TIME AND COST OF ENGINEERING
(formal title)

DRAWING REPRODUCTION

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CHAPTER I

INTRODUCTION

Marketing a space age product requires the versatility to design, develop, and manufacture an item which subsequently must undergo technical changes at a rapid rate. This capability depends not only on engineering and manufacturing potential but also on the suitability of the communication system by which all information must be transmitted in usable form to the participants. This paper deals with the communication system vitally necessary to the functioning of large size rocket engine manufacturers and involves the transmission of engineering design information from the engineer to the purchasing, manufacturing, and inspection operatives. This is done by depicting the information on an engineering drawing and reproducing copies of the drawing for all concerned parties.

The Problem and Its Importance

The time lag between the presentation of the drawing for reproductions and the availability of drawing prints is three days in a representative company in this field. The cost of reproducing prints of engineering drawings is approximately one-third of a million dollars annually. These time and cost factors constitute a significant problem since the rocket engine market is so highly competitive from the standpoints of time and cost that prompt services must be provided at a
minimum expenditure.¹ Positively stated, the problem to be dealt with in this paper is the reduction of the time and cost required for reproduction of engineering drawings, a problem area which applies to any large engineering type company.

The importance of providing reproduction of engineering drawings is strikingly apparent in an industry which is largely dependent on engineering designs to develop space age products. New innovations and inventions are the mainstay of the industry; yet creative communication must precede the actual transfromance of a creative idea into a usable product.² Engineering drawings are the basic communication medium through which the engineer describes, in a language understandable to the manufacturing employee, the engineering design which is to result in a highly complex and technical product.³ There can be no doubt that the engineering drawing itself is an indispensable element to the manufacture of the product, but these drawings are extremely costly since they represent hundreds of hours of design and drafting effort. A single drawing may easily be worth thousands of dollars and is far too valuable to be used directly in the shop.⁴ Additionally, the speed and the extent of specialization required in modern industry


²Joe W. Coffman, The Role of Visual Communication, an address to the 75th Anniversary Convention of the Photographers' Association of America, Chicago, August 15, 1955 (Holyoke, Massachusetts: Technifax Corporation), p. 2.


⁴Ibid.
are only possible on the basis of concurrent action implemented by simultaneous issuance of multiple copies of the drawing.5

The copies of the drawings (generally referred to as prints or blueprints regardless of the process used to make them) represent a sizeable production requirement in themselves since their bulk may well approach or exceed the size and weight of the product they are used to build, be it an airplane or a submarine.6 The Boeing 707 jet transport, as an example, required an estimated 250,000 pounds of prints and drawings which is nearly as much as the weight of the plane itself.7

The reproductions effort required for a company in the industry is obvious. The problem faced by all contractors in the defense industries is the collective sum of the problems of the individual contractors. The size of the documentation problem in general, of which drawings and prints represent a considerable part, is readily apparent when it is realized that the Department of Defense spends from 2 to 2-1/2 billion dollars a year for documentation.8 This huge expenditure serves to point out the fact that, for government, as well as for the industry and the company, the cost of paperwork and resulting prints is worthy of close scrutiny and constant pursuit of more efficient means of performing the reproductions function. The

5Ibid.

6Joe W. Coffman, Technology of the Diazoype Process (Holyoke, Massachusetts: Technifax Corporation), p. 1

7Ray Good Jr., "Secretary's Corner," The International Blueprinter, October, 1958, p. 66

handling of drawings and prints and the time consumed by reproduction of prints is a major problem to the government because after they are delivered from the contractor, they must be used for logistics purposes. At the Air Material Command Headquarters, over 3,500,000 active drawings are on file for supplying requests to their various procurement agencies.9

The problem of reducing the time and cost of reproductions is highly significant from the company standpoint since competitive standing in the rocket engine product market is enhanced or retarded in proportion to the efficient accomplishment of services required to expedite product delivery at lower cost. Briefly summarized, rapid reproduction and distribution of prints is essential to the communication network which must transform engineering ideas into manufactured parts in order for progress in the company to take place in a given direction. It may truly be said that progress begins on paper; therefore, the first place to decrease the time required for progress is to decrease the time required to place the print in the hands of the user.10

Central Theme and Hypothesis

The content of this paper is based primarily on the concept that it is possible to reduce the time and cost required to provide the drawing reproduction service. The hypotheses which will be proven


10Rau, p. 2.
are as follows:

1. The nature of the industry is such that the time of three days required for reproduction of drawings can and must be significantly reduced.

2. The cost of one-third of a million dollars annually for reproduction of drawings is excessive and can be reduced. 11

3. The means of reducing both the time and cost of communicating designs is available and suitable to meet short and long run reproductions requirements.

Philosophy of Presentation

The problems of time and cost reduction are the focal points of discussion throughout this paper. The necessity for reducing the number of days required to make drawing prints will be thoroughly discussed and substantiated from the position of the company in the field of rocketry. The relationship between the demand for rapid communication in this field and the parallel development of suitable reproduction equipment to meet this need will be made clear. All major facets of consideration leading to the reduction in reproduction flow time will be examined in the light of reproductions processes and equipment suitable for the purpose.

In establishing a reduced flow time, the problem of cost is also analyzed. In this regard, the system of cost compilation and analysis to be used is presented and applied to equipment and process alternatives for comparison of relative cost advantages.

For each major problem area, a specific equipment recommendation will be made so that a final summary of alternatives may be presented with a recommendation and justification for a specific selection.

Objective of the Thesis

The hypotheses of the time and cost reduction potential will be proven in the text of this paper. A firm conclusion will be reached as to a recommendation for solving the basic problems. The recommendation will provide a solution to the problem of excessive time and cost required for engineering drawing reproduction and, thereby, will facilitate and expedite company operations as well as add to profits.

Further, since the rocket industry is a field of rapid change and the supporting services of the company must be capable of performing in this environment, both a short range and a long range recommendation to the time and cost problem will be provided. In so doing, the company may be assured of an immediate remedy while having advanced recommendations to cover anticipated future efficiencies in engineering design communication.

Definitions and Terms

The use of technical trade and commercial terms in this paper will be kept to a minimum in order to make as clear a presentation as possible of the factors which must be evaluated in the reproductions problem by essentially non-technical management. The intent is to present bases and recommendations for managerial decision rather than to provide a physical or chemical analysis which would have little direct application in the evaluation and expenditure of company funds.

A few general terms are defined in this section. Others will be defined in the text where first used when necessary. A pictorial and written description of reproductions processes is presented in the second chapter for reference and use in understanding the basic
process under consideration. All terms and definitions used in this paper are consistent with commercial and industrial reproductions terminology, especially as described in the trade glossary published by the Research and Standardization Committee of the National Association of Blueprint and Diazotype Coaters.

Commonly used reproductions terms employed in this paper are as follows:

1. Reproductions is the collective term used to describe the producing of an image copy by chemical and mechanical means such as by use of blueprinting, printing, and photographic processes.

2. Blueprinting (wet process) is the reproductions process traditionally used to reproduce engineering drawings. A negative blue image is produced on paper coated with light sensitive iron salts. A blueprint is the resulting print of this process. The term is also applied to other prints having a white image on a blue background. Organizationally speaking, the term "blueprint unit" or "blueprint shop" has continued to be applied to reproductions areas which have replaced blueprinting with white-printing.

3. Whiteprinting (also known variously as dry process, moist process, direct positive process, diazotype, and blueline) is the reproductions process used to produce a dry positive original from an engineering drawing or other translucent original. The most common color of image is blue and such prints having a blue image on a white background are known as blue-lines. A blueline print may also be made by exposing a negative to the blueprint process.

4. Printing is the reproductions process used to make ink impressions from engravings, type, or other kinds of prepared printing plates. The type of printing most generally used for making prints of smaller sizes of engineering drawings is known as offset printing.

5. Photographic processes involve the reproduction of an image by use of a light sensitive silver emulsion coating on various base materials. In relation to engineering drawings, the photographic processes are used for microfilming and making duplicate originals.
6. A drawing is a pencil or ink image on a base such as paper, cloth, or plastic. For reproduction purposes, drawings are made on translucent or transparent bases which permit the passage of light through the base material to permit exposure to sensitive blueprint and whiteprint material. Drawings are also referred to as tracings.

7. Electrostatic printing is a reproductions process which depends on electrical and mechanical duplication by the use of photoconductive materials. It is a dry, relatively inexpensive and rapid process new to the reproductions field and rapidly gaining popularity.

8. Microfilm is a film of relatively small size used to maintain a compact and permanent record of otherwise voluminous reports, drawings, etc.

Research, Authorities, and Sources on the Subject

The author has had three years experience as a member of supervision in a reproduction service organization, one year of experience in general administration, and two years of experience supervising an engineering administrative systems and procedures unit. This time has been spent with a company in the rocket engine industry. Prior to this time, the author had worked approximately seven years for a company engaged in the manufacture of offset printing plates.

In gathering data and information for this thesis, the author has made an intensive study of the reproduction of engineering drawings at the Rocketdyne Division of North American Aviation, Incorporated. In addition, an extensive study has been made of the reproductions functions of many of the major aerospace companies in the Southern California area by visiting the plants, interviewing reproductions management, and observing reproductions facilities in operation for
the past six years. Companies visited include the Autonetics, Space and Information Systems, and Los Angeles Divisions of North American Aviation, Incorporated; the Santa Monica plant of Douglas Aircraft Corporation; Bendix Pacific Division of Bendix Aviation, Incorporated; the Pomona plant of the Convair Division, General Dynamics, Incorporated; the Burbank plant of Lockheed Aircraft Corporation; and other firms. Commercial reproductions suppliers visited include Economy Blueprint and Supply Company; American Blueprint Company; Westwood Blueprint Company; Haloid-Xerox Company, Incorporated; Ozalid Division of General Aniline and Film Corporation; American Type Founders; Charles Bruning Company, Incorporated; Addressograph-Multigraph Corporation; Eugene Dietzgen Company; Delta Lithograph Company; the Microfilm Company of California; and many other companies in the business of supplying reproductions material, equipment, and services.

Reproductions sales and management personnel of the above mentioned companies constitute a prime source of authoritative information in the field of engineering drawing reproduction. Little has been written on the subject giving comprehensive treatment of the time and costs involved in drawing reproduction. However, with the background of information established by the above sources, research has been undertaken in specific topical areas where authorities on the subjects do exist. Engineering and aerospace periodicals, business periodicals, technical publications, industrial association literature, and texts on industrial management and cost control have all been searched for support material for use in this thesis. On this foundation, the following pages present, examine, and resolve the problem of reducing the time and cost required to make prints of engineering drawings.
CHAPTER II

TIME URGENCY AND REPRODUCTIONS ADVANCEMENT

Since the advent of the industrial revolution, the growth of industry and the expansion of scientific knowledge have proceeded concurrently so that man in the twentieth century, who has barely adjusted himself in the transition to the age of mechanization, is now compelled to race ahead ever faster into the space age.

The purpose of this chapter is to show that reducing the flow time required in support activities such as drawing reproductions is necessary to shorten the lead time required to produce the space age product. Then, the development and advancement of reproduction technology to keep pace with the needs of the aerospace industry will be outlined. This will provide a basis for progressing from the current reproduction system to the system necessary for minimum reproduction flow time.

Time Impact on the Rocket Engine Manufacturer

It is the atmosphere of urgency which marks the company position in the space products market as being substantially different from that of past technological products markets. The explosive growth of technology is the dominant factor affecting our national security in the space age.¹ Space accomplishments have captured the imagination of

the world and thus only first place in the war of scientific development will confirm first place in world leadership.2 The incumbent requirement is to assure peace power, which is space power, by overcoming the inordinately long lead time between the development of a technological concept and the availability of the resultant product. It is recognized that the time element is the decisive factor in the field of technological competition.3 The successful company will be the one that constantly shortens the time element required to deliver an advanced product. Evaluation of bids and awarding of contracts are largely determined by this consideration.

The heart of the space machine is the combination of rocket engines known as the propulsion system. The Air Force concentrates a large part of its research effort in the field of propulsion, recognizing that no space achievements are potentially possible until adequate power is available to propel the space craft on its mission. As Lieutenant General Wilson says: "Propulsion is the latch key that opens the door to space—and we give it research emphasis accordingly."4 The rocket engine manufacturers are striving to meet the challenge with rapid design and development of their products. At Rocketdyne, a leader in this field, all programs are recognized as rush needs of the customer. More speed is urged to produce more results sooner.5


4Wilson, Air Force Magazine . . . , p. 54.

Lead time reduction must be emphasized from an organizational, managerial, and administrative standpoint to generate improvement of the supporting systems and procedures involved. The reproductions products manufacturers, like any other successful producer, must always keep abreast of the needs of the market they supply. The products and processes must constantly be changed in unison with and anticipation of the changing market. Suppliers of reproductions materials and equipment and developers of reproductions processes have met the challenge in the past when necessary. The indications are that the new reproductions requirements of today are also being met.

Advancement of Reproductions Technology

The blueprint process

Blueprinting is the traditional method of reproducing prints of engineering drawings. Blueprint use has been so firmly associated with the graphic presentation of working plans and instructions that the word is still frequently applied in manufacturing to prints made by other processes such as whiteprinting and offset printing even though the prints are positives and are not blue. The common and widespread acknowledgement of the blueprint as an instrument for communicating plans for action is attested to by the analogical use of the term in such phrases as "blueprint for peace," "blueprint for the future," etc.

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The blueprint process, invented in 1840, consists of exposing the drawing to materials sensitized with a coating of iron salts. The material is then washed in water solutions to remove excess coating and to fix the image on the print. The early use of this process was for making photographic negatives. It later became commonly used for making negative print copies of drawings (i.e., prints showing the image in white lines on a dark blue background or the reverse of the original drawing which is a dark line on a white background). The primary advantages which lead to the use of blueprinting as the nearly standard process for reproducing drawings were its cheap material costs, permanency of prints, and simplicity of method. The process was time consuming due to the lack of a controlled light source since exposure was by daylight or direct sunlight in a contact frame as illustrated in Figure 1. Eventually, as the need developed, exposure was made by use of electric devices such as carbon arcs and high intensity lamps. Because of the availability of adequate light sources, the use of the exposure frame gave way to the continuous printer. By this means, a continuous roll of paper feeds into the blueprint machine, around a glass cylinder within which the light source is contained, through the developing solutions, and around cylindrical drying drums as illustrated in Figures 2 and 3. Exposure is controlled by the intensity of the light source and the speed of the paper moving through the machine.9

In the present day state of development, the speed of making blueprints is only limited by the speed with which the operator is

Fig. 1.--Early method of blueprint processing

Fig. 2.--Continuous blueprint processing
A. The blueprint paper is threaded through the baths, washes, and dryers. The operator feeds the drawing into the machine on top of the blueprint paper and it returns to him while the prints are moving through the machine.

B. The blueprints feed out the rear of the machine onto a table where they are trimmed and folded to size. Note the constant trimming required on the cut size prints shown in the above illustration. When even smaller sizes are run, a trim in two directions is required and blank unprinted surfaces are wasted.

Fig. 3.--Blueprinting in action
capable of feeding in the prints and with which other personnel can trim and fold the prints as shown in Figure 3. Though it is possible to trim and fold prints mechanically, no mechanical devices are apparent which satisfactorily perform this operation. Therefore, it is still most generally a hand operation.\textsuperscript{10}

The blueprint machine produces a print of the same size as the original image from which the print is made. Since the print is exposed by light passing through the original, any transparent or translucent intermediate carrying an opaque image is satisfactory for print making. The drawing may be used directly for making blueprints or other reproduced intermediates made from the drawing may be used. The time advantages of using an intermediate are discussed in the development of the print size standard.

Blueprint and whiteprint processes utilize print paper which is sensitive only to high intensity ultra violet light and which may be safely used in a normally lighted room. Other light sensitive materials are primarily photographic in nature and must be handled under special subdued "safe lighting" or darkroom conditions.

A large scale print production operation in a very dimly lit area would impose serious limitations. Special darkroom facilities are required, thereby restricting layout flexibility. Personnel have difficulty in adjusting their eyes to extremely changed lighting conditions. Further, the print trimming operation requires the use of long sharp shears, a definite safety hazard in dimly lit areas. Adjustments on the large, rapidly moving machine would also be unsafe.

without proper light.

The advantages of the blueprint process today are becoming less distinct as improvements are made in other processes. Relatively low cost, simplicity, permanency of print, and relatively rapid production are now factors in which other processes can compete and possibly excel. In addition, the disadvantages of blueprint are not present in many other processes. These main disadvantages are embodied in the nature of the process which requires a continuous moving band of paper running through the machine.

Several feet of paper are threaded through the machine before production begins. Since the paper is thoroughly wet during processing, it is easily torn due to machine or other operating malfunction. Such interruption to print production obviously causes lost time though skill in operation and good equipment should limit any severe problems in this area.

A more important consideration is the variety of drawing sizes from which prints have to be made. Size standards, established in the next chapter, are essential to minimize production fluctuations. However, even with standardization, there will be some large and some small drawings. Depending on the available work load and the ability of the operator, varying degrees of waste material occur since the print paper is constantly moving through the machine. Many small drawings require quick placement on the paper causing the machine to operate at slower speeds. The additional problem with the small drawing sizes is that extra trimming effort is required on the prints.

since the print paper size is of a constant width, regardless of the
length or width of the drawing.

In addition to feeding in the originals for exposure, the blue-
print operator must control the speed, light exposure, and drying heat
of the machine, all of which are interdependent variables requiring
alert operation in a job not classified as highly skilled from a wage
classification standpoint. Constant surveillance by supervision is
required to avoid waste. Such supervisory attention to a repetitive
production line type job creates the appearance of encroachment on the
freedom of the operator and impedes production. While it is theoreti-
cally possible through studied and concerted motivational approaches
to solve this problem, the repetitive nature of the work tends to
deter top performance. Efficiency by the operator usually means
more work for the trimmers, and, since effort of a working team tends
to seek a level acceptable to the group, the operator is discouraged
from being efficient.

The nature of the process makes it inherently impossible to
alleviate the need for high temperature drying as well as a goodly
volume of running water and sewage facilities. These requirements
seriously affect plant layout and restrict the use of areas and loca-
tions of reproductions facilities. The use of concrete and steel con-
struction employed in the modern plant involves a high cost of
alteration. Concrete walls or floors pose difficulties for installa-
tion of piping. The heating needs require high electrical power or

12 Gordon S. Watkins et al., The Management of Personnel and
p. 151.

gas plumbing, one or the other of which is normally available. Dispelling the heat which is generated is a more difficult problem since such ventilation often works at cross purposes with central air conditioning units. Multi-story buildings may be of such a nature as to limit the location of blueprint equipment because of restricted locations available for vent and blower pipes. Buildings not already equipped with water and sewage facilities pose unnecessary difficulties in plant layout in that a make-shift accommodation must be improvised.\textsuperscript{15} If blueprint equipment is to be moved, the problem of facilities is again encountered.

Continuous blueprint machines are the largest and bulkiest equipment likely to be present in most reproductions shops, being approximately 6 feet wide and 12 feet long. This size is another adverse factor involved in the layout of small areas. In addition to the length of the machine, a folding table of 12 feet is needed at the back of the machine and in line with it unless prints are to be rolled up and then unrolled for trimming and folding in another area. Such a step is inconvenient and not conducive to continuous production operations in the layout of a synthetic process, i.e., a process which brings component materials together to produce the product.\textsuperscript{16}

The blueprint process served the need well for many decades when other processes were not available to reproduce engineering drawings. Evidence is mounting that this once dominant process is giving way to whiteprinting, which does much the same job without all of the noted disadvantages, or to other processes using a much different approach.

\textsuperscript{15}Ibid., pp. 202-205.  \textsuperscript{16}Ibid., p. 227.
The whiteprint process

The whiteprint process involves the same feeding and exposure technique as blueprint, but the sensitized coating on the print paper is different, and, therefore, the method of development is different. A whiteprint is a positive print having dark lines on a white background which is the natural form for drawn and printed materials. The process was imported from Europe in the thirties and has gained in popularity ever since. In 1957, there were approximately 700,000,000 square yards of sensitized paper used in the United States of which 80 per cent was for whiteprint and only 20 per cent for blueprint. It appears likely that the high relative use of whiteprint will continue to increase.

The whiteprint process does not require the thorough wetting and washing of prints, and, therefore, the processing machine is much more compact, approximately 6 feet high, 6 feet wide, and 3 feet long. The primary advantage is the versatility of feeding either a continuous roll of paper or separate sheets precut to size and individually fed as illustrated in Figure 1. Materials are generally cheaper than blueprint and machine set up time at the start of the shift (and shut down time at the end of the shift) is less because there is not special developer preparation, rinse tank plugs, and water faucets with which to contend. Operating speeds may be much faster than blueprint and the making of small size prints is much more practical since use of sheets cut to

17Coffman, Technology . . ., p. 2.

The operator feeds individual cut sheets into the machine as shown. The drawing returns in the tray immediately above the feeding surface. Prints process through the machine and out the tray at the top of the machine or at the rear of the machine onto the folding table.

Fig. 4.—Whiteprinting
size precludes trimming, facilitates handling, and eliminates waste. 19

The primary disadvantage of the whiteprint process is the use of ammonia fumes to develop prints. One type of whiteprinter, known as the moist process, moistens the paper with chemical developer and offers the advantage of odorless development. The Charles Bruning Company is the only significant manufacturer of this equipment. The machines of other major manufacturers (Ozalid, Paragon Revolute, and C. F. Pease Companies) use gaseous ammonia. 20 This preference is based on the disadvantage of moistening and then drying the print, the possibility of ruining the drawing if it accidentally comes in contact with developer, and the machine set-up and clean-up requirements of preparing the special developer. Visits by the author to local reproductions organizations have revealed that Douglas Aircraft, Lockheed, North American, Bendix Pacific, and Economy Blueprint use the ammonia type of whiteprinting equipment. Because of the preference for this type of machine, the sensitized paper for its operation is more readily available and in a greater variety of sizes, weights, speeds, and materials. 21

The presence of ammonia fumes in the reproductions area definitely causes a health and safety problem if not properly controlled. Most machines come equipped with large blower capacity to expel fumes produced within the machine. The more difficult problem is to remove the fumes from the print paper after development. Since the machine

19Coffman, Technology . . . , p. 2.


prints and develops at speeds which can range as high as the exceptionally fast rate of 125 feet per minute, a large amount of ammonia is carried out of the machine on the print paper.\textsuperscript{22} The answer to this problem is the installation of a special hood and exhaust system over the trimming and folding table to draw the fumes off the paper.\textsuperscript{23} The same type of venting required to expel heat from the blueprint machine is thus required with the same attendant installation costs and layout inflexibilities.

Even with proper venting for acceptable health levels, there is still a noticeable trace of ammonia fumes in the area of any large volume whiteprint operation. This causes a morale problem, especially among women operators, and also in adjoining areas into which the fumes may carry depending on prevailing air current conditions. In addition to the moral obligation of the company to provide a pleasant working environment, it is of real productive value to create a healthful environment of clean fresh air at a controlled temperature appropriate for the human activity level involved.\textsuperscript{24} The reproductions areas can only approach this aim and not completely achieve success from a practical standpoint where ammonia type prints are involved since the paper absorbs a certain amount of ammonia and retains the odor thereof for several hours. The best effect management can have on morale in this case is to show employees that they are constantly trying all possible means to improve the situation in whatever way is possible. One means of aid is by use of the "odorless" ammonias marketed to minimize

\textsuperscript{22}O\textsuperscript{D}R Guide, pp. 172, 173. \textsuperscript{23}Watkins, p. 738.
\textsuperscript{24}Ibid., pp. 633, 736-739.
the problem as much as possible. The odor of ammonia in these formulas is not completely neutralized but is masked with counteracting agents. 25

The whiteprint process appears to offer the most advantageous method of reproducing a wide range of sizes of engineering drawings of any currently available hand fed process.

The offset printing process

Printing is by far the oldest reproduction process. There are three basic types of printing by press utilizing ink impressions. Letterpress or relief printing involves the use of movable type or engravings which stand out in relief, pick up ink, and impress the inked image on the material to be printed. Gravure or intaglio printing involves the opposite technique of etching or depressing the image into the press plate or cylinder. 26 The time and cost required by these processes, which are designed for running hundreds of thousands of impressions, would be impractical for reproduction of a few drawing prints.

The third process is lithographic printing which is a chemical process of printing from a plane surface. The principle involved is the natural repulsion of water and grease. A water repellant image on the printing plane picks up the greasy lithographic ink while the non-image areas are moistened and thus repel the ink. The first lithographic prints were made on stone. About 1820, it was discovered that zinc made a satisfactory printing plate or master. Today, aluminum and plastic are primarily used. 27

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With the advent of the power press in 1865, flatbed presses were developed which could print 600 sheets per hour on paper 44 x 64 inches. Rotary presses were developed which could print 1100 sheets per hour. Up to this point, all lithographic images were prepared in reverse in order to create right-reading images. In 1875, the offset press came into being, and, after the turn of the century, offset printing started increasing in popularity to the point where it is currently the most widely used industrial printing process. 28

Offset printing, illustrated in Figures 5 and 6, is a lithographic printing process which transfers or "offsets" the right-reading image from the master to a blanket cylinder. The blanket cylinder image is in reverse and becomes right-reading when transferred to the print material. Offset printing is a highly versatile and adaptable, very accurate, and very fast method of reproduction. Paper and ink manufacturers have kept pace by supplying desirable materials for this process. 29

The advantages of using offset printing to reproduce engineering drawings are many. The press will print on nearly any unsensitized paper, which is far less costly than sensitized blueprint and whiteprint paper and less subject to spoilage from light or moisture. The press operates at very high speeds ranging from 2000 to 9000 automatically fed and stacked prints per hour. 30 A near comparable speed is possible, theoretically, for the smallest size print produced by the whiteprint process, but practical operating speed is far less due to hand feeding. Another advantage is that no special developing is re-

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Fig. 5.--Offset printing
A. Small duplicating press used for prints up to 11 x 17 inches. Offset masters made on the electrostatic camera/printer may be used on this machine to make drawing prints.

B. Large offset press for prints up to 25-1/2 x 36 inches. Note the complexity as compared to the duplicating press at the left.

Fig. 6.—Offset printing presses
quired, thereby eliminating the heating, drying, and fumes disadvantages present in the blueprint and whiteprint processes.

The primary preventative from totally utilizing the offset process is the size of the drawing. Though some offset presses have capabilities of running drawings as long as 6 feet, the longer drawings used in the aerospace industries would not be capable of offset reproduction. Even if this were possible, these large size presses are of an extremely complex nature requiring the skill of a capable pressman. These presses are expressly designed for long runs ranging in the area of tens to hundreds of thousands of copies. The make-ready time and cost required to prepare and mount the large size metal master on the press would be prohibitive for drawing reproduction purposes. The author has found no instances where presses of this size have been used for normal engineering drawing reproductions purposes. Typically, offset presses are high quality and high precision machinery needing large production for practical operation.

The use of offset presses has been more extensive for print production from smaller drawing sizes. The impetus to do so is provided by relatively simple press operation, relatively low cost, rapid master preparation, and relatively rapid set-up time. Low cost paper masters prepared by non-photographic processes are provided in sizes up to 25-1/2 x 36 inches and are commonly used for 17 x 22 inch prints.31 Rapid set-up has been substantially limited to the small offset presses which make prints to 14 x 20 inches.32

The use of offset printing for the purpose of drawing repro-

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31 Ibid., pp. 120, 121, 124, 125. 32 Ibid.
duction is increasing due to the rapid and low cost methods being developed. It is anticipated that low cost specially designed presses will be available soon to meet drawing reproduction needs of 20 to 200 prints per run. The offset press then becomes an inviting process to use for sizes it is capable of handling. A press presently capable of modification by the manufacturer on a customer option basis is the Copilith Senior. This press can be modified to clamp the master in less than 5 seconds, an operation which requires 5 to 15 minutes on a normal press. The clamping adaptation on this specific press is particularly attractive since the press handles a sheet size of 18 x 24 inches. Contractors with the Department of Defense are obliged to meet microfilm requirements whereby each frame of microfilm represents a maximum of 48 inches of drawing length. A 50 per cent reduction in print size would permit running all microfilmed print requirements on this press.

The most important contribution to the advent of offset printing of engineering drawings is the ability to make a master quickly and economically. This is done by a variety of means, many of which involve the use of the electrostatic process, next described.

The electrostatic process

The electrostatic process is looked upon as the most important

33Von Meister, International Blueprinter, pp. 60, 61.

34Interview with Phil Miranda, offset representative of Los Angeles Office, Copease Corporation, November, 1960.

development of the century in the graphic arts field. Its application to engineering drawing reproduction holds much promise, and, by use of this process, the first practical applications of automated engineering drawing reproductions systems have been made possible.

The electrostatic process is a very recent development, approximately ten years old, and is a major contribution to reproduction technology advancement. The process utilizes the principle of making a material light sensitive by charging it with electricity. The image to be reproduced is reflected or projected onto the electrostatically charged surface over which is flowed a toner or pigment carrying the opposite electric charge and thus attracted to charged areas. The image is then transferred and fused to print paper in the Xerographic process developed by Haloid Xerox, Incorporated. Variations in this process eliminate the transfer step by coating the print paper with an electrostatically light sensitive compound so that the image is directly projected and fused onto the print paper. The electrostatic reproduction principle is portrayed in Figure 7.

The Xerographic process is the best known and most widely recognized electrostatic process. Various models of cameras and printers are available as illustrated in Figures 8 and 9. The largest and most applicable for drawing reproduction is the Copyflo 24 which will produce prints 24 inches wide by any required length from roll microfilm at the rate of 20 feet per minute. It is this machine

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36 ODR Guide, p. 47.
38 ODR Guide, p. 47.
39 Ibid.
Fig. 7.--Electrostatic process
Drawings are fed directly into the machine on the feed board at the top and return in the tray underneath. Offset masters 11 inches wide roll up at the bottom.

Fig. 8.--Continuous electrostatic camera/printer
A. Continuous electrostatic printer of the type used to make 18 inch wide prints of roll size drawings from either roll microfilm or aperture cards. (High volume.)

B. Electrostatic printer used for making 18 x 24 inch prints or offset masters from microfilm aperture cards. (Low volume.)

Fig. 9.--Electrostatic printers using microfilm
that permitted Westinghouse to automate its engineering drawing reproduction system by microfilming the drawings and using microfilm aperture cards fed through the Copyflo machine for reproduction purposes. Once the drawings are available in aperture card form, they can be either hand or machine sorted and filed for immediate availability when prints are required. A major factor in being able to use this automated drawing system is the length of the drawing which in the case described herein was only 40 inches and could thus fit on one aperture card.\textsuperscript{40} No known use is made of this automated system in aerospace companies using drawings of longer length. The Copyflo is capable of producing a longer print but does not presently possess the capability of repetitively printing additional copies.

Since the advent and success of Xerography, other companies have entered the electrostatic field in an energetic attempt to further advance reproductions technology. In 1954, RCA developed the Electrofax process which produces a direct electrostatic print. The Keuffel and Esser Company has recently marketed its Kecofax Projector-Printer which electrostatically produces prints as large as 34 x 48 inches from 35mm, 70mm, or 105mm photographic negatives. This job is performed automatically in 40 seconds.\textsuperscript{41} Kecofax is thus capable of making masters for very large offset presses.

The latest electrostatic adaptation is the Videograph Printer and Scanner developed at Stanford Research Institute for the A.B. Dick Company. A special cathode ray tube is utilized as the electro-\textsuperscript{40,"Automating Engineering Data," Industrial Photography . . . , p. 12.\textsuperscript{41} ODR Guide, p. 50.
static printing device to reproduce microfilm or documents directly. Capabilities are also present for high speed scanning and facsimile transmission from magnetic or punched tape or punched cards. Video-graph is not presently adapted to drawing reproduction since its maximum print width is only 8-1/2 inches. However, the possibilities for future development for drawing reproduction appear very promising.

The electrostatic process offers the advantages of relatively low materials cost, relatively small size, flexibility of location in the plant, use in open room light, simple installation, and high versatility. The process allows printing an image in reduced or enlarged size from the drawing or microfilm onto offset press master stock, translucent reproducible stock for whiteprinting or blueprinting, or normal print paper. It is the most economical and rapid process for making a master for the offset press. The production of small size drawing prints by offset is thereby greatly facilitated. The convenient methods of preparing a reduced size offset master by photography and platemaking would take from 15 to 30 minutes as compared to the availability of the electrostatic master in a few seconds.

The microfilm process and reduction flow cameras

Many of the reproduction processes depend upon the use of some intermediate process to translate the drawing image into usable form for print production. This intermediate process has many means of accomplishment where the intent is to create a size-for-size duplicate of the drawing or where a small size drawing is to be reduced in size by the intermediate process. However, a reduced size intermediate of

\(^{42}\text{Ibid.}\)
Drawings are exposed in frames covering a maximum drawing surface of 36 x 48 inches. Either roll microfilm or microfilm aperture cards are produced.

Fig. 10.—Microfilm camera for stationary exposures
large drawings 36 inches wide by several feet in length is currently obtainable only by photographic means. The photographic process most applicable to engineering drawing reproduction is microfilming.

The term microfilm applies to photographic processes which reduce the size of an image to a small fraction of its original size. For example, a drawing 36 x 48 inches can be photographed onto a 35mm microfilm frame 1-1/4 x 1-3/4 inches. Common microfilm sizes are 8mm, 16mm, 35mm, 70mm, and 105mm, the latter three being applicable for purposes of drawing reproductions. In addition, continuous flow reduction cameras are sometimes classified as microfilm, though the size of the film used may range from a very few inches to 21 inches in width.\(^{43}\) Continuous flow cameras will be discussed in this paper under this heading because the processes used are substantially identical to those for microfilm.

Regardless of the film size, the photographic principle employed is the same. The image is placed at a fixed distance from a lens through which the reflected image passes and is recorded on photographic film coated with light sensitive silver salts. The film is then processed, developed, and either mounted on aperture cards for sorting, handling, storage, and reproduction or retained for use in roll form. Various processes permit the individual single frame exposure of the drawing or utilize the flow principle by which the film and the drawing have a continuous synchronized movement through the camera.

The 35mm process shown in Figure 10 is the most widely used

microfilm process in government and industry today and its future use will increase. As already cited, a large amount of the engineering drawings and related data required on government contracts is submitted in 35mm microfilm form. The Department of Defense is encouraging an automated reproduction system throughout its agencies as well as in its supporting industries. The Department has sponsored studies and established specifications which cover in detail the many aspects of preparation and submittal of microfilmed engineering documentation. It is anticipated that within the next 3 years 80 to 90 per cent of new engineering data will be first reproduced on microfilm.\footnote{44}

After extensive studies, the General Engineering Laboratory of the American Machine and Foundry Company recommended that all major divisions and departments use 35mm microfilm mounted on aperture cards (shown in Figure 11) since the greatest savings in storage space results with this size. The 35mm aperture card is adaptable to electronic data processing whereas 70mm and 105mm are not.\footnote{45}

Bell Laboratories not only realizes substantial savings in storage space but also cites small efficient print-producing equipment as a significant advantage of miniaturization through 35mm microfilm. Bell uses a continuous feeding Flofilm camera to reproduce drawings on microfilm. Instead of sending out full size prints or intermediates to its many branches around the country, microfilm aperture cards are sent as needed. Prints are reproduced by the


The aperture card (actual size shown) is a normal electronic data processing type card with a 35mm microfilm frame mounted thereon. The card can be processed on automatic sorting equipment. It is the fundamental tool of unitized microfilm systems used for automated engineering drawing reproductions.

Fig. 11.--Microfilm aperture card
Copytron electrostatic process when needed. This program is now in the trial stages at Bell and can be a real breakthrough in drawing handling for that company since it has an active file of nearly 2,000,000 drawings.⁴⁶

The Naval Air Station at Philadelphia has a like need and utilizes 35mm aperture cards of its 4,000,000 drawings to make Copyflo electrostatic prints and to send out microfilm cards to its agencies or to suppliers for contract bidding purposes.⁴⁷

The continuous or single frame microfilm cameras normally used for reproducing drawing originals are to some degree manual processes involving judgement decisions and individual drawing handling by the operator. Such cameras do not meet the requirements of the vast operations at Wright Air Development Center. Special equipment technology has produced an automatic camera which is self feeding and self adjusting. The operator loads several hundred drawings into the hopper and automation proceeds from that point. The camera films 1200 frames per hour, approximately 10 times faster than the normal equipment available, and will greatly shorten the time required to film the 5,000,000 drawings scheduled for processing.⁴⁸ Though industrial application is not warranted for this particular equipment, the accomplishment demonstrates another advance toward automating drawing reproduction with attendant promise of probable application to less voluminous operations.

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⁴⁶"Bell Puts Microfilm to the Test," PMI, March, 1959, pp. 32-34.


Less in evidence but nevertheless a suitable process for many purposes is the 70mm microfilm operation. The 70mm film frame is 2-5/8 x 3-1/2 inches or twice the width of 35mm and therefore capable of accurately reproducing drawings twice as large. The Ford Motor Company utilizes 70mm and makes full size enlargements known in reproductions vernacular as blowback prints. The greater accuracy of 70mm results from the fact that the size reduction ratio is less than 35mm. Thereby, the resolution of the image, i.e., the ability to clearly distinguish the image, is greatly enhanced when blowback prints are made.49

Due to the resolving power of 70mm, the Babcock and Wilcox Company chose the 70mm process to microrecord its 1,500,000 drawings. Drawings are filmed as they come to the blueprint area for other purposes, using a 12X (12:1) reduction ratio. The negatives are filed in 3 x 5 inch Kraft envelopes.50 Drawings processed in accordance with military specifications on 35mm may have a maximum reduction of 29X, but often this reduction ratio is considered too great for usable print reproduction purposes.

The 105mm process is specifically prescribed by the Department of Defense for architectural and construction drawings.51 Since the 105mm is 3 times the width of 35mm, the drawing image requires less size reduction with consequently less image resolution loss upon


50 "Debulking Over a Million Drawings," Industrial Photography, August, 1958, p. 57.

51 MIL-M-8857 (ASG) . . . , p. 9.
blowback. In fact, 105mm is sufficiently large to permit direct reading of the negative without the special reader that is required to read 35mm and 70mm negatives. It is also easy to file and, with some personnel training, the negatives can be corrected for flaws and areas blocked out.52 This size has an important use in the faithful true scale reproduction of drawings by projection on sensitized sheet metal surfaces for patterns and templates.53

The Army Corps of Engineers distributes drawings to its regional offices in the form of 105mm negatives which can either be read or reproduced as needed. An interesting feature of this usage is the capability of projecting the drawing image onto the special ground glass surface of the drafting table where reference or trace over is possible.54 Such a use could greatly aid the draftsman where mating surfaces of component parts are involved or where outline of the image is to be transferred to another drawing.

The most directly related use of 105mm in an engineering drawing reproduction system which the writer has observed is the reproduction operation at Bendix Pacific. The drawings are limited to 36 x 60 inches maximum size, reduced on 105mm negatives, and blown back to 18 x 30 inch transparent intermediates for use in whiteprint reproduction. The plans are to blowback on offset masters for offset printing when this process becomes practical. The 105mm negative is


53Lewis and Offenhauser, p. 58.

54James Hughes, "105mm Program Helps Solve Distribution Problem," Industrial Photography, March, 1958, p. 103.
used as a second original to perform many of the functions normally done only with full size intermediates or with the drawing itself.55

The last process to be described here is the continuous reduction camera (Figure 12) by which drawings may be continuously reproduced on negatives in reduction ratios ranging from 2:1 to 8:1. This type of camera is used by many of the major aircraft companies such as Boeing, Lockheed, North American, Douglas, Convair, and others. It was specifically developed as a time and cost savings device for firms having voluminous drawing print production problems. The camera is commonly referred to as a half size camera since it is primarily used to reduce the drawing size to one half its length and one half its width for use as a half size intermediate. Blueprinting and white-printing produce images by contact and thereby require an intermediate the same size as the print. Readable working prints, more fully described as print standards, can be no smaller than half the size of the original drawing.56

Summary of processes

All of the processes mentioned in the above section constitute the primary areas considered feasible and used for engineering drawing reproductions. New processes are constantly being advanced while offshoots and adaptations of existing processes are also taking place. Future developments may bring about radical changes in drawing reproduction technology. The use of thermoplastics, television technology, 55


56Sales literature of Peerless Photo Products, Inc., Shoreham, N. Y.
Roll drawings are fed continuously into the camera. The film is developed in the processor. The negative (rear) is half the width of the original drawing.

Fig. 12.--Half size reduction camera and processor
and specialized electronic devices all threaten to create a technological revolution in the near future of the reproductions industry. The processes specifically described have provided a basis for indicating that advancement in the field is sufficient to serve the needs of the space age company.

The Reproductions Framework

To a company which does not have an existing reproduction system, the problem of process and equipment selection is somewhat simplified by the fact that no internally established system, equipment, organization, and print files must be considered. Few companies are in this position. Any company except one newly formed must contend with the existing reproduction system used at the time of analysis. Knowing that an improved system is potentially available to reduce the time and cost required for reproduction, the company must progress from the point of its existing reproductions system and organization framework.

Aligning the existing system for consideration as a starting point is necessarily an individualized approach which starts each company at a different plane of analysis and which may well cause different companies to arrive at different recommendations for improvement. Though the rocket engine manufacturer is used as a typical example for developing the individual approach, a similar approach can be applied to any large engineering company wishing to improve its reproductions efficiency. In the typical reproductions department, the existing print producing method is full size blueprinting, though offset printing and electrostatic master capabilities are also present.

The drawings travel from the drawing boards through the review
and approval channels to the reproductions area where full size prints are made and distributed to the various files. Vendor reproductions services are used as required to handle overloads. Drawing sizes used are those allowed by the military specifications as described in the next chapter. Additional details of the operation will be introduced wherever of importance to the immediate subject under discussion. Proceeding from this framework, standards will be established, costs and methods analyzed, and the time reduction steps determined.
CHAPTER III

STANDARDS FOR REDUCING FLOW TIME

The establishment of working standards is required to eliminate every unnecessary hour between drawing completion and print distribution. The standards will in turn establish the criteria which reproductions processes and equipment must meet in order to qualify for further analysis and possible selection. The standards necessary to the selection of a process are the size, quantity, and quality of both the drawing and the resultant print.

The variety of reproductions processes available has come into being to satisfy specific needs of size, quantity, and quality. Machinery designed for making any product will vary considerably depending on the size of the item it produces and the quantity of like items it produces. Reproductions equipment follows the same pattern, as can be seen in the illustrations in Chapter II. Printing presses are designed for high revolution automatic feeding in order to produce a large quantity of prints from a standard size original. The blueprint machine is designed to handle various large size drawings many feet in length. The quality of the drawing being reproduced is a factor in the determination of the appropriate process since poor drawing quality requires more sensitive equipment just as closer machining tolerances require more precise production machinery.

The analysis of size, quantity, and quality requirements may lead
to shorter flow times by eliminating unnecessary effort, and the
analysis is necessary to establish standards for the reproductions
processes.

Standards for Drawing Sizes

The only drawing sizes which may be used by government con-
tractors are specified in MIL-STD-2A, Drawing Sizes. There are two
general categories into which the drawings fall: flat size and roll
size. Flat size drawings are relatively small in size and are sup-
plied and filed in a flat or unrolled state. Roll size drawings are
relatively long and are supplied and filed in rolls. The standard
drawings sizes are noted in Table 1.

TABLE 1

<table>
<thead>
<tr>
<th>DRAWING SIZES (in inches)</th>
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<tbody>
<tr>
<td>Flat Sizes</td>
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<tr>
<td>Size</td>
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<tr>
<td>------</td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>B</td>
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<tr>
<td>C</td>
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<tr>
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<tr>
<td>E</td>
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<tr>
<td>F</td>
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<tr>
<td>T</td>
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</tbody>
</table>

The roll sizes should be kept as short as possible so as to
permit easy handling and prevent drawing damage. The recommended
maximum is 12 feet but many drawings used in the aerospace industries

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exceed this length because of the size of the product and the difficulty of adequately presenting the detail required by reduced scale drawing. This will be discussed further when the quality standard is analyzed.

The standard sizes to be selected from the allowable standards in Table 1 will depend on individual product and company preference. The use of as few sizes as possible is desirable because of efficiency of operations. Good standardization practices indicate that few variables and a high degree of standardization decrease cost as well as time to produce. A large number of sizes imposes additional stocking and handling problems, more operating time lost in selecting stock, and more frequent interruption of production.²

The standard sizes recommended in this paper are B, D, and J. The B and D flat sizes are readily adaptable to standard size offset printing presses, and the B size is one quarter the size of the D size sheet. Whenever paper stock is not available in one size, the larger size may be easily cut for use. The smaller size may be printed on the same size sheets in exact multiples of the larger size sheet, thus eliminating the necessity for changing machine-fed paper stock. Standard print files accommodate prints to 8-1/2 x 11 inches and each of these sizes is a multiple of 8-1/2 x 11 inches. The D size may be reduced by photographic means to one-half its length and width as illustrated in Figure 13, and this half size reduction may be run on the same sheet as the B size. These considerations also

follow the principles of standardization. 3

Fig. 13.--Comparison of B and D size drawings

The J roll size is selected for its convenience in handling. Few reproductions processes handle roll size prints and those that do involve flat table types of exposure equipment or some type of continuous feeding exposure mechanism. These printing devices are most generally available in 42 inch and 54 inch widths. 4 The 42 inch machines allow little variation in adjustment when feeding 42 inch width drawings, increasing the possibility of damage when using this size. Drafting, machine feeding, and folding is more difficult since the normal reach of a person of average height is far less than this distance. Women are frequently employed in the blueprint folding operation and undue physical strain required by excessive bending and reaching should be avoided for purposes of morale and productivity. 5

3 Ibid., p. 18.


For these reasons, the J size has long been a standard in the aerospace industries and the bulk of the print requirements measured in square footage of prints produced is derived primarily as a result of the J roll size print production. The reproductions processes which may be used separately or conjunctively to produce prints of the standard sizes are listed in Table 2.

### TABLE 2

**DRAWING SIZE CAPABILITIES OF REPRODUCTIONS PROCESSES**

<table>
<thead>
<tr>
<th>Process</th>
<th>B</th>
<th>D</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whiteprinting</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Blueprinting</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Offset Printing</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Photocopying</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Electrostatic Printing</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Microfilming</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Standards for Print Sizes

Before the advent of the camera, reproductions processes only provided contact prints. A contact print is one in which the drawing is placed in direct contact with the sensitized print paper and exposed to a light source as illustrated in Figure 14. The blueprinting and whiteprinting processes utilize this principle while offset printing makes a contact print using an ink impression on unsensitized.

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paper rather than exposure by light source. Most of the other processes can utilize either the contact or camera principle.

When a camera is used, the drawing and the sensitized material are not in direct contact but rather are spaced apart in parallel planes as illustrated in Figure 15. Reflected light on the drawing image passes through the camera lens to the sensitized material which receives the image in proportionate size to the relative distances of the drawings and sensitized material from the lens. 8 Microfilm equipment, continuous flow reduction cameras, and some electrostatic equipment utilize this optical arrangement. The print material may receive the image in a variety of sizes, either larger or smaller than the original. Because this is true, the size of the

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Fig. 15.—Use of camera principle to vary print size
resulting print is not restricted specifically to the size of the original drawing. A drawing drawn to any convenient scale for drafting purposes may be used to produce prints to any convenient smaller size for reading and handling purposes.

The reduced sizes are fractions of the length and width of the original. The area of the print as compared to the drawing is reduced in proportion to the square of the fraction. A one-half size reduction correspondingly reduces the print area to one-quarter of the original drawing size, a one-third size reduction reduces print area to one-ninth, one-quarter size reduction reduces print area to one-sixteenth, etc.

**Benefit of reduced size prints**

The benefit of considering the print size standard apart from the drawing size standard now becomes apparent. A reduced size print standard permits a shorter print length and width and less paper area which will correspondingly reduce the time required for print production. Reducing the size of print shortens the time required for production since more smaller size prints can be made in a fixed period of time. Numerically portrayed, an example of this relationship is shown in Table 3. If 85 drawings per day were to be reproduced on one machine, 42-1/2 hours of machine time would be required for full size prints as compared to 21-1/4 hours required for half size prints. It can be seen that shortening the print length by size reduction will decrease the machine flow time required for production.

The total benefit of size reduction, i.e., reduction in area, also aids in minimizing production time since less bulk must be handled and handling is more easily accomplished. The standard
### TABLE 3

**COMPARATIVE MACHINE FLOW TIMES OF PRINTS**

<table>
<thead>
<tr>
<th></th>
<th>Full Size</th>
<th>Half Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of print (using average drawing length of 10 feet)</td>
<td>10'</td>
<td>5'</td>
</tr>
<tr>
<td>Number of prints</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Total running length per drawing (prints x length)</td>
<td>600'</td>
<td>300'</td>
</tr>
<tr>
<td>Running time at 20 feet per minute required per drawing</td>
<td>30 min.</td>
<td>15 min.</td>
</tr>
<tr>
<td>Drawing volume, 85 per day (x minutes per drawing)</td>
<td>42-1/2 hrs.</td>
<td>21-1/4 hrs.</td>
</tr>
</tbody>
</table>

Drawing reduced to half size for running prints would allow four prints to appear in the same area formerly required for one full size print. It is thus theoretically possible with a half size reduction to cut flow time to one quarter of that required for full size prints. This is not the practical result because the four prints on one sheet require additional trimming and handling steps over and above the one print at a time handling procedure used for full size prints. Aside from the substantial time savings effect of size reduction, a considerable cost savings also results from the reduction in labor and materials as will be discussed in Chapter V on cost.

The smallest scale print, reproduced from a good quality drawing, which would be generally usable in the shop for working purposes
is the half size print. Military specifications, in consideration of
the possible use of half size reduction, have established minimum let-
tering sizes for drawings to permit legibility for easy and rapid
execution of drawing information.\textsuperscript{9} The careful reproduction of half
size prints from good quality originals will assure the accrual of
optimum advantage from reduced size printing.\textsuperscript{10}

Acceptance of the half size print standard

To assure the workability of these prints, a company proposing
to establish the half size print standard in place of the full size
print should thoroughly coordinate this intention with the using de-
partments to secure acceptance and cooperation in advance of the change.
Though the use of half size prints is not new in industry, it is a
radical change for a company using full size prints. Since "blueprints"
are the vital communication media used to obtain product fabrication,
careful preparation is necessary for instituting any significant change
in this communication system which might adversely affect the product.
No advantage would be gained from saving time in reproduction if by
doing so the production or quality of the prime product were jeopard-
ized. An organization must be psychologically prepared for such a
change in its operating systems. The sociological effect of the change
must not be overlooked or its technological potential will surely not
be realized. The cooperation of those affected by the change is most
readily assured by advance coordination enlisting their aid, comments,

\textsuperscript{9}MIL-STD-1A, General Drawing Practice (Washington: U. S.

\textsuperscript{10}Robert P. Kowalsky, "Engineering Drawing Reproduction,"
Graphic Science, May, 1960, p. 15.
and suggestions. The psychological effect of participation should be utilized in such instances as this where the value of the change will be directly related to its acceptance by those involved. A good selling job is as important to the adoption of a new method or new system as it is to marketing the product. In this case, the selling job is easy since the advantages quickly gain the enthusiastic response of the print users. The user is provided with less bulky prints which take up less space, are easier to handle, and are often of superior quality to the full size print. Adhering to these principles, Rocketdyne prepared sample prints and sent them to the management of the manufacturing, purchasing, engineering, and quality control departments for review with their employees. The response was a complete acceptance of the proposed standard and an assurance of cooperation upon implementation.

Half size prints of J roll size drawings will be the most valuable because they are the largest drawings. Half size prints of the D size drawings offer equal advantage. The B size drawing will be retained full size in printed form because a half size print of the B size drawing would result in a sheet size of 5-1/2 x 8-1/2 inches which is too small and impractical to handle and file conveniently.

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12 Watkins et al., p. 185.


14 "Proposal for Half Size...", Exhibit.
Standards for Drawing Quantity

It is not possible to establish an unchanging standard number of drawings which will require reproductions each day since the number of drawings will vary with the rate of design engineering effort. Engineering drawing effort must be minimized by all possible means commensurate with design requirements. This is done by establishing specific drafting policies and drafting standards. With the minimum possible drawing effort, a forecast can be made of anticipated drawing volume for a given period based on historical performance and future expectations.

Large engineering type firms find it convenient to publish their own drafting room manuals to present the drafting standards best suited to the needs of the company. Many industrial and association manuals are available for users not having their own standards. Many of the drafting practices are also controlled by military specifications. In recent years, there has been increased emphasis on reviewing drafting standards for correcting inadequacies because standards applicable to full size print reproductions are frequently not valid for half size and microfilm reproductions.\(^\text{15}\)

In the reappraisal to meet reproduction quality requirements, an important factor is being brought to light which makes emphasis on up-to-date drafting standards extremely valuable for another reason. Progressive application of latest concepts of drafting standardization frequently provides the means for significantly reducing the time and

cost involved in making a drawing.

The subject of drafting standards and practices is a separate field of analysis in itself. A brief enumeration of the basic standards which bear on the efficient use of drafting time is as follows:16

1. Simplify or eliminate delineation on drawings by using description and symbols wherever practical.

2. Show only partial views of symmetrical objects.

3. Omit excessive details, part details on assembly drawings, and unnecessary dotted lines.

4. Use cross-sectioning only when necessary and, when used, partial cross-sectioning is preferred.

5. Use tabulated drawings for variations when practical.

6. Use typing, pre-printed forms, and decals in preference to hand lettering.

The additional time savings realized depends largely on the effective communication and use of these standards, and the extent to which the underlying principles are already in effect. The application does affect both the number of drawings and the area of drawing surface requiring reproduction.

Other significant time saving devices which should be utilized wherever possible are the use of imprinted grid lines on drawing formats, the use of reproduction duplicate techniques, and the use of standard design parts and specifications. The grid lines are imprinted in a faint blue color which does not reproduce. The lines save con-

16 Ibid., pp. 1-5 but note that many articles are available on this subject. The various articles available through the Filmsort Company are particularly applicable to drawing reproductions discussion, especially as related to microfilming.
siderable drafting time by their ready availability as lettering guides and for locating dimensions.\textsuperscript{17}

The second item mentioned above, reproduction duplicates, represents a very significant avenue of time saving. The terms "photodrafting," "photodrawing," "repro duplicate," "duplicate tracing," etc. refer to various methods by which the original drawing is reproduced in duplicate as a means for preparing another drawing having somewhat similar features. This takes full advantage of drafting effort already expended. Erasures or eradications may be made and additional or changed information is then added to the duplicate to make the new drawing. A wide range of variations in methodology permits substantial savings, especially in preparing lengthy and intricate drawings.\textsuperscript{18}

Standard parts and specifications should be invoked on engineering drawings wherever possible to eliminate unnecessary drawing effort and thereby reduce the number of drawings from which prints are made. When a standard fitting, test specification, or material specification is available, the designer does not have to prepare a document for this purpose. Specification in government contracts specifically state that standards will be used where applicable and their order of precedence of application (government standards, society and association standards, company standards) is listed as a mandatory requirement.\textsuperscript{19}

Application of all of these described techniques by industrial management greatly increases efficiency, reduces manpower requirements,
raises morale by eliminating unnecessary and tedious effort, and cuts drafting time by 30 to 50 per cent. The representative drawing quantity requirements subsequent to implementation of the drafting policies and standards outlined herein are 85 drawings per day averaging 10.7 square feet for each drawing.

Standards for Print Quantity

There are two general approaches taken to the matter of distribution of prints. One approach is to establish an average distribution to various blueprint files areas. Each time a drawing is reproduced, a fixed number of prints is sent to the files and special requirements are set up as needed in addition to the basic distribution. The second approach is to analyze print requirements for each drawing released for reproduction and to make a specific determination of the number of prints required on an individual drawing basis.

The Martin Company of Baltimore reduced print quantity from more than 50 prints per drawing to approximately 17 prints per drawing by using the individual analysis method, thereby reducing reproductions time and cost substantially. The analyst screens requirements to avoid duplicate distribution of prints and considers drafting and release procedures, plant layout, and scope of the involved operation. A card is set up for each drawing, and an entry is made of the estimated distribution based on the analysis. The quantity is reviewed each time the drawing is subsequently reproduced. Handling and processing time is

20 "How to Save Time With New Drafting Technique," Management Methods, October, 1957, pp. 68, 69.

greatly reduced leaving more time available for better treatment of drawings and prints.  

There are certain drawbacks to analyzing each individual drawing for distribution requirements. First, there are some departments that automatically need prints of all drawings. Among these are planning, scheduling, manufacturing, engineering, logistics, and inspection. The quantity needed will vary in accordance with the effort required by each function. In a relatively small close-knit organization, one could possibly analyze each drawing in terms of specific tasks and estimate the number of prints required for its support. This becomes a difficult and improbable condition in companies having many departments and facilities offering a wide variety of possible means of accomplishment. Geographic separation of facilities also decreases the practicality of individual analysis. The prints required by the purchasing department for subcontractors and vendors cannot always be pre-determined. There is an increasingly greater emphasis placed upon subcontracting with small business firms which means that many subcontract tiers of suppliers require prints in order to perform their services. The print quantities often greatly exceed the internal company needs when large assemblies are subcontracted. There is no way of accurately estimating these needs on an individual drawing basis since purchasing decisions and subcontracts are negotiated only after prints are available.

It would seem prudent from a managerial standpoint to initiate an analysis of requirements to determine an average distribution basis,

22 Martin Cuts Cost by 'Cutting' Blueprints, "Aviation Week, April 17, 1950, p. 34.
and then to review this basis periodically for possible operating changes which may have taken place. Such a change might result, for example, from the automation of an operational sequence originally done by many operators on various machine tools, or from changes in make-or-buy policies which may increase or decrease purchases of the item.

Of major importance in the analysis of historical information is the determination of frequent large quantity reorders of prints. If print quantities are excessively cut back, frequent reorder may result causing possible duplication of reproduction job setup effort and defeating the very intent of the reproduction communication system by delaying effort until prints can be made available. The balance of consideration should be given to an estimate which may possibly overstate requirements rather than understate them. An average quantity of 55 prints per drawing is considered to be representative.

Standards for Drawing Quality

Many of the items mentioned in connection with the drawing quantity standards are essential to the quality of the drawing. The test of drawing quality is the accuracy with which additional drawing effort may be applied and adequacy of all required reproductions. The sole practical test of drawing quality is its continued usefulness for reproductions purposes since this need demands the more rigid control.

Drawing quality is controlled primarily by drafting standards and procedures. In addition to those already mentioned, the procedures

essential for acceptable drawing reproductions are as follows:

1. The drawing medium (usually a special drawing paper) must be of high quality, translucent, having a surface receptive to pencil, and of material capable of withstanding frequent erasures and machine processing.

2. Drawings must be neat and clear, free of smudgy erasures and soiled areas, with legible lines, dimensioning, and lettering.

3. Line weight should be consistent and lines should be sharp and even.

4. Lettering should be consistent, evenly spaced, and at a minimum height of one-eighth of an inch.

5. Care must be exercised in the handling and storage of drawings.

6. Drawings must be thoroughly checked prior to submittal for reproductions to see that minimum acceptable standards are met.

As in all company functions in which good results are expected, management must see to it that the drawing quality standards are stressed and compliance is obtained. The management techniques used to accomplish this are the sales approach as well as disciplinary action in cases of chronic non-compliance. With respect to selling those involved in the preparation and handling of the drawing, it is good practice to provide full indoctrination of the importance and use of the drawing. Regardless of the ingenuity of the design, the drawing is of no value unless legible reproductions can be made therefrom.

\[24\text{Rau, pp. 8-29.}\]

\[25\text{A good example of a progressive managerial approach to this problem is the descriptive brochure Microfilming and You, The Draftsman (Bell Telephone Laboratories, Inc., 1958). Bell Labs describes to their draftsmen the whole idea of the microfilming reproduction program and the relationship of careful drawing preparation to the success of the program.}\]
The drafting standards are a matter of contractual requirement to Department of Defense contractors as stated in the various military specifications controlling drawings and reproductions. The specifications exercise control by establishing drawing standards such as are enumerated above. These can be visibly checked on the drawing itself prior to reproduction. Also, indirect control of drawing quality is derived from the quality of the resultant reproductions.

Standards for Print Quality

The print quality is most generally ascertainable by visual inspection. It is a requirement that high grade materials be used to make the prints and that images thereon be clear and legible. Legibility, or readability, can be improved for two basic reasons. First, the drawing image may be faulty. The print image reflects the drawing image and cannot improve any poor drafting techniques which may be inherent in the drawing. Print quality is a positive check on the degree with which drafting standards have been met. After some experience in comparing drawings and resulting prints, the draftsmen and checkers quickly develop an adeptness in perceiving faulty lettering or linework.

The second basic cause for a faulty print image lies in the area of the reproduction process itself. The drawing image may be clear but the print image may be indistinct due to lack of contrast between the image and its background. For example, a good blueline print has a deep blue line standing out in distinct contrast to its

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white background. Had the print been underexposed, the line would be a faint or light blue and the background may also have a bluish hue. Due to lack of contrast, the image is not easily legible. Many inadequacies can cause poor prints in the processing stage.

The materials used should be tested thoroughly under operating conditions to assure their dependability. Most manufacturers use standardized raw materials and provide adequate specifications for determining that the paper stock is of sufficient grade. Testing under actual conditions provides the basis for differentiation and selection of the satisfactory materials. On processes utilizing nonsensitized papers, selection is primarily determined by such characteristics as handling, feeding, surface suitability, and size accuracy. Sensitized papers must additionally be tested for the relative merits of the sensitized coatings including color, sensitivity, speed, latitude (ability to print within a wide range of exposures), contrast, etc. Processing chemicals and other materials must also be tested for their overall quality in order to control all aspects of printmaking. An example of the specification and testing requirements is provided in Appendix I. Though this specification is for blueprint and whiteprint paper, it serves to exemplify the type specification that would be employed to control any reproduction material.

When utilization of the government specifications does not afford adequate assurance of high quality raw materials for reproductions, the using department should establish its own specifications and tests based upon requirements for performance on each individual piece of equipment. A management consideration in the choice of equipment must be a machine capable of high speed output which will produce good
Quality prints.

Control of print quality

As in any production process, a means of quality control is required to prevent unacceptable products from being delivered to the customer. Several means of controlling the quality of prints produced are afforded to prevent unacceptable prints from being distributed to the users. Regardless of the process used, the final check is made at the distribution desk before prints leave the reproductions area to assure that the general quality level is high. In the blueprint and whiteprint process, individual inspection of each print is performed by the trimmer and folder during the folding operation. When prints are produced by offset or electrostatic process, a check of the initial production copy is made before the production run is commenced in order to ascertain adequate quality and proper setup. Whenever an intermediate is used (such as microfilm or photocopy) from which prints are run on other equipment, the intermediate is checked before turning it over to the production process. Microfilm requires special inspection equipment to ascertain acceptable quality prior to release for use.

In all of the operating phases, continuous checks are to be made by lead personnel and supervision to assure high quality standards. A requirement of good reproduction management is that operating personnel are thoroughly indoctrinated with the knowledge of the use of the print, the need for readability, and examples of non-acceptability. Part of the skill required by the operator is his ability to perform to acceptable quality standards. When performance is below these
standards, it is easily ascertainable. Pride of workmanship and the respect of fellow employees for their work usually keep operators at satisfactory performance levels. The machine operator invariably has the highest wage classification in the reproduction department and may be disciplined by downgrading for continuously poor performance.

Summary of Standards

By way of summarization, it is seen that the choice of specific equipment and process must be determined from the group of prospective equipment and processes that can meet the standards established in this Chapter. These standards are as follows:

1. B, D, and J size drawings.
2. Half size prints for D and J size, and full size prints for B size.
3. Drawing quantity of 85 drawings per day minimum.
4. Print quantity of 55 prints average per drawing.
5. Drawing quality in accordance with internal drafting procedures and government specifications.
6. Print quality controlled by visual and inspection devices and use of quality raw materials in accordance with internal procedures and government specifications.
CHAPTER IV

FLOW TIME OF QUALIFYING PROCESSES

A selection must be made from the processes which qualify under the established standards as to the best performance capabilities in terms of time. A comparison of the flow times of each size drawing through the prospective processes will be made considering the layout and handling procedure best suited for drawing reproduction. The method of production control and the full size reproductions time-spread will be analyzed in order to ascertain that all possible steps are taken to minimize flow time prior to additional recommendations.

Production Control System

The production of engineering drawings is similar to continuous process manufacturing because large volumes of standardized prints are required on a pre-established schedule, but the aspects of intermittent manufacture are also present because production only takes place when specific orders are received. The control of this type of production must necessarily be a hybrid of serialized and order control whereby work is released in batches or blocks and must be controlled to bring the component parts of each batch together at the right time to produce the complete article.\(^1\) Applying these production}

control principles to all processes used in drawing reproduction, control methods must be provided to sort the drawings to the print-producing equipment and to collect the prints according to priority for simultaneous distribution. The pertinent information is the release to which the drawing belongs and the relative priority of the release. Normally, the release priority is determined by the number of hours that have expired while the drawing is awaiting reproduction. The first releases into the reproductions unit would thus be the first ones due out. Should emergencies arise which require engineering management to approve a special priority out of sequence, reproductions supervision would see that the special priority order is run first.

It is the practice to mark the quantity of prints required for each drawing outside the border on each drawing. Coding the drawing with the other information would also be practical. The release number is usually several digits and in itself does not denote priority or indicate date of receipt. The code system should do all of these things and should be sufficiently simple to be understood by all operators. The day the release comes in is significant in determining when it should be completed so a factor in the code will be a letter representing the day of the week, i.e., M for Monday, T for Tuesday, W, Th, and F. The sequence of receipt indicates the relative priority so a consecutive number starting with one will be assigned to each release coming in during the day. On Monday, the drawings in the first release will be coded M-1. Those in the second release will be coded M-2. The first release on Tuesday will be coded T-1. The code is simple, easily applied, and significant without any special memoriza-
tion effort needed. Figure 16 illustrates the use of the following enumerated steps:

1. Distribution clerk makes work order listing the code and all drawing numbers being released. Places work order in control book.

2. Drawings distributed to various machines for intermediates to be made.

3. Drawings or intermediates moved to production machines incoming work bin to wait for prints to be run from them.


5. Finished prints returned to distribution area. Drawing number crossed off as complete on work order in control book.


The placement of prints in a numbered bin makes it unnecessary for the clerk to constantly reshuffle miscellaneous stacks of prints. By the control book review, it is known immediately which releases are completely ready for distribution and which ones are delinquent. The person delivering the prints and crossing off the last drawing number notifies the clerk of completion. Prints are combined into the release package for the hourly delivery to the various files.

Full Size Print Flow System

In a typical full size reproduction system, drawings come to the reproductions organization in a package released together because of the interrelated effect of the drawings to each other. The prints of these drawings must be distributed together in order for print users to have all the information required to do their job. The drawing package is received by a distribution control clerk who makes a
Fig. 16.—Work order code for production control
record of the drawing numbers, the release number, and the time and date received. The clerk notes the quantity of prints required and takes the roll size drawings to the whiteprinter for preparation of an intermediate transparent copy from which the blueprint copies are made. This step is considered essential due to the fact that hundreds and even thousands of design and drafting hours are spent on these drawings making them extremely valuable. The number of drawing changes they undergo is substantial and each change must be reproduced and distributed. The time and cost invested in these drawings are far too substantial to permit their normal use as production reproducibles.

Figure 17 illustrates a representative flow in a full size reproduction system; the flow time required for each operation is unduly long. The recording of incoming releases and the making out of the order for prints at Step 1 takes no significant amount of time. The making of an intermediate, Step 2, is required for 42 roll size drawings per day, an operation needing approximately 1 hour of continuous production. The fact that 4 to 8 hours of time are lost in this operation is attributed to the use of the whiteprinter almost exclusively to meet other reproductions work order requirements and only secondarily for release drawings. Though the making of intermediates is a high priority requirement, it must be done at a time when waiting service demands are not present. Several hours of flow time may be eliminated by improving the production control system as already described.

Step 3 involves the use of two blueprinters to produce prints from the cut size drawings and the roll size intermediates. Practical production techniques to assure relatively constant printing speed and
Fig. 17.—Full size reproduction flow system
maximum utilization of print paper surface necessitates programming of
drawings to run similar types together. Usually, 2 long roll drawings,
3 short ones, or several cut sizes are run at a time. Mating drawings
of the same release is thus forfeited for production expediency.

After the blueprints are run, they are moved to the distribu­
tion table, Step 4, to be matched up by the distribution clerk with
the rest of the release package. The prints are stacked up in carts
or bins. A constant exploring through the stacks of prints takes place
in order to match prints with their release package. Far more flow
time is encountered than is required to perform the actual job if the
production control system is followed.

Half Size Camera for Roll Drawings

There are only 2 processes which will produce an intermediate
for running half size prints of roll drawings. Both involve the
feeding of drawings through continuous flow cameras and both can
utilize the same production control system already described. One
process continuously produces a half size intermediate which can be
run on the blueprinter or whiteprinter. The other process produces a
roll of microfilm which must be run on the Haloid-Xerox electrostatic
printer to produce half size electrostatic prints or a half size inter­
mediate for blueprinting or whiteprinting.²

The operational flow system using the half size camera is il­
ustrated in Figure 18. This same illustration is used for later dis­
cussion of the electrostatic print and cut size print production. The
half size process requires a dust free, temperature controlled,

²Refer to Chapter II for illustration and explanation of
processes.
Fig. 18.--Half size reproduction flow system.³

³Data derived from personal contacts and sales literature of Peerless Photo Supplies, Inc., Shoreham, N. Y.; Haloid-Xerox, Inc., Rochester, N. Y.; Addressograph-Multigraph Corp., Cleveland, Ohio
humidity controlled, light tight room. Erecting partitions in the middle of the reproductions area would seriously retard the effectiveness of the central ventilating and air conditioning system. No appreciable gain in layout efficiency would be achieved since the significant flow for efficiency purposes is from the machine work table to the particular machine and from the folding table to the distribution areas.

The drawings move through the primary operational steps as illustrated, and the total time required for each operation is noted adjacent to the step number. All of the work for the day comes in on the day shift between the hours of 8:00 a.m. and 4:30 p.m. This work is divided into 3 runs or batches to provide the shortest possible schedules through application of the principle of concurrency of action. Applying the principles of production scheduling, the chronological times for performance are determined by working backward from the delivery time taking into consideration the available machine capacity and load.4

The run schedule shown in Figure 18 depicts the time when each operational step starts and when it finishes. The interim between start and finish is the time required for the operation and is one-third of the total run time shown for each step. Since the greatest length of time required in the print making process is the operation of the blueprinter, Step 3, the schedule is set up to permit continuous operation of that machine. This is possible by using personnel from other operations to fill in during breaks and lunch periods. The schedule is, of course, established on the assumption

4Woris, p. 129.
that all work each day will be consistent in terms of quantity, size, time of daily input, etc. The standards established will contribute a great deal toward this end, but the ideal circumstance will not be reached. Wherever disproportionate amounts of work are received, the schedule can easily be adjusted for the other operations as long as the actual print production process, the blueprinter, is kept in constant operation. There is ample time to take care of unexpected volumes since the anticipated blueprint utilization of 13 hours per day leaves 4 hours per day (including the lunch hour) of the two 8 hour shifts for overflow volume and for running work orders for special requirements.

The first run is so established that 1 full cycle is completed by the end of the first shift. The schedule is worked backward from that point to allow approximately 1 hour for Step 4, print gathering and distribution; 4-1/2 hours for Step 3, blueprint production; and 1 hour for Step 2, preparation of half size intermediates. Thus, the cycle is started at 10:00 a.m. and releases coming in between the hours of 8:00 a.m. and 10:00 a.m. are completed and prints distributed by 4:30 p.m. Releases collect between 10:00 a.m. and 2:30 p.m. when filming of half size intermediates is initiated to coincide with the schedule to support the blueprinter backlog for the second cycle. The same method is applied during the third cycle as drawings are gathered between 2:30 p.m. and the end of the first shift. The end of the third cycle coincides with the end of the second shift.

All releases received during a normal day are run and distributed in less than 24 hours, thus meeting the shortened flow time requirement of the hypothesis. Most of them are ready to support
second shift manufacturing operations, though this is seldom necessary. Should any releases be left over the following day, the first 2 hours of that day are available for print making and distribution without disrupting basic schedules. Allowing for this eventuality, the schedule is still less than 24 hours from the time of drawing receipt.

An important element in the workings of this system is the standardized production of only roll size prints on the blueprinter. Constant intermingling of roll and cut sizes disrupts the pace of production. It imposes excessive effort on the blueprinter operator and the trimmers and folders. Meeting the requirements of the schedule necessitates supervisory control to direct the effort in accordance with the planned system. The system requires that the production of prints be done on the equipment specifically tailored for that operation. More flexibility is possible in the preparation of intermediates in that any size can easily be run through the half size camera.

Electrostatic Half Size Reproduction of Roll Drawings

The other possibility for running half size prints of roll drawings is by use of the continuous electrostatic printer utilizing microfilm as the running intermediate. The layout and flow time for electrostatic printing would be very similar to that presented in Figure 18 for the half size camera operation. In place of the half size camera, a continuous microfilm camera would be substituted. Operating and exposure methods would be quite similar. The film would be sent to the photolab for specialized photographic handling techniques. Microfilm requires skill in handling due to the minute size of the image and the serious results of any flaws or development
errors.

The electrostatic printer would be located where the film processor is shown. This printer operates at 20 feet per minute, the same as the blueprinter. The schedule used in the half-size-camera-to-blueprint system would be substantially identical to that used for the microfilm-to-electrostatic-print system. The blueprint folding table would be used to fold the electrostatic prints which are on rolls as they come from the electrostatic printer.

One major advantage of the electrostatic printer is the automatic running of prints once the microfilm is mounted in the machine. An operator does not have to feed in the intermediate to make each print. This factor leads to several desirable consequences from an efficiency standpoint. Operator errors and labor hours are eliminated, a constant rate of production is assured, and material waste is at an operating minimum.

Offset Printing of Cut Size Drawings

The standards established for cut sizes require that B size prints, 11 x 17 inches, be run full size and the D size prints, 22 x 34 inches, be run half size which makes all cut size prints 11 x 17 inches. There are many processes which can be used to obtain these sizes as noted in Table 2, Chapter III. The purpose at hand is to run a production workload of 55 prints each of 43 cut size drawings. As discussed in Chapter II, the most rapid and economical cut size reproduction processes are offset printing and whiteprinting. Running on the whiteprinter requires placing the drawing or intermediate on the print paper and feeding through the whiteprinter each time a print is
to be made. This can be done at the average rate of about 5 prints per minute. The operator must constantly reach for more print material since a limited number of copies can be stacked on the machine. The light sensitive whiteprint material can not be left uncovered for an extended period of time. The whiteprinter workload is such that a wide variety of print sizes must be made ranging from 8-1/2 x 11 specification pages to the full range of drawing print sizes.

The alternative of running by offset requires that an offset master be prepared and mounted on the press. After this is done, the prints run automatically. The machine is a specialized piece of equipment utilized to run the one 11 x 17 inch size. Paper is fed automatically into the machine and is not sensitized. As many as 5000 sheets can be stacked in the feeding mechanism at one time and are automatically stacked in the receiving mechanism.

Allowing 1 minute for master preparation and 1 minute for machine setup, prints are made on the offset press at the rate of 7200 per hour or 120 per minute.\(^5\) In terms of time, the use of offset would be practical for any quantity over 15 copies. With the other advantages noted in the above comparison, offset is recommended where many masters are involved even though 20 or less prints per master are required. The supervisor of reproductions at the Bendix Eclipse Pioneer Division recommends offset for as few as 10 prints per master.\(^6\) Offset is definitely recommended for the cut size drawing requirements of 55 prints per drawing.

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5. Sales literature of Addressograph-Multigraph Corporation, Cleveland, Ohio.

The flow system for offset printing of cut sizes is shown in Figure 18 along with the half size system for roll size drawings. These 2 systems are illustrated together to show their interrelationship schedulewise and are subsystems of the overall half size system of handling all releases. The operational steps for both roll and cut sizes are numbered the same to portray the similarity of operations required even though separate reproductions processes are employed. As with roll sizes, the print production process is the most time consuming operational step in the cut size flow. The entire processing time of cut sizes is far shorter than for roll sizes because they are smaller drawings and the system is highly mechanized with many automatic functions.

The work is divided into 3 runs to coincide with the roll size schedules since both size categories are frequently contained in the same release batch or package. The cut size cycles illustrated in Figure 18 are derived from the starting and completion times of the roll size cycles. Whenever only cut sizes are involved in the release, a greatly shortened time period for distribution is possible. Starting into the process at the same times, the cut size prints are complete approximately 4 hours sooner than roll sizes. This is an extremely important reason for making a serious effort to shift to smaller drawings wherever practical.

Offset printing is basically a function of the print shop and is used for printing brochures, letters, specifications, procedures, manuals, handbooks, parts lists, etc. The drawing print requirements are but a minute portion of the volume that is handled by the presses. A more efficient overall layout is achieved by sending the drawings to
the printing unit because only 20 per cent of the daily operating
time of 1 press is required for drawing reproduction.

The location of the master-making equipment is also a factor
in determining offset press location. The electrostatic camera shown
is a different model than that required for printing roll drawings
from microfilm. This camera is capable of producing electrostatic
prints 11 inches wide by any length directly from original copy fed
into the machine as illustrated in Figure 8, Chapter II. The electro-
static camera is essentially intended to meet the duplicating need for
many hundreds of opaque originals from which whiteprints cannot be
made due to lack of translucency. Electrostatic printing will replace
other relatively high cost or low volume processes such as photocopy
and photostat. If several copies are required, a translucent inter-
mediate is made for blueline. If more than 20 copies are required, a
master is made for offset. All originals may be reduced to half the
original size or blown up twice the original size.7 Other relatively
high cost and low volume processes for making masters can be supplanted
by this process where quality is adequate. The presence of the small
electrostatic camera greatly facilitates drawing reproductions though
the drawing volume (about 2 per cent of the total load) is far too
insufficient to support the camera or to dictate its layout location.

Time Required for Commercial
Reproductions Services

It can often be practical to use commercial services rather
than to establish in-house facilities. Doing so requires that packing
sheets be made out, drawings packaged, security clearance obtained,

7Sales literature of Haloid.
and print packages opened and checked upon return. This is all additional effort not encountered with internal reproduction and requires 1 to 2 hours. Transportation round trip requires 2 or more hours. Very few services offer half size reproductions. None are known to offer half size electrostatic service from roll drawings. Outside services could improve on the schedule of Figure 18 only by putting more blueprint or whiteprint equipment on the job than was scheduled in-plant. Even then, there is no basis for a significant time reduction since 3 to 4 hours extra would be required to handle and ship the drawings and prints. Suppliers can offer aid in emergencies and should be used for that purpose but a daily service would definitely lengthen the proposed schedule and cannot be recommended unless substantiated by a significant cost advantage.

The half size electrostatic print and the half size blueprint meet the time requirements for roll drawings. The offset print is superior for cut drawings. The final major determinant to be considered for selection will be the relative costs of the various systems.
CHAPTER V

COST OF QUALIFYING PROCESSES

The cost factor is a major element of consideration in seeking to improve the drawing reproduction system. The costliness of space systems and extensive competition in this field forces the government procurement agencies to award contracts on the basis of economical choice as well as short delivery schedule.¹

The company management is vitally interested in the cost factor. The industrial enterprise exists for the purpose of making a profit. Profit may be increased in two general ways: either sales are increased or costs are decreased, other factors remaining unchanged. Since drawing reproductions is a supporting service rather than the primary product, its contribution to the company profit picture must come by greater efficiency to make possible cost reduction. Cost control is, to a large extent, profit control.²

A cost comparison of the qualifying reproductions processes must be made to permit the selection of the most efficient process available. The estimated cost of operations of the alternatives must be compared to the existing cost of operations to determine the cost


effect of the change in process. Consideration must also be given to capital costs of the alternatives. Costs of the existing operation must be provided by some practical method while cost estimates for the alternatives must be tailored to fit in with the probable operating circumstances within the company.

Reproductions Cost Control

The analysis and control of reproductions cost must invoke the use of a simple but adequate system. Inputs into this system may be derived partially from available company cost data such as procurement, personnel, plant engineering, and financial records. There is usually little in the way of established cost reporting directly applicable to drawing reproductions since the company accounting systems are oriented toward collecting costs for a cost center comprising several functions and units of organization.

The question before management is whether or not a more detailed and specific cost system is necessary. Many companies take the approach that overhead and supporting departments are justified as necessities and thus only broad cost control is necessary. One large department considers all of the reproductions costs as part of the overall engineering costs and makes no attempt to apportion them on any basis. 3

The effect of the expenditures of supporting departments on company profits cannot be overlooked. More companies are looking toward these supporting areas with a desire to institute some type of

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3"The Bendix Corporation," PMI, Section Two, November, 1960, p. 32.
measurable accountability. The idea is to have a means whereby performance in these support areas can be measured against a yardstick for purposes of evaluation. The yardstick frequently used in reproductions is the in-plant cost as compared to that of a commercial supplier of reproduction services. In-plant costs must not be considerably higher without causing management to discontinue their use.4

Cost data is required for many reasons such as informing management of the cost of the operation, providing a breakdown of expenses, and providing a basis for cutting costs and increasing efficiency through comparative analysis with other methods of accomplishment.5 Once detailed costs are available, it is possible to establish cost rates for each kind of reproduction. These costs include charges for direct as well as applicable overhead expenses. The cost of the job is then available for application as management desires.6 An industrial example of this common application is the Allis Chalmers Manufacturing Company where the individual costs of prints are charged to the requesting department.7 Government agencies are also applying this method as exemplified by the large offset printing division of the United States Department of Agriculture where complete job costing is used to bill requesting agencies.8 One of the major benefits of charging to the requesting department or organiza-

4"Cost Accounting," PMI, January, 1960, p. 64. 5Ibid., p. 45.
6Ibid.
tion is that the requesting management then has at its disposal a basis for evaluating the relative merits of doing the job, performance by some less expensive means, or deciding the work is not sufficiently important to incur the cost.

The individual job costing technique is not valuable for application to engineering drawing reproductions because management has ascertained the legitimacy and need of the effort and set up control mechanisms such as the standards for the effort. The primary interest for management is the continuing cost of the operation over a period of time as compared to other means of accomplishment. Detailed cost data must be organized to permit managerial review on this basis.

Operating Cost of Drawing Reproduction

The detailed cost data has been made available by preparation of estimates as illustrated in Appendix II. The costs are considered representative for purposes of illustration only since actual costs change due to material prices and costs, labor rate changes, and changes in the price of equipment and services. The methodology presented herein can be applied to any type of reproduction operation or equipment and is not limited to this specific analysis.

The writer has tried to emphasize economic cost rather than accounting cost in the formulation of the following analyses in order to closely approximate the effect of the changes on actual operating.

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9The supplier prices and performance information on the proposed equipment, the continuous electrostatic printers and continuous microfilm camera, is available through Haloid-Xerox, Inc., Rochester, N. Y. The information on the proposed half size camera is available through Peerless Photo Suppliers, Inc., Shoreham, N. Y.
expenditures. The cost of depreciation is based on the economic life of the equipment. Common costs such as utilities, which are not traceable in conventional accounting records, are estimated for each machine because they are direct costs of operation. Costs which are not controllable within the framework of the analysis being performed should be excluded from consideration. General and administrative costs of the company which will most likely continue regardless of whether or not the reproductions effort is performed are uncontrollable and have not been included in the costs of reproduction. The significant costs for reproduction are differentials among the possibilities of providing no service at all, purchasing commercial services, or maintaining some type of in-plant service.

The costs of the various possibilities are compared in Table 4. The significant statistics from the managerial standpoint are the cost reduction possibilities available by adopting a half size reproduction system. In general, a half size system is recommended on the basis of operating costs, and the purchase of the electrostatic camera offers the greatest cost reduction as illustrated in Table 5. Offset printing of cut size drawings is less than half the cost of the whiteprinting process and requires no additional investment since most reproductions organizations have offset equipment available. If it were necessary to purchase this equipment, no significant cost re-evaluation would be necessary since offset is the least costly of all of the concerned equipment (approximately $5000).

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10Dean, pp. 264, 265.

11Ibid., p. 267.
<table>
<thead>
<tr>
<th>Description</th>
<th>Per Day</th>
<th>Per Month</th>
<th>Per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full size blueprints</td>
<td>85 dwgs. x 55 prints x 10.7 sq. ft. x 0.025&lt;sup&gt;a&lt;/sup&gt;</td>
<td>$1,300</td>
<td>$28,600</td>
</tr>
<tr>
<td>Half size blueprints of roll drawings</td>
<td>Half size negative: 42 x 7.5 x 0.35&lt;sup&gt;b&lt;/sup&gt;</td>
<td>111</td>
<td>2,442</td>
</tr>
<tr>
<td></td>
<td>Blueprints: 42 x 7.5 x 55 x 0.018</td>
<td>312</td>
<td>6,864</td>
</tr>
<tr>
<td></td>
<td>Total cost of half size blueprints</td>
<td>423</td>
<td>9,306</td>
</tr>
<tr>
<td>Half size electrostatic prints of roll drawings&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Microfilm: 42 x $0.36</td>
<td>15</td>
<td>330</td>
</tr>
<tr>
<td></td>
<td>A. Prints (purchased machine): 42 x 7.5 x 55 x 0.0196</td>
<td>340</td>
<td>7,480</td>
</tr>
<tr>
<td></td>
<td>B. Prints (leased machine): 42 x 7.5 x 55 x 0.2337</td>
<td>411</td>
<td>9,042</td>
</tr>
<tr>
<td></td>
<td>Total purchased electrostatic printer</td>
<td>355</td>
<td>7,810</td>
</tr>
<tr>
<td></td>
<td>Total leased electrostatic printer</td>
<td>426</td>
<td>9,372</td>
</tr>
<tr>
<td>Whiteprints of cut size drawings</td>
<td>Electrostatic intermediate: 21 x 0.10&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>Whiteprints (11 x 17): 43 x 55 x 0.021&lt;sup&gt;b&lt;/sup&gt;</td>
<td>49</td>
<td>1,078</td>
</tr>
<tr>
<td></td>
<td>Total cost of whiteprints</td>
<td>51</td>
<td>1,122</td>
</tr>
<tr>
<td>Offset prints of cut size drawings</td>
<td>Electrostatic master: 43 x 0.20</td>
<td>9</td>
<td>198</td>
</tr>
<tr>
<td></td>
<td>Offset prints (11 x 17): 43 x 55 x 0.006</td>
<td>14</td>
<td>308</td>
</tr>
<tr>
<td></td>
<td>Total cost of offset prints</td>
<td>23</td>
<td>508</td>
</tr>
</tbody>
</table>

<sup>a</sup>Minimum commercial costs are the same and range up to $0.10 or more per square foot of blueprint.

<sup>b</sup>Commercial cost comparison not developed since prices per unit range from 75 per cent to 200 per cent higher.

<sup>c</sup>Commercial service not available.

<sup>12</sup>See Appendix II for unit costs.
### TABLE 5
COMPARISON OF ANNUAL COST REDUCTION BY HALF SIZE REPRODUCTIONS SYSTEMS

<table>
<thead>
<tr>
<th>Cost of System</th>
<th>Cost Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full size prints</td>
<td>$343,200</td>
</tr>
<tr>
<td>Half size blueprint &amp; offset</td>
<td>117,744</td>
</tr>
<tr>
<td>Cost reduction</td>
<td>$225,456</td>
</tr>
<tr>
<td>Full size prints</td>
<td>343,200</td>
</tr>
<tr>
<td>Half size electrostatic &amp; offset (leased equipment)</td>
<td>118,536</td>
</tr>
<tr>
<td>Cost reduction</td>
<td>224,661</td>
</tr>
<tr>
<td>Full size prints</td>
<td>343,200</td>
</tr>
<tr>
<td>Half size electrostatic &amp; offset (purchased equipment)</td>
<td>99,792</td>
</tr>
<tr>
<td>Cost reduction</td>
<td>213,408</td>
</tr>
</tbody>
</table>

#### Leasing versus Capital Investment

The electrostatic camera, which offers the greatest annual savings, costs approximately $126,000 and is a relatively new reproduction media as discussed in Chapter II. No application has yet been made to roll size drawings so there is no existing operation which can be observed and evaluated.

Equipment of this nature is seldom sold outright and is most generally leased because the state of technological advancement is such as to cause rapid obsolescence. Equipment on lease can be periodically changed without cost penalty whereas purchased equipment cannot be
easily traded without a loss when a better product is available, especially if product improvement comes from a different source than the purchased equipment. Industrial leasing of office equipment has been on the increase in recent years due to the flexibility of equipment disposition permitted by renting, the complex maintenance problems which require experienced servicing by manufacturers' representatives, and obsolescence caused by the advent of superior equipment or changes in systems and procedures in the organization which necessitates changes or elimination of equipment. The equipment under discussion falls into this category in every way, and purchase is not recommended from this standpoint.

The cost of electrostatic prints using a leased camera is greater than the cost of half size blueprints run from negatives made on the half size camera. Purchase rather than lease of the half size camera can be recommended because it is common equipment that can be used with any volume blueprint or whiteprint operation, it does not require servicing by manufacturers' representatives, it is not unusually high in cost, and it can be easily resold in a wide market.

Capital Cost Consideration

Two bases commonly applied in evaluating capital are payout period and rate of return. The payout period analysis has particular application here since the half size system is expected to be of relatively short duration, between 2 and 5 years, as will be more fully discussed in the next chapter. A large part of the cost reduction comes about by shifting the reproduction of cut size drawings to the

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13 "Industrial Leasing Up," Iron Age, January 8, 1959, p. 27.
offset equipment and this cost must be extracted to evaluate the relative costs of the roll size reproduction alternatives. The annual cost reduction attributable only to half size reproduction of roll drawings is shown in Table 6.

**TABLE 6**

**COST REDUCTION FOR ROLL SIZE REPRODUCTION**

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of full size blueprints of roll drawings</td>
<td>$196,080</td>
</tr>
<tr>
<td>Cost of half size negative and blueprints</td>
<td>$111,672</td>
</tr>
<tr>
<td>Total cost reduction, half size blueprints</td>
<td>$84,408</td>
</tr>
<tr>
<td>Cost of full size blueprints of roll drawings</td>
<td>$196,080</td>
</tr>
<tr>
<td>Cost of half size electrostatic prints (purchased)</td>
<td>$93,720</td>
</tr>
<tr>
<td>Total cost reduction, electrostatic prints</td>
<td>$102,260</td>
</tr>
</tbody>
</table>

The extremely short payout period, computed in Table 7, for the half size camera assures management of a near negligible time for the return of invested capital. The payout period for the electrostatic printer and continuous microfilm camera is 4 times longer than that of the half size camera, but is still a relatively short period of time for the return of the invested capital.

The principles of our industrial economic system dictate that capital be used to secure the greatest economic reward at the least cost to the company. The earning power or rate-of-return on invested
capital for the half size camera is noted in Table 8 to be 4 times greater than that for the electrostatic printer system. The analysis

TABLE 8
RATE OF RETURN COMPARISON

<table>
<thead>
<tr>
<th>System</th>
<th>Savings per Year</th>
<th>Capital Cost</th>
<th>Rate of Return</th>
</tr>
</thead>
<tbody>
<tr>
<td>Half size camera</td>
<td>$84,408</td>
<td>$25,300</td>
<td>290%</td>
</tr>
<tr>
<td>Electrostatic printer and microfilm camera</td>
<td>$102,260</td>
<td>$138,000</td>
<td>74%</td>
</tr>
</tbody>
</table>

of cost reduction over the period of 7 years in Table 9 provides a final basis for managerial selection on the basis of capital cost. The capital costs of both the half size camera and the electrostatic printer and microfilm camera have an imputed 3-1/2 per cent interest cost for the first year of assumed operation. The half size camera shows a net savings the first year to which is added the estimated increment of cost reduction each year thereafter. The electrostatic printer and microfilm combination does not show a savings above capital cost until half way through the second year after which the estimated yearly increments are added. It takes 7 years of estimated operation before the net savings from the electrostatic printer become greater than the savings from the half size camera.

The half size camera must be recommended on the basis of overall cost and investment considerations. Though the yearly operating cost reduction by this method is less than that of the electrostatic printer, the short run accumulated savings are greater. The equalization of cost reduction opportunity in 7 years is considered too far into the future to recommend the greater capital investment because of the long
run potential for technological change.

TABLE 9
SEVEN YEAR RETURN ANALYSIS

<table>
<thead>
<tr>
<th></th>
<th>Capital Cost Plus Interest Cost @ 3.2%</th>
<th>Annual Net Savings (Cost Savings less Capital)</th>
<th>Accumulated Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First year</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Half size camera</td>
<td>$26,186</td>
<td>$58,222</td>
<td>$58,222</td>
</tr>
<tr>
<td>Electrostatic &amp; Microfilm</td>
<td>142,830</td>
<td>(40,570)</td>
<td>(40,570)</td>
</tr>
<tr>
<td><strong>Second year</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Half size camera</td>
<td>...</td>
<td>84,408</td>
<td>142,630</td>
</tr>
<tr>
<td>Electrostatic &amp; Microfilm</td>
<td>41,438</td>
<td>60,822</td>
<td>60,822</td>
</tr>
<tr>
<td><strong>Third year</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Half size camera</td>
<td>...</td>
<td>84,408</td>
<td>227,038</td>
</tr>
<tr>
<td>Electrostatic &amp; Microfilm</td>
<td>...</td>
<td>102,260</td>
<td>163,082</td>
</tr>
<tr>
<td><strong>Fourth year</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Half size camera</td>
<td>...</td>
<td>84,408</td>
<td>311,446</td>
</tr>
<tr>
<td>Electrostatic &amp; Microfilm</td>
<td>...</td>
<td>102,260</td>
<td>265,342</td>
</tr>
<tr>
<td><strong>Fifth year</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Half size camera</td>
<td>...</td>
<td>84,408</td>
<td>395,854</td>
</tr>
<tr>
<td>Electrostatic &amp; Microfilm</td>
<td>...</td>
<td>102,260</td>
<td>367,602</td>
</tr>
<tr>
<td><strong>Sixth year</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Half size camera</td>
<td>...</td>
<td>84,408</td>
<td>480,262</td>
</tr>
<tr>
<td>Electrostatic &amp; Microfilm</td>
<td>...</td>
<td>102,260</td>
<td>469,862</td>
</tr>
<tr>
<td><strong>Seventh year</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Half size camera</td>
<td>...</td>
<td>84,408</td>
<td>564,672</td>
</tr>
<tr>
<td>Electrostatic &amp; Microfilm</td>
<td>...</td>
<td>102,260</td>
<td>572,122</td>
</tr>
</tbody>
</table>
CHAPTER VI

ANALYSIS OF LONG RUN REPRODUCTION ALTERNATIVES

Industrial progress and technological development do not aim at a plateau of achievement and stop further action when that goal is reached. Progress of this nature must be dynamic and continuing. Similarly, reproductions advancement must be progressively developed to keep pace or the goals achieved in the short run will become antiquated drawbacks. Areas of further advancement must be planned and ready for implementation when practical. This chapter is devoted to setting forth a progressive plan of gradual development to succeedingly more sophisticated systems of communicating engineering designs over a period of time.

Increased Use of 11 x 17 Offset Printing

The recommendation of greatest advantage developed in the short run was the use of electrostatic offset masters and offset printing of cut size drawings. It will be remembered that the advantages of offset printing over the other conventional processes discussed are:

1. Non-sensitized low cost print paper.
2. A high degree of mechanization.
3. A high rate of production.
4. Relatively low cost equipment.

The requirements for adopting this process are a standard cut size print, sufficient volume to cover the cost and time required for
master preparation, and rapid press setup. All of these factors are present in the making of 11 x 17 inch prints. One approach is to examine the possibility of a planned elimination of roll size drawings in favor of a maximum drawing size of 22 x 34 inches (which reduces to 11 x 17 inches for running half size offset prints). It is impractical to suggest that roll size drawings already in existence be redrawn, but it may be possible to require that future drawings be prepared on the 22 x 34 inch format. Contracts for aerospace products usually run from 2 to 5 years so it is easily possible to have a great majority of the active drawings of a company on the smaller format within 2 to 5 years from the inception of the changeover.

Use of multi-sheet drawings

Separate detail parts can and usually are drawn on cut size drawings. The longer drawings are usually assembly drawings and installation drawings.¹ The use of a standard cut size instead of roll drawings essentially means dissecting longer drawings by some type of presentable and workable method. Two possibilities are the use of smaller scale views and, most necessary, the use of several pages or multiple sheets. The time for producing prints is only slightly less on offset but the cost reduction is significant. Figure 19 is a simple example of how the use of multi-sheet drawings might apply. It is possible that multi-sheets might actually take up less total drawing surface.

¹A detail drawing presents all the design information necessary to fabricate an individual piece or part. An assembly drawing shows the assembled relationship of 2 or more parts. An installation drawing shows the positioning of assemblies and attaching hardware in the general configuration. Other types of drawings are used to some degree, including diagrams, wiring, etc. Complete descriptions are found in MIL-STD-7, Types and Definitions of Engineering Drawings (Washington: U. S. Government Printing Office, 1959).
Fig. 19.—Use of multi-sheet drawing to replace roll size
than one long drawing because the tendency is to space information and views over a greater area on a larger sheet. An example of the benefit of this approach is presented in Table 10. The switch from full size to half size blueprints effected a healthy 66 per cent reduction in the cost of roll size drawing reproduction. For each roll drawing that a company is able to plan for cut size format and offset reproduction, an additional 74 per cent cost reduction over the half size blueprint method is possible.

The secret of the savings of the half size blueprint over the full size method is a large reduction in material cost due to greatly reducing the quantity of materials required as well as reducing the total labor required because of less volume. The savings of offset over half size blueprint is also derived largely from material cost reduction, but in this case it is due to a change to less costly materials rather than a reduction of material quantity. The cost of 5 electrostatic offset masters is less than 40 per cent the half size negative cost required for the roll drawing. The cost of the sensitized blueprint paper is approximately 5 times greater than the cost of the unsensitized printing paper used on the offset press.

Every new roll which is planned as a multi-sheet cut drawing will save the company $7.42, considering that the half size blueprint process is already in use, or $27.05 if full size blueprinting is in use. In the latter case, this is a phenomenal 91 per cent cost reduction. The multi-sheet method has an additional benefit of actually lowering total reproduction requirements since a change in one area of the drawing might require only one small sheet to be reproduced and distributed whereas a change to a roll drawing generates print copies
### TABLE 10

**COST COMPARISON OF ROLL AND 11 X 17 CUT SIZE REPRODUCTION**

<table>
<thead>
<tr>
<th></th>
<th>Print Cost</th>
<th>Cost Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Amount</td>
<td>Per Cent</td>
</tr>
<tr>
<td>Full size blueprints of 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>roll size dwg.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average dwg.: 30 sq. ft.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>x 55 prints x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>.018/print</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$29.70</td>
<td>$19.63</td>
<td>66%</td>
</tr>
<tr>
<td>Half size blueprints of 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>roll dwg.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average negative: 7.5 sq.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ft. x .35/sq. ft.</td>
<td>2.63</td>
<td></td>
</tr>
<tr>
<td>Average print: 7.5 sq.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ft. x 55 prints x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>.018/sq. ft.</td>
<td>7.44</td>
<td></td>
</tr>
<tr>
<td>Cost &amp; savings over full</td>
<td>10.07</td>
<td>$19.63</td>
</tr>
<tr>
<td>size blueprint</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Half size offset prints (22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>x 3½ inches) (equivalent to</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 average roll dwg.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 dwgs x .20/offset</td>
<td></td>
<td></td>
</tr>
<tr>
<td>master</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>5 masters x 55 prints x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>.006 per print</td>
<td>1.65</td>
<td></td>
</tr>
<tr>
<td>Cost &amp; savings over half</td>
<td>2.65</td>
<td>7.42</td>
</tr>
<tr>
<td>size blueprint</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost &amp; savings over full</td>
<td>27.05</td>
<td>91%</td>
</tr>
<tr>
<td>size blueprint</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Half size offset prints of</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2½ dwgs. (36 x 48 inches)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(equivalent to 1 average roll</td>
<td></td>
<td></td>
</tr>
<tr>
<td>dwg.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2½ dwgs. x .40/offset</td>
<td></td>
<td></td>
</tr>
<tr>
<td>master</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>2½ masters x 55 prints x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>.010 per print</td>
<td>1.38</td>
<td></td>
</tr>
<tr>
<td>Cost &amp; savings over offset</td>
<td>2.38</td>
<td>.27</td>
</tr>
<tr>
<td>of 5 dwgs. (22 x 3½)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost &amp; savings over half</td>
<td>7.69</td>
<td>76%</td>
</tr>
<tr>
<td>size blueprint</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost &amp; savings over full</td>
<td>27.32</td>
<td>92%</td>
</tr>
<tr>
<td>size blueprint</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
of the total drawing surface regardless of the localized nature of the drawing change.

The relationship of fixed costs per drawing is shown in Figure 20. At the volume of 42 roll drawings per day or 924 roll drawings per month, the blueprinter fixed cost is relatively incidental. As less roll drawings are made, the incremental fixed cost per drawing increases. Commercial services become more practical than continuing to incur the large fixed cost per drawing when the roll drawing requirements drop to about 80 per month. This figure does not include the fixed cost increase per drawing of the half size camera since it is assumed that this camera will continue to be used for other reproduction purposes. If this were not the case, the fixed cost would be greater and the total cost per drawing would increase to make commercial services practical at some volume near 170 drawings per month. The other practical alternative is to run the roll drawings on whiteprint equipment if such is available. In either case, the shift to multi-sheet drawings will permit the complete elimination of the blueprint facilities at some point in time when roll size drawings make up between 5 and 10 per cent of the total active drawings. A large area of floor space is made available and a serious venting and air conditioning deterrent is eliminated.

Increased offset printing of drawings will gradually require the full time of 1 press. The specialized use of the press for this particular type of work will allow a standardized setup and thus faster production. As an aid to print users, it is recommended that a blue ink be used which closely approximates the color of the blueprint in order to provide increased readability of soiled prints and
Fig. 20.--Incremental fixed cost per drawing
to minimize print glare. Soiled areas of black and white prints tend to make the image appear indistinct whereas a blue color stands out in contrast, one of the advantages of the blueprint which can be adopted at no increase in cost or time.

Microfilm and Offset Printing

The system described above could be implemented wherever practical using the same reproductions equipment recommended in the short run proposal. It is realized that many companies may not find it practical to be limited to a 22 x 3½ inch drawing size standard. The Department of Defense has recently established a maximum drawing length of 12 feet for roll drawings. A latitude of discretion is available to management to decide upon a drawing size standard between 22 x 3½ inches and 36 x 14¼ inches.²

The half size print standard will be retained because of the tremendous time and cost advantages. The maximum print size thus becomes 18 x 72 inches if the maximum drawing size is used. This size print can be run on an offset press so one alternative is to use offset prints for all drawings as soon as new contracts are in effect long enough to establish the 12 foot maximum requirement on roll drawings. It has previously been mentioned that press manufacturers are becoming aware of this market potential, and it is possible that efficient reproduction of large drawings may become possible on offset.³ The large size will in all probability still create a complex...


³See Chapter II for a description of printing and particularly note the complexity of the large offset press in Figure 6.
and relatively costly operation so that other avenues should also be explored.

Any drawing size larger than 22 x 34 inches exceeds the size capability of the electrostatic printer camera and other rapid low cost master-making equipment must be sought. The electrostatic process is utilized in several types of equipment which will produce a relatively low cost master ranging up to the maximum size required for drawings. The problem is to decide on the size standard in order to select the most appropriate master-making and printing equipment.

The recommendation if the 22 x 34 inch drawing proves too small is a maximum size of 36 x 48 inches. The use of any larger size requires the use of some type of special press equipment not yet developed. The 36 x 48 inch drawing breaks a 12 foot drawing into only 3 sections and provides full drawing width. It is the largest size which can be accommodated on 1 frame of 35mm microfilm as discussed in Chapter II. Once the microfilm is made to satisfy contractual requirements, there is no additional expense involved in its use as an intermediate to make offset masters. Electrostatic printers are available to make 18 x 24 inch offset masters from microfilm, and efficient high speed offset presses are available for running this size. A reduction of 25 per cent over the half size blueprint flow time is provided by the special instant clamping device on the press. A comparison of electrostatic master-making equipment utilizing 35mm microfilm is provided in Table II.

The Copyflo printers are illustrated in Figure 9, Chapter II, and are selected on the basis of minimum performance time and versa-

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4See Chapter II, Offset Printing.
### Table 11

**ELECTROSTATIC MASTER MAKING EQUIPMENT FROM 35MM MICROFILM**

<table>
<thead>
<tr>
<th>Electrostatic Printer</th>
<th>Time Required per Master</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kecofax Project-Printer&lt;sup&gt;a&lt;/sup&gt; (Keuffel &amp; Esser Co.)</td>
<td>40 sec.</td>
</tr>
<tr>
<td>Copytron Enlarger-Printer&lt;sup&gt;a&lt;/sup&gt; (Chas. Bruning Co.)</td>
<td>40 sec.</td>
</tr>
<tr>
<td>Copyflo 182&lt;sup&gt;b&lt;/sup&gt; (Haloid-Xerox, Inc.)</td>
<td>30 sec.</td>
</tr>
<tr>
<td>Copyflo 24C (Haloid-Xerox, Inc.)</td>
<td>6 sec.</td>
</tr>
</tbody>
</table>


<sup>b</sup>Sales literature of Haloid-Xerox, Inc., Rochester, N.Y.

...ility of material. The other electrostatic printers require special treated surface paper whereas Copyflo does not. Refer back to Table 10 and it will be noticed that in spite of the huge cost reduction obtained by using 5 drawings 22 x 34 inches printed by offset in place of one roll drawing, an even greater potential is possible by using 2-1/2 drawings 36 x 48 inches in place of one roll drawing. The larger size offset print results in a greater savings because fewer press runs and fewer labor hours are required to produce the same total print surface. The time factor is also cut in half so that by use of the 18 x 24 offset print in place of either half size blueprint or 11 x 17 offset print, print production time is reduced...
from a total of 13 hours a day to 6-1/2 hours a day.

The 18 x 24 press would require an additional capital investment whereas the other systems are already considered as on hand. The approximately $11,000 would be paid off by savings (over the 11 x 17 offset press) of approximately $3,108 a year. The additional workload on the 11 x 17 press might well raise the cost by premium time or might prove impossible to meet because of other printing demands. In this case, the choice would be narrowed to a $5,000 investment for an 11 x 17 press and an $11,000 investment for an 18 x 24 press. The offset print should be adopted in either case since this method pays for the smaller press in 1 month or the larger press in 2 months of operational savings over the half size blueprint.

Results of actual operations with microfilm and offset printing

The above analysis of potential possible with equipment now on the market is considered conservatively realistic. One user of the 35mm microfilm and electrostatic print system has estimated monthly cost reduction at 78 per cent ($41,000 to $11,000). Another reproduction organization has cut its labor force in half (43 employees to 23); another is saving $100,000 a year on labor alone; and a third company is saving $200,000 a year on labor.6 Labor savings is only a fraction of the cost reduction since materials costs are not included.

The recommendation herein has gone 1 step beyond the electrostatic print to the running of offset prints. At the time the electrostatic print systems were adopted in the reference cited above, there

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was only the costly continuous electrostatic printer available on the market which requires high volume print production in order to obtain a low unit cost, thus prohibiting the making of low cost offset masters. The relatively low cost 1824 electrostatic printer was not available for delivery until 1961. The smaller size (11 inch width) electrostatic printer has been used at IBM since 1959 to make 2000 offset masters a day from which more than 100 prints each are run. The recommendation to adopt the 36 x 48 drawing size standard is considered essential in order to permit automated reproductions and handling of microfilmed drawing files by offset printing until a more advanced system becomes practical.

Direct Use of Microfilm

The primary consideration to this point has been devoted to arriving at rapid and efficient means of reproducing prints, but this is only one of many potential means of disseminating design information. The discussion will now be broadened to consider other possibilities for application such as those depicted in Figure 21. The use of the microfilm frame mounted in an aperture card as illustrated in Figure 11, Chapter II, permits a unitized system by which the cards can be key punched and processed on automatic electronic data processing equipment. The drawings are reduced onto microfilm and can be automatically filed, sorted, or selected instead of hand filing bulky prints. A company usually has many areas where print files would be unnecessary if another means of information were available to satisfy

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7 Sales literature of Haloid.

Fig. 21.—Design information flow pattern and means of dissemination
reference needs. The only choice in the past has been to secure a full or half size print of the drawing whenever any information was needed therefrom. A film aperture card can now be supplied for this purpose to gain the advantage of large savings in filing space, mailing and handling costs, and reproductions costs as well as machine sorting according to customer, model, location, or other required selection.

Uses of aperture cards for reference might include distribution to such areas as test sites, customers, field service representatives, and within the engineering department. A duplicate aperture card can be made at a cost of $0.05 and as many as 76,500 cards can be filed in a single cabinet costing $1.55 while a 100 foot roll of film, representing approximately 650 drawings, can be stored in a vault for about $0.20 per year.9 The space saving possible by having aperture card reference files instead of print files and by storing microfilm in place of inactive or obsolete drawings is 95 per cent. Westinghouse estimates a space saving of 10,500 square feet at an annual cost of $25,000 by using centralized microfilm files.10 The Army's Redstone Arsenal has reduced clerical personnel 40 per cent and stored 100,000 drawings in only 4 square feet of floor space through implementation of unitized microfilm. Aperture cards are distributed for reference purposes and a low cost viewer is used to


view the drawing or make a print in 10 seconds if required.\textsuperscript{11} Bell Laboratories utilized 2 file cabinets of microfilm aperture cards to replace 500,000 prints filed in 40 file cabinets and concurrently reduced the number of file clerks by one-third.\textsuperscript{12}

The above examples indicate the possibilities of the unitized microfilm reference file. A typical classification of file usage is illustrated in Figure 21, the Class I files being areas requiring detailed working prints as for inspection and manufacturing whereas the Class II files are areas requiring only reference use as for field service and engineering. Table 12 shows the marked advantage of using aperture cards instead of print files based on relative savings taken from the cited examples. The areas of reference requirements should definitely be supplied with aperture cards since readers-printers can be obtained in the price range of $100 to $1,200 each. Converting the Class II reference files shown in Figure 21 to aperture cards would permit an annual savings of more than $10,000.

Decentralized reproductions from microfilm

A large volume print mailing requirement to a branch 300 miles distant is assumed and 2 means of satisfying the requirement are presented in Table 12. One method is to decentralize drawing reproduction by reproducing an intermediate that can be mailed for reproducing whiteprints at the branch plant. An even greater cost reduction is possible by sending microfilm aperture cards. A true


\textsuperscript{12}"Bell Puts Microfilm to the Test," \textit{PMI}, March, 1959, p. 32.
<table>
<thead>
<tr>
<th></th>
<th>Annual Cost</th>
<th>Cost Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Amount</td>
</tr>
<tr>
<td><strong>Print files</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wages: 2 clerks</td>
<td>$8,000</td>
<td></td>
</tr>
<tr>
<td>Area Cost: 600 sq. ft.</td>
<td>1,500</td>
<td></td>
</tr>
<tr>
<td><strong>Total print file cost</strong></td>
<td><strong>9,500</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Aperture card files</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wages: 1 clerk</td>
<td>4,000</td>
<td>$4,000</td>
</tr>
<tr>
<td>Area cost: 30 sq. ft.</td>
<td>75</td>
<td>1,425</td>
</tr>
<tr>
<td><strong>Total aperture file cost</strong></td>
<td><strong>4,075</strong></td>
<td>5,425</td>
</tr>
<tr>
<td><strong>Mailing cost</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mail 15 prints per drawing</td>
<td>$7,327</td>
<td></td>
</tr>
<tr>
<td>Prepare whiteprint reproducibles</td>
<td>488</td>
<td></td>
</tr>
<tr>
<td>Mail whiteprint reproducibles</td>
<td>781</td>
<td></td>
</tr>
<tr>
<td><strong>Total cost of mailed whiteprint reproducibles</strong></td>
<td><strong>1,269</strong></td>
<td><strong>$6,058</strong></td>
</tr>
<tr>
<td>Prepare 1 set of aperture cards</td>
<td>488</td>
<td></td>
</tr>
<tr>
<td>Mail 1 set of aperture cards</td>
<td>61</td>
<td></td>
</tr>
<tr>
<td><strong>Total cost of mailed aperture cards</strong></td>
<td><strong>549</strong></td>
<td><strong>$6,778</strong></td>
</tr>
</tbody>
</table>
picture of the possible cost reduction cannot be determined without considering the cost of print reproduction at the branch. The effect of combining the savings on the cost of files with the savings on mailing costs is illustrated in Figure 22 using random printout as needed from aperture cards on the 1824 electrostatic printer at the branch plant. The aperture cards are efficient even up to a print volume requirement of 500 per day or 160,000 per year. The use of a reproducible intermediate for whiteprints is inefficient and should be replaced in instances where volume is in the economical range of aperture cards and electrostatic prints. The requirement for a volume of 15 or more prints per drawing or a volume greater than 160,000 prints per year makes centralized reproduction by offset printing economical in spite of the high mailing costs. Where a very large number of prints per drawing is required, extending the chart would show the economic feasibility of mailing an offset master for decentralized offset printing to save print mailing costs.

The use of aperture cards mailed to areas for reference provides the combined benefit of minimum file cost and minimum mail cost. The type of reader-printer used will depend greatly on the volume of prints required since the incremental cost curve rises very steeply for the inexpensive equipment which has low volume photographic printout at unit costs of $0.25 to $0.50 per print.

Advanced Technological Potential

The use of the systems and processes discussed above as well as those to be discussed are based on application according to need and are not intended to be exclusive. It is probable that a complex combination of processes will continue to be used for some time even
Fig. 22.--Print vs. aperture files and incremental print costs
though many are rapidly becoming obsolete. Blueprinting is rapidly
decaying in use and the growth of whiteprinting is leveling off as
offset printing, electrostatic printing, and microfilming become more
efficient and practical. Other processes are on the horizon which
may in time rise to replace these though a large amount of the equip-
ment as well as reproductions research budgets are being devoted to
systems compatible with microfilm.¹³

**Numerically controlled**

**machine tools**

Elimination of drawing reproductions is desirable wherever
prints serve no necessary function. Aperture cards for reference are
a step in this direction. The rise of industrial automation by use
of numerically controlled machines permits elimination of many print
requirements since the design information which the machine tools use
for fabrication and inspection is communicated on punched tape.¹⁴ The
use of numerically controlled machines permits rapid transmission of
design information to manufacturing plants in distant locations be-
cause the digital machine language on punched tape or other forms can
be transmitted by telephone, teletype or radio equipment.

**Automated electronic**

**reproductions**

The storage, handling, processing, and transmitting of all
forms of data are receiving intensive study, and there is rapid

¹³David A. Loehwing, "Photostat to Verifax," Barron's, May,
1958, p. 21.

¹⁴Paul H. McGarrell, "Numerically Controlled Milling Machine
Uses Analog and Digital Techniques," SAE Journal, February, 1959,
p. 66. Transition to numerical control is a very real and present
development of techniques and processes for accomplishment. Tremen-
dously fast computers and electronic brains spew forth information far
more rapidly than available equipment can print. The electrostatic
printer has been coupled with electronic equipment to print information
at the rate of 65 feet per minute (5,000 lines per minute) so that the
equivalent of a 300 page book is produced every 3 minutes.15 This de-
vice is used with the Naval Ordnance Research Station calculator to
plot X and Y coordinates on graphs at the rate of 10,000 points per
second.16 It appears quite likely that all of the written transactions
of a business firm could be put on a photographic pattern which would
permit random access of desired bits of information at very high
scanning rates.17 The long run analysis of drawing reproduction
potential would be incomplete without questioning the possibility of
applying these data processing techniques to drawings. The great
problem is that machines can understand and digest written or coded
symbols and characters but so far do not satisfactorily read, remember,
and print pictorial images.

The techniques of electronic data processing can be applied if
certain conditions are met. These conditions are:

occurrence as evidenced by Rocketdyne plans to have 85 per cent of its
machine tools numerically controlled in 2 years, according to lectures
on this subject presented at the third Rocketdyne Value Engineering
Seminar, April 3 to April 14, 1961.

15Loehwing, Barron's, p. 3.


17D. M. Bauman, "A High Scanning Rate Storage Device for Computer Applications," Journal of the Association for Computing
Machinery, January, 1958, pp. 77-81.
1. A means of recording drawings in miniature form.

2. A means of storing all of the drawing images within the machine.

3. A means of random and instantaneous selection of the drawing required.

4. A means of instantaneous printout of a drawing print at any location.

The use of microfilm is said to be miniaturization but far greater size reductions are required for recording drawings in a form easily accessible for machine programming. The need is for a high concentration of drawing images on a compact roll of tape or other recording media. One method of recording is by magnetic videotape which is frequently used for television filming and has possibilities of some day replacing conventional photographic filming though existing equipment is expensive and bulky.\(^{18}\) Three times greater image concentration is possible on General Electric's experimental thermoplastic recording tape so that a 24 volume set of encyclopaedias can be recorded on a roll approximately the size of a spool of thread and instantaneously processed during the recording.\(^{19}\)

The storing operation is approached by the Kodak Minicard System of information retrieval by which documents are reduced in size 60X (60 magnifications) and stored manually in files on "sticks" of 2,000 cards approximately 3\(\frac{1}{4}\) x 1\(-\frac{1}{2}\) inches. The "stick" is a device for placing and indexing the miniaturized images for automatic selection and printout, after an operator finds the stick in the files


having the required information and puts it into the selecting machine. This system was developed for the military at a cost of $2,500,000. Other equally unique systems are under development or in the prototype stages. 20

An example of a system having the all-around data processing capabilities described is IBM's Project Walnut which uses a somewhat similar system to the Kodak Minicard and actually stores film miniatures reduced 52X on film strips in a mechanized electronic memory device so that each film can be automatically selected at random. 21

The new Recordak Dacom system offers printout of digital computer information onto microfilm which in turn can be printed onto 12 inch wide print paper at the rate of 100 feet per minute, about 4 times faster than available equipment on the market. 22

A final example of the advanced state of development is the A. B. Dick Videograph Scanner (approximately $20,000) and Videograph Printer (approximately $36,000). This equipment is of a facsimile type, meaning that a copy fed into the scanner is transmitted electronically and printed out in exact facsimile on any number of printers any number of miles distant at the rate of 15 lineal feet (or 10 sheets) per minute. 23 A special high speed Videograph Printer (approximately $125,000) is capable of printing at the rate of 180 lineal feet per

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20 Francis Bells, How to Cope With Information, a pamphlet reprinted from Fortune, September, 1960, and distributed by Recordak Corporation, N. Y., N. Y.

21 Personal attendance at IBM Customer Executive Program, March 8-10, 1961, San Jose, California.


Electronic equipment potential holds great promise for communication-conscious management. A combination of the various equipment and process characteristics appears sufficiently satisfactory to meet the requirements listed at the beginning of this section which are considered necessary for electronic processing of engineering drawings. Examples of the potential put into practice are shown in Table 13.

**TABLE 13**

PROJECTED CAPABILITIES, ELECTRONIC DRAWING PROCESSING

<table>
<thead>
<tr>
<th>Operation</th>
<th>Time</th>
<th>Cost</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatic dwg. image recording onto tape</td>
<td>1 min.</td>
<td>$0.01 per dwg.</td>
<td>Eliminates all intermediate reproduction equipment &amp; operators</td>
</tr>
<tr>
<td>145 cut dwgs./day</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Automatic processing of tape through printer</td>
<td>1-1/2 hrs.</td>
<td>$0.03 per print</td>
<td>Eliminates all reproduction printing equipment, operators, trimmers, mail clerks, etc.</td>
</tr>
<tr>
<td>to any geographic location</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>145 dwgs. x 55 prints</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Automatic printout</td>
<td>1 sec.</td>
<td>$0.03 per print</td>
<td>Eliminates all necessity for file clerks, duplicate files at contractors &amp; government agencies</td>
</tr>
<tr>
<td>to any station on demand</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The primary significant costs involved would be fixed capital. Storing drawing images on tape could be done at an infinitesimal material and labor cost per drawing since drawings of standard cut sizes could

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be automatically fed through the recording device. A printer speed of 180 feet per minute is used to print out any selected print to any destination. A time is shown for running a typical number of prints per day but actually there would be no need since a print could be obtained in 1 second when needed and thrown away after use. While there is no basis for estimating the cost of the potential recording equipment, the printer can be estimated at between $125,000 and $200,000 with no significant labor cost and low material cost. Multi-sheet drawings would come off from this printer at twice the speed of offset presses and already collated in page number order whereas prints run on the offset press must be separately collated. Speed of printout is actually many times greater than offset because no machine setup or individual master preparation is required. Such a system would be too inefficient if used for drawings alone but would be of equal or greater benefit when used in conjunction with storing and printing out specifications, manuals, and other supporting data. It is quite likely that the elimination of volume reproductions, large areas of floor space and equipment, and all related print files and equipment would amount to several hundred thousands of dollars annually and would justify the investment in the electronic equipment by cost reduction, just as half size and offset printing were demonstrated to be efficient.

Automated control of machine tools is becoming a reality which is decreasing drawing print requirements while the potential of electronic drawing processing will be translated into reality in the near future. The inter-action of these 2 factors makes it imperative that the progressive company be prepared for the transition to succes-
sively more refined reproductions systems to assure advanced communications on a parallel with advanced industrial technology.
CHAPTER VII

RECOMMENDATIONS AND CONCLUSION

Conclusion

The hypothesis is supported in this paper since the time required for engineering drawing reproduction can be cut from 3 days to less than 1 day by adopting the half size camera-blueprint system for roll size drawings and offset printing for cut size drawings. Adoption of these processes additionally substantiates the hypothesis that full size drawing reproductions cost of a third of a million dollars annually (as represented by the typical blueprint cost summary in Schedule 2, Appendix II) can be significantly reduced to approximately $120,000 annually. Based on the typical case used in developing this thesis, it is conservatively estimated that utilization of the half size reproduction principle can be applied to any large volume roll size reproduction operation at a minimum time and cost savings of 50 per cent. The use of offset printing instead of blueprinting for volume cut size reproductions should result in a minimum time and cost savings of 75 per cent.

It has been demonstrated that the long run potential exists to reduce reproduction time and cost even further by successive progression to offset printing of multi-sheet drawings, use of microfilm aperture card files, and ultimately electronic drawing processing.
Short Run Recommendation

The two main objectives of this thesis are to develop a means to reduce the time and reduce the cost of engineering drawing reproductions. All of the known practical reproductions processes which might apply were discussed and illustrated in Chapter II. The standard requirements for size, quantity, and quality were established in Chapter III and were applied to qualifying processes to determine the time effect in Chapter IV. The analysis shows that a minimum flow time for roll drawings is provided by both the half size blueprint system and the half size electrostatic print system. Half size roll blueprints can be obtained commercially in cases of equipment breakdown or other emergency whereas electrostatic roll prints cannot.

The recommendations based on time requirements in order of preference are as follows:

1. Half size camera and blueprint.
2. Microfilm and electrostatic printer.
3. Use of commercial half size services.

The costs incurred by use of the above processes were analyzed in Chapter V. Consideration was given to both capital cost and operating cost, and, based on that analysis, the recommendations in their order of preference are listed below:

1. Purchase of the half size camera.
2. Purchase of the continuous microfilm camera and lease of the electrostatic printer.
3. Purchase of the microfilm camera and purchase of the electrostatic printer.
4. Use of commercial half size services.

Chapters IV and V analyzed in like manner the time and cost
considerations for cut size drawings and on both of these bases, the
process recommendations and order of preference are:

1. Electrostatic master and offset printing.
2. Whiteprinting.

Long Run Recommendation

Chapter VI presented several long run possibilities for com-
munication of engineering design information. The less complicated
and proven processes were discussed first and the future potential
processes were then considered. In order to continue to promote time
and cost reduction in engineering drawing reproduction (or some other
future form of design communication), the following steps should be
taken in the order listed.

1. Over a period of 2 to 5 years, substantially eliminate
   the use of roll size drawings in favor of multi-sheet
drawings having a maximum size of 36 x 48 inches.

2. Concurrently initiate the use of offset printing for
   substantially all drawing reproduction requirements.

3. Concurrently reduce print quantity requirements by
   using microfilm aperture cards in place of drawing
   prints for all reference files.

4. Discontinue the use of all blueprint equipment (if
   that process has continued in use) when roll size
drawings comprise only 5 to 10 per cent of the
   total active engineering drawings.
APPENDIX I

MATERIALS TEST SPECIFICATIONS

Paper, Diazo, Sensitized, Blueline

1. SCOPE. This specification covers diazo, blueline, sensitized paper for producing direct positive prints from transparent or translucent line originals by contact printing and ammonia vapor development.

1.1 Speed. In addition to the speeds listed, commercial designation may be used to specify faster speeds.

2. APPLICABLE DOCUMENTS.


Standard , Test, Performance, for Sensitized Blueprint and Diazo Materials.

Standard , Charts, Test, Exposure.

3. REQUIREMENTS.

3.1 All sensitized diazo papers shall conform to the requirements of the current issue of Federal Specification UU-P-220, Type II, Class 2, except as noted herein.

3.2 Splices. All splices shall be neatly made with not more than one splice per roll. At least one yard of paper shall be allowed for each splice. A single shipment shall contain not more than 10 percent of such spliced rolls. All splices shall be flagged at both ends of the roll with projecting colored markers.

3.3 All diazo paper shall be rated for performance in accordance with Standard .

4. METHOD OF TEST AND INSPECTION.

4.1 Test methods shall conform to Federal Specification UU-P-31, except as noted.
4.2 Test Chart. Test charts used shall be Standard Test, Exposure.

5. PACKAGING AND MARKING.

5.1 Packaging shall be in accordance with Federal Specification UU-P-220, except as noted.

5.2 Each roll shall be wound on a stiff core.

5.3 Grain direction shall be indicated on packages of sheet paper.

5.4 In addition to other marking, each roll shall carry the following information:

   Paper, Diazo, Sensitized, Blueline Standard

   Paper, Blueprint, Sensitized

1. SCOPE. This standard covers sensitized blueprint paper.

1.1 Speeds. In addition to the speeds listed, commercial designations may be used to specify faster papers.

2. APPLICABLE DOCUMENTS


   Standard , Performance Test for Sensitized Blueprint and Diazo Materials.

   Standard , Charts, Test, Exposure.

3. REQUIREMENTS

3.1 All sensitized blueprint paper shall conform to the current issue of Federal Specification UU-P-79, Type I, Grade B, except as noted herein.

3.2 Consistency. The sensitized coating shall be uniform, essentially free from coating streaks, pinholes, dirt, abrasion marks, spots, mottling, and areas of marked higher or lower sensitivity which will affect print quality.

3.3 Wet Strength. Paper shall not break or tear, or show evidence of other damage, when subjected to normal wetting in blueprint machine for one hour after shutdown and restart in accordance with paragraph 4.2.
3.4 Splices. All splices shall be neatly made with not more than one splice per roll. At least one yard of paper shall be allowed for each splice. A single shipment shall contain not more than 10 per cent of such spliced rolls. All splices shall be flagged at both ends of the roll with projecting colored markers.

3.5 All blueprint paper shall be rated for performance in accordance with Standard and shall average satisfactory or better.

4. METHOD OF TEST AND INSPECTION

4.1 Test methods shall conform to Federal Specification UU-P-31, except as noted.

4.2 Wet Strength. Paper shall be processed in any blueprint machine until operating conditions stabilize. Machine will be shut off as normally done for short periods of inoperation. Machine shall remain inoperative for the specified period of time and restarted in accordance with usual practice. Paper shall be then examined for evidence of failure.

4.3 Test Charts. Test Charts shall be Standard Expos., Charts, Test, Exposure.

5. PACKAGING AND MARKING

5.1 Packaging shall be in conformance with Federal Specification UU-P-79 for Type I sensitized blueprint paper, except as noted.

5.2 Each roll shall be wound on a stiff core.

5.3 In addition to other marking, each roll shall carry the following information:

   Paper, Blueprint, Sensitized Standard

   Test, Performance, for Sensitized Blueprint and Diazo Paper

1. SCOPE

This test standard specifies performance evaluation procedures for sensitized blueprint and diazo blueline paper under operation conditions.

2. APPLICABLE DOCUMENTS

   Standard , Charts, Test, Exposure.
   Standard , Paper, Diazo, Sensitized, Blueprint (Ammonia Processings)
3. REQUIREMENTS

3.1 General

3.1.1 All exposure tests shall be made using standard test masters in conformance to Standard, Charts, Test, Exposure.

3.1.2 All tests shall be concluded under normal division operating conditions which shall include the extremes of conditions usually experienced.

3.1.3 Where substantial differences in operating conditions or types of equipment exist between divisions, tests may be repeated at those divisions.

3.1.4 During performance of tests specified, the quality of the following characteristics should be observed with respect to the requirements of the detail standard:

- Consistency - Areas of higher or lower sensitivity
- Wet Tensile Strength
- Folding
- Uniformity - Visible Defects

3.1.5 At least three different types of paper shall be evaluated at the same time for test results to be considered valid.

3.1.6 Any single unusual condition encountered in testing a paper shall not be considered disqualifying until tests of additional paper of the same type substantiate the results.

3.2 Detail Requirements

3.2.1 A paper shall be considered satisfactory under this standard if each of the following conditions are met:

3.2.1.1 Paper must average satisfactory or better. Minimum score 50 points.

3.2.1.2 Paper must not score poor on test items A through E.

3.2.1.3 Paper must score satisfactory or better on at least five of the test items F through N.

4. METHOD OF TEST AND INSPECTION

The following tests will be performed in the manner indicated with each paper tested assigned a point rating for each test item. Results will be entered on the rating sheet and summarized as indicated.
GROUP I

Rating: Excellent - 10 Satisfactory - 5 Poor - 0

(A) Resolution - Using a standard test master film positive run representative prints from all samples. Examine prints for separation of details.

(B) Latitude -- Using a standard test master determine speed range over which each sample produces acceptable print. (Degree of latitude to be recorded for comparison purposes.)

(C) Contrast -- Ease with which image may be distinguished from background. Judge in terms of readability.

(D) Density -- Using a standard densitometer, check for maximum density on the basis of a standard test neg run at 20 f.p.m. on blueprinter or fully developed blank sheet on diazo.

(E) Trimming, Folding & Handling Qualities

Trimming, folding and handling qualities will be evaluated and rated by experienced personnel.

GROUP II

Rating: Excellent - 8 Satisfactory - 4 Poor - 0

(F) Printing Speed

Operating at the speed most useful on a particular machine. Obtain the best print (determined at time of testing) from each sample using standard vellum.

(G) Bleeding -- Examine prints run from test negatives for bleeding.

GROUP III

Rating: Excellent - 6 Satisfactory - 3 Poor - 0

(H) Curl -- Observe extent of curling after processing normally.

(I) Hue -- Compare standard master color wedges with color of emulsion after exposure and development.
(J) **Color Quality of White Paper Stock**

Compare standard master color wedges with paper samples before and after processing. Grade best print of each sample.

**GROUP IV**

Rating: Excellent - 4  Satisfactory - 2  Poor - 0

(K) **Cracking & Brittleness**

Make several sharp folds in each sample with normal wood folding paddle. Examine for cracking or weakening.

(L) **Tear Resistance**

Trim samples in normal manner, grade according to tear resistance.

(M) **Striking Through**

Note discoloration on back of unprinted paper due to "strike through" of coating. Examine finished prints for "striking through" of color, and for color along back and edges.

(N) **Finish (Texture)**

Feel and observe printed samples for smoothness and texture.
APPENDIX II

REPRODUCTIONS COST RECORDS

SCHEDULE 1

ESTIMATED REPRODUCTIONS COSTS PER UNIT

<table>
<thead>
<tr>
<th>Method</th>
<th>Cost per square foot, roll size print</th>
<th>Cost per square foot, including cut size</th>
<th>Cost per B size print</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blueprint</td>
<td>$0.018 per sq. ft.</td>
<td>0.025 per sq. ft.</td>
<td>0.05 each</td>
</tr>
<tr>
<td>Whiteprint</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Offset print</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Setup cost per B size master</td>
<td>$0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Run cost per B size print</td>
<td>$0.005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Per print cost B size, 55 each basis</td>
<td>0.006 each</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrostatic master</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost per B size offset master</td>
<td>0.20 each</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Half size intermediate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost per square foot of negative</td>
<td>0.35 per sq. ft.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost per square foot, commercial service</td>
<td>0.83 per sq. ft.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrostatic print</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost per square foot, purchased machine</td>
<td>0.0196 per sq. ft.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost per square foot, leased machine</td>
<td>0.0237 per sq. ft.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microfilm, continuous</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost per roll drawing</td>
<td>0.36 each</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\( ^a \) See Schedules 2, 3, 4, and 5 for detailed development of typical or representative unit costs. Unit costs for other methods of reproduction are developed by use of similar techniques and records.

\( ^b \) This figure does not include the cost of the offset master, as that is listed as a separate item. The print cost is partially fixed (setup cost) and partially variable (run cost) and thus decreases as the number of copies run per master increases.
### SCHEDULE 2

#### TYPICAL MONTHLY BLUEPRINT COST SUMMARY

<table>
<thead>
<tr>
<th>Labor</th>
<th>Units</th>
<th>Cost/Unit</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight time(^a)</td>
<td>1056 hrs.</td>
<td>2.30</td>
<td>$2,429</td>
</tr>
<tr>
<td>Overtime hours(^a)</td>
<td>321 hrs.</td>
<td>3.45</td>
<td>1,107</td>
</tr>
<tr>
<td>Indirect(^b)</td>
<td></td>
<td></td>
<td>554</td>
</tr>
</tbody>
</table>

**Total labor cost**

<table>
<thead>
<tr>
<th>Materials(^c)</th>
<th>Units</th>
<th>Cost/Unit</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper</td>
<td>343 rolls</td>
<td>35.00</td>
<td>12,005</td>
</tr>
<tr>
<td>Tape</td>
<td>4 rolls</td>
<td>5.00</td>
<td>20</td>
</tr>
<tr>
<td>Developer</td>
<td>10 bags</td>
<td>15.00</td>
<td>150</td>
</tr>
<tr>
<td>Paste</td>
<td>3 jars</td>
<td>5.00</td>
<td>15</td>
</tr>
</tbody>
</table>

**Total materials cost**

**Fixed costs and overhead\(^d\)**

| Total monthly cost in-plant | 16,841 |
| Supplier blueprint cost     | 12,704 |
| **Total blueprint cost for month** | 29,545 |

**Cost per square foot, roll drawing**: $0.018.

**Cost per square foot, cut drawing**: $0.025.

\(^a\) Obtained from weekly personnel records.

\(^b\) This figure represents the fixed labor cost of supervision, lead personnel, and stock clerks and is re-evaluated annually.

\(^c\) Obtained from inventory control records.

\(^d\) See Schedule 6.
SCHEDULE 3

ESTIMATED MONTHLY HALF SIZE CAMERA OPERATING COST\textsuperscript{a}

<table>
<thead>
<tr>
<th>Labor</th>
<th>Units</th>
<th>Cost/Unit</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight time</td>
<td>66 hrs.</td>
<td>2.40</td>
<td>$158</td>
</tr>
<tr>
<td>Indirect</td>
<td></td>
<td></td>
<td>353</td>
</tr>
<tr>
<td>Total labor cost</td>
<td></td>
<td></td>
<td>511</td>
</tr>
</tbody>
</table>

Material

<table>
<thead>
<tr>
<th>Material</th>
<th>Units</th>
<th>Cost/Unit</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Film negative</td>
<td>46 rls.</td>
<td>32.00</td>
<td>1,472</td>
</tr>
<tr>
<td>Developer</td>
<td>6 pkgs.</td>
<td>10.00</td>
<td>60</td>
</tr>
<tr>
<td>Fixer</td>
<td>6 pkgs.</td>
<td>17.60</td>
<td>106</td>
</tr>
<tr>
<td>Acetic Acid</td>
<td>4 btls.</td>
<td>1.90</td>
<td>8</td>
</tr>
<tr>
<td>Lamps</td>
<td>12 each</td>
<td>1.60</td>
<td>19</td>
</tr>
<tr>
<td>Tape</td>
<td>2 rls.</td>
<td>6.20</td>
<td>12</td>
</tr>
</tbody>
</table>

Total materials cost 1,677

Fixed costs and overhead\textsuperscript{b} 243

Total monthly cost 2,431

Cost per square foot of negative: $0.35

\textsuperscript{a}Estimated on the basis of 42 roll drawings per day, 22 days per month.

\textsuperscript{b}See Schedule 6.
## Schedule 4

**Estimated Monthly Electrostatic Half Size Print Cost**

<table>
<thead>
<tr>
<th>Labor</th>
<th>Unit</th>
<th>Cost/Unit</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight time</td>
<td>858 hrs.</td>
<td>2.40</td>
<td>$2,059</td>
</tr>
<tr>
<td>Indirect</td>
<td></td>
<td></td>
<td>823</td>
</tr>
<tr>
<td><strong>Total labor cost</strong></td>
<td></td>
<td></td>
<td>2,872</td>
</tr>
</tbody>
</table>

**Material**

<table>
<thead>
<tr>
<th>Material</th>
<th>Unit</th>
<th>Cost</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Print paper</td>
<td>107 rolls</td>
<td>15.00</td>
<td>1,605</td>
</tr>
<tr>
<td>Toner</td>
<td>2 cans</td>
<td>142.00</td>
<td>284</td>
</tr>
<tr>
<td>Developer</td>
<td>2 drums</td>
<td>236.25</td>
<td>473</td>
</tr>
<tr>
<td>Cores</td>
<td>1/2 box</td>
<td>10.00</td>
<td>5</td>
</tr>
<tr>
<td>Drum</td>
<td>1 each</td>
<td>750.00</td>
<td>750</td>
</tr>
<tr>
<td><strong>Total material cost</strong></td>
<td></td>
<td></td>
<td>3,117</td>
</tr>
</tbody>
</table>

**Fixed cost and overhead**, purchased machine<sup>b</sup> 1,497

**Fixed cost and overhead**, leased machine<sup>b</sup> 3,052

**Total operating cost**, purchased machine 7,486

**Total operating cost**, leased machine 9,041

**Cost per square foot**, purchased machine: $0.0196

**Cost per square foot**, leased machine: $0.0237

---

<sup>a</sup>Estimated on the basis of 42 roll drawings per day, 22 days per month.

<sup>b</sup>See Schedule 6.
<table>
<thead>
<tr>
<th>Labor</th>
<th>Unit</th>
<th>Cost/Unit</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight time</td>
<td>33 hrs.</td>
<td>2.40</td>
<td>$ 80</td>
</tr>
<tr>
<td>Indirect</td>
<td></td>
<td></td>
<td>59</td>
</tr>
<tr>
<td>Total labor cost</td>
<td></td>
<td></td>
<td>139</td>
</tr>
<tr>
<td>Material</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Film &amp; processing materials</td>
<td>924 ft.</td>
<td>.00</td>
<td>7</td>
</tr>
<tr>
<td>Fixed cost &amp; overhead</td>
<td></td>
<td>185</td>
<td></td>
</tr>
<tr>
<td>Total operating cost</td>
<td></td>
<td></td>
<td>331</td>
</tr>
</tbody>
</table>

Cost of microfilm per roll drawing: $0.36

---

*a* Estimated on the basis of 42 roll drawings per day, 22 days per month.

*b* See Schedule 6.
<table>
<thead>
<tr>
<th>Equipment</th>
<th>Approx. Capital Cost</th>
<th>Interest Cost of Capital&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Depreciation&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Taxes&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Maintenance&lt;sup&gt;d&lt;/sup&gt;</th>
<th>General Area &amp; Utilities&lt;sup&gt;e&lt;/sup&gt;</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blueprinter</td>
<td>$16,500</td>
<td>$48</td>
<td>$56</td>
<td>$21</td>
<td>$68</td>
<td>$378</td>
<td>$571</td>
</tr>
<tr>
<td>Half size camera</td>
<td>25,300</td>
<td>74</td>
<td>74</td>
<td>36</td>
<td>10</td>
<td>49</td>
<td>243</td>
</tr>
<tr>
<td>Electrostatic camera</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Lease</td>
<td>3,000 per month</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>52</td>
<td>3,052</td>
</tr>
<tr>
<td>(2) Purchase</td>
<td>126,000</td>
<td>368</td>
<td>656</td>
<td>158</td>
<td>263</td>
<td>52</td>
<td>1,497</td>
</tr>
<tr>
<td>Microfilm camera</td>
<td>12,500</td>
<td>37</td>
<td>65</td>
<td>16</td>
<td>21</td>
<td>46</td>
<td>185</td>
</tr>
</tbody>
</table>

<sup>a</sup>The interest cost of capital is estimated at 3-1/2 per cent per annum.

<sup>b</sup>Depreciation is based on the expected economic life of the equipment.

<sup>c</sup>Taxes are estimated at 1-1/2 per cent of capital cost per annum.

<sup>d</sup>Maintenance cost estimate varies between 1/2 per cent and 5 per cent of equipment cost per annum.

<sup>e</sup>Area or space cost is estimated at $0.162 per square foot of floor space per month. Water and electricity consumption is based on machine ratings and anticipated operating hours.
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