next section of 30 kilometers (18.641 miles) in length, to Rio Blanco, would soon be ready. This will bring the portion completed to 121 kilometers (75.187 miles), leaving 54 kilometers (33.5 miles) on the Argentine and 42 kilometers (26 miles) on the Chilean side (on which the earthworks are well advanced) to complete communication between the Atlantic and Pacific Oceans; 93 per cent. of the distance from ocean to ocean can now be traversed by rail, and the works are far advanced upon the remaining 7 per cent.—*Engineering*.

ON THE DURABILITY OF PICTURES PAINTED WITH OILS AND VARNISHES.*

By A. P. LAURIE.

WHEN we look at the Van Eyck, No. 186 in the National Gallery, we are at once struck with its wonderful state of preservation. The reds, probably produced by glazings of lac, or Brazil wood, or kermes lake, over a yellow or red ground, seem certainly to have slightly faded, and turned brown, when compared with fresh preparations of the same lakes made from the old receipts; but they are in very fair condition, and the green on the wife's dress is marvelously brilliant. This green is worthy of special attention, as it seems to be agreed among the authorities on these matters that it can only have been produced by a glazing of verdigris, a pigment which we now know to be of a most dangerous character, turning black, and corroding and destroying other colors. The oranges in the corner are apparently painted with orpiment, another dangerous color to use.

With reference to the reds, I have already mentioned the three lakes, which are most commonly referred to in old receipts, madder being hardly ever mentioned. Of these, Brazil wood is very fugitive, turning a dirty brownish red, and fading very much if only exposed to sunshine for a few days. Lac lake, though better than the last, is not a permanent lake, and of kermes very little is known beyond the fact that it yields a permanent dye. Unfortunately these lakes, when prepared from the old receipts, are so much alike that it is impossible to identify them on a picture. Judging, however, by these receipts, one lake is as likely to have been used as another.

In this picture, then, painted early in the fifteenth century, we probably have verdigris, a notoriously fugitive pigment; orpiment, a pigment very apt to change; and a lake which, assuming that kermes is a permanent color, may or may not be permanent, according to which of the three lakes above mentioned has been used.

It cannot, then, be held that the preservation of the picture is due to the pigments used, and we must, therefore, look elsewhere for an explanation of its freshness.

If, then, the secret does not lie in the pigments, it must lie in the vehicle; and this leads us to consider what properties a vehicle must have, to produce so remarkable an effect.

This question is very easily answered.

It has been again demonstrated by Prof. Russell and Captain Abney, in their report on water colors (1888), that most fugitive pigments are permanent, if protected from moisture, and a still larger number, if protected both from air and moisture. If, then, we can obtain a vehicle which will really protect the particles of the pigment from moisture, we may use with safety many pigments that are now regarded as fugitive.

At this point one is apt to think that the inquiry is concluded, as we are accustomed to assume that ordinary varnishes and oils do preserve surfaces from the action of moisture; but, unfortunately, if a sufficiently delicate test is applied, this is not found to be so. The method I have devised for doing this is to use as a pigment ignited sulphate of copper, which is, of course, a very hygroscopic body. If we grind a little of the ignited sulphate with linseed oil, and paint it out on a glass slide, we get an enamel-like white surface, with sometimes a slight greenish tinge in it.

If this is placed in a desiccator to dry, it remains the same in appearance; if, however, when dry, it is exposed to the air of a room, it gradually turns green and transparent; or if it is exposed under a bell jar beside a dish of water, the change takes place much more rapidly, twelve hours being often sufficient. If we now examine the slide under a microscope, we usually find that no definite crystalline formation is visible, but occasionally here and there are to be found complete crystals of sulphate of copper, due, apparently, to a slow aggregation of molecules in the colloid linseed oil.

I shall begin by describing the experiments I have made on linseed oil alone.

LINSEED OIL.

The linseed oil of modern commerce differs in several important particulars from that used by the old masters. Hot pressed from adulterated seed, refined by the addition of sulphuric acid, and then probably further adulterated with other oils before it is put on the market, it is a very inferior product. The oil of the old masters seems to have been cold pressed from pure seed, and then refined by exposure to sunlight, and washing with water.

In converting it into boiled oil, various methods and substances were used, such as exposure merely to the sun till it thickened; boiling it with bone ashes and pumice; boiling it with ignited sulphate of zinc; boiling it with litharge or with white lead, or with amber; or exposing it to the sun exposed in leaden dishes, or mixed with white lead.

The modern practice is probably, in many cases, similar, salts of manganese having been added to the list, and such substances as sulphate of zinc having been abandoned.

My impression from the study of the old receipts is that, probably, in most cases litharge or white lead was used, just as it is most commonly used now. We have, then, to look rather to the earlier stages of the preparation of the oil to find any serious difference between ancient and modern practices.

With a view to finding whether the capacity of linseed oil for resisting moisture would be improved by following any of the old methods, I tried the following experiments. I obtained:

1. A sample of ordinary pale drying oil of the best quality.

2. A bottle of drying oil from one of the leading firms of artists' color men.

3. A sample of Bell's medium from Messrs. Bell & Co., of Oxford Street. This medium is prepared by cold pressing carefully sifted seed, and then keeping the raw oil at a temperature of about 100° C. for some weeks, until it becomes thick and viscous. This "fat oil" is then thinned with oil of spike for use.

4. I obtained some raw oil, cold pressed, from sifted English seed, which I then refined in the following manner: A bottle was filled one-third full of salt water and sand, and one-third full of oil, and was placed out in the sun, with a loose cap over the top, for four weeks. By the end of that time no more precipitate was formed, and the oil was drawn off, filtered, and converted into boiled oil by heating to 120° C. for 120 hours with borate of manganese.

5. Another portion, after refining, was converted into oil, by heating strongly for three hours with bone ashes, adding ignited sulphate of zinc, and allowing it to settle and stand in the sun, according to an old German receipt, which is quoted by Eastlake in his "History of Oil Painting." Slides were painted out with these different oils, mixed with sulphate of copper, and, after having been dried by a desiccator, were exposed to moisture. They all turned green at approximately the same rate, and repeated experiments did not show that one had much advantage over another. If a slide is varnished with oil, after being dry, it, of course, resists a little longer; but four layers of such varnishing only protect the slide for three days instead of one.

As far, then, as experiments are concerned, there seems to be no reason to suppose that the pure oil, sun refined, has much advantage over the commercial oil, or the different methods of converting it into boiled oil exercise an appreciable effect. Only one point seemed to remain unsettled. It seemed possible that the old oil, imperfectly pressed, might be superior to that obtained by the hydraulic press. In order to test this, I had some fresh seed pressed, and took samples during the pressing, dividing the oil into three parts. Taking the first part of these, I refined it, boiled it with borate of magnesia, and tested it. The moisture penetrated through it as before.

These experiments seem to show, then, pretty conclusively, that linseed oil, no matter how pure or how carefully refined, or in what way it is converted into boiled oil, cannot be depended upon to protect a surface from moisture. In the course of these experiments I was struck with the fact that linseed oil which had been kept for some time after it was dry in the desiccator seemed to resist better than lately dried oil, when exposed to moisture. Three weeks was found to make a considerable improvement, and two months still further improvement. These experiments are being continued, with a view to finding at what point the improvement will cease.

When we consider the nature and constitution of linseed oil, I do not think we need be surprised at its permeability to moisture. Besides containing linoleine, it also contains considerable quantities of non-drying fatty acids, which being unaltered during the oxidation of the linoleine must tend to produce a spongy and porous surface. According to Allen, the dried film contains free glycerine, which must not only tend to increase its porosity, but also to act as a carrier of moisture. Taking these different facts into consideration, the passage of moisture through linseed oil is not surprising.

I should like to refer here to a theory which has been recently advanced, that lead driers are injurious to pictures on account of the formation of lead soaps. As far as these experiments are concerned, we have no confirmation of this; and I confess that the theory seems to me a very startling one in the light of the fact that the white lead used by the old masters was prepared by the Dutch process, and therefore contained large quantities of lead hydrate, and of the fact that the oldest receipt I am familiar with for preparing drying oil devices that this should be done by boiling with oxide of lead.

When Mr. Scott Taylor tells us that the Venetian painters were accustomed to grind their white lead repeatedly in vinegar, I can only suppose that chemists, like poets, are sometimes caught nodding. It seems to me more probable that treatment with lead salts may remove some of the fatty acids other than linoleic acid as lead soaps. I do not find, however, that the oil which rises to the surface of ground white lead protects from moisture any better than ordinary oil.

WALNUT OIL.

Walnut oil is frequently referred to in the old receipts, and seems to have been largely used by the old masters for painting. It can be prepared by pressing the kernels of walnuts after slightly warming them. The walnuts should be about three months old. The oil obtained is very pale, and dissolves white lead freely on boiling, becoming darker in color. I prepared a little by boiling the kernels of the walnuts with water, after pounding them in a mortar, roughly separating the oil which rose to the top, dissolving the oil in ether, filtering, and evaporating off the ether. I then converted this oil into a boiled oil by heating it with white lead. On testing it with the sulphate of copper, I found that moisture rapidly penetrated, showing that it is no better in this respect than linseed oil. As these were the two oils which were used by the old masters, the protection of their pigments cannot have depended upon the moisture of the oils used.

RESINS.

In order to test how far pure resins will protect the sulphate of copper from moisture, I dissolved them either in spirits of turpentine or in benzole, ground the sulphate of copper with the solution, and painted it out on a glass slide. I have not attempted an exhaustive examination of resins, but have contented myself with a few typical ones, namely, colophony, mastic, Sierra Leone copal, and amber. The varnishes were all prepared by first fusing the resin and then gradually adding the spirits of turpentine to the fused mass.

The change of appearance on exposing one of the slides thus prepared to moisture was quite different to the appearance in the case of oil. The surface became an opaque greenish blue in the course of a few hours in the case of colophony, mastic, and Sierra

Leone copal, but after that there was no further change. On then examining these slides under the microscope, this appearance was explained. The whole surface was rough and covered with blue cones of sulphate of copper with unaltered white plains between. Apparently the varnish on drying became full of small cracks or holes, through which moisture penetrated, but in itself resisted the passage of moisture. These holes were so close together as to give the whole surface a blue appearance when examined with the naked eye. The one exception to this was the amber varnish. It resisted the attacks of moisture for weeks without change. I think, however, that we may consider that such solutions of resins protect a surface from moisture sufficiently well for all practical purposes. The slight change taking place in the sulphate of copper does not go any further, and would, I think, be imperceptible in the case of a fugitive pigment.

I need hardly point out, however, that such solutions are quite unfit to be used as mediums in place of oil, and that the surface formed is brittle and not very durable.

OLEORESINOUS VEHICLES.

Eastlake, in his "History of Oil Painting," devotes himself principally to trying to determine what medium was used by Van Eyck and his immediate followers. As his book is the most important work on this subject, and he has devoted immense pains to investigating all the documentary evidence, the theory he advances requires specially careful examination.

Briefly, his theory is this: that the Flemish painters ground their colors in oil; that they prepared a varnish, by dissolving a resin, preferably amber, in oil, and that they mixed a little of this with the color. He claims that such a medium protects the pigment from moisture, and that it is only necessary, in the case of specially fugitive pigments, such as yellow lake, verdigris, etc., to increase the proportion of varnish and diminish the proportion of oil, in order to effectually lock them up, and protect them from the action of a moist climate. This he calls the oleoresinous vehicle; and while undoubtedly showing that this, in all probability, represents their usual practice for ordinary pigments, I think he fails to make out that they relied upon this method in the case of notoriously fugitive pigments. In fact, curiously enough, as I shall presently show, any evidence he brings forward points in quite a different direction. At the same time, he quotes from a sufficient number of authorities to show that he correctly describes their general practice; a practice for which there are sufficient reasons, apart from the question of the preservation of specially fugitive pigments.

It has been shown by Professor Church that even so hard a resin as copal, when dissolved in a volatile medium, after a year becomes covered with minute cracks; that this is also true of copal dissolved in the usual quantity of oil necessary to make a varnish. But he finds that if a copal oil varnish is mixed with a certain proportion of oil, it forms a surface which is hard, and, therefore, preferable to oil alone, which is soft, but which does not crack. There seems to be no doubt, therefore, that apart from other considerations, the mixture of a resin dissolved in oil with oil produces the most permanent surface. It remains to be seen whether such a medium has the quality claimed for it by Eastlake of protecting the pigments from moisture.

In order to experiment upon this matter, I obtained (1) a very fine sample of a genuine copal varnish from Messrs. Freeman; (2) Mander Bros., Coburg varnish; (3) I dissolved Sierra Leone copal in my own pure linseed oil, and heated it till it became stringy, as directed in the old receipts; (4) I dissolved amber in the same way in the pure oil; (5) I boiled some of the amber varnish mixed with white lead till almost solid, and then diluted it with spirits of turpentine. I then prepared slides with these varnishes mixed with the sulphate of copper; comparing the slides painted with pure oil with slides painted with a mixture of oil and varnish, and slides painted with the varnish alone.

In some cases, the slides after drying were varnished with the mixture that had been used in painting them out. In making the varnishes, I mixed about one-third resin with about two-thirds oil.

None of these preparations resisted the attacks of moisture. Those containing varnish resisted a little longer than those merely containing oil, but the difference was probably due to the greater thickness of the protecting layer.

As far, then, as we can judge, by the sulphate of copper test, Eastlake's theory that an oleoresinous vehicle will protect a fugitive pigment is not correct. It seemed to me necessary, however, to check these results by some experiments made in another way, and I therefore determined to try whether such mediums would protect a fugitive pigment.

In order to reproduce, as near as possible, the conditions necessary in the case of one of the old masters, I prepared some Brazil wood lake, according to one of the old receipts, and after careful washing and drying, ground it with the following mediums:

1. Commercial pale boiled oil
2. Rowney's boiled oil.
3. My pure oil.
4. The pure oil mixed with amber varnish.
5. The pure oil mixed with copal varnish.

All of these faded when exposed to sunlight, and apparently faded at the same rate.

To confirm this result, I next rubbed out on two glass plates carmine ground in pure oil. After the two plates were dry, I put one away in the dark, and exposed the other to light. At the same time I rubbed out on two other plates carmine ground with pure oil and a little amber varnish, and exposed one of these to light. The two plates kept in the dark retained their brilliancy, while the two exposed to light quickly turned brown at the same rate.

I think that these experiments show pretty conclusively that whatever method may have been used to preserve fugitive pigments by the old masters, it cannot have been that of grinding colors with oil, and then mixing in a little oil varnish, as supposed by Eastlake.

In order, then, to solve this problem as to the nature of the vehicle used to preserve fugitive colors, it is necessary to lay aside the theories of such writers as Eastlake, and examine carefully such old receipts as are available. This is all the more necessary, as the

* A paper recently read before the Society of Arts, London.

word varnish is used so carelessly by writers on this subject, for they seem to think that all varnishes have similar properties, and therefore it does not matter whether the nature of the varnish is stated or not.

The result of a more careful and minute inquiry has been the discovery of an old medium of remarkable properties. It is too early, however, to say anything in public as to this medium, until it has been thoroughly tested. I, therefore, shall say nothing of it here, but reserve to some future date the complete statement of its preparation and properties.

Leaving this question, I will next describe the experiments we have made on the effect of a layer of varnish of different kinds over linseed oil.

Sulphate of copper was ground with linseed oil, painted out on glass slides, and allowed to dry in a desiccator. They were then varnished respectively with copal dissolved in oil, copal dissolved in turps, amber dissolved in turps, and mastic dissolved in turps. The first to give way and show the passage of moisture were the slides varnished with copal in turps and amber in turps; while the slide which resisted moisture longest was the one coated with mastic and turps.

I find that a good mastic varnish will protect for some weeks a slide which would otherwise turn green in a few hours.

The reason for the superior behavior of mastic is, I think, not far to seek. It forms a soft elastic coating over the elastic oil, which is more durable and less likely to crack than the hard brittle coating formed by the amber or the copal. Experiments upon other resins have confirmed this view. These experiments then add another argument in favor of the use of mastic varnish for pictures to those already known.

To repeat these arguments briefly: The use of an oil varnish for a picture has this objection, that it will turn yellow with age, or even, if it contains lead driers, as in most cases it does, dark brown with age, thus increasing the defects of an oil picture, and cannot be removed without great risk of destroying the coatings of color underneath; while, as has been shown by these experiments, it affords little or no protection to the picture from the action of moisture.

The use of copal or amber, dissolved in spirit, is also objectionable, because the varnish is difficult to remove. By using mastic, we have a varnish which, while affording the best protection to the picture from moisture, is easily removed and renewed, without any danger of injury to the picture underneath. This seems of special importance in a country like this, where pictures are exposed to the greasy, sticky dirt produced by coal smoke. As might be expected, from its capacity of keeping out moisture, mastic varnish also affords a good protection to white lead from the blackening action of sulphur gases.

It must not be supposed, however, that in selecting the best varnish for a picture, we have solved the problem before us. Not only can moisture readily penetrate through the back, but supposing the back to be protected, it is only a question of time for the moisture to penetrate through the front, as having once succeeded in passing through cracks in the varnish, it is able to move about freely through the oil underneath.

There is another danger in the use of an ordinary oil medium. There is no doubt that if certain pigments ground in oil are mixed together, they will act chemically upon each other. Such, for instance, as cadmium yellow and emerald green, which, if mixed together, rapidly turn black. At first sight this is difficult to understand, as it seems unlikely that dry particles of color, each isolated by a layer of oil, could act upon each other. When we remember, however, the complicated nature of linseed oil itself, and the complicated changes that take place while it is drying, resulting in the presence of free fatty acids, of glycerine, and of moisture, it seems quite possible that certain pigments could be dissolved and decomposed, and once in solution they would probably diffuse through the oil, even though the oil was dry, just as we know that salts will diffuse through solid gelatine.

Mr. Holman Hunt has got in his studio a remarkable example of such diffusion. A patch of emerald green placed on the canvas ran down until it came in contact with a patch of cadmium yellow; the blackening caused by this is not confined to the point of contact, but has gradually spread.

With a view to testing this point more carefully, I rubbed out on a glass slide two patches of cadmium yellow. When they were dry I rubbed over one of them some emerald green and over the other some boiled oil. When the boiled oil was dry I rubbed over that some emerald green, so that in the one case we had the emerald green isolated from the cadmium yellow by the thin layer of oil which rose to the top of the cadmium yellow in drying, and in the second case by the thick layer of oil which was purposely placed between them. After keeping for some time, both of these patches began to grow dark, the one with the thin layer of oil changing markedly, while the one with the thick layer of oil changed slightly. These films were then stripped off, cut in sections, and examined under the microscope. This can be very readily done by embeddings such a film in paraffin wax, and cutting and mounting in the way used in the biological laboratories at Cambridge.

Though little could be seen in the case of the film with the thick layer of oil, it was quite easy to see, in the film with the thin layer of oil between the two colors, that the emerald green was unaltered, but that the top of the cadmium yellow was covered with a line of black spots, showing that the emerald green must have dissolved and diffused through the oil to attack the cadmium yellow.

These experiments, I think, show that we have not only in oil paintings to guard against external dangers.

We have, then, two policies before us. One is to obtain a medium which will effectually lock up pigments from external danger and from internal solutions and diffusions; and the other is, recognizing the imperfection of the medium we are using, to select pigments which are unaffected by the medium, and least likely to injury from external sources, such as moisture, and so on.

Apparently the most durable surface that can be produced with modern mediums is that obtained with a mixture of copal oil varnish and linseed oil.

Until, then, the proper medium is discovered, the best we can do is to paint our pictures with this medium and a carefully selected group of pigments, and then,

as a further precaution, coat the pictures, when thoroughly dry, with a layer of mastic dissolved in turps.

DISCUSSION.

The Chairman, Dr. W. Holman Hunt, thought the observations which they had just listened to would be of the greatest possible value in teaching them what to avoid, though, for practical purposes, the inquiry had a somewhat negative result. Speaking of copal and amber, he might say that certain pictures painted by men who took the advice of Linnell and others had been remarkably well preserved, but in the case of one picture at South Kensington, which had been so treated, Mulready found certain inexplicable white spots upon it. At first it was impossible to account for these spots, and Mulready asked the authorities to let him take the picture to his studio to investigate it, and, if possible, to cure the defect. Upon examining the picture with a strong microscope, he found that each little spot was a round ring, and in the center there was a little circumference of the color which it had actually been before, but that outside there was the bare canvas. On examining it more carefully, Mulready discovered that these spots had been caused by the saliva of the people standing in front of the picture, the saliva as it dried having contracted the color. This was a proof that amber varnish was not sufficient to protect a picture. The picture was restored by Mulready, and a similar mishap had been avoided by placing glass in front of it. Many of the pictures painted with amber and copal had stood in a way which could not be expected from oil alone; they were not more substantial, but the color had been better preserved. One could not be certain about pictures painted by other people, but he might refer to one painted by himself in 1850, entitled "The Rescue of Christian Priests from the Persecution of the Druids." One priest had a robe of great brilliancy, with a white linen dress underneath, and another had a red coat with a white garment beneath, the vegetation being painted from nature out of doors in the sunlight, and this picture, which was now in the possession of Mrs. Coombe, at Oxford, had stood remarkably well. The way in which that was done was as follows: Each morning he put into a cup a portion of copal varnish, and an equal quantity of linseed oil, combining the two with a little rectified spirit of turpentine, and used it for his day's work. No doubt, microscopically, many defects might be found in the picture, but to the eye none were apparent. Pictures painted by Millais at the same time were painted at once on a white ground, as his were, and with copal or amber, and the picture from Keats at Liverpool was a marvel in its condition as to color and purity. With regard to the superiority of mastic for preserving paint, he thought it necessary to utter a word of caution, as many picture dealers were in the habit of giving a picture, if it was dull, a coat of varnish without any regard to how the picture was painted. If the picture was painted in one coat, as in the case of the Van Eyck, there was very little oil in the earths, and colors made from the juice of vegetables to protect them, and therefore, before having a coat of mastic, it was desirable that it should have a further coat of a mixture of resin varnish and oil.

Mr. Walter F. Reid said that he had made many experiments in the laboratory on this subject, but he had found it necessary at the commencement to take one line only; and the line which he took related chiefly to the vehicles, and not to the pigments. As to the remark about the Van Eyck, that the green had been produced by verdigris, he thought it was possible that it might be malachite, as he had lately come across an old recipe for grinding up and mixing the verdigris with powdered marble; the result of this mixture would practically be malachite. As to moisture, he thought the question arose whether the water might not be produced in the decomposition of the organic substance of the medium itself. It was highly probable that during the oxidation of the linseed oil water was formed, but this was a subject which might possibly form a subject for future experiment. In boiling linseed oil many peculiar substances had been mentioned which had to be added during the boiling, but the majority of these had no action whatever upon it. The oil was usually boiled with litharge and red lead, though he preferred a mixture of both, as this gave a perfect oil for all practical purposes. In refining the oil, if it was treated by mixing it with water, and exposing it to the air, in the sun, part of it was oxidized, the unoxidized oil, being heavier than water, would settle at the bottom, which was an important matter. Some of the old masters put the percentage of oil which was lost in the refining at from 50 to 70 per cent. The residue was not diluted with a fatty oil or drying oil, but with a volatile substance, such as oil of spike or oil of lavender. Having spent many hours in trying to solve the problem as to what were the distilled oils formerly used, he had come to the conclusion that in nearly every recipe for distilling oils mentioned by the old Italian and German writers, some substance was used which gave a volatile distillate; in some cases they either mixed mastic varnish or mastic itself, and in one case the painter recommended the mixing of linseed oil with sufficient lavender flowers to absorb it, and then to distill the mixture with water. It was probable, therefore, that some distilled oil which was used was not any product from the distillation of linseed oil itself, but from substances mixed with the oil in distilling. He did not agree with Mr. Laurie that a spirit varnish could be easily removed without injury to the picture, his own opinion being that it was very difficult to remove it without acting on the medium of the picture. As to the solubility of the colors in the medium, and the interaction of the colors, he thought this might be accounted for by the formation of certain salts which acted upon each other. Old writers dwelt on the importance of not using too much oil, and he thought in this respect they were correct. The difficulty with linseed oil was that up to the present its subsequent history was not known. Pettenkofer stated that dried oil was insoluble in water, spirits of wine, ether, oil of turpentine, and other liquids, and this was correct when the oil was fresh, but after a time a change took place in it upon being exposed to the air, and this change was of great importance to artists. After four or five years the surface of a piece of pure oxidized oil, either boiled or raw, became sticky, and after a lapse of ten years the whole of it was converted into a sticky substance which changed its qualities. In the first instance, oxidized linseed oil was insoluble in different substances, especially alcohol. If linseed oil at that

age was treated with alcohol, it would be dissolved entirely. A new picture might be immersed in alcohol without its being injured, but an old picture would be destroyed. On the table were two specimens of oxidized oil, one being boiled linseed oil oxidized in 1878, the surface of which, after four or five years, began to get sticky and to run down, the other sample being raw linseed oil of the same age, which was perfectly oxidized. The first specimen had been boiled in the ordinary way with one half per cent. of litharge and a half per cent. of red lead. In the first oxidation of linseed oil there was a great increase in weight and bulk, the increase in weight being about 11 per cent., though he had not been able to tell the exact increase on the second oxidation. The consequence was there must be wrinkles on the oil, if the film was thick, owing to this increase in weight. The properties of the modified oxidized oil were of the greatest importance for the subsequent treatment of pictures; and Pettenkofer was not aware of this, as he distinctly stated that the oxidized oil was insoluble in alcohol, which was not correct. One might, perhaps, wonder why pictures were not sticky after a length of time, but the reason was, first, that the basis on which they were painted was porous, so that the liquid was absorbed by it, and the pigments themselves absorbed a great part of the semi-liquid products as they were produced; and, in the next place, they would combine with them, especially lead. This brought him to the consideration of the quantity of oil which artists used for different pigments: 100 parts by weight of white lead required 12 parts by weight of boiled linseed oil, 100 parts of zinc white required 14 parts of boiled linseed oil, 100 parts of chrome yellow required 19 parts of linseed oil, 100 parts of ivory black required 112 parts of oil, 100 parts of burnt sienna required 181 parts of oil, and 100 parts of raw sienna required 240 parts of oil. Dark colors required more oil, as they were not of a basic nature and did not combine with acids; consequently the oil, doubly oxidized, remained in its semi-liquid or liquid state unless the canvas absorbed it. As the results of experiments made with gums, he found that melted gums were not so fine as gums in their natural state. If you took a piece of copal and melted it, it would be found to be beautifully bright, but after a time it became covered with cracks, though the reasons for this have not been ascertained.

Professor Roberts-Austen, C.B., F.R.S., thought the author of the paper had made an extremely happy selection of a material to test the presence of moisture in anhydrous sulphate of copper. It was quite true they did not know much about thin films, though they knew more about thicker films. One might suppose that stretching a thin, transparent sheet of India rubber over a picture would protect it, but such was not the case, as carbonic anhydride and sulphurous acid would find their way through its surface. These gases, which were always present in a place like London, might lead to the permeation of water through the film. With regard to diffusion, it might not always be a question of diffusion of a crystalline pigment in a colloid salt, for solids could diffuse through solids; e. g., if one floated a piece of pitch on water, and placed a cork beneath, the cork would find its way up through the pitch. The Japanese had been most successful in preserving the colors they employed beneath their lac; and he suggested that the nature of the lac used by them was well deserving of further examination. With regard to the formation of malachite, which had been referred to in the Van Eyck, he thought that the suggestion was quite probable.

Mr. John Hughes said he should be glad to have Mr. Laurie's opinion of a medium composed of equal parts of linseed oil, turpentine, and water. This medium formed a milky-like fluid, and was very nice to paint with.

The chairman said in his younger days he recollected a medium which was composed of linseed oil, water, and sugar of lead, to combine with which there might have been turpentine, but about this he was not quite certain. With regard to the green in the Van Eyck, he thought verdigris alone could not have been used, and that there must have been an admixture—an opaque pigment, possibly—of malachite to give solidity. If verdigris alone had been used over the yellow ground, there would not have been a solid color; it would have been filmy and stony.

Mr. Laurie, in reply, said he thought the rate of change depended entirely on the external moisture, it being more rapid according to the way the experiment was performed. If done in an ordinary room it would be very slow, but if under a bell jar, with a saucer of water, it would go on very rapidly. With regard to refining oils, so far as his experience went, the bulk of the water was not very much affected; a considerable amount of white flocculent precipitate separated out, though it was a small proportion to the bulk of the oil. The oil got faint in color and the precipitation seemed to stop. He had not noticed the removal of a large quantity of oxidized oil, his aim being simply to get the oil to a pale color and to remove from it the gross impurities. In the case of the films he examined microscopically, his first idea was that solid particles were falling through the oil, but on examination he found no trace of this, so he came to the conclusion that it was more likely the color had been partially dissolved, and was diffusing as separate molecules than as actual particles. With reference to the verdigris in the Van Eyck, he was not able to say that it had not been mixed with other things. After what had been said, he thought the best thing artists could do would be to avoid the use of linseed oil altogether. In order to arrive at a definite conclusion upon the subject it was necessary that three people should work together, viz., the manufacturer of color, the artist, and the man of science. He was unable to answer the question put by Mr. Hughes, as he had no knowledge one way or the other of the medium named, though he could not imagine that any advantage would be gained by the admixture of the water.

ALUMINUM is one of the most difficult and uncertain of metals to deposit electrolytically. The following recipe is given by Herman Reinbold, who states that it furnishes excellent results: Fifty parts by weight of alum are dissolved in 300 of water, and to this is added 10 parts of aluminum chloride. The solution is heated by 200° Fahr., and when cold 39 parts of cyanide of potassium are added. A feeble current should be used.