Principles of Paint Formulation

Edited by

R. WOODBRIDGE
Formerly Technical Director of Berger Decorative Paints
Bristol
and
Past President of the Paint Research Association
Teddington, Middlesex

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Preface

During the last century the art of paintmaking has progressed at an ever increasing pace from a craft to a science. But within one aspect of paint technology, the art of formulation, some craft attitudes still prevail. Review of the wealth of technical literature available today identifies a paucity of information available to the newcomer to the industry, or to the practising paint technologist who wishes to improve his skills, on how to approach the challenge of reformulation or the development of a new product. Quite naturally, a paint manufacturer will not disclose his formulations to a competitor, but the basic principles of formulation should be common to all. Guidance on this has been restricted to the recommendations of raw material suppliers who, not surprisingly, bias their investigations and recommendations towards highlighting the benefits of their products. This is not a criticism of their activities – indeed, without their contributions, formulation of paint might still largely be in the hands of craftsmen, albeit scientifically trained craftsmen who had developed or inherited their skills.

This volume aims to set out the basic principles of formulating paint in a competitive commercial environment, which should be applicable to most types of liquid surface coatings. The procedures recommended in the early chapters have been developed and used over many years and have withstood the test of time. Their aim is to save work and time. They have been used within the development laboratories of a major paint manufacturer in a flexible way, being adapted according to the specific needs of individual projects. Other companies may require a different approach, but the same principles are likely to apply. Only by careful consideration of objectives and by adequate planning at all stages will the desired result be achieved in the most cost-effective way.

A book on paint technology would not be complete without some basic information on the raw materials available and their correct selection, which is the subject of Chapter 3. Subsequent chapters by co-authors, recognised as specialists in their fields, concentrate on specific aspects of paint formulation, such as Fred Stieg's review of the importance of volume relationships and ways in which simple techniques can assist in approaching reformulation in a more scientific way. For anyone involved in, or about to consider, computer techniques, Luigi Cutrone's chapter on the use of computers is essential reading, covering the basic design of experiments through to the latest 4-component contour plotting technique in formulation development. Ike Berg adds his years of experience in adapting formulations from the laboratory scale to bulk manufacture, with guidelines on correct operating techniques for most types of equipment. The book also includes a chapter on the use of alternative 'dry hiding' technologies as a means of reducing usage of titanium dioxide, and concludes with guidance on the selection of test methods and some useful appendices on paint calculations, international units and conversions, health and safety, and a glossary of terms.

To all authors I extend a special thanks, not only for their willingness to contribute, but for their forbearance in responding to suggestions for minor changes or additions. I also wish to thank members of the staff of the Paint Research Association at Teddington – particularly John Bernie, Len O'Neil, Dip Dasgupta, Norman Morgan, Len Tysall and Catherine Hayworth, for their helpful advice, retrieval of information and references, general encouragement and support, and for permission to republish the 'Units for the Paint Formulator' and the 'Glossary of Terms'.

R.W.

Contributors

Ken Arbuckle	Consultant, 20 Oak Lodge Avenue, Chigwell, Essex IG7 5HZ, UK
Ike Berg	Consultant, 22 Gladstone Court, Anson Road, London NW2 4LA, UK
Luigi Cutrone	Tioxide Italia SPA, Stabilimento di Scarlino, Contrada Casone CP113, 58022 Fallonica, Italy
Fred Stieg	Pigmentech, 903 Beachview Drive, Jekyll Island, California, USA
Richard Woodbridge	Consultant, Rest Harrow, Staunton Lane, Whitchurch, Bristol BS14 0QG, UK

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1 Getting the basics right

RICHARD WOODBRIDGE

1.1 Introduction

This chapter concentrates on the development of methods of working which establish a basic structured background to any development project. The aim is to encourage a disciplined approach which should lead to more efficient work practices and hence to more effective formulation.

Clear and unambiguous laboratory records must be maintained in order to allow easy retrieval of information. It is strongly recommended that a loose-leaf system is adopted rather than the alternative diary approach. This system enables the incorporation of preprinted standard forms, for the entry of formulations and results, into the finished project file (see Section 1.5).

1.2 Availability of raw material data

Raw materials are the building blocks of any paint formulation. Selection of the correct grades is fundamental to the development of a balanced product within the identified cost target. Guidance on the correct selection and optimum levels of usage will be given in Chapter 3. Selection implies that the formulator has at his or her fingertips, if not already in mind, all necessary information on the available raw materials appropriate to the particular formulation being developed. The relevant information is specific to individual countries and indeed to individual companies within each country. The availability of some resins or latices at realistic cost levels may be influenced by the commercial availability of intermediates or monomers to the resin producer. These differences in availability can influence significantly the relative cost effectiveness of different grades of raw materials, leading to positive differences in the 'local' approach to formulation. As examples of this, the early growth of latex paints in the United States was based on styrene butadiene, while in the United Kingdom early developments were based on vinyl acetate homopolymers. Even in the development of vinyl copolymers differences in the comonomer used in world markets, or differences in the relative costs of vinyl copolymers and 100% acrylics are found. Similarly, in the field of extenders wide differences in the grades available and their costs, depending on indigenous supplies, are also found. Such factors make the range of 'available raw materials' specific to each country.

What information, therefore, is required by the formulator and should be immediately accessible to ensure correct choice? It will vary according to the class of raw materials, but should include the following basic data.

Chemical composition is required to establish any possible interactions or influence on final product performance. It is also essential to enable the technologist to assess any potential hazard in the storage or handling of the raw material or the finished product. From this aspect it is necessary to be aware of the presence of any minor constituents which may influence the overall degree of risk in handling or use. While such information was not always readily available, current health and safety regulations and increasing concern for the environment place a statutory obligation on suppliers and users to disclose, or to be aware of, the nature of any risks based on the evidence of composition.

Physical properties are also important indicators of which grade of many raw materials are suitable for a particular application. In the case of pigments or extenders, information on properties such as mean particle size and size range (not necessarily full particle size distribution), oil absorption and specific gravity are required. For coloured pigments an indication of light fastness and durability, etc., is important. Data on resin solutions or latices should include solid content, specific gravity of both the solution and the solid resin and viscosity data. For comparative purposes it is useful to have an indication of solids content at a standard low viscosity – 200 cP is often quoted. In the case of resins supplied in low boiling point solvents, flash point is a critical property. For solid resins, melting point may be a useful record. For solvents specific gravity, boiling point or range, evaporation rate, and flash point should be recorded.

Most of this information is readily available from the supplier's literature, together with a mass of other information on every product in their range, all presented in individual styles ranging from simple printed sheets to voluminous glossy brochures. In this form it is not readily available to the formulator and, more importantly, in technical data sheets there is no reference to cost. Cost information is important to the formulator if targets are to be met but is subject to negotiation on quantity purchased and varies from one company to another. For most 'dry' raw materials, cost is quoted on a weight basis but since most paint products are sold on a volume basis, the formulator's target is to achieve a given cost per litre or gallon. Particularly in the case of extenders it is important to recognise the cost contribution of a unit *volume* of extender towards the total product cost. This may give a very different viewpoint on the relative costs of extenders being considered. This consideration has a significant impact on the approach to formulation of a product traditionally sold by weight and now to be sold by volume.

There is a very strong argument for assembling the key data required for formulation, for all the raw materials currently in use or being considered, into a standard format readily accessible to the formulator. This may be a concise raw material data file set up on a computer or simply a card index system. Such data should not be cluttered with unnecessary facts but must include all key information required for formulation. The summary data card should, however, indicate sources from which more detailed information may be retrieved if required. A suggested format is shown in Figure 1.1

<table>
<tr><td colspan="4">R.M. Name:</td><td rowspan="2">R.M. Code Number:-</td></tr>
<tr><td colspan="4">Supplier:</td></tr>
<tr><td colspan="3"><u>Chemical Composition</u>:</td><td colspan="2" rowspan="2"><u>Hazard/Safety data</u>:</td></tr>
<tr><td colspan="3"><u>Physical Constants</u>:
Solids content:
S.G. of solution:
S.G. of solids:
Viscosity as supplied:
% Solids at 200 cP

Date:</td></tr>
<tr><td rowspan="2">COST:</td><td>per Kilo:</td><td></td><td colspan="2" rowspan="2">Full details in:-
Filing Location:-</td></tr>
<tr><td>per Litre</td><td></td></tr>
</table>

Figure 1.1 Summary data card

1.3 Clarifying the objective

It may appear to be stating the obvious to say that it is most important to clarify the objective of any project before starting work at the desk and particularly before starting any benchwork. To quote from the FSCT (Federation of Societies for Coatings Technology) introductory booklet, 'Today, in the paint industry, as in many other industries, progress is dependent on team work between production, sales, management and technical departments. All of these groups share in the creativity and productivity, which combine to make a successful company.'

Individual projects may be initiated at the request of marketing, sales, purchasing or production personnel or be technically generated but, whatever the origin, there will be an impact on all other functions if the project is successful. It is only logical therefore to ensure that the project has each of their input, if not wholehearted support, at an early stage rather than to find it blocked for a very good reason after completing a full development programme.

Preliminary discussions may reveal that the initial brief was not as clearly expressed as it might have been, or that it could create a difficult or impossible situation within manufacture if certain possible routes were followed. A further benefit of such discussion is that it helps to crystallise any thoughts on the logical and acceptable route to a satisfactory conclusion before leaping into action on the basis of a 'hunch' or 'first thoughts'. Possibly more important is that it helps to avoid the situation in which the target is impossible but the worker must be seen to be trying–such activity benefits no one and is best recognised before any time is wasted.

Having clarified the objective, it is good discipline and practice to state it clearly and unambiguously on a project initiation sheet. Cost, performance and anticipated completion date targets, if agreed, should all be recorded. Should a review of the progress of the project lead to agreement that the brief should be modified, such revised objectives should be recorded on the same initiation sheet. Figure 1.2 shows a possible simple project request form which acts as the project initiation sheet and to which all subsequent formulations and test results should be attached.

1.4 Identifying formulating constraints

Within the discussion to clarify the brief it is essential to identify any possible formulating constraints. These can arise particularly as a result of inadequate flexibility within the manufacturing operation. Progressive moves towards bulk handling and computer-controlled manufacturing operations, while giving positive improvements in productivity and hence a reduction in the cost of manufacture, can have the effect of restricting the opportunities for the introduction of additional bulk-handled raw materials or intermediate solutions. Problems arise from the lack of availability of segregated storage tanks, pumps and pipelines. A degree of flexibility may have been built into the system at the design stage, but may over the course of time, have become fully utilised.

Problems arising from such constraints can be avoided by formulating on existing standard bulk-handled raw materials. In the case of other key projects dependent on the use of a new non-standard raw material, discussion at the planning stage allows the production department to reconsider their operation and identify possible means of handling the new raw material by the time development work has been completed and bulk production is ready to start. These comments may seem obvious, but experience has shown that problems do arise as a result of lack of awareness of the potential problems and inadequate discussion at an early stage.

A further source of constraint is the proposed introduction of a raw material requiring special handling on account of its hazard rating, flammability or consistency. While means are available for handling materials in any of these categories, the introduction of such methods may be incompatible with the

TECHNICAL PROJECT REQUEST

To:	Date:
Project Title:	Project No:
	Category:

Objective:

Completion Required By: Signed: ....

Modification to original objective: Date:

Signed: ....

Date Project completed:

Hrs. Spent:

Report Issued: Signed: ....

Figure 1.2 Technical project request.

existing manufacturing operation or may require significant capital expenditure. In such circumstances the production department would have every right to refuse to handle them.

A third potential barrier to the introduction of a new raw material may be the purchasing department. Existing contracts will have been negotiated on the basis of anticipated offtake, and 'standard' costs established on those assumptions. A significant reduction in that offtake as a result of partial replacement by a material from another source could lead to an increase in the 'actual' cost, giving adverse cost variances against standard. Additionally, purchasing policy may have been established and agreed at board level, identifying preferred suppliers. Such opposition may be overcome by discussion, highlighting the benefits of the new raw material, but agreement to such introductions should always be obtained before starting a detailed evaluation.

Essentially this section reinforces the point that the technical department is part of a team and that successful innovation flows from a commitment of the whole company towards new opportunities. Time spent in evaluating new raw materials, however promising they may appear to be, will be wasted if subsequent events show that their introduction is not possible for one valid reason or another.

1.5 Use of standard formulation format

Formulations may be entered in a number of alternative ways, depending on the particular purpose for which they are to be used. In the simplest case the total composition is listed in terms of raw materials used with quantities expressed in appropriate units, depending on convention in each country. Commonly formulations were entered on a weight percentage basis, possibly because for many years paint was sold by weight and the importance of volume relationships had not been recognised. Today, however, paint is sold in most countries on a volume basis, either in litres or gallons and pints.

In such circumstances it is logical to formulate always to a constant volume. This makes true comparisons of the possible formulations, since variations in specific gravity of individual raw materials or the finished product will be taken into account. It will also be demonstrated in Chapter 4 that a number of volume relationships are important in paint formulation and such relationships can be calculated much more readily if formulations are always in volume terms. A well proven route is to calculate formulations to give a constant yield of 1000 litres, entering the quantities of individual raw materials in either kilogram or litre units depending on how they are normally dispensed. Trial laboratory makings of such formulations can use the same quantities, expressed in grams or cubic centimetres (cc), to give a yield of 1 litre – a