of the enlargements will be wholly or partly illegible. In every case, the photoprint is somewhat sharper; and, unless you can

afford to rent your own Xerox enlarger, there will usually be some delay before you receive your enlargements. Xerox is manufactured by the Haloid Co.

Recently, R. C. A. has developed Electrofax, which applies similar technical principles. It has one major difference from Xerox. Instead of exposing a plate and transferring the powder image of the text to a sheet of paper, Electrofax is able to omit the plate and expose directly on a specially coated paper. This paper, by virtue of a chemical coating, can be charged electrically and then reacts just as the plate does in Xerography. The light rays reflected from the white portions of the original destroy the electric charge on the corresponding sections of the paper, the powder is dusted on and is fused to the paper permanently. The Electrofax system still requires a great deal of testing and development of machinery. Some sample prints that I have seen suggest that this method might be both more economical and qualitatively superior to Xerography. The Electrofax-continuous-microfilm-enlarger sells for $85,000, which puts it out of reach of most libraries, but the process is one about which we should hear a great deal more in the next few years.

The second method of reproduction I want to discuss is called Diazo. This process is very easily understood. It is based on the bleaching action of light on certain dyes. If you have ever left a book lying in the sun, with some small object on top of the book, and you found the book cover faded except for the spot covered by the small object, then you have observed the essentials of the Diazo process. You could take a translucent document, printed on one side only, and place it on top of a piece of paper colored with an unstable dye. If you left this combination in the sun long enough, you would bleach out all color in the dyed paper except in those parts protected by the print image, and thus you would have a positive copy of the original. In practice, the process is modified for the sake of speed. A paper is coated with a dye-forming chemical which at this point is colorless, and then, in contact with a translucent original, it is exposed under a high-intensity light source. Where the light strikes the copy paper, it destroys the dye-forming properties of the chemical coating. The paper is then subjected to either a gas or a liquid which produces a visible image in those parts of the paper that were shielded from the light. Since these shielded portions correspond to the text of the original, we have a positive copy. Such a copy may be produced in any one of several colors, black, red, blue, and others. Whether gas or liquid processing is used, the finished, dry copy is obtainable in about a minute.

Diazo paper is very cheap, costing about one to two cents per print. Unfortunately, the process is, in actual practice, resricted to single-sided translucent originals (in the sense in which a thin sheet of typing paper is translucent), because the light must pass through the original to the copy. Incidentally, this method of exposing is known as transmission printing. Most rapid-copying devices employ reflex copying, which means that the exposing light first passes through the copy paper, then bounces back from the original and exposes the copy paper on its return journey.

It would take us beyond the scope of this talk to discuss the relative values of the various methods of exposure. Suffice it to say that Diazo does not lend itself readily to copying from opaque or two-sided originals. There is, in fact, one machine made, and only one, that does copy from books by the Diazo process. That is the Copyflex Model 6, made by the Bruning Co. This machine merely proves, however, that it is possible but neither practicable nor economical to make single copies of pages in bound volumes by means of Diazo. If a better Diazo book-copier can be developed, it will provide a much cheaper method of rapid copying than is now available. There is hope that we can ultimately reduce the cost per copy to about one cent. Diazo reproductions have excellent sharpness; they are not permanent but should last from 5 to 25 years. The two best known manufacturers of Diazo equipment are the Ozalid Co. and the Bruning Co. Machine prices start at $410. Ozalid uses ammonia gas for processing. This gas gives off unpleasant, pungent fumes, and a hose is attached to the Ozalid machine to carry these fumes out through a window. Charles Bruning Co. uses liquid for processing. This liquid does not seem to me to work quite so cleanly as the gas, and the copy emerges slightly damp and requires a few more minutes of drying time. On the other hand, liquid processing frees you from the need of ventilating the equipment.

The first two processes we have discussed do not, in their present stage of development, enable us to make one or two copies quickly and inexpensively. We now come to two methods that will do so.

I am going to take Thermography first. This method of document reproduction is not photographic, for it makes no use of the action of light at all. The only Thermographic equipment now available is that manufactured by the Minnesota Mining Co. under the name of Thermofax.

The Thermofax copy paper used in this process is sensitive not to light but to heat. When a copy is made, this is what happens. The copy paper and the original are put into the machine in such a

way that the paper backing and not the heat-sensitive side of the Thermofax paper is in direct contact with the original. Infrared rays, playing on the Thermofax paper for a few seconds, pass through the paper to the original. The white portions of the original deflect these rays without any effect on the copy paper. The printed black part of the original (in other words, the text) absorbs the infrared rays and converts them into heat, which is bounced through the back of the copy paper to its heat-sensitive coating, where, by means of a chemical change, it produces a black image. This is a single-step operation, completely dry and very fast. One of the three different Thermofax models made by Minnesota Mining (it is called the Premier) is designed to copy from books as well as from single sheets. The machine is excellently designed; and, from the point of view of easy operation, this book copier stands head and shoulders above any other. There is an exposure control dial, which must be adjusted for different types of originals; but the use of such a control dial is necessary in all other copying devices also.

If it were not for two faults inherent in the heat process, Thermofax would have sent all other manufacturers of rapid-copying equipment into bankruptcy. These two faults, however, are serious enough to merit careful consideration before this machine is purchased. We have seen that the infrared rays are converted into heat by the black print. This conversion is dependent on the presence of a metallic compound in the ink of the original. While all black printing inks contain such compounds, a great many colored printing inks do not, nor does the ink used in ball-point pens. Most originals printed in color that I have attempted to reproduce by Thermography did not come out well, and none of the light colors reproduced at all. The second fault is lack of sharpness of the copy. In this respect the process is, in my opinion, quite inferior to most of the other rapid-copying devices. Normal text is legible enough, but small letters have a tendency to be blocked up, rendering them hard to read. The inferior sharpness of the Thermographic copy as compared with a photographic copy apparently is due to an inability to focus heat and make it travel in a more or less straight line as a ray of light would. It is hard to see how this difficulty can be overcome.

The cost of the Premier model of the Thermofax is $425, and the paper, which is available in a variety of colors, costs 4¢ a sheet. The manufacturer of Thermofax paper claims that the copy will last as long as the paper stock on which it is produced. Not knowing the exact composition of the Thermofax image, I cannot either

endorse or deny this claim. It is obvious, however, that the stored copy, by virtue of its sensitivity to heat, is more subject to damage by heat than photocopies. For a test, I placed a piece of Thermofax paper on a home radiator, and dark streaks became apparent after an hour. If excessive heat is avoided, copies should last a long time; but I have grave doubts about their lasting as long as a photostat that has been properly processed for archival permanence.

We now come to a copying process that in the last few years has grown in popularity more than any other. It is known as Transfer.

There are two subdivisions in this process: diffusion-transfer and gelatin-transfer. Transfer is a process eminently suitable for reproduction from bound volumes as well as from single sheets. Since most manufacturers make several models, I shall leave out of my discussion transfer equipment that copies from single sheets only, for obviously such a machine is of little value in the library.

To copy a page from a book by the diffusion-transfer method, you require an exposing unit and a processing unit. Occasionally these two units are combined into a single machine. Normally, the exposing unit is like a photographic darkroom contact printer: a box with a glass top containing a battery of lights, a timer to control the exposure, and a hinged lid, which presses down and holds original and copy paper in contact during the exposure. Two different sheets of paper are used to make the copy. One is the negative, which is light-sensitive; and this is the one exposed in contact with the original. The other, the positive paper, is not sensitive to light. The negative can generally be handled in normal room light for brief periods.

After the exposure in the contact printer, the negative and the positive are sandwiched with their chemically coated sides touching and are fed into a slot in the processing unit. Inside this unit the prints are mechanically drawn through a liquid and then squeezed between two revolving rollers, which press the paper surfaces together and at the same time remove as much moisture as possible from the prints. The prints then emerge from the processor slightly damp. After the chemical process has continued for another 30 seconds or so, the two sheets are pulled apart. The negative, which bears a mirror image, is discarded, and the positive, which is an exact copy of the original, is retained. It generally takes a few more minutes before the copy is completely dry.

Perhaps you would like to know what happens after the negative and positive in contact are fed into the processor. The negative is developed immediately, and those areas in it that correspond to the

white background of the original turn black. The unexposed areas of the negative, and these of course constitute a white mirror-image of the text, give up their unused silver salts to the positive paper. Here, in contact with the chemical coating of the positive paper, these silver salts form a black image.

Some of the better known machines using the diffusion transfer process are the Apeco, Copease, Contoura-Constat, Cormac, Duplomatultra, Dristat, Exact Photocopy, Heccokwik, Transcopy, Photorapid, and Copy Cat. With one notable exception, namely the Contoura-Constat, all these machines are much alike, conforming to my earlier description of the light box for exposing and the separate processing unit.

The Contoura-Constat is a much more compact two-unit machine. It is the only truly portable machine available in this class. It was designed with the Library in mind, and it is also less expensive than any of the other transfer equipment. Prices start at $171. In two respects, the Contoura-Constat is slightly inferior to its competitors. It does not copy text that runs very close to the binding of the book, and the prints have to be hand-cranked through the developing solution, a process that requires a certain amount of skill and good judgment. The motor, which in most other machines transports the copy through the liquid, is here omitted for reasons of economy and portability.

The copying procedure for gelatin-transfer is similar to that employed for diffusion-transfer, but events inside the processor are quite different. Again we have a negative and positive paper. The light-sensitive paper, the negative (generally called matrix in this process), is coated with a gelatin that is fairly soft. This gelatin contains a dye-forming compound and a hardening agent. The positive is just plain paper. After it has been exposed, only the matrix is put into the liquid, where a black dye is formed throughout the entire gelatin layer. But only the exposed areas, the areas corresponding to the white background of the original, are hardened. The unexposed area of the matrix, corresponding to the text image of the original page, has blackened also, but has remained soft. The wet matrix is pressed into contact with the dry positive, and a thin layer of the soft gelatin transfers readily to the plain paper when the two sheets are peeled apart. By reimmersing the matrix in the liquid, five or six additional positive copies can be made from it. Each copy pulls a thinner layer of gelatin from the matrix than the preceding one, and finally the image is too weak to be legible.

I have described the positive as "plain paper." This is true in

the sense that it is not coated with chemicals that contribute to the making of the image. Not all papers, however, have the property of attracting gelatin from the matrix; and it is advisable, though not necessary, to use the positive paper marketed for this purpose. There are only a few gelatin transfer machines. The best known is Eastman Kodak's Verifax. Photostat Instant Copier is another. The Verifax combines exposing unit, processing unit, and paper storage shelf, all in one compact piece of equipment.

A copy obtained by the transfer process is better in point of legibility than any made by other rapid-copying methods. It is still, however, inferior to the photoprint or photostat. The diffusion transfer prints are a little sharper than the gelatin transfer ones. Neither process reproduces pictures well, but diffusion gives a subtler reproduction of colored text or charts than does gelatin. Most salesmen claim permanence for the copy produced by their rapid-copying equipment, but in doing so they misuse the term permanent. A well-processed photoprint or photostat will equal or exceed the life of a printed book. It should last for hundreds of years under good storage conditions. No similar claim can justly be made for transfer prints, whose life has been estimated at from 5 to 25 years. Gelatin transfer is temperature-controlled, and excessive heat or cold or extreme humidity can interfere with the process.

Most of the transfer equipment is excellent for office copying, but its value to the library or archives would be considerably enhanced by a really good book-copying unit. All the present exposing units make it most difficult to achieve good contact between the page of a book and the copy paper. Some of the machines are better than others in copying text close to the binding of the book, but, on this point also, an over-all improvement is desirable.

Transfer equipment for institutional use costs about $400, unless you find the inexpensive Contoura-Constat adequate. Some machines are a little cheaper than others, but they seem less sturdy, and the $50 or so you might save would probably soon be spent on replacement parts. The cost of materials for one 8½″ x 11″ copy is approximately 9½¢. Since several good copies can be made from one gelatin matrix, additional copies of any one page are much cheaper by this process than by diffusion.

The processing liquids used in transfer must, for best results, be renewed about every 100 sheets, and the life of the solution is limited to about one week. Each manufacturer of transfer equipment markets his own copy-paper and processing liquid. As a rule,

you cannot use the materials of one company with the equipment of another.

I want to touch but briefly on our last class, facsimile. Here is a very simplified version of how it works. The surface of the material to be copied is traversed by a light-beam-and-photoelectric-cell arrangement, which translates the light and dark areas of the original document into a correspondingly variable flow of electricity, or into radio waves, which are then transmitted by wire or by radio. A receiving apparatus then reverses the process and retranslates the electrical or radio signal into a legible image. This is done by means of a stylus, which marks a chemically treated paper in response to the received signal.[2]

We note at once the major difference between this kind of copying and all other copying processes. Here the copy can be made miles away from the original. Facsimile has found an increasing number of commercial applications. News pictures and weather maps, for instance, are radio-transmitted in this fashion. Facsimile equipment varies greatly in scope, and there has been relatively little experimentation with transmission from one library to another. The main reason is that the equipment is expensive; it runs to many thousands of dollars. As yet the legibility of the copy leaves very much to be desired. Equipment that can now be bought would have to be redesigned to copy from books. Companies manufacturing such equipment are: Western Union, the Times Facsimile Corp., Air Associates, Inc., and the Alden Impulse Recording Co.

I paid a visit to the Alden Co. the other day to see their latest equipment and to consider its possible application in the library. The machine I examined consisted of a transmitter, a unit about 2′ high and 1½′ wide and deep. In front, it had a lot of fascinating colored lights and dials. The lights are trouble indicators to enable the unskilled operator quickly to locate burned-out tubes or other minor difficulties that he can correct himself. This transmitter will copy from loose sheets only, but it could be adapted to reproduce from bound volumes also. To use it, all you have to do is place the original under a roller. The rest is done by the machine.

I then went across the room to the receiver, which is a little smaller than a typewriter, and watched my copy appear line by line, until, a few minutes later, it was complete, and the machine stopped. The copy was slightly moist, but it dried completely in 5 minutes. Legibility was fair. The copy could be read, but you would not care to

[2] The author is largely indebted to the *Columbia Encyclopaedia* for this description of Facsimile.

read such reproductions for several hours. The receiver that I watched did not have to be in the same room with the transmitter, of course. We could, for instance, have a reciprocal arrangement between Harvard and M. I. T. with a transmitter and receiver at each end. We should then use a telephone line to transmit copy back and forth. If we bought such equipment outright (it could also be rented), it would cost about $20,000, and the telephone line and upkeep would probably cost an additional $300 or $400 per year. The copying paper costs about 4¢ to 5¢ per print.

The Stenafax is a combination of transmitter and receiver, which uses the principle of transmission but is designed for copying in one place. In about 3 minutes, it makes a copy that in quality may be rated just adequate.

Ultrafax is the name of a combination system using television and microfilm. The microfilm is scanned by a television camera, which transmits it, and the receiving unit prints a microfilm copy. An Ultrafax was set up in the Library of Congress in 1954 to supply information to the National Institutes of Health in Bethesda, Maryland, in place of interlibrary loan.

Now, what of the future? I am tempted to say that the not far distant future will see a tremendous development of the microimage in its many forms in conjunction with machine-coding and mechanical selectors, and that only those copying methods that are capable of resolving the fine lines of a microimage will survive. But my friends, who know me, will say that I am slightly biased in favor of microphotography; so I shall not make that statement.

Most certainly I think that we shall soon see the end of all wet-processing methods. There are so many new methods under development that it would take many hours to describe them. One method not yet on the market looks particularly promising. It exposes by ultraviolet light and develops with infrared. This process, named Calvar, has all the advantages of the Thermofax, but it does not have the latter's faults. It does reproduce colors, and it has excellent sharpness. The manufacturer of Calvar is also developing a revolutionary new microfilm process, which promises to enable us to make a microfilm ready to go into the reader a minute or two after exposure. No wet processing is involved at all.

For some years now, the Standard Register Co. has been perfecting the Photronic reproducer. This machine, based on electromagnetic principles, is somewhat similar to Xerography, but it cuts down the five steps involved in making a print to one single step. The manufacturer feels that he would like further to improve

the quality of the copy before offering the machine for sale, and this is surely a laudable attitude.

A friend of mine who owns a microfilm service agency here in Boston has a dream. He visualizes the interlibrary loan of tomorrow like this: a scholar in a midwestern university desires a copy of a document from Harvard. He goes over to a little machine standing against the wall in the library. It looks a little like a juke box. He puts in a dime, then presses a series of numbered buttons, and a copy of the document he needs comes out of the slot. I suspect that the part about the dime is due to a touch of the mercenary in my friend, who, while he is dreaming, dreams himself into holding all the rights to the machine. It may be that he is looking quite a few years ahead, but there is little doubt in my mind that the future of the interlibrary loan and perhaps of all copying rests with facsimile equipment.

One final point. Practically all existing copying equipment was designed for business use, and this is quite natural since business has a somewhat larger budget than the library. But it is wrong and unnecessary that so little of this equipment is adaptable to library or archival use. In many cases, minor modification would have made a machine much more useful to the libraries without in any way diminishing its value to the businessman.

This would point to a lack of communication between libraries and the manufacturers. The producer of rapid-copying devices (and, incidentally, this holds good also for microfilm and microcard equipment) has approached the library in a very half-hearted manner, to say the least. It seems, therefore, that we must approach the manufacturer, individually and through official library organizations, in order that he may have a better understanding of our needs.