NBS

Technical Note 261

SUMMARY OF CURRENT RESEARCH ON ARCHIVAL MICROFILM

C. S. McCAMY AND C. I. POPE

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

The National Bureau of Standards is a principal focal point in the Federal Government for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. Its responsibilities include development and maintenance of the national standards of measurement, and the provisions of means for making measurements consistent with those standards; determination of physical constants and properties of materials; development of methods for testing materials, mechanisms, and structures, and making such tests as may be necessary, particularly for government agencies; cooperation in the establishment of standard practices for incorporation in codes and specifications; advisory service to government agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; assistance to industry, business and consumers in the development and acceptance of commercial standards and simplified trade practice recommendations; administration of programs in cooperation with United States business groups and standards organizations for the development of international standards of practice; and maintenance of a clearinghouse for the collection and dissemination of scientific, technical, and engineering information. The scope of the Bureau's activities is suggested in the following listing of its four Institutes and their organizational units.

Institute for Basic Standards. Electricity. Metrology. Heat. Radiation Physics. Mechanics. Applied Mathematics. Atomic Physics. Physical Chemistry. Laboratory Astrophysics.* Radio Standards Laboratory: Radio Standards Physics; Radio Standards Engineering.** Office of Standard Reference Data.

Institute for Materials Research. Analytical Chemistry. Polymers. Metallurgy. Inorganic Materials. Reactor Radiations. Cryogenics.** Office of Standard Reference Materials.

Central Radio Propagation Laboratory.** Ionosphere Research and Propagation. Troposphere and Space Telecommunications. Radio Systems. Upper Atmosphere and Space Physics.

Institute for Applied Technology. Textiles and Apparel Technology Center. Building Research. Industrial Equipment. Information Technology. Performance Test Development. Instrumentation. Transport Systems. Office of Technical Services. Office of Weights and Measures. Office of Engineering Standards. Office of Industrial Services.

---

* NBS Group, Joint Institute for Laboratory Astrophysics at the University of Colorado.
** Located at Boulder, Colorado.

NATIONAL BUREAU OF STANDARDS

Technical Note 261

ISSUED APRIL 16, 1965

SUMMARY OF CURRENT RESEARCH ON ARCHIVAL MICROFILM

C. S. McCamy and C. I. Pope

NBS Technical Notes are designed to supplement the Bureau's regular publications program. They provide a means for making available scientific data that are of transient or limited interest. Technical Notes may be listed or referred to in the open literature.

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C., 20402 Price 25 cents.

Preface

One method of preserving records for archival purpose is to photograph the records, producing images of reduced size made up of silver dispersed in a gelatin film, and to keep the film under conditions suitable for its preservation. This method has been in use on a commercial scale for more than a third of a century and is widely used in Government and industry. In recent years it has been found that blemishes not previously noted developed on some such microfilms years after the films were processed and placed in storage.(1)* Some of these blemishes were described in detail by Henn and Wiest and others by McCamy. (1,2) Reference 2 gave recommended procedures for sampling and inspecting film and reporting blemishes. Large numbers of rolls of microfilm in use in the Government have been inspected, utilizing these techniques, and the results of those inspections are being analyzed. The mechanism of formation of aging blemishes and methods of preventing their formation are being studied at the National Bureau of Standards and in laboratories of the photographic industry. The mechanisms are being elucidated and very promising methods of prevention have been proposed. Though these matters are still being studied, those now engaged in microfilming and those planning records systems for the future have an immediate need for current information. The purpose of this publication is to provide guidance based on the findings to date. Although any prediction of long term stability is subject to change in the light of new observations, predictions based on these findings are more than usually tentative because new experimental results are accumulating daily.

This Technical Note is a summary of a more detailed paper entitled "Current Research on Preservation of Archival Records on Silver-Gelatin Type Microfilm in Roll Form" prepared for publication in the Journal of Research of the National Bureau of Standards.

---

*Numbers in parentheses refer to numbered references at the end of the paper.

Contents

SUMMARY OF

CURRENT RESEARCH ON ARCHIVAL MICROFILM

C. S. McCamy and C. I. Pope

The discovery of aging blemishes on microfilm in storage has prompted a study of the statistical relationship of incidence to conditions of preparation and storage, the chemical and physical nature of the blemishes, and measures to be taken to prevent their formation. This paper is a report of progress in that study with recommendations based on current information. With few exceptions, reports of aging blemishes refer to negative silver-gelatin type microfilm in roll form. Extremely small amounts of information loss have been reported. In some large collections of microfilm, no blemishes have been found. No evidence of biological attack has been found. Apparently, image silver is ionized, migrates, and is reduced to colloidal silver. The reaction often proceeds in the manner described by Liesegang for other silver-gelatin systems. In laboratory tests, blemishes formed in the presence of minute amounts of peroxides, certain imbibed chemicals, and solid contaminants. Recommendations include: avoiding excessive densities on film, careful avoidance of physical damage to the image layer, the use of a small concentration of iodide ion in the fixer, thorough washing, uniform drying, storage at low temperature and humidity in sealed cans, careful avoidance of air-borne reactants, increased use of positive copies for archival storage, and careful periodic inspection of record films.

1. Introduction

If a document is intrinsically valuable, an archivist may elect to preserve the original as long as he can. By preserving a photograph of the document, in a separate place, the preservation of the appearance of the document is further assured.

There are a number of other reasons that photography is employed for the preservation of records. Perhaps one of the most obvious is that a camera can reduce the area occupied by the record. Systems commonly used today produce images having areas 1/100 to 1/1000 of the areas of the originals. Photography preserves practically all of the appearance characteristics of the original and does not make transcribing errors. When placed on a roll of microfilm, a miscellaneous assortment of documents becomes a uniform continuous film. Once a file has been put in order in this way, it stays in order. Images on film can be stored and retrieved by highly automated means. Microfilm can be copied by automated means for dissemination to users, for duplication to gain redundancy and thus more assurance of preservation, for dispersion to insure against local hazards, or to gain the advantages of new photographic materials.

Perhaps one of the less obvious reasons for microfilming is that the microphotograph is often more stable than the original document. Very often a record becomes of archival interest long after the original is generated. Thus, a high grade of paper is not always used in anticipation of the archival value of the document. In the federal records there are many letters from private citizens or foreign sources. The Government cannot control the quality of paper and ink used in the correspondence it receives.

These factors led to the use of microfilm in commerce, industry, and Government.

NBS Miscellaneous Publication M-158, published in 1937, gave recommended properties of film for permanent records.[(3)] By Act of Congress, in 1940, the National Bureau of Standards was assigned the responsibility for the maintenance of suitable standards for the reproduction of permanent Government records by photographic and microphotographic processes. Subsequent legislation assigned this responsibility to the Administrator, General Services Administration.

The actual maintenance of the standards was continued from 1940 until 1957 by the Photographic Research Section of the National Bureau of Standards. In 1945, the American Standards Association adopted a standard Specification for Photographic Films for Permanent Records.[4] This standard was revised in 1957,[5] the NBS standard was rescinded, and Federal Standard No. 125A, which simply referenced the ASA standard, was issued.[6] A modest research program on the stability of photographs was continued in the Photographic Research Section of NBS. The chemical mechanisms of fixing, fading, and sulfiding of photographic images, and chemical analytical techniques for determining residual thiosulfate were studied.[7,8,9]

Large numbers of rolls of microfilm processed and preserved at the National Archives are in good condition after many years and have no aging blemishes. This demonstrates that, under the right conditions, microfilm is stable. It is important to know what conditions of film processing and storage are necessary and sufficient to achieve this stability consistently. These conditions can be stated with complete confidence only when the mechanism of formation of aging blemishes is fully understood. Although a number of questions remain, much has been learned by inspecting films, correlating the incidence and severity of blemishes with conditions of processing and storage, and subjecting films to extreme conditions to induce suspected reactions at an accelerated rate. This note is a summary of the results of these recent investigations to date and provides as much guidance as current information permits.

2. Film Inspections

Large numbers of rolls of federal record film were inspected by personnel of the National Bureau of Standards, but it would have been impossible for the staff of the Bureau to inspect any large fraction of federally held microfilm in a reasonable time. Employees of other Government agencies were trained to inspect films and report their findings, using the procedures given in Reference 2. To date over 7 thousand rolls of film, representing a sampling of about 10 million rolls, have been inspected and reported. The information is being encoded for a detailed statistical study, by means of a digital computer, of the interrelationship of all variables considered to be of importance. The reports have shown no obvious indications of conditions greatly different from those encountered in the initial NBS inspections, upon which the following observations are based.

Aging blemishes were observed on microfilm in roll form but not on other films, with the following exceptions. There were two instances involving <u>nitrate-base film</u>, which has not been used in this country for many years. One case involved some 9-inch aerial film about 25 years olf, the other was 35 mm motion picture film about 50 years old. The aerial film blemishes looked like Type 1* blemishes but those on the motion picture film were atypical, resembling general fading more than aging blemishes. A collection of 2 1/2-inch square (No. 120) pictorial negatives on a fine-grain roll-film manufactured, exposed, processed, and stored in Europe were found to be very badly affected. No blemishes have been reported on such pictorial negatives in this country. Blemishes have

*Type designations are defined in Reference 2.

been reported on one collection of microfilms mounted on aperture cards. Since the film had been stored in rolls for some time before it was mounted, the blemishes may have been on the films at the time they were mounted. No other cases of attack have been reported on films mounted on aperture cards. About 35,000 positive microfilm chips mounted on aperture cards were accumulated in our own office during the period between 1953 and 1957. This collection has been exposed to ordinary office conditions, including air conditioning during the summer months. The collection was recently inspected and no aging blemishes were found. Films on aperture cards have not been studied further at this time. Though they are outside the scope of this paper, they are being studied as part of this research program.

Aging blemishes were not observed on the information areas of positive copies having dark characters on a light background, although aging blemishes have been observed on the high-density borders of one such film and others have been reported.

Microfilm was found stored on reels made of plastic, painted steel, anodized aluminum, and fiberboard. Some was stored on cores, without flanges, made of plastic or wood.

The film was stored in cardboard boxes, one reel to a box. Most boxes were those generally supplied commercially but some agencies, such as the National Archives, had boxes specially made for their use. The boxes of film were usually stored in shallow drawers in painted steel cabinets or on painted steel shelves.

Blemishes were not usually observed on the outer convolution of film but began, often remarkably abruptly, at the beginning of the second convolution. A frequent exception was the observation of a pattern of blemishes beneath a rubber band, string, or adhesive tape, used to bind the roll.

On a given small area on a film, the spots very often displayed a remarkable uniformity of size. The general features of the outer rings of ringed spots also tended to display similarity over a small spatial range.

Given the conditions for blemish formation, blemishes appeared to form more readily at higher densites. When the leaders were fogged, they were the densest parts of the films and typically had many more blemishes than other areas on the film.

Blemishes were often concentrated at places corresponding to high gradients of density. The straight boundary between the dense background of a filmed document and the clear space between frames was sometimes marked by a nearly solid line of blemishes.

Blemishes were often observed in a nearly continuous string along scratches in the emulsion.

In a series of frames of copies of documents on identical forms, blemishes were observed on the corresponding characters of as many as 25 consecutive frames.

One of the most significant findings was a collection of about 37,500 rolls of microfilm without blemishes. This film was exposed and processed at the National Archives and was stored there. The film was 35 mm microfilm manufactured by two different American manufacturers since 1940.

Two aspects of the processing at the National Archives are considered notable: the presence of an exceptional amount of iodide ion in the fixing bath and an exceptionally high consumption of wash water per unit of film area. The iodide in the fixing bath presumably resulted from the processing of considerable amounts of positive film along with negative film. Pope has reported that the presence of the iodide ion prevents most of the sulfiding of the image during fixing and aids in the elimination of residual chemicals during washing.[7] Researchers at Eastman Kodak Company have found that iodide in fixing baths was associated with a reduction or complete elimination of aging blemish formation in a number of private and Government processing plants. Mr. Robert O. Bieling of Bell and Howell Company found an increase in general fading on accelerated aging after such iodide treatment. This result was confirmed at NBS. Since general fading has not been associated with iodide in the fixer in actual practice, the accelerated test may be too severe. On the other hand, the test may be predicting actual future performance. We have no reports that properly washed film has faded objectionably, while aging blemishes have actually destroyed small amounts of information. Since most microfilm images have rather high contrast, a considerable amount of general fading could be tolerated without loss of information. On the basis of these considerations, the addition of 0.2 g of potassium iodide per liter of fixing solution, to fixing solutions not otherwise containing an equivalent amount of iodide ion, appears desirable if the films are stored according to the recommendations given below.

Mr. Albert H. Leisinger, Jr. of the National Archives arranged to see what a film once looked like and follow its changes with the passage of time. A certain roll of negative film was manufactured in 1936 and processed in 1936 or 1937. (Since the film was not exposed or processed at the National Archives the exact date is unknown.) A copy of the film was made between 1936 and 1944, one in 1958, and another in 1963. The original and the copies were photographed using a magnification of about 20. The pre-1944 copy shows that there were no noticeable blemishes at that time. The 1958 copy revealed about 300 blemishes on one frame of the negative at that time. The 1963 copy exhibited only those blemishes already on the negative film 5 years earlier but some growth in the diameter of spots was observed. The ratio of diameters, as measured on a number of spots on the prints, ranged from 1.5 to 2. There was no perceptible information loss. The growth was in the size of spots rather than in the number of spots.

The blemishes appear lighter than the normal background and transmit more light at long wavelengths than at short wavelengths. Because of this spectral transmittance and the ultraviolet and blue sensitivity of photographic copying materials, the blemishes very often are not noticed on photographic prints of films having blemishes and the legibility of the prints appears better than that of the blemished film.

One of the objectives of the initial film inspections was to find the extent to which Government films were affected by blemishes and to ascertain whether or not any information had been lost. Of the total number of collections of microfilms, there was a large fraction that had some blemishes. In the collections having blemishes, a fraction of the rolls had blemishes. On a roll, blemishes sometimes were and sometimes were not on the information frames. When blemishes occurred on information frames, only a fraction of the frames were affected. On a blemished frame, only a fraction of the blemishes were on or around information characters. Of the six types of blemishes, only the infrequently occurring Type 2 formed in the characters, although Type 1 sometimes crossed over lines of characters. Other types showed a natural aversion to attacking the characters. As a result of the redundancy of the records, the statistical distribution of blemishes, and the characteristics of the mode of formation of blemishes in the vicinity of characters, the amount of loss of information in federal records appeared to be extremely small. Nonetheless, one agency reported some such loss in the only existing copies of certain reports having tabulated numerical data. The only observed cases of actual loss of information resulted from Type 2 blemishes.

P. R. Achenbach and C. W. Phillips of the NBS Building Research Division, who are experienced in heating and air conditioning engineering, examined a few Government microfilm storage facilities. They found that the buildings were not always well designed for the purpose, air conditioning was not always adequate, and the practice of monitoring temperature and humisity at some central location in a room did not always assure proper control of these variables at the perimeter of the room where some of the films were stored.

3. Experimental Research

3.1 Structure of Blemishes

The structure and chemical nature of blemishes have been described by Henn and Wiest[1] and various types were described and illustrated in color by McCamy.[2] The normal photographic grain pattern is absent in the light colored areas of the blemishes. Cross sectioning of spots reveals the fact that the whole thickness of the image layer is generally involved. Spots have been treated in a variety of chemicals to study the chemistry of various parts of the spots. The structure of spots has been studied by means of the electron probe microanalytic technique. All indications are that the yellow to red color is mainly attributable to the presence of colloidal silver in the interior of the spots. The dark concentric rings, dark rims, and mirror-like formations are made up of silver with some silver sulfide.

3.2 General Mechanism

The currently favored hypothesis is that blemish formation is a chemical reaction in which the normal silver grains are corroded away, the silver ions migrate, and are in large part redeposited as colloidal silver or as mirror-like deposits of silver and silver sulfide at the upper or lower surface of the gelatin layer. Considerable evidence obtained here and elsewhere supports this hypothesis.[1] An oxidation reaction of some kind is required to ionize the metallic silver and a reduction reaction is required to redeposit the silver. Peroxides can bring about oxidation-reduction reactions with silver so it is natural to suspect that blemishes are formed by peroxides attacking the image silver.[1] Why the attack should be localized and why the blemishes should assume their typical forms are not entirely clear. The heavy concentration of blemishes along scratches in the gelatin may be attributed to the removal of the protective gelatin layer. Any weakness in the gelatin layer, in the form of a local abnormality of the permeability to chemicals, or a concentration of reactive or catalytic species could determine the site of attack. In the normal image, the nature of the gelatin depends on the local density of image silver. The local concentrations of various chemicals, such as thiosulfates, retained in the image also depend on the local image density. For these reasons, the strong influence of the image upon the location and form of blemishes is consistent with the working hypothesis.

3.3 Liesegang Ring Phenomenon

The very regular concentric ring patterns in the Type 1 blemishes and less regular concentric ring patterns in Type 4 blemishes are strongly reminiscent of the phenomenon first described by R. E. Liesegang[10] and known as Liesegang ring formation. To determine whether or not Liesegang rings could form on the small scale of interest in this investigation, the classic experiment of Liesegang was repeated using a microscopic droplet of silver nitrate solution on a gel layer containing potassium dichromate. The reaction proceeded as Liesegang reported, but in this case forming a concentric ring pattern in the size range of Type 1 aging blemishes, proving that the phenomenon is demonstrable on this scale. The literature abounds in references to rings formed in reactions with silver salts in gelatin. Thus, the ring structure in aging blemishes is not fully explained but neither is it unprecedented in silver-gelatin systems. It is likely that the mechanism is the same as that producing Liesegang rings in general.

3.4 Experimental Humidity Control

To obtain various conditions of temperature and humidity for experimental purposes, various saturated salt solutions were placed in closed containers and the containers were placed in ovens thermostatically controlled at various temperatures. Numerous studies of such procedures are reported in the literature, e.g., Reference 11.

3.5 Effect of Imbibed Chemicals on Film Exposed to Hydrogen Peroxide

Processed and dried microfilm samples were treated 3 min in 0.1 percent solutions of compounds which might be in processing solutions or wash water. The concentration of the compounds was about 8 $\mu g/cm^2$ of film. The excess solution was shaken from the samples, which were then placed in a 16-oz jar and stored at 60° C and a relative humidity of 43 percent in the presence of hydrogen peroxide. Spots the size of natural aging blemishes formed in 17 to 72 hours on films containing aluminum potassium sulfate, boric acid, calcium carbonate, magnesium sulfate, mono-methyl-para-aminophenol sulfate, potassium bromide, sodium chloride, sodium nitrate, sodium silicate, and sodium sulfite. Samples without imbibed chemicals formed no blemishes under the same conditions of storage.

3.6 Experiments With Dry Chemical Contaminants

The emulsion sides of dry microfilm samples were pressed against powdered salts and tapped gently to remove loose powder. The films were stored in 16-oz jars at 60° C and 43 percent relative humidity. Irregular but generally round spots formed on film contaminated with ferric sulfate, potassium iodide, sodium thiosulfate, or sulfur. Samples without chemical contamination formed no blemishes under the same conditions of storage.

3.7 Biological Studies

Dr. E. H. Zeitler, of the Armed Forces Institute of Pathology, found no evidence on blemishes of attack by micro-organisms, confirming the report of Henn and Wiest.[1]

In our laboratories, dried spores were obtained from cultures of fungi grown in a gelatin solution. Samples of processed microfilm were contaminated by brushing dry spores onto the surface of the film and by treating films with water containing spores. Tests were run at 46 percent and 75 percent rh at room temperature, and 50° C, in desiccators. Some fungal growth was observed at 75 percent rh at room temperature but no spots were formed by the spores. Although spore incubation might weaken the gelatin and invite attack by peroxides, this effect has not been observed. Bacterial action by a few organisms on the gelatin surface, perhaps during drying, later permitting peroxide attack, seemed a possible biological mechanism. Evidence of such activity has not been observed, though it should be detectable if present.

3.8 Studies of Peroxide Formers

In the presence of a certain kind of grease, spots developed in two to four weeks at 46 percent rh and 50° C. This grease had a very faint odor of rancid vegetable oil, but the mass spectrograph detected nothing more than water. Infrared spectra of the grease itself and the iodine number identify it as castor oil hydrogenated about 30 percent. The double bond compounds of the kinds found in castor oil form peroxides with the oxygen in the air and polymerization bonding of a molecule with another double bond molecule releases hydrogen peroxide which can bring about the oxidation-reduction reaction with the image silver.

The interior of some desiccators was coated about 1/8 inch thick with this grease, from the top to the porcelain plate near the bottom.

Microfilm samples were stored at various temperatures and humidities. Numerous spots formed. The areas of the samples closest to the grease surface were affected first. The spots formed in the presence of this grease were visually indistinguishable from naturally occurring spots.

The unsaturated compounds in linseed oil and castor oil and oleic and linoleic acids were tested for their ability to form spots on film. Linseed oil and linoleic acid caused numerous spots in 25 days at 50 percent rh and 50° C on samples close to the oils. These experiments were done in small 16-oz lotion jars having small openings to permit the influx of air. In large unvented desiccators the reaction was less severe. Some spots formed. Corresponding control samples without this treatment formed no blemishes under the same conditions of temperature and humidity.

Films were exposed to turpentine in large vented desiccators at room temperature with the following results: 58 percent rh, general bleaching in 35 days; 76 percent rh, general bleaching and spots in 9 days; 90 percent rh, heavy yellow and red coloration, general bleaching, and yellow spot formation in 4 to 5 days; 97 percent rh, considerable general image bleaching but no spot formation in 4 days.

The effects of dipentene, pinene, and turpentine were compared in separate closed desiccators at room temperature and 90 percent rh. At 9 days the attack was about the same, with turpentine showing slightly stronger attack.

Films were exposed to powdered rosin placed in culture dishes in closed desiccators. At 85 percent rh and room temperature, heavy image bleaching and a few spots were observed at 6 days and an increase in bleaching and formation of reddish spots at 15 days. At 58 percent rh and room temperature, weak general bleaching was found at 2 days and considerable yellowing and many spots, including Type 3, at 5 days. A gold treated sample (1) showed slight yellowing at 5 days. Abietic acid, the chief constituent of rosin, is known to form peroxide under certain conditions of temperature and humidity.

The liberation of peroxides by the special grease, turpentine, pinene, dipentene, and rosin was demonstrated by chemical tests.

3.9 Experiments With Cardboard

Rosin is widely used in paper making although the concentration may be only a few percent. Cardboard may contain natural resins. Alum is often added to papers, creating an acid condition favoring peroxide formation. Measurable amounts of peroxide form in the natural aging of commercial paper pulps and the peroxide formation rate is related to fiber length. These facts strongly suggest that minute amounts of peroxides generated in the aging degradation of the boxes in which the film is stored can cause aging blemishes under some conditions.

To obtain further evidence on this point, microfilm was aged in contact with cardboard from microfilm storage cartons. Cartons marketed by five major American suppliers and one foreign supplier were used. Both old and new cartons were used. Some films were clamped between two pieces of cardboard. Others were stapled to the carton in such a way as to hold the emulsion against the cardboard, the film strip running from one side tab, down the side, across the bottom, and up the other side to the tab. Some were stored in the presence of acetic acid vapor; others were stored without acid.

Films were clamped between pieces of cardboard from film storage boxes, and were placed in desiccators with acetic acid in the humidistat solution. Many spots were formed at temperatures and humidities somewhat above normal room conditions. Corresponding control samples without this treatment formed no blemishes under the same conditions of temperature and humidity.

Samples were placed in cartons so the emulsion lay against the sides and other short samples were laid emulsion down on the bottom of cartons in large desiccators. No acid was used. Spots were formed and some were very similar to naturally occurring spots. Corresponding control samples without this treatment formed no blemishes under the same conditions of temperature and humidity. The tendency toward spot formation increased with humidity, as would be predicted on the basis of the paper degradation hypothesis. The effect of temperature was not as important as the effect of humidity.

3.10 Effect of Density

In the laboratory studies of blemish formation, the dependence of the tendency to blemish formation on density could be more readily observed than it could be in field studies, since laboratory specimens had step tablets on them. The results confirm the field observation. For example, on a step tablet exposed to the very reactive grease, there were no spots on the density steps 0.16 to 0.43 but spots on density steps 0.58 and above. The small density difference of 0.15 made the difference between spots and no spots. The degree of attack increased with density at densities above 0.58.

3.11 Effect of Gold Protective Treatment

Henn and Wiest proposed a gold protective treatment for microfilms. (1) The chemistry of their proposal appears theoretically sound. Microfilms processed and treated with the gold protective treatment both during processing and after processing, in a commercial microfilm laboratory, have been studied. In all tests to date, the gold treated film has been consistently more resistant than untreated film to general attack by mild peroxides and has been virtually free of spot formation. The inertness of the gold treated image is demonstrated by its resistance to a short exposure to strong nitric acid. With severe and prolonged exposure to a peroxide atmosphere, the gold treated material is affected and, under these conditions, can even exhibit a resistance inferior to the untreated material, but it is questionable whether tests of this severity are pertinent to practice. Since this process has just been introduced commercially, there is no background of practical experience.

4. Recommendations

One method of preserving records is to photograph them, producing images of reduced size made up of silver dispersed in a gelatin film, and to keep the film under conditions suitable for its preservation. This method has been in use on a commercial scale for more than a third of a century and is widely used in Government and industry. In recent years it has been found that blemishes not previously noted developed on some such films years after the films were processed and placed in storage. We are attempting to determine the pertinent characteristics of the photographic materials and the effects of various conditions on them. Though research on these blemishes has not been completed, those now engaged in microfilming and those planning records systems for the future have an immediate need for current information. Decisions with regard to expenditures of resources for the preservation of private and public records require value judgments based upon various considerations. However, since some technical judgments are involved, we offer the following suggestions and recommendations based upon our recent findings, past experience, and consultations with many people responsible for microfilming and preservation of records in Government and industry. The recommendations should be viewed in that perspective.

The blemish formation process, like all chemical processes, requires a combination of conditions. The elimination of one contributory factor may prevent the formation of blemishes under a given set of conditions, but we recommend, as a conservative policy, that all contributory factors be avoided, insofar as it is practical to do so. The following recommendations and suggestions are based upon this principle.

We recommend the use of film having a safety cellulose-ester base meeting applicable raw stock requirements, the viscosity retention requirement, and flexibility requirements of the American Standard Specifications for Photographic Films for Permanent Records[5] until that standard is revised.

The observation that the incidence and severity of blemishes tend to be greater on high density areas suggests that for archival purposes it would be desirable to use no higher density than is required to serve the intended purpose, rather than strive for a high density for the sake of appearance.

Throughout the exposing and processing operations it is important to avoid scratching film, not only because scratches are undesirable in themselves but because blemishes form along scratches.

Since the processing conditions establish the conditions of the image and the gelatin, they play a role in establishing the probability of attack. The contributions of all the various processing conditions are not yet sufficiently well understood to warrant detailed recommendations with respect to all aspects of processing. As noted in a previous section of this paper, the addition of 0.2 g of potassium iodide per liter of fixing solution, to fixing solutions not otherwise containing an equivalent amount of iodide ion, appears desirable.

Long experience as well as the results reported here of the effects of imbibed chemicals on microfilm support the conclusion that for archival purposes, film should be thoroughly washed to remove chemicals remaining after processing. Failure to do so invites general fading reactions and spot formation.

Efficient removal of water droplets before drying greatly aids in preventing deposition of chemicals on the film surface and promotes uniform drying, with less tendency to introduce local variations in image and gelatin characteristics. The nature of the drying process plays an important role in establishing the characteristics of the gelatin layer. The effects of time, temperature, humidity, and air velocity are not sufficiently well known to allow us to make detailed recommendations, but the facts presented here strongly suggest that great care be taken to avoid dust, fumes of any kind, and gases other than those in normal clean air.

We recommend that the American Standard Method for Determining the Thiosulfate Content of Processed Black-and-White Photographic Film and

Plates be used until it is revised.[12] We suggest the method of Pope[9] as an improvement for a revised standard.

The provisions of the American Standard Practice for Storage of Microfilm,[13] with the few variations noted in this paper, should be carefully observed.

The use of paper, string, adhesive tape, or rubber bands to bind the roll introduces chemical and physical variables which should be evaluated for each material. Such study may be justified if there is a real need for the use of such materials.

Chemicals or materials employed in splicing operations should be scrutinized carefully in light of the present findings. The use of such "foreign" materials can be avoided by the use of a thermally welded joint. This method is in satisfactory use in a Government agency which is one of the larger users of microfilm.

To avoid the peroxide generated in paper cartons and protect film from gases and vapors originating elsewhere, it is suggested that rolls of film be stored in sealed containers as defined in American Standard Practice for Storage of Microfilm.[13] Unpainted anodized aluminum appears to be a desirable material. Hundreds of thousands of aluminum cans and reels have been used by one Government agency and they have been found practical and not too expensive. The reels were made of 0.051 in. thick anodized 2024 aluminum alloy and the cans were made of 0.032 in. thick anodized 3003 aluminum alloy. The 2024 duralumin alloy provides the elasticity required for a reel to maintain its shape. Other materials should be scrutinized carefully, in the light of our findings. In this connection it should be borne in mind that spots were formed readily by amounts of material too small to be detected by a mass spectrograph which could detect amounts in the range of 10^{-7} to 10^{-9} moles.

Low temperature and humidity appear to be desirable storage conditions. It is recommended that materials to be in inactive storage be placed in the can in equilibrium with air at a relative humidity of 15 to 20 percent at 50 to 60° F and that films for active files be placed in the can in equilibrium with air at a relative humidity of 30 to 35 percent at 50 to 60° F. It is recommended that the storage temperature not be permitted to exceed 70° F and that it be maintained between 50 and 60° F where practical. Films may be stored at a lower temperature if they are warmed sufficiently before opening to avoid condensation on opening the can.

Archival films should not be exposed to sulfur dioxide, hydrogen sulfide, peroxides, ammonia, engine exhaust gases, or gaseous industrial wastes. The fumes from turpentine, linseed oil, or drying paints containing such materials should also be avoided. To prevent fingerprints, clean cloth gloves, available from dealers in photographic supplies, should be used whenever film is handled. The film should be handled by the edges, rather than the surfaces to avoid scratching the surfaces or depositing dust. Film handling equipment must be kept clean at all times and should be inspected periodically for cleanliness and any condition likely to scratch or otherwise damage film. Areas in which film is handled must be kept as clean and dust free as practical operations permit. Special air filtration and air washing may be required to avoid objectionable air-borne contaminants. Since the gaseous decomposition products evolved by nitrate-base film are very corrosive, such materials should be removed from any building housing permanent records.

No aging blemishes have been observed on the information areas of positive prints having dark characters on a nearly clear background, although aging blemishes have been observed on the high-density borders of one such film and others have been reported to us. For this reason the retention of such positive films is a recommended procedure when additional security is desired. A positive copy appears to be the best choice when only one film is to be retained in a permanent file and a positive copy will serve the intended purpose.

The probability of loss of information can be very greatly reduced by making more than one microfilm copy and preserving the copies in separate places.

The only positive assurance that records are being preserved is obtained by a regular program of inspection. This principle was recognized in the American Standard Practice for Storage of Microfilm adopted in 1957.[13] Detailed sampling and inspection procedures are outlined in NBS Handbook 96.[2] Experience has amply demonstrated that the routine satisfactory use of microfilms does not constitute adequate inspection. The attention of the user is on the information rather than the condition of the film and the optical nature of the blemishes makes them difficult to detect in the routine use of film. Undoubtedly there will now be a keener awareness of the condition of the film on the part of professional microfilm users, but systematic and well designed sampling and inspection are still necessary parts of record preservation. The sampling procedure should be regulated so that inspectors obtain a different sample each time. Careful inspection of each stratum every two years should reveal unsatisfactory conditions in time to allow appropriate action to be taken. After a number of years, if no problems have been encountered, this inspection period could be reasonably extended.

We recommend that existing collections of archival microfilm be stored under the same conditions recommended here for new archival microcopies. If the films have aging blemishes which appear to threaten legibility, the information on the films can be preserved by copying the films and preserving the copies.

Nothing in these recommendations should be construed to mean that silver-gelatin type microfilm is the only possible material for archival record storage or that the roll form is necessarily preferred. There are, indeed, other possible materials but we have not conducted sufficient studies of their properties to make recommendations with respect to their use for the storage of records of permanent value.

This research was sponsored in part by the National Archives and Records Service, the Library of Congress, the Social Security Administration, the Navy Bureau of Weapons, and The Adjutant General's Office of the Department of the Army. In addition, the National Microfilm Association solicited and secured financial support from the Bell and Howell Company, E. I. Du Pont De Nemours and Company, Dynacolor Corporation, International Business Machines, Minnesota Mining and Manufacturing Company, Recordak Corporation, and Xerox Corporation.

The authors wish to express their appreciation of the cooperation of the sponsors and many other Government agencies who permitted access to records, supplied old films for research, permitted inspections and measurements to be made, and gave advice and helpful leads. A most cooperative spirit was found in the laboratories of the film manufacturers.

Miss Anna-Mary Bush assisted in the preliminary inspections and carried out the research on the Liesegang phenomenon.

5. References

1. R. W. Henn and D. G. Wiest, Microscopic spots in processed microfilm: their nature and prevention, Phot. Sci. Eng. 7, 253 (1963).

2. C. S. McCamy, Inspection of processed photographic record films for aging blemishes, National Bureau of Standards Handbook 96, (U. S. Government Printing Office, Washington, 1964).

3. J. R. Hill and C. G. Weber, Evaluation of motion-picture film for permanent records, NBS Misc. Publ. 158 (1937).

4. American Standard Specifications for Photographic Films for Permanent Records. Z38.3.2-1945. (American Standards Association, New York).

5. American Standard Specifications for Photographic Films for Permanent Records. PH1.28-1957. (American Standards Association, New York).

6. Federal Standard 125a, Federal Standard:Film, Photographic and Film, Photographic, Processed; (For Permanent Record Use), April 24, 1958.

7. C. I. Pope, Formation of silver sulfide in the photographic image during fixation, J. Research NBS 64C, 65 (1960).

8. C. I. Pope, Stability of residual thiosulfate in processed microfilm, Ibid, 67C, 15 (1963).

9. C. I. Pope, Determination of residual thiosulfate in processed film, Ibid, 67C, 237 (1963).

10. R. E. Liesegang, Naturw. Wichschr. 11, 353 (1896).

11. A. Wexler and S. Hasegawa, Humidity-temperature relationships of some saturated salt solutions in the temperature range 0° to 50° C, J. Research NBS 53, 19 (1954).

12. American Standard Determining the Thiosulfate Content of Processed Black-and-White Photographic Film and Plates, Method for. PH4.8-1958. (American Standards Association, New York).

13. American Standard Practice for Storage of Microfilm. PH5.4-1957. (American Standards Association, New York).

U.S. DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20230

OFFICIAL BUSINESS