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THE INTRODUCTION OF MICROFICHE FOR DISSEMINATING TECHNICAL INFORMATION IN THE UNITED STATES

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THE INTRODUCTION OF MICROFICHE

FOR DISSEMINATING TECHNICAL INFORMATION IN THE UNITED STATES

ABSTRACT N66-37272

The development of an economical, reproducible, and convenient flat microfilm format that can be used and enlarged on existing equipment is described. The microfiche format, virtually unknown in this country in 1961, was selected as the most feasible means of meeting NASA's specifications for an easily read microform unit that comprised a single report and permitted reproduction of both additional copies of the microform and original size reproductions of the report. Production of a 5 x 8 microfiche was initiated for NASA in 1962. Factors leading to the selection of size and reduction ratios, the use of diazo film as the sensitive medium, and the standardization of the microfiche format are discussed. The evolution of camera modifications, film processing, and make-up techniques for quantity production is described. Although there are still some technical problems remaining, the NASA Scientific and Technical Information Facility produced over 5 million high-quality microfiche of reports in 1965. The adoption of the 105 x 148 mm microfiche format standard by government and industry insures its continued, expanded use and provides a ready market for developers of microfiche equipment.

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INTRODUCTION

The history of microphotography is full of surprises. Not the least of these is the age of the art. The first microphotograph was made 125 years ago, within a few months of the announcement of the Daguerre process. Equally astonishing is the fact that World War II's V-Mail has a 70-year-old ancestor in microfilmed messages flown (by pigeon) into the besieged city of Paris during the Franco-Prussian War. But the most remarkable thing about microphotography is not so much what has been done as what has not. One of the earliest applications suggested for microfilm was the pocket library. What a boon for the scholar or the scientist to have a complete reference library at his fingertips wherever he might be! Unfortunately, although this idea has been reannounced with great fanfare a dozen times in the last hundred years, the "microlibrary" has never become quite the commonplace that its various proponents have predicted. Curiously, the lack of equipment or materials has never stood in the way—the technology required to produce books in microform was reduced to practice over a century ago.

Nevertheless, until 1928 when the Library of Congress began its microfilm program, microfilm was little more than a laboratory curiosity, and it was another decade before any serious effort was made to publish, rather than store, in microform. In 1939, almost simultaneously, the Readex Microprint Corporation was founded in New York, and the Mikrokopie-Verlag was established in Mainz to publish microform. But even then, the emphasis was on making available publications or collections which were out of print or otherwise hard to get. Some wartime experiments in microcopy dissemination of current information - notably the Army Medical Library Program - ended with the emergency.

Finally, in 1952, nearly a hundred years after the first documented suggestion, a continuing, organized program of disseminating current information in microform was started by the Atomic Energy Commission. Under this program, current technical reports were reduced to Microcards (3 x 5", opaque positive photographic prints on card stock, approximately 30 pages per card) and distributed to AEC contractors and affiliates. This was a start, but only a start. The same technique was tried by the Armed Services Technical Information Agency (now Defense Documentation Center) and abandoned in favor of filmstrips supplied on demand. The Department of Commerce's Office of Technical Services (now Clearinghouse for Federal Scientific and Technical Information) also stayed with roll film. Microcopy of current information was available but its use was still not widespread.

Much could be written about the failure of microforms to "catch on," but the purpose here is to establish the climate in which a virtually unknown (in this country at least) microform format was selected for disseminating the information gathered by NASA's Scientific and Technical Information Facility (hereafter referred to as the Facility). In 1961, almost everything available in microform was on roll film (the AEC material being the only exception of any significance). There were many experimental installations (e.g., Minicard, Walnut, FOSDIC, etc.) either proposed or being tested, but the only development in the previous decade which had had any real impact on the industry was the adoption by the Department of Defense of aperture cards for microfilmed engineering drawings. Except for the standards imposed by this program, there were no widely accepted standards on format, orientation, image size, reduction ratios, or blowback magnifications - every system had its own peculiar combination.

This was the situation when NASA issued a Request for Proposal (RFP) calling for the production of an economical, reproducible, convenient microform which could be used and enlarged on existing equipment. The RFP further prohibited any "major equipment development". This paper describes how this challenge was met.

REQUIREMENTS AND DESIGN

The type of microform to be used was not specified, but the requirements and the results of an end-use study substantially dictated the choice. The requirements were ". . . an easily read microform unit that comprises a single report. The microform unit will permit the distribution and filing of each report as a separate item, the economical reproduction of additional copies of the microform, and the economical reproduction of original size copies from the microform."

Style

The selection of style was easily arrived at by a process of elimination. The unit-record concept eliminated reels of film. The requirement of economical reproduction and blowback eliminated the micro-opaques. Unit-record microtransparencies are aperture cards, film strips in cassettes, film strips in jackets, and microfiche. Aperture cards are designed for engineering drawings, and in available formats the average report would require a dozen or more cards—hardly a unit-record in this application. A study of end-use requirements indicated the need for filability, retrievability and browsability. These needs effectively eliminated cassettes. Finally, the necessity that the microform itself be readily reproducible, both in the Facility and in the field, eliminated the jackets, leaving the microfiche as the logical choice.

Size And Reduction Ratio

Size and reduction ratio are interdependent factors. From the standpoint of the unit-record concept, the microfiche had to be large enough, ideally, to accommodate any report entering the system, but, since reports may vary from half a dozen to thousands of pages, economic considerations dictated a compromise. From the same point of view, the reduction ratio had to be as great as possible, in order to accommodate the maximum number of pages per unit, but, again, economic considerations and the requirements that it be easily read and blown back to full size with available equipment, dictated compromise.

A study of existing equipment, which also took into account the image degradation that could be expected through two or three generations of microform reproduction, indicated that the optimum reduction from which adequate blowbacks could be obtained was in the neighborhood of 15 to 1. Considerations of the equipment to be used as the NASA Facility for blowback led to the selection of a reduction ratio of 15.5 to 1.

Two factors governed the choice of size. Available filing equipment limited size to the choice of 3" x 5", 4" x 6", tab card (3-1/4" x 7-3/8") or 5" x 8". The selection among these was made on the basis of estimates of the size of the reports to be microformed. These estimates indicated that the average size of reports would be about 50 pages and that 90% of the reports were less than 100 pages. Applying a normal distribution curve to these two points, it was determined that the 3 x 5" and tab card sizes would permits only 31% and 53%, respectively, of the documents to be included on a single card, whereas the 5 x 8" size would hold 80% of the documents on a single card, and almost all of the remainder on two cards. In keeping with the unit record concept, the 5 x 8" size was selected because it was felt that the cost of unused image space would be partially offset by the reduced production and handling costs of fewer cards and that the increased convenience to the user of having fewer trailer cards to file was worth more than the remaining difference. This conservative choice was fortunate. While the estimates were reasonably valid for the NASA material entering the system, they were low for the non-NASA material which forms a substantial part of the input. Our experience has been that the average number of pages for all documents photographed is about 70. Fortunately, however, the size of documents entering the system does not follow a normal distribution pattern, so that during the first year, for example, 75.3% of the documents filmed were accommodated on a single microfiche, which is not too far below the original goal of 80%.

Medium

The requirement for economical reproduction of original size copies from the microform led to the choice of negative, rather than positive images, since generally, the negative is the preferred form for printers. The parallel requirement for economical reproduction of the microform led to the choice of diazo for the sensitive material because diazo materials do not reverse the image (negative to positive or vice-versa) as silver halide emulsions do, and this property eliminates unnecessary generations. An added value in the use of diazo is that in diazo material, the sensitive material is not a coating, but rather an intrinsic part of the base material, so that it is far more scratch-resistant than conventional photographic material.

The use of diazo, however, did present a problem in contrast ratio. At the time of the Facility start-up, most diazo applications were for line copy, and consequently, the materials had extremely high contrast ratios. While these would produce extremely good line copy, they were unsuitable for continuous tone photographs and similar material.

The Facility prepared specifications for a diazo film suitable for microfiche and submitted them to Ozalid Division (General Aniline and Film Corporation). After several groups of samples had been submitted and tested, a material was produced which, although slower than required by the specifications, was adequate for beginning production. Over succeeding months continuing efforts were made by the Facility, Ozalid, and other organizations to improve the quality of the diazo film, culminating in the production of the material in current use.

Format

An example of the initial format of the microfiche is shown in Figure 1. This format provided for 6 rows of 6 double-image frames on each fiche, or a maximum of 72 page images. However, the first two frames of the first card were reserved for a target image containing the accession number, the document security classification, and the distribution code, and for a poor-copy statement when the original document was not sufficient quality to produce good micro-images. Further, when it would not result in the use of an extra card, an end target followed the last page.

A masthead readable with the unaided eye permitted easier filing and provided for browsability of the microfiche files. This masthead included the accession number in large, bold type, followed by the document title, originator's report number, the classification, the distribution code number, and the card and number of cards identification (Card 1 of 3, 2 of 3, etc.). An opaque white backing was applied behind the masthead on distribution copies to make it legible when filing. To facilitate identification of some material processed, microfiche of documents announced in CSTAR (Classified Scientific and Technical Aerospace Reports) had a colored strip added to the extreme right end of the masthead—blue for Unclassified, green for Confidential, and red for Secret.

Analytics. Shortly after the beginning of production, the Facility encountered a problem in dealing with analytics. These are documents, such as symposium reports, conference proceedings, etc., which are collections of individual papers which may be on different subjects. For greater selectivity of retrieval, these are frequently "broken up" for announcement and indexing. Normally, an accession number is assigned to the document as a whole and then following accession numbers are assigned to each paper. At first, each paper was made into a separate microfiche, but since they were generally much shorter than the average document, this was wasteful of time and materials. Further, a problem was created in attempting to fill requests for the entire document, since there was no microfiche with that number. Very quickly, the Facility adopted the policy of filming such documents as a whole, showing the "Mother" number on the masthead and beginning target and inserting an additional target with the specific accession number before each of the articles or papers in the collection. Currently, the masthead shows the accession numbers of both the "Mother" item and the last item in the document.

Fold-Outs. A second problem which did not lend itself to easy solution was the problem of fold-out pages. An 11" x 17" fold-out presented no real problem and even longer foldouts could be handled fairly readily as long as the height did not exceed 11". However, when a fold-out exceeded normal page size in both dimensions, there was a serious problem. If a great enough reduction were applied to bring the page within the normal double-page image area, existing readers and printers could not enlarge it sufficiently to make it usable, even if the resolution of the micro-image were adequate to define the detail. On the other hand, if the reduction ratio was kept constant, special processing would be required to strip up the microfiche, and existing equipment could not handle the image size to permit study or blowback of the image as a whole. A similar problem occurred when a standard size page incorporated an image—such as a computer print-out—which had already been reduced several diameters in the printing of the document. The Facility experimented with several techniques, including photographing large pages in overlapping sections, with mixed results. Currently, in order to comply with the Federal Microfiche Standards, the Facility cuts fold-outs to page size and photographs the sections in sequence.

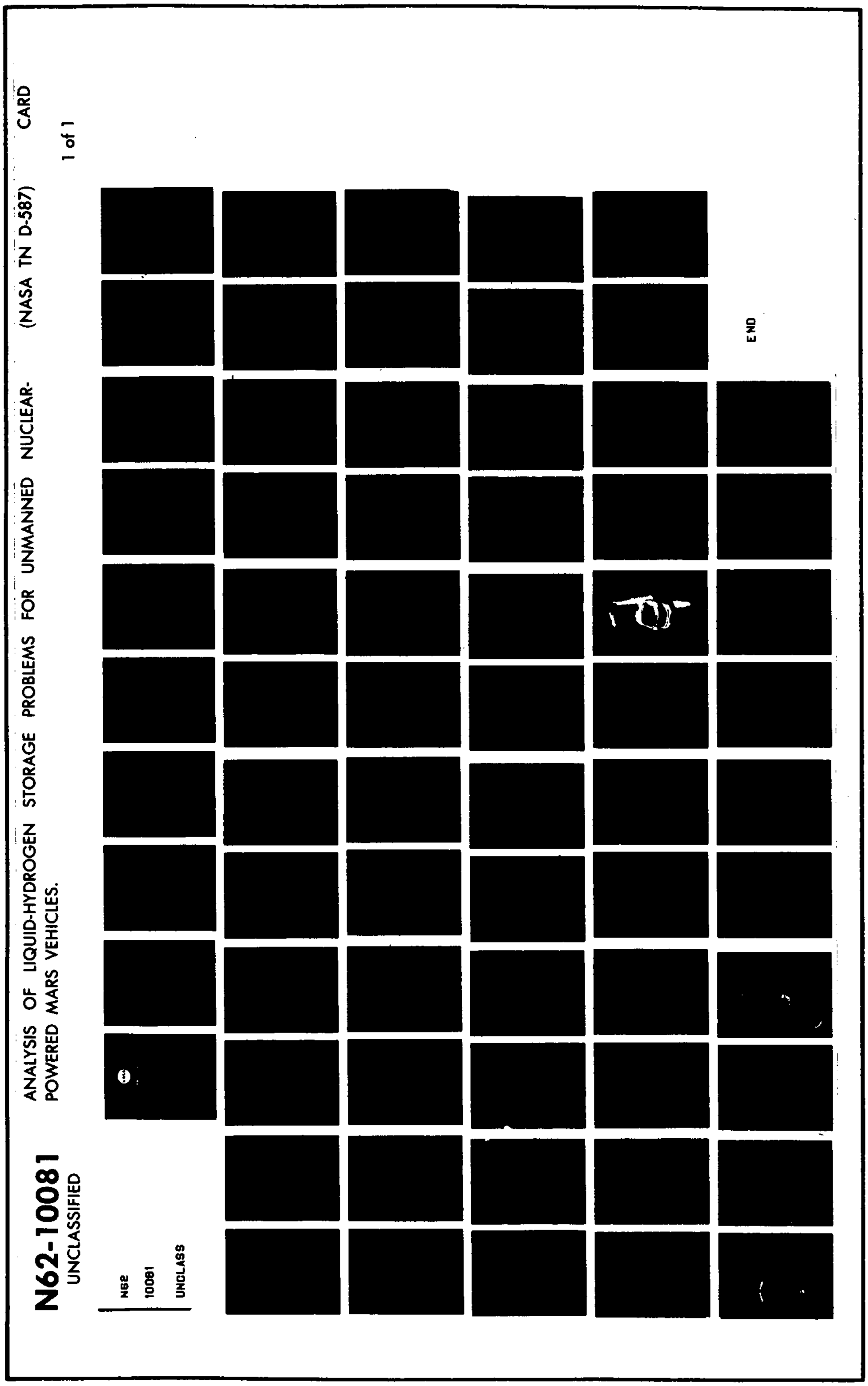


Figure 1. Initial Format of NASA Microfiche (Shown Actual Size)

STANDARDIZATION

Within a year after the initiation of the microfiche program, its impact began to spread. AEC began offering both the opaque positive microcard and the transparent negative microfiche, and NASA and AEC agreed on a standard reduction ratio of 18 to 1 and a standard image size of 16-1/2 mm by 23-1/2 mm (center-to-center, two page double frame). By this time, the Facility had had sufficient experience with the 15.5-to-1 reduction ratio, so that it was felt (and later demonstrated) that the possible loss in resolution from the higher reduction ratio would not be sufficient to compromise the original requirements. The new standard provided several benefits to the Facility program. The reduction in image size permitted the addition of twelve more page images for a total capacity of 84, and the image spacing left a transparent border between image rows, permitting the addition of image numbers readable with the unaided eye under each image position. This made much easier the identification of page images for blowback or return reference. Coincident with the adoption of the 18 to 1 reduction ratio, the Facility added to the end target the date the document was filmed. Figure 2 is an example of this format.

The initial agreement between AEC and NASA provided a basis for the National Microfiche Standards Conference held by the National Microfilm Association in Washington, D.C. in September, 1963. The development of standards for an article so soon (barely 16 months) after its introduction is uncommon, but there was strong impetus behind the movement. First, there was the widespread acceptance of the logic upon which the choice of microfiche for the NASA requirement was based. More impelling was the recognition that further extension of microfiche applications depended upon the availability of better equipment for production and use, but before manufacturers could—or would—design and build such equipment, they must be assured of a wide market by the existence of accepted standards.

There was a remarkable unanimity among the 40-odd government and industry representatives participating in each of the four subcommittees of the conference. The extent of this accord is demonstrated by the almost immediate publication—and acceptance—of the standard.

The standard (NMA Standard M-1-1963) provided for all four of the card sizes (3" x 5", 4" x 6", 5" x 8", and 3-1/4" x 7-3/8") in general use, but in the spring of 1964, the four major report-producing agencies (NASA, DOD, AEC and Commerce) agreed on a common card size, selecting the 105 mm x 148 format (approximately 4" x 6"), which was smaller than the 5" x 8" being used by NASA, but larger than the 3" x 5" used by AEC.

This format provided a masthead and 60 page images on the first fiche for a document, but for unclassified documents eliminated the masthead on the second and following fiche, providing space for an additional 12 images. Classified microfiche had an abbreviated masthead and 60 images on all follower fiche. To compensate for the lack of a masthead on follower fiche, these agencies agreed to reserve the first image area on each follower fiche for an additional eye-legible target image carrying the accession number, card number, classification, distribution code, and the subject category. On all fiche, the second image area was left blank to permit other agencies to insert their own identification in anticipation of a fully-coordinate microfiche program, wherein the filming of the same documents by several agencies would be eliminated. The one exception

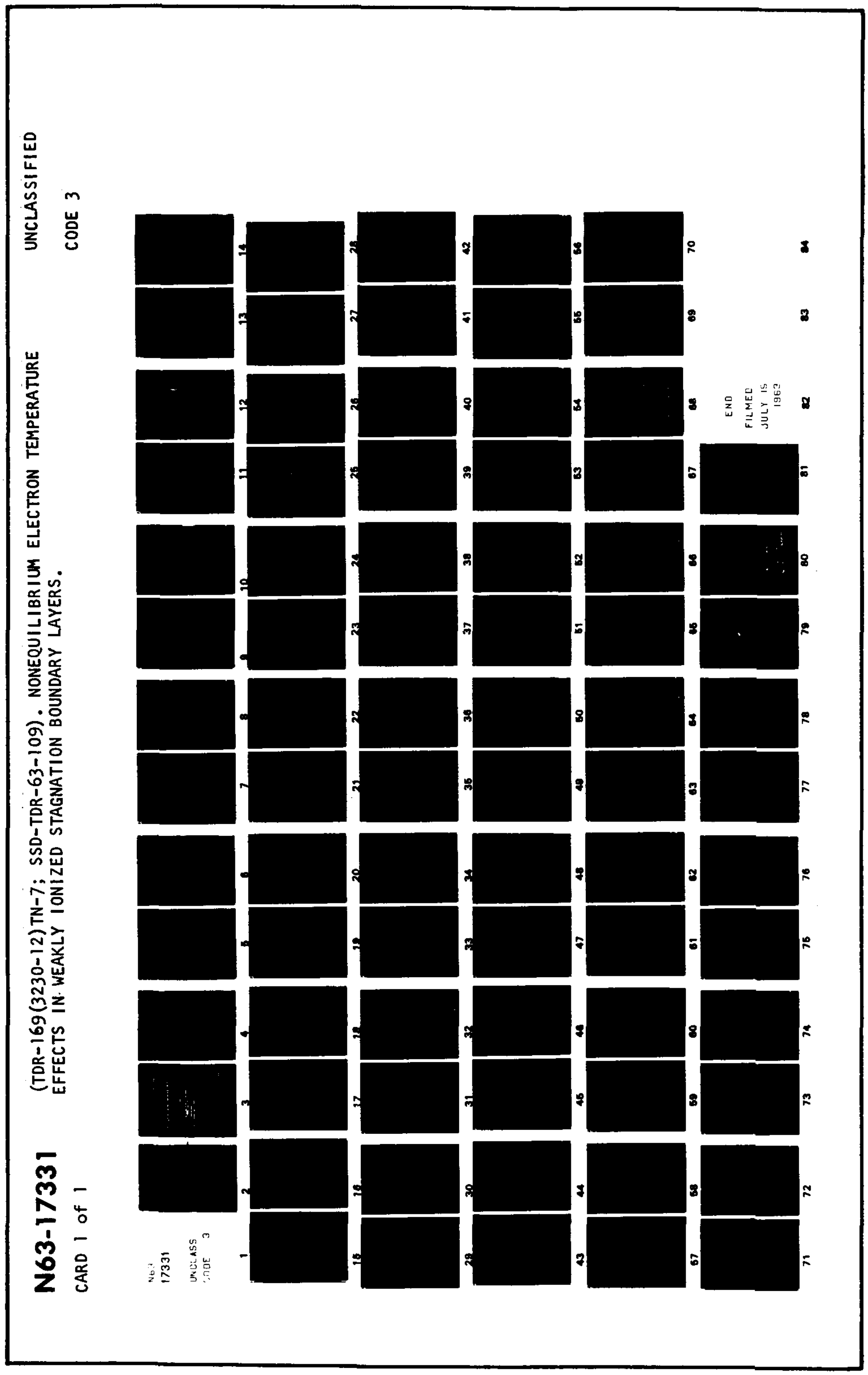


Figure 2. First Intermediate Format of NASA Microfiche (Shown Actual Size)

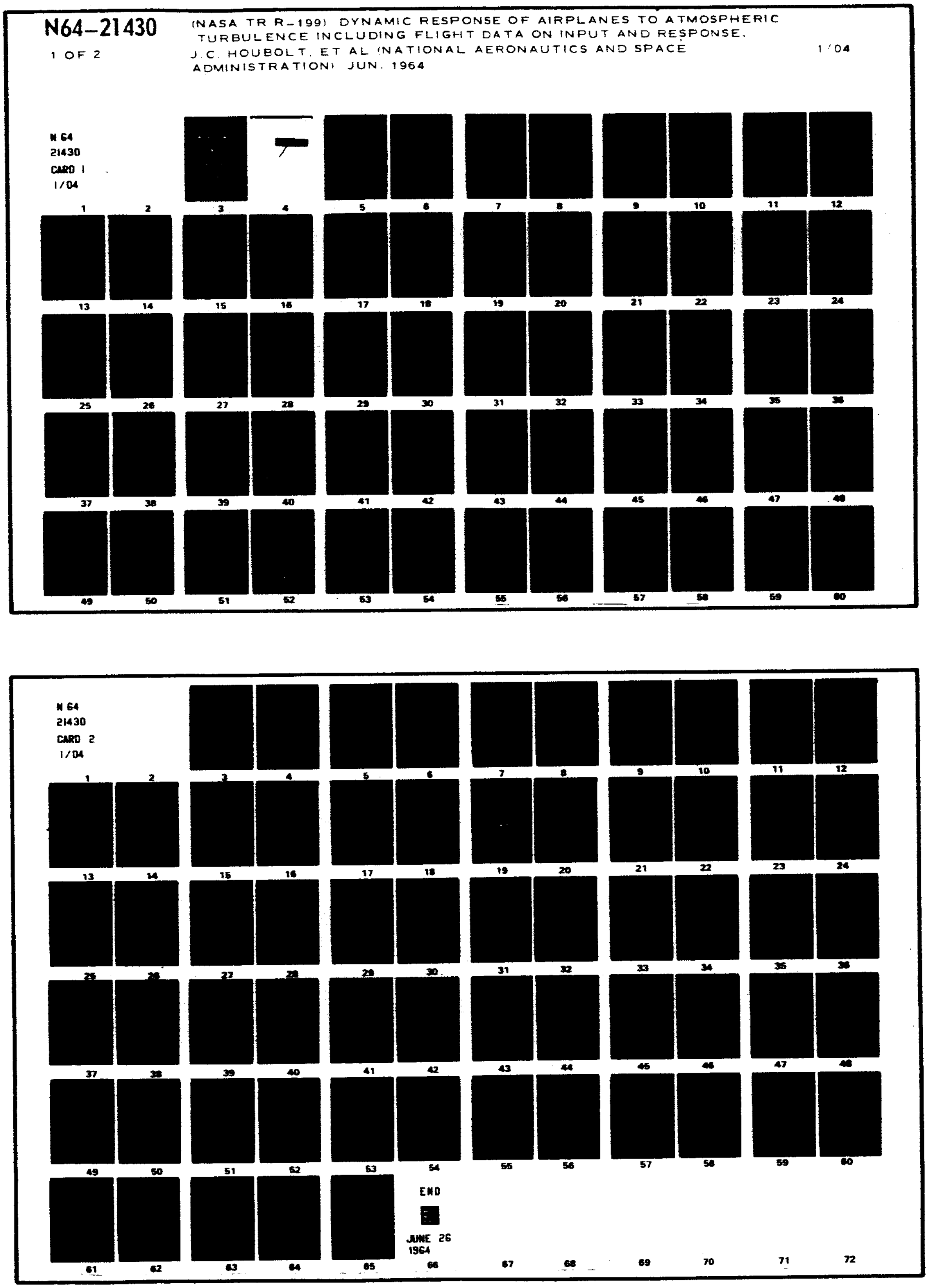
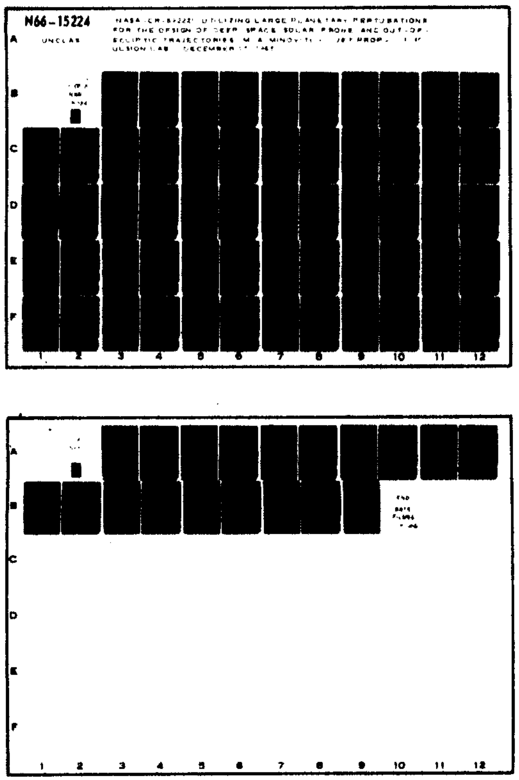


Figure 3. Second Intermediate Format of NASA Microfiche (Shown Actual Size)

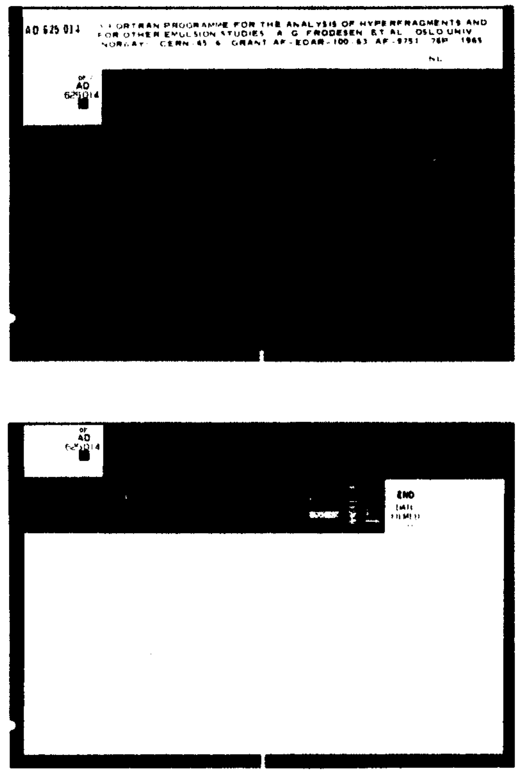
made by the agencies to the NMA standard was the omission of a "continued" target as the last image on a fiche which has a follower. Figure 3 is an example of this format.

The Facility began production in the new format in the summer of 1964, AEC, DOD, and the Clearing House for Federal Scientific and Technical Information (CFSTI) began later. Their combined annual production of over 10,000 microfiche in a single format and reduction ratio had a significant effect upon the microreproduction industry, but this was not the end of the standardization effort.

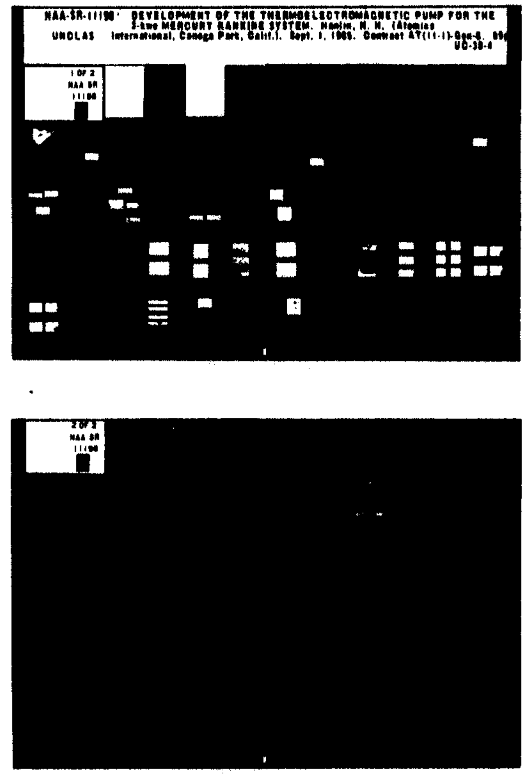
An ad hoc microfiche committee of the Committee on Scientific and Technical Information (COSATI) continued standardization efforts, culminating in the publication of Federal Microfiche Standards (Department of Commerce Publication PB 167 630) in September 1965. The implementation of these standards (which actually took place several months before publication) made the microfiche of the four major report producing agencies of the Federal Government truly interchangeable. Figure 4 shows microfiche produced to the Federal Microfiche Standards by NASA, AEC, and CFSTI.



NASA Microfiche



DOD Microfiche (Prepared by CFSTI)



AEC Microfiche

Figure 4. Microfiche Prepared in Accordance with Federal Microfiche Standards (Approximately 4 x 6 inches)

PRODUCTION—PHASE I

The discussion of microfiche production at the Facility can be divided into two distinct phases. Phase I, or the start-up phase, describes the Facility's efforts to achieve volume production of microfiche with equipment designed to do something else. Phase II, or the coming-of-age phase, describes the new equipment that is being phased in, now that wide acceptance and standardization have made possible, and practical, the development and production of equipment designed specifically to produce microfiche.

After determining that diazo microfiche was the appropriate medium for meeting the microform requirements, the Facility faced the problem of developing a system for producing them in the required quantity. Although there had been some low-volume production of microfiche in Europe (mostly positive and all silver), microfiche was almost unheard of in this country. Consequently, there was no equipment specifically developed for the production of microfiche. With both the schedule and the terms of the request for proposal prohibiting major equipment development, the problem became one of adapting equipment that did exist to the production of microfiche. The following is a description of the Facility's efforts in that direction.

Cameras

An obvious camera for producing a microfiche would be a step-and-repeat device, employing strip film as wide as one dimension of the microfiche and an automatic optical system to place the page images on the film in the required format. However, at the time, there was no camera available which would produce the reduction ratio, image placement, and total size necessary to meet the Facility's requirements. Further, because all of these are interrelated factors, the production of a camera to meet the Facility's needs would have involved a completely new design, rather than a modification. Therefore, a standard 35 mm roll microfilm camera (Recordak MRD) was selected.

The choice of 35 mm rather than 16 mm was initially necessary because a 15.5 reduction of an 11-inch page produced an image 18 mm high. The 35 mm size was retained after conversion to 18 to 1 for a number of reasons:

(a) To provide space for the image numbers, it was necessary to reduce the image by masking out the page margins. This resulted in a 14.5 mm image, and there is no practical way to remove 0.75 mm strips from each side of 16 mm film on a production basis.

(b) By this time, there was a requirement that the original roll film be duplicated as a back-up roll, and for possible use in future automatic retrieval systems.

(c) The use of 35 mm film virtually eliminated problems of edge-fogging and interference from manufacturer's trademarks which are normally impressed on the edges of the film.

Film Advance. Initially, only one modification to the basic camera mechanism was felt necessary, and this was the film advance. Normally, film advance ratchet gears have a great many points, closely spaced. Since most microfilm cameras are made to handle a variety of formats, this is necessary to permit variations in film advance. For microfiche, however, where several strips would be adjacent, it was felt that these errors could cumulate and would not only result in poor appearance, but would adversely affect any future attempts to develop automated blowback equipment. Therefore, at the Facility's request, the manufacturer modified the ratchet, reducing the number of points to provide only the advance required for the reduction ratio and format chosen.

External Shutter. Since roll film was to be stripped up to form microfiche, it was necessary to leave several blank frames between each set of six double-page images (one row) to provide for cutting and mounting. It was necessary that these frames be unexposed, but, unfortunately, there was no provision for advancing the film without opening the shutter. Initially, the operator had to count six image exposures and then hold a piece of cardboard in front of the lens while he tripped the shutter to advance the film. To eliminate this obviously inefficient procedure without major modifications to the cameras, the Facility devised and built an external shutter. This is simply a solenoid-operated metal gate which swings across the camera aperture when the operator presses a button. With this modification, the operator simply presses a button and trips the shutter the number of times required to produce the skip.

Camera Control System. This system proved satisfactory until the conversion to the 105 x 148 mm format. With the addition of a requirement for an accession number target in the first frame of each follower fiche, it became necessary to keep track not only of the number of exposures per row, but the number of rows exposed so that the target could be photographed in the appropriate place. This was further complicated by the fact that follower cards for unclassified microfiche had an additional row of images. Recognizing that operators could not be expected to perform this double count mentally, the Facility designed a dual counter system to count both exposures and rows and signal the operator when a follower target must be inserted.

Dual Counter. The counter is a relatively simple combination of stepping switches. Each time the shutter is tripped, an electrical pulse from the camera circuitry is used to actuate the primary counter. When the count reaches six (12 page images), the row counter is advanced one, and the external shutter closes and the shutter and film advance operate the number of times required for the skip. When the row count reaches five, the external shutter closes as before, and a signal light goes on. This light remains lit through the skip and until another image is photographed. For the second fiche, the image and row counts proceed as for the first, except that the row count is controlled by a two-position switch so that the signal will light after either six rows have been exposed (unclassified document) or after five rows (classified or restricted document). The pattern continues until the entire document has been filmed. The operator then films the end target, closes the external shutter with a manual control, completes the row and inter-document skip, and resets the counter with a push button. This device not only prevented operator counting errors, but made possible increased production rates.

Exposure Control. Quality microfilming requires precise exposure control, and there are two major variables which affect exposure settings. First, there are variations in sensitivity between batches of film produced at different times, and second, the flood lights used to illuminate the material being filmed lose brightness as they age. To provide for illumination control, the MRD cameras are supplied with an exposure meter mounted on an arm which allows it to be swung over the material being photographed to measure the reflected light. However, since the readings taken in this manner are affected by the amount and density of the print on the page, inaccuracies can be introduced. To eliminate this problem, the Facility removed the arm and mounted the exposure meter on the camera pedestal over a standard target. The readings at which the best micro-images are produced are determined by a standard calibration routine for each batch of film received, and the lights adjusted accordingly. Continuous monitoring of the exposure meter reading is provided by a dial visible to the operator at all times.

Aperture Change. Increasing workloads imposed the requirement for increased productivity at the same time that the conversion to 18 to 1 and the use of image numbers imposed requirements for greater precision and made the photography operation more difficult. The reduction of the photographed area to accommodate frame numbers made it necessary to overlap the edges of adjacent pages to get the text within the horizontal dimension of the image area. Maintaining separation of page images could be accomplished by laying a black strip on the easel, and sliding the pages under it, but this slowed down the photography significantly. To avoid this problem, the adjustable apertures, with which the cameras were supplied, were replaced by a precision-machined, fixed aperture with a cross member across the center to blank out a vertical section between the adjacent pages. At the same time, the camera was pinned on the pedestal at the exact height required to produce an 18-to-1 reduction, and the lens was disconnected from the focusing ratchet and precisely adjusted. To compensate for the loss of flexibility entailed in these modifications and to provide for the increasing workload, a third camera (Recordak Microfile D-2) was procured. This camera was used for photographing odd-size documents and documents with fold-outs where separation of double-page image area was not required. When required, separation was accomplished on this camera by a flexible metal strip with a dull black surface.

Film Processing

The only unmodified standard equipment used in the microfiche production cycle for the first four years was the film processor (Remington-Rand, Unipro, Model F). This is a variable-speed device which permits balancing processing time with water temperature and chemical concentration to achieve the best possible grain structure in the developed film for better resolution and image quality.

Make-Up

In approaching the problem of stripping the film into microfiche format it was necessary to start from scratch. There was simply nothing available which could be modified to do the job.

Slitting. The first task was removing the excess of the 35 mm film from the 18 mm page image. To accomplish this on a production basis, the Facility had a pair of matching offset rollers specially machined. The film was fed between the rollers, and their scissor-action quickly and accurately sliced off the excess film as the trimmed images were wound on a take-up reel. Later, this fixed-distance device was replaced with two pairs of rollers (one pair for each edge) which were adjustable for both image size and placement on the film.

Stripping. The actual conversion of the roll film to microfiche begins with the stripping of the individual rows onto an acetate frame. This frame was simply a sheet of 7-1/2-mil acetate with an aperture in the center the size of the microfiche. Initially, each row was butted against the previous row to maintain horizontal alignment and the first image of each row was aligned against a ruled guideline on a blank microfiche fastened to the light table. The film was fastened to the frame by strips of double-sided pressure-sensitive tape. However, when it became necessary to leave space between rows for the image numbers, a jig was milled from transparent plastic to maintain both alignment and separation. On this jig, the guideline was ruled in the center and the separator line of the center exposure (seven double-page impages per row) was used as the reference line for the row. This distributed film advance errors equally to either side and improved the appearance of the fiche. With the adoption of the NMA standard in the 105 x 148 mm format, the guideline on the jig was replaced with a copy of the standard grid underneath the jig. This was precisely aligned with the channels in the jig to maintain vertical placement, and the operator adjusted the film horizontally to place all page images in the image areas of the standard. If all page images could not be properly placed, the film was rejected.

Mastheads. During start-up, the mastheads were set on film by the photocomposition machine used for the production of announcement journals. However, as workloads in both journal preparation and microfiche production increased, it became necessary to develop an alternate method. The first step was to have only the accession numbers set on the photocomposition machine and to prepare the rest of the masthead on white paper with an IBM typewriter. The numbers were stripped onto the sheets; the sheets were photographed; and a positive transparent print was made. The mastheads were then cut from the transparency and stripped onto the acetate frames.

With further increases in workloads, a means was sought for eliminating the multiple handling required by this process. For this purpose, a Varityper (which is capable of preparing copy in a number of different sizes and styles of type) was obtained. The mastheads are prepared on acetate drafting film which has a matte surface that will accept impressions from ordinary typewriter ribbon. While this material is translucent to visible light, it is effectively transparent to the ultraviolet used for producing diazo copies. Although the actual keying of the masthead information is considerably slower than with previous methods, the elimination of handling requirements resulted in a significant cost reduction and an even more significant improvement in schedule.

The installation of the Varityper adjacent to the stripping operation made it possible to hold the preparation of mastheads until stripping was completed, without introducing an inordinate delay. This was necessary because, as long as each card carried a masthead, the number of cards required had to be determined quite accurately so that the correct number of mastheads could be prepared and the total number of cards could be entered on each. Since there is no predictable ratio between the number of pages and the number of cards (because of such things as fold-outs, etc.) the accurate determination of the number of cards is difficult until they have been stripped.

The adoption of the NMA standard with only a single masthead reduced the requirement for accuracy to the point where mastheads could be prepared in advance, since an error in the number of cards now required only the correction of a single number on the one masthead.

Diazo Intermediates

In order to preserve the stripped-up silver master, and make volume production possible, it was necessary to prepare diazo intermediates which could be used in continuous flow machines. These intermediates were made by exposing a diazo fiche through the silver master in a vacuum-bed, point-source, plate maker, and developing it in a modified diazo processor.

It is in producing intermediates that the size of the aperture in the acetate frame becomes significant. Making the aperture the exact size of the fiche to be produced allows the diazo intermediate to be exposed in direct contact with the silver film, minimizing quality degeneration, and maintains the alignment of the rows and masthead with the edges of the microfiche. The quality transfer is enhanced by the fact that there is no movement of the master and intermediate during exposure, and by the fact that only a small section in the center of the plate-maker bed is used for exposure of the intermediates. With the 5 x 8" format and the 15.5-to-1 reduction ration, four intermediates could be exposed at a time, but at the increased reduction ratio of 18-to-1, the fall-off in quality at the edges made it necessary to expose only two at a time, until the smaller 105 x 148 mm format made it possible to expose four again.

Image Numbers. It was in the preparation of the intermediate masters that the image numbers were added to the microfiche, and this was accomplished by the simple expedient of placing an underlay beneath the silver master on the platemaker. These underlays are prepared by laying out a matrix of image numbers in an oversize format, photographing the layout at a carefully controlled reduction, and preparing positive transparencies from the negative. In production, the silver master was placed on the underlay so that the image numbers fell under the appropriate images and was fastened with tape. The diazo intermediate blank was placed in the frame aperture and exposed on the platemaker. Additional intermediates were made by simply replacing the exposed diazo intermediate with unexposed sheet and re-exposing.

Duplication

By far, the most difficult and stubborn problem of microfiche production was the duplication of quantities for distribution. The Facility was faced with the lack of equipment designed for the job, but here the problem was most critical because no equipment had been designed to even approach the quality and production levels required. After many engineering discussions, Ozalid Division of General Aniline and Film Corporation modified their Super Ozamatic diazo printer-developer to meet the Facility's specifications. Among the major modifications specified were: replacement of multiple narrow perforated belts in the printer with two wide solid belts, each with an individual tension adjustment; collimation of the light source; cylindrical grinding of the glass printing cylinder; replacement of the cloth belt in the developer with stainless steel mesh; and modification of the drive mechanism to achieve maximum accuracy in exposure time.

Even before production began, it was recognized that the requirements far exceeded the original design parameters of the equipment and that, under the circumstances, production problems were almost inevitable. When production began, this expectation very soon became a reality.

The problems stemmed from many interrelated causes, but the result was always the same—double-images. They occurred in many ways in many locations—in the center, at the leading edge, at the trailing edge, and to either side. Each time, the cause seemed to be different. In many cases, the cause was positively identified as, for example, uneven belt tension or overheating because a modification of the exhaust vent had increased the back-pressure, but frequently, the identification was, at best, tenuous. In one case, there was even a strong suspicion that slippage between the intermediate and the copy was caused by a tank car falling into the Potomac in West Virginia, (thereby contaminating with oil the water used to develop the intermediates). Even in "normal" operation, the difference between belt tension that was tight enough and tension that was too tight was so small that inserting film in one belt changed the tension in the other belt beyond acceptable limits, so the double-belt system had to be abandoned, effectively halving production and requiring the procurement of additional machines.

The critical nature of the reproduction operation made it necessary to institute 100% inspection of reproduced fiche and maintain constant surveillance of machine performance.

Nevertheless, in spite of sporadic outbreaks of trouble, high quality was maintained and output closely approximating original estimates was achieved. During the last seven months of 1962, upwards of a million microfiche were produced and in 1963, with the same machines, almost 2,000,000.

In early 1964, three developments in rapid succession radically changed the microfiche reproduction picture. The first of these was a new diazo film with the same contrast characteristics but with twice the sensitivity of the film previously used. This permitted higher production rates and reduced significantly the heat problem. Closely following this, the 105 x 148 mm format was adopted and this smaller size reduced the bending problem created by the small radius of the printing cylinder. And finally, delivery of the first Microdupe Unimatic microfiche duplicator. This machine was designed specifically to meet the Facility's requirements for volume duplication of microfiche. Among the improvements were: a 10" printing cylinder; twin light sources; improved collimator; automatic separation and feed of the duplicate for developing; and an elastic printing belt, which permitted parallel feeding of up to four microfiche at a time. These developments practically eliminated major interruptions in production. This is not to say that problems disappeared, but they did diminish to the point where reproduction became almost a routine operation.

Title Backing

In a file of microfiche, the numbers and titles would be virtually unreadable if the masthead area were transparent, so it was necessary to provide an opaque backing behind the masthead. Several alternatives were considered, but the simplest solution was the application of a white enamel foil with a heat stamp. Two Kensol heat stamps were procured and the only modifications necessary were machining the press bar to the depth of the masthead area and the construction of a simple jig to position the microfiche.

Distribution

In the beginning, when microfiche were being distributed only to NASA Centers, distribution was no problem, and a simple post-office type bin arrangement was used. As both the distribution list and the volume of microfiche being produced grew, a degree of automation was introduced with the acquisition of a drum-type collater. Even the problem of various distribution limitations was readily handled by grouping the recipients on the basis of the limited distribution groups they were authorized to receive. However, simultaneously with the conversion to the 105 x 148 mm format, NASA decided that, in order to make the most efficient use of its production capacity, microfiche should be distributed by subject category on the basis of interest profiles submitted by users. This complicated the distribution task, since the permutations and combinations of 34 subject categories, 12 levels of distribution limitation, and 3 levels of classification is an enormous number. Manual sorting with so many variables was neither fast enough nor accurate enough, so a means had to be found to simplify the task. This was accomplished by procuring an inexpensive static card reader with 168 switch positions, and wiring each switch to an indicator lamp fastened beneath a distribution bin. Each bin (and each switch position) is assigned to a specific user. A card is prepared for each subject category, and a hole is punched in the card in the appropriate position for each user receiving that category. Similar cards are prepared for distribution limitations and classification level. In use, the operator picks up a batch of microfiche and reads the distribution class and subject category from the masthead. He then selects the appropriate subject category and distribution cards and inserts them together into the reader. A TEST switch enables him to check the indicator lights for burn-outs, and a READ switch cuts in the card reader so that only the lights corresponding to positions where both cards have holes will light. If classification is a factor, a third card can be added. Distribution is made by placing a microfiche in each bin under which the indicator is lit. Mailing labels for each user are kept in the bin assigned to him, so that when the bin is full, both the fiche and the label can be taken out for wrapping and packing.

PRODUCTION—PHASE II

The strip-up method of master preparation served NASA well, and, by the end of 1965, over 12,000,000 microfiche had been produced this way. The flexibility of the method has enabled the Facility to make three major changes in format (see Figures 1, 2, 3, and 4) without losing a single day's production for changeover, but as the adoption of the Federal Microfiche Standards became imminent, the need for this flexibility declined, and NASA began looking for a less flexible but more efficient production system. Such a system has been developed, and while the transition has just begun, the system and its components can be described in some detail.

Cameras

The first and most obvious step in a more efficient system is the use of step-and-repeat cameras. With the adoption of the 105 x 148 mm format by the information services of the Federal Government, it became apparent that there was going to be a substantial market for production equipment, and a number of manufacturers undertook camera development. The assured market and a competitive environment brought step-and-repeat camera prices down to a reasonable level, and in the summer of 1965, three Bell & Howell Micro-Data cameras were ordered for the Facility. These were delivered early in 1966, and operational use has begun.

The Bell & Howell cameras are designed specifically to produce microfiche in the format of the Federal Microfiche Standards providing a standard-size page image at any reduction ratio between 10.5 to 1 and 26 to 1. As a part of this variable reduction feature, a field projector is incorporated in the camera which projects an image of the aperture on the easel with the exact size and placement of the area which will be photographed at a given setting.

Film Positioning. The placement of the images in the appropriate positions on the film is accomplished by a servo-controlled film carriage, consisting of supply and take-up reels and a pair of guide rollers which hold a segment of the film (somewhat over 150 mm in length) flat for photography. As each exposure is made (two pages or frames per exposure), the servomechanisms move the entire carriage the distance required to place the area for the next exposure in front of the aperture. When the film is in position, a pneumatically controlled platen is applied to the back of the film to hold the area to be exposed in the focal plane. When the last exposure in a given row is made, the servomechanisms move the carriage down one row and back to the position for the first exposure on that row.

When the last exposure on the last row is made, an indicator lights to inform the operator that the fiche is in position for photographing the masthead. If no masthead is required (second and following fiche for an unclassified document), the operator pushes a Reset button, the film is advanced about 153 mm, and the carriage returns to the position for the first exposure in the first row. Simultaneously, row and column indicators are reset to Row A, column 1.

Mastheads. When a masthead is required, the operator pushes the Row Advance button and begins photography on Row B. Mastheads are photographed by a completely separate optical system at a 1-to-1 ratio. The aperture of this optical system is so placed that the carriage shift after the last exposure on the last row of the fiche places the masthead area of the film (Row A) in position for photographing the masthead. The indicator light previously mentioned alerts the operator to this fact.

In order to have a positive (black letters on a clear background) masthead on the fiche, it is necessary that the original to be photographed be a negative (white letters on a black background). Presently, this is accomplished by typing the titles on acetate drafting film and making a contact photographic print from this. However, other methods of producing negative titles are being investigated.

The mastheads are cut to size and placed in a holder which fits in a slot in the camera body. A manually operated platen holds the masthead area of the fiche in the focal plane of the masthead optical system, and the shutter is tripped by a standard shutter cable. Interlocks prevent opening the masthead shutter unless the platen is in position and prevent movement of the film when it is in position.

Film Processing

Film from the step-and-repeat cameras is processed in the normal manner in an Oscar Fisher processor.

Master Preparation

The laborious slitting and stripping operation of earlier operations has been replaced by a simple cutting operation.

Diazo Intermediates

In order to preserve the silver master, diazo intermediates are still prepared for use in production duplication. At present, the requirement for including frame coordinates on the fiche makes it necessary to use an underlay like the one used for adding frame numbers and expose the intermediates on the flat-bed printers. However, with the introduction of the Card-to-Roll Printers discussed below, the frame coordinates will be engraved on the plate. Therefore, the intermediates will not require the coordinates, and, without the underlay, they can be produced from the master on the belt-fed machines formerly used for production.

Duplication

The major difficulty in acquiring automated duplication equipment is the fact that the production quantities for microfiche vary with code, category, and classification, ranging, as of May, 1966, from as few as 25 to more than 200. The problem was to find a device which could produce from a single master any reasonable number of copies automatically, and keep the copies together. Again, the implementation of the Federal Microfiche Standards provided the impetus. In December of 1965, NASA put out a request for proposals for an automatic microfiche duplicator to meet the Facility's requirement.

The equipment selected was the Card-to-Roll Automatic Processor (CRM Processor) designed and built by Documentation, Inc. The CRM Processor will accept a single microfiche master (silver or diazo), and, based on a simple control setting, produce from 1 to 1,000 copies on 105 mm diazo roll film at a rate of 15 per minute. Exposed film is automatically processed in a developing unit which is an integral part of the machine, so that the product is a completely processed roll of film.

The CRM Processor incorporates a number of unique features to accomplish its task. The light source is a battery of four 3,000 watt mercury arc lamps with a special reflection system and a high efficiency air cooling system. Even the most efficient air cooling system, however, can only remove the convective heat, so the problem of protecting the master or diazo intermediate from radiant heat remains. This will be accomplished by making the transparent platen upon which the master is placed with two plates of ultraviolet transmittant material and circulating a coolant between them to carry off the heat absorbed by the lower plate. The shutter device consists of four rotating plates, designed to overlap so that most of the acceleration and deceleration during opening and closing occurs either before light is admitted to exposure point or after the master is completely uncovered.

Delivery of four CRM Processors (anticipated in the summer of 1966) is expected to significantly reduce the cost of producing distribution copies from the standpoint of both materials (roll film is cheaper than cut fiche) and labor (at least a 50% reduction).

Cutting and Title Backing

With the diazo duplicates coming from the CRM Processor in 1,000-foot rolls, the next step is conversion to individual fiche. With current production volumes on the order of 20,000 fiche per day, any kind of manual operation would have cancelled out the savings of the card-to-roll process, so simultaneously with the order for the step-and-repeat cameras, an automatic cutter-stripper-stacker was ordered from Bell & Howell.

This device accepts the diazo roll film from the CRM Processor and cuts it into fiche at a rate of approximately one per second. The cutting is accomplished by a pair of accurately spaced knives which are triggered by a rectangular spot placed on the bottom edge of the film by the camera during photography. The spot sensor can sense either a black spot on a clear background or a clear spot on a black background and can be adjusted to any position of the spot with respect to the reference corner of the fiche. This feature enables the use of the cutter-stripper-stacker for cutting fiche produced from masters prepared by CFSTI and AEC.

Another feature of this device eliminates the necessity for heat stamping the title backing on the individual fiche. Prior to reaching the cutting position, the roll film passes across a roller which, in striping position, applies a thin coat of quick-drying white lacquer to the title area. Between the brush and the cutting position, there is sufficient travel distance so that the lacquer is dry before the fiche is cut. The brush is on a pivot, so that if backing is not required, it may be moved away from the film.

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