A MULTI-COMPONENT STUDY OF THE ADMINISTRATION AND PRESERVATION OF NITRATE NEGATIVES

by

William Scott Reid

B.Sc. The University of Manitoba

B.A. The University of Manitoba

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR

THE DEGREE OF MASTERS OF ARCHIVAL STUDIES

in

THE FACULTY OF ARTS

FACULTY OF GRADUATE STUDIES

(School of Library, Archival and Information Studies)

We accept this thesis as conforming to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

JUNE 1991

Abstract

Cellulose nitrate negatives pose serious problems of preservation and accessibility to archival institutions, and create pressure on an archives physical and administrative resources. Archivists must take precautionary actions designed to prolong the life of the images in their care until they can be copied, and to safeguard against damage to other archival material that shares space with them.

This thesis presents and discusses the issues surrounding the management of nitrate negatives in archival institutions of all sizes. The physical and chemical characteristics of cellulose nitrate, and its role in the historical development of photography introduces the specific archival concerns of preservation and access. A diplomatic analysis of the photographic negative, which shows that it does not need to be retained for evidentiary purposes, prompts the recommendation that cellulose nitrate negatives can be copied onto stable base film and then destroyed. The need for proper long term storage facilities is however recognised, and types of facilities are presented.

Finally, this thesis provides guidelines for the preservation of cellulose nitrate negatives, and discusses the types of procedures presently in Canadian archival repositories.

This thesis proposes that archivists concentrate their efforts towards the preservation of the information contained in the images themselves, rather than in their physical form, and thereby minimise the danger posed

by the nitrate negatives by investing in a systematic copying program and in the construction of separate storage vaults.

Table of Contents

Unit	Page Number
Abstract	ii
List of Tables	v
List of Figures	vi
Acknowledgement	vii
Introduction	1
Chapter I: The Nature of Cellulose Nitrate	10
Chapter II: Cellulose Nitrate and the Photographic Process	30
Chapter III: The Preservation and Administration of Nitrate Negatives within Archival Institutions	55
Chapter IV: Conclusion	87
Appendix I: The Survey	102
Appendix II: CD ROM Technology and its Application to the Storage of Visual Images	110
Appendix III: Brand Names of Cellulose Nitrate Products	119
Appendix IV: Some Trade Names for Cellulose Nitrate	120
Bibliography	122

List of Tables

Title	Page Number
Table I: Nitrogen Content of Various CN Materials	21
Table II: Types of Nitrogen Gases Released During CN Deterioration	25
Table III: Dates of Discontinuation for CN Film Formats	44

List of Figures

Title	Page Number
Figure 1: Cellulose Chain	16
Figure 2: Hydrogen Bonding Between Cellulose Chains	17
Figure 3: Cellulose Sheets in Layered Structure	18
Figure 4: Crystallisation of Cellulose Bundles	19
Figure 5: The Nitration of Cellulose	20
Figure 6: Cross Sections of CN and Cellulose Diacetate Film	43
Figure 7: Direct Duplicate Negative Method-Variation A	73
Figure 8: Direct Duplicate Negative Method-Variation B	74
Figure 9: Direct Duplicate Negative Method-Variation C	75

Acknowledgement

First and foremost I would like to thank my thesis advisor, Professor Luciana Duranti for her patience, hard work and advice which made this thesis a reality. I would also like to thank Betty Blight at the Provincial Archives of Manitoba for suggesting the topic, Mike Moosberger for his support and Rosaleen Hill and the conservation department at PAM for their advice and help. Finally, my wife Karen and the rest of my family deserve much credit for lending their support and encouragement in this endeavour.

Introduction

Prior to World War II, the amount of photographs and photographic materials which found its way into archival institutions was very small; consequently there was little regard for the acquisition and special preservation needs of images. After the War, many institutions which had previously survived with scant resources were able to expand their staff and the scope of their acquisition policies, and to establish new and far reaching programs. This fervour of archival activities affected all levels in the established local, state and federal repositories in the United States, and a large number of new programs was brought into being in local and regional historical societies, local public libraries, business firms, professional associations, social service agencies, churches, and educational organisations. This increase in the activity of archival repositories coincided with an increase in the numbers and types of materials acquired, and among them there was a growing amount of photographs.

In the United States, the Library of Congress and the National Archives and Records Service established separate still image collections. Yet, even as late as the 1950's photographic material was still considered by most repositories to be of a secondary importance.[1] Because the profession was relatively new to the acquisition of historical images, archivists tended to handle the disposition of photographs in a tentative manner; furthermore, the nature of the medium was such that its usefulness as a historical source was not easily recognised, therefore photographs tended to accumulate passively in archival repositories as accessional components of textual fonds. In the 1970's this situation changed rather dramatically as the interest in photography as a source for the documentation of society grew considerably. Archivists were now compelled to deal with a new demand for historical images from the historical as well as other research communities. This meant that the repositories could no longer allow for the passive accumulation of images; and the existing collections would now have to be properly managed and preserved.

Today, most archives acquire photographs, just like other cultural institutions, such as historical societies, libraries, museums, research centres, and private companies. Thus, archivists now find themselves involved in the management of what is now known as one of the most powerful and self-sustaining popular media in modern society. Along with the images of the past which have come down through the generations as part of the historical record, archivists now have to deal with the tremendous production of images which has come about through the increase of such popular activities as amateur photography, due to the development of technology. Over the years, the camera has become increasingly simplified and easy for the non-professional to use, with the result that the number of photographs being produced annually in North America alone is estimated at an amazing 10 billion.[2]

Given that archivists are now dealing with historical photographs in a more comprehensive manner, it appears that a great deal of work still needs to be done. This realisation is enunciated by Leary when he writes that,

> Despite the growing intellectual respectability of photographs as historical documentation, an enormous task of education and proselytising lies ahead. Very few archival institutions have devoted more than a token of their resources to the acquisition and preservation of photographs and other visual records. In far too many archives, photographs are treated as an afterthought.[3]

However, even if all still images of research value made their way into the proper repositories serious problems would have to be solved. The preservation component of photograph administration can at times be very problematic as the modern day archivist and conservator must cope with a technological revolution which has been ongoing for over a century. Although its roots are in the late 19th century, and even though the pace of the initial developments do not come close to the speed of today's advances, this continuing progress still has repercussions on the way we have to deal with the photographic medium in the modern context. This problem is compounded by the labour intensive nature of the medium, and costs which are part and parcel of the administration of photographic collections; with these factors in mind it becomes obvious that archivists are faced with a daunting situation indeed. They now find themselves in need of resources and supplies which are outside the realm of the management of textual records: photographs, as other types of modern media records, require very specific types of environmental conditions and conservation activities. The situation becomes more complex if one introduces into the equation the factor of spontaneous degradation of the visual image with which archivists are faced when they are involved in the preservation and administration of large numbers of cellulose nitrate negatives.

Cellulose nitrate film is proving to be a serious challenge for archivists and their resources. While there is little disagreement amongst professionals that the presence of such self-destructive materials in archival vaults has become a problem, there still seems to be a good deal of variance in opinion on how to administer the functions of preservation, appraisal, and access in light of their physically sensitive and ephemeral nature. The actual amount of these items in archival repositories varies to a great degree, but even small quantities can be a problem for those who must deal with them. The unstable nature of nitrate, and the risks it poses to other archival material with which it shares storage space requires the archivist to take special precautionary actions. These actions must be designed to prolong the life of the image and to safeguard other archival material, not to mention the health of the people who have to work with nitrate negatives in advanced stages of disintegration.

Cellulose nitrate film was first introduced in 1887 by George Eastman. The composite from which this film gained its name was the first plastic backing with sufficient clarity and strength to be used as a photographic emulsion support. It proved to be something of a breakthrough for the time, as it was stronger than gelatin film, resisted breakage, and laid flatter in a roll holder for a sharper picture. Its use continued for about sixty years: dates of discontinuation vary by format, manufacturer, and country, but the dates for the United States range from 1933 for x-ray film to 1951 for motion picture film. Furthermore, it became common practice for photographers to respool cinema film onto 35mm still camera holders after the discontinuation date: the result was that nitrate negatives became far more ubiquitous than one might think.

Cellulose nitrate is a generic name for several plastics that can be differentiated by their degree of nitration. Plastics with approximately 10.5% nitration are considered to be of low concentration and are common bases for lacquers, adhesives and collodion; and this concentration is considered to be relatively stable. At greater nitration than 12.5% the plastic is called gun cotton and is both flammable and explosive.

The sensitive nature of nitrate negatives and the threat they pose to other archival material raise specific issues that must be directly dealt with. These issues include: (1) The length of their retention period. If nitrate negatives are to be retained indefinitely, the archivist must be fully aware of the requirements for preserving this material and cognizant of the potential hazards of keeping nitrate negatives in less than ideal conditions. (2) Their destruction after duplication. (3) The reliability and authority of copies as evidence of their context and content.

The overall aim of this thesis is to synthesise and address the issues which surround the preservation and administration of nitrate negative photographs. A survey of the existing literature on this topic reveals extensive but diffuse resources, especially in terms of archival considerations. There is a perceived need to fill in the gaps in the archival literature dealing with the conservation aspects of nitrate negatives and the related appraisal, diplomatic and legal issues. It would seem that the problems presented by nitrate negatives have been recognised in those repositories that have significant accumulations of this material, and yet there is a distinct lack of commonality in the way nitrate is handled at the basic level. Furthermore, the conservation and archival considerations which are associated with nitrate negatives can often work against each other, and some form of harmony between solutions must be reached.

Sources for this thesis span a range of disciplines, from writings on chemistry and the nature of cellulose polymers and synthetic chemical derivatives, to work done on the conservation aspects of nitrate materials as well as writings on the history of photography, the archival administration of ephemeral material, and diplomatics.

The thesis includes a description of the nitrate negative as a physical entity, including an analysis of its production, its chemical composition and the specific nature of its breakdown over time; a history of nitrate negatives in the context of the development of photographic processes, including their use and proliferation; a presentation of the conservation aspects of nitrate negatives, including their identification, handling and long term storage characteristics; a discussion of the archival concerns of access, including an analysis of the types of decisions which have to be made in order to preserve this material, and of how these decisions impinge on archival functions, and a brief review of the types of procedures which are being implemented in other repositories; an analysis of practical approaches in dealing with nitrate negative collections within the realistic parameters of institutional resources; and a consideration of the practical implications of maintaining nitrate collections indefinitely.

In the final analysis, this thesis recommends that nitrate negatives be copied with the best and most reliable methods possible and then disposed of. Although this is a radical solution, the physical and intellectual characteristics of the material renders it expendable after it has been properly reproduced. In fact, the negative has little artifactual or evidential value, while the first perfect document, the first print, is the item of historical, juridical and artistic consequence.

Because of the increasing recognition of the photograph as an art medium and an historic document, it has become important for the archivist to acquire, reproduce and make available photographs for the use of the people. Unfortunately, little attention was given at first to the technical aspects of photographs because the basic criteria for acquiring images was simply the importance of the artist and of the subject matter. Much of this has changed now, and archivists are much more aware of the unstable and unpredictable nature photographic images. As Pamela Haas has noted, a photograph is "chemistry, chemistry and more chemistry. It exists thanks to a chemical reaction, and its inherent complex and unstable chemistry makes it more susceptible to environmental variation than paper alone or than even a piece of ink-imprinted paper."[4] Because of this, the preservation of the historical image in the public institution requires the combined skills of many experts, that is, paper conservators, chemists, archivists, librarians, scientific photographers, and art photographers. However, where the archivist cannot have the benefit of the expertise of different professionals, it is of the utmost importance that he or she be as knowledgeable as possible about photographic materials. There is indeed much to learn about the medium, the various processes available, and the various possible courses of action as well as the ramifications which arise from choosing a particular strategy. What archivists are attempting to do when dealing with the historical image is to straddle the worlds of history, technology and art in order to keep for posterity those materials which are bound irrevocably to the technology of the day. In order to do this job properly we have to be fully prepared to do what is possible within the constraints of the archival institution and its resource and budget considerations. It is the ultimate objective of this study to provide a rational and practical guide for the archival preservation and administration of nitrate negative materials.

[1] Mary Lynn Ritzenhaler, Gerald J. Munoff and Margery S. Long, Administration of Photographic Collections, (Chicago: Society of American Archivists, 1984), 55.

[2] Ann Elizabeth Carroll, "Acquisition of Photographs Determining Archival Quality" (MAS diss., University of British Columbia, 1989), 4.

[3] William H. Leary, The Archival Appraisal of Photographs: A Ramp Study With Guidelines, prepared for the General Information Programme and UNISIST, (Paris: UNESCO, 1985), 4.

[4] Pamela Haas, "The Conservation of Photographic Collections." Curator. Vol. 26 No. 2 (1983) 90.

Chapter One

The Nature of Cellulose Nitrate

The history of cellulose nitrate (CN) is long and varied. There is some dispute as to when the first form of CN was developed and by whom, but there is little doubt that this polymer was first developed in the mid 1830's or 1840's. Maynor and Van der Reyden believe that CN was the first major plastic in commercial use, having been formulated in 1832 by Braconnot. They trace the origin of its production back to 1845 in England, where it seems to have been initially used by the military as an explosive commonly known as gun cotton, and later plasticised with camphor to produce the first successful synthetic plastic.[1] An alternate history of the CN polymer is that Charles. F. Schonbein first patented it in Switzerland in 1845, followed in 1861 by Alexander Parkes who patented parkesine CN in Britain. However, it is known that, by the mid-1860s, John W. Hyatt and others were producing CN in the United States and, in 1870, Hyatt patented a more stable variation of the material which made greater use of camphor.[2] Early trade names for CN include parkesine, celluloid, pasbosene, xylonite, and zylonite.[3]

CN was one of the first major plastics in commercial use and has been utilised in a variety of ways throughout its one hundred fifty years of existence. Because of its early viability as a polymer and its development during the industrial revolution, CN became a very popular material for the production of a great many articles. For these reasons CN can be classified as truly ubiquitous. Although its use has declined over the years, its initial popularity amongst the early, technically oriented industries has ensured that it will remain a problem for archivists, museum curators and conservators for many years to come. In fact, this plastic was popular during the great expansion of the photographic industry in the late 1800s and early 1900s, because it provided a flexible and transparent support for light sensitive emulsions. Therefore, cellulose nitrate was used as the basic film support for many years.

Because of the problems associated with its preservation, an archivist who is responsible for the care of film on this support must be armed with a certain degree of knowledge as to the chemistry involved in the production of CN. One might argue that this sort of understanding should not be part of the professional knowledge of the archivist because it is more closely associated with the competence of the conservation profession. Yet it has to be considered that CN appears in a variety of forms and is found among the holdings of many different archival institutions which have correspondingly diverse budgetary and resource constraints. It is therefore imperative that archivists be adequately armed with a knowledge of why CN behaves the way it does: by learning some basic chemistry, they would be better equipped to deal with the practical problems of dealing with this material.

Cellulose nitrate was produced by dissolving cellulose in the form of cotton linters or wood pulp in a mixture of sulphuric and nitric acids; by varying the strength of the acids, the temperature, time of reaction, and the ratio of acid to cellulose, a wide range of products with varying characteristics could be produced. CN, in its most basic form, had the consistency of dough, and this characteristic allowed it to be pressed into blocks and then sliced into thin sheets. The sheets could subsequently be heat pressed together to form a striated texture known as French Ivory; or they could be blow moulded. CN could not be injection moulded or compression moulded using early technologies, because of its sensitivity to heat. However, it was easily worked by cutting and abrading, and the edges could be tapered with solvents.[4] CN was water white transparent, and could be finished with a high surface gloss; it could also have a faint yellow tint from a possible trace contamination of iron. It could be dyed and mixed with fillers to simulate other more expensive and decorative materials, and these imitations usually took the form of ivory or tortoise shell.[5]

CN was at one time a very popular material among artisans, and it was used in the production of all kinds of articles besides film, such as safety glass, celluloid collars and cuffs, early spectacle frames, combs, buttons, dressing table sets, blow moulded toys in the form of dolls and rattles, and false teeth. It is still used today for adhesives and lacquers, although on a much restricted basis. Ping pong balls are still fabricated from CN as no other plastic has the requisite speed and bounce.[6]

The basic component of this polymer is cellulose. Cellulose molecules are built up from glucose molecules bonded together into long chains. The atoms of carbon, hydrogen and oxygen which make up glucose are held together by essentially two types of chemical bonds, or atomic interactions, called covalent and hydrogen bonds. Covalent bonds are the primary forces which hold together glucose molecules making up the cellulose chain; hydrogen bonds play an intermediate role in linking adjacent cellulose chains into sheets. Covalent bonds are formed when atoms share one or more pairs of electrons between their outer energy "orbits". These electrons are not lost to a particular atom, but are shared, and each pair of negatively charged electrons spends a greater or lesser amount of time in each of the outer orbits of the various atoms comprising the molecule, depending on their relative attraction to the nuclear charge of the atoms. This atomic configuration results in a stable situation within the molecule, because atoms enter into such chemical reactions in order to achieve a stable outer orbit energy level of eight electrons.[7] Different atoms vary in their ability to attract electrons. Thus, when atoms are covalently bonded to molecules, the negatively charged electron spend a disproportionate amount of time orbiting the nucleus of the atom which most strongly attracts them.

Hydrogen bonds are formed as a result of the relative ability of different atoms to attract electrons. The imbalance in the time spent by electrons within the different outer orbits of bonded atoms results in an electrostatic polarity within the molecule: the molecule essentially behaves like a bar magnet, where one end has a slightly more positive or negative charge than the other end. In the case of molecules of hydrogen and oxygen bonded together within the cellulose molecule, the electrons spend a longer period of time orbiting the nucleus of the oxygen molecule, due to the greater attraction that it exercises on these electrons.[8] This gives the oxygen atom a more negative charge in relation to the hydrogen atom which is in turn positively charged. When separate molecules containing an oxygen atom bonded to a hydrogen atom (as in cellulose) approach each other, the electrostatic polarity inherent in this covalent bond will hold these two molecules together; the hydrogen atom with its positive charge on the one molecule will be attracted to the oxygen atom with its negative charge on the other: this is what is referred to as a hydrogen bond.

Cellulose is built up from glucose molecules bonded covalently together to form long chains. Each alternating glucose ring is flipped over and a water molecule is split off, leaving an oxygen molecule between each ring. The aspect of such chains is shown in Figure 1 below:

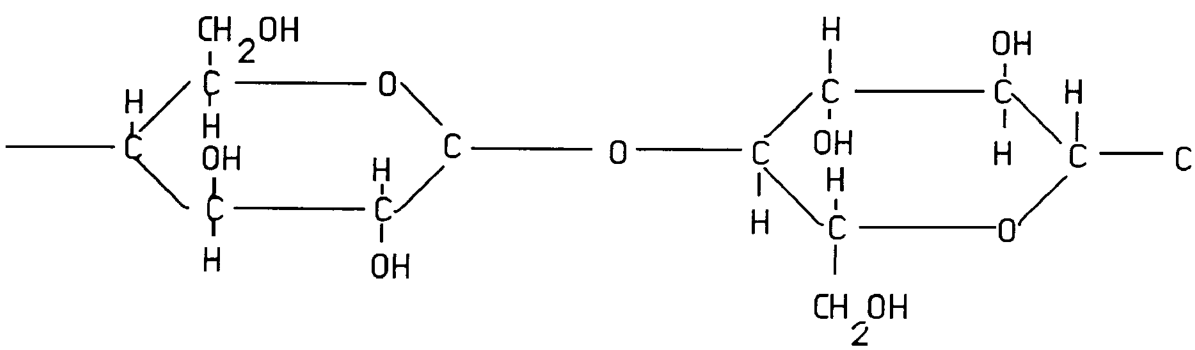

Figure 1: Cellulose Chain.[9]

These chains continue for as many as 3000 to 5000 units and, through side by side hydrogen bonding, are built up into sheets. Figure 2 shows how these chains are built up into sheets by side-by-side hydrogen bonding. The black arrows represent hydrogen bonds.

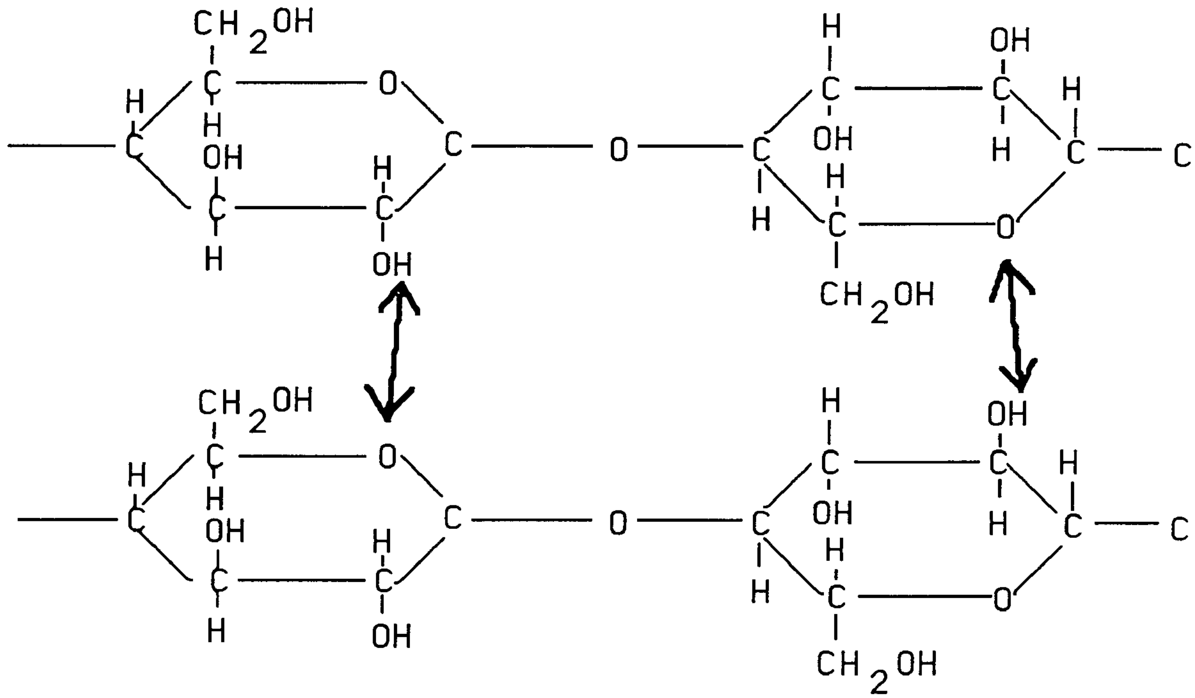

Figure 2: Hydrogen Bonding Between Cellulose Chains.[10]

These sheets will in turn be held together in staggered layers, one on top of the other, by forces known as Van der Waals forces. A Van der Waals force is a combination of three different types of forces: 1) a dipole attraction, such as it is found between the positive and negative poles in a magnet; 2) an induction force, corresponding to the way a magnet can affect a non-magnetized piece of iron; and 3) a form of weak attraction which all molecules have for each other.[11] Figure 3 shows the way in which cellulose sheets crystallise from chains of cellulose. The arrows indicate Van der Waals forces which join these sheets in staggered layers.

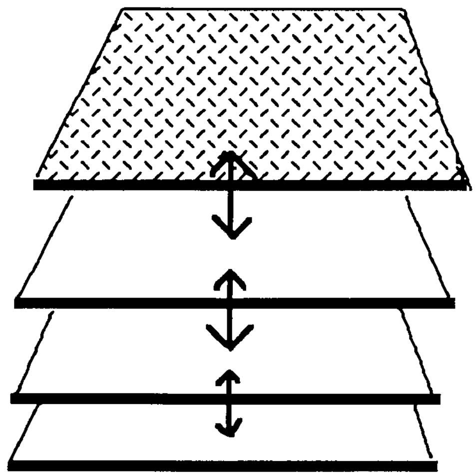

Figure 3: Cellulose Sheets in Layered Structure.[12]

The result of these interactions are small units of cellulose known as microfibrils. Microfibrils are then crystallised by means of the same side-by-side hydrogen bonding and layered Van der Waals forces into cellulose bundles. Bundles are further crystallised into fibres by the same interaction of forces. It is important to note that, in the early stages of microfibril formation, the bonding is nearly perfect at both side-by-side and inter-layering levels, but each successive stage of formation has a progressively less perfect bonding, due to the fact that any imperfection present in the early stages is magnified throughout the crystal structure: the final fibre formation and its resiliencies are therefore very much dependent on the quality of the early interactions between the chains of glucose. Figure 4 shows how microfibrils are arranged into bundles, and how bundles are then crystallised into fibres. It is essential not to lose sight of the fact that the basic building block of the cellulose fibre is the chain of glucose molecules covalently bonded.

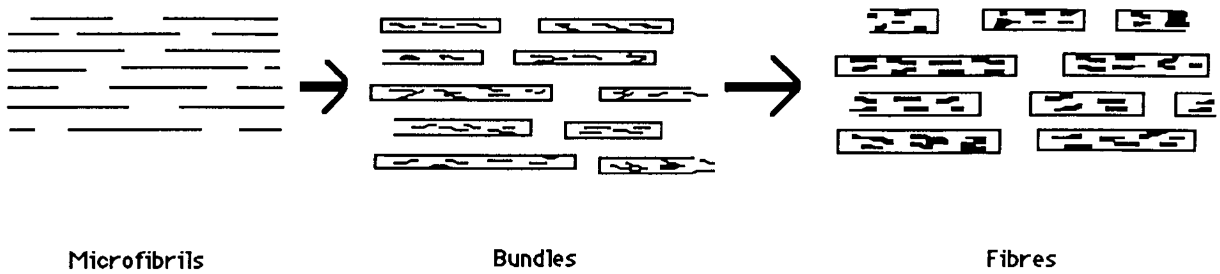

Figure 4: Crystallisation of Cellulose Bundles.[13]

As mentioned earlier, CN is produced by dissolving cotton fibres in mixtures of nitric and sulphuric acids, and plasticising the resulting slurry with camphor or some other agent. By manipulating a number of processing parameters, a variety of material characteristics can be produced. The nitrate process serves to replace one to three hydroxyl groups within the glucose ring. A hydroxyl group consists of an oxygen atom bonded to a hydrogen atom, and each may be replaced by a molecule of NO_3, or nitrate. Figure 5 illustrates the nitration process; as shown, three molecules of nitrate supplied by the sulphuric and nitric acids can replace the three hydroxyl groups on the glucose ring structure. As a result of this chemical reaction, three molecules of water are split off.

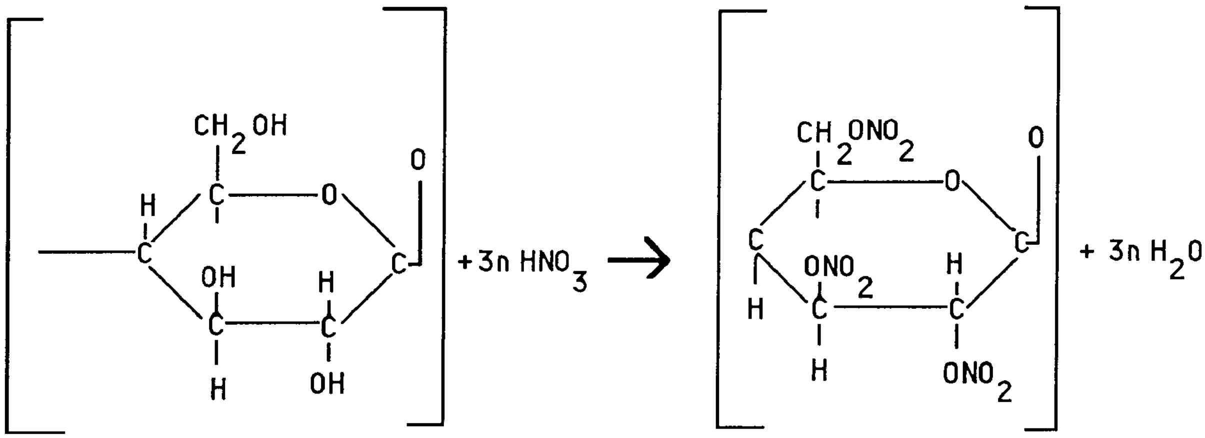

Figure 5: The Nitration of Cellulose.[14]

Theoretically, all three hydroxyl groups can be replaced by nitrate groups, thus producing a calculated nitrogen content of 14.14%. However, this is not practically feasible, because the resulting material could be unstable, being the upper limit of nitration at approximately 13.8% nitrogen content. The product of this process is referred to as gun cotton, which is highly explosive. Most commercial CN's have a nitrogen content which ranges between 10.9% and 12.2%. Types of CN where the degree of nitration is relatively low are used as lacquer bases because of their rapid drying characteristics. Collodion and pyroxilin are other forms of low nitrate plastics which vary in actual nitrogen content.[15] The cellulose nitrate used for film tends to be in the region of approximately 11.8% to 12.3%, while CN adhesives tend to be highly nitrated. Table I shows the range of nitrogen content as it corresponds to different types of CN applications:

Percentage of Nitrogen	Names	Uses
10.9-11.2	Pyroxilin Plastic, Soluble CN	Paper coatings, plastics, low odor lacquers, printing inks
11.3-11.7	Pyroxilin plastic, Soluble CN	Cellophane and paper coatings, alcohol-soluble lacquers, textile coatings
11.8-12.2	Pyroxilin Plastic, Soluble CN, Collodion, Photocotton	Dopes, adhesives, coatings, artificial leather, collodion, fast drying lacquers
12.6-12.8	Purocellulose Pyrocollodion	Propellants
13.0-13.8	Guncotton, Smokeless Powder	Propellants, explosives, Smokeless powder

Table I: Nitrogen Content of Various CN Materials.[16]

It is clear that the stability of cellulose nitrate is strongly influenced by the amount of nitrogen present within the glucose ring structure: the greater the nitrogen content, the more inherently unstable the resulting material will be. Some products with high nitrogen content, for example those with a percentage of 13.5, will explode if subjected to heat, friction or shock. Objects with less nitrogen component are not explosive but can, under certain conditions, be extremely flammable.

CN degrades to produce acidic (and oxidising) nitrogen gases, including nitrous oxide, nitric oxide, and nitrogen dioxide.[17] In closed areas with restricted ventilation, high concentrations of these gases build up and can corrode metals, embrittle and discolour organic materials, and accelerate the degradation of the CN itself. In fact, the process of denitration is autocatalytic; this means that, the greater the rate of degradation, the greater will be the concentration of gases within the plastic, and this causes the material to degrade at an even faster rate. Cellulose nitrate essentially "stews in its own juices" and a critical point can be reached if this degraded material is heated.

The progressive deterioration of CN is accompanied by a steady decrease in the auto-ignition temperature. The auto-ignition temperature of a particular substance is defined as the lowest temperature at which it will self ignite without a direct source of heat[18]. Fresh undegraded CN auto-ignites at 150 C, a relatively low temperature when one considers that the auto-ignition temperature of paper is 315 C to 375 C. In the last stages of decomposition, CN can self-ignite at temperatures as low as 50 C, a condition which can easily be present near light bulbs, radiators and heating equipment, or in unventilated buildings and attics during hot summers. The heat from these indirect sources is sufficient to set the process of deterioration into motion; once started, the deterioration is self sustaining and constantly grows and produces heat. The heat continues to build until the ignition temperature is reached and a fire is started. The presence of camphor in CN is very important in this respect as it tends to retard its decomposition; aging stock, however, can lose camphor through normal evaporation and the remaining plastic is very vulnerable.[19] Reports of spontaneous ignition of cellulose nitrate films have regarded only collections of photographic motion pictures and x-ray films which have been stored in dense masses in poorly ventilated, bulk storage deposits.

The extreme flammability of CN is related to the amount of free oxygen present in the nitrated cellulose molecule. A highly nitrated molecular structure contains a great degree of oxygen in the form of NO_3. The greater the oxygen component, the greater will be the combustion. Once CN is ignited the burning process is very thorough, and CN cannot smoulder, for there are no places in the molecular lattice structure which can be reached by outside O_2. Because of this built-in supply of oxygen, methods of extinguishing the fire based on the exclusion of air are totally ineffective, and it has been shown that CN can actually burn under water.[20] A given quantity of CN does not produce as much heat as the burning of an equal amount of wood or paper but the comparison becomes irrelevant when one considers the speed of CN combustion, which is a dozen times faster than that of wood and paper, and a ton of CN can be completely consumed in little more than one and a half minutes.[21] The liberated heat is truly remarkable, the flames can extend like blow torches in all directions, and the fire can spread very rapidly; this speed of combustion qualifies CN as a hazardous material.

There are several outward manifestations of deterioration which are present in all types of cellulose nitrate artifacts. These include the formation of oily brown liquid droplets, consisting of nitric acid or oozing plasticisers on the surface of the material; this process is often referred to as "weeping" and its probable cause is storage in conditions of high relative humidity.[22] "Crazed" cellulose is another sign of CN decay: the term refers to the fine surface cracking which gives the material a crystalline appearance with or without opacification, softening, yellowing or darkening.[23] This severely damaged condition is probably caused by internal stresses which have been created within the molecular structure during the manufacturing process, and released as soon as CN is weakened by the loss of plasticiser. Ultraviolet light and the presence of fumigants also seem to be responsible for this type of damage. If the concentration of the gaseous byproducts of this breakdown remains unventilated, the material may eventually be reduced first into a soft sticky mass and then into a formless brown powder. Other manifestations of deterioration in CN are: discolouration of translucent CN in sunlight, with a concomitant alteration of pigment additives; distortion and discolouration from heat (for example from exhibition lighting); and damage from microorganisms.[24]

The problematic nature of CN, and the special requirements associated with its proper storage and preservation have been recognised and debated for some time in the literature of the photographic arts, museology and archives. However, a facet of the nitrate problem which seems to have been given little attention is the potential for cellulose nitrate to cause health problems to those who work with it for extended periods of time, or to those whose work space includes storage areas where cellulose nitrate is kept under less than optimum conditions. Decaying CN can indeed represent a problem of some importance when one considers the possible human consequences of working with a material which is extremely volatile and can degas a variety of irritants over potentially long periods of time.

In their report, Deteriorating Negatives: A Health Hazard In Collection Management, Hollinshead et. al. have noted incidents of eye irritation, rashes, sores on the skin, and breathing problems amongst personnel involved in the cataloguing of film collections. A photography technician also experienced episodes of vertigo, nausea, headaches and swollen glands.[25] It is reasonable to expect that an individual's symptoms in such cases may be directly related to his or her degree of sensitivity to such substances and yet it is to be noted that many of the byproducts of cellulose nitrate decay are recognised as being potential irritants and quite hazardous to the body if prolonged exposure is maintained. Deteriorating CN produces a range of nitrogen oxide gases as well as a powdery base which can be irritating to the skin, eyes and respiratory system. These nitrogen gases can further deteriorate into nitric acid, another dangerous chemical agent. Table II shows the range of nitrogen gases which can be released by decaying cellulose nitrate:

Name	Chemical Formula
Nitric Oxide	NO
Nitrogen Dioxide	NO_2
Nitrous Oxide	N_2O
Nitric Acid	HNO_3

Table II: Types of Nitrogen Gases Released During CN Deterioration.[26]

Nitrogen oxide gases are primarily deep lung irritants, although irritation of the lung and other mucous membranes may occur. If repeatedly inhaled, these gases may cause chronic headaches, blurred vision, and loss of appetite. A distinction has to be made in the degrees of exposure one might face in dealing with these types of gaseous byproducts: acute exposure refers to a brief exposure to relatively large quantities of gas, whereas chronic exposure describes a condition where the individual has been exposed to a moderate quantity of gas over a long period of time. The latter condition would be representative of a situation where a person is performing a specific operation with cellulose nitrate objects, for example arrangement and description of a collection of photographs, or where nitrate collections stored in substandard conditions occupy the same areas as the employee's work space. Acute exposure to these gases can result in fever, nausea, dyspnea and vomiting, while chronic exposure may result in chronic headaches, blurred vision, loss of appetite, and other symptoms of systemic damage.[27] The following is a brief summary of the types of symptoms to be expected from exposure to these types of gases:

Nitric oxide: There are presently insufficient data from animal or human studies showing that NO is a health hazard; it is, however, potentially toxic, because it can oxidise to NO_2, producing nitrogen dioxide.

Nitrogen dioxide: Nitric oxide oxidises in air to form nitrogen dioxide in a light catalysed reaction. Nitrogen dioxide is highly toxic if inhaled, and has the ability to penetrate to the deep lung; this can sometimes result in a build up fluid in the lung, a condition which is known as pulmonary edema. This is accompanied by a decrease in lung area suggestive of emphysema, and a potential for the increase in lung infection. Evidence seems to suggest that the development of these forms of respiratory dysfunction is equally a result of the length of exposure as of the level of exposure to these gases.[28]

Nitrous oxide: This gas may or may not be present in the decomposition of aging CN materials, and takes the very same form as the common anaesthetic; chronic exposure to it over prolonged periods of time has been linked with various nervous system disorders, but this will occur at only very high levels.

Nitric acid: Gaseous nitrogen dioxide may combine with water to form nitric acid. This is a very corrosive agent and a primary irritant for the mucous membranes of the eye, nose, and throat. The fumes are highly toxic by inhalation, and may cause chronic bronchitis and emphysema.

Other gases which may be emitted during the deterioration of cellulose nitrate include acetone, mesityl oxide, and acetic acid. Acetone has a relatively low acute and chronic toxicity, and there have been no confirmed reports that prolonged inhalation of low vapour concentrations may result in the incidence of serious chronic effects in humans.[29] Mesityl oxide is a derivative of acetone used as a glue base in the making of plastics, acetates, and films; it can effect the skin, eyes, respiratory system, and the central nervous system. Acetic acid is irritating and corrosive to the epithelial layer of the cornea, and other mucous membranes, and it can irritate the upper respiratory tract, and result in bronchial constriction.

The foregoing physical ailments associated with decaying cellulose nitrate need not be considered a problem if the necessary safeguards are in place; the potential for problems exist, but it should not be considered cause for undue alarm. Nonetheless, it is important to exercise caution, especially when one is dealing with obviously decayed material.

The greatest problem associated with the collection and preservation of CN film lies not in the health hazard which this material presents to the archivist or conservator who works with it, but rather in its self destructive properties. CN poses a threat not only to itself but also to other archival materials with which it may share storage space. Therefore, it is advisable to possess a knowledge of the role CN has played in the development of the photographic process. The detection and proper appraisal of nitrate negatives is greatly facilitated by an understanding of the history of cellulose nitrate as a flexible film support in the period 1890-1950. In the next chapter the history of the development of the photographic industry in relation to the development of CN will be examined, as will the problems that this particular polymer has caused to those who are involved in the preservation of historic images.

[1] Catherine J. Maynor and Diane Van der Reyden, Paper Conservation Catalogue (Washington: American Institute of Conservation of Historic and Artistic Works,1989), 38.

[2] Julia Fenn, Ethnographic Conservator for the Royal Ontario Museum, a preliminary draft of a monograph on plastics and polymers (untitled), (May 1989), p. 1.

[3] Ibid.

[4] Ibid.

[5] Ibid.

[6] Ibid., p. 2.

[7] Ibid.

[8] Ibid. This ability to attract electrons is determined by the number of protons, or positively charged particles, within the nucleus of the atom. In an atom the number of protons is equivalent to the number of electrons.

[9] Ibid., p. 4.

[10] Ibid., p. 6.

[11] Ibid., p. 3.

[12] Ibid., p. 6.

[13] Ibid., p. 6.

[14] M. Lazar, T. Bleha, and J. Rychly, Chemical Reactions of Natural and Synthetic Polymers, (New York: John Wiley and Sons, 1989), 75-76.

[15] Maynor, op. cit., 39.

[16] James H. Meidl, "Plastics: Cellulose Nitrate. (Cellulose Nitrate Fire Hazards; Shipping and Storage)." Flammable Hazardous Materials. (Beverly Hills: Glencoe Press, 1970), 219.

[17] R. Scott Williams, Display and storage of Museum Objects containing Cellulose Nitrate, (Ottawa: Canadian Conservation Institute, 1988), 1.

[18] Ibid., p. 2.

[19] Meidl, op. cit., 220.

[20] Ibid., p. 219.

[21] Ibid.

[22] Fenn, p. 2.

[23] Ibid., p. 3.

[24] Ibid.

[25] Patricia W. Hollinshead et. al., Deteriorating Nitrate Negatives: A Health Hazard in Collection Management: (Tucson: Arizona State Museum, 1987), 1.

[26] Ibid., p. 3.

[27] Ibid.

[28] Ibid., p. 4.

[29] Ibid, p. 5.

Chapter Two

Cellulose Nitrate and the Photographic Process

Cellulose nitrate has been associated with the photographic process for nearly one hundred sixty years. CN product names which may be familiar to those who have studied the development of photography include collodion, celluloid, nitrate and nitrocellulose. Collodion was first mentioned in the scientific literature in 1847, when Louis Menard and Flores Domont communicated their discovery in the French Academy of Science.[1] In 1848, the Englishman Frederich Scott Archer discovered a way to light sensitise a glass plate which had been coated with collodion. This was known as the "wet plate" method, and by 1860 had become the dominant process in the photographic industry and had supplanted the daguerreotype and the calotype.[2] Collodion's popularity as a sensitising base was due to its ability to stick tenaciously to the glass plate even after repeated submersions in the various chemical sensitising and developing baths. The process was indeed quite cumbersome but remained the technique of choice until the 1880s, when the gelatin dry plate process became viable. It is in the development of the wet and dry plate methods of photography prior to the advent of flexible film that cellulose nitrate was first used, but it was to play an even greater role in the quest for a clear plastic support on which to place a sensitised emulsion.

The idea of having a lightweight and flexible support for the sensitised emulsion came early in the history of photography; but the relatively primitive technology of the time proved to be the major stumbling block for developing such a support. The calotype process of William Henry Fox Talbot was essentially the first process to utilise a flexible support: the calotype technique involved treating paper with solutions of silver nitrate and potassium iodide to produce a light sensitive silver iodide in the paper. The paper was made more sensitive by washing it with a mixture of gallic acid and silver nitrate, and exposing it for a few minutes. The invisible latent image was developed with a solution of gallic acid and silver nitrate and heated to produce a clearer print; it was then fixed with a solution of potassium bromide, which was later abandoned in favour of hyposulphite.[3] Generally, the calotype could not compete with its contemporary daguerreotype for portraiture, but it was better suited for the broad effects of landscape panoramas and architectural photography; in fact the paper grain tended to obscure fine details in the negative, and the prints tended to fade appreciably unless carefully processed.[4] Nevertheless, historians point to the calotype as the precursor to the modern photographic process.

The next step in the evolution of photography was a further development of the glass plate. Despite its popularity amongst photographers, it soon became evident to amateurs and professionals alike that some sort of replacement for the glass plate was needed; in fact it was heavy, bulky and inefficient for those photographers who wished to travel any sort of distance to capture images. It proved exceedingly difficult, however, to find a material which was as transparent and smooth as glass, yet free from impurities and grain. The ideal material for flexible films, celluloid or Parkesine, as mentioned earlier was developed in 1861 by the Englishman Alexander Parkes, but it did not find use as a flexible support until the technology was available to slice it thinly and evenly. Until this time, photography on film took two forms: stripping film and flexible film, with a brief revival of the paper negative process.[5]

Stripping film was a paper negative with a difference; the paper was merely used as support for the emulsion and was later peeled off before printing to avoid the effects of the paper grain. Frederich Scott Archer first developed a stripping film in 1855, by coating a finished and varnished plate negative with a layer of gutta-percha; on immersion in water, the sensitised collodion could be peeled from the plate leaving a film from which positive photographs could be made. This process helped to reduce the weight which had to be carried during long trips as, once stripped, the film could be kept in a portfolio and the plates used over again. This process did not find favour with the day-to-day photographer, however, nor did the variations on plate stripping produced by such notable individuals as Rev. J. B. Beade a few months later, Alexander Parkes in May of 1856, and J. A. Ferrier in September of 1857.[6] The technique of film stripping was taken up again in 1875 by Leon Warneke, whose complicated process involved coating glazed paper with coatings of collodion and india rubber solution, thereby producing a transparent support for the sensitised collodion emulsion. After exposure, the emulsion could be stripped from the paper and placed on a moistened glass plate, and could then be treated like a normal glass plate negative. This process proved to be very expensive and failed to generate sustained interest in the photographic community.[7]

Several other types of stripping film were on the market up until the late 1880's, but the one that generated the greatest interest was the film produced by George Eastman in 1886. This particular stripping film was manufactured for the Eastman/Walker Rollerslide camera in 1886 and for Kodak in 1888. Its life was very short, for it was superseded only a year later by cellulose nitrate roll film and its production was ceased in 1891. Because developing was so complex, it necessitated the Eastman Kodak Co. to process the film itself in the Company laboratories.[8]

Another process which was developed for the production of flexible films was the paper negative; it was not so much a revival of the old calotype as it was an improvement and refinement of this process. The speed of the sensitive coating had been greatly increased and the grade of paper had by this time been improved. Moreover, whereas the calotype had produced an image in the paper, the paper negative produced an image in the emulsion itself, with the paper acting only as the support. Eastman/Walker lent a certain impetus to the production of paper negatives with the production of the rollerslide; the camera was loaded with enough paper negative to produce twenty-four exposures and it was introduced in the US and England in the summer of 1885. The negative material was fine grained paper coated with a gelatin emulsion.[9] A few months later Warnecke produced a paper negative which was superior to even the Eastman/Walker negative and involved the coating of the paper with emulsion on both sides. Warnecke reasoned that any imperfections in the original negative would be cancelled out by the reverse image on the opposite side of the paper, and the grain would be removed by the double exposure. Warnecke believed that this process would usher in the paper era in photography, and it may well have been so had it not been for the arrival of cellulose nitrate film merely three years later.[10]

The flexible film which dispensed with a glass or paper support had its beginnings with Alexander Parkes, who formulated the aforementioned Parkesine, or celluloid-cellulose nitrate, in 1861. The one problem with using celluloid as a base for flexible films at the time was that it was still a thick and streaky material; manufacturers could not be persuaded to prepare the material thin enough to render it applicable to photography, arguing that the process was too expensive to make it cost-effective. This did not stop certain individuals, such as Ferrier and Pumphrey, from experimenting with such materials as collodion and gelatin to produce flexible film without the need for a support.[11] On the whole, these attempts fell short of becoming successful, and it was not until 1888 that a viable alternative, in the form of thin cellulose nitrate sheets, was introduced.

Celluloid was registered as a trademark in the United States and Great Britain in 1873 by John Wesley Hyatt of the Celluloid Manufacturing Company of Newark, New Jersey. He had been persuaded by John Carbutt, an English photographer living in America, to produce celluloid in thin sheets of 1/100 inch thickness.[12] John Carbutt had previously laid claim to the distinction of having been the first to produce the gelatin dry plate in the Unites States, and in 1888 was the first to produce emulsion coated celluloid films called "Carbutt's flexible negative films".[13] These sheets were produced by slicing thin sheets off a condensed block of cellulose nitrate, which were then coated with a sensitised gelatin emulsion. The results of Carbutt's four years of experimentation were published in the *Journal of the Franklin Institute* in Philadelphia.[14]

The next logical step in the production of flexible films was to find a method by which this union of cellulose nitrate and gelatin emulsion could be produced in the form of roll film. As previously mentioned, roll holders were already in existence and had been used extensively with the paper negative roll film, but the technical problems in producing a cellulose nitrate roll film were indeed quite formidable: the CN solution had to be fluid enough to flow onto the film forming support (usually a glass drum), then to be mechanically spread into a uniform layer, but also had to be viscous enough to stay in position. Furthermore, the solvents used to dissolve the cellulose nitrate had to be of a specific volatility; if they evaporated too quickly, air bubbles would be left in the film. If, on the other hand, the solvents evaporated too slowly the process was not cost effective.[15] These problems were solved by three Americans: the Rev. Hannibal Goodwin and, together, George Eastman and Henry Reichenbach, a chemist with the Eastman Dry Plate Company of Rochester New York.

Goodwin had in fact applied for a patent for his flexible roll film made of cellulose nitrate and camphor eighteen months before Carbutt had introduced his perfected cut film to the market. Goodwin's patent was delayed for some time as he was acutely short of money and his claim was not considered specific enough by the patent examiners.[16] While Goodwin's claim was under examination, Eastman was able to corner the market for roll films. His chemist, Henry Reichenbach, had been experimenting with the process of producing thin, flexible sheets of cellulose nitrate and had found the answer to the roll film question. Reichenbach discovered that thin sheets of celluloid could be produced by pouring a solution of cellulose nitrate in alcohol on to glass plates; the resulting sheet was thin and transparent, but rather brittle. He added camphor and found that the film was more flexible, but crystallisation of the finish rendered it uneven and spotty. Finally, Reichenbach added two more solvents to the mixture, amyl acetate and fusel oil, and found that a thin, strong and perfectly transparent film could be produced. A patent for the new process was applied for in April of 1889, and was issued in December.[17] Unlike Hannibal Goodwin, Reichenbach was able to supply the patent examiners with an exact formula for his process. Goodwin, for his part, was still hamstrung by money difficulties and was unable to raise enough money to begin production of his film until 1900. Shortly before this, he died in an accident.[18]

Eastman's production of the new material began in August of 1889, using an apparatus devised by Eastman himself. Transparent film was made by pouring the liquid mixture of cellulose nitrate and solvents on to plate glass tables two hundred feet long and three and a half feet wide. When the mixture had set, the cellulose was coated with the emulsion. When this was dry, the film was stripped from the tables, slit into rolls, and cut to sizes which fit the Kodak camera and the roll holders. The new film was called Eastman's Transparent Film, and was the first commercially available transparent roll film.[19] Within one year, the demand for the new film had become so great that Eastman Kodak had to build new plants just to keep the production up to the demand.[20] The Eastman's Transparent Film was produced from 1889 to 1903; it was very thin and curled rather easily. A slightly thicker, non-curl film was produced in 1903 with a coating of gelatin on the back to prevent curling; this gelatin backing also tended to reduce flammability and improve stability.

After Hannibal Goodwin's death, the firm of Anthony of New York acquired controlling interest in the Goodwin Film & Camera Co., and began to produce the CN roll film in December 1902. At the same time it sued Eastman Kodak for infringement, on the grounds that Eastman's manufacture of the film had departed from the formula devised by

Reichenbach, and was in fact the same formula as Goodwin's. The lawsuit which ensued was long and complicated; it occupied the courts for twelve years and was documented in 5,500 printed pages by the time it was settled in March 1914. The Appeal Court, at that time, held that Goodwin's application, filed in 1887, had indeed revealed the essential features of the new process, and that the Eastman Company was guilty of infringement. Eastman Kodak was ordered to award a settlement to the Ansco Company, by now the owner of Goodwin's patent, based on its profits from the sale of the film in question. The settlement was for five million dollars.[21]

With the advent of the flexible film, the modern era of photography had begun. The increased convenience of this type of film allowed the professional photographer to shoot more pictures under varying conditions, but it was the amazing increase in the number of casual photographers which proved to be the real blessing to the industry. Eastman Kodak's cameras were immensely popular with the amateur and casual photographer, and the company catered to the demand by providing excellent service. The swiftly developing amateur market soon became the economic foundation of the photo industry. The types of cameras which were developed for this market removed photography from the realm of the "serious" or "art " photographer, and made the novice the prime target for the sale and distribution of photographic equipment. The camera was no longer a complicated apparatus whose manipulation was best left to experts, but rather a toy for the amusement of all. The upshot of this was that all the photographic components had to be mass produced, and this technical base served to establish a large industry and a consumer package which in turn served to fuel the demand around the world. At the heart of this new era in the industry were the flexible film and the standardised camera.

It soon became apparent to those who produced and worked with CN film however, that it had some rather severe drawbacks; the material was inherently unstable over even short periods of time, and was dangerously inflammable if stored improperly. Photographers were swift to notice that the film tended to decompose over time and a series of fires at warehouses, cinemas and businesses provided clear evidence of the danger of nitrate film. The Ferguson Building fire in Pittsburgh in 1909 was an early example of the dangers of CN; thirty people were injured in the fire and subsequent explosion. The building itself was improperly designed and held several film groups. Nitrate film was the cause of at least two major fires a year in such companies as Metro, Famous Players, Thanhouser, Universal, Pathe, Edison, and Lubin during the early 1900s. A fire at the Lubin location in 1914 caused particular interest as it appeared to have started in a poorly designed nitrate vault.[22]

The disaster at the Cleveland Clinic Hospital on May 15, 1929 caught the attention of the world and facilitated the growing general awareness of the potential problems of CN film: a huge explosion and fire caused the death of one hundred and twenty five people, and injuries to many more.

The greatest cause of death was the gas produced by the fire and explosion; people were seen to drop where they stood from inhalation of the fumes, and the situation was further exacerbated by the explosion which blasted the gas through the building ventilation shafts.[23] In subsequent inquiries into the disaster, CN x-ray film was determined to be the culprit. The National Chemical Warfare Board which investigated the disaster determined that a number of potentially lethal gases were produced during combustion of the film. The Board found that the primary gases produced during the combustion of CN film are carbon monoxides (47%-59%), carbon dioxide (21%-24%), and nitrous compounds (7%-9%). It was also determined that, on the average, twenty five cubic feet of carbon monoxide were released by five pounds of nitrate film, equivalent to one reel of motion picture film or one hundred and twenty five 8 x 10 negatives.

Although its ready combustibility had been understood for some time prior to the Cleveland disaster, little had been done to draft and enforce regulations on the handling and storage of the film. The early, initial attempts to codify fire regulations by various underwriting associations were given added impetus by this disaster.[24] At the time of the disaster, Eastman Kodak admitted that cellulose nitrate film was indeed inflammable but only if it was kept in inadequate storage conditions. The dangers of CN were fully recognised by 1930, and it began to be replaced by cellulose acetate, or safety film, which had much reduced burning properties.[25] In 1937, cellulose diacetate, as well as other film bases composed of mixed cellulose esters, were produced. In 1947, cellulose triacetate film was introduced, but CN roll film continued to be produced up until 1950.[26] Eastman Kodak discontinued production in 1951.

Figure 6 serves to compare the structure of cellulose nitrate and diacetate films; cellulose nitrate still plays a part in the production of diacetate films but primarily in the subbing layer as an adhesive. Cellulose diacetate is much more stable than nitrate and is certainly not as prone to combustion; advances which have been made since the introduction of diacetate have ensured stabilities which are several times greater than the earlier safety films.

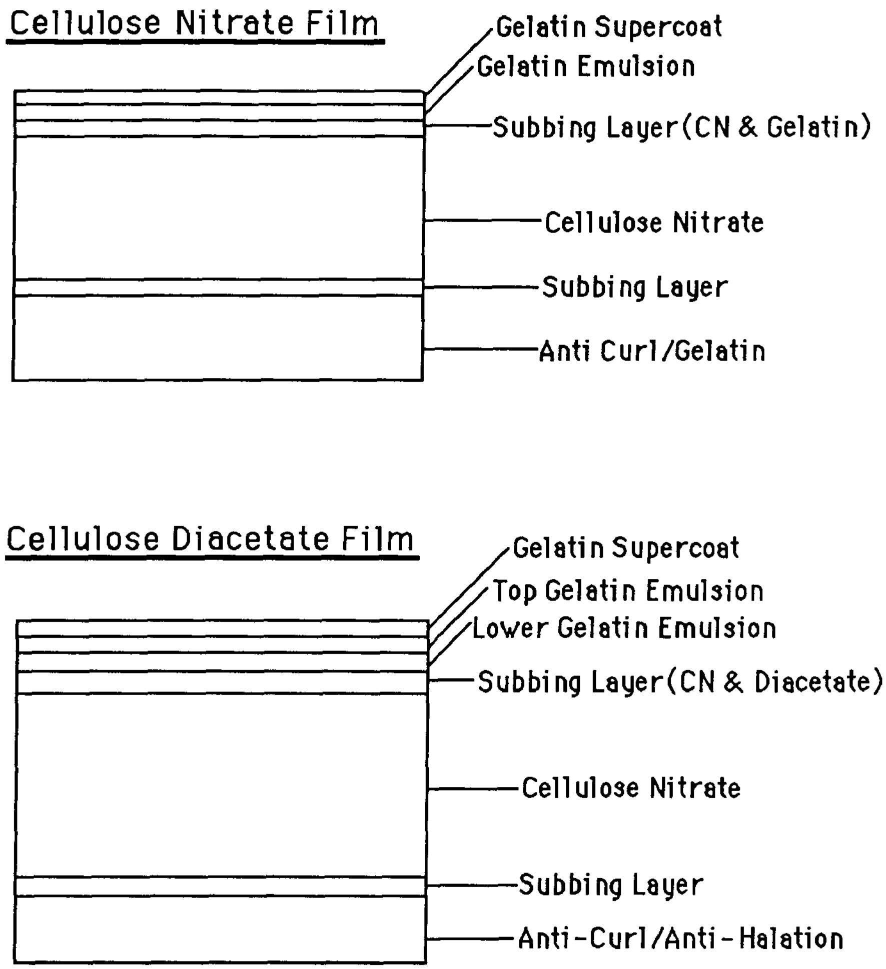

Figure 6: Cross Sections of CN and Cellulose Diacetate Film.[27]

Institutions which acquire photographs from the period 1890-1950 are very likely to have CN films in their possession; it is therefore of the utmost importance that those films be identified in order that they might be adequately dealt with in the context of the institution's mandate and resources. There are several ways in which CN films can be identified; some are complicated and require certain expenses, while others are much simpler but concomitantly less reliable. It certainly helps to know the age of the film; there are certain general date guidelines which might be used to determine the likelihood that the film in question is cellulose nitrate. The following table serves to show the general dates of discontinuation for various formats of cellulose nitrate film:

Type of Film	Last Year of Nitrate Manufacture
X-ray films	1933
Roll films in size 135	1938 (A)
Portrait and commercial films sheet films (B)	1939
Aerial films	1942
Film Packs (C)	1949
Roll films in sizes 616, 620, etc. (D)	1950
Professional 35mm motion picture films	1951

Table III: Dates of Discontinuation for CN Film Formats.[28]

It is important to bear in mind the following notes when considering the above dates as they will help in the physical identification of the film beyond simply dating them. Taking the date and the following into consideration will aid in the identification of the film.

(A) It has been common practice for photographers to buy bulk rolls of 35mm film and respool it onto cassettes for still camera use. Because of this, it is not uncommon to find still camera negatives on nitrate film for some time after this date or until any amounts of CN held in reserve were used up after the 1951 discontinuation date for motion picture reel film.

(B) Nitrate sheet film tends to have a very thick and rigid base, while professional sheet film will also have coded notches on one corner to allow the photographer to determine the emulsion side in the dark.

(C) Film pack negatives were produced in the same sizes as professional sheet film but have a much thinner and more flexible base, and will feel like roll film. They lack a notch code, but may have a negative number, generally 1 through 12.

(D) These sizes were called amateur roll film formats and were very popular with the casual photographer; they are quite common in personal and private collections.

A problem inherent in identifying photographs by date is that Eastman Kodak is the only manufacturer to supply any dates on the discontinuation of cellulose nitrate films, and these dates cannot be applied to other manufacturer's films. Another complication is that in almost all cases there was a carry over period during which both nitrate and safety films were in use. Because there is no specific date as to when safety films were actually introduced, it is not possible to tell with certainty whether a film is a safety format based solely on its date.[29]

Border markings are also a relatively simple, yet not entirely reliable way of determining whether a film is nitrate. Many manufacturers stamped professional sheet films along one edge with identifying markings and the words generally identified the manufacturer and the type of film: nitrate or safety. This is the easiest way of determining the type of film if the markings are there, but unfortunately border stamping was not done by some manufacturers; and the practice was not present for early nitrate films nor for some roll formats. Amateur roll films were not marked, but they can be identified by their tendency to curl into very tight scrolls; roll films were eventually coated on both sides to reduce this tendency.[30]

One established method for film type identification is the float test. A small portion of the film can be clipped with a hole punch from an unexposed section of the film and placed in a test tube of trichlorethylene. This test is a measure of the film's specific gravity; nitrate film is heavier than both acetate and polyester safety films, and trichlorethylene is a solvent with a specific gravity between that of nitrate and acetate. A clipping of a nitrate film will therefore sink in the test tube while safety films will float or remain suspended in the liquid. Caution should be exercised when using this particular test as the solvent trichlorethylene is extremely toxic, and the test should only be performed under a fume hood.[31]

Burn tests are also fairly accurate in determining the nature of the film material. A sliver of film trimmed from a non-image margin can be held upright in a pair of tweezers and ignited. CN film will burn rapidly and constantly, whereas safety films will burn much more slowly or not at all and may often simply self-extinguish after a short period of time. It is a good idea to experiment with several edge stamped films so that the specific burning characteristics can be noted and recorded for future reference.[32]

The diphenylamine spot test is a fairly reliable means for establishing whether a film is nitrate or safety. This test consists of taking a small chip from the unexposed portion of the film and placing a small drop of diphenylamine solution (6% in concentrated sulphuric acid) on it. In the presence of nitrate the spot will change to a distinctly blue colour.[33] A fresh batch of diphenylamine solution must be kept on hand as the reaction becomes less distinct with aging of the solution, and the test should also be done under a fume hood. A final means of determining the nature of the film is by observing its infrared spectrum. This test requires the use of an infrared spectrometer, a technical piece of equipment whose cost is prohibitive for small institutions; the test, however, is very accurate because, on an infrared spectrum, CN shows prominent and distinctive bands at 6.1 and 11.9 micrometers.[34]

The progressive deterioration of nitrate negatives can be broken down into five stages:

Stage One: Amber discolouration of the film base, and beginning of image fading.

Stage Two: The emulsion becomes adhesive, negatives tend to stick together or to their enclosures, and may have an acidic smell.

Stage Three: The film shows gas bubbles and emits a strong noxious odour.

Stage Four: The film becomes soft, welded to adjacent film and is frequently covered with a viscous froth.

Stage Five: The film mass degenerates partially or entirely into a brownish acrid powder.[35]

While it is important to note that there is no clear demarcation between these different stages, and that a particular negative may exhibit characteristics associated with one or more of them, this means of identifying the deterioration of nitrate is nevertheless a very important practical tool. Most negatives will retain legible photographic detail into the third stage of decomposition. They may indeed be brittle, but, if carefully handled they can be duplicated. Generally, negatives in stages four and five have little or no image detail, and should be disposed of immediately.

The rate of deterioration is erratic and unpredictable; some nitrate films degrade slowly and steadily over a period of years, whereas other nitrate films show little or no signs of deterioration for fifty years or more and then reach stages four or five in a matter of months. Furthermore, several different stages of deterioration may be seen on the same reel of film, and there is absolutely no predictability in the way individual negatives shot on the same stock will behave over a given period of time. Films from the same manufacturer, processed by the same photographer, and stored side by side often exhibit distinctly different rates of deterioration; this phenomenon has yet to be explained.[36]

There are several factors which contribute to the degradation of nitrate film, and no single cause, but rather combinations of factors tend to be the cause of CN breakdown. To begin with, there is the matter of the original quality and purity of the film base itself; much of the film manufactured in the years during and immediately after the Second World War was of inferior quality due to the scarcity of raw materials.[37] Furthermore, the standards of production may well have varied considerably within a particular company, and certainly between companies. The early industrial era in which CN was initially produced was not known for its high standards of production overall, let alone for the film industry by itself.

Temperature also plays an important role in the decay of cellulose nitrate film stock; it has been estimated that the deterioration of CN is accelerated by a factor of four for each 10 C rise in temperature (approximately a factor of two for every 10 C rise in temperature).[38] Humidity plays a major role in deterioration because water is necessary to the formation of acids and other deteriorants within the film itself. High relative humidity accelerates the process of deterioration dramatically; the maximum humidity level within a storage area should not exceed 40%.[39] Also the gases which are produced during the decay of cellulose nitrate should be allowed to escape the film storage area because of the autocatalytic nature of the reaction.

The temperature in the storage area should not exceed 21 C (70 F) and a lower temperature is desirable, if it can be maintained without increasing the relative humidity above 45%. A relative humidity below

40% is desirable, but there is a risk that the film will become very brittle if conditions are too dry. With nitrate negatives, the relative humidity is critical because a compromise must be reached between making the base too brittle and making the gelatin so tacky that it will adhere to sleeves or other negatives.[40]

The format also has an effect on the rate and nature of the deterioration of nitrate film; it is the format of the film which has the greatest direct effect on the mobility of those gases which are produced during the break down of nitrate. Professional sheet film is the thickest plastic with a nitrate base of 8mm, and consequently it has the least inherent stability. On the other hand, professional motion picture film, with a base of 5mm is the thinnest nitrate-based film, and thus should logically have the greatest inherent stability. But because motion picture film is tightly rolled onto itself, its relative mass is greatly increased and its actual stability is therefore much lower than sheet film. Similarly, sheet films which are stored together without individual sleeves are much more prone to deterioration than sleeved or interleaved sheet films. These varying stabilities are not the result of varying chemical compositions, but rather they are a reflection of the ability of the deteriorant gases to escape the film.[41]

It would be remiss at this point not to consider an alternative analysis of the progressive deterioration of CN negatives. In his article, "Fire Risk by Storing Nitrocellulose and its Behaviour During Combustion."

Rudolf W. Gobel takes a somewhat different approach in analysing the nitrate problem. Through extensive tests conducted on a very large amount of nitrate reel film, Gobel comes to the conclusion that the ignition temperature of cellulose nitrate is independent of the degree of disintegration. Evidence shows that the ignition temperature is linked directly to the degree of dessication of the film base, and is therefore closely associated with the relative humidity of the storage area.[42] Gobel notes that the ignition temperature was particularly low for films whose silver image and emulsion were still completely intact but which showed signs of dessication. CN films reach a very dangerous stage when they are, irrespective of age, dry and brittle; in this regard the quality of the original film base can be considered a strong influencing factor on the rate of dessication of the film base. Furthermore, dessication phenomena were particularly noticeable in films which were stored in rooms heated with steam or water central heating; another influencing factor may be a method applied for some years in which the films were rinsed with alcohol after fixing in order to obtain fast drying. The alcohol withdraws humidity and plasticisers to such an extent that the base loses its ability to reabsorb them.[43]

Gobel also notes that throughout his extensive investigations of nitrate deterioration, little evidence was produced showing that self ignition of nitrate was indeed possible.[44] This assertion would seem to contradict the findings of the National Bureau of Standards, which in 1949 showed that deteriorated nitrate could undergo spontaneous combustion at temperatures as low as 106 F, and possibly much lower.[45] It would seem irrefutable that auto-ignition of cellulose nitrate is indeed a pressing concern in regards to the storage of motion picture films, but is only secondary for nitrate sheet negatives. Overall, it is the general deterioration of cellulose nitrate film which is the most pressing issue for archivists and conservators who have only limited resources.

Ideally, in order to minimise the decomposition of nitrate, it should be separated from other archival materials, placed in airtight enclosures, and stored in a freezer. At freezing temperatures the natural decomposition and the production of deteriorant gases is completely stopped. Small quantities of film can be frozen relatively easily, but the cost and inconvenience involved in freezing large quantities of cellulose nitrate can be very high and may prove to be hard to manage logistically. A less costly option is to provide a controlled environment with the temperature maintained between 50 and 70 F and a relative humidity of 30-50%. Cycling of the climatic conditions must be avoided at all costs as fluctuations in the relative humidity and temperature will hasten the deterioration of the nitrate negatives. The area around the negatives should also be well ventilated to allow the gases to dissipate.[46] It will be necessary to return to these procedures in a later chapter and examine them in terms of the effects they can have on administrative and preservation policies.

In the next chapter, the nature of cellulose nitrate films which are being kept in archival institutions will be examined. The relationship between the hazardous qualities of CN and the administration of institutional policies of preservation, access, copying and disposition of archival CN will be considered. The archival administration of nitrate can be very difficult indeed, and the decisions which are made in regards to its disposition may have lasting, and not always good consequences. The problems involved in maintaining cellulose nitrate in an archives must be considered in a holistic manner. With this in mind, the different methods of preservation and administration of nitrate film material will be considered. Emphasis will be placed on the administration of nitrate negatives in their various formats, although much of what will be said will also be applicable to motion picture film.

[1] Michael Hager, "Saving the Image: The Deterioration of Nitrate Negatives," Image 26, 4 (1983): 2.

[2] Ibid.

[3] Helmut Gernsheim and Alison Gernsheim, The History of Photography 1695-1914 (New York: McGraw-Hill,1969), 62.

[4] Brian Coe, George Eastman and the Early Photographers, (London: Priory Press, 1973), 33.

[5] Gernsheim., p. 405.

[6] Ibid.

[7] Ibid., p. 406.

[8] Ibid.

[9] Ibid., p. 407.

[10] Ibid.

[11] Ibid.

[12] Hager., p. 3.

[13] Gernsheim., p. 408.

[14] Hager., p. 3.

[15] Ibid.

[16] Gernsheim., p. 408.

[17] Coe., p. 71.

[18] Gernsheim., p. 408.

[19] Ibid.

[20] Steven Puglia "A Short Guide to Nitrate Negatives: History, Care, and Duplication" (Andover, Mass: Northeast Document Conservation Centre, 1987), 1.

[21] Gernsheim., p. 409.

[22] Karr., p. 2.

[23] "Poison Gas Kills 100 in Cleveland Clinic; Explosions Spread Fumes, Fire Following; Patients, Nurses, Doctors Die in Flight," New York Times, 16 May 1929.

[24] "Strict rules Guard Hospital film Here," New York Times, 16 May 1929.

[25] Gernsheim., p. 409.

[26] Cellulose Nitrate and Safety-base Photographic Films, p. 1.

[27] Ibid.

[28] Puglia., p. 3.

[29] Ibid.

[30] Ibid.

[31] Cellulose Nitrate and Safety-Base Photographic Film, p. 3.

[32] Christine Young, "Nitrate Films in the Public Institution," History New Technical Leaflet, 44, (July/August 1989): 3.

[33] Fenn and Coxon., p. 2.

[34] Maynor., p. 39.

[35] Puglia., p. 5.

[36] Ibid., p. 3.

[37] Karr., 3.

[38] Young., p. 3.

[39] Ibid.

[40] Coe., p. 34.

[41] Ibid.

[42] Rudolf W. Gobel, "Fire Risk by Storing Nitrocellulose and its Behaviou During Combustion-A Contribution to Film Preservation by the FIAF," Institut Fur Filmkunde (nd). , 2.

[43] Gobel., 2. Gobel also takes a different approach in identifying stages of film deterioration by noting three stage rather than the more familiar five. These identifications are typified by extensive physical descriptions of the film, in conjunction with its behaviour under combustion.

[44] Ibid., p. 4.

[45] Young, p. 3.

[46] Puglia., p. 5.

Chapter Three

The Preservation and Administration of Nitrate Negatives within Archival Institutions

Today the bulk of extant nitrate film is held in cultural institutions rather than in photographer's files or in commercial film establishments. The ramifications of this situation can be very far-reaching. The most obvious is that the primary handlers of nitrate film may tend to be less knowledgeable about its physical nature, and unaware of the hazards it may present, and consequently they may handle it without all the necessary care. This lack of proper knowledge and care is sometimes aggravated by the fact that insurance companies and fire fighting agencies may feel that nitrate film ceased to be a problem when its manufacturing was discontinued, and may be unaware of its continuing presence in archival institutions.[1] For example, in the United States, the National Fire Protection Agency has not updated the code for professional film since 1936, while the code pertaining to motion picture film has been revised as recently as 1982, but remains focused on the handling of the film within the film industry: no code regulates the conditions of storage of film in public institutions.[2]

The risks of such a situation should not be underestimated, particularly in view of the fact that film which was once preserved in small private repositories is now being concentrated in great quantities in large public buildings. Concomitantly, the resources and institutional infrastructures of the public bodies now responsible for the preservation of nitrate film material vary, and there may be a great discrepancy between the capability of one institution to cope with this material and that of another. Furthermore, the nitrate films which are being collected by cultural institutions are often decades old, and may have already begun to deteriorate.

Many archival institutions which have acquired films manufactured prior to 1951 will have nitrate within their vaults. In acquisition decisions, the unique visual information on this material has been a more important factor than its instability and potential for destruction. But archivists need to weight the hazards presented by nitrate film against the importance of the information contained in it. In order to do so, they have to consider that (1) permanent retention of nitrate materials implies that measures must be taken to guarantee its preservation and to eliminate or reduce the risk of damage to adjacent material; (2) separation of the film from the other documents of the fonds in which it belongs, for reasons of preventive conservation, will require the establishment of tracking systems able to maintain both the physical and intellectual control of items removed from their documentary context; and (3) certain preservation techniques, such as cold storage, must be applied judiciously and with proper guidelines in place.

In dealing with CN film, archival institutions have to focus on preventive conservation rather than on restoration. In fact, attempts to restore deteriorating nitrate negatives have not proven entirely successful, with the exception of the process developed by Vilia Reed, a colour retoucher at Eastman Kodak. The process involves removing the image bearing emulsion from the nitrate support, and transferring it to a new safety type film base.[3] Reed bases her technique on an emulsion stripping system for colour materials, owned in part by Sears, Roebuck and Co. The system consists of removing the nitrate support with a solvent and placing the image bearing pellicle on a new, stable support previously wetted with a solution of water and Photo-Flo. It is a very delicate operation, and the film material is very easily damaged by excessive handling. Although proven successful in the hands of a skilled technician, this type of process cannot be used in large scale operations. When the gelatin emulsion is wetted, it expands, distorts and becomes extremely fragile; this problem can be further compounded by hand manipulation and squeegeeing.[4] Over-manipulation can result in image-silver migration, which causes permanent tonal variations in the negative. In addition, this method is relatively slow, and the cost of labour and materials is so high that it renders it prohibitive for most institutions.

Because of the problems involved in restoring nitrate negatives, and of the large quantity of this material which is currently accumulating at an increasing rate in public institutions, the administrative emphasis has been placed on preventive conservation of nitrate negatives, and eventually on preservation of the images they contain by copying them on another support. Preventive conservation programs have been adopted in several archival institutions, with a great degree of variation in the actual procedures put in place, and with consequently differing results. This lack of uniformity in the administration of nitrate negatives is due to a number of factors, ranging from the specific needs of each institution, to limited budget and resources.

There are several archival issues which are to be addressed when considering the preservation and administration of nitrate negatives, and a few rather broad concerns which may impinge on other areas of decision making. In examining nitrate preservation policies we will move from the archival issues, which are strictly related to appraisal criteria, to the broad concerns which are peripheral for archivists.

An initial decision has to be taken as to whether or not nitrate films are to be kept. A decision in favour of retention would have to be based on the intrinsic and evidentiary value of the film; the willingness of the institution to establish more or less elaborate tracking systems, which by guaranteeing proper intellectual control allowsthe repository to physically separate the film from the fonds in which it belongs and to preserve the significance of the fonds as a whole; and the ability of the institution to cover the ongoing costs of using expensive equipment and regularly inspecting the material.

If, on the other hand, it is the intention of the institution to destroy the negatives after duplication, the implementation of this decision would have to be preceded by the establishment of copying priorities, the determination of the means of interim storage and handling of the material waiting to be copied, and a choice of the means of destruction of the copied material. Indeed, before adopting a general policy, its effects on specific situations have to be considered. For example, it should be investigated what effect would such a policy have on the appraisal of a fonds for monetary or tax credit purposes? Destroying the originals places the focus of the archival institution on the reproduction technique, which must be chosen very carefully. The process must be proven and reliable, because, once an original image is destroyed, there is little or no recourse if the copy image is seen to deteriorate.

In late May 1990, this author conducted, in conjunction with the Provincial Archives of Manitoba (PAM), a poll of various archival institutions across Canada. Its purpose was to help PAM to develop a policy for the administration of its own rather extensive collection of nitrate-based negatives. PAM has on-site cold storage facilities in place, and it was felt that guidelines needed to be developed and finalised with regards to the storage of nitrate negatives and other sensitive photographic materials. PAM, as well as the Hudson's Bay Company Archives (HBCA) conducted a survey of their holdings, and determined that the number of nitrate negatives held by the Historical Division of PAM numbered around three thousand, while HBCA had a collection numbering between six and ten thousand, with conceivably more yet to be found. It seemed to be a logical move to start dealing with the problem presented by such large numbers of photos on nitrate film by conducting a survey of the procedures in place at other institutions. The findings of this survey shed a great deal of light on how the problem is being approached by various Canadian archives. The findings, which follow are not reported here for evaluative or judgmental purposes, but for showing how various institutions with correspondingly dissimilar budgets and resources are coping with the disappearing images on nitrate film.

The questionnaire used for the survey was very straight-forward, and consisted of the following questions:

(i) Do you retain the original nitrate negatives or do you copy and then destroy them?

(ii) If you retain the originals, then what criteria are used for selection, (i.e. intrinsic value, artifactual value, etc.)?

(iii) If you destroy the originals, then what process is used?

(iv) What are your copying costs? What method do you use to prepare copies?

(v) If you isolate sensitive materials in cold storage, what are your procedures for doing so? Are these materials still accessible for research? What procedures are used to retrieve them from cold storage?

Responses to the questionnaire were swift in arriving, indicating the importance of this problem for the archival profession; most responses came through the mail, although some information was received through telephone conversations. The most striking preliminary observation was that the various guidelines used by archival institutions did not constitute a unified body of accepted and standardised procedures for the handling of nitrate negatives. The fact that there appeared to be little commonality in the way in which archival institutions approached the nitrate problem can be attributed primarily to the differences in fiscal responsibilities and restrictions in money support for such specialised programs. The institutions themselves realise the necessity of dealing with the problem of administering nitrate collections, and yet the variety of what is actually accomplished seems to be primarily dependent on the means and resources at hand, and not on any disagreements of an archival or purely administrative nature.

All the institutions surveyed agreed that there were problems involved in the storage and preservation of nitrate collections, and that the basic components of any program for the preservation and administration of nitrate negatives should include their identification, separation from other archival material, duplication of those deemed to be of historical significance, and identification of new acquisitions of nitrate material. Also, all institutions agreed that such programs should be continuing and not ad hoc. However, if we examine the way in which the various institutions attempt to fit their basic understanding of the problem into existing fiscal considerations, it is possible to see how differences in practise develop.

The way most institutions deal with budgetary constraints regarding ephemeral visual media is familiar and time-tested: it basically involves targeting special needs and making priority decisions. An example of this is provided by the Provincial Archives of Alberta (PAA), where the intention is to copy and dispose of all nitrate still and moving image negatives, pending the acquisition of the necessary budget. As it stands now, a good deal of copying has been done, but those films which have not been copied are retained and monitored for any signs of deterioration. However, this remains a policy as yet to be implemented as the Archives is unsure of the stability of direct copying film, and therefore retains for the present all copied originals until the relative stability of direct-duplication film is fully determined. Of course, given a large budget, a particular institution has the option to carry on larger and more intensive programs, while smaller budgets oblige the targeting of certain needs and the use of the available technology. The National Archives of Canada, (NAC) is a good example of the first situation, while the Saskatchewan Archives Board (SAB) is a typical example of the latter. The SAB shows an ability to improvise with its procedures, as it employs a commercial frost-free refrigeration unit at a temperature of 3 C and 34% relative humidity for storage, and actually takes care of some of the disposal on its own. This is a good example of a well directed program which is run on a smaller budget and limited resources.

Another approach is used with regard to a special project. The

Toronto City Archives has the extensive Globe and Mail collection of journalism photographs, many of which are on nitrate base. The Archives has in place a special project whereby a certain amount of time and money is set aside each fiscal year for the expressed purpose of copying a portion of the negatives onto polyester safety-base film. The project is run for approximately twelve weeks, and six hundred negatives are copied during this time. This type of approach is particularly useful when the targeted collection is too large to be copied all at once, or when funds are limited.

It is on the question of whether the original nitrate negatives should be disposed of or kept in storage after they have been copied that there are some differences of opinion between institutions. It seems that most archives would choose not to keep the originals, if there were no questions as to the dependability of the various copying systems. The Provincial Archives of Alberta (PAA), states emphatically that the original would be destroyed given that the stability of the duplicating film can be maintained, whereas the Notman Photographic Archives retains the originals until they show signs of deterioration. The latter approach parallells that of other archival institutions, for example NAC and the SAB. It must be noted that, as in most situations involving nitrate material, to keep or not to keep is a question which is distinctly influenced by the availability of certain resources. Here, as with other facets of administration, policy decisions reflect what works for an archives within an existing fiscal framework.

Conscious decisions have been made on certain copying procedures in order to get the most out of the available resources, and to ensure that proper preservation techniques are followed; for example, the negative-interpositive method seems to be quite popular, as it provides more than one copy of the negative, which can be retained for preservation and security purposes. Although the direct duplication method is generally regarded as being less expensive and labour intensive in the long run, some institutions are hesitant to implement such a process for fear of its possible instability. An example of this sort of decision can be seen with the PAA, which has delayed the destruction of recently copied material for fear of silver migration in negatives copied by direct duplication methods.

The survey, the results of which are shown in greater detail in Appendix I, shows that procedures for the preservation of nitrate collections vary from one institution to another. However, these differences reflect more the fiscal variation among institutions than specific contrasts in archival policy and implementation. Still, it should be possible to formulate general guidelines for the preservation, copying, disposition, and handling of nitrate films, which might be followed to a greater or lesser degree depending on various fiscal and policy responsibilities.

Pamela Haas suggests some actions that can be undertaken relatively easily, and which may provide good administrative results in many different situations. She writes that, after local fire codes have been studied, cellulose nitrate-based material must be identified, and periodically rechecked for decomposition.[5] One must endeavour to obtain information as to the numbers of nitrate films which have been selected for permanent preservation within each fonds, their condition, the amount of film presenting extensive decomposition, as opposed to those still intact. Once this process of identification is complete, specific actions must be directed to the proper preservation of nitrate negatives. Nitrate material should be segregated from other material, if possible in a totally different air space. It is especially important to avoid areas in which books or other paper materials are stored.[6] An attempt should be made to control the climate in such a way as to prolong the life of nitrate negatives: if it is impossible for the institution to provide cold storage for nitrate, then every avenue should be explored to ensure that the temperature of storage is maintained between 50 and 75 F and the relative humidity between 30% and 50%. Other options include the use of commercial frost-free refrigerators; in which it is possible to monitor constantly the relative humidity. Reel film should be dealt with first: as it presents a concentration of hundreds or thousands of feet of nitrate film, it is more dangerous than sheet film. The whole process of administration and preservation of nitrate material requires the use of significant resources, in terms of time, money and staff. At one time, experts considered it appropriate to duplicate all nitrate film by photographic processes, and then dispose of the originals. Now this is no longer the prevailing philosophy. As Haas puts it,

> Now it is felt that the appraisal of the intrinsic value of the material must first come into play. At this time we are advised to copy-at different levels of accuracy with commensurately different price tags-and then to store the originals in a safe place.[7]

It is generally accepted that nitrate negatives of permanent value must be kept intact until the resources to have them copied become available; whether they are to be destroyed or not after copying is a decision which must be based on archival principles, and on a realistic consideration of administrative, fiscal and human resources. Whatever this decision will be, it is incumbent on the archivist or conservator to be aware of the technologies available for the copying of nitrate negatives. The efficacy of any program dealing with CN material hinges on the reproduction techniques which are utilised; poor workmanship or uninformed decisions can have disastrous consequences.

When determining a duplication program, the administrator must first consider the quantity of negatives to be reproduced on to safety film, and the amount of resources available. The latter element is often the determining factor in the choice of the type of technique which will be adopted. The administrator should first consider the following issues: (1) What are the different methods for duplicating negatives and what would the costs entail? Due attention should be given to the relative merits and disadvantages of each method. (2) Which method would be best for a particular project? (3) How much lab work, equipment, and supplies would be needed, and furthermore, how much archival work would be necessary to locate the negatives, prepare them for duplication, catalogue them, and then prepare them for refiling? The cost of supplies would have to be taken into account as would the need for additional storage cabinets for the new duplicates. (4) How much time will be required to train project staff and maintain quality control? (5) How will the archival staff recognise the deteriorating negatives? (6) Which of the endangered negatives will be duplicated? (8) What would be the plan of work? (9) What will be done with the originals and, if they are to be kept, will storage space and equipment be needed?[8]

In any copying program, several decisions are taken simultaneously; the duplication method chosen will determine the design of the camera and the lab procedures, and these in turn will have a bearing on the identification and cataloguing procedures. What follows is an evaluation of the various copying procedures available.

Ways to Produce New Negatives

1. CAMERA COPY

From an original negative, a positive paper print (preferably 8x10) is is made by contact or enlarger. Then, a new negative (preferably 4x5 or larger) is produced from the positive paper print by camera. Compared to other methods, this technique is relatively simple and inexpensive, but it yields a new negative which is less accurate in scale of tones than the original, and presents a concomitant loss in resolution.[9]

2. INTERMEDIATE POSITIVE METHOD

An intermediate positive is made on film from the original negative; from the intermediate positive a duplicate negative is made. This method can reproduce the original image accurately tone for tone, if it is properly done. The film interpositive serves as an insurance against loss or damage of the original duplicate; this process also uses familiar film emulsions which have been tried and tested. There are three variations to this method.

Variation A: Contact positive to contact negative. From the original negative, a same-size intermediate positive is made, emulsion to emulsion by contact. From this intermediate positive, a same-size duplicate negative is made, emulsion to emulsion on film by contact. This is a very good way of making duplicates of nitrate negatives: because both the intermediate positive and the duplicate negative are made by contact in a vacuum frame, they are the same size as the original and reproduce fine detail with a resolution which is greater than that of a lens system. Having an intermediate positive image is also an advantage. However, this system is quite expensive, and may be beyond the budget of many institutions.

Variation B: Contact positive to reduced-size negative. From the original, a same-size film intermediate positive is made, emulsion to emulsion on film by contact. A reduced-size duplicate negative can then be made through a lens system. This process produces an intermediate positive the same size as the original negative and with very high resolution, while the duplicate negatives can be made in reduced sizes. An advantage of this process is that, by using the lens system to produce the duplicate negatives, this final step can be delayed if funds are not available, or if relative scarcity of funds dictates that final duplicates be produced at a slower rate.

Variation C: Reduced-size intermediate positive to duplicate negative, same size. The original negative is placed on the light box of a duplication camera, and a reduced-size intermediate positive is produced on film, (4x5 sheet film, 70mm roll film, or 35mm film), through the camera's lens system. A duplicate negative is then made from the intermediate positive, usually by contact. Larry and Jane Booth believe that duplicate negatives should not be made any smaller than 4x5, unless the nature of the material is such that there is not a great demand for the highest resolution, for example, the duplication of thousands of progress shots.[10] If small duplicate negatives are feasible, they can be produced with a good deal of savings in cost.

3. DIRECT DUPLICATE NEGATIVE METHOD

A direct duplicate negative can be made from an original negative in one step, using Kodak Professional Direct Duplicating Film (Estar Thick Base) with conventional processing techniques. Tone is reproduced accurately, and because only one piece of film is used to produce a direct duplicate negative, this method is less expensive size for size than the copy camera method or the intermediate positive method.

Variation A: By contact , exposed through film base with point source of light. The original negative is placed emulsion side up over the 4168 film, also emulsion side up. The exposure is by contact to produce a right-reading duplicate negative. See Figure 7.

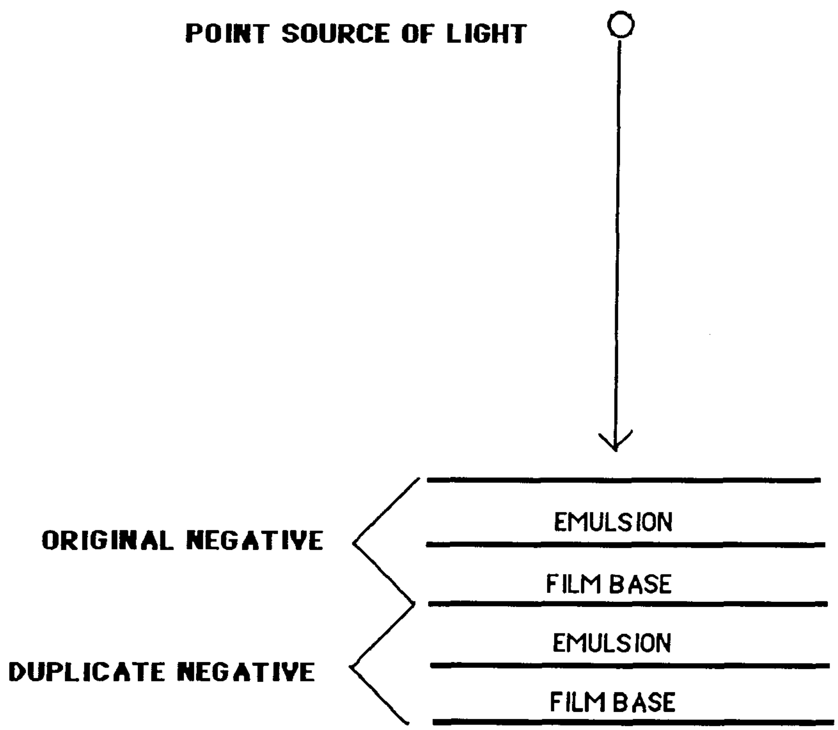

Figure 7: Direct Duplicate Negative Method, Variation A

Because it is made by exposure through the original negative's film base, this duplicate negative has poor resolution, even though a point source of light is used. This method would be suitable only for films where high resolution is not a critical factor.

Variation B: By contact, emulsion to emulsion The original negative and the duplicating film are placed emulsion to emulsion, and exposed by contact to yield a same-size direct duplicate negative. The negative will, however, be wrong reading. See Figure 8.

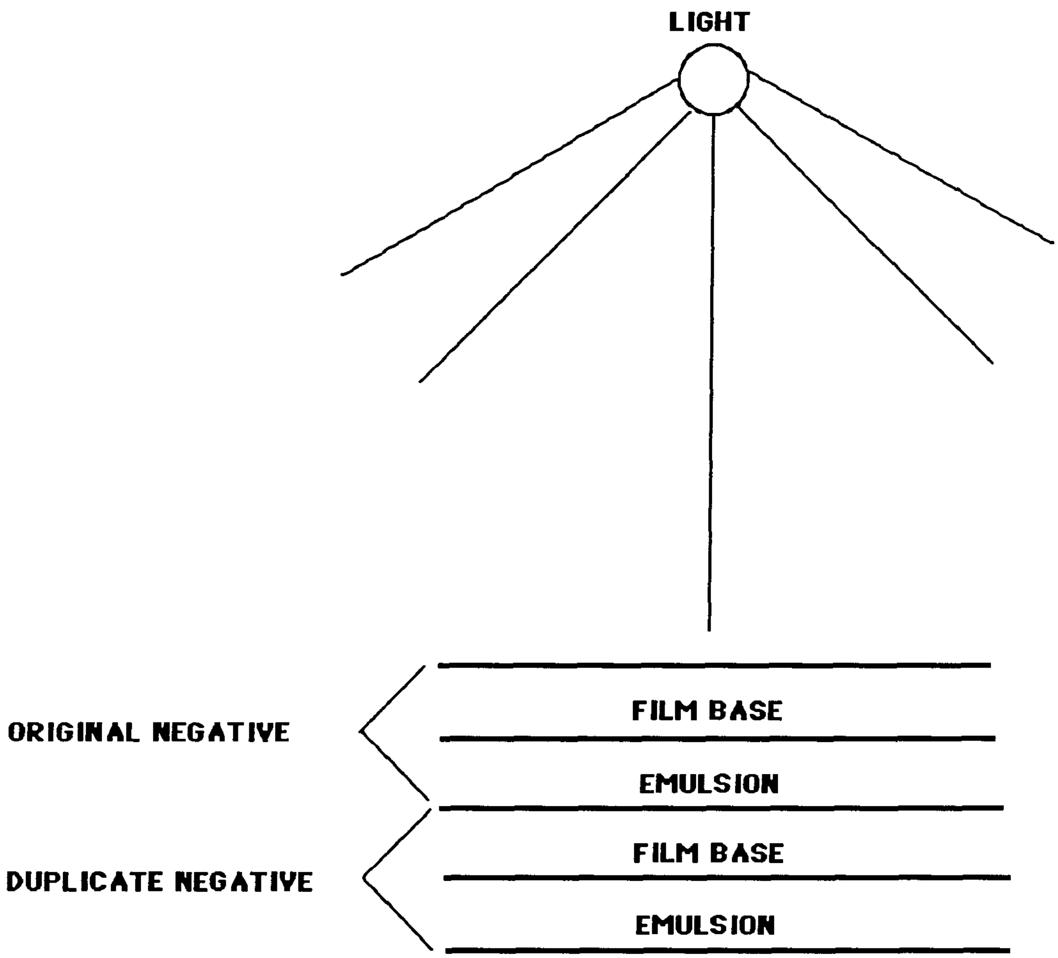

Figure 8: Direct Duplicate Negative Method, Variation B

It has been found that a duplicate negative made by contact, emulsion to emulsion, in a vacuum frame will be of the highest resolution. Besides being rather expensive, this method can prove problematic because the resulting negative will be wrong reading, and sharp contact prints cannot be made from such negatives using conventional methods.

This process can be used for negatives which will always be printed by enlarger, because the negative can be placed in the enlarger emulsion side up to produce right-reading prints.

Variation C: By camera, emulsion down. With the original negative placed emulsion side down on the light box of a duplication camera, SO-015 film is exposed to make new duplicates of any size. The new duplicate will be right reading. See Figure 9.

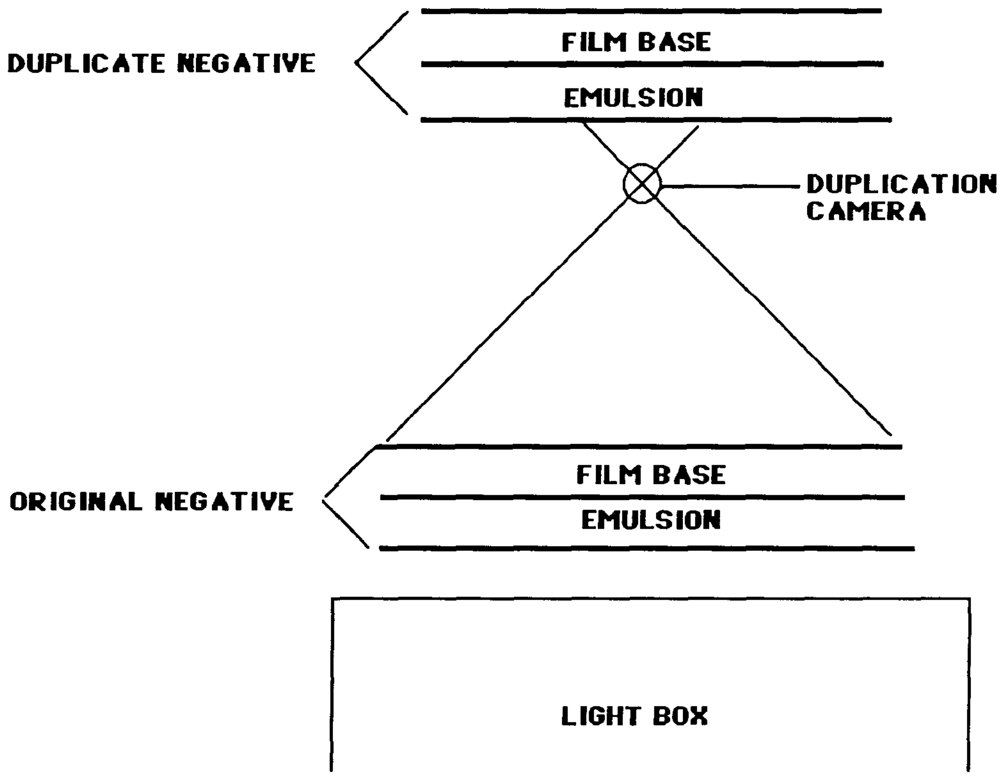

Figure 9: Direct Duplicate Negative Method, Variation C

This variation can produce duplicate negatives of any size. The quality of the reproduction depends on the duplicate negative size, a properly aligned camera system, and a good lens designed for the magnification range corresponding to the particular size of duplicate negative.[11]

The relative merits and faults of all duplication methods have to be weighed before designing the duplication program, in order to ensure that the maximum number of images with high resolution are produced within a given budget. Booth maintains that no duplicate smaller than 4x5 would be considered of acceptable quality, because "even the most careful handling of a negative less than 4x5 in size results in wear scratches objectionable for high-resolution enlarged prints".[12]

In their report on the program for the duplication of the TICOR collection of photographs, Larry and Jane Booth explain why Kodak Professional Direct Duplicating Film, at the time named SO-015, (now called 4168 Direct Duplicating film), was used for this particular large-scale project. Two reasons are mentioned for choosing this particular film: first, it is capable of yielding high resolution negatives when an 8x10 image is reduced through a camera lens system to 4x5 film, and secondly it makes possible for normal contrast negatives an exact reproduction, tone for tone, of the original negative. The film is also suitable for the reproduction of sharp, high resolution 4x5 negatives by contact in a vacuum printing. A problem inherent in this process is that the resulting duplicate is always wrong-reading, which implies that a contact print made from such a negative would also be wrong-reading. This would result in the production of many historically and diplomatically inaccurate prints if the negatives are not clearly coded to ensure that the darkroom personnel properly orient them to produce right-reading prints, that is, with the emulsion side up. The Booth's solution to this problem is to put a new notch on the duplicate print at the other end of the same edge that has the factory's notch; the factory notch would then be snipped off. This new orientation of the notch automatically leads the darkroom worker to make right-reading prints both by contact and by enlarger.[13]

Another potential problem exists with Kodak 4168 film. In the early eighties, when the SO-015 version of this film was first being used in the reproduction of sensitive images, it was determined that negatives produced on this direct duplicating film were more susceptible to tarnishing in storage than conventional emulsions, and that the image tone was sensitive to strong light. At the time, Kodak began testing the image stability of SO-015 and other types of Kodak films. The results of these tests, as published, indicated that the image stability of SO-015 was indeed less than that of Kodak Commercial Film and Super-XX, when stored under the same conditions. Thus, serious questions arose as to the appropriateness of using this type of duplication film. Kodak implemented a full-scale program of testing on it, and published a report with specific recommendations for processing and post-processing of SO-015 negatives to obtain greater image stability. Since that time, Kodak's extensive research into the matter has proven that the film will retain its stability characteristics if its-processing and storage guidelines are followed exactly.[14] These guidelines have been illustrated in a publication titled, "Stability and Restoration of Kodak Professional Direct Duplicating Film SO-015", by F.J. Drago and W.E. Lee.[15]

Direct duplication should not be used to reproduce nitrate negatives which are to be discarded. In fact, such duplication produces only one copy, and therefore there would be no back up image in the event that, after the original is destroyed, the new copy is damaged. If the original is retained in proper storage conditions, then direct duplication can be used for large quantities of nitrate negatives, as the process is most appropriate for mass reproduction techniques. Where originals are retained, direct duplication can be used effectively to make negatives for consultation purposes.

The interpositive/duplicate negative method of copying has certain advantages over other methods besides its better reproduction of tone and detail: in implementing a program based on this method, the process could essentially be split into two steps. Those films which are in immediate danger of decay could be saved by producing an interpositive copy on film, while the making of duplicate negatives could wait. This would save the images, and allow an indefinite time period for the institution to raise further funds for making duplicate negatives.

Many institutions do not have the budget or the resources to conduct in-house duplication programs, and therefore must send their negatives to outside processors. If this is done, then certain guidelines should be set up in advance for having a guarantee of good quality. A logical first step is to investigate the various laboratories in light of the procedures to be used in the duplication process and the type of equipment required: it would be wise to consult independent labs or university photography departments for assistance in setting up quality control guidelines. Once an outside laboratory is chosen, a contract should be drawn up specifying the amount of residual silver thiosulphate and sodium thiosulphate allowable in the negatives. Such standards are defined by the American National Standards Institute Specifications for Photographic Films for Archival Records, Silver Gelatin Type, on Cellulose Ester Base, ANSI PH 1.28-1976, and on Cellulose Ester Base, ANSI PH 1.41-1976.[16] Independent tests may be performed on random samples of the processed duplicates in order to measure the amount of residual chemicals in the duplicate. This might be done at an independent testing lab, provided that the institution has the budget or the necessary contacts for such a procedure. At all times, the new duplicate negatives should be checked against the originals for accuracy of tone reproduction, dirt, dust, fingerprints, scratches, and stains. If the contract is to include the production of prints with the duplicate negatives, then the other conditions to be specified in the contract should include the type of process to be used, the size of the duplicate, the type of paper for the prints, and whether the print is to be made from the original or from the duplicate negative.[17]

From a budgetary point of view, there are several possible ways in which a copying program can be carried out. Some institutions use "special event " situations in which to carry out copying of collections; for example, they mark an important event or person to which a specific set of images pertains, or bring attention to a particular body of photographs. Another approach, and one which is especially effective in larger institutions with correspondingly bigger budgets and collections of photographs, is the establishment of an ongoing program in which funding is set aside according to specific budgetary considerations and fiscal policy. Either approach to copying may indeed be successful depending on the nature of the institution and its budget and resources. Whatever the case, the greatest danger in implementing any type of policy of duplication is procrastination: nitrate material is not only decaying at an accelerating rate, but is also being acquired actively in the present. At the very least, a program for the location, description, and assessment of nitrate negatives could be instituted while planning a program of copying.

There are further risks in delaying the implementation of a duplication program: additional nitrate negatives can be lost through continuing deterioration; funding set aside for nitrate duplication may be redistributed within the institution for other purposes, or even disallowed later on; finally, the institution's administration or the local fire officials may insist on the removal of the negatives from the premises before they can be properly duplicated.

It is wise to consider an ongoing program of duplication as the logical step in the administration of nitrate negatives. Unfortunately, for some institutions, this program is not feasible for a variety of reasons. While sometimes it is just not possible to garner the necessary funding for an ongoing project, other times the sheer volume of material does not make it possible to duplicate the negatives with the desired speed. In these cases, it is important for the institution to maintain the nitrate negatives in such conditions that will ensure their relative safety during the waiting period for duplication.

It is important that the institution consider in advance whether it will keep nitrate originals which have been duplicated, or whether it will destroy them. This should be a policy decision, rather than an ad hoc decision and should be carried out as a routine. In fact, it is no small matter to destroy material of this nature, and the decisions made in this regard should be considered carefully in advance. The archival and historical ramifications of such a policy will be dealt with later on. At this point it is essential to point out that, if nitrate is to be destroyed, it should be only under carefully controlled conditions, with supervision of the proper fire authorities. Only a small number of nitrate films in good condition can be disposed of through normal waste channels. Nitrate negatives should not be incinerated with office paper.[18] Large quantities of decayed film should be handled with the same degree of care which is given to explosives and other unstable materials; if a large quantity of material is on hand and awaiting disposal, it should be attended to in observance of the local fire codes.

The safest way to dispose of nitrate negatives is through carefully controlled burning by qualified personnel in the open air. In most cases, fire prevention and environmental regulations will require that such disposal be supervised by the proper authorities. A suitable location would have to be selected which would be removed from any building or from other combustible materials, such as gases, brush, or litter. Nitrate films should never be burned in a furnace or other enclosed spaces, because of the toxicity of the gases and their high pressure. A high quality incinerator may be used if it is equipped with pollution-control devices, and if the rate of burning can be limited by controlled-rate feeding. Only small quantities of nitrate should be burned at a given time.

If, however, nitrate material is to be kept for an indefinite period of time after duplication, or if the quantity of material is such that long term plans for duplication are necessary, then it is very important that steps are taken to prevent these films from deteriorating while they are waiting to be copied. If the original film is considered to be of value beyond the image itself, then long term storage, with or without duplication may be considered as the best option. If long term storage is considered to be necessary, for whatever reason, then the institution is bound morally, and in some cases legally, to provide storage conditions which will reduce the rate of deterioration and which will guard against the risks of fire and the build-up of toxic fumes. Basic guidelines have been already mentioned as to the steps which can be taken to prevent the further decay of nitrate negatives. The techniques to be employed may vary from institution to institution, and are dependent on the mandate and resources of the particular archives. For organisations with adequate budgets, cold storage should be considered as the most viable method of long term conservation of nitrate negatives.

Ideally, to minimise the decomposition of CN negatives, they should be placed in airtight enclosures and stored in a frost-free freezer. At very low temperatures, the natural decomposition of cellulose nitrate is effectively reduced to near zero. The freezing of small quantities of material can be done with relative ease, but to do it for larger quantities of nitrate negatives can prove to be quite prohibitive in cost. If a commercial frost-free refrigerator is used for even short term storage of small quantities of film, great care should be exercised in monitoring the relative humidity of the environment, as these units are known to fluctuate and they are not built to a standard suitable for the long term storage of nitrate films.

Cold storage vault requirements will undoubtedly vary from one institution to another, but there are several basic considerations to be made when planning and implementing a cold storage program. First of all, it may be necessary to precondition film prior to refrigeration, especially if the following conditions exist:

- The room in which the film is packaged for storage has a relative humidity greater than 40%-50%;

- The refrigerator is not frost-free;
- The storage temperature is less than 55 F.[19]

When conditioning film for storage one must ensure that the humidity is dropped below 40% in the preparation area, because cooling the air will bring a concomitant increase in the relative humidity (RH), if the RH becomes high enough then condensation will occur. In the winter time the humidity is often already low enough due to heating, and the preconditioning phase can sometimes be omitted, but in the spring and summer it is almost always necessary to properly condition the film. Small quantities of film can be dehumidified by placing them in sealed plastic bags with a dessicant such as silica gel.[20] Once the film has reached the desired humidity it should be placed in the freezer as quickly as possible.

Nitrate negatives should be inserted in acid free buffered paper enclosures, and then placed in air-tight sealable plastic bags; Kodak manufactures a bag which has been used successfully in these cases. The use of these types of bags is somewhat problematic as the hermetic seal will maintain a certain amount of moisture within the bag, but at the same time will trap any gases which are emitted by the film; if however, the refrigeration compartment is truly frost-free (the cooling apparatus is exterior to the compartment), then the internal humidity of the refrigeration unit will be low, and sealed bags will serve little positive function beyond the occurrence of fluctuations of temperature due to equipment malfunction. If the refrigeration is only pseudo frost-free (does not need defrosting but the cooling coils are internal to the unit), then it is quite possible that the RH will fluctuate greatly and will occasionally be quite high; in this case sealed bags would be desirable. Standard refrigerators that require defrosting have generally low humidity and can be used for storage of nitrate without bags so long as alternate storage is available when the units have to be defrosted.

A cold storage vault will probably have a storage atmosphere of around 2 C and a relative humidity of approximately 35%. Maintaining these conditions requires very specialised and rather expensive equipment. Therefore guidelines must be set in place in order to maintain the physical integrity of the collections contained within the vault. Items to be placed in the cold storage vault should be preconditioned with their storage materials for a period of twenty four hours in the stack area (for example, at 4 C and 47% RH). After this period of acclimatization is complete, the materials could then be moved from the stack area to another place, where they will be allowed to acclimatize to the vault conditions for a further twenty four hours. Storage materials which could be used are individual mylar sleeves for each negative, and Kodak Storage Envelopes (Cat. 148 6398), in which these mylar sleeves would be placed. In order to keep the workload at a minimum, a system could be devised whereby the nitrate materials and their envelopes are properly identified and partially assembled prior to acclimatization in the stacks. This would mean that the mylar sleeves containing the nitrate negatives would only have to be placed in the envelopes by the worker in the vault.

Mylar sleeves have several advantages with respect to paper; they take up less space in the envelope, do not stick to decaying negatives, are inert, and facilitate checking for deterioration. Identification for the proper tracking of items can be done by using gummed labels on the outside of the mylar sleeves, or by marking the sleeve itself with a stable insoluble pen. Some concern has been expressed as to whether nitrate negatives should be placed in alkaline buffered envelopes, but this is inadvisable as the buffering compound may cause deterioration of the image.[21]

The mylar sleeves containing the negatives should be placed in the envelopes to a thickness of no more than one-half inch; this is to ensure that no physical distortion occurs. Air can then be pressed out of the envelopes, and then they can be heat sealed; the resulting vacuum, and the low temperatures will reduce or eliminate altogether the possibility of oxidative reactions. The Kodak envelopes can be opened and resealed in order for negatives to be removed and inspected for signs of deterioration or for copying. These types of sleeves can only be resealed a certain number of times, however, as each time the envelope is sealed a certain amount of it is used up in the process, and the envelope would have to eventually be discarded.

Items which are to be removed from cold storage could be inserted into a closed polyethylene bag to prevent condensation, and allowed to acclimatize to stack conditions for twenty four hours; the Kodak storage envelopes should remain sealed. These items could then be moved to room temperature for twenty four hours prior to being opened. The preconditioning procedures outlined above must then be repeated when the materials are returned to the vault.

These procedures are necessary in order to ensure that the negatives retain their original clarity and tone, free from oxidative deterioration. Needless to say, such storage procedures can only be undertaken in an archives where there is a program of copying already in place and running; the materials which are to be put into cold storage vaults should not be accessed on a regular basis as the logistics do not provide for easy and quick retrieval. This is long term storage in the strictest sense; and is to be maintained in intellectual deference to the original image, and as a proper safety precaution with modern copying methods.

At this point attention might be given to a new form of technology which may come into play in the long term mass storage of both images and textual material in archival institutions. This new technology is known as CD ROM storage and has come on line in recent years as a practical alternative to conventional information storage techniques. However, as the presentation of this type of technology is outside the immediate scope of this thesis, and is highly technical, it has been included in Appendix II.

This chapter has attempted to deal with some of the most important issues which surround the preservation of nitrate negatives in public institutions. The matter is not a simple one, and various organisations have developed guidelines and procedures which are often institution specific. It is not the purpose of this thesis to establish a set of rules and regulations which must be adhered to, but to highlight certain circumstances or ramifications which may arise from various courses of action. It has at all times to be remembered that the consequences of the decisions made today will remain for many years, and that a bad course of action taken at the outset will prove very hard to reverse in the course of setting future administration policy.

[1] Young., p. 4.

[2] Ibid.

[3] Eugene Ostroff, "Rescuing Nitrate Negatives," Museum News, (Summer/October 1978): 35.

[4] Ibid., p. 42.

[5] Pamela Haas, "The Conservation of Photographic Collections," Curator, 26, No.2 (1983): 95.

[6] Ibid.

[7] Ibid.

[8] Larry and Jane Booth, "Duplication of Cellulose Nitrate Negatives," Picturescope, 30, No.1 (Spring 1982): 12.

[9] Ibid., p. 13.

[10] Ibid.

[11] Ibid., p. 14.

[12] Ibid. p. 13.

[13] Ibid., p. 15.

[14] Puglia., p. 7.

[15] Cited in Booth, Larry and Jane, p. 18.

[16] Ibid., p. 17.

[17] Fiber-based prints should be chosen for long term archival copies whereas resin coated papers are sufficient for work prints. Also, it has long been recognised that toning of images on paper prints enhances the image permanence, and this is a standard recommendation for enhancing the stability of paper prints. The addition of potassium iodide to the fixing solution has been used in the production of microfilms since 1969, this has been recommended to provide protection from micro dot stains. Toning should be looked into as a possible way to maintain stability in silver-gelatin images.

[18] Eastman Kodak Co, The Preservation of Photographs (Rochester: Eastman Kodak Co.,1979), p. 34.

[19] Young, p. 6.

[20] Ibid.

[21] Interview with Jane Dalley, Head Conservator for the Provincial Archives of Manitoba.

Conclusion

Because the hazards of nitrate films are not generally known, it is important to educate and encourage the archival community to arm itself with the facts before attempting to deal with them. Nitrate's reputation may cause some to take radical actions which are not befitting the circumstances. As G. William Jones states, it is important to "do the whole job of talking about the preciousness as well as the danger" of nitrate film. In other words, nitrate film is certainly no demon; it is possible to put in place programs and operations which allow one to deal with its volatile nature, and at the same time, avoid risks for the material itself or for the people who work with it. Despite many commonly-held perceptions of the dangers of nitrate film, it is indeed possible to care for it in such a way as to render it safe as well as long-living. With some education and practical experience, the archivist can deal with the material in a rational and logical manner, much like s/he would with any other sensitive material within the framework of established procedure. It would be rather unfortunate if archives were to go so far as to avoid acquiring nitrate film because of its perceived danger; the fact is that nitrate film is as dangerous as the methods which are used to store it. If the necessary precautions are taken there should be few problems. The main reason why archives should not shy away from the further acquisition of nitrate film is its historical function in the creation of a mass photographic interest: this film was the basis of the growing popularity of photography in the late decades of the nineteenth century, and many of the images which are captured on nitrate film lend a perspective not only on important events in the past, but on every-day life as well. It is therefore not uncommon, given the time-frame in which nitrate film was used, as well as its popularity as the first viable flexible roll film, to find large amounts of nitrate negatives and reel film within an archive's fonds.

Once nitrate film is within an archival institution, there are several options open for its administration. The first and most important question to be answered is whether the film is to be kept in storage for the long or the short term, that is, whether the material will be copied and then destroyed, or copied and retained. These two courses of action must be considered well in advance of implementing the copying policy as they have a bearing on the type of duplication processes used as well as on how this and other types of ephemeral material will be approached over the long run.

The consideration of this particular aspect of nitrate preservation hinges on the concept of the form of the document, which in this case is the nitrate negative. If the physical form of the negative is not necessary to our understanding of the image, then we need do little else than to acquire nitrate film, copy it, and then destroy it. If, on the other hand we are to consider the form of the negative to be functional to the understanding of the image then we must build a case for retaining the nitrate negatives past the copying stage. The simple assertion that the original is unique and holy and is the only entity which is capable of providing true and admissible evidence is not a valid argument for preserving it, because a copy would be capable of accomplishing the same evidentiary functions as the original, if it is properly authenticated. To understand better the problem of form with regard to nitrate negatives we must turn to diplomatics and the concept of documentary forms.

According to diplomatics, every written document has a form, that is, the information it contains is expressed by means of rules of representation which are themselves part of the message. These rules of representation, or form, reflect specific political, legal, administrative and economic structures, as well as culture, habits, myths, and, "constitute an integral part of the written document, because they formulate or condition the ideas or facts which we take to be the content of the documents".[1] The form of the document comprises both physical and intellectual components: the external makeup, which is the physical form of the document, and the internal articulation which is its intellectual form. To understand the document fully one must comprehend its physical and intellectual forms. However, the strict observance of rules of form cannot always be expected in a personal context, because the inner freedom of human beings is such that the diplomatic study of forms may reveal little with regards to documents which result purely from personal activity.[2]

One can argue in light of diplomatic analysis that a photograph has all the basic elements of a written document: an emulsion adhered to a flexible transparent backing (physical form), a message to transmit, constituted of that which the photographer sees and wishes to express (content), and an internal articulation expressed in the photographer's choice of angles of composition, apertures, speeds and possibly special lenses (intellectual form). Therefore, a photograph can be analysed to the same degree in which we approach any written document. This approach may seem more suited to the photographs taken by an art photographer or by the so-called professional, and less to the simple amateur photograph. This is not true, however, because intellectual form does not necessarily result from a conscious choice; rather it is the natural result of the effort to communicate.

One must wonder, however, whether we can approach the photograph and the negative from which it results as we would a written document produced according to administrative and legal rules. The answer to this question is especially important in the identification of what is original, and can determine whether a nitrate negative should be kept for as long as possible, even if it has been reproduced in the best way that technology has to offer.

In diplomatic terms, the concept of originality hinges on two important precepts: the first, primitiveness, and the second, perfection. Primitiveness means simply that the document is the first in order, while perfection in a document indicates that it is complete, finished, without defect and enforceable. A document having the status of original is capable of producing the consequences for which it was created, and is therefore a means to an end as well as an end in itself. Therefore, in establishing the status of a document, the medium is a consideration, "if it influences the enforceability of the document".[3] In the case of photographs, the negative is the precursor of the print, and therefore exhibits primitiveness, but at the same time it lacks perfection, because it is not a complete and finished photograph. Most importantly, it is not an enforceable document because it is not fully capable of producing the consequences for which it was created. It is, in fact, the first print which creates the consequences and achieves the end for which the photograph was taken in the first place, and it is therefore the first perfect document. In instances where we have many first prints, we have many originals of the same document; where subsequent prints are made at different times and distributed, the first one to be transmitted is the original, while subsequent images are copies in the form of the original.[4]

If the original is the first perfect document, and with photographs, that original is indeed the first print and not the negative, then can we consider the negative to be a draft? In diplomatic terms, the draft of a document is a sketch or outline of the definitive text, it is prepared for purposes of correction and is considered to be provisional. The final draft of a document generally has most of the elements of the original but not the physical form. The draft of a document represents the creative moment in the documentation process and, "because of this, has the greatest importance not only for a diplomatic understanding of that process, but also for the diplomatic understanding of the fact and will determining the creation of the document".[5] Indeed, the negative of a photograph will contain all the information of the first perfect print, but the opposite is not necessarily true and the transmission of the information from negative to print may alter it in such a way that that only the trained eye can determine the relationship between the negative and the first print: for example, apertures can be changed, and resolutions can be manipulated so that the actual information which is conveyed in the original is much different from the information conveyed in the negative.[6] Therefore, it may be said that the negative is the essential vehicle in the final production of the print and is a draft, yet it is not like a final draft. It defines a creative moment, but only one in a series of creative moments which culminate in the production of the first perfect document, the original print. Moreover it is not a draft in the traditional sense, because it tends to carry more, rather than less information than the original and much of it is included in the negative not by the will of the photographer but by the mechanics of the technology. This implies that the will of the author can only be visible in the first print, which would contain only that which the photographer wishes to convey to the observer. Thus while with traditional documents the draft constitutes the creative moment and the original the formal moment, with photographs both draft and original contain elements of creativity as well as of formality.

In the art community, the emphasis is placed on the first and subsequent prints of a given negative rather than on the negative itself: the print is of the greatest importance and the negative is of much less value to the art curator. The negative is merely the means to the final print, which is the end; it is the instrument for the production of the final and artistically significant print. Archivists may balk at the thought of aligning their ideas with those of the art curator, but such an approach, aimed at understanding the relationship between two states of transmission, would be diplomatically orthodox. Besides, the issue here is that form, in a draft, is not an essential part of the document, but usually it is precisely that part which is meant to be different in the original. As a matter of fact, a document is made complete and effective by its form, the perfection of its form makes it original. Therefore, we do not need to preserve the initial form of the negative to capture the information in its entirety, as long as the historical context provided by the material is preserved in its form of descriptive information. Many of the nitrate negatives which are acquired by archives can be classified as amateur in nature and their form does not add to the meaning of the image even in the print.

It is important to note, however, that the policy of copy-and-destroy in no way eliminates the need for facilities which will ensure the safe, long term storage of nitrate material. Nitrate negatives are truly ubiquitous and can be found in almost all institutions which acquire photographs.

Because nitrate was the first roll film to gain a foothold in the mass market and is closely tied to the boom in amateur picture taking which occurred in the late eighteenth and early nineteenth centuries, the actual number of nitrate negatives which exist in the world today is enormous; concurrently, the number of those images which are of lasting historical importance is also very large. It would be materially impossible for most archives with fixed budgets to copy all the negatives in their holdings at one time; most often, copying programs are carried on in the long term. Long term storage facilities are therefore important to ensure that those images which are to be copied in the future are maintained in good condition so that the best copy images are produced, and that both their safety and the safety of the archives is guaranteed. Such facilities would also allow for a "cooling off" period for the copied images: the nitrate negatives should be retained on hand for a specific period of time in order to ensure that the techniques and materials used in the copying process are stable and reliable and that the highest possible quality is maintained.

Some may argue that if we can justify the disposal of original nitrate negatives after copying, then we can also rationalise the destruction of documents in other media. It might be contended that when written documents are photo-reproduced, as for example on microfilm, it would be logical to destroy them, just as we would do with nitrate negatives. This reasoning, however, can be proven incorrect. The original journals of the Hudson's Bay Company posts held in the Hudson's Bay Company Archives may be taken as an example; they have all been microfilmed, and many of them are in such delicate condition that they have been removed from circulation. Is it correct to contend that the journals may be destroyed, on the basis of the same argument used for nitrate negatives? The answer is unequivocally negative. With a photographic negative, we would be destroying the equivalent of a draft, which lacks enforceability and does not carry forth the the intentions of the photographer. With the Hudson's Bay Company journals we would be destroying the originals; the microfilm, if authenticated may be as enforceable as the original, but lacking some of its formal elements would be bereft of much of the information which only the original is capable of conveying. The actions and intent of the writer are expressed and carried out in the act of writing, whereas for the most part, the actions of the photographer are fully conceived and carried out in the act of printing of the first original print.

Moreover, the artifactual value of the nitrate negative is minimal; the techniques are established and fully documented, and the negative is familiar to those who have studied it. Therefore, a representative sample of this material is all that is necessary for the purposes of historical study of the technology[7] . To attempt the preservation of all nitrate negatives would put needless pressure on resources and management time, not to mention the fact that we run the risk of falling into the trap of preserving evidence of the material itself and not of the facts it attests to. Such an approach would increase the likelihood that the central purpose of photographic administration, that is, the preservation and dissemination of the photographic "record"-and not the whole-hearted yet misdirected curatorship of objects-be missed.

It is important in the final analysis to consider a set of recommendations which pertain to the administration of nitrate negative materials:

(1) It is recommended that a copying program be put in place at the archives, and that nitrate negatives should be copied and destroyed.[8]

(2) If a copying program does not exist, then the necessary precautions must be taken to ensure that the negatives can be stored until such time as they can be copied. This may involve storing the negatives in an existing stack area separate from other archival materials and within reasonable ranges of temperature and humidity, or placing them in long term cold storage in a frost free refrigerator or advanced technology cold storage unit.

(3) If the material is to be copied and then destroyed, the techniques used should guarantee stable copy negatives. It is advisable that more than one copy be produced and preferably two or three; so that one may be used as a research/reproduction copy, while the others serve as security and archival backups.

(4) A "cooling off" period is suggested for the copied negatives before disposal. If the negative is at less than stage three of deterioration, and is therefore reproducible, then it should be kept on hand until such

time as it can be determined that the copy image is stable. Such a routine should be established in cases where there is no recourse to producing more than one copy image.

(5) It must be decided at the outset whether the archives is going to carry out the copying program on-site or if the negatives are to be sent to a commercial laboratory for copying. If the work is to be "farmed out", it is imperative that the arrangement be a contractual one, which specifies that certain standards of reproduction and processing be maintained; the archives must reserve the right to have the tonal quality of the reproductions tested by an independent lab, and to send back at no charge negatives not adhering to the agreed upon standards. It can at times be a risky proposition to have such critical procedures done outside the institution, and any potential problems must be considered and accounted for well in advance.

(6) At all times archival controls must be exercised to maintain the integrity of the fonds in which the negatives belong; this is especially important in the duplication and storage procedures, as poorly devised location inventories may cause the future retrieval of individual negatives to be problematic. With this in mind it would be sensible to run a pilot project on the entire procedure using a small but representative group of negatives. In the pilot stage any bugs in the operation can be worked out well in advance of attempting a large collection of negatives. It goes without saying that any perceived problems may be rectified more easily

in a situation where the sample is manageable.

(7) Any quantity of nitrate negatives should be destroyed under the auspices of the local fire safety inspector. Because of the extreme volatility of the material, nitrate should not be destroyed either privately or on a do-it-yourself basis, for reasons of personal and environmental safety.

(8) If a copying program is not yet in place, or if the quantity of nitrate negatives is such that copying and destruction must be carried out over an extended period of time, it is advisable that the institution implement procedures whereby a survey of the existing nitrate in storage is performed on a regular basis. Because of the unpredictable way in which nitrate deteriorates, a survey carried out over one or two years would be sufficient to determine if any particular image is in danger of deteriorating past the reproduction stage. This of course would not be necessary where long term cold storage procedures are in place. However, in instances where the cold storage is not state-of-the-art, the close monitoring of any temperature and humidity fluctuation is important.

(9) A common sense approach to the implementation of a copying program would be to build up case files on particular fonds which are partially or entirely made up of nitrate. The necessary accession information would be included with an initial report as to the state in which the material was acquired; this would serve as the basic information on which a tracking system might be based. This case file, in conjunction with a regular survey, would greatly facilitate the organisation of a logical

copying program.

(10) In any copying program, it is necessary to prioritize photograph collections; this can be done by balancing the factors of historical significance and stage of deterioration. In some instances this may constitute little more than an archival gamble. Realistically, groups of negatives of greater significance should be copied ahead of those of less importance. However, an archives may choose to postpone the copying of a group of historically important negatives in a fresh, undeteriorated condition in favour of a less significant group which is showing signs of progressive deterioration. This is an institutional prerogative. In cases where a group of negatives documents the activities of a well known photographer, the institution may deem the artifactual value of the negatives offsets the historical value of other collections and it may be copied first.

(11) Finally, it is very important that guidelines produced as part of a rational approach to the administration of nitrate negatives be incorporated into the overall procedures of the institution. A manual should be compiled, agreed upon and published as a standing document within the archives. This would ensure the program's continuity through changes in personnel and administration, and would allow for more efficient revision of the guidelines where ongoing research or changes in technique may dictate.

Following the above recommendations would certainly be a first important step towards the preservation of historical images on nitrate film and the protection of the total holdings of archival institutions which have acquired nitrate material. Furthermore, by ensuring the physical integrity of nitrate negatives, the health of those people who work them will also be safeguarded.

Archivists must become aware of the fact that the dangerous nature of nitrate negatives does not require their complete destruction, something which would not only be unnecessary but also unfeasible, given the ubiquity of the material. The danger needs to be demystified as much as it needs to be known. Ultimately, this too is a question of education.

[1]Luciana Duranti, "Diplomatics: New Uses for an Old Science," Archivaria 28 (Summer 1989): 15.

[2] Ibid.

[3] Ibid., p. 20.

[4] Ibid.

[5] Ibid.

[6] "A Picture is Worth.......?", ACA Bulletin, January 1993, 15. In this article the conclusion is reached that the destruction of Mr. Weston's negatives was not indeed the destruction of his work, but an act designed to ensure that his work would never be misrepresented.

[7] In the case of aerial photographs, it would not be appropriate to keep a simple representative sample. If one negative is to be kept after copying then all should be retained as the loss of one link in the chain of information renders the entire fond extremely diminished in information. Furthermore, the aerial photo is one of the few cases where the negative and the first original print contain identical informational elements; the will of the photographer in taking the photograph is represented completely in the finished print. The principle of *Respect des Fonds* may therefore encourage institutions to retain all aerial photos on nitrate base if proper conditions are maintained for their storage.

[8] "Principles of Institutional Evaluation (proposal)", SAA Newsletter, July 1992, 17.

Appendix I

The Survey

The survey instrument consisted of a very basic questionnaire in an open-ended form; it was initially intended by the Provincial Archives of Manitoba to gather information about the procedures used by other institutions for the preservation and administration of nitrate negatives. There was never any intent to analyse statistically the information gathered; rather the questionnaire was seen merely as an instrument for the qualitative representation of the procedures in place at a number of institutions. The sampled population was non-random and was determined by consideration of the type of material which might be acquired by the various archives and museums. A concerted effort was made to poll a broad spectrum of institutions: from large institutions with significant budgets, to small ones with much more restricted resources. The goal was to learn how archival institutions were coping with nitrate film, and to what degree budgetary considerations had a role to play in the type of program chosen; the method of copying; the type of storage; and whether there were any particularly innovative procedures being followed.

The questionnaire was sent to twelve preselected institutions; and the response rate was 100%. The responses were generally in the form of written letters, although Toronto City Archives phoned in a reply.

Some institutions included with their replies some additional technical information in the form of pamphlets and product advertisements.

The questionnaire was sent to these institutions: Notman Photographic Archives; National Archives of Canada; Provincial Archives of Alberta; Provincial Archives of New Brunswick; City of Vancouver Archives; Saskatchewan Archives Board; Provincial Archives of Newfoundland and Labrador; Glenbow Museum Archives; Archives of Ontario; Public Archives of Nova Scotia; Les Archives Nationales du Quebec; and the Toronto City Archives.

The following is a more detailed description of the courses of action taken by the various institutions involved in the survey. The report, which was compiled under the auspices of Betty Blight and the Provincial Archives of Manitoba, was titled, "A Report in Conjunction with the Provincial Archives of Manitoba Regarding Nitrate Collections," (Winnipeg, Manitoba: 1990) .

Both the Archives of Ontario and the Glenbow Museum Archives have expressed an interest in a responsible administrative program for the proper appraisal, preservation, and access to nitrate negatives. Unfortunately, circumstances have been such that implementing a program has proven to be difficult. The Glenbow is still using nitrate negatives to produce research copies; occasionally, when a particular negative is found to be significantly deteriorated, a new negative is made from a reference print. Whether or not the negative is retained depends on the degree of deterioration, but generally the Archives would tend to retain it. No mention was made as to whether the nitrate negatives are retained separate from the rest of the holdings. If funding is secured in the future, the Glenbow will institute a duplication program using the interpositive method, while no plans have been made for cold storage.

Until recently, the nitrate problem was not considered at the Archives of Ontario; there has been no selective retention of nitrate material, and CN negatives have not been separated from the existing fonds when the images had any archival value. Some items were in the past copied on to safety film, but the original was not destroyed. The archives has recommended that nitrate material be preserved only until it begins to show signs of serious deterioration. Preservation negatives are to be made while the nitrate is still in good condition, and a periodic and systematic evaluation is made to record the process of deterioration. The archives has stated that the artifactual nature of the negatives becomes irrelevant when the material poses a threat to the other holdings .

The policy of the Provincial Archives of Alberta (PAA) has been to copy all its nitrate negatives and dispose of the originals, but budgetary constraints have not allowed for the completion of this program. There are no cold storage capabilities in place at present, but they are included in the plans for a proposed new facility. Separate storage is provided only for the working copies of cinefilm, while none of the original stills (including nitrate) are available for public consultation; reference copies are produced for this purpose. The staff has expressed some concern over the evidence of silver migration and instability in direct duplication film, and this has resulted in the holding back for destruction of recently copied material. The PAA does not, however, see any intrinsic or artifactual value in the original nitrate negatives which would justify their continued preservation if an acceptable method of archival copying is determined.

The Saskatchewan Archives Board maintains its collection of nitrate negatives separate from the rest of its holdings, and stores them in a frost-free refrigerator with a temperature of 3 C and a relative humidity of 34%. The respondent to the questionnaire expressed reservations about sealing the Kodak envelopes, expressing the opinion that the gases emitted by the decomposing nitrate should be vented from its confines.

The City of Vancouver Archives is currently in the initial stages of developing policies to deal with the problem of nitrate preservation. The current holdings of nitrate negatives have been separated from the rest of the photographic material, and are maintained in one central location in the stacks at a temperature of 19.5 C and 52% relative humidity; this would appear to be an interim measure on the part of the archives as plans for a cold storage unit are being considered, but it has yet to be determined what type of cold storage would be best suited to the needs of the institution. For the most part, copy prints have been produced from the nitrate negatives and, as reprints are required, a copy negative is made from the copy print. The City of Vancouver Archives hopes to develop criteria for determining more appropriate duplication priorities based on standard appraisal techniques for intrinsic and informational value. A high priority for duplication would be given to those negatives which are showing obvious signs of deterioration: those showing signs of extreme degradation would be destroyed upon duplication. The archives feels that the best method of duplication is an interpositive/negative method .

The National Archives of Canada retains the nitrate negatives, provided that they are not showing significant signs of deterioration; copies are made of those negatives which it is physically possible to copy, and which are of sufficient historical significance. The archives destroys those negatives which have reached greater deterioration than stage two. NAC uses the interpositive/negative method of duplication; the photographic laboratory retains the copy negative in order to respond to requests for reproductions, while the photographs division retains the interpositive as an additional preservation copy. Negatives which are selected for preservation copying are coded, resleeved in acid-free enclosures and then copied. Duplicated originals which show signs of serious deterioration are destroyed, while those which are to be sent to cold storage are placed in acid-free archival boxes and sent to the Rockcliffe Vault location where they are kept at 10 C and 50% relative humidity. Information on the contents of each box and its location is maintained in an automated box label/home location data base, which is used to generate box labels and a location inventory list. NAC is currently performing a survey of existing negative collections in an attempt to locate and segregate nitrate material. The negatives so identified are separated from the existing collections, copied and sent to the Rockcliffe vaults for permanent storage. These vaults are used for material which is still circulating on a regular basis, while another storage area at Tunney's Pasture is used for essentially dead storage. The material currently being held at the Rockcliffe location is in varying stages of archival processing; the system is currently undergoing something of an overhaul, as there has not been a full-time collections manager at the NAC for some time .

The Provincial Archives of Newfoundland and Labrador retains all nitrate negatives, and stores them in deep-freeze units: retrieval time is approximately 24 hours. Most of the negatives are in individual acid-free envelopes, and contained in sealed acid-free Hollinger boxes. Some of the nitrate negatives have been copied to print format and, when this is done, a safety negative is also produced, so that the original nitrate negative will not have to be used, but will remain available in case it has to be viewed in specific instances. The archives hopes to render their collections of nitrate negatives more accessible to the public through a program of duplication in the near future.

The British Columbia Archives and Records Service has in the past performed a general culling, and has destroyed those negatives which are in poor condition. It only intends to destroy more if and when they deteriorate to the point at which they become a hazard. No mention was made of the stage at which the negatives were destroyed, and there is no policy for routine destruction. The criteria for evaluating the negatives remain the same used for other forms of archival material, but with special consideration for the medium.

The Toronto City Archives is currently in the process of copying its collection of negatives from the Globe and Mail; this is a project for which specific funding has been obtained, and there are no other plans in place for the balance of the nitrate material in the holdings of the archives. This project is being carried out on a twelve week basis every year and approximately 600 photographs are copied each time and the originals destroyed.

The Notman Photographic Archives at the McCord Museum retains the original nitrate negatives, and bases its appraisal of the image on intrinsic and artifactual value. The negatives are copied as 4x5 negatives. There are no cold storage facilities, and the negatives are stored loosely on open shelves. The only time the Museum destroys nitrate negatives is when they show serious signs of deterioration.

Les Archives Nationales du Quebec acquires nitrate material in the form of nitrate based audio and visual tapes and several thousands of still images. The Archives copies nitrate material before disposing of it through a Quebec firm which specialises in its destruction. For audiotape, budgetary considerations have dictated that the copying process be done in stages. A laboratory in Montreal is contracted to copy an optical positive soundtrack off the original negative and transfer it to 35 mm safety base. After the soundtrack has been properly mixed and corrected for sound quality, another optical copy is made. For film, the archives produces master-positives from which it makes duplicate negatives for copying purposes. The archives has many thousands of still images in a variety of formats; they are stored in a refrigerated vault in acid-free envelopes. It is not foreseen that these still images will be disposed of as the refrigeration decreases the risk of deterioration substantially.

Certainly there is a great deal of variation as to how various institutions deal with nitrate material, and these differences of approach seem to be dependent primarily on financial matters rather than on archival concerns and theory. It is still important, however, to formulate a set of guidelines for the proper administration of nitrate collections.

Appendix II:

CD ROM Technology and its Application to the Storage of Visual Images

CD ROM represents an exciting new breakthrough in information storage technology. It constitutes a new publishing medium, the centre of a new genre of computer applications, and an educational tool of unprecedented power; it allows for the efficient manipulation of extremely large databases and allows almost any organisation to exchange, sell, buy and use these databases through the implementation of certain specialised technologies.[1] Each CD ROM disc can carry at least 550 megabytes of digital data with the accuracy and reliability of the best in computer peripheral devices; and can hold the equivalent of 150,000 printed pages, 15,000 document pages, 1200 standard 5.25-inch floppy disks; and can provide a crisp colour picture and ten seconds of narration for each 3,000 segments of an educational or reference program, equivalent to eight hours of content. [2]

Despite all its impressive capabilities, CD ROM is not the multi-purpose storage medium which will render all others obsolete: this new technology still requires the support of conventional systems such as disc, tape, and RAM products. One of its greatest limitations is that it is a read-only medium, therefore it is especially suited for large and unchanging databases, but not for those which are evolving. CD ROM can, however, be used in changing archival databases, if smaller sub-units of the larger database are created as more material is acquired. This would involve the creation of subsequent CD ROM discs. The new material is digitised onto an applicable format, for example a storage tape, and then sent to a company specialising in the creation of CD ROM master discs containing the "archived information". This process can prove to be rather cumbersome, and in evolving collections, technical and specialised cross-indexing software would be required to deal with several discs carrying related information. For rapidly evolving databases, a high-capacity writeable medium such as the optical disc WORM could prove more suitable. The advent of CD ROM could indeed be a boon for the storage of copies of fragile photographs, if some drawbacks to the system, not the least of which is the high cost of this technology, can in some way be circumvented.

Much of the excitement surrounding the advent of CD ROM can be attributed to the compact audio disc, or CD. As it is well known, the CD has proven to be enormously successful in the music marketplace, supplanting the vinyl record as a means of distributing music. The great success of this medium has raised hopes within the industry that its progeny, the CD ROM, will be equally successful. The technology behind all of today's optical storage of digital data comes not from the computer industry but from the consumer electronics industry.[3] The concept of the CD ROM grew up during the eighties; and as the CD matured and became accepted by the consumer, it became apparent to some that the CD ROM could be used as a medium for the storage and distribution of digitally encoded data.

A CD ROM disc is 120 mm in diameter, 1.2 mm thick and has a hole 15 mm across in the centre. The information on the disc is represented by a spiral series of small pits moulded onto the surface. The surface is coated with a reflective metal layer, which is then coated with a protective lacquer. The structure of the disc is such that the total length of the track on the CD ROM disc is almost three miles, and the total number of pits which represent information is almost 2 billion.[4] The information is encoded on the disc by a process called mastering. Mastering begins when the information to be encoded is transferred from magnetic tape to a powerful laser beam which then passes over the surface of the disc, burning a spot on the coating of the disc. In order to read the information from the disc, a laser beam is focused on the spiral track of the pits and the light is reflected back into an objective lens. When the beam hits a pit, most of the light is refracted and very little light is reflected back into the objective lens. Conversely, when the light beam strikes a clear spot on the track, most of the light is reflected back into the objective lens. This modulated beam of light entering the lens represents the digital information stored on the disc, which is then converted into an electrical current which is read by the computer as a series of 0's and 1's, the basis of computerised digital information.

There are several important criteria to be considered when developing CD ROM applications for the storage of images; they are also determining factors in the scanning and processing technology. The criteria are: the frequency of update of the information base; the suitability of the content for image capture and processing; the number of copies needed to meet the market demand; the value of the information content to the user as measured by the cost and availability of other sources; and the degree of sophisticated search and retrieval required by the user. All these factors have a bearing on the resources needed; it is therefore important that the necessary planning be done far in advance of implementing a CD ROM program for the storage of images.

Image scanning and processing consists of five basic elements: image capture, data manipulation, storage and retrieval, and display and printing. Capturing an image requires that it be converted into a set of digital data. This implies that: (i) the image is to be moved into a position to be scanned; (ii) an optical system forms the image of the document onto the photo-detection system; and (iii) the photodetector converts the light into a digital signal which can be stored. Data manipulation is generally only included in the more expensive packages; manipulation may be needed in instances where large quantities of images are stored, and some need to be recaptured for the sake of quality control. Manipulation of the digitised image also has some interesting possibilities, as deteriorated or poorly exposed areas of the original image can be enhanced to a certain degree in the database, thereby saving possible labour intensive work on the original. In CD ROM, there are two steps involved in storage: a master disc is made for the process of duplication, and then the copies of the master are made. Retrieval usually involves some form of database management system, with a separately maintained indexing system. Display and printing can be discussed together. There are some technical problems associated with the printing and display of digitised images, the most serious of which lies in converting the images into a displayable form which takes into account the differences in resolution, aspect ratio, and pixel geometry of the various kinds of display devices which are available[5].

There are three basic scanner designs which are currently used in image capture. These are camera based systems, flatbed systems, and paper moving systems. Camera systems are particularly flexible in their application, because camera emulation and lenses can be selected for a particular application. The type of camera which is used in these situations is of broadcast quality, with very high resolution and correspondingly high cost. Resolution can be increased or decreased by moving the lens either closer to or farther away from the image to be scanned. Camera systems tend to be somewhat more expensive and more obtrusive than other systems, but their flexibility makes up for this.

Flatbed systems are derived from photocopier technology, where the document is held in one place and the scanning device creates an optical path over the surface of the document. This allows for precise positioning of the document. Fixed optics in these systems allow for the simplification of the process with an associated decrease in the cost.

Paper-moving systems are essentially the opposite of flat-bed in that the optical path is kept in the same place but the document is moved, in a way analogous to facsimile technology. The result is an even simpler mechanism and reduced costs.[6] Flatbed and paper-moving systems have a much greater resolving power than camera systems, but they are much less flexible and cannot scan three-dimensional objects. Furthermore, as in the case of paper-moving systems, sensitive or fragile documents may be damaged. Once the information is scanned into the machine, some manipulations, such as thresholding, halftoning, and windowing, can be used to maintain basic control over the image captured, and to enhance areas of the scanned image where there might be problems in clarity or tone, and where there is a need for resolution compensation in instances in which a picture and text are joined together.[7] To be added to these concerns for the preservation and accessibility of images is the need for the necessary display technology for the database being created; high resolution displays tend to be very expensive, but the cost has been coming down over the last few years as greater emphasis has been placed on the need for high quality graphics for business applications.

A document retrieval system must, of course, attempt to capture all the significant elements in an image without requiring a large amount of storage; images tend to occupy more memory space at a much greater rate than the written page, because the amount of information to be digitised in an image is much greater than that in a page. Therefore, any attempt to convert an infinitely variable, continuous image into a discrete form can cause some undesirable changes in the image due to a necessarily finite memory capacity. These changes are known as quantization effects, and can have an effect on the resolution of the image, its pixel geometry, and in the scaling of the image. Resolution in an image can be adversely effected by digitisation, and in situations where images are electronically communicated between users, some standard resolution must be maintained, so that the users can see the image in its totality at the desired resolution. In terms of pixel geometry, pixels themselves have a definite size and shape associated with them, and if the size and shape of the captured pixels do not correspond to that of the displayed pixels, then changes will occur in the appearance of the image. Scaling is a process whereby the user can change the effective pixel spacing in order to enhance a portion of the image for greater analysis; there are several methods for doing this, but they can effectively degrade the image if there is no recourse to the original. No method of enhancement will improve upon the quality of the first image taken and digitised in the scanning process therefore the scanning process must be of the highest quality for preservation and for reproduction on a display screen or on hard copy.[8]

Some new copying and storage technologies other than CD ROM are now available and may prove to be of greater use for archives in the near future. One such technology is the WORM (write once read many) drive units, in which the laser effectively burns a non-eraseable spot on the disc to record a data bit.[9] This is a more flexible system, which allows for the conversion of rapidly expanding databases into digital storage units. Other, more recent units, such as multi-function and erasable/WORM drives are opening up the horizons of digital storage for the archivist.[10]

The technologies available to the potential user of mass storage are expanding rapidly in complexity and dynamism. Moreover, their costs are decreasing and will probably continue to do so over time. This having been said, it is still important to note that the costs will remain prohibitive to all but the most affluent archives for some time to come.[11] Thus, it is unlikely that this technology will be pervasive in archival work. It is, however, foreseeable that, as archivists continue to embrace technologies as copying, storage, and retrieval tools, as opposed to simply office resources, they will increasingly use mass storage techniques in the preservation of a variety of archival materials.

[1] Leonard Laub, "What is CD ROM," CD ROM, The New Papyrus, Steve Lambert and Suzanne Ropiequet eds., (Redmond: Microsoft Press, 1986) 47.

[2] Ibid.

[3] Ibid., p. 53.

[4] Ibid., p. 58.

[5] Truett Lee Smith, "Compressing Digitised Images," CD ROM, The New Papyrus , 260-261.

[6] James P. McNaul, "Image Capture and Processing for CD ROM," CDROM, The New Papyrus , pp. 246-247.

[7] Ibid., pp. 248-249.

[8] Smith, pp. 263-269.

[9] Charles Seiter, " Optical Outlook," MacWorld, (June 1991): 148.

[10] Ibid., p. 145.

[11] Ibid., p. 141. A single drive costs on the order of between $4 000 and $7 000, while the drive cartridges cost between $200 and $300.

Appendix III
Brand Names of Cellulose Nitrate Products

Amberloid
Ambroid (glue, US)
Amerinth (Celanese Corp., US)
Celluloid (Celanese Corp., US)
Chrolitihion (Collar & Cuff)
Duco (glue, DuPont US)
Duro (glue, US)
Durofix (glue, England)
Ercalene (cellulose nitrate lacquers, England)
Fibrolithoid
Fiberloid (Fiberloid Co., Monsanto Corp., US)
Frigelene (cellulose nitrate lacquers, England)
HMG (glue, England)
Ivoroid
Lixothyl (US)
Nitrocellulose (generic misnomer)
Nitron (Monsanto Corp., US)
Nixonoid (Monsanto Corp., US)

Parkesine (Parkes, England)
Pasbosene (Marchant's Manu. Co., US)
Pyralin (DuPont-Arlington Manu. Co., US)
Pegamoid (Leathercloth with castor oil, Anison, England)
Pyroxilin(e) (Bracannot, France)
Randolph's Universal Cement (glue, USA)
UHU Hart (glue, West Germany)
Viscoloid (US)
Xylonite (US)
Xylonith (US)
Xyloidine (US)

Zapon (glue)

Appendix IV
Some Trade Names for Cellulose Nitrate

Trade Name	Manufacturer
Aceloid	American Cellulose Co., Indianopolis, Ind.
Amerith	Celanese Corp of America., New York
Celluloid	Celanese Corp of America., New York
Durakalf	Respro Inc., Rhode Island
Duralin	Respro Inc., Rhode Island
Fabrikoid	DuPont & CO., Delaware
Febroid	Textron Inc., Belleville N.J.
Gemlike	Gemloid Corp., Elmhurst, N.Y.
Gemloid CN	Gemloid Corp., Elmhurst, N.Y.
Herculoid	Hercules Powder Co., Delaware
Hycoloid	Celluplastic Corp., Newark, N.J.
Inceloid N	American Products Manufacturing, New Orleans, Louisiana
Koda	Joseph Davis Plastics Co., Arlington, N.J.
Kodaloid	Eastman Kodak Co., Rochester New York
Macoid	Detroit Macoid Corp., Detroit
Miracle	Miracle Adhesives Co., New York
Multipruf	Elm Coated Fabrics Co., New York
Nitron	Monsanto Chemical Co., Springfield, Mass.
Nixon C/N	Nixon Nitration Works; Nixon N.J.
Plastite	Adhesives Plastics Mastic Co., Chicago
Polybond	Polymer Industries Inc., Springdale, Conn
Pyraheel	DuPont & CO., Delaware
Pyralin	DuPont & CO., Delaware
Reskraf	Respro Inc., Rhode Island
Resyn	National Starch & Chemical Co., New York
Tan-O-Tex	Columbia Mills Inc., Syracuse New York
Terek	Athol Manufacturing Co., Athol, Mass

Appendix IV
Some Trade Names for Cellulose Nitrate

Trade Name	Manufacturer
Textileather	Textileather Corp., Toledo, Ohio
Texiloid	Textileather Corp., Toledo, Ohio
Tuflex	Respro Inc., Rhode Island
Tufskin	Respro Inc., Rhode Island
Wopaloid	Worbla Ltd., Papiermuhle-Bern, Switz.

Bibliography

"A Picture is Worth.......?", ACA Bulletin, (January 1993).

Booth, Larry and Booth Jane. "Duplication of Cellulose Nitrate Negatives." Picturescope Vol. 30 No.1 (Spring 1982): 12-18.

Calhoun, J.M. "Storage of Nitrate Amateur Still-Camera Negatives." Journal of the Biological Photographic Association Vol. 21 No. 3 (August 1953): 1-11.

"Care of Black and White Photographic Negatives on Film," CCI Notes, Ottawa: Canadian Conservation Institute, 1986.

Carroll, Ann Elizabeth. "Acquisition of Photographs Determining Archival Quality." Masters of Archival Studies thesis ., The University of British Columbia, 1989.

Cellulose Nitrate and Safety-Base Photographic Film. (nd)

Coe, Brian. George Eastman and the Early Photographers. London: Priory Press, 1973.

Collard, Paul. "Pictures for Posterity." Image Technology (March 1990) 94-99.

Conservation Resources. Archival Storage Materials and Conservation Supplies (February 1990): 2-7.

Duranti, Luciana. "Diplomatics: New Uses for an Old Science (Part I)." Archivaria 28 (Summer 1989): 7-27.

Duranti, Luciana. "Diplomatics: New Uses for an Old Science (Part II)." Archivaria 29 (Winter 1989-90): 4-17.

Duranti, Luciana. "Diplomatics: New Uses for an Old Science (Part III)." Archivaria 30 (Summer 1990): 4-20.

Eastman Kodak. Preservation of Photographs Rochester: Eastman Kodak, 1979, 29-35.

Fenn, Julia. Ethnographic Conservator for the Royal Ontario Museum, a preliminary draft of a monograph on plastics and polymers, May 1989.

Gernsheim, Helmut and Gernsheim, Alison. The History of Photography 1685-1914. New York: McGraw-Hill, 1969.

Gobel, Rudolph W. "Fire Risk by Storing Nitrocellulose and its Behaviour During Combustion- A Contribution to Film Preservation by the FIAF." Deutsches Institut fur Filmkunde (nd).

Haas, Pamela. "The Conservation of Photographic Collections." Curator. Vol. 26 No. 2 (1983): 89-105.

Hager, Michael. "The History of Nitrate Film." Image Vol. 26 No.4 (December: 1983): 2-9.

Hodsoll, Frank. "Our Heritage Must be Saved." Variety, January 19, 1983, 132.

Hollinshead, Patricia et al. Deteriorating Negatives: A Health Hazard in Collection Management. Tuscon: Arizona State Museum, 1987.

Jones, G. William. "Nitrate Film: Dissolving Images of the Past." Conservation Administration News No. 31 (October 1987): 1-31.

Karr, Lawrence F. "Film Preservation Why Nitrate Won't Wait." I.A.T.S.E. Official Bulletin. (Summer 1972): 1-4.

Laub, Leonard. "What is CD ROM?" "Image Capture and Processing for CD ROM." CD ROM the New Papyrus. Steve Lambert and Suzanne Ropiequet eds. Redmond: Microsoft Press, 1986, 47-71.

Lautenbach, Adrian. "The Disintegrating Image." Australian Photography Conference: Working Papers on Photography. (1980): 77-79.

Lazar, M, Bleha, T, and J. Rychly, Chemical Reactions of Natural and Synthetic Polymers. New York: John Wiley and Sons, 1989.

Leary, William H. The Archival Appraisal of Photographs: A Ramp Study With Guidelines. Paris: UNESCO, 1985.

Maynor, Catherine J. and Vand der Reyden, Diane. Paper Conservation Catalog, Washington: American Institute of Conservation of Historic and Artistic Works, 1989, 38-41.

Meidl, James H. "Plastics: Cellulose Nitrate. (Cellulose Nitrate Fire Hazards; Shipping and Storage)." Flammable Hazardous Materials. Beverly Hills: Glencoe Press, 1970, 218-229.

"Motion Picture Films of the National Archives of the United States," Science, Vol 82, No. 2123 (1985).

McNaul, James P. "Image Capture and Processing for CD ROM." CD ROM the New Papyrus. Steve Lambert and Suzanne Ropiequet eds. Redmond: Microsoft Press, 1986, 239-254.

National Archives and Records Society. "NARS Responds to GAO Report on Film Program." SAA NewsLetter (1979): 4-5.

Nitrocellulose Film Identification. (nd)

Ostroff, Eugene. "Rescuing Nitrate Negatives." Museum News (September/October 1978): 34-40.

"Poison Gas Kills 100 in Cleveland Clinic; Explosion Spreads Fumes, Fire Following; Patients, Nurses, Doctors Die in Flight." The New York Times, May 16, 1929.

"Principles of Institutional Evaluation (proposal)", SAA Newsletter, (July 1992), 17.

Puglia, Steven. "A Short Guide to Nitrate Negatives: History, Care, and Duplication." Northeast Document Conservation Centre Technical Paper. (1986).

Rattee, Colin. "Conference Report Nitrate 2000." Journal of Photographic Science. Vol. 36 No. 1 (1988): 31.

Reid, Scott, "Report to the Provincial Archives of Manitoba on the Preservation and Administration of Nitrate Negative Collection." Manitoba, 1989.

Reilly, James et al. "Stability of Black-and-White Photographic Images, with Special Reference to Microfilm." Presentation at the "Conservation in Archives Symposium". National Archives of Canada. (May 1988).

Reilly, Julie A. "Celluloid Objects: Their Chemistry and Preservation." Journal of the American Institute of Conservation No. 30 (1991): 145-162.

Ritzenhaler, Mary Lynn, Munoff, Gerald F., and Margery S. Long. Administration of Photographic Records. Chicago: Society of American Archivists, 1984.

Schellenberg, Theodore. Modern Archives: Principles and Techniques. Chicago: University of Chicago Press, 1956.

Seiter, Charles. "Optical Outlook." MacWorld, June 1991, 138.

Smith, Anthony. "Mixing Chemistry with Culture." Screen Digest (London). May 1981).

Smith, Truett Lee. "Compressing Digitised Images." CD ROM the New Papyrus. Steve Lambert and Suzanne Ropiequet eds. Redmond: Microsoft Press, 1986, 255-270.

Soupcoff, Murray. "CD-ROM Technology Chasing Paper Blues Away." The Globe and Mail, Wednesday, January 29, 1992.

"Strict Rules Govern Hospital Film Here." The New York Times, May 16, 1929

Westerblom, Hans. "City of Toronto Nitrate Negative Conversion Project at Ryerson, Summer 1986." Report to the Department of the City Clerk, Toronto 1986.

Williams, R. Scott. "Display and Storage of Museum Objects Containing Cellulose Nitrate." CCI Notes (April 1988).

Young, Christine. "Nitrate Films in the Public Institution." History News. Vol. 44 No.4 (July/August 1989) .