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The Use of Low Energy Radioactive Isotopes in the Examination of
Paintings on Thin Supports*

MASTER

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The importance of the examination of paper and textile supported art objects by means of low energy X-rays has been ably discussed in the preceding papers of this session. The apparatus used for such radiography, however, has tended to be both expensive and confined to laboratory use. A lack of mobility arises from the weight and size of X-ray apparatus and the fact that its installation frequently requires shielding and special electric power lines. An inexpensive radiographic apparatus that required no special installation or external power and is small and light enough to be easily portable should be quite useful.

Mr. Rano Bourgeois of the Conservation Center of the New York University Institute of Fine Arts and I have constructed such a device through use of a radioisotope of iron. The development of this new radiographic apparatus may be described as having been a joint Brookhaven National Laboratory-Conservation Center project which received considerable encouragement and support from Mr. and Mrs. Randall.

The isotope of iron with atomic mass 55 undergoes a spontaneous radioactive change in which, in an individual instance, an electron is transferred from an outer shell of an iron atom into its nucleus. During this

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process the iron is transmuted into manganese and X-rays characteristic of manganese are emitted. These X-rays are very soft. Approximately seventy percent of them are of six kilovolt energy, and thirty percent less than one kilovolt. Since the usual soft X-ray radiographs are obtained with tubes operating in the region of five to ten kilovolts, the X-rays from iron-55 should be rather similar, although more monochromatic, than those customarily employed. Iron-55 decays only slowly, with a half life of 2.6 years. A source prepared with this radioisotope, therefore, could reasonably be expected to continue to be useful for a period of at least four to five years.

The device itself is shown in Fig. 1. It is simply a five by seven inch glass plate upon which a uniform layer of polyvinyl alcohol, containing approximately one half of a millicurie of iron-55, has been deposited. For convenience in carrying and for radiographing small objects the plate is placed in an ordinary five by seven inch photographic contact print frame. In use the radioactive film is placed against the back of a painting and an appropriate photographic film is placed opposite to it against the painting face. Close contact must be maintained between the three layers. If the painting is too large to fit into the print frame, the contact can be maintained by laying the X-ray film, painting and plate in order upon a table and applying a moderate pressure to the top by means of a book, a small sand bag or other convenient weight. The radiograph can be taken in normal room illumination if the photographic film is first enclosed in a protective envelope of thin but light-tight black paper or plastic film.

The uniform iron-55 containing polyvinyl alcohol film was prepared in the following way. The glass plate was carefully cleaned and an area of approximately 200 square centimeters marked off upon its top surface with a wax marking pencil. The plate was placed upon three leveling screws and

carefully leveled in an environment controlled to 50 percent relative humidity. We had purchased from the Oak Ridge National Laboratory a millicurie of iron-55. It was delivered in the form of 0.15 ml of an aqueous solution containing 0.17 mg of ferric chloride. The solution had been acidified with hydrochloric acid to a concentration of 1.2 normal. This radioactive iron solution was added to forty milliliters of a five percent aqueous solution of polyvinyl alcohol. The final solution was poured onto the leveled plate where it was confined by the wax pencil markings, then allowed to dry for one week in the 50 percent relative humidity atmosphere. After drying the film was trimmed to a square ten centimeters on a side in order that possible nonuniformity of thickness at the original edges would be eliminated, and in order that there would be a reasonably broad edge left on the plate, by which it could be handled without contacting the radioactive film. The total cost of materials contained in the final source was approximately fifty dollars.

The radiation hazards that might be encountered in using this source must of course be carefully evaluated. These hazards can be of two types, (1) the dose of radiation directly received from the source, and (2) the possible contamination of the user through accidental removal of some of the radioactive material from the source. As an extreme of the latter possibility one can envision the user accidentally ingesting some of this radioactive material. Because of the low energy of the radiation emitted by this source and the low concentration of radioactive material within it, we believe neither of these hazards are serious. The basis for this judgment are the permissible radiation doses for occupational exposure defined in this country by the National Bureau of Standards. These permissible doses

are very conservative estimates of the amount of radioactivity an individual might encounter without expectation of measurably affecting his well being. The present definition of permissible dose to external radiation is the equivalent of 100 milliroentgen-equivalent-man units per week for total body exposure and 1500 rem per week for exposure on the hands and forearms,¹ this rate of dose being continued for a quarter of a year. Upon the basis of calculations which were checked by measured darkening of calibrated film badge packets placed in direct contact with this source, it can be estimated that at least several hours of close exposure to the source, involving almost direct physical contact with it, would be required to experience this weekly allowable dose. The supporting plate has reasonably broad edges extending well beyond the radioactive layer by which it can be handled. Also the thickness of the supporting plate is sufficient to virtually fully stop these soft X-rays. If this plate is handled with even reasonable care one should incur at most a small fraction of the permissibly allowable dose.

The National Bureau of Standards occupational hazard restrictions consider the internal accumulation of three millicuries of iron-55 throughout the total body to be the permissible limit.² The accumulation within the spleen, the organ most sensitive to iron-55 radiation, is limited to one millicurie. Since only one half of a millicurie is contained within this source, it is obvious that the small amounts that might come off in handling could at most add up to a very small fraction of the permissible level. It would seem reasonable to expect, therefore, that a competent, experienced person could handle this radioisotope source safely. It should also be noted that a painting upon being radiographed by this source should not be affected more greatly than had it been radiographed by a conventional X-ray tube.

It has been shown that the iron-55 source is reasonably safe, is relatively inexpensive, and is portable and simple to use. It remains to be demonstrated that it produces good radiographs.

We are particularly grateful to Mr. Roland Koscherak for lending us, through the good agencies of Mr. and Mrs. Randall, two eighteenth century Japanese paintings for study. The paintings were in part chosen because they were on supports that were too heavy and opaque to permit them to be examined by transmitted visible light. The painting of a standing woman in a brown plaid robe shown in Fig. 2 is attributed to the first half of the eighteenth century and, although unsigned, is thought possibly to be the work of Bawku Eishuu. In Fig. 3 two radiographs of the face of this figure are compared. The radiograph on the left was taken with radiation from a beryllium window X-ray tube operated at 5 kilovolts and 3 milliamperes. In both instances Kodak no screen X-ray film was employed. The radiograph on the right was obtained with the iron-55 source. Essentially the same details show up in both radiographs. Losses are clearly visible and a detail of the painting technique is revealed in that the eyes show up clearly in the radiographs. The significance of the appearance of the eyes is that they were not applied on top of a basic paint layer extending over the face. Rather the face was carefully painted around them. The major difference between the two radiographs would appear to be that slightly greater contrast was obtained with the iron-55 radioisotope.

The painting shown in Fig. 4 is from Nagasaki, probably of the eighteenth century, and represents two foreign men with two Japanese women. The face of the woman on the left was radiographed by the conventional and radioisotope techniques. In Fig. 5, again the isotope radiograph appears on

the right and the conventional radiograph on the left. In both, details of cracking and other damage are revealed, particularly the presence of some later restoration in painting at the edge of the nose. It is also interesting to note, in contrast to the preceding radiographs, that the eyes in this face are not revealed. In this case the eyes apparently were added in on top of a basically painted face area. The information revealed by these radiographs would seem to be a type that would be of interest and value to the conservator and art historian.

The most serious defects of this particular radioisotope source are 1) the close contact that must be maintained between the painting and the photographic emulsion, 2) a failure to reveal positions of purely organic pigments, 3) the need for rather long exposure times, and 4) its small size. in Fig. 5

The slight fuzziness of the isotope radiograph we believe arose from lack of good contact and exemplifies the first of these problems. The fact that the support of this painting was unusually heavy and stiff probably contributed to this lack of good contact. The difference in the ability of conventional X-ray radiography and the iron-55 source to reveal purely organic pigments is not exemplified in the radiographs in Figs. 3 or 5. However, in some radiographs of very thin specimens, organic pigments were revealed by conventional radiography but not by the iron-55 source. We do not believe, of course, that iron-55 is necessarily the optimum radioisotope that might be used for this purpose. A carbon-14 source, in which low energy beta rays would be utilized instead of X-rays might be more sensitive to a greater range of atomic weight components. The more than 5000 year half-life of carbon-14 also makes it an attractive candidate. The range of exposure times required to obtain good radiographs with this particular iron-55 source was

from 20 minutes for quite thin specimens to 2 to 3 hours for the paintings on moderately heavy supports. These exposure times are a little inconveniently long. They could be shortened, of course, by constructing a more intense source. The source could quite easily be increased in size.

Mr. Bourgeois and I feel that although this particular radioisotope source might not be ideal in all respects, it does indeed demonstrate the feasibility of radiographing art objects supported by paper or textiles by means of radioisotopes that emit low energy radiation.

We are very grateful to Mr. and Mrs. Randall and to Mr. Koscherak for providing us with material for study.

References

- (1) Title 10 Code of Federal Regulations-Atomic Energy Section 20.101
Exposure of Individuals to Radiation in Restricted Areas.
Federal Register, Nov. 17, 1960.
- (2) National Bureau of Standards Handbook 69, Maximum Permissible Body
Burdens and Maximum Permissible Concentrations of Radioisotopes in
Air and in Water for Occupational Exposure. June 1959, page 30.

Figure Captions

Fig. 1. Iron-55 radioisotope source with photographic contact print frame in which it is carried.

Fig. 2. Eighteenth Century Japanese painting, possibly attributable to Bawkui Eishuu.

Fig. 3. Radiographs of the face of the woman in the picture of Fig. 2.
Radiograph at left taken with soft x-rays from a tube with a beryllium window.
Radiograph on the right taken with the iron-55 source.

Fig. 4. Probable eighteenth century painting from Nagasaki.

Fig. 5. Radiographs of the face of the woman on the left in the painting of Fig. 4.
Radiograph on the left taken with soft X-rays from a tube with a beryllium window.
Radiograph on the right taken with iron-55 source.

QUESTIONS

Dr. Sayre: I shall first ask Mr. Bridgeman of the Eastman Kodak Company to comment on some other interesting methods for the radiography of art objects.

Mr. Bridgeman: The discussion, so far, has been mainly with the use of low voltage radiography. This may be a bit of reiteration to some of the members of the IIC I see here, but I'd like to bring out that we can radiograph materials on thin supports, whether they be postage stamps or Japanese works of art, at extremely high voltage, such as two hundred and fifty-thousand volts, in that this very high voltage radiation will create within the pigments of the painting, a secondary electron emission, that depends on the atomic number of the element.

Now, electron emission is not new. I think that it was Prilard in France who brought it up first. We know that when certain elements are hit with ultra-violet light, they will fluoresce. Likewise, elements when hit with infrared will fluoresce. This is something that I am studying right now. And when they are hit with very high voltage X-rays, they will emit electrons.

Now, let us take a stamp and X-ray it with low voltage radiography such as has been described this afternoon. For this I use eight kilovolts on a tube with a beryllium window and a single emulsion film. I don't use X-ray film, but rather a photographic high contrast film, because it is fine grained and has good contrast without the problem with double emulsion. The radiograph will show not only the absorption by iron oxide ink on the stamp but it also shows part of the paper structure.

Now, what if we wanted to study the paper structure of this alone, to determine whether areas had been damaged, or repaired, or to look for

watermarks? If we were working on some of Goya's prints, any of those of which one uses a watermark catalogue to help date the print, we would be able to proceed as follows. We lay the film in a cassette, or a film loader, where we will have good contact, put the print face up on the film and lay a sheet of lead foil on top of the print. We hit that with two hundred and fifty thousand volts, with eight millimeters of copper at the tube to filter out all of the soft radiation, so all that we get is the hard radiation, and we will not observed any image whatsoever of the design. All we will see is the paper structure. Now, that is very helpful, as I say, when you are working with watermarks or damaged areas that have been repaired, and there have been some awful clever repairs.

A valuable stamp that has been torn can be repaired so that you cannot see even under visible illumination with a hand loupe any mark of demarcation where the restoration was made. One can, however, see immediately where new paper has been added with this technique.

Now, if one takes up the lead foil and lays the painting or print with the painted surface down upon the film and then hits it with very hard radiation of high voltage, it will cause the pigments to emit their own characteristic radiation and produce an image of the design layer, without the superimposition of the design of the base. One must have absolute contact. I have used a vacuum bag on our specimens.

I would just like to call your attention to the fact that with extremely high voltages of hard radiation, you can examine paintings on thin sources and get rather interesting results. Thank you.

Question: Could a high energy gamma ray be used for such irradiation.

Mr. Bridgeman: Yes. This has been attempted, I would say by Calla in Chicago. He hasn't been quite as successful.

Dr. Sayre: With this technique, would you not also generate a fair number of fluorescent X-rays from your bombarded material?

Mr. Bridgeman: Yes, but they are an order lower than the electrons.

Dr. Sayre: I should now like to call on Dr. Jane Sheridan of the Conservation Center for comment.

Dr. Sheridan: I believe that the use of radioactive isotopes has a definite place, however the practical problem of using radioactive isotopes is extremely great. I don't think that the present attitude of the United States Atomic Energy Commission will permit non-licensed people to use much radioactive carbon, oh, for the next hundred years. As you will recall, just recently, they permitted the use of one microcurie tritium on watch faces. The chances of them allowing non-licensed users to have five hundred millicuries of iron-55, I think Dr. Sayre will agree, is a pretty small one at the moment.

On the other hand, Dr. Sayre has shown how we can use very sophisticated and selected X-rays that can be more useful than the general spectrum X-rays normally used. Also the cost of the Kodak equipment is quite more expensive than most museums can afford, while Dr. Sayre's device is one that could be afforded.

Dr. Sayre: It is quite true that the licensing of such devices will be a problem, but I would imagine that licenses could be obtained. Radio-isotope devices of various types are being increasingly used in industry and the Atomic Energy Commission encourages the development of such devices. I do not believe the iron-55 source is sufficiently hazardous intrinsically to warrant severe restriction of its use. Moreover, should American policy severely restrict its use here, it might well find application in other countries.

Mr. Randall: A particular advantage of the iron-55 source is that it could be taken on field studies. Cobalt-60 sources have been so used for field study, and the iron-55 source is considerably less cumbersome and less hazardous than they.

Unidentified Speaker: Hospitals use radioisotopes for medical treatment, so we would simply be doing something that the hospitals do. We could train operators to do this kind of work.

Mrs. Randall: I wonder if it isn't about time that some people in the conservation field begin to obtain the training that would permit them to go into this kind of field.

FIGURE 1

FIGURE 2

FIGURE 3

FIGURE 4

FIGURE 5