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Testing and Decision-Making Regarding the Exhibition of Blueprints and Diazotypes at the Canadian Centre for Architecture

ABSTRACT

At the Canadian Centre for Architecture (CCA), a museum and research center devoted to architecture and its history, our collections include many thousands of architectural reproductions. Since we have a very active loan and exhibition schedule, it is inevitable that we frequently encounter requests to exhibit some of the most common and most light-sensitive types of architectural plans—blueprints and diazotypes.

In 1997 our Getty post-graduate intern Jennifer Koerner carried out a research project with the intent of formulating practical guidelines for exhibition of the most commonly found types of architectural reproductions in the CCA collections. As part of her research, Jennifer carried out microspot fading of blueprints and diazotype samples. Jennifer's tests demonstrated to both conservation staff and to curators how quickly blueprints fade and showed that even after reversion of the faded areas to a color approximating the original value, the hue may be permanently altered. This visual evidence made it easy to convince CCA's curators that we should henceforth substitute copies of blueprints rather than exhibiting the originals.

Jennifer's microspot fade test results for diazotypes were less dramatic, and we maintained our existing policy of limiting their light exposure during exhibition. In 1998 however, in an attempt to minimize damage to a group of diazotypes which were already on display, Jennifer returned to the CCA to carry out some "quick and dirty" fade tests on a small number of diazotype samples. Over the course of a few days, she exposed the samples to the number of lux-hours that we estimated that the diazos on display would have accumulated by that time during the exhibition. After she examined the samples for color change she exposed them to more light to demonstrate the potentially damaging effect of the addition of one more venue. The resulting information prompted the CCA to send the conservator responsible for the exhibition, Karen Potje, to the venue to unframe many diazos, to assess their condition, and to make recommendations regarding their continued exhibition.

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INTRODUCTION: RESEARCH GOAL—PRACTICAL GUIDELINES FOR THE EXHIBITION OF ARCHITECTURAL REPRODUCTIONS

At the Canadian Centre for Architecture (CCA) in Montreal, architectural reproductions of many different types form a large part of the museum's collections. Such prints frequently present identification headaches, as well as conservation-related problems that can give us pause, especially when it comes to their exhibition. Within the context of a year-long Getty conservation internship, Jennifer Koerner undertook a research project with the primary goal of outlining realistic and practical guidelines for the exhibition of architectural reproductions.

These guidelines were based on the prevailing observations and results found in previous research and trade literature. As a counterpart, very preliminary and relatively unscientific testing of the light-fastness of some of the most commonly found reproductions in the CCA's collections, such as blueprints or cyanotypes, Vandyke prints, diazotypes, and hectographs was carried out. The most interesting results obtained were for blueprints and diazotypes, which will be the focus of this paper, as will a case study of a traveling exhibition which included a large group of diazotypes.

LIGHT-FASTNESS TESTING: METHODOLOGY

When she began her research, Jennifer had hoped that real-time exhibition situations could be simulated, using

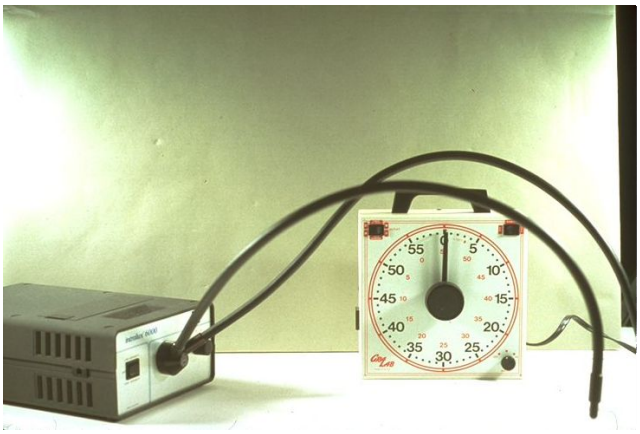

Fig. 1. Microspot fade test equipment, part 1

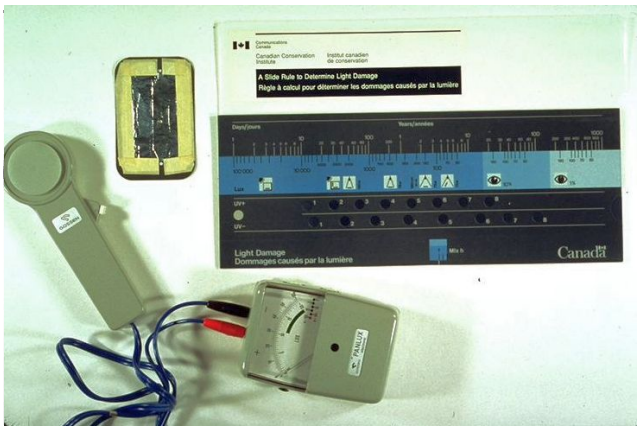

Fig. 2. Microspot fade test equipment, part 2

actual museum objects. Most of the previous research on reproductions which she reviewed for this project relied on newly made samples and accelerated ageing techniques or used environmental situations that tended to be more extreme than would be found in a museum environment. Unfortunately, the real-time exhibition scenario would not be possible due to time constraints of the internship as well as other factors.

As an alternative, the use of a microspot fading test was investigated. This test was developed by Charlie Costain at the Canadian Conservation Institute (CCI) in Ottawa, as a means of predicting (and visually demonstrating) the light sensitivity of specific media or material in a relatively easy, practical, and low cost manner (Costain n.d.). Theoretically, this test could also allow one to more accurately predict an individual object's behaviour under specific exhibition conditions. A partial collections survey was carried out and objects were then selected from the CCA's collections and approved for use as test subjects by curatorial staff.

The basic equipment used for the test are a fibre-optic lamp with a tungsten-halogen bulb (which has negligible ultraviolet content), a light meter, the CCI's light damage slide rule (CCI 1994), a template with an aperture of approximately 3 mm (an eraser template was used in these tests), and a timer, as shown in figures 1 and 2. The procedure involves exposing through an aperture in the template an area approximately 3 mm in diameter until a just perceptible change is seen in the test location. The area tested is so small that it may be acceptable in certain cases to subject this spot to the risk of just visible fading in order to avoid fading of the entire object through overexposure. The exposure time is calculated based on the intensity of the light used and the time it takes for the change to occur.

Because the research began with the assumption that the reproduction types selected were for the most part very light-sensitive, and as there were time limits, it was decided to base the length of the test exposures on an average exhibition period, which at the CCA is 16 weeks at a light level of 50 lux with 60 hours exposure per week. As most shows which travel go to more than one venue, an exposure equivalent to three venues was used as an average test length. This corresponded to average test conditions of 4 hours exposure at 36,000 lux. Theoretically, if an object was able to undergo this test period without showing any change, it could be safely exhibited for the equivalent amount of light exposure.

BLUEPRINTS OR CYANOTYPES: INTRODUCTION

Twenty-two blueprint samples were tested, including twelve historical CCA collection prints and ten small non-collection samples of various dates. The blueprint, now obsolete as a commercial process, was the prevalent type of reproduction for a good part of a century, only losing ground to the speed and efficiency of diazotypes by the 1950s, though blueprints still remained available long after that. Earlier in the session at which this paper was presented, Mike Ware discussed the blueprint process thoroughly. Please refer to his paper for technical details on the process (Ware 2002).

In considering the suitability of blueprints for exhibition their most relevant characteristics are their sensitivity to light and to alkaline substances. The main focus of this paper is light sensitivity. Variables such as the quality of the paper used and the type and quality of processing may affect the stability of the individual print. Until Dr. Ware's recent work, the light sensitivity of blueprints and their ability to undergo color reversion in dark storage had been much discussed, but most often in an anecdotal fashion (Fireman 1997; Lathrop 1980; Lavrencic 1987). In the studies consulted, contradictory reports were often found: some referred to the relative stability of blueprints and their apparent ability to withstand exposure to light (Hendricks et al. 1991, 162; Lathrop 1980, 133; Lavrencic 1987, 144), while some unpublished reports, relying on testing with

newly made samples rather than historic materials, found that blueprints are quite sensitive to light, and do undergo color reversion. Thanks to the invaluable work of Dr. Ware we are now able to comprehend more fully the changes which occur when blueprints are exposed to light and how they undergo reversion.

BLUEPRINTS: RESULTS OF LIGHT-FASTNESS TESTING—FADING AND REVERSION

During testing, all twenty-two blueprint samples reacted in a very similar way—all experiencing fading and subsequent reversion. Typically fading occurred within a very short period of time. For example, at an average light intensity calculated to provide an exposure equivalent to slightly less than one exhibition venue, perceptible fading occurred within 5 minutes.

In all samples, reversion began to take place within 24 hours after the objects were placed in dark storage. After one week reversion was not yet complete in all cases. It should be noted that after testing the collections materials were placed in their storage folders within a Solander box or drawer, while the small non-collections samples were wrapped in aluminium foil and placed in a Solander box. Mike Ware has illustrated that the presence of oxygen is required for reversion to occur and clearly the foil wrapping was not air-tight.

Interestingly, one non-collections blueprint sample of unknown date, which was allowed to fade to a more extreme extent (shown in figure 3) experienced reversion even though it was not placed in dark storage after testing, but was left out in the CCA conservation laboratory under normal work lights (which are UV-filtered fluorescent lights having an intensity of approximately 250 lux). These lights were left on only during working hours; hence, with only faint sources of light in the lab at night, the piece did spend some time in near darkness.

Figure 4 shows the sample after one week of exposure in the lab. Besides reversion, the sample also experienced an overall color shift under the UV-filtered lab lights. In other words, in about one week the area lightened by the test gradually reverted, while the area around the tested spot shifted to a blue-gray tone, until the two areas were similar in color and had probably reached an equilibrium between the fade and regain.

After six months of continuous exposure to the lab lights the sample, including the tested area, had become very gray and faded. It was then placed in dark storage. After one week it appeared to have darkened slightly overall, including the tested area. After five months in dark storage the sample was considerably darker than it had looked after six months of exposure in the lab, although it still appeared grayish and faded in comparison to a blueprint sample that had not been exposed to light; however, the test spot had become visually indistinguishable from the surrounding area. Today, several years of dark storage later, the sample appears even darker though it still doesn't match its original color.

Based on these tests, it appears that complete reversion took longer to occur for non-collection samples which were faded for more extreme periods of time; in some cases the areas tested still appeared faintly gray one month after testing. When testing was taken only to the point of first perceptible change (which was the case for all the collection objects), reversion was usually complete within a week or less. And, as mentioned previously, in collections objects some reversion was noticeable in one day.

BLUEPRINTS: CONCLUSIONS

Based on these preliminary tests and on the available literature at that time, it was concluded that the exhibition of blueprints should not be recommended until the long-term effects of reversion were better understood. The test results prompted the CCA to institute a policy of substi-

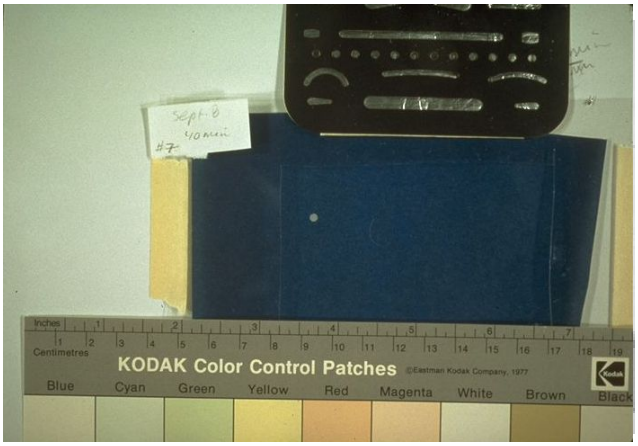

Fig. 3. Non-collections sample after extreme fading

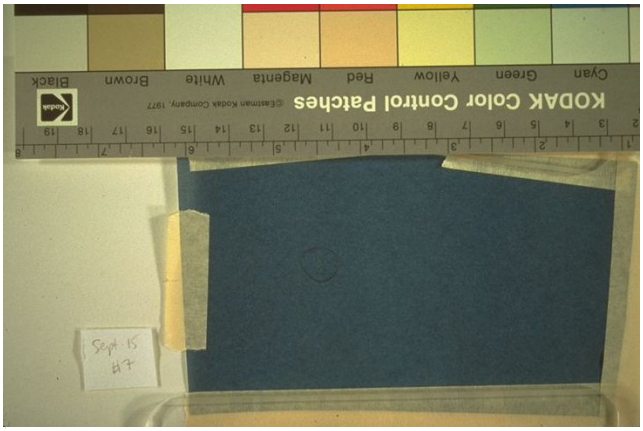

Fig. 4. The same sample after one week of exposure in lab

tuting facsimiles rather than exhibiting original blueprints. Although Dr. Ware's subsequent work has demonstrated that the changes are not irreversible, caution is still called for, especially when dealing with unique collections objects.

DIAZOTYPES: INTRODUCTION

Diazotypes eventually superseded blueprints in popularity, and since the 1950s they have remained dominant in the reproduction industry, though they are becoming obsolete now that large-scale plain paper copying is available. This paper will not go into any technical detail about the diazotype process as there are many publications on the subject,[1] except to say that many different diazo colors, even a vibrant pinkish red, are possible, but generally the most commonly seen image colors are blue, brown, maroon, or black.

As with many other types of reproductions, incomplete or poor quality processing contributes to the inherent instability of diazotypes. A salesman's manual from the 1940s from one of the major producers of diazo papers explains some of the causes of instability in unexposed or newly made diazoprints which we may be able to relate to historic materials: for example, when exposed to ultraviolet light the prints can continue to develop, causing darkening of the emulsion covering the paper support in the background areas and loss of contrast with the image as a result of premature coupling of the diazo compounds. Conversely, exposure to light can also cause fading of the image and support, as ultraviolet light burns away residual chemicals and breaks down the diazo compounds.[2]

To complicate matters further, residual chemicals such as phenyl coupling agents undergo oxidation which causes yellowing and discoloration of the support, which is most often seen at the edges of prints. This type of edge degradation can be accelerated by conditions of high relative humidity. Diazotypes can also react with other materials, causing staining and discoloration, and should not be kept in contact with any other objects. They may also be reactive to alkaline substances, though there has be very little research done on this.

DIAZOTYPES: RESULTS OF LIGHT-FASTNESS TESTING

Tests were carried out on four diazotype samples (three historical collections objects and one historical non-collections material). In all cases, no changes were observed after the average test length equivalent to three venues. Based on these results, the CCA decided to maintain its existing policy of limiting the light exposure of diazotypes to a maximum of 50 lux with short exhibition periods, but not barring them from exhibition.

DIAZOTYPES: A CASE STUDY OF THE LIGHT STABLITY OF DIAZOTYPES ON EXHIBITION—BACKGROUND OF THE EXHIBITION

Almost one year after Jennifer completed her internship at the CCA she was given the opportunity to put her interest in the light-sensitivity of diazotypes to practical use. Designing the Disney Theme Parks: the Architecture of Reassurance, an exhibition coordinated by the CCA and Walt Disney Imagineering, had been touring North America since spring 1997. Some four hundred drawings, prints, photographs, and three-dimensional objects drawn from the archives of Walt Disney Imagineering traced the evolution of Disneyland as "a key symbol of contemporary American culture" (Olsberg 1997, 9). There were sixty diazos in the show, all of which were hand-colored with colored pencil, paints, and inks. Some of these works can be seen in figure 5.

While planning the exhibition with the CCA in 1996, Walt Disney Imagineering (WDI) had weighed concerns about potentially light-sensitive objects against the exhibition's mandate to provide a new perspective on the Disney

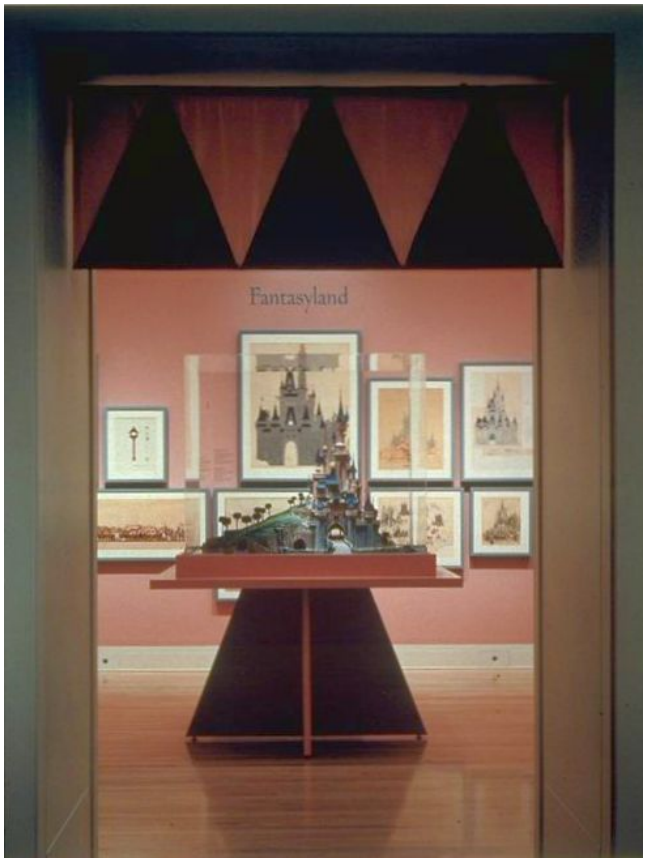

Fig. 5. The Architecture of Reassurance: Designing the Disney Theme Parks. Installation view of the exhibition: Fantasyland Gallery (with several hand-colored diazotypes on the wall). Photo Michel Legendre, Centre Canadien d'Architecture/ Canadian Centre for Architecture, Montréal.

theme parks as a cultural phenomena. They concluded that a six-venue exhibition was appropriate. But before the end of the sixth venue a proposal to add a seventh venue sparked new concern for the diazotypes in particular. In order to evaluate the impact of a seventh venue, Karen Potje asked Jennifer to carry out new light fading tests simulating an exposure period of 99 weeks, or six exhibition periods of 16 weeks each at 50 lux, and then extending the test period to simulate the addition of a seventh venue.

DIAZOTYPES: FADE TESTS TO ESTIMATE THE EFFECTS OF THE EXTENDED EXHIBITION PERIOD ON THE EXHIBITED DIAZOS

Instead of using the microspot fading technique, a bank of fluorescent lights was used to expose a wider sample area, about 1 inch by 2 inches, on six historical but non-collections diazotype samples of various colors, including one with no image lines at all. Figure 6 shows the test set-up. The samples, shown in figure 7, were matted on one side and glazed with UV-filtering acrylic sheeting and a backing of Coroplast and the edges sealed with tape to simulate a typical CCA frame package. With the UV-filtering acrylic the ultraviolet emission of the lights was cut to below 50 microwatts per lumen. The average intensity of the lights was 13,000 lux.

After the equivalent in lux/hours of six venues, four out of six samples showed significant fading of the exposed areas of the previously yellowed support and of image lines and background flecks. In the sample with no image lines only fading of the previously yellowed support occurred. With the addition of the equivalent of a seventh venue, it was observed that in at least three of the six samples, the light-induced changes had become more pronounced. Figure 8 shows one of the samples after testing simulating the seventh venue, the area on the right side of the sample having been exposed. In one sample, which had showed no change after the equivalent of six venues, the paper turned more yellow and the purple lines and flecks faded after the simulated seventh venue.

These test results prompted WDI and the CCA to send Karen Potje and Kristen McCormick, the registrar of the WDI Archives, to the sixth venue to examine the Disney diazotypes before decisions regarding extending the show would be made. They unframed and examined four of the ten blue-purple diazos and twenty-four of the fifty brown-line diazos in the show. Of these, one blue-line diazo had changed, showing fading of the previously yellowed paper and of the diazo image lines and background flecks. Nineteen of the brown-line diazos had changed—most slightly to moderately but a few more dramatically. In most instances the support yellowed slightly. In three cases when the support yellowed the diazo media became paler, and in two instances it also became warmer in tone. Only two of the Disney brown-line prints showed fading of the previously yellowed paper, the type of damage that three of the earlier diazo microspot fade test samples had experienced.

It is hard to draw conclusions from these observations: subtle differences in how the many diazos were produced may have caused them to react to exhibition conditions in different ways. Damage was not predictable but it was widespread and confirmed our assumption of the vulnerability of diazotypes, even though the initial microspot fade tests had shown no changes on the small number of samples tested.

Fig. 7. Diazo test samples lined up in frame packages

Fig. 6. Larger diazo test samples under light bank

Fig. 8. Diazo example after testing equivalent to seven venues

Light-Induced Deterioration of Diazotypes Observed after Eight Venues

CONDITION	BLUE-LINE DIAZOS	COMMENTS ON BLUE-LINE DIAZOS	BROWN-LINE DIAZOS	COMMENTS ON BROWN-LINE DIAZOS
Cannot be determined (No overmatting)	1	from 1969 and 1980	0	
No apparent change	9	from 1963 to 1992	18	from 1957 to 1994
Yellowing of support where exposed to light	0		10	7 from 1953 to 1955; 3 from 1960 to 1986
Yellowing of support, fading of diazo image and background flecks where exposed to light; diazo image warmer, more brown in tone	0		1	1954; shown at a lengthy preceding venue
Yellowing of support where exposed to light; greying of support over hinges where protected from light	0		11	from 1953 to 1955
Greying of support over hinges where protected from light	0		1	1955
Fading of previously yellowed areas of support where exposed to light	0		1	1975
Fading of previously yellowed areas of support and of diazo image and background flecks where exposed to light	1	1981	1	1981
Fading of diazo image and background flecks	1	1963	1	from 1953; faded diazo image warmer, more brown in tone
Support became pink in tone where exposed to light	0		1	from 1991
Total	12		45	

Fig. 9. Chart of light-induced deterioration of diazotypes observed after eight venues

WDI considered these results and decided to withdraw five of the brown-line diazotypes but to extend the exhibition. Given the inherent instability of diazos, it is almost certain that these prints had changed in appearance to some extent even before this exhibition. How important then is the degree of change that these diazos experienced during the exhibition when they were already far from their "original state"—whatever that *may* have been? We may be able to understand Disney's point of view—that the exhibition should continue despite changes in the appearance of many objects.

DIAZOTYPES: VARIOUS EFFECTS OF THE EXTENDED EXHIBITION ON THE DIAZOS

And continue it did—to a total of eight venues. Then, when the exhibition ended, Karen unframed and examined *all* of the remaining diazos. Figure 9 shows the results: out of eleven blue-line prints produced from 1963 to 1995, seven showed no change after eight venues, one showed fading of the diazo image only, one showed fading of the diazo image and background flecks *and* fading of previous yellowing of the paper, and two were not overmatted, making it impossible possible to recognize changes which may have occurred. The number of blue-line images was too small to make any generalizations about how they, as a group, responded to light exposure.

The effects of eight venues' worth of light exposure on the brown-line images were extremely varied. Out of forty-four brown-line diazos remaining in the show, eighteen ranging in date from 1957 to 1994 showed no apparent change. Twenty-one (eighteen of them from 1953 through 1955, and three others from 1960 to 1986) showed yellowing of the paper support. Two prints from 1975 and 1981 exhibited fading of the previously yellowed paper in addition to media fading where exposed to light. One 1975 diazo showed fading of previously yellowed paper with no apparent change in the color of the diazo image, and one print from 1953 showed fading of the diazo media without any apparent change in the color of the support.

An interesting and unfortunate phenomenon that Karen observed in thirteen 1953 to 1955 brown-line diazos after eight venues was a slight "graying" of the paper support over the areas that were hinged with Japanese tissue and wheat starch paste. Twelve of these also showed yellowing of the support. In two prints the hinges extended beyond

General Exhibition Recommendations for Architectural Reproductions

Factors to Consider Prior to Exhibition

- Identification of the object—critical to proper display and storage
- Make potential damage and risks of exhibition known to relevant personnel
- Reproductions such as blueprints, diazoprints, Vandyke prints, and ferrogallic prints should be matted with non-buffered materials passing the PAT test, or at least neutral pH rag board
- Be aware of internal sources of pollutants—such as display case materials

Factors to Consider During Exhibition

- Be aware (and keep records) of exactly what the gallery conditions are, especially in terms of light levels
- Monitor—use both UV and LUX meters as well as temperature and RH monitors
- Exclude ultraviolet—incandescent or tungsten bulbs recommended
- 30–100 lux range—balance exposure length and light levels to achieve best illumination of the object with least potential damage
- Temperature and relative humidity—stay in safe ranges (19–21°C ± 1.5° and 38–55% RH ± 5%) and avoid rapid fluctuations

Before and After Exhibition

- Record—keep data on conditions—establish exhibition histories for objects and monitor changes in individual objects using densitometry or colorimetry

Fig. 10. General exhibition recommendations for architectural reproductions

the borders of the mat into the window opening and the paper was *not* grayed where it was exposed to light—it was only grayed where hidden by the mat border. We have discussed several possible scenarios related to local humidity and pH to explain the graying of the hinge areas, but have come to no definite conclusion. But based on this experience, the CCA will favor non-adhesive methods such as corners and edge strips rather than hinges for the matting of diazos.

While the CCA has made its decision *not* to exhibit blueprints, they have still developed no firm exhibition policy on diazos. They will be much more cautious in displaying diazotypes but will consider their exhibition on a case-by-case basis. Microspot fade testing will be a useful tool for making decisions about individual objects, and densitometry or spectrophotometry will be used to monitor the condition of diazotypes once they are on exhibition.

EXHIBITION RECOMMENDATIONS

In order to bring together the observations and conclusions that were made through Jennifer's research and Karen's exhibition experience we have outlined some general exhibition guidelines which also encompass the other types of reproductions that were mentioned at the beginning of this paper.

Figure 10 presents a table of general recommendations which identifies some factors to consider before, during, and after exhibition periods. A second table, illustrated in figure 11, outlines stability issues, other factors to consider, and exhibition recommendations for blueprints and diazotypes. Note that although we have recommended using matting materials which are non-buffered and pass the PAT test for blueprints and diazotypes, the CCA had matted the diazos in the Disney show in buffered boards, with no apparent damage after four years of contact.

CONCLUSION

It is clear from this preliminary research and exhibition observations that there is a great need for more work in this area. In our study only a limited number of samples were used, and there may be objects which react differently than those tested here. Also, the intent of both the microspot fade tests and of the fade tests carried out under the light bank was to do something quick and practical. It would be useful to repeat such tests in a more scientific and quantifiable way and to compare the results of accelerated fading under extreme lighting conditions with the effects of real-time exposure. Although we have assumed that changes in the exhibited diazos were caused by light exposure, such a comparison might indicate the significant role played by other variables such as temperature and rel-

Exhibition Recommendations for Blueprints and Diazotypes

REPRODUCTION TYPE	STABILITY ISSUES	OTHER FACTORS TO CONSIDER	EXHIBITION RECOMMENDATIONS	MONITOR*[1]
Blueprint or Cyanotype	• Sensitivity to light and alkaline substances • Especially sensitive to temperature and RH • Poor quality processing can cause degradation • Quality of paper support can vary	• Reversion phenomenon • Use non-buffered matting materials passing the PAT test	• Not recommended • If decision is made to exhibit, low light level—30 lux*[2] —and short exposure time	Yes
Diazotype	• Inherently unstable—residual chemicals and poor quality processing contribute to degradation • Especially sensitive to temperature and RH • Older prints can be of a better quality than more recent prints	• Also found on translucent paper or film supports • Use non-buffered matting and storage materials passing PAT test	• Light levels of 50 lux and short exposure time	Yes

*[1] Monitor objects before and after exhibition using densitometry, colorimetry or spectrophotometry.

*[2] For all lux values, strict adherence to the given lux number is not intended, rather a value that falls within a close range of that level is recommended, depending on the unique circumstances of the particular venue.

Fig. 11. Specific recommendations for blueprints and diazotype

ative humidity. Similarly, a comparison of the effects of accurately quantified real-time exposure in known environmental conditions with accelerated fade testing for blueprints would enrich our understanding of their vulnerability to exhibition conditions.

Blueprints and diazotypes present significant conservation challenges. We hope that our work will inspire more research into how we can reduce the risks of exhibition without completely limiting our use of these objects.

ACKNOWLEDGMENTS

We would like to thank the Getty Grant Program for their support and Charlie Costain at the Canadian Conservation Institute for the test which made this work possible and his advice on using it. Thanks also to Marty Sklar at Walt Disney Imagineering for giving us permission to discuss the challenges encountered during the Disney exhibition, and to Disney registrar Kristen McCormick for her help in examining and discussing the condition of the Disney diazos.

NOTES

1. A useful general explanation can be found in the 1961 *RM* article "Diazo."

2. For a discussion of some of the numerous sources and manifestations of degradation seen in diazotypes see the Keuffel & Esser Co. manual of 1948. Although this manual deals mainly with unexposed diazo paper and newly made prints, it has some invaluable explanations of types of damage that can occur which relates as well to aged materials.

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