Weight Changes in Acrylic Emulsion Paints and the Implications for Accelerated Ageing

Introduction

Acrylic emulsion paints were introduced commercially in the 1950's, and by the 1960's artists' paints were readily available. A useful history of solvent and emulsion acrylic paints appears in the book by Crook and Learner (1). Because the artists'acrylic emulsion paints are relatively new, both craft experience and scientific analysis are not as detailed as with other older more established painting materials. A study of acrylics suitable for restoration use has appeared with comments on accelerated ageing (2). This paper reinforces the need for baseline studies of artists' materials. The effects of artists' technique, ageing, and conservation treatments are open areas for investigation.

The use of synthetic painting materials does not obviate the need for an understanding of just what is meant by "dry" and what the implications are for waiting or not waiting while the film formation processes continue. This point is analogous to oil paints, where the oil paint is "dry-to-the-touch" long before the immediate reactive chemical behavior slows down and slower, longer term processes begin to dominate. After paints dry, their behavior over long periods of time are important to the conservator and those responsible for their exhibition and transport. Since few old acrylic emulsion films are readily available for studies such as solvent treatments or mechanical testing, attempts may be made to accelerate age specimens so that they behave as older acrylic films. The attempt to accelerate age polymers is not as simple as one may expect.

In order to lay the foundation for long term studies or to perform accelerated ageing experiments, a baseline study of the initial behavior of acrylic emulsion paints was conducted. This paper is a summary of one of these studies.

Materials and Methods

Acrylic emulsion paints and gessoes from several manufacturers were purchased and then cast into strips. Some specimens were spread with a spatula on mylar strips and weighed for four years and their weight losses recorded. Measurements were made to 0.1 mg using a Mettler AT 201 balance. The drying environment was an interior laboratory kept at 21°C and an RH of 40 to 50%. One gesso reported here is the professional acrylic gesso from Utrecht. The acrylic paints reported here are the yellow ochres from: Golden acrylics, Winsor & Newton Finity Artists' acrylic colour, Grumbacher Academy acrylics, Liquitex Basics acrylic color, and Dick Blick Artist's acrylic. Four other pigments were studied as well: titanium white, ultramarine blue, burnt sienna, and burnt umber. The more extensive results will be published elsewhere.

Results

The weight losses are due initially to the loss of water in the emulsion and then later to the loss of less volatile components. There may be many components of varying volatility since the acrylic emulsion paints are a complex mixture of compounds containing glycols, surfactants, thickeners etc. While the paint film can appear to become dry to the touch very quickly, the process of volatile loss continues with the emulsified particles of polymer coalescing and other chemicals redistributing themselves. If the evaporation process is still going on, then it seems that heating the polymer films at early times in their drying may alter the coalescing of the film and even remove some of the chemical agents that induce this process. It becomes important to know when these processes are near completion to determine *when and even if* accelerated ageing can begin.

A linear XY plot of weight loss against time for the Winsor & Newton Finity yellow ochre acrylic paint is shown in Figure 1. The change in weight is quite rapid within the first few days but gradually the rate of change becomes slower. From this point on the rate seems to level off and after the first hundred or so days the rate seems to level off and no change is apparent. Mathematically, many long term processes can be seen better by plotting data on a logarithmic scale. Figure 2 shows the data in Figure 1 replotted and expanded to include data for almost 4 years. The data then provides a clearer picture of what is occurring. The first

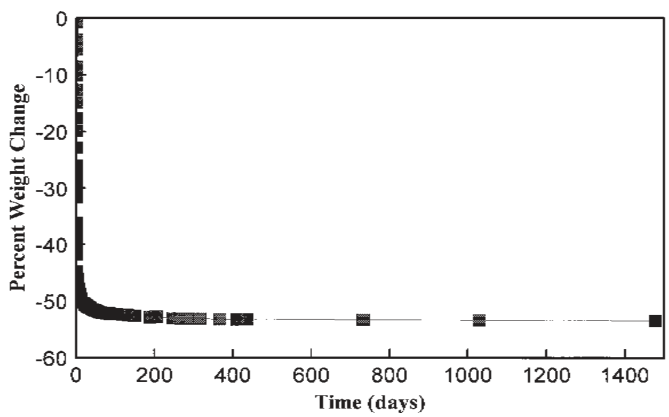

Figure 1 shows a plot of weight loss versus time for a Winsor & Newton yellow ochre acrylic emulsion paint. The plot appears to level off by about 120 days. The greater part of the weight loss is within 2 days but changes occur for a much longer time.

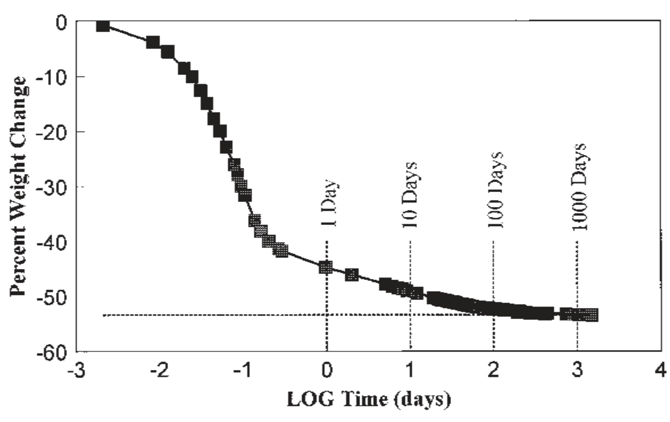

Figure 2 shows a logarthmic plot of weight loss versus time for the Winsor & Newton yellow ochre acrylic emulsion paint. Unlike a linear plot this figure shows changes occurring even at 3 years. The line at the bottom of the plot shows the weight loss at 4 years and indicates small but measurable changes.

region of rapid weight loss is followed by a second region of slower rate loss which gradually appears to approach zero. The line at the bottom of the graph shows the lower limits of weight loss after 4 years.

Figure 3 shows a plot similar to Figure 2 but for the weight loss of the Utrecht gesso against the logarithm of time, also in days. After the large expected initial drop, the loss of water and other volatiles continues for well over 100 days and the data indicate further changes even after as long as 4 years. Certainly these changes belie the statement on the container that the diluted gesso will dry in " ... one to three hours." Another manufacturer, Winsor & Newton, states that their gesso primer " ... dries in about 30 minutes ...." Clearly these statements refer only to the development of a non-tacky surface and do not take any other factors into consideration.

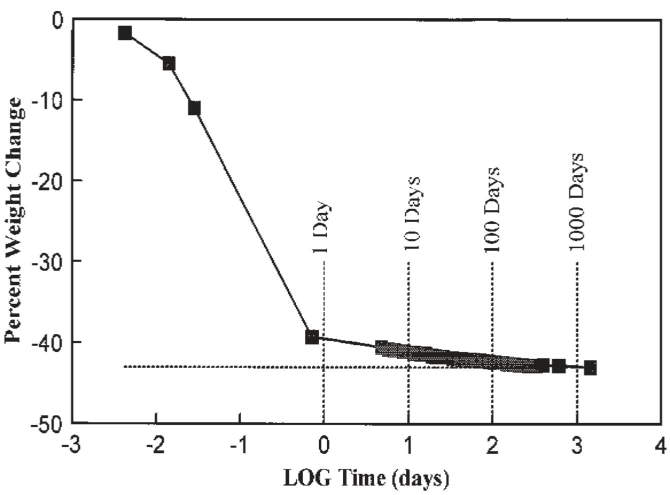

Figure 3 shows a logarthmic plot of weight loss versus time for Utrecht professional acrylic emulsion gesso. The leveling off of the weight loss is faster than that of the W&N paint but nevertheless changes are occurring even after several hundred days.

What is evident from the previous three plots is that the evaporative processes are going on for months if not years.

In an effort to understand the variability among different manufacturers, the weight losses of five specimens of yellow ochre were tabulated at 4 months, 1 year, and 4 years and plotted in Figure 4. This plot illustrates the ongoing changes over this period. It is evident that the bulk changes occur rather early, by four months, but nevertheless continue afterward. Another point to be made is that the amount of volatiles also varies among the formulations. Similar data is available for other pigments as well.

In looking at the changes in weight for the yellow ochre pigments, it would appear that the weight losses occuring after a year or more are small or negligible. This is misleading. Figure 5 shows the weight loss for the same five manufacturers of paint but the percentage of weight changes are determined from the weight of the paint film as mea-

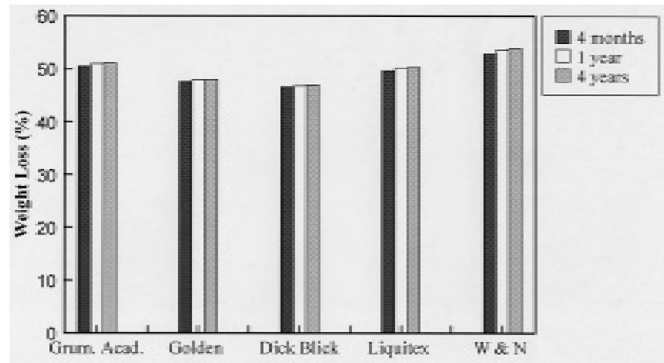

Figure 4 shows a bar graph of 5 different acrylic emulsion paints and their total weight loss at 4 months, 1 year, and 4 years. There are measurable differences in total volatiles and ongoing losses up to the final measurement at 4 years.

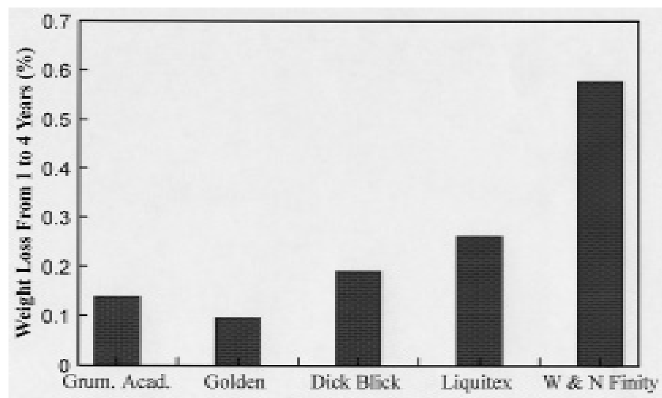

Figure 5 shows a bar graph for the same 5 paints as Figure 4. The weight changes are measure from the 1 year value to the 4 year value. The weight changes are significant and highly variable among the paints.

sured at 1 year rather than from the initial applied weight. These numbers represent the weight loss of the "mature" film as it ages. These numbers are highly variable within the small group tested but changes over 0.5% must be considered significant. Changes in weight correspond to loss within the film and either will result in increased porosity and lower density or a collapse in volume.

Conclusions

Accelerated ageing must insure that all processes are sped up by the same factor for the ageing to mimic natural ageing. From an examination of the log plots it is apparent that at least two processes involving the loss of volatiles are going on and that these processes are not near completion for at least one year and probably much longer. The bar graphs in Figure 4 show that for at least five major acrylic emulsion paints measurable changes occur even after a one year period. Paint manufacturers themselves have varying opinions as to when acrylics dry (3). While small, these are changes that must be determined and characterized in both naturally aged and accelerated aged paint films in order to validate the accelerated ageing protocol. Heating specimens to mimic ageing will not affect compounds with different

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volatilities in the same way. An analogous condition exists in the thermal ageing of oil paints (4). It is generally recommended that museums and collectors restrict the amount of UV in exhibition areas, and protocols using high levels of ultraviolet radiation in ageing experiments may be problematic since they are unlike weathering tests that must attempt to reproduce natural or outdoor conditions.

On a practical note, the product literature states that the acrylic gesso can be used with both acrylic paints and oil and alkyd paints. If water is still present in the gesso film and other components such as antioxidants are either not completely volatilized or still mobile in the film, then the application of an oil layer could be problematic. Water and antioxidants will significantly alter the drying rate of oil paints and surfactants can change the adhesion of an applied oil layer. Other compounds such as glycols may diffuse into the oil paint layer and alter its mechanical properties. The difficulties with mixed media are not at present clearly understood but research is continuing.

References

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