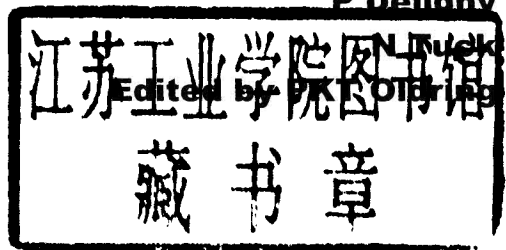


Resins for Surface Coatings

VOLUME II Alkyds & Polyesters

P. Deligny



JOHN WILEY AND SONS

CHICHESTER • NEW YORK • WEINHEIM • TORONTO • SINGAPORE

Published in association with

SITA TECHNOLOGY LIMITED

LONDON UK



Copyright © 2000 SITA Technology Limited
Kings Chambers, 50/52 Bernard Street, Leith
Edinburgh EH6 6PR

Published in 2000 by
John Wiley & Sons Ltd
in association with SITA Technology Ltd.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, scanning or otherwise, except under the terms of a Copyright Designs and Patents Act 1988 or under the terms of a licence issued by the Copyright Licensing Agency, 90 Tottenham Court Road, London W1P 9HE, UK, without the written permission of the publisher.

Wiley Editorial Offices
John Wiley & Sons Ltd, Baffins Lane,
Chichester, West Sussex PO19 1UD, England

John Wiley & Sons, Inc, 605 Third Avenue,
New York, NY 101580012, USA

VCH Verlagsgesellschaft mbH
Pappelallee 3,
D-69469, Weinheim, Germany

Jacaranda Wiley Ltd, GPO Box 859, Brisbane
Queensland 4001, Australia

John Wiley & Sons (SEA) Pte Ltd, 37 Jalan Pemimpin 05-04,
Black B, Union Industrial Building, Singapore 2057

John Wiley & Sons (Canada) Ltd, 22 Worcester Road,
Rexdale, Ontario M9W 1L1, Canada

Copublished with J. Wiley & Sons Ltd, Chichester

Library of Congress Cataloguing-in-Publication Data

A catalogue record for this book is available from the British Library

ISBN 0471 978 957

Printed and bound in Great Britain by Short Run Press Ltd, Exeter.

**RESINS FOR
SURFACE COATINGS**

**Volume II
(Second Edition)**

Alkyds & Polyesters

INTRODUCTION

Since the 1980's there have been many significant changes in surface coatings which have necessitated major changes in the resins used, even though many may still be referred to by generic names. Thus it is appropriate that a series of books⁽¹⁻³⁾ written for graduates new to the resins and surface coatings industries, which became recognised globally as an overview of the technology of resins for surface coatings should be revised and issued in time for the new millennium to reflect the recent advances within these industries, whilst retaining the basic understanding for which this original series of books was renowned.

It is reported⁽⁴⁾ that there was a time when the surface coatings industry dealt with a relatively small number of materials and processes for making paints and varnishes. Indeed it is claimed⁽⁴⁾ that between 1736 and 1900, Watin's book on varnish formulations was reprinted 14 times with only minor modifications. This was claimed⁽⁴⁾ to be the industry standard. Compare that with today's situation. A book which lasts for 200 years to the turn of the century, followed by a series of books⁽⁴⁻⁸⁾ published in the 1940's which last 40 years to be superseded by a set which lasts 20 years before needing to undergo major revisions. It is not the writing which is inadequate, but it is a true reflection of the increasing rate of change of the surface coating industry.

Reference to some of the earlier text books written for the surface coatings industry reveal how far this industry has progressed over the last 50 or so years. Examination of a 5 volume set of books published by Wiley⁽⁴⁻⁸⁾ will be used to illustrate the changes and progress which have occurred and the approximate dates for introduction of what were considered new technologies over the last hundred or so years. Dates for new technology developments may be the subject of debate, because it was often different between North America and Europe and even within some parts of Europe. Dates are given to try and put this industry and its developments into perspective.

In the early 1900's resins used for surface coatings were based upon naturally occurring materials, albeit with some degree of modification or processing in some cases. Some of the early resins for surface coatings resembled alchemy, with secret ingredients and/or processing techniques being handed down from father to son (at the turn of the century, there were few female resin chemists).

In the opening paragraph of Volume III, Chapter 4 of Mattelio's book⁽⁶⁾ written in the early 1940's as reproduced here, the reader will note a lot of similarities to the above paragraph and some would question if the situation had changed. Rest assured it has changed beyond all recognition from the 1940's let alone prior to 1900!

"The art and skill of the old-time varnish maker have yielded slowly to more scientific control and to the developments of the chemists and engineers who have entered the

coating-materials industries. The complexity of the organic molecules which they have had to deal with, however, has necessitated the continued use of methods which, although more exact and more scientifically grounded than those of their predecessors, nevertheless are still quite empirical”.

“.....it is well to remember that the molecular complexity of the drying oils and resins which are now (1943) in commercial use has provided a formidable variety of problems, which have long proved perplexing... Under such circumstances, one hardly need wonder that empiricism has so long prevailed or why there have been so many recorded differences of opinion and conflicting experimental observations”.

To quote a recognised industry standard publication⁽⁴⁾ 55 years ago, “manufacture was in the hands of untrained men. Chemists or engineers, if there were any in this industry one hundred years ago (ca 1850), were a curiosity. The breadth of science had not yet touched it, and most manufacturers at that time saw no reason why it should.”

When resins were processed, early controls consisted of mainly empirical factors, such as string length – how long a piece of resin could be stretched before breaking. The objective was to process a resin as close to its ‘gel point’, without actually gelling. Much thermal processing was on gas fired open iron vessels, which resembled a pan on a gas cooking ring. Foam over and associated fires were common place. Indeed, folklore has it that some resin processing was controlled by processing until it “foamed over” or ignited.

Early surface coatings were limited to mainly air drying systems which film formed by either evaporation of solvent, to leave a dried film of the natural resin or oxidative crosslinking of any unsaturation present in vegetable oil based binders. French polish, based upon shellac is an example of the first type of coating, whilst alkyds or oleoresinous based systems are examples of the latter.

Alkyds and oleoresinous based coatings were originally used for many surface coating applications, where there was a performance demand, such as increased durability or resistance to water or alkali, compared to alternative systems. The unsaturation in the vegetable oil portion of the resin enabled crosslinking reactions, induced by oxygen in the air, to form resistant and durable films. Some decorative paints, based on linseed oil, for example, could easily yellow. Other systems (varnishes, rather than coatings), were often based upon solutions of hard, naturally occurring resins.

Today coatings can be divided into thermoplastic and thermoset. Thermoplastic systems primarily film form by evaporation of solvent. As a general rule, thermoplastic coatings are based on high molecular weight polymers. Solutions of high molecular weight thermoplastic resins are normally too high in viscosity for the desired applications solids, hence dispersions of thermoplastic resins are frequently used. A dispersion in water, maybe an acrylic latex or emulsion, typically used in

home decorative emulsion wall paints. Thermoplastic polymers may also be dispersed in organic solvents, although the solvent is not a solvent for the polymer. An example would be a dispersion of PVC in organic solvents, commonly known as an organosol. Organosol coatings are used for architectural coil for claddings and the internal coatings, mainly coil applied, of easy open ends for beer and beverage cans.

Another approach to obtaining a resistant film of high molecular weight, whilst having good application solids viscosity relationships is to use thermoset systems. Here relatively low molecular weight resins with chemical functionality are used. Being of low molecular weight, they give relatively low viscosity at the required application solids. Film formulation is induced by either mixing the two components, as in a two pack epoxy, polyamine heavy duty coating, or by the application of heat to a one pack epoxy phenolic can coating. The stability of a thermoset coating, once mixed, is of great importance. Should chemical reaction be prematurely induced, then the viscosity could rapidly and easily increase to a point where the coating is unusable. For one pack coatings the unusable period is referred to as the shelf life, normally measured in months, whilst for two pack coatings it is the pot life, normally measured in hours. The latter is normally taken as the time for the coating to double in viscosity.

Protective coatings have been used for many years. They are no restricted to industrial coatings and include house paints, because the paint or varnish protected the wooden parts of the house. Varnishes are also covered by the term 'protective coatings', because varnishes, such as spar varnishes, protect the spars on sailing ships.

Not only were the paints and varnishes derived from vegetable oils and natural materials, many of which have disappeared, but they were classified in a way which few resin and paint chemists would recognise today, particularly if they are relatively new to this industry.

Varnishes in the past were divided⁽⁶⁾ into two types, with many sub-divisions, as follows:

Oleresinour varnishes

- Oil plus natural resins
- Oil plus synthetic resin
- Oil
- Oil modified glycerol phthalate
- Oil modified chlorinated rubber

Spirit varnishes

Solvent plus natural resins

Solvent plus synthetic resins

The first group dry by oxidation or process initiated by oxidation, whilst the second dry by evaporation.

Before 1905⁽⁴⁾ house paints consisted of white lead, linseed oil, driers and thinners (solvent). Later, zinc oxide was used at about 20-30% of the pigment by weight. Extenders, such as barytes and magnesium silicate, only started to be used from about 1910 onwards. A red lead primer was often used for metal structures, such as bridges. The mid 1900's saw a rise in the use of aluminium top coats for metal structures.

Lacquers referred to certain natural products used in the Chinese and Japanese or solutions of resinous materials in volatile solvents. However, this term also came to cover solutions of nitrocellulose. These became of great importance to the automobile industry in the 1920's, seeking a faster finish than that obtainable for oleoresinous materials. The commercial availability of ketonic and ester solvents greatly assisted the market penetration of nitrocellulose lacquers. These lacquers came to also be used on furniture. However, due to its brittle nature, nitrocellulose films needed plasticising. Alkyds were developed for this purpose and the resulting properties of an alkyd nitrocellulose film were beneficial.

Some of the natural resins used in the protective surface coatings industry in the past were dammar, kauri, copal, congo, east india, zanzibar, sandarac, manila and amber. As the name suggest, they often reflected their geographic origin.

Natural resins were often 'run' to impart oil solubility. This involved heating to some extent to depolymerise the resin. Weight losses up to 30% could occur and the process generated copious fumes. With synthetic resins, such as phenolics, polymerisation occurs.

Spirit varnishes used lacs, which are of insect origin. It has been estimated⁽⁴⁾ that 1,500,000 insects are required to produce sufficient lac for 0.5 kg of shellac.

The use of natural resins has decreased in the USA since about 1930, with them being replaced by synthetic resins. Rosin was, and is, an important member of this family. It is used in the preparation of both varnishes and synthetic resins and as such its usage did not drop to the same extent as other natural resins. Rosin is used to form ester gums, which are based upon the glycerol reaction with rosin, plus other components in many cases.

In 1938, 61% of linseed oil consumption was for paints and varnishes. Other uses included linoleum, oil cloth, printing and patent leather. Certainly at this time as in

days before, linseed oil was of major importance to the surface coatings industry. Linseed oil was subdivided into numerous types depending upon its processing. Some of these were raw linseed oil, alkali refined linseed oil, acid refined linseed oil, oxidised linseed oil, heat bodied drying oils, air bodied versus vacuum bodied. Linseed oil was normally pre-bodied before combination with natural resins, whilst this was not needed for tung oil.

Tung oil was first imported into the USA about 1870. It took time for formulators to learn how to process the oil to avoid the problems of wrinkling, crow's feet, rapid bodying or onset of gelation and matt appearance. Between 1915 and 1925, varnish making was adapted to utilise this new material by gaschecking the oil, which involved heating it to 500°F. Many of the varnishes used 90% tung oil and 10% linseed oil⁽⁴⁾. Phenolic resins had a major impact on the use of tung oil.

Perilla oil, which has similar properties to those of linseed oil, with faster drying and harder films, only came into importance during the 1930's. It was often used in combination with tung oil (75% tung and 25% perilla) and alone in alkyds.

Otocacia oil was first used in about 1923 and was believed to be similar to tung oil, but later this was found not to be the case, being inferior in water and lacking alkali resistance and with behaviour more like that of a resin than an oil causing embrittlement. However, by modification of the resins used with this oil, it could be used as a replacement for tung oil. Ester gums based on this oil have also been prepared.

Castor oil, not being a drying oil, was used as a plasticiser for lacquers. Whilst the dehydration of this oil was the subject of much study over many years, it was not until about 1937 to 1939^(4,6) that dehydrated castor oil (DCO) became commercially available. Even then, it was only 75 to 85% dehydrated, which gave rise to a tackiness in the dried film. By late 1938, 95% to 98% dehydrated castor oil was available, and many of the earlier obstacles and objections to the use of this oil were overcome. Bodying the oil under vacuum gave low acid value stand oils, which could be used to replace, fully or partially, tung oil.

Soyabean oil was unknown in 1909 as a raw material for paints and varnishes. It became an important oil in the mid-1930's. It was used for non-yellowing, white baking enamels. When fortified with tung oil, alkyd resins suitable for automotive finishes were obtained. Combination with phenolic resins also gave acceptable varnishes.

Fish oils, such as sardine oil, have been used, but today this practice has virtually ceased. Odour and variable composition of the oils were two main reasons, with availability as fish stocks decline being an additional one.

Synthetic resins used in the middle of the 20th century included:

Ester gums, based upon reaction of rosin with glycerols or other polyhydric alcohols, were used from about 1900 onwards, and were important raw materials. Nowadays their use is limited. Other natural resins, such as copal, were sometimes used to produce ester gums.

Coumarone indene resins were in commercial production in the USA before 1920 and as such could be considered as the first commercially available synthetic resins. They impart alkali, acid and brine resistance, good adhesion and fast drying. They were also used in combination with phenolic resins.

The reaction of phenol with aldehydes was documented in 1872. Phenolic resins have been used commercially since about 1916 in Europe, and in 1922 in the USA. Many of the phenolic resins used today would bear little resemblance to the early phenolic resins. They were primarily based upon phenol and formaldehyde.

It was not until about 1926 that intensive developments of modified phenolic resins got underway in earnest. In 1931 p-tert-butylphenol and p-phenylphenol based phenolic resins were introduced, whilst 1937 saw the use of bisphenol A in phenolic resins. Many of these modifications were brought about by attempts to improve the oil solubility of the phenolic resins. Reaction of modified phenolic resins with rosin or copal made the resulting product oil-soluble. Modification of phenolic resins with ester gums was common practice. Fast drying times of touch dry within 4 hours were achieved. Tung oil varnishes modified with phenolic resins gave vastly improved water and alkali resistance finishes. Even when modified with ester gums, significantly improved water and alkali resistance was obtained compared with that from natural resin based varnishes.

It has been known since 1901 that phthalic anhydride reacts with glycerol, a by-product of refining oils (triglycerides) to form fatty acids. This was the forerunner to the largest class of synthetic resins which are still in use today, namely alkyds. They are based upon oils or fatty acids with polyhydric alcohols, such as glycerol or pentaerythritol, and polybasic acids such as phthalic anhydride. In addition, monofunctional acids or alcohols may also be present. Initially, drying oils or fatty acids were used for baking or air-drying finishes. In 1929, differentiation between air (oxygen) and heat convertible alkyds was made. Alkyds have been a major resin in the surface coatings industry since about 1928-1930. Automobile finishes (enamels) were based upon alkyd resins, even though they required baking at higher temperatures than the alternative nitrocellulose lacquers. Even nitrocellulose based automotive lacquers contained a proportion of alkyd resin. Due to the final properties of the alkyd, the complexity of combinations of type of oil or fatty acid and other components and the various ways of processing, a generation of alkyd chemists emerged.

Polyvinyl acetate was the first important vinyl resin and was available in about 1912⁽⁶⁾. Aldehyde treated polyvinyl acetate resins were used for spirit type varnishes, lacquers and enamels which has good weathering properties. Some of the higher aldehyde modified polyvinyl acetates gave good baking varnishes. Copolymers of vinyl acetate and vinyl chloride then became available. They tended to be more used in Europe, whilst the USA tended to use polyvinyl chloride resins for surface coatings. One reason was the rubber-like characteristics of polyvinyl chloride. Indeed, it was used as a rubber substitute.

Acrylic resins were first used in surface coatings in about 1935. Since this time, hundreds of different acrylic based resins have been made commercially available, with a wide range of characteristics. Many in the coatings industry tend to consider styrene as an acrylic comonomer. Polystyrene is claimed⁽⁶⁾ to be the oldest synthetic resin, having been 'discovered' about 1800. They are commercially available in Europe in the 1920's and it was not until the late 1930's that they were produced in the USA.

Chlorinated rubber is soluble in many solvents and has good compatibility with many materials used in paints. It imparts alkali and moisture resistance to films containing it. Chlorinated rubber resins were used in the USA from about 1934 onwards, having been used in Europe for a few years before.

Urea formaldehyde resins, which are part of the aminoplast family, and their use with alkyd resins were reported⁽⁴⁾ in about 1930. Applications reported⁽⁴⁾ in the 1940's included metallic articles requiring resistance to adverse conditions, whilst retaining good appearance, of which automobiles, refrigerators and bicycles were three such examples. In 1945 it was stated⁽⁵⁾ that the era of urea formaldehyde resins as coating materials was just beginning. Viewed from today's perspective, this was a very apt vision, especially when one considers the other aminoplast resins now available which complement the early urea formaldehyde resins. Melamine formaldehyde resins started to become available from about 1940 onwards. These materials are co-curing resins, which means that in addition to film forming themselves they can crosslink with other resins containing functional groups, such as hydroxylic groups in alkyds, polyesters, epoxies and acrylics, acidic groups in alkyds, polyesters and acrylics, epoxy groups in epoxy resins and amine groups in acrylics. Phenolic resins can also be considered as co-cure resins.

Epoxies resins only became commercially available in about 1947. Since then their usage has grown to over 550,000 tonnes per year (1990), but all are not for coating applications. They impart outstanding resistance properties and find many applications, including 1 and 2 pack air drying systems. The latter includes the polyamine, polyamide or polyamino amide heavy duty coatings, where the amine functionality crosslinks the epoxy resin to give a durable and resistant film. They are typically used for marine applications such as ship's hulls, decks, superstructure and tanks, oil rigs and other off-shore installations, storage tanks for food, chemicals and

water, pipe linings and paints for concrete and cement. Heat cured coatings based on epoxy resins are used for can linings or internal lacquers, automotive primers and powder coatings.

Epoxy resins can be reacted with other materials to improve the performance of either. There are two types of epoxy esters. One is for air drying coatings and the other is for stoved ones. For air drying epoxy esters, epoxy resin is reacted with air drying oils or fatty acids. For good colour retention, fatty acids with low degrees of unsaturation, such as coconut, would be reacted with the epoxy resin/ film formation would be through crosslinking, probably through the use of an aminoplast.

Polyurethanes did not gain any prominence in surface coatings until the latter half of the 20th Century. Based upon isocyanates and hydroxyl functional materials, a wide range of properties could be attained. Additionally, isocyanates are used to crosslink resins.

In the period 1930-1940, pigments consisted of white lead, basic lead sulphate, litharge, red lead, zinc oxide, leaded zinc, lithopone and blanc fixe. Titanium dioxide started to become commercially available in about 1918 and even in 1943 it was stated⁽⁴⁾ that the tonnage consumed by the paint industry had grown considerably. High opacity rutile titanium dioxide was available from 1941. It had superior exterior durability and hiding power compared to anatase titanium dioxide.

Synthetic organic pigments which had a usable level of lightfastness were made possible in 1914, when it was realised that reaction of the dyes with complex inorganic acids imparted such properties. Phthalocyanine based pigments came into being about 1927.

For air drying oils or fatty acids to dry efficiently, it was normal practice to add 'driers' which were mainly based upon lead, manganese and cobalt. They were often used in the form of naphthenates or linoleates. Today, whilst driers are still required they are based upon less toxic metals such as calcium, barium or zinc.

As the demands on surface coatings increased, and as the complexity of the resins needed to meet these demands also increased, so the resin raw materials and processing techniques changed out of all recognition.

Some of the earliest modern resin process controls used 'wet chemistry' techniques such as acid value in conjunction with solids (non-volatile content – NVC) and viscosity measurements. By plotting acid value against viscosity during the process it was (and is) possible to safely continue a reaction to close to the 'gel point', without gelation. This approach also ensured a greater degree of reproducibility. In essence, the monitoring of acid value and viscosity for alkyds and polyesters, was a means of controlling the molecular weight of the resin. With analytical techniques rapidly

improving, it is now possible to routinely monitor molecular weights using Gel Permeation Chromatography (GPC).

Improvements in Spectroscopy, such as Fourier Transform Infra Red (FTIR), enables rapid checking of quality of either raw materials or finished products. The area of Statistical Process Control (SPC) is now commonplace in resin and coating manufacture. As the requirements for coatings increase and formulations have to balance numerous opposing properties, the need for consistency of product becomes more important.

In the early days the quality of the raw materials could be variable, to say the least. With many being based on naturally occurring materials, their composition could vary due to variable climatic conditions during the growing season(s) or geographic region(s). This is true of some of these materials even today. For example, the compositions of North American and Scandinavian tall oil fatty acids, which are derived from the stumps of trees, is different. For some applications this doesn't matter, but for other more sensitive ones, this difference can exclude the use of tall oil fatty acid from a particular source. With ever improving analytical techniques and understanding of the science of processing of raw materials, variations in composition are now much reduced.

Raw material innovations and developments have been fundamental for the development of resins and coatings with improved performance, lower cost and improved environmental acceptability. The more sophisticated the raw materials, the greater the process control necessary and the better the product consistency.

Initially, most coatings were solvent based, many of low solids content. With environmental pressures, there has been a move towards waterborne or high solids content systems. However, many waterborne systems still contain organic solvent. Additionally, neutralising amine is also present. Both solvent borne and water borne systems have to meet VOC (volatile organic compounds) legislation. The applicators and users of coatings have the option of incineration of solvent or waterborne to reduce their emissions of organic materials. However, it has to be borne in mind that incineration of solvent whilst reducing the fuel costs of the incinerator will increase the emissions of carbon dioxide, which has the potential for being the subject of a future tax for some European countries. However, with the environmental requirement of some countries, it may be necessary to continue to incinerate to comply with 'odour' emissions at the boundary fences of the factory site, even for waterborne systems.

Hence there will be the balance of costs of incinerator fuel verses calorific value of solvent versus size of incinerator – incineration of a waterborne system requires a much smaller incinerator than that for an equivalent volume of solvent based coatings.

Before the Second World War many surface coatings were based on alkyds. The rate of change in the last 40 years is truly remarkable. The demise of alkyds has been

predicted many times, but the fact that they are still a major class of surface coating resin is a tribute to their versatility. Alkyds have been modified to suit the demands placed upon them. Today waterborne and high solids alkyds are commonplace. Twenty or so years ago, these alkyd technologies were in their infancy. It would take a brave person wagering against the alkyd technology continuing for another 100 years due to the ability to relatively easily modify them and the fact that they are based upon the renewable raw materials (vegetable oils) and are extremely cost competitive. Many of the traditional areas of surface coating will continue with modifications to suit external pressures. Heavy duty coatings will continue to be, for the main part, based upon epoxy polyamine/polyamide technology. For certain applications, waterborne heavy duty coatings are commonly used as are some solventless systems. One of the reasons for the continued use of tried and trusted technologies, is the fact that they are tried and trusted. In the case of heavy duty and many industrial coatings, the cost of the coating is small compared to the article being coated, and normally results in an enhanced value or prolonged lifetime of the article. Thus, the fabricators of articles and applicators of coatings tend to be conservative and use tried and trusted coatings, albeit with modifications to suit environmental or other concerns. The can coating business, with its use of epoxy phenolic internal lacquers, is another example of tried and trusted technology surviving.

In some areas, however, there have been dramatic changes in the coating technologies used. One such example would be "white goods" which are domestic appliances such as washing machines and refrigerators. This market is now predominantly powder coating, whereas a few years ago acrylic technology dominated. The automotive market is another which has seen 'leaps' of technology. Electro deposition, initially anodic and now cathodic, dominates for automotive primers.

Some areas have seen rapid adoption of what were considered at the time as radical technologies, with powder coatings and radiation curable being two good examples. Both of these technologies whilst being solvent free, are unable to meet all of the demands of the end applications. Hence, there is and will continue to be a place for liquid solvent based or waterborne coatings, even if major modifications are required to enable them to meet environmental legislation.

In some cases, such as wood coatings, geographic preferences dictate the technology used. The choices are alkyd aminoplast or radiation curable unsaturated polyesters or epoxy acrylates.

The success of many solvent based and waterborne industrial coatings depends upon the correct amount of crosslinking occurring to give a balance between, for example, the opposing properties of resistance and flexibility. As a general rule, for a given system, the higher the crosslink density, the greater the resistance, but the less the flexibility. There have been great advances in understanding crosslinking, consequently there have been great advances in developing improved crosslinking or co-curing resins, such as aminoplasts or phenoplasts.

Another factor driving the thermally cured industrial coating market today is reduced temperature curing systems. This is to reduce energy cost and greenhouse gas emissions.

It should not be forgotten that coatings are not only protective and decorative, but they can play a major role in the fabrication or filling of articles. For example, some can coatings are used to enable cans to be formed through deformation of a flat sheet. Can coatings also impart the mobility to beverage cans to allow them to be filled at up to 2,000 cans per minute. As the speed of fabrication or filling increases, so the technology of the coating needs to be changed. In some cases this may be a minor modification such as changing an additive, but in others it may necessitate the adoption of a new technology. Coatings can be applied to many articles per minute, as in beverage can coatings with up to 2,000 cans being made and coated per line per minute, or one article over several days or weeks as in the heavy duty coatings for the hold of a ship or oil rig.

Industrial coatings have to be formulated for their conditions of use. Arguably, more sophisticated systems can be used under factory conditions than by a semi skilled person painting an oil rig under adverse weather conditions in the North Sea.

Many systems, such as powder, radiation curable and thermally cured ones, can only be applied satisfactorily under factory conditions and for the best and reproducible results, these conditions have to be carefully and rigorously controlled.

In this set of books the chemistries of different types of resins for surface coatings are explained. Radiation curable coatings is the subject of a separate series of books. For the reader interested in more detailed information, there are books dedicated to each class of resin.

TABLE OF CONTENTS

Introduction	i - xi
Chapter I Paint Technology - Some important factors	3-22
I Introduction	3
II Principal tests for paints and paint films	3-8
1. Tests on liquid paints	3
(i) Measurement of fineness-of-grind	3
(ii) Measurement of viscosity	3
2. Tests on wet paint films	5
(i) Measurement of drying time	5
(a) Dust method	5
(b) Touch dry	5
(c) Through dry	5
3. Tests of dry paint films	6-8
(i) Pendulum hardness	6
(ii) Impact resistance	6
(iii) Grid or cross-hatch adhesion test	6
(iv) Pencil hardness	7
(v) Measurement of gloss	7
(vi) Exterior exposure (weathering)	7
(vii) Corrosion resistance	8
III Paint application methods	8-15
1. Brushes and rollers	9
2. Spray techniques	9-12
(i) Pneumatic spraying	9
(ii) Airless spraying	9
(iii) Airmix spraying	10
(iv) Electrostatic spraying	10
(v) Comparison of different spray application techniques	12
3. Immersion painting (dipping)	13
4. Flow coating	13
5. Curtain coating	13
6. Coil coating	13
7. Electrodeposition	14
IV Effects of pigments and filler on film performance	16-22
1. Pigments	16
2. Anti-corrosion pigments	18

3.	Fillers	19
(i)	Talc	19
(ii)	Mica	20
(iii)	China clay	20
(iv)	Carbonates	20
4.	Effect of amount of pigment on paint properties	21
(i)	Pigment by volume concentration (PVC)	21
(ii)	Changes in characteristics as a function of the amount of pigmentation	22
(a)	Gloss	22
(b)	Blistering	22
(c)	Corrosion	22
(d)	Permeability	22
Chapter II Alkyd Resins		25-115
I	Introduction	25
II	Alkyds	26-31
1.	Types of alkyd	26
(i)	Long oil alkyds: air drying and aliphatic solvent compatible	26
(ii)	Medium oil alkyds: air and oven drying aliphatic and aromatic solvent compatible	27
(iii)	Short oil alkyds: air and oven drying aromatic hydrocarbon and ester solvent compatibility	27
2.	Modified alkyds	27
(i)	styrene-based alkyds: air drying and aromatic solvent compatible	28
(ii)	Vinyltoluene-based alkyds: air and induced air drying and aliphatic solvent compatible	28
(iii)	Acrylic (methyl methacrylate, for example) modified alkyds: air drying and aliphatic solvent compatible	28
(iv)	Epoxy modified alkyds (epoxy esters): air and oven drying: aliphatic solvent compatible	29
(v)	Urethane alkyds: air and oven drying: aliphatic solvent compatible	29
(vi)	Phenolic modified alkyds: (long oil varnishes) air and induced air drying: aliphatic solvent compatible	30