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Communications from the

National Gallery of Art Research Project

Mellon Institute

ON THE SUBJECT OF ILLUMINATION, ULTRAVIOLET FILTERS, AND EFFECTS OF LIGHT AS RELATED TO THE CONSERVATION ON MUSEUM OBJECTS

The National Gallery of Art has maintained a research laboratory at Mellon Institute, Pittsburgh, Pennsylvania, since 1950. The primary objective has been to conduct long-range investigations on fundamental problems relating to the permanence of artists' materials and the materials used in the conservation of objects of art. The first major project consisted of a study of solvent-type varnishes. New findings concerning the formulation, analysis, classification, removal and aging of these materials were summarized in a number of publications, including a book, On Picture Varnishes and Their Solvents, published by the Intermuseum Conservation Association, Oberlin, Ohio, 1959. Although work on varnishes has not been fully terminated, the study of the effect of light on protective coatings led naturally and gradually to the investigation of a wider range of materials. The subject was first considered to be a separate and major research project in 1957. The work on damage by light has grown until it now occupies the major portion of the laboratory time.

One of the reasons for locating the research laboratory at Mellon Institute is that its unique facilities provide opportunity for consultation with experts in many specialized fields: analytical chemistry, paper, ceramics, plastics, etc. In addition to the experts within the Institute, however, we have had the kind cooperation and advice in this latest work from such specialists as Mr. Ralph Stair of the National Bureau of Standards, Mr. T. H. MacDonald of the Office of Meteorological Research, U. S. Weather Bureau, Dr. Paul Davidson, Strathmore Paper Company, Mr. R. Schwenker of the Textile Research Institute; Mr. M. Saltzman, National Aniline Division Allied Chemical Corporation, Mr. S. P. Burck, Eastern Regional Engineer, Sylvania Lighting Company, and Miss Ruth M. Johnston, color expert at the Research and Development Center, Pittsburgh Plate Glass Company, as well as colleagues in the International Institute for the Conservation of Historic and Artistic Works.

The results of the research at Mellon Institute are shared as widely as possible through the participation in various professional organizations and through formal presentation in meetings, seminars and publications. There have been eight major technical publications thus far, including the book on picture varnishes. Numerous communications have been of a somewhat less formal nature. This folder brings together the communications since 1957 which the National Gallery of Art Research Project has prepared on the subject of illumination, ultraviolet filters, and the effects of light.

Robert L. Feller
Fellow, Mellon Institute
Pittsburgh, Pennsylvania

FROM THE ANNUAL REPORT OF MELLON INSTITUTE FOR 1956-1957

Annual Report Series No. 44 p. 44

INSURING THE PROTECTION OF PAINTINGS AGAINST DEGRADATION BY LIGHT

The protective qualities of picture varnishes are being considered by the Fellowship on Artists' Materials, sustained by the National Gallery of Art, Washington, D. C. The action of light in causing pigments to fade and polymers to crosslink received particular attention during the past year.

As a general rule the shorter wave lengths of radiation give rise to the greatest photochemical action. Activity is not confined entirely to the ultraviolet region of the spectrum, however. Photochemical action upon textiles and paper has been observed with the short wave lengths of the visible spectrum, violet, and blue light. Moreover in the fading of colors the absorbed wave lengths of visible light may contribute to degradation in a major manner. With this thought in mind the Fellowship measured the fading of the fugitive artists' colors, alizarin, magenta, carmine, and indigo. The investigation demonstrated that filters which remove only ultra-violet radiation do provide slight protection to these pigments.

If a picture varnish should lose its solubility upon aging, its removal from a painting would present serious difficulties. The Fellowship found that certain methacrylate thermoplastics tend to crosslink and lose their solubility more readily than others. The speed at which this reaction occurs is affected primarily by the short wave lengths of ultraviolet radiation. For example window glass eliminates radiation only below about 320 mμ. Nevertheless a filter of window glass, eliminating only a portion of ultraviolet radiation, is capable of reducing by one-half the speed of crosslinking observed with unprotected polymethacrylates. Several compounds which absorb wave lengths below 350 mμ have been found to inhibit crosslinking at concentrations of 0.5 to 1.0% of the weight of methacrylate polymer. These compounds may provide protection to pigments and vehicles, in addition to their effectiveness in reducing the tendency of the film of varnish to lose its solubility because of the action of light. A solution containing such an inhibitor will furnish protection, even when sprayed on a varnish already applied to the picture.

In conjunction with this problem the Fellowship developed a paper-chromatography method to measure the degree of degradation of polymers. In this manner samples of varnish can be taken from pictures periodically and tested for signs of crosslinking before the resistance to solvents becomes serious.

Ultraviolet filters provide partial protection to several fugitive pigments and retard the loss of solubility of certain thermoplastic polymers of the methacrylate type. These recent developments are being applied in the search for new and improved techniques in the care of museum objects.

CROSS-LINKING OF METHACRYLATE POLYMERS BY ULTRAVIOLET RADIATION

R. L. Feller
National Gallery of Art Fellowship
Mellon Institute, Pittsburgh, Pa.

Paper #73

The durability of coatings is generally judged on the basis of discoloration or mechanical failure. In seeking thermoplastic polymers which, in addition to being highly resistant to discoloration and mechanical failure, also retain their solubility in petrol
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technique of removing coatin

DIVISION OF PAINT, PLASTICS,
and PRINTING INK CHEMISTRY

PAPERS PRESENTED AT
THE NEW YORK MEETING

SEPTEMBER 1957
Volume 17 - - - Number 2

Report on Crosslinking of Methacrylates, Circulated
to Interested Parties

Recvd 4/28/58

MELLON INSTITUTE OF INDUSTRIAL RESEARCH
UNIVERSITY OF PITTSBURGH

PITTSBURGH 13, PA.

April 10, 1958

CROSS-LINKING OF METHACRYLATE POLYMERS

This report has been prepared in order to explain more fully certain problems related to the cross-linking of polymers and to inform authorities concerned with the use of methacrylate polymers in conservation regarding the latest information available. Research on all phases of the problem continues. (See G. Thomson, Studies in Conservation, 3, 64 (1958).

Prediction of the Durability of 27H Varnish

The accompanying figure explains how the Fellowship has attempted to estimate the durability of 27H Varnish under gallery conditions.

There are many difficulties involved in predicting durability on the basis of so-called "accelerated ageing" tests. The Fellowship has developed a chromatographic test which is useful in following the course of cross-linking during the first 70 hours in the fadeometer, and it also has developed a time-of-removal test with various solvents on a cotton swab, useful over a long period of time. Extensive investigations permitted the Fellowship to relate these measurements reasonably well to the time of exposure (1) in the fadeometer and (2) on the roof of Mellon Institute. The data were envisioned as a graph, Figure 1 accompanying this discussion. (The slope of the curve for removal in toluene is now better expressed in Figure 3).

Estimates of durability are usually made in as many ways as possible. The first method was based on the index of exposure (intensity x factor of damage per foot candle) outdoors vs. that indoors. The resultant estimation is: that the condition of 27H Varnish attained after 7 months exposure on the roof of Mellon Institute would be attained in 18 years indoors at an average annual level of 174 foot candles of daylight illumination. The condition attained after 11-14 months outdoors would be attained in 28.6 - 36.4 years under the described conditions indoors. The exposure indices were taken from Table VI of the Harrison Report of the Metropolitan Museum of Art.

A second estimate was based on the chromatographic values of samples of various methacrylate polymers found at the Fogg Museum of Art (report regarding tests upon aged samples of methacrylate polymers, dated March 20, 1958). After 10 years, these exhibited a relative R_F of about 0.80. It is then estimated, if they were to continue to change at the same rate, that they would reach the stage equivalent to 7 months on the roof of Mellon Institute (resistant to removal in cyclohexane) in 27 years. The 11-14 month state would, accordingly, require about 51 years.

A fourth method of estimation was made on the basis of experiments where the varnish had been heated in an oven at 160 to 200°C. and upon the rule-of-thumb that the reaction rate usually doubles with a rise of 10°C. in temperature. On this basis, the 11-14 month state should be arrived at in 28-56 years.

The third method of estimation was based on exposures tests in the fadeometer vs. the years of exposure of a Class V dye indoors (see R. Feller, Paper 73, Division of Paint, Plastics, and Printing Ink Chemistry, A.C.S. Meeting, N. Y. C., September, 1957). This estimate we now consider is probably low, owing to an increased rate of cross-linking at the high temperature of the fadeometer. The durability underglass on the roof, we now realize, is also effected by the high temperature in summer.

It may also be pointed out that (1) alizarin, a pigment found in many paintings, fades noticeably in the times indicated by bars in the figure, (2) dammar and Rembrandt varnishes crack when exposed on the roof at the points so indicated, and (3) the Fellowship has never found, under gallery conditions, 27H Varnish or a relative methacrylate coating in a condition any worse than that represented by the arrow labeled "Fogg Museum Samples, R_F".

It is customary to take the lowest estimate when one wishes to be safe. From these considerations came our figures of 10-15 years as the minimum time before 27H Varnish would arrive at the first state, 20-25 years at the second state of resistance to solution. The Fellowship has demonstrated (1) that the "accelerated" tests are severe, (2) that estimates represent the minimum expected durability, (3) that we definitely have tests which can detect early stages of cross-linking.

Cross-Linking of 27H Varnish in Fadeometer

The rate of formation of insoluble (cross-linked) matter in 27H Varnish is shown graphically in the accompanying Figure 2. The results of an extensive investigation show that following an inhibition period of about 25 hours, the coating rapidly attains a state of being at least 90% insoluble upon extraction with toluene at room temperature. Tests of solubility made with cyclohexane between 20 and 35 hours indicated that there was no marked difference in the occurrence of insolubility either in toluene or the "milder" solvent. The data refer to samples on aluminum foil in the ordinary fadeometer, which attain a temperature of about 60°C.

Figure 3 compares the formation of insoluble matter in 27H Varnish (the data of Figure 2) with several other measurements. Note that the time required to remove 27H Varnish with a cotton swab dipped in cyclohexane follows closely the rise in insoluble matter. We have previously stated that it is the degree of cross-linking (hence, the degree of swelling) which influences the ease of removal in toluene and acetone, not the per cent insoluble matter. This is born out by the data shown for the time of removal with swabs dipped in toluene.

This is an important point to realize; that, even when the polymer has become 90% or more insoluble, it still may be removed as a swollen gel for a longer period of exposure. "Insolubility" and "removability" are not the same matter.

The data in Figure 3 also tell much about the chromatographic method that the Fellowship developed for detecting the incidence of cross-linking. It has been observed that the relative R_F only became less than 1.0 about 20 hours. This apparently was not due to insensitivity of the method but, instead, coincides well with the first appearance of insoluble material. The method becomes unreliable after 40 hours. It is known that the relative R_F is influenced by the size of the sample. We see in Figure 3 that when the per cent insoluble resin rises sharply, the amount of soluble material placed upon the chromatographic strip would become more difficult to control; consequently, the chromatographic method would be expected to give erratic results. A relative R_F of zero occurred when the insoluble matter amounted to at least 90% of the varnish.

Method: The method of extraction in 120-mesh stainless-steel cages is similar to the determination of gel-content described by Shultz and Bovey (A. R. Shultz and F. A. Bovey, J. Polymer Sci., 22, 485 (1956)). Samples were shaken for 48 hours. The toluene was replaced once during this period. Drying was done in an ordinary oven, heating the samples at 70°C. for 24 hours. The initial weight of resin was between 50 and 30 mg.

Effect of Temperature on Cross-Linking of 27H Varnish

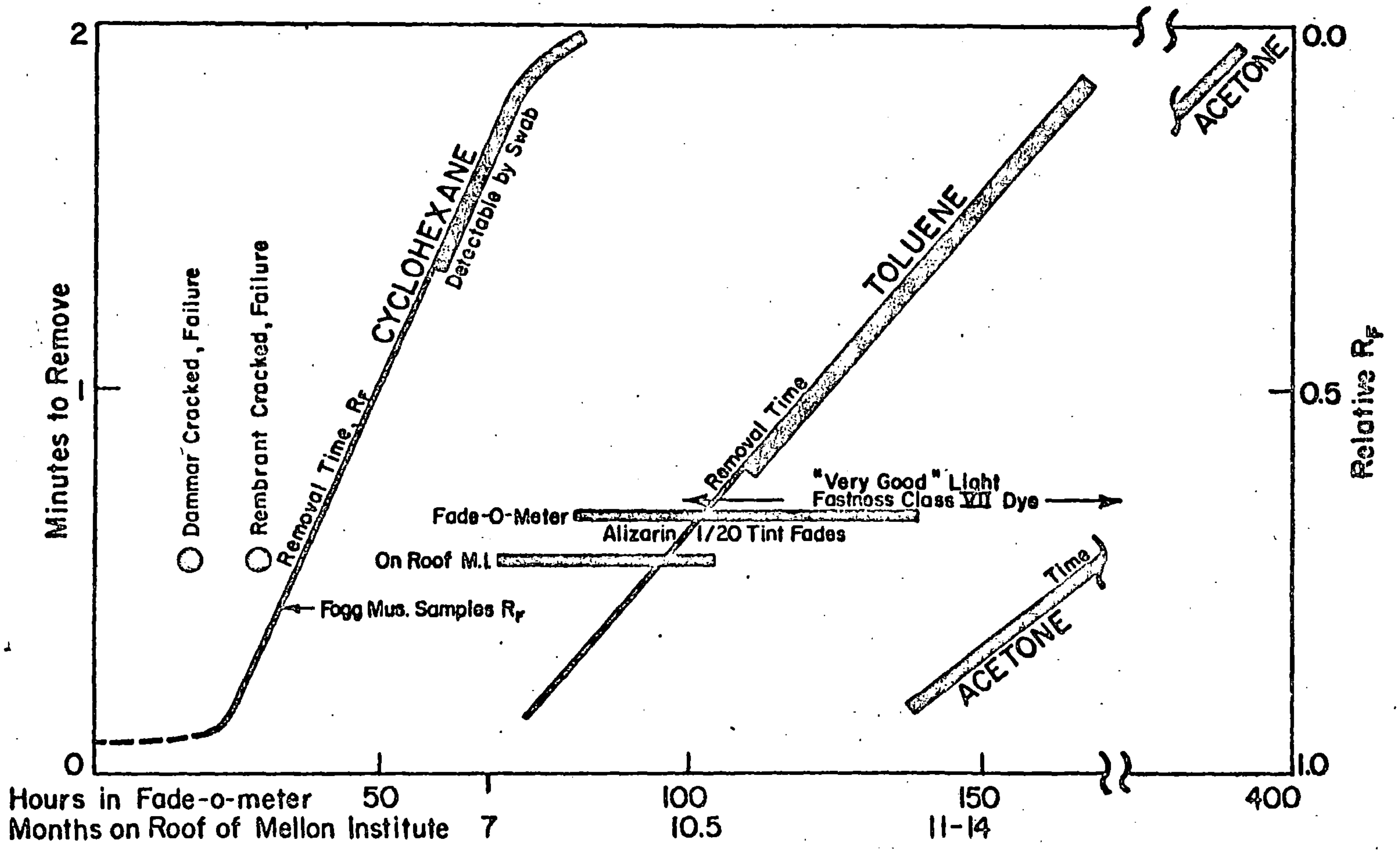
The accompanying Figure 4 shows that at 16°C. the formation of insoluble matter in 27H Varnish proceeds at a rate 31 times slower than at the normal temperature in the fadeometer. If the normal temperature were 66°C., the reaction may be calculated to proceed at a rate 32 times slower at 16°C., using the rule-of-thumb that the reaction rate doubles in a rise of 10°C. This analysis of the data strongly suggests (1) that the change in rate is very much as should be expected from the difference in temperature, and (2) that since the relationship is practically linear between 50 and 84% insolubles, essentially the same process is going on at the two temperatures. The profound effect of temperature has been confirmed recently with several other methacrylate polymers.

DRAWINGS ATTACHED

RL Feller

FELLOW

Robert L. Feller:mab



ESTIMATES, IN YEARS, OF MINIMUM DURABILITY IN GALLERY AT AVERAGE ANNUAL LEVEL 174 F.C. ON WALLS, BASED ON:

1. IX Outdoor / IX Indoor Harrison Table VI	18	28.6-36.4
2. Fogg Museum, R_F	27	51
3. Paper 73 Fade-O-Meter vs. Years Indoors	8-16	15-30
4. Heating Double Reaction Rate For 10° Rise		28-56

FIGURE I.

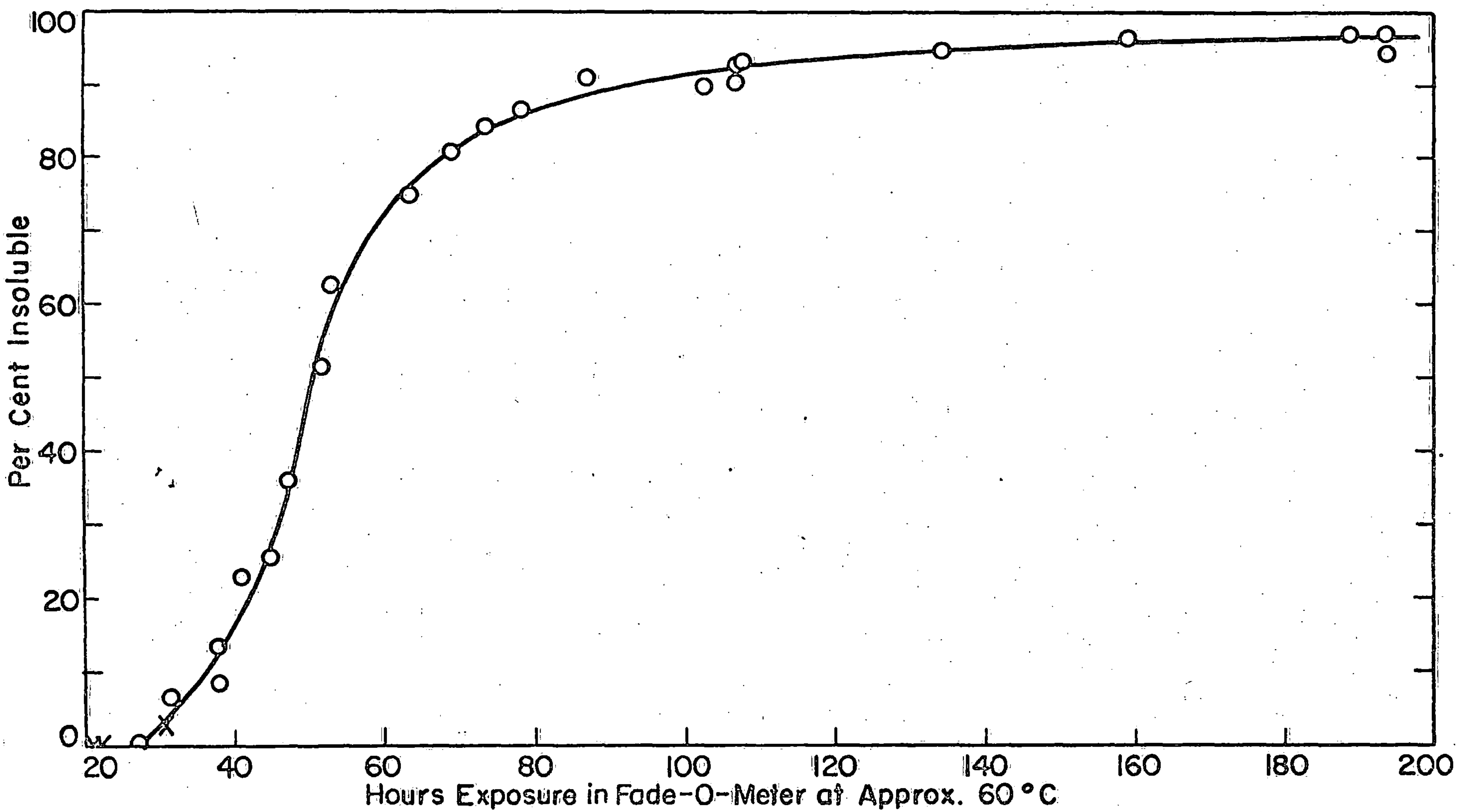


Fig.2.

PER CENT OF 27H VARNISH INSOLUBLE IN TOLUENE AT ROOM TEMPERATURE, AFTER EXPOSURE ON ALUMINUM FOIL IN THE FADE-O-METER. X = Insolubility in Cyclohexane

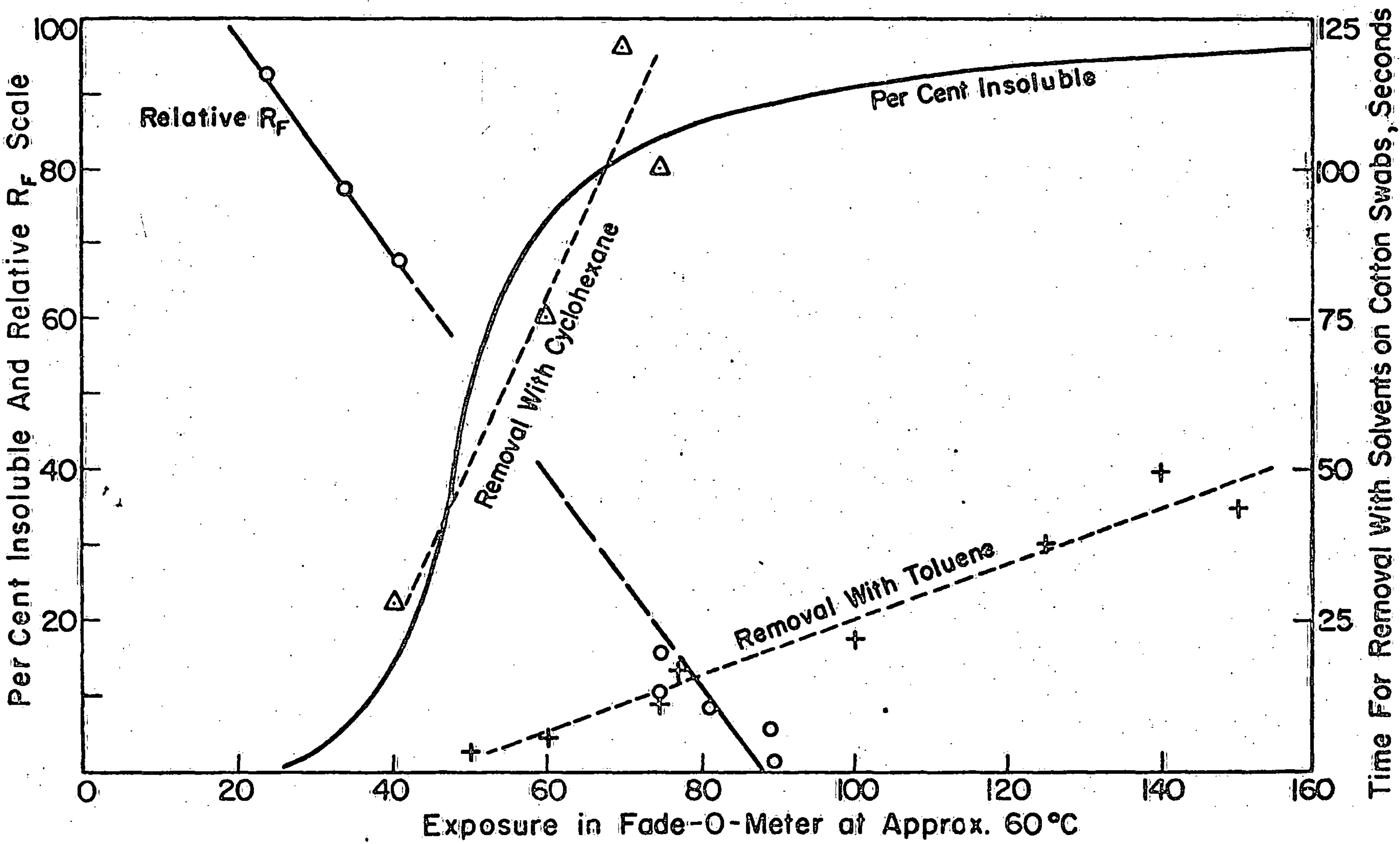
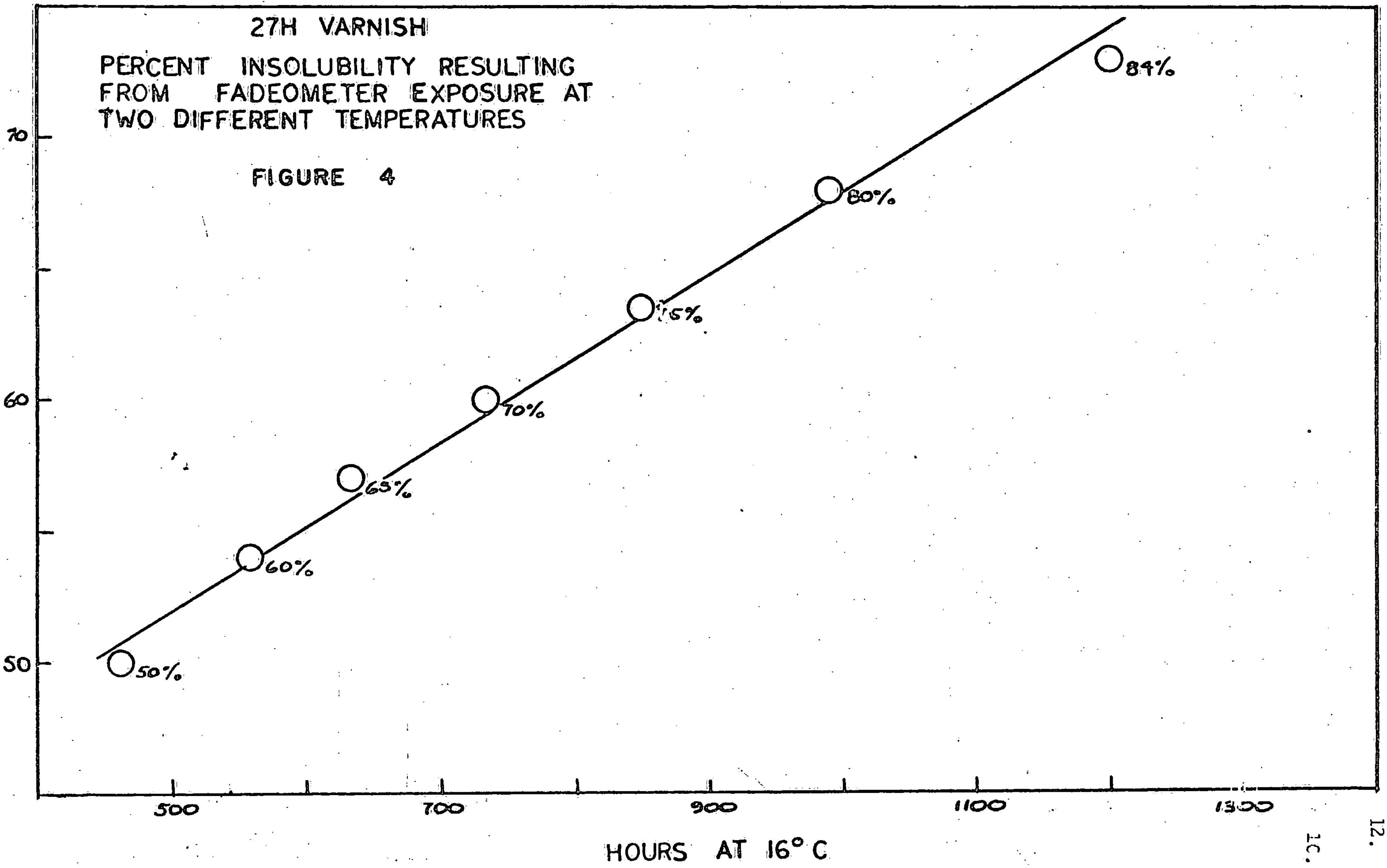


Fig. 3.
27H VARNISH COATED ON ALUMINUM FOIL



27H VARNISH

PERCENT INSOLUBILITY RESULTING FROM FADEOMETER EXPOSURE AT TWO DIFFERENT TEMPERATURES

FIGURE 4

Critical Review of Balder's Booklet, from Studies in Conservation, 4, 155 (1959)

BOOK REVIEWS

J. J. **Balder**, *The Discoloration of Coloured Objects under the Influence of Daylight, Incandescent Lamplight and Fluorescent Lamplight*. De Museumdag, The Netherlands Museums Association, Leiden, 1956. In English. Pp. 42 + 5 diagrams + 1 color + 1 black and white plates.

This booklet is a report of an investigation by Ir. J. J. Balder of the Lichttechnisch Laboratorium at the Philips factories, Eindhoven, regarding the relative tendencies of four sources of light to discolor paints and colored textiles. The investigation was undertaken at the suggestion of the board of the association, De Museumdag, for the purpose of choosing between daylight, incandescent lamps, and two fluorescent lamps, the type of illumination that might give rise to the least discoloration. At the end of the report, eight pages and a photograph describe the illumination of an exhibition of Rembrandt drawings at the Boymans Museum, Rotterdam, 1956. The publication evidently did not first appear in English; the separate dates of publication of the Dutch and the English editions are not indicated, however.[1]

A series of eighty colored specimens were exposed to daylight (designated as D), incandescent lamps (G), a Philips warm-white-de-luxe fluorescent lamp (32) and a Philips white-de-luxe fluorescent lamp (34) until the specimens under each source received an equivalent exposure of about 8 million lux hours (8 Mlxh). The specimens consisted of thirty oil paints on canvas, thirteen water paints on drawing paper, twenty pieces of Gobelin restoration yarns, twelve pieces of cloth, and five water colors. The discolorations were rated visually with values 0 to 5 by three observers. Part of the rating scale is as follows: 0, no discoloration; 1, only slight discoloration—hardly perceptible; 2, distinctly noticeable discoloration. The average change of the samples after exposure was numerically 1·65, that is to say, between the ratings of hardly perceptible and distinctly noticeable. A comparison between the ratings made visually and measurements made with a Donaldson colorimeter demonstrated that the use of subjective ratings was justified.

The conclusion of this investigation is that, after 8 Mlxh, on the average the discoloration of the objects is greatest under daylight, in the order D, 34, G, 32 and in the experimentally-determined ratio 237: 151:127:100. The ratio was determined on the basis of the change expressed in number of units of minimum perceptible difference, the least change being arbitrarily set at 100. The order, but not the ratio, is as expected from consideration of the factors of damage per foot candle (D/fc) discussed in the report by L. S. Harrison to the Metropolitan Museum of Art. The respective values of D/fc are 0·7 : 0·250 : 0·118 : 0·096.

The description of the Philips lamp, 'TL' color number 32, and the new lamp 34, is most interesting. A report of the development and the color-rendering qualities of lamp 32 may be found in a reference cited.[2] This lamp is described as having an extra layer of fluorescent powder that reduces the factor of D/fc sufficiently that practically colorless ultra-violet-absorbing filters, such as described by Harrison, are of little consequence, incapable of suppressing the minimal amount of 3500–4000 Å ultraviolet present in the lamp's radiation.

One should identify as completely as possible the constitution of materials used in an investigation. This report could be much improved in this respect. For the purpose of determining the relative discoloration caused by the four sources of illumination, the composition of the objects may not seem to be especially significant. Yet, in one particular aspect it is of greatest importance: the age of the varnishes and oil paints was not given. Changes that take place in fresh coatings are likely to occur more rapidly than those of more advanced age and may also differ significantly in their nature.

Balder does not distinguish, as is suggested in British Standard 1006 : 1955, between changes that are noticeable after a short exposure, but which show no further change when the exposure is prolonged, and those which continue throughout prolonged exposure. One may consider at least four types of discoloration of paints: those owing to changes in (*a*) hue of vehicle, (*b*) refractive index of vehicle, (*c*) hue of pigment, and (*d*) value and chroma (fading, shall we say) of pigment. It seems rather certain that discoloration reported for many of the oil paints must have been due to changes in the vehicle. Many in experimental group a_3 darkened, for example. Such a change may be more immediate in its effect on color than continuous with increased exposure.

One must not assume that the discolorations reported would continue at the same rate (about 1·65 units per 8 Mlxh). The exposure of 8 Mlxh is rather modest, equivalent to that which is incurred in about three years on the walls of a gallery 'with sun louvers properly operated' (Harrison's example). It is also approximately equivalent to the exposure in a fadeometer necessary to cause noticeable fading in a Class V dye: twenty hours. Most of the varnishes and oil paints selected by Balder

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[1] A report by **Balder**, in German, of the essential data occurs in *Lichttechnik*, 8, No. 2 (1956), pp. 57–61; I.I.C. Abstract Vol. I, abstract No. 655.

[2] A. A. **Kruithof**, *Philips Techn. Review*, 6 (1941), p. 69.

were among those known to be sensitive to light. Those in the tests that do not particularly have such a reputation may have undergone change of an immediate rather than progressive type. The oil paints discolored on the average 1·93 + 0·12 units, about as much as the textiles 1·84 ± 0·17 units. The water colors discolored least of all, 1·44 units! These considerations are cited to caution one in attempting to make additional interpretations or to draw further conclusions from these data.

The most serious experimental problem and possible source of error in this investigation is the matter of the temperature of the samples. The technical literature abounds with studies of accelerated deterioration, which, because the temperature is either elevated or insufficiently specified, make it practically worthless to attempt to apply the data to the problems of preservation at room temperature. The control of the temperature of samples exposed to high levels of illumination presents certain problems to the experimenter, but the time has arrived when the effect of temperature and relative humidity can no longer be neglected in investigations of the deterioration of museum objects under accelerated conditions. In this particular investigation, the exposure under window glass to daylight was done at approximately room temperature. The samples under incandescent lamps were, on the other hand, 12° to 19°C. (15·5° ± 3·5°, shall we say) above room temperature; those under fluorescent lamps, 12°C. above room temperature. Data on fourteen oil paints that seemed definitely to be affected by temperature were left out in the determination of the final results. Having dropped these data from consideration, Balder concludes (*a*) that results in his table VIII give a picture in which the temperature effect is no longer present to any appreciable extent, (*b*) that the temperature effect, if present, would *only* mean that the discolorations under daylight would be greater than the figures indicate (more in line, incidentally, with that estimated on the basis of D/fc), and (*c*) that the discolorations under incandescent lamps would be somewhat smaller, but would not upset the conclusion of the test. These three conclusions do not seem completely justified. The last point, (*c*), whether G gives 1·19 ± 0·06 times more discoloration than lamp 32, is a critical one in which temperature may be a deciding factor. While it is true that many simple photochemical reactions are little influenced by temperature, there is considerable evidence that the complex events that occur in the deterioration of paints, paper and textiles are significantly influenced by temperature. A rise of 12°C. above room temperature will increase the rate of reaction of processes with activation energies[3] of 14 and 5 kcal, about 2·54 and 1·39 times respectively. The slight variation in the temperature of samples under incandescent lamps would increase reactions having these two activation energies by factors of 1.32 and 1·10, respectively, for a rise of 3·5°C. These estimates of the possible influence of temperature emphasize the attention that must be given to this factor. A temperature effect appears evident in Balder's table Va, in the behavior of wool yarn as opposed to silk. The temperature of the sample, of course, also controls the relative humidity of the immediate environment of the sample, further influencing the process of deterioration.

Progress in science requires that a problem be investigated from many points of view. The sponsors are to be commended on the publication of this formal report, prepared in sufficient detail that various aspects may be analysed, thoroughness evaluated and sources of possible error judged. Only with adequate reporting of research will foundations be established upon which the field may base further inquiry and eventually build a sound body of special knowledge. There are many excellent contributions in this report: the description of the solution to the problem of illuminating an exhibition of drawings, the application of statistical analysis to observations of discoloration in a sample of considerable size, the experimental verification of the order of discoloration caused by four sources of illumination, the demonstration of the validity of subjective ratings of discoloration, and the description of Philips fluorescent lamps 'TL' 34 (newest type) and 32, the latter a warm-white-deluxe lamp, stated to possess a low factor of D/fc and very good color-rendering qualities. Future investigations will no doubt wish to consider further the qualities of these lamps, the claim that colorless ultraviolet-absorbing filters improve little the D/fc factor of lamp 32, and the particular influence of humidity and temperature upon the general problem of deterioration.

Robert L. Feller

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[3] No pigment changes by itself: it must be supplied with energy in some form, usually heat or light. The *activation energy* of a chemical change is a measure of the energy that must be supplied before that change can take place. Since heat is a form of energy, all chemical changes occur more readily at higher temperatures unless there is some other overruling factor.—*Ed.*

Letter on Subject of Photochemically-Active Titanium White,
Circulated to Interested Parties, Including Manufacturers
(see first paragraph)

MELLON INSTITUTE
4400 FIFTH AVENUE
PITTSBURGH 13, PA.

January 14, 1960

Mr. Richard D. Buck
President, IIC-American Group
Director, Intermuseum Laboratory
Allen Art Building
Oberlin College
Oberlin, Ohio

Dear Dick:

Some time ago, we discussed the possible effect of white pigments upon the durability of retouches. While we are a long way from understanding many aspects of the problem, we have uncovered something which may have considerable interest. I am taking the liberty of duplicating this letter and sending it to a number of conservators and manufacturers.

In the course of examining white pigments to see if we could trace our difficulties to one particular pigment, we ran across four cases of the use of <u>anatase</u> titanium white, out of a half a dozen samples examined. This struck me as rather curious. The anatase variety of titanium white was the first sold commercially, I believe. It was soon found that this pigment had the property of causing paint to deteriorate rapidly and to "chalk". This property is used to great advantage in the modern paint industry, by so arranging that white paints used out of doors will "chalk" and be washed away by the rain. In this way, the white appearance is kept fresh. However, in certain applications, the paint industry wished to have pigments that were not as photochemically active as anatase. The literature from the Titanium Pigment Corporation says that in 1941 <u>rutile</u> titanium dioxide was offered on the market and in 1948 a special "non-chalking" variety of rutile was put into production. Explanations of the photochemical reactions of these pigments were published in the years shortly thereafter: Jacobsen, A. E., <u>Industrial and Engineering Chemistry</u>, <u>14</u>, 523 (1949); Weyl, W. A., and Forland, T., <u>Industrial and Engineering Chemistry</u>, <u>42</u>, 257 (1950). In a letter to Mrs. Keck of some years back, Norman Brommelle said that the National Gallery, London, switched to the use of rutile titanium white for retouching in 1950.

Recently, A. D. Hibberd (Paint Technology, 23 (1959), p. 45) reported some interesting results of an investigation into the nature of chalking. He showed that phthalocyanine blue and green, madder maroon, and even carbon black were able to be oxidized and bleached by the action of light in the presence of titanium white. This result dramatizes the profound photochemical effects that can take place in the presence of certain white pigments.

I believe that it would be good practice, if titanium white is to be used, that the special non-chalking varieties be employed. The Titanium Pigment Corporation, 111 Broadway, New York 6, New York, markets a variety known as "Titanox" - RA-NC and the pigments department of E. I. duPont de Nemours and Company Inc., 1007 Market Street, Wilmington 98, Delaware, markets a variety known as "Ti-Pure" R-610. Some manufacturers of artist's materials in this country are already using pigments of this type. According to the data of Hibberd and the data of the Titanium Pigments Corporation, anatase that has been treated to reduce its tendency to chalk, and the unmodified rutile, is not as resistant to chalking as is the especially-treated rutile. Therefore, the simple switch to a rutile type is perhaps not enough, but one should employ the special non-chalking varieties in order to obtain the very lowest photochemical activity.

I cannot say now whether any of our difficulties with retouching has been due to photochemical interaction with the white pigment or whether the conservator would run into difficulty if he does not use the non-chalking variety. However, the photochemical activity of anatase titanium white is well known, and modern museums are frequently well lighted. The use of varieties of rutile that are known to exhibit a very low tendency for photochemical activity might profitably be considered. A review of the photochemistry of zinc and titanium white appears in the J. Oil & Colour Chemists' Assoc., 40, 935 (1957), H. F. Clay.

Our research is still in progress on this subject. I do not wish at this time to make a specific recommendation to anyone regarding the methods and materials that may employ in their particular problem. However, I am not sure that many colleagues are aware of this story of the titanium dioxide pigments. I have taken this opportunity to bring these details of the chemistry of titanium dioxide to your attention.

With very best regards.

Sincerely yours,

R. L. Feller
Fellow

RLF:rab

From "Recent Advances in Conservation", Rome Conference IIC, 1960; to be published by Butterworths in 1963, p. 171

Problems in the Removal of Coatings

There are fundamental problems associated with spirit varnishes which involve their ease of removal. The use of polymers in the range of viscosity grade of 9 to 80 centipoises has raised a problem of fundamental interest to the field of conservation: among the ways that a polymeric substance may become altered in time, one manner is through the formation of crosslinks. As has been pointed out, it does not take very many chemical crosslinks to cause a thermoplastic polymer to become insoluble (FSJ, p. 203). Although this phenomenon is not one which is of major importance with polymeric materials of the average molecular weight of dammar, mastic and AW-2 resins, it is one that must be faced by the chemist if we wish to use polymers of much higher molecular weight.

The tendency for thermoplastic polymers to crosslink upon aging has been found to be more the general rule, and the lack of this tendency, the exception, than one might at first expect. The activation of certain chemical bonds in polymers by light and heat imparts to them the tendency to form new chemical bonds. Bond formation, of course, may take place with neighboring chains, linking them together until eventually they fail to be dispersed in solvents. Thus, our investigation of polymers of the higher alkylmethacrylate esters traced the tendency to crosslink particularly to the presence of "tertiary hydrogens" in the side-chain (FSJ, p. 152). The tendency to crosslink has also been observed in poly(vinylstearate-acetate) copolymers, poly(vinylbutyral), and cellulose acetate-butyrate.

The first phase of an extensive investigation of crosslinking was to determine the structures in the methacrylate side-chain that possessed the greatest tendency to become insoluble. This led to the conclusions just stated and to the selection of materials with a reduced tendency. The second phase was to determine the nature of the radiation that caused crosslinking. The data in Table III demonstrate that ultraviolet radiation is primarily responsible for crosslinking and that the influence of wave length upon the rate is almost precisely that predicted by the probable damage factor (D_λ) for a given wave length, described in the Harrison report of the Metropolitan Museum of Art. The relative rate at which the films to reach 50% insolubility follows equation A.

$$\text{(A)} \quad R = T_{305/T_\lambda} = 0.16\ D_\lambda - 0.05$$

where T_{305} is the time to reach 50% insolubility under the 305λ filter, T_λ is the time under other filters. Investigation also showed that increasing the temperature of the samples increased the rate of crosslinking.

Table III

Average Rate of Crosslinking of Poly(n-butylmethacrylate) and Poly(isoamylmethacrylate) on Aluminum Foil, Under Various Filters in the Fadeometer at 62°C.

Filter	Filter: Wave Length at 50% Transmission	Relative Rate For Films to Reach 50% Insolubility	Relative Rate Calculated by the Equation A
Corex D Glass	305	1.0	0.97
Window Glass	330	0.44	0.49
Uvinul M-40 Filter	359	0.19	0.21
Plexiglas II UF	396	0.05	0.05

The marked influence of heat and ultraviolet radiation upon crosslinking point up the difficulty in judging the importance of this problem under museum conditions: most of the accelerated-aging tests that were first used to detect and study the phenomenon involved both elevated temperatures and ultraviolet radiation not normally encountered under gallery conditions. To minimize the effect of temperature, a series of tests were carried out under "daylight" fluorescent lamps in an air-conditioned room at 80°F. and 50% relative humidity. Under these conditions, the butylmethacrylate polymers from du Pont developed 50 to 80% insolubility in 8 to 10 million-footcandle-hours of exposure. (After this exposure, the polymers could still be removed with ease with toluene.) This degree of insolubility might be expected to develop in a matter of 50 to 100 years if the objects were to be illuminated at a level of about 50 footcandles during the day. From this first estimate, we may conclude that the phenomenon is not one to cause immediate alarm. Nevertheless, crosslinking can take place on the walls of museums and the possibility warrants particular attention wherever ordinary fluorescent lamps are to be used without filters or where daylight enters through ordinary window glass.

Paper Presented at Conference, NYU. Fading of Writing Inks Was Discussed.

FRIDAY, APRIL 14

AFTERNOON (2:00 - 5:00 P.M.)

Introductory remarks
Craig Hugh Smyth
Institute of Fine Arts

2:15 The Conservat
Curator

4:0

The labora
will be ope

Tea will be se
o'clock.

THE CONSERVATION CENTER

INSTITUTE OF FINE ARTS
NEW YORK UNIVERSITY

PROGRAM OF LECTURES

April 14th and 15th, 1961

FRIDAY, APRIL 14

EVENING (8:15 - 10:00 P.M.)

8:15 The Treatment of Some Byzantine Mosaics and Frescoes
Lawrence J. Majewski
Conservation Center ✓

9:00 Considerations on the Possible Damage by Fluorescent Lighting
Robert L. Feller
Conservation Center and *Mellon Institute*

SATURDAY, APRIL 15

NING (10:00 AM. - 12:30 P.M.)

The Problem of the Efflorescence of Salts in Oil Paintings
Sheldon Keck
Brooklyn Museum

e Spectrographic Examination
rt Objects
dward V. Sayre
okhaven National Laboratory

sed Publication of a
k for Analysis of
of Paintings
ord J. Gettens
llery Laboratory

THE JAMES B. DUKE HOUSE
1 EAST 78TH STREET
NEW YORK 21, N. Y.

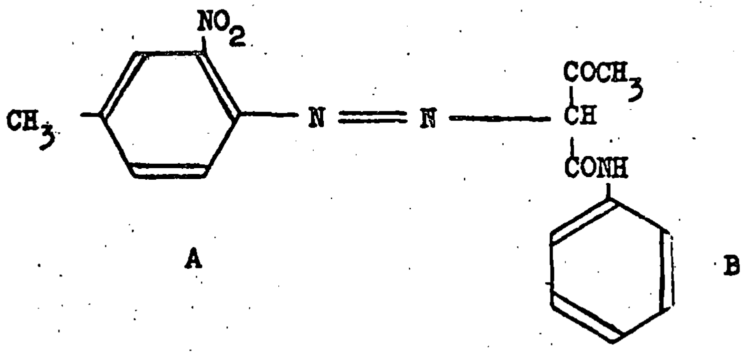
Vol. 1, No. 1, November 1960

STANDARDS ON ARTISTS' OIL PAINTS

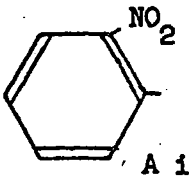
The standing committee on Commercial Standard CS98-42, Artists' Oil Paints, met on March 8 of this year for the first time in ten years. Mr. Ralph Mayer is the current chairman of the committee, made up of representatives of Grumbacher, Bocour, Permanent Pigments, and other interested parties. R. J. Gettens was the first chairman of the standing committee and is still a member. Together with F. W. Sterner, he was instrumental in establishing the standard in the years between 1938 and 1942. R. L. Feller joined the committee in 1950. Among other items of business that were transacted at the latest meeting, it was agreed to prepare and issue a revised version of the standard, since the current one is out of print, and to meet again in two years. The text of the standard can be found in the appendix of "The Artists' Handbook" by Ralph Mayer.

At the meeting, it was agreed that the chemical name "phthalocyanine" should be placed in parenthesis below any proprietary names that might be used, such as Grumbacher's "Thalo", to indicate the true composition of the pigment.

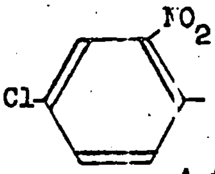
By action of this meeting, Hansa Yellow 10G, 5G, and G was added to the list of pigments by Class I permanency, pigments that resist fading at full strength in direct sunlight under glass for two months. V. C. Vesce has recently reported that tints of Hansa Yellow 10G, at concentrations of 5, 25, and 50% in mixtures with titanium white, changed only about 5 NBS units in color after nine months outdoor exposure in Florida (*Official Digest*, *31*, No. 419, Part 2, 1960). In contrast, alizarin at a concentration of 25% in titanium white changed 21 NBS units in only three months of exposure. Hansa Yellow G, Colour Index No. 11680, has the following chemical structure; the others are made with slight variations in the fundamental structure:



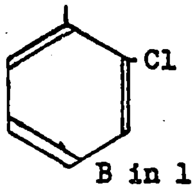
HANSA YELLOW G



A in 5G, B the same



A in 10G



B in 10G

An aspect of standard CS98-42 that may be of interest to conservators is the fact that artists' oil paints may be labeled as "titanium white" if they contain as little as 30% titanium white, no lead, and the balance made up of barium sulfate or zinc white. The National Gallery of Art research project at Mellon Institute has found a number of proprietary paints that are of this composition. This formulation provides certain desired qualities to oil paint. But, if one wishes to use in research rutile titanium dioxide of known composition, it is advisable to have the pigments analyzed, at least by emission spectroscopy and x-ray diffraction, or to obtain the dry pigment directly from the manufacturer. Non-chalking varieties of rutile titanium white are "Titanox-RA-NC" from the Titanium Pigment Corporation, 111 Broadway, New York 6, New York and "Ti-Pure R-610", from the Pigments Department, E. I. du Pont de Nemours and Company, Inc., 1007 Market Street, Wilmington 98, Delaware.

ibid., Vol. 2, No. 1, October 1961

Show Cases with Gray Glass

The Remington Rand Company supplies show cases fitted with an optically-gray glass that filters 42% of the visible light, and 31% of the solar ultraviolet radiation. The color specifications of the glass are: dominant wave length 480 millimicrons, exitation purity 2.3%, trichromatic coefficients, X = .305, Y = .312, Z = .383. The glass transmits 5% at 350 millimicrons, whereas ordinary window glass transmitts greater than 5% at wave lengths above 320 millimicrons. Gray glass is available from the Pittsburgh Plate Glass Company, (Solargray Plate Glass) and the American Window Glass Company (Lustragray) in Pittsburgh.

ibid., Vol. 2, No. 2, April 1962

Ultraviolet-Absorbing Plexiglas

The Rohm and Haas Company is now offering sheets of Plexiglas UF-3, an ultraviolet filter that removes more of the ultraviolet light than UF-2 and is just slightly yellow in color. Rough calculations of the factors of damage per footcandle (D/fc) show that, indoors under skylights, UF-2 will theoretically increase the lifetime of objects about 2.8 times; UF-3, 4.9 times. Under cool-white Deluxe fluorescent lamps (4300°K), these factors would be 2.0 and 3.5 times respectively (data for UF-2: Plexiglas LPC-518K, Harrison Report, Table V, p. 1e).

Sheets of Plexiglas UF-3 and tubes of ultraviolet-absorbing Plexiglas, designed to be slipped over 1-1/2"-diameter fluorescent lamps, are available in retail quantities from Glass Distributors, Inc., 1741 Johnson Avenue, N.W., Washington D. C., telephone DE 2-9000. The production of tubes of other diameters is contemplated for the future. Inquiries should be to the attention of Mr. Buchard.

ibid., Vol. 2, No. 2, April 1962

Tubes of Ultraviolet Absorbing-Plexiglas for Fluorescent Lamps

The National Gallery of Art research laboratory at Mellon Institute is making a detailed study of ultraviolet-absorbing materials. In a letter dated November 2, 1961, the Rohm and Haas Company kindly informed the editor that the tubes distributed by Glass Distributers Inc., Washington, D. C. (see previous Bulletin, p. 10) are extruded by Westlake Plastics, Lenni Mills, Pennsylvania, from Plexiglas V-100, UVA-5 molding powder. This material closely resembles the durability and filtering characteristics of the well-known Plexiglas II UF. The plastic tubes are designed to be fitted over fluorescent lamps.

The Rohm and Haas Company also stated that Plexiglas II UF has been re-named Plexiglas UF-1. They now market two ultraviolet-filtering sheets: Plexiglas UF-1 (practically colorless) and UF-3 (slightly yellow) (see previous Bulletin, p. 10).

ibid., Vol. 2, No. 1, October 1961

EFFECT OF EXTERIOR PAINT UPON TEMPERATURE DEVELOPED WITHIN A CONTAINER DURING EXPOSURE TO SUNLIGHT.

In designing a closed van in which to transport paintings overland, consideration was given to the reflectivity of the exterior, since the van would be exposed to sunlight during the trip. R. D. Buck and R. L. Feller last year conducted a few experiments with cardboard boxes wrapped in aluminum foil, in which it was found that white paint gave the greatest protection against a rise in temperature of the air within the container. The results of several tests are reported in Table I.

TABLE I

Temperatures Developed Inside Various Containers Exposed to Direct Sunlight

Exterior of Container	Temperature of Air in Container, °F Outdoors	 Indoors in Window
White paint on Aluminum Foil	95	96
Unpainted Bright Aluminum Foil	95.6	97.6
Aluminum Paint on Aluminum Foil	104	102
Glossy Black Paint on Aluminum Foil	117.5	115

These results confirm those reported by D. G. Nicholson (Paint, Oil & Chemical Review, 103, No. 21 (1941) p. 20), in which the temperature of test panels coated with black paint was found to be 12.5°F higher in temperature than panels coated with white. The rise in temperature followed closely the reflectance of the panels: a drop of 50% in the reflectance of dark paints compared to white was responsible for an increase of 9°F. in the temperature of the panels. An aluminum paint, having 20% less reflectance than white, gave rise to an increase of about 3.8°F. Nicholson's data for paints based on mixtures of white with red and yellow pigments and with aluminum powder are shown in the accompanying figure.

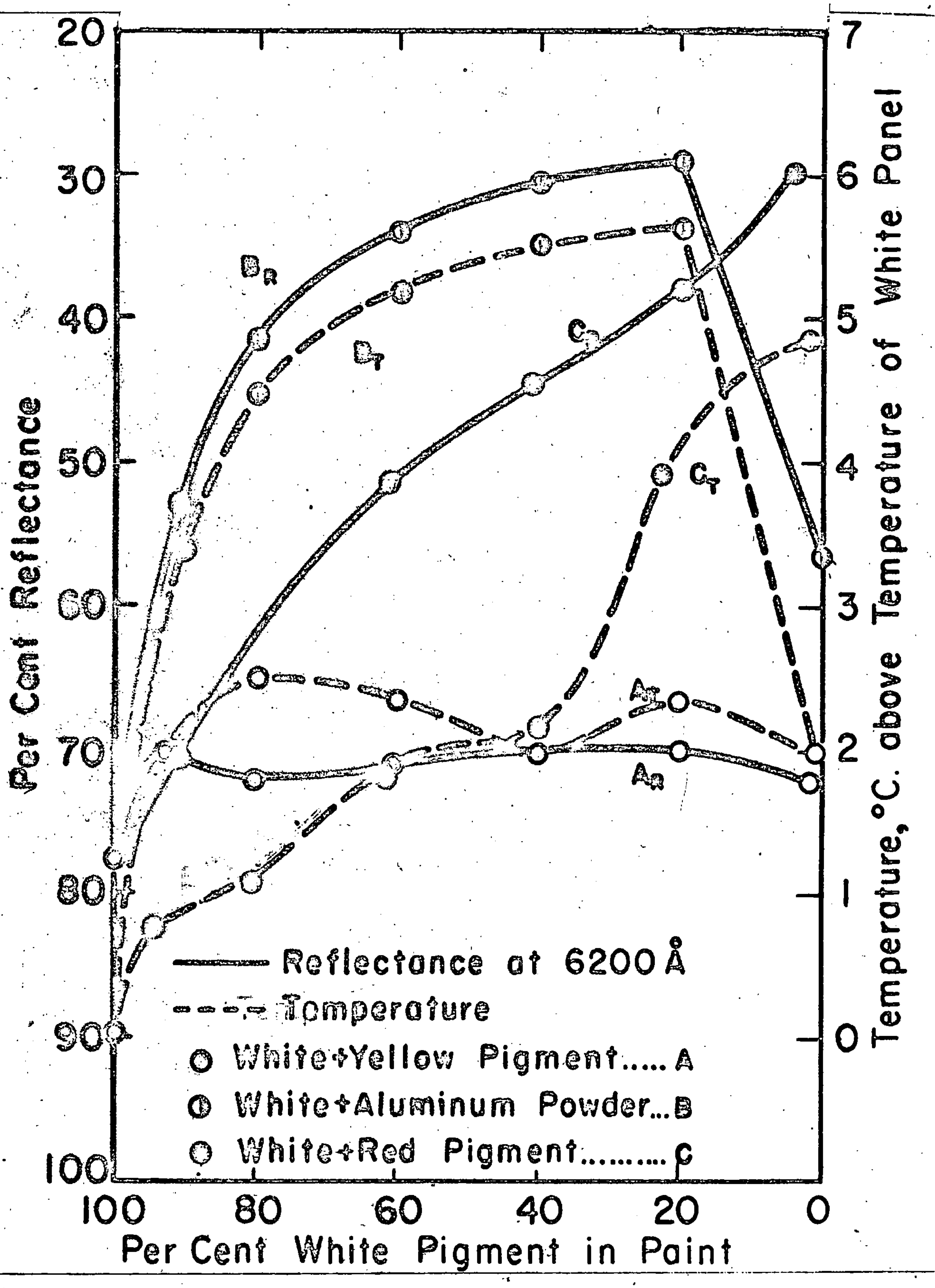
The key to the temperature inside containers is the ratio of absorption to emission of energy, which M. E. Sibert (Inorganic Surface Coatings for Space Applications, Division of Organic Coatings and Plastics Chemistry, Am. Chemical Soc., Papers Presented at the Chicago Meeting, September 1961, Vol. 21, No. 2. p. 350) reports as follows:

TABLE II

Ratio of Absorptivity to Emissivity for Various Materials

Material	Absorptivity, α	Emissivity, ϵ	α/ϵ
Aluminum 2024	0.27	0.02	13.5
Aluminum 6061	0.41	0.04	10.3
Aluminum gray anodized	0.53	0.50	0.76
Titanium white paint	0.15	0.90	0.167

Bobalek and von Fisher (Organic Protective Coatings, Reinhold Publishing Corp., New York, 1953, p. 97) report that Dr. Pfund of the Department of Physics, Johns Hopkins University, developed a paint during World War II that reflected greater than 95% of the total sun energy. This was based on basic carbonate of white lead in a minimum amount of a water-white vehicle. Recent reviews of the reflectivity problem may be found in First Symposium, Surface Effects on Spacecraft Materials, J. Wiley & Sons, New York, 1960, and in Evaluation of the Mechanisms Which Effect the Performance of Thermal Radiation Resistant Coatings, WADC., TR 57-334, April 1958.



RELATION OF REFLECTANCE OF PAINTED PANEL AND ITS TEMPERATURE WHEN EXPOSED TO SUNLIGHT.

(D. G. NICHOLSON)

ibid., Vol. 2, No. 2, April 1962

EFFECT OF EXTERIOR PAINT UPON TEMPERATURE DEVELOPED WITHIN A CONTAINER DURING EXPOSURE TO SUNLIGHT

Considerable interest has always been shown in the rise in temperature that museum objects may experience when exposed to spotlights, floodlamps and direct sunlight. A sub-committee of the ICOM Committee on Museum Laboratories is currently studying the problem. Recent investigations by a number of research laboratories, concerning control of the temperature of space vehicles, have resulted in several new and thorough reviews of the subject.

In the last issue of the Bulletin, a few brief remarks were made concerning the relative merits of white and aluminum paints in controlling the temperature inside a container that may be exposed to sunlight. Shortly thereafter, there appeared in England (R. N. C. Strain, "Solar Reflectivity of Paints," J. Oil & Colour Chemists' Assoc., 44 (Oct. 1961), pp. [illegible] to 712) and in America (Los Angeles Society for Paint Technology, Subcommittee 17, "The Emissivity and Reflectivity of Coatings", Official Digest, 33 (Feb. 1961), pp. 283-299), publications that reviewed the technical aspects of the subject in some detail. It seems profitable, therefore, to cite these important new references and to reaffirm the conclusions previously stated, specifically, that white paint is one of the best reflectors of solar radiation.

A simple way to determine the amount of radiant energy being emitted by a source is to measure the rise in temperature of a dull black surface that receives the emitted radiation, i.e. a surface having high absorption, low reflectivity. A description of such an emissimeter is given in the Official Digest publication. Based on much the same principles, experiments in the period 1929 to 1933 are described by G. [illegible] New ("Radiation and Paint," J. Oil & Colour Chemists' Assoc. 19, (1936) pp. 156-170) in which the evaporation of liquids from storage tanks was used to demonstrate the effectiveness of the exterior paints in reducing the heat generated within. New's remarks are not cited in the two most recent publications, but a table in Strain's publication reports much the same results as those given by New, by D. G. Nicholson (Paint, Oil & Chemical Review 103, No. 21, (1941) p. 20) and [illegible] H. Haldenwanger and S. Purucker-Neus (Energy Absorption of Thermoplastic Films, Kunstoffe, 46, (Sept. 1956) p. 407).

Rise in Temperature of Painted Test Panels in Sunlight

(from Cottony and Dill, Bur. Standards Building
Materials and Structures Report No. 64, (1941), p. 1)

Surface Coating	Temperature of Panel
Lamp Black	100°C
Galvanized iron (unpainted)	69
Aluminum paint	63
Canary yellow paint	41
White paint	28

The publication by Strain is recommended to those who wish to have a sound introduction to the subject. In connection with the use of infrared photography in the examination of paintings, Strain's data on the reflectivity of coatings of varying thickness over black and white under-paints are particularly interesting.

RLF

INTERMUSEUM CONSERVATION ASSOCIATION

Information Bulletin #6 July 1962

LEVELS OF ILLUMINATION AND ACTION OF LIGHT ON OIL PAINTINGS

Note: A recent inquiry from a member of the Association regarding the hazards of high levels of illumination in museums was passed on to Dr. Robert L. Feller of the Mellon Institute for comment. Dr. Feller is investigating this problem currently because the question has been raised in a number of museums here and abroad. The architectural trend towards large glass walls gives particular point to the problem. Dr. Feller's memorandum to this laboratory dated April 17, 1962, is a preliminary report, but it contains data that can have immediate application and may be of interest and use to our member museums. For this reason, the remainder of the Bulletin is information directly quoted from that memorandum as follows:

"Recommended Levels of Illumination:

Various lighting groups have determined suitable levels of illumination for various "seeing tasks". There are levels recommended for classrooms, libraries, public passageways, and so forth. There have been little or no standards recommended for museums, other than the few figures stated by museum people themselves.

The values given in the Harrison report of the Metropolitan Museum of Art are pretty much the same as the figures cited by other authorities, particularly the articles that have appeared in Museum and Museum News. A level of 12 to 15 footcandles has been recommended and used to illuminate prints and drawings. This seems to be about as low as one can go conveniently. A level of 20 to 25 footcandles probably is more generally encountered. The Harrison report suggests a level of 60 footcandles for emphasis lighting.

These figures are cited to show the range which one should consider and strive for. Certainly, levels of over 150 footcandles are to be avoided in the exhibition of textiles, many paintings, and other susceptible materials.

The amount of light that is pleasing to the eye varies considerably with the circumstances of viewing and illumination. A level of 20 footcandles can be entirely satisfactory under one situation and can be entirely inadequate in another. This is because the eye adapts itself to the general conditions of viewing, to the "surround". For this reason, the eye is no judge as to the absolute level of illumination. The level must always be measured with a light meter. Generally, this is done by measuring the reflectance from a standard reflecting surface such as a photographer's white and gray reflectance card.

Evidence of Fading in Oil Paintings

There is relatively little published and little factual material to offer in evidence for the fading of colors in oil paintings. For this reason, our own laboratory is making an extensive study of the problem. If one looks into the literature, one can find references, here and there, to certain colors that have faded. If one begins to study paintings that are removed from the frame, one can find evidence, from time to time, where the colors that have been protected by the rabbet of the frame are brighter than the colors in exposed areas. It is my opinion that considerable color change has occurred in many paintings. It will be our business in the next few years to gather as much evidence as we can to support this opinion.

The problem is complicated by many factors: deterioration is seldom apparent if the colors are used at full strength. We are also seldom aware of fading and cannot be positive about it unless one of the fugitive colors happens to be on the edge of the painting and runs under the rabbet. One can see, therefore, it's only in a limited number of colors, in a limited number of tints (as opposed to full strength), and in a limited area (next to the rabbet) that we can hope to see signs of fading.

Most of the colors in Commercial Standard CS-98-42, the list of permanent pigments for artists' oil paints, are quite durable and will show little change. Unfortunately, artists in history have not always employed the most durable colors. Pigments that we know were extensively employed and which we know are able to fade are indigo, carmine, perhaps Prussian blue, and all varieties of alizarin (madder). There are certainly others, such as gamboge, which we believe were used, but concerning which there might be some argument as to the occurrence or frquency in which they may occur in paintings.

It is the sensitivity of tints of alizarin that, in the opinion of my laboratory, make the concern for the illumination of paintings well worth everyone's attention. There can be no doubt concerning the sensitivity of this material to light and the extent to which it has been used.

Other Actions of Light

One must bear in mind that there are other actions of light besides fading that need to be considered. Light can hasten the aging of oil paint, increasing its refractive index (leading to pentimenti). Light can hasten the deterioration of varnishes, making them more difficult to remove, if not leading to all sorts of cracking and embrittlement.

Conclusions

I think that the above paragraphs show that the concern for levels of illumination over 150 footcandles is not only important on a theoretical basis, but evidence is also available to convince ourselves of it practical importance.

It is difficult to arrive at a satisfactory solution to the illumination of objects of all kinds, particularly once the building is built. We hope, however, that architects will be asked to consider these problems in their original design. This is a particularly difficult problem, but one that we are currently investigating in detail."

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12 fc. (60 fc. emphasis), 4200° K.: Harrison, L. S., Report on the Deteriorating Effects of Modern Light Sources", Metropolitan Museum of Art, 1954.

10 to 30 fc., 4200° K.: Kalff, L. C., Museum News, 38, No. 4, 26 (1959); 4500° K.: McCandles, S., Museum News, 37, No. 1, 10 (1959).

3 to 4 fc.: Mouseion, 27-28, 198 (1934); 6 to 10 fc.: Mouseion, 33-34, 191 (1936).

2.5 to 10 fc.: Ramsay, A. G. and Smith, G., Mouseion, 33-34, 185 (1936).

18 fc.: Hannah, A., Museums J., 59, 66 (1959).

5 fc.: MacIntyre, J. A. and Buckley, H., Burlington Mag., 57, 31 (July 1930).

6.5 to 18.6 fc. (46.5 fc. for emphasis): Abstract 1529, IIC Abstracts, 2, No. 3 (1959).

9.3 to 30 fc.: Balder, J. J., op. cit.

8 to 25 fc.: Baucik, C. and Kammerer, H., "Die Beleuchtung der Alten Pinakothek in Munchen", Lichttechnik, 9, 547 (1957); see also Maltechnik, 67, No. 1, 5, (1961).

From EPC Workbook, Brooklyn Museum, October 1962

CONSIDERATIONS REGARDING THE ILLUMINATION OF MUSEUM OBJECTS

A. QUALITY OF ILLUMINATION

The quality of illumination is a subjective matter. It is not possible to state rigid rules for what is satisfactory in any particular situation. Some knowledge of the various technical aspects of light and color is required, however, in order to control properly the various factors that influence ones subjective reaction. The quality of illumination may be divided into at least three aspects: distribution, color, and intensity.

1. Distribution: Is the illumination to be sharp or diffuse? Flat objects need only a single source of illumination, but objects in the round often require illumination from several sources and may benefit from a mixture of sharp and diffuse illumination.

With overhead lighting, one must always guard against the frame of a painting casting a shadow. Many authorities suggest the location of a lamp at an angle of 60° above the horizontal from a point of illumination on the wall 5'6" from the floor[1, 2]. Distracting reflections need always to be considered.

2. Color: To understand properly discussions of illumination by colored lights, one must understand something of the concept of a "black body radiator" and "color temperature". Nearly all discussions of color are accompanied by a diagram similar to Figure 1. In a perfect black body radiator, the distribution of the energy among the various wavelengths from blue light (near 400 millimicrons) to red light (near 700) produces the family of curves shown in Figure 1. These are the characteristics of the radiant energy that one would see if one "looked through the window of a closed furnace as the temperature was gradually raised through dull red to brighter red, and finally, through yellow to a pale, brilliant blue at the highest temperatures"[3].

Incandescent lamps have distributions of energy similar to yellow heat at 2400 to 3000°K (Kelvin temperature is the Centigrade temperature plus 273°). An overcast sky is said to have a color temperature of between 5000 and 7000°K., North light, a color temperature in the neighborhood of 6000°K; one may judge from Figure 1 that this would be light that had nearly an equal amount of red and blue energy. Many authorities believe that museums must make an effective compromise around 4500°K[2]. It has been found, too, that at levels below about 23 footcandles, yellowish illumination is preferred, color temperatures immediately below 4000°K[4]. A discussion of intensities and color temperatures used in the number of museums has been presented by Kalff[5].

The introduction of fluorescent lamps has given rise to a number of problems in color rendering and in possible damage by ultra-violet radiations. The distribution of energy among the various wavelengths of radiant energy from these lamps is usually not closely related to the smooth curves of energy found in black body radiators (for a detailed discussion, see reference 3). Hence, the statement has been made that no single lamp at the present time gives light that is closely similar to daylight[6]. New and improved lamps are coming on the market all the time, however.

Generally, a combination of lamps is used to give a distribution of energy close to those expected of a black body radiator. With the use of a single variety of fluorescent lamp on the market today, it is seldom possible to get "good color rendering" as would be obtained under radiation from a black body radiator of the color temperature that is used to characterize the particular fluorescent lamp. Lamps of rated color temperatures, 4900°[7], 4500°[2], and 4200°K[4, 8], have been used in various museum installations. For the best results in color matching, a qualified expert needs to be consulted.

3. Intensity: The eye adapts itself readily to varying levels of intensity. Hence, the absolute intensity under any particular circumstance is difficult to judge. The level of illumination of the surrounding area strongly influences ones opinion regarding the true intensity. For this reason, the intensity must always be measured with an instrument.

Certain photoelectric light meters used by photographers measure illumination in terms of footcandles. These are perhaps best used by measuring the intensity of light reflected from a standard white surface such as the photographer's reflectance cards. The Kodak Neutral Test Card is sold by the Eastman Kodak Company; the white side reflects 90% and the gray side reflects 18% of the incident radiation. In critical cases, one must report the intensity of illumination received in a direction perpendicular to the surface of a painting, drawing, or cloth object. The intensity of illumination coming from a limited source, such as a spotlight, is usually higher than the value of the intensity in a direction perpendicular to the surface, just as the winter sun strikes at a lower angle and is less intense than summer. In technical considerations of possible damage by light, it is the intensity of illumination perpendicular to a surface that is of particular interest. In critical cases, a qualified expert is needed to make the measurement.

The level of illumination necessary for the comfortable viewing of objects depends on the adaptation of the eye. Levels of the order of 10 to 25 footcandles have been suggested for the illumination of many museum objects and a level of 60 footcandles has been suggested for emphasis lighting[8]. Thomson has suggested three classifications of museum objects according to their sensitivity to light and has recommended no more than 5 footcandles for especially sensitive objects such as water colors, textiles, tapestries, and other susceptible materials[9].

B. GENERAL CONSIDERATIONS

1. Is the installation to be semi-permanent or flexible? Must it blend with daylight and if so, are rheostats and other means of dimming the light required? Remember that cleaning and dusting are necessary. In showcases and other semi-permanent installations, easy access to facilitate dusting, cleaning and removal of insects is much to be desired. Incandescent lamps with built-in reflectors stay clean and in focus. In most showcases, a sheet of shatter-proof plastic or glass is usually placed between the objects and the lamps for safety.

2. What are the power requirements for the installation? This is particularly important in the adaptation of an old building where the existing electrical lines are already installed and place limitations on the amount of power that can be drawn. Fluorescent lamps are most efficient in terms of amount of light that is produced for a given power input. This is one reason for their popularity.

3. Does special attention need to be given to susceptible materials? The exhibition of materials susceptible to the action of light, such as water colors, objects on paper, cloth, writing inks, dyes, etc., are not recommended to be on a permanent basis (Harrison, page 19). Levels even in temporary exhibits, should not exceed 5 to 15 footcandles.

If incandescent lamps are to be used, the heat of the lamp must be considered. When fluorescent lamps are used, heat can be further reduced by having the electrical ballasts placed outside the showcases or in a separate location.

Wherever daylight or fluorescent lamplight is used to illuminate objects that may be affected in any way by ultraviolet radiations, ultraviolet filters such as the Rohm and Haas Plexiglas UF-1 (practically colorless) or UF-3 (slightly yellow) should be used. Glass Distributors, Inc., 1714 Johnson Avenue, N.W., Washington, D. C., sell tubes of these materials designed to be slipped over 1-1/2" diameter fluorescent lamps. The Solar Screen Corporation, 1023 Whitestone Parkway, Whitestone 57, New York, sell thin plastic envelopes designed for the same purpose. The Verd-a-ray Corporation, 615 Front Street, Toledo 6, Ohio, sells fluorescent lamps coated with an ultraviolet-absorbing lacquer called Fadex.

It should be strongly emphasized that ultraviolet filters usually reduce the hazard of deterioration, but do not prevent it.

Robert L. Feller, Ph.D.
National Gallery of Art Fellow
Mellon Institute
Pittsburgh 13, Pennsylvania

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