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PAINTING PLASTER

Definitions: In this letter circular the term "lime plaster" is used to designate a white finish coat plaster consisting of lime and white sand or marble dust that contains no gypsum (sometimes called an all lime finish); and the term "gypsum plaster" designates the commonly used white finish coat plaster made of hydrated lime and plaster of paris (sometimes called lime plaster gaged with gypsum).

There is more trouble from paint failures on plaster than on interior wood or metal. An ordinary interior varnish which will fail utterly in a few months outdoors if applied to wood, is generally in excellent condition after twenty years of service provided it has not been exposed to direct sunlight. But the paint on an interior plastered surface sometimes flakes off in a few years. While these failures are sometimes seen on walls, they more frequently occur on ceilings, and as such flaking is easily brought about by water back of the film, the painter generally attributes the trouble to water. But flaking also occurs on painted plaster that has never been wet since before the paint was applied. In numerous instances of paint failures (flaking off) on walls and ceilings, a laboratory examination of

that side of the flake which was next to the plaster has demonstrated the presence of plaster. Such flakes collected from ceilings that had never been wet after the paint was applied, consisted of four or five times as much powdery plaster as of paint.

Since even the very brittle flat lithopone paints when applied to interior wood or metal very seldom flake off, and long-oil tough paint like that used for stippling probably never flakes from interior wood or metal, we are forced to the conclusion that the causes of failure of oil paint on plaster are different from the causes of failure on wood and metal. On exterior exposure the peeling of paint from very smooth metal, notably zinc and galvanized steel, is not uncommon; also paint may blister and flake off from wood that gets wet, but these flakes are all paint. No layer of wood or metal is pulled off by the paint. With plaster, however, the flakes often have enough adhering plaster to be easily detected. This plaster adhering to the peeled paint is seldom a hard solid mass like the plaster remaining on the wall, but is a non-coherent soft fine powder. With brittle paints this film is generally very thin, but with tough paints which are strong enough to support appreciable loads the film of powdery plaster may be several times the thickness of the paint that flakes and falls off. The plaster from which the flakes of paint have fallen frequently shows a hard smooth

surface, apparently indicating that the plaster has not changed, but an examination of the paint flakes frequently shows that some plaster came off with the paint. In other words, while the plaster on the wall may show no change, the plaster on the paint flake shows that there has been a change in the film of plaster next to the paint. It is evident, therefore, that one of the main causes of oil paint peeling from plaster is the change of the surface layer of plaster from a hard coherent mass to a powder, which change is not necessarily connected in any way with the strength of the plaster as a whole, or with cracking or falling of solid pieces of plaster.

In order to discuss intelligently the painting of plaster one must give some consideration to finish coat plaster and its components.

While gypsum plaster has been known for many centuries, the white coat plaster used in America until within the last 50 or 75 years consisted of lime and white sand or lime and marble dust, with no gypsum. The ordinary white coat plaster today (commonly called lime putty finish gaged with gypsum) is made from lime putty (hydrated lime and water), in which a varying amount of plaster of paris is mixed shortly before spreading. The ratio of hydrated lime to plaster of paris varies from equal parts to 3 hydrated lime and 1 plaster of paris. Hence, the white coat seldom contains less than 25 per cent of plaster of paris and occasionally may contain as much as 50 per cent.

The old type of white coat contained no plaster of paris but consisted of approximately equal quantities of hydrated lime (calcium hydroxide) and white sand or marble dust. The change that takes place in a plaster made of lime and sand or marble dust is first a simple drying out accompanied by some conversion of the hydrated lime into calcium carbonate by reaction with the carbon dioxide in the air. This reaction continues slowly for a long time, gradually converting more and more of the hydrated lime into carbonate ($Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$). Since hydrated lime has been detected in plaster that was centuries old, it seems probable that all plaster, no matter how old it is, may contain some hydrated lime. While of course the same conversion to carbonate occurs with the hydrated lime in the more commonly used plaster made of hydrated lime and plaster of paris, the important reaction which gives the quick setting is the hydration of the plaster of paris with the reformation of gypsum, $(CaSO4)_2\ H_2O + 3H_2O = 2(CaSO4 2H_2O)$.

The following facts regarding the various components of plaster are important enough to be of interest to any one concerned with the decoration of plaster surfaces.

Sand is mainly silica, one of the stablest compounds. For all practical purposes it is unaffected by heat and insoluble in water.

Calcium hydroxide undergoes no change on heating to temperatures considerably above that of boiling water. The dissociation temperature at 0.02 atmosphere is 389°C and at atmospheric pressure 547°C (J. Johnston) (Mellor, Vol. III, p. 682). Its solubility in water is 0.19 parts in 100 parts water at 0°C and 0.12 parts in 100 parts water at 60°C. As mentioned above, it combines with carbon dioxide to form calcium carbonate and water.

Calcium carbonate is a stable substance that can be gently ignited without decomposition. Its solubility in water is less than that of calcium hydroxide (0.0065 g at 20°C and 0.0038 g at 50°C in 100 g water). Marble is calcium carbonate.

Gypsum is the least stable and the most soluble of the components of plaster. 100 g of water will dissolve 0.241 g at 0°C and 0.267 g at 53°C.

The following is a selection from the vapor pressure measurements of J. H. van't Hoff and E. F. Armstrong[1] for the system

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[1] A Comprehensive Treatise on Inorganic and Theoretical Chemistry, by J. W. Mellor, Vol. III, p. 768.

$CaSO_4.2H_2O$ - $CaSO_4.1/2\ H_2O$ - H_2O showing the vapor pressure at different temperatures.

Temperature	32°F 0°C	50°F 10°C	68°F 20°C	104°F 40°C
Vapor pressure (or rather decomposition pressure)	1.17	2.78	6.24	26.3

The corresponding values for water are

Temperature	0°C	10°C	20°C	40°C
Vapor pressure	4.57	9.14	17.4	59.4

It is evident from the vapor pressure measurements of van't Hoff that $CaSO_4.2H_2O$ is metastable when the relative humidity of the surrounding air is less than 25 per cent saturation at 0°C, less than 30 per cent saturation at 10°C, less than 35 per cent saturation at 20°C and less than 44 per cent saturation at 40°C.

Today in Europe and less than 40 years ago all over the world a house was considered comfortable in winter if the temperature was 60°F and few houses were ever that warm in cold weather. Today in the United States 70°F or more is generally demanded. Temperatures are measured only a few feet above the floor level, but they are notably higher at the ceiling. It is an exceptional case when adequate steps are taken to increase the water content of the air in our buildings. When the outside air at 32°F is saturated with water vapor, on heating it to 60°F it will be 36.5 per cent saturated, on heating to 70°F it will be only 26.2 per cent saturated, on heating to 80°F it will be only 19.1 per cent saturated and on heating to 90°F only 14.2 per cent saturated. The corresponding figures for outside temperatures of 0°F are 8.1, 5.9, 4.3 and 3.2 per cent and for outside temperatures of -10°F, 5, 3.5, 2.5, and 1.9 per cent.

There is no single cause of the occasional flaking of oil paint from plaster. The dehydration of gypsum under very dry conditions may sometimes be the cause. On the other hand, alternate wetting and drying will tend to disintegrate plaster, and aside from any destructuve action on the material to which paint is applied, water back of a paint film acts mechanically to cause flaking or blistering. Water coming through plaster is more destructive to oil paint than water coming through wood because there is practically always some hydrated lime in the interior of plaster. This hydrated lime makes the water alkaline, and alkaline water tends to destroy (saponify) the oil in a paint film. All authorities agree that plaster should be thoroughly dried before applying oil paint.

It must not be forgotten that a new building or even an old building that has been replastered contains an enormous amount of water. Even under the most favorable conditions it takes a long time for plaster to become dry enough for the application of the ordinary oil paints. The demand of the owner or builder for hast in finishing is very liable to result in paint being applied to plaster that is not dry. Even with dry plaster the common method of applying full pigmented oil paints giving a distinct layer of paint over the plaster seems illogical. If such coatings are to be applied, probably the best preliminary treatment is first to be sure that the plaster is dry and then slightly roughen the sur-

face by sandpapering, dust thoroughly, and apply a size coat of water-resisting varnish thinned with turpentine or mineral spirits. After this is dry, use a first coat paint containing considerable boiled oil and use the fewest possible number of coats to give the desired appearance.

Recently there have been developed special primers for plaster surfaces which consist of a small amount of very opaque pigment in a vehicle which penetrates into porous surfaces to a very much less extent than ordinary paint vehicles. These special primers, called suction primers, are said to largely prevent the variation of gloss and color due to uneven absorption of paint by the plaster and also to overcome at least in part the appearance of wall cracks through the finished coatings. It would seem that this type of material is intended to replace, in one operation, the varnish coat and first paint coat mentioned above.

The Bureau of Standards has no authentic information on the service rendered by these new suction primers. Some of them are being investigated by Mr. H. A. Gardner of the Institute of Paint and Varnish Research of the American Paint and Varnish Manufacturers' Association, 2201 New York Avenue, Washington, D. C., and the reader is referred to Mr. Gardner for more detailed information.

When the desired appearance can be obtained by the use of an oil stain on plaster a durable finish free from flaking might be

assured. The surface of the plaster is first slightly roughened with sandpaper or steel wool, dusted thoroughly and one coat of thin stain is then applied, the object being to have the stain penetrate and color the plaster. Of course only lime-proof pigments should be used.

The fresco process of painting fresh wet plaster is one of the oldest and most durable methods of painting, and while it seems particularly well adapted to our modern demand for speed in finishing a new building, it is seldom used or heard of. In this process no solid white is necessary or advisable as the plaster itself is white and hydrated lime is the only white pigment used for tinting the colored pigments. Finely divided lime-proof pigments suspended in pure water, with or without the addition of hydrated lime, are applied to the wet plaster. The old masters always applied the fresco painting the same day the plaster was laid. The painter avoided retouching except when absolutely necessary and the whole operation was completed before the plaster had time to dry. What takes place is that the pigment suspended in water partially penetrates into the plaster, and the solution of calcium hydroxide in the plaster during the process of drying is drawn to the surface, surrounds the particles of pigment on the surface, and by reaction with the carbon dioxide in the air is converted into calcium carbonate,

thus binding the pigments on the surface. With modern plaster containing some gypsum, the gypsum, being more soluble than the hydrated lime, though present in smaller amounts, will by crystallizing around the pigment particles contribute to the binding action. In other words the paint becomes part of the plaster. While large areas can be colored by this process, it is best adapted to the popular irregular finishes, such as "sponge effect" "crumple roll", etc. The paint, which as mentioned above is a suspension of lime-proof pigment in water without binder, may if desired contain alkaline or neutral volatile dispersing agents. For exmple, with some lots of ultramarine a little ammonia has been found to be a desirable addition to the water. While such paint can be applied with brush or sponge, spraying and then mottling with sponge or paper is certainly one of the best methods of application. With this method of painting the decoration of the walls can be completed within twenty-four hours after the last of the plaster is applied.

Some of the most celebrated pictures in existence are frescoes on plaster made of lime and sand or marble dust and they have stood for centuries. Michael Angelo started work on the frescoes in the Sistine Chapel at the Vatican in 1508 and finished in 1512. Thus they date back to the beginning of American history. The unusual artistic ability of the masters, such as Michael

Angelo, combined with the fact that they considered it necessary to use thick coats of plaster, to complete the painting the same day that the plaster was laid, and to do the work right at the first painting - without retouching, may serve to explain why true fresco work is now seldom used. If, however, it is applied to present-day decorative methods that do not involve pictures of terrestrial and celestial beings there appears to be no reason why it can not be used by any competent decorator with saving in cost of material, labor and particularly time. The decorator may be sure that the paint will outlast any oil paint on plaster and that when redecoration is desired the plaster will be in a better condition for the application of oil paint than it would be if it had been originally painted with oil paint.

Fresco painting must be applied the same day that the plaster is laid. Painting with oil paint should not be attempted until the plaster is thoroughly dry. Water paints with a casein binder can be applied to damp walls and are probably the safest kind of paint to apply to plaster that has hardened but has not thoroughly dried. The amount of non-volatile binder in properly-formulated casein water paint is much less in proportion to the pigment than in any oil paint. The film is therefore more porous, allowing water to evaporate through the film with less danger of the film flaking off than with oil paints. Formerly

casein paints were always made with the so-called extending pigments which are transparent when wet, but now there are paints of this kind on the market in which the pigments are opaque and which show much greater opacity when wet. Such modern casein paints are now obtainable both as powders and as pastes to be mixed with water and sometimes with a mixture of water and a small amount of oil. While these products are of such recent origin that no positive opinion can be given of their probable durability, they appear to be promising additions to the available coatings for use on plaster. They are obtainable in white and a variety of tints and solid colors.

This letter circular makes no attempt to discuss plaster except in so far as it is necessary to understand the problem of painting plastered walls and ceilings. For descriptions of plasters see Bureau of Standards Circular No. 151, "Wall Plaster: Its Ingredients, Preparation and Properties", which can be purchased for 15 cents from the Superintendent of Documents, Government Printing Office, Washington, D. C.