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New Nitrate Film Storage for Library and Archives, Canada

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HISTORY OF THE NITRATE COLLECTION

As early as 1947, the National Film Board of Canada (NFB), confronted with a collection of over 36 million feet of nitrate film, began to investigate safe storage. A purpose built facility was constructed at the Canadian Forces Base Rockcliffe in Ottawa in 1947, housing approximately one third of the collection. By 1949 the facility was deemed woefully inadequate. Considerable testing was carried out in 1951 to determine the explosive forces and requirements for a "state of the art" facility. Unfortunately, subsequent plans to build a 90 vault depot never came to fruition. 1951 also brought the formation of the Canadian Film Archives (CFA) in partnership with the NFB, the latter assuming custodianship of both historical film collections. In the 1950's the NFB relocated to Montreal taking most of these collections with them; by 1967 they were being stored in an old metal hanger in Beaconsfield, Quebec, a suburb of Montreal.

On a hot July day that year, the hanger went up in flames, leaving only ash and molten cans, 62 million feet of film gone. It was a catastrophic loss for the NFB, the CFA and most profoundly for Canadian film history. It was also a pivotal event in Canadian nitrate film preservation history. In its wake, the film community galvanized and in 1968, the Public Archives of Canada now the Library and Archives Canada (LAC) undertook a film acquisition program, evolving into the National Film Archives by 1973. The bulk of the nitrate film collection has been stored in the Rockcliffe Forces Base depot since that time. Included also is the renowned Cinematheque Quebecois collection, under a special custodial arrangement. LAC has added numerous other collections over the years including public and private acquisitions, with the largest volume of sheet film arriving in 1993 following a massive nitrate segregation project from all still negative collections in the Archives. The total number of items currently stands at approximately 650,000 stills and 5200 reels of motion picture film, filling 15 vaults. Copying has been completed on 80-90% of the motion picture film collection but only 3-4% of the sheet film. As a result, researchers are currently allowed access to original sheet film in the reading rooms in the LAC building at 395 Wellington Street, Ottawa. Motion picture film on the other hand is viewed only very rarely and under tight supervision in the Archives' Gatineau Preservation Centre in Gatineau, Quebec. This is the current status of the collection at LAC. Its proposed status in the next 2 years is the focus of this paper.

COLLECTING CELLULOSE NITRATE FILM

LAC continues to collect and maintain nitrate collections because they represent the earliest celluloid imagery in Canada, including the first Canadian fiction feature from 1919, "Back to God's Country" and rare drawn-on-film work by renowned animator, Norman McLaren. Essentially, LAC is mandated to ...acquire, preserve and provide access to private and public records of national significance...[1]. This includes the artifact. There are many examples of collections having been inexpertly copied and the originals destroyed, leaving a legacy of loss. Due to the high artifactual value of nitrate originals, "copy and destroy" is not an option.

CELLULOSE NITRATE AND MECHANISMS OF DETERIORATION

Attempting to preserve what is generally considered a chemically unstable material necessitates an understanding of what it is and how it deteriorates. When cellulose, preferably in the form of purified cotton, is treated with nitric acid and a smaller quantity of sulfuric acid, gun cotton is produced, an explosive widely used even today. A lower degree of nitration, less than 13%, results in a non-explosive product, which, in combination with a plasticizer such as camphor or butyl at about 10%, produces a polymer that can be coated on a smooth surface to form a thin, tough and transparent film suitable as a flexible base for photographic emulsions. [2]

The problem with nitrate film base is twofold: extreme flammability and chemical instability. It was primarily the former and not the latter that provided the impetus for change in photographic film bases. While not explosive like gun cotton, the nitrate film base was highly flammable, requiring strict storage and handling regulations, and used only in approved projection booths. Chemically unstable, to varying degrees, nitrate film volatilizes nitrogen oxides. As the quantity of nitrogen oxides builds up in the confined spaces of canisters and film boxes, it reaches a critical point, initiating an autocatalytic reaction that in turn speeds the deterioration of the film base. Nitrate deterioration involves both oxidation and hydrolysis reactions and is a very complex process not yet fully understood by researchers.[3 &4]

As strong oxidizing agents, nitrogen oxides also destroy the gelatin and the image silver, which in fact exhibit the first signs of deterioration. Total destruction of the film is the end result. The gases are not considered explosive in themselves, but do support combustion. Recent research at the Image Permanence Institute has shown some films could in fact survive for hundreds of years while others are gone in less than a decade.[5] Why this happens is subject to much speculation by researchers, but is undoubtedly linked to the manufacturing process, exacerbated by adverse storage environments. The manufacturing of nitrate was never an exact science and manufacturing standards were nonexistent. The quantity of sulfuric acid used in the production of celluloid, the degree to which the sulfur was removed, and possible inconsistencies during the sheet forming process are just some potential sources of instability.

If there is one thing that people know about nitrate film, it's that it is highly flammable. With a high degree of deterioration comes a lowering of the point of combustion. Deteriorating film can reach its point of combustion as low as 106EF.[6] In depots with uncontrolled environments, summer temperatures easily reach these levels and there are many examples of fires initiated in this manner. Upon ignition, inside the can where there is insufficient oxygen for complete combustion, the film base smolders, releasing carbon monoxide and dioxide, and nitrogen oxide, dioxide and tetroxide at very rapid rates. It is the evolution of these gases that causes the explosions experienced in nitrate fires, and it is these gases that are extremely toxic. Once in full, bright yellow flame with sufficient air, the combustion products become harmless, primarily nitrogen, carbon dioxide and water vapour. Once ignited, the fires are autocatalytic. Sufficient oxygen is released by the films *nitri* side groups (ONO_2) to sustain combustion in the absence of outside air. The rate of combustion of nitrate film is about 15 times that of wood, although the calorific output is roughly equivalent, making the temperature rise extremely rapidly.[7] Conventional sprinkler systems offer no ability to put fires out but can inhibit fire propagation due to the cooling effect of water.

While decomposing motion picture film has been known to self-combust, sheet film has not, with the exception of the Cleveland Clinic fire of 1929 in which X-ray films ignited. 123 people died, primarily due to the inhalation of toxic fumes emitted in the initial stages of combustion.[8]

STORAGE AND HANDLING STANDARDS

Storage and handling requirements were first laid out by the (American) National Fire Protection Agency in1919 in their Standard #40 or NFPA40, revised most recently in 2001. As there is no Canadian standard, NFPA40 is widely accepted as the standard here along with ISO 10356. [9] Recent changes to NFPA40, 2001 edition, require sheet film to be treated in the same manner as motion picture film. Prior to this, no standard existed for nitrate sheet film storage and handling. The change has had little impact on LAC since, as of 1993, following the massive nitrate segregation project in the still collections, all still nitrate holdings have been housed in the Rockcliffe vault. However, in spite of this fact, as a member of NFPA 40, LAC strongly objected to the change for 2 basic reasons: firstly, there is no evidence to suggest that sheet film provides the same safety risk as motion picture film, and secondly, many small collections will not be able to afford to store their sheet film according to NFPA40 standards and will therefore likely copy and destroy, simply destroy or donate the material to institutions that can provide the regulated environment.

COLD STORAGE

With preservation as the primary concern in the planning of a new facility, determining optimum storage environments was the first step. The benefits of cold storage are well known, and having considerable experience with cold storage for colour film and photo collections in the Gatineau Preservation Centre, the initial architectural program was predicated on it. The Gatineau cold vaults set points are -18EC and 25% RH. However, to further justify the decision to freeze collections, reports were commissioned from two experts, The Image Permanence Institute[10] and McCormack-Goodhart Inc./Wilhelm Imaging[11] respectively. Both provided what was considered solid evidence of the benefits of cold storage. LAC accepted their recommendations and plan accordingly. Environmental set points for the long term storage vaults are now -20EC and 35% RH. By lowering the temperature to - 20EC and raising the RH to 35%, in accordance with recommendations from Mark McCormack-Goodhart, the energy cost savings would be significant. The added benefit of cold and even cool storage is the mitigation of any combustion hazard that nitrate may pose. However, one is confronted with access issues as acclimatization becomes a requirement. This will be discussed later.

NEED FOR NEW FACILITY

The reasons for a new facility are twofold. Firstly, the existing structure does not meet our current preservation requirements, nor is it deemed possible to retrofit it to do so. Secondly, the Military is decommissioning the land and selling it.

In the early planning stages, the National Archives Gatineau Preservation Centre was to have been the new home of the nitrate collection. Concern over the potential impact of storing hazardous material in the same structure as our most valued national treasures prompted the push for off-site storage. There also was some resistance on the part of the municipality to allow the storage of hazardous material within the town centre.

Many sites were evaluated, the final selection being Industry Canada's Communications Research Centre at Shirleys Bay, on the edge of Ottawa approximately 30 minutes from the Gatineau Preservation Centre. It is a large tract of land with little development and a secure perimeter. Proximity to residential development, geo-technical concerns and the impact of a catastrophic event were all evaluated, with this site meeting all criteria. The site consists primarily of bedrock under three to four feet of top soil.

CONSTRUCTION PROJECT

Purpose built government buildings are often built and remain under the direction and ownership of the Public Works Government Services Canada (PWGSC). Essentially, LAC becomes a tenant of Public Works who work on their behalf hiring consultants, managing all contracts, overseeing construction and maintaining the building in perpetuity. This relationship has been very successful to date as they have been extraordinarily responsive to LAC needs. LAC's responsibility is to identify and justify all requirements for the building including size, environments, work spaces, work flow and equipment needs. The original Architectural Program was developed by LAC with the assistance of an architect, largely following the precedent of the Gatineau facility cold storage vaults. The Request For Proposal (RFP) was posted in the spring of 2001 and by June an architect was selected. By the fall of 2001, the Preliminary Project Approval (PPA) was submitted to Treasury Board and granted, allowing preliminary design concept work to be completed, site assessments done and move readiness projects identified. Following PPA, in order to clarify needs and rationalize all aspects of the program, the project manager from PWGSC began a review of the Architectural Program. By choosing cold storage, NFPA40 guidelines, which assumes storage at ambient temperatures, had been greatly exceeded, rendering irrelevant certain of their requirements, such as sprinklers in the vaults. Agreement in principle from the Dominion Fire Commissioner has already been received to remove sprinklers from the cold vaults pending final design review.

This building was initially conceived as being un-staffed, excluding circulation activities and occasional archival processing and rehousing of collections for which work spaces are planned. Subsequently, as the digital platform of LAC’s On Line Services augments, so have the access requirements for this collection. Consequently, scanning stations have now been incorporated into the design and the building is now being viewed as a staffed facility.

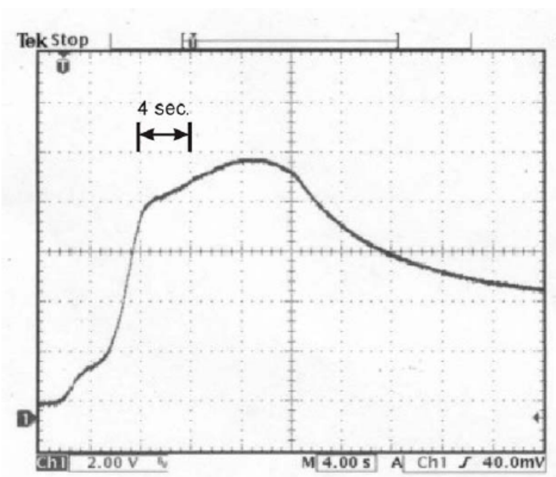
Once the decision was made for off site storage, money was allocated from the Program Integrity One Initiative. This was a government wide initiative intended to address safety and health related concerns in government buildings, and replacement of aging capital assets. The total budget for the project is fixed at $10 million. There will be no more. Figure 1 outlines the differences between the existing facility and the proposed new facility.

Rockcliffe Site **167Codd Road**	**Shirley’s Bay Site** **3701 Carling Avenue**
294m² usable space	1450m² usable space
Cool vaults– 15 @10ºC & 45% RH	Cool vaults– 4 @10ºC & 35% RH
Cold vaults– none	Cold vaults– 27 @-20ºC 35% RH
Irretrievable/deteriorating vaults – 2 @ 10ºC 45% RH	Irretrievable/deteriorating vaults – 2 @ -20ºC 35% RH
Acclimatization chambers– none	Acclimatization chambers - 2
Dirty Records Storage– none	Dirty Records Storage– cool vault @ 10ºC & 35% RH
Processing room- none	Processing, registration, scanning stations, shipping/circulation of holdings, storage, staff room- @ 20-22ºC & 45% RH

Figure 1:

BLOW-OUT PANELS

Blow-out panels are a requirement of nitrate storage vaults in order to provide pressure release in the event of a fire, thereby limiting the spread of damage to adjacent vaults. Providing blow-out panels at minus 20EC becomes extremely problematic due to potential icing up at the point of contact with outside air or moisture seepage if a heating coil is installed. To better understand the actual needs of the facility for explosion venting in the event of a fire, PWGSC contracted the Canadian Explosives Research Laboratory (CERL) of Natural Resources Canada to determine the explosive forces of burning nitrate.[12] Initial pipe bomb tests indicated that, yes, there are were explosive forces associated with the burning of nitrate film in confined spaces - the smaller the confined space, the greater the explosive force. Next, burn tests were conducted in a closed 20 litre vessel with a 120 gram sample of film, and the explosive forces and the rate of combustion recorded. (Figure 2)



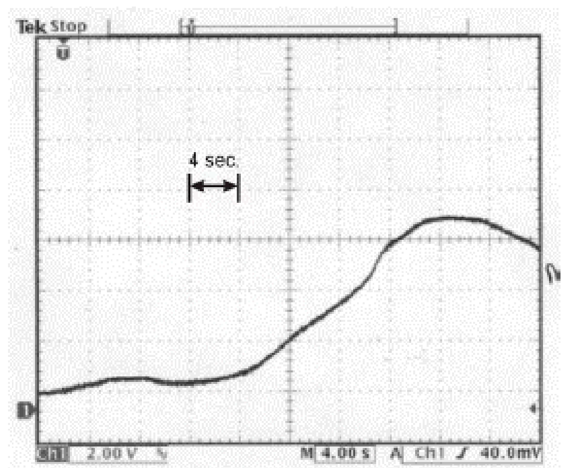


Figure 2 **Figure 3**

Figure 2: Pressure rise in 20 litre vessel, 120 g of film at room ambient temp.

Figure 3: Pressure rise in 20 litre vessel, 120 g of film at -20E C.

The results were for the most part predictable. On the other hand, repeating their tests at -20EC proved interesting. As seen on the charts in Figures 2 and 3, the rate and temperature of combustion of nitrate was significantly reduced (Figure 3) at the lower temperature. This has validated the decision to go with freezing conditions. From this information, CERL was able to confirm the absolute requirement for explosion relief vents and to extrapolate the opening size requirements for venting. How the venting is to be engineered has yet to be determined. Venting down into a blast tunnel that would then vent to the outside at one end of the building is a possibility. Vent panels in each vault would require secure one-way openings to ensure that all other vaults would not be affected by panels blowing inward from the force of an explosion.

ACCESS, HANDLING, AND TRANSPORTATION OF COLLECTIONS:

Access to collections stored in freezing environments of course necessitates proper acclimatization to ensure no condensation forms on the film. Automated chambers similar to those in the Gatineau facility are planned for the nitrate vault. The temperature and humidity are slowly ramped up over a 48 hour period until they reach ambient temperature. Temperature ramping has been very successful in these chambers, where as humidity ramping has not. We are still pursuing a suitable design, perhaps taking a less high tech approach for humidity control. A passive acclimatization is also being considered. As devised by Mark McCormick-Goodhart and Henry Wilhelm, the approach is very basic. A well insulated picnic cooler is outfitted with thermal couplers inside and out. When the internal temperature reaches the exterior temperature the cooler can be opened without fear of condensation. The volume of material in the cooler will affect the length of time required for acclimatization. This will provide portable acclimatization chambers as coolers will be loaded, placed in the truck and transported[13].

The transportation of nitrate material by truck between buildings has always been the weakest link in the access chain. Because nitrate is considered a hazardous material, the Transportation of Dangerous Goods Act of Canada[11] is invoked . The TDGA addresses workers' short term exposure to hazardous goods, dictating: training for drivers and their supervisors, the quantity of material transported at a given time, signage, and accompanying paper work. Figure 4 shows the section of the act relating to cellulose nitrate film. The UN number is assigned by the United Nations committee, Economic and Social Council (ECOSOC) Committee of Experts (COE) on the Transport of Dangerous Goods, and is an international standard. In the general scheme of things, nitrate, classified as 4.1, is considered relatively low risk. Nitrate is shipped exclusively in what is considered a small container not a bulk container to which other regulations apply. The small container is limited to 5Kg and is placed in another means of containment, a box and for this box, a 30kg limit is imposed. At approximately 2.5 kg per can, this is roughly equivalent to12 cans of film inside a box. The number of these boxes piled inside a truck is limited by a combined weight of 500kg in order to apply for certain regulatory exemptions. The act applies to all nitrate film, regardless of its format or condition.   Mandatory training for drivers and their supervisors includes: a full understanding of the nature of the dangerous goods being transported, the proper naming of goods, the requirements for shipping documents, and signage requirements. As well, an Emergency Procedures plan is necessary in the event of a road accident.

Col. 1	Col. 2	Col.3	Col.4	Col.5	Col.6	Col.7	Col.8	Col.9	Col.10
UN Number	Shipping name and description	Class	Packing group/Risk group	Special provisions	Explosive limit and limited quantity index	ERAP index	Passenger carrying ship index	Passenger carrying road vehicle or passenger carrying rail vehicle index	Marine pollutant
UN1324	Films, nitrocellulose base, gelatin coated, except scrap	4.1	lll	38	5		Forbidden	25	

Figure 4:

Nitrate on the road and nitrate in the building are regulated under different yet complementary legislation. Work Hazard Material Information System (WHMIS) dictates safety requirements for long term worker exposure to hazardous materials in the workplace. WHMIS training is required, although because production of nitrate stopped in 1951, long before the advent of the Material Safety Data Sheet, we are having to supply Health Canada with all we know about nitrate and they in turn will provide us with guidelines on how to handle it and what safety equipment must be made available to staff. As contact dermatitis and various respiratory ailments are possible with long term exposure, the Archives has long provided gloves masks and respirators for staff, and portable fume hoods were provided during the 1993 segregation project. Prior to the project, health inspectors were brought in to monitor the nitrate sheet film storage area. The TLV limits and results of the inspection are shown in **Figure 5**.

Nitric oxide TLV = 25ppm - levels detected in sheet film storage = <0.05-0.09ppm

Nitrogen dioxide TLV = 3ppm - levels detected in sheet film storage = <0.05ppm

TLV – Threshold Limit Value as determined by the American Conference of Governmental Industrial Hygienists

Figure 5:

The environment was remarkably clean. However, in spite of this several employees working on the nitrate segregation project for extended periods developed chronic sensitivity to it.

MOVE READINESS

Obviously, as collections are better described and copied, the need to handle and transport nitrate will be reduced. Much work is required prior to the move of the collections. The motion picture film is in good order but new cans are required. Due to freezing storage, plastic vented cans are deemed appropriate.

Much more work is required in the sheet film collection. Currently, 50% of the collection needs re-sleeving and re-boxing. As much of that material is currently un-sleeved, we anticipate a substantial increase in the total number of boxes, with an expansion factor of eight times in some collections. The general organization of collections is poor and finding aids are inadequate. One proposal is to essentially create a giant finding aid by taking digital photographs of negatives on a light box with their original sleeve, assign them numbers, compile a data base and put them up on the WEB for researchers as. This will allow browsing of collections like never before at a minimal cost to LAC. Proper high resolution scans will then be available on demand.

Move specifications have been drafted based to a large extent on the Archives experience in moving to Gatineau. As with any move, an informed experienced mover is essential.

CONCLUSION

This project has been a long time coming, with many different fingers in the pie. However, the advantage of long overdue projects is the luxury of time to thoroughly review requirements. With preservation as the overriding consideration, Library Archives Canada and Public Works Government Services Canada has tried to be as thorough as possible in developing safe, long-term storage for this unique and valuable cultural asset. The proof, as always, is in the polymer.

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