Paints, Pigments, Varnishes & Enamels Technology Handbook (with Process & Formulations) 2nd Revised Edition
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The use of paints, varnishes and enamels for decoration is nearly as old as human culture itself. These are widely used in homes as well as in industry because painted surfaces are attractive and easy to keep clean. Paint is generally made up of a pigment. It is a chemical material, which alters the color of reflected or transmitted light due to wavelength-selective absorption. Varnish is a transparent, hard, protective finish or film primarily used in wood finishing but also for other materials. Varnish is traditionally a combination of a drying oil, a resin, and a thinner or solvent. The technology of paints, varnishes and enamels is changing rapidly and becoming more complex each day. The paint industry is an important segment of the chemical industry. Enamel paint is paint that air dries to a hard, usually glossy, finish, used for coating surfaces that are outdoors or otherwise subject to wear or variations in temperature.

The Indian paint industry has seen a gradual shift in the preferences of people from the traditional whitewash to higher quality paints like emulsions and enamel paints with improvement in lifestyle. India is the second largest consumer of paint in Asia. Over the past few years, the Indian paint market has substantially grown and caught the attention of many major players. The market for paints in India is expected to grow at 1.5 times to 2 times GDP growth rate in the coming years. In terms of volumes, pigments demand is expected to reach 4.4 million tonnes. Due to increased Government funding for infrastructure, demand for paints both in industrial and decorative segment is set to rise, thereby rendering Indian paint industry to be poised for further growth.

This handbook is designed for use by everyone engaged in the paints, pigments, varnishes and enamels industry. It provides all the information of the various formulae and processes of paints, pigments, varnishes and enamels. The major content of the book are paint testing, color in paint, maintenance paints, emulsion paints, exterior or interior paints, exterior or interior multicolor paints, exterior swimming pool paints and enamels, interior ceiling paints, metal paints, marine paints, enamel paints, interior fire-retardant paints, interior gloss paints, paint formulation, manufacture of natural copal varnishes, floor paints and enamels, varnishes, lacquers and floor finishes, white pigments, colored pigments, pigment dispersion etc. The book contains addresses of plant & machinery suppliers with their Photographs.

It will be a standard reference book for professionals, entrepreneurs, those studying and researching in this important area and others interested in the field of paints, pigments, varnishes and enamels technology.

Content:
1. TESTING OF RAW MATERIALS FOR COATINGS
Pigments
Oil Absorption
Color
Tinting Strength of Colored pigments
Tinting Strength of White Pigments
Coarse Particles
Oils
Mono-Di-and Triglycerides
Instrumental Analysis of Oils
Gas Chromatography
Resins, Polymers, Plasticizers
Solvents

2. PAINT TESTING
Importance of testing
Classification
Discernment of Appropriate Qualities
Selection of Test
Conduct of Test
Interpretation of Results
Establishment of Standard Variances
Color Testing
Incorrect Standards And Test Procedures in Industry
Statistical Analysis

3. COLOR IN PAINT
Visible Spectrum
Three Dimensions of Color
Tristimulus Values X, Y, Z
Chromaticity Coordinates
Color Order Systems
Sample Preparation for Color Measurement
Tolerance Specification
Color Control by Visual Observation
Color Control by Instrumentation
MacAdam Tolerances
Instrument Accuracy for Tolerance Limitations
Gloss and Its Effect on Color
Light Sources For Color Matching
Color Formulation

4. MAINTENANCE PAINTS
Paint Types and Selection
Barrier Protection
Sacrificial Protection
Coating Types
Resistances
Description by Generic Types
Oil Derived
Sacrificial Metal
Silicones
Thermosetting Resins
Neoprene
Waxes and Greases
Bitumens
Rubber Base
Vinyl Chloracetate
Principles of Effective Maintenance Painting
Failure Mechanism
Coating Thicknesses
Number of Coats
Wood
Nonferrous Metals
Effect of Exposure
Paint System and Application
Surface Preparation
Priming
Intermediate and Finish Coating

5. EMULSION PAINTS
Ingredients of an Emulsion Paint
Surfactants
Structure of Surfactants
Types of Surfactants
Behavior of Emulsions
Protective Colloid
pH
Emulsion Formation
Emulsion Polymerization
Polymerization.
Ingredients
Post-emulsification
Stability of Emulsions

6. EXTERIOR OR INTERIOR PAINTS
Exterior or Interior White Medium Texture Masonary Paint
(TT-C-00555) (Styrene-Acrylate/Chlorinated Paraffin)
Exterior or Interior White Medium Texture Masonary Paint
(TT-C-00555) (Styrene-Acrylate/Chlorinated Paraffin/Resin)
Exterior or Interior White Medium Texture Masonry Paint
Exterior or Interior White Medium Texture Masonry Paint
(Vinyl Toluene-Acrylate/Chlorinated Paraffin)

Exterior or Interior White Medium Texture Masonry Paint
(TT-C-00555) (Vinyl Toluene-Butadiene/Chlorinated Paraffin)

Exterior or Interior General Purpose Aluminum Paint (Alkyd)
Exterior or Interior General-Purpose High-Quality Aluminum Paint (Coumarone-Indene/Menhaden Oil)

7. EXTERIOR OR INTERIOR MULTICOLOR PAINTS
Exterior or Interior White Multicolor Paint
(Vinyl Toluene-Butadiene)
Exterior or Interior Tint Base Multicolor Paint
(Vinyl Toluene-Butadiene)
Exterior or Interior Black Multicolor Paint
(Vinyl Toluene-Butadiene)
Exterior or Interior Red Multicolor Paint
(Vinyl Toluene-Butadiene)
Exterior or Interior Varnish
Exterior or Interior Clear Varnish (Polyurethane)

8. EXTERIOR SWIMMING POOL PAINTS AND ENAMELS
Exterior White Swimming Pool or Masonry Paint
(Chlorinated Rubber/Hydrocarbon Resin/Chlorinated Paraffin)
Exterior Semigloss Blue Swimming Pool Paint
(TT-P-95A) (Styrene-Acrylate)
Exterior Gloss Blue Swimming Pool Paint
(Styrene-Acrylate)
Exterior Gloss Blue Swimming Pool Paint
(TT-P-95A) (Styrene-Acrylate)
Exterior Blue Swimming Pool Enamel
(Chlorinated Rubber/Chlorinated Paraffin)
Exterior Light Green Swimming Pool Enamel
(Two Component: Urethane-Catalyst)

9. INTERIOR CEILING PAINTS
Interior Flat White Ceiling Paint (Alkyd)
Interior Flat White Ceiling Paint (Alkyd)
Interior Flat White Ceiling Paint (Alkyd)
Interior Flat White High-Quality Low Cost Ceiling Paint (Alkyd)

10. METAL PAINTS
Ready-Mix Aluminum Paint
(Linseed Oil)
Galvanized Metal Primer
Zinc Chromate Primer
Specification of Suspension Properties
Lower Cost Utility Red Oxide Primer
Corrosion Resistant Top Coat
Deep Yellow Aerosol Enamel
Gray Automotive Enamel
Gray Automotive Enamel
Implement Enamel
Screw-Cap Coating
White Coating for Can Bodies
Metal Protective Coating
Valve and Actuator Selection
Application
Zinc Rich Primer
Zinc Chromate Primer
Iron Oxide - Zinc Chromate Primer
Epoxy-Ester Zinc Chromate Spraying Primer
Lead Silico Chromate Primer
Baking Primers
Red Lead Metal Primer
Uses
Red Lead/Red Iron Oxide General Purpose Flash Dry Primer
Iron Oxide Primer
Red Primer
Automotive Flash Primer
Strontium Chromate Primer
Appliance and Metal Furniture Primer
Detergent-Resistant Appliance Primer
Stainless Steel Industrial Maintenance Primer
Gray Baking Sanding Primer Surfacer
Uses
White Appliance Enamel
Epoxy White Gloss Enamel
White Enamel
White Brushing Enamel
White Metal Deco Enamel
Machinery Enamel
Gray Enamel
Epoxy Green Enamel
Clear Epoxy Coating
Application
Epoxy Clear Film
Black Aerosol Enamel
Gray Spraying Finish
Uses
Unpigmented Can Coating
Can Coating and Drum Lining
Unpigmented Drum Lining
Clear Interior Drum Lining
Uses
Unpigmented Tank Lining
High Solids Tank Liner
Chemical Resistant Metal Coating
White Roller Coat Tube Enamel
Red Lead-Iron Oxide Mastic Coating
Resin Coating
Procedure
Aluminum Paint
Interior Mill White Gloss Enamel (Triamino-Ester)
Coil Coating - Resistant Siding Type
Polyester White Coil Coating Enamel
White High Gloss Electrocoating
Primer for Galvanized
Red Iron Oxide Primer
Procedure
Dark Grey Single Coat or Primer
Beige Single Coat
Latex Maintenance Enamels
Exterior Latex Metal Paint
Interior Latex Flat Wall Paint for Machine and Tube Colorants
Latex Aluminum Paint
Latex Aluminum Paint
Zinc Chromate, Corrosion Inhibiting Primer
Maintenance Primer
Acrylic Lacquer Aerosol Metal Coating
Package
Directions for Use
Precautions
Aerosol Aluminum Enamel
Aerosol High Temperature Aluminum Paint
Package
Directions for use
Precautions
Lead Primer
Lead Silico Chromate Primer
Anticorrosive Primer
Anticorrosive Chlorinated Rubber Thick Coatings Primers
Anticorrosive Chlorinated Rubber Topcoats
Thixotropic Zinc Chromate Primer

11. MARINE PAINTS
Marine Anticorrosive Primer High Flash Point Solvent
Marine Anti-Fouling Ship-Bottom Paint with High Flash Point
Marine Vinyl/Alkyd Enamel (Black)
Grey Marine Vinyl/Alkyd Enamel
Zinc Dust Primer
Underwater Coating
Composition of Rosin-Vinyl Antifouling Paints
(Nonvolatile Portion Only)
Rosin Antifouling Coatings
Chlorinated Rubber Marine High-Build Coatings with Inhibiting Pigment for Airless Spray
Metallic Lead Primer
Chlorinated Rubber Antifouling Coatings
Chlorinated Rubber Antifouling Marine Paint System
(Metallic Coatings)
(Thick Coatings)
(Antifouling Topcoat)
Marine Coating for Cold, Damp Weather Application
Marine Primer for Cold, Damp Weather Application
Tri-Amino Marine Enamel
Tri-Amino Marine Spar Varnish
12. ENAMEL PAINTS
Semi-Gloss Enamel
White Semi-Gloss Enamel
Dark Green Porch and Deck Enamel
High Quality Semi-Gloss Enamel
Black Rapid-Dry Enamel
Gloss White Architectural Enamel
Semigloss Tint Base
Odorless Alkyd Gloss Enamel
Odorless High Gloss White
Nonpenetrating Semi-Gloss
Nonpenetrating Gloss Enamel
Spraying Red Automotive Enamel
Alkyd Aerosol Enamels
Aerosol Packing
White Aerosol Enamel
Deep Yellow Aerosol Enamel
Stipple Gloss Enamel
High Solids, Light Blue Enamel
Preparation of Base Component
High Solids, Beige Enamel
Preparation of Base Component
White Tinting Enamel
Black Aerosol Enamel
White Aerosol Enamel
Epoxy-Amine High Solids White Spray Coating
Epoxy Solventless Enamel
Gloss Enamel
Semigloss Enamel  
Painter’s Enamel  
Gray High Solids Epoxy-Polyamide Spraying Enamel  
Varnoxy Green, Enamel  
Red Epoxy Enamel  
Epoxy Green Enamel  
Epoxy White Enamel  
Yellow Gloss Epoxy Enamel  
Gloss White Enamel  
Blue Gloss Enamel  
Yellow Industrial Enamel  
Automotive and Equipment White Enamel  
Bright Red Automotive Enamel  
Industrial Orange Enamel

13. INTERIOR FIRE-RETARDANT PAINTS
Interior Intumescent Fire-Retardant White Paint  
Interior Intumescent Fire-Retardant White Paint  
Interior Intumescent Fire-Retardant White Paint  
Interior Intumescent Fire-Retardant White Paint  
Interior Fire-Retardant White Paint

14. INTERIOR GLOSS PAINTS
Interior Gloss White Paint (Acrylic)  
Interior Gloss White Paint (Acrylic)  
Interior Gloss White Paint (Acrylic)  
Interior Gloss White Paint (Acrylic)  
Interior Gloss White Paint (Acrylic/Vinyl Acetate-Acrylic)  
Interior Gloss White Paint (Acrylic/Vinyl Acetate-Acrylic)  
Interior Gloss White Paint (Latex)  
Interior Gloss White Paint (Styrene-Acrylate)  
Interior Gloss White Paint (Vinyl Acetate)  
Interior Gloss White Paint (Vinyl Acetate-Acrylic)  
Interior Gloss White Paint [Vinyl Acetate-Acrylic(S)]  
Interior Gloss White Paint (Vinyl Acetate-Ethylene)  
Interior Gloss White Paint (Vinyl Acetate-Ethylene)  
Interior Gloss White Paint (TT-p-1511A, Type II) (Acrylic)  
Interior Full Gloss White Paint (Acrylics)  
Interior High Gloss White Paint (Acrylic)  
Interior Gloss White And Tint Base Paint (Vinyl Acetate)  
Interior Gloss White And Tint Base Paint  
Interior Gloss White and Tint Base Paint  
Interior Gloss White And Tint Base Paint (Vinyl Acetate - Ethylene)  
Interior Gloss Tint Base Paint (Vinyl Acetate-Ethylene)  
Interior gloss enamels
15. INTERIOR SEMIGLOSS WHITE PAINTS

Interior Semigloss White Paint (Acrylic)
Interior Semigloss White Paint (Acrylic)
Interior Semigloss White Paint (Acrylic)
Interior Semigloss White Paint (Acrylic)
Interior Semigloss White Paint (Acrylic)
Interior Semigloss White Paint (Acrylic)
Interior Semigloss White Paint (Acrylic)
Interior Semigloss White Paint (Acrylic)
Interior Semigloss White Paint (Vinyl Acetate-Acrylic)
Interior Semigloss White Paint (Vinyl Acetate-Acrylic)
Interior Semigloss White Paint (Vinyl Acetate-Acrylic)
Interior Semigloss White Paint (Vinyl Acetate-Acrylic)
Interior Semigloss White Paint (Vinyl Acetate-Acrylic)
Interior Semigloss White Paint (Vinyl Acetate-Acrylic)
Interior Semigloss White Paint (Vinyl Acetate-Acrylic)
Interior Semigloss White Paint (Vinyl Acetate-Acrylic)
Interior High Quality Semigloss White Paint (Vinyl Acetate)
Interior High Quality Semigloss White Paint (Vinyl Acetate-Acrylic)
Interior High Quality Semigloss White Paint (Vinyl Acetate-Acrylic)
Interior High Quality Semigloss White Paint (Vinyl Acetate-Acrylic)
Interior High Quality Semigloss White Paint (Vinyl Acetate-Acrylic)
Interior Low Cost Semigloss White Paint (Acrylic)
Interior Low Cost Semigloss White Paint (Acrylic)
Interior Low Cost Semigloss White Paint (Acrylic)
Interior Low Cost Semigloss White Paint (Acrylic)
Interior Low Cost Semigloss White Paint (Vinyl Acetate)
Interior Low Cost Semigloss White Paint (Vinyl Acetate-Acrylic)
Interior Medium Priced Semigloss White Paint (Vinyl Acetate-Acrylic)
Interior Semigloss White and Tint Base Paints
Interior Semigloss White and Tint Base Paint (Acrylic)
Interior Semigloss White and Tint Base Paint (Vinyl Acetate)
Interior Low Cost Semigloss White and Tint Base Paint (Vinyl Acetate)
Interior Low Cost Semigloss White and Tint Base Paint (Vinyl Acetate-Acrylic)
Interior Semigloss Tint Base Paint (Acrylic)
Interior Semigloss Tint Base Paint (Acrylic)
Interior Semigloss Tint Base Paint (Acrylic)
Interior Semigloss Medium Tint Base Paint (Acrylic)
Interior High Quality Semigloss Tint Base Paint (Acrylic)
Interior Semigloss Enamel
Interior Semigloss White Enamel (Acrylic)
Interior Semigloss White Paint (Acrylic)
Interior Semigloss White Enamel (Acrylic)
Interior Semigloss White Enamel (Acrylic)
Interior Semigloss White Enamel (Acrylic)
Interior Medium Gloss White Enamel (Acrylic)
Interior Medium Gloss White Enamel (Acrylic)
Interior High Quality Semigloss White Enamel (Acrylic)
Interior High Quality Semigloss White Enamel (Acrylic)
Interior High Quality Semigloss White Enamel (Acrylic)
Interior Low Cost Semigloss White Enamel (Vinyl Acetate)
Interior Moderate Cost Semigloss White Enamel (Acrylic)
Interior Semigloss White and Tint Base Enamel (Alkyd)
Interior Semigloss White and Tint Base Enamel (Alkyd)
Interior Semigloss White and Tint Base Enamel (Vinyl-Acetate Acrylic)
16. PAINT FORMULATION

Art
Science
Raw Materials
Manufacture
Cost
Performance
Principles
Pigment - Volume Concentration
Critical Pigment Volume Concentration
Pigments
Vehicle
Solvents and Driers
Formulation Example
White House Paint
Computer

17. MANUFACTURING TECHNOLOGY

1. Process Technology
   1.1 Paint Manufacture
   1.2 Powder Coating Manufacture
   1.3 Resin Manufacture
2. Equipments
3. Laboratory Equipment
4. Quality Control
5. Automation

18. THE MANUFACTURE OF NATURAL COPAL VARNISHES

Disintegration or Size Reduction of the Copal
Method of Heating
Stirring
Capacity of the Kettle
Condensation of Vapours
Addition of Drying Oil
Addition of Driers – Lithorge, etc.
Addition of Liquid Driers and Thinners
Temperature Measurement
Discharging
Access to the Inside of the Kettle
Flanged or Welded Bottoms
Choice of Metal
Special Accessories
Fire Risks
Special Plant Designs
Choice of Running Kettle
General Plant Arrangement

19. THE MANUFACTURE OF BLACK VARNISHES
Charging the Vessel with Bitumen
Heating and Sweating
Addition of Resin
Addition of Oil
Addition of Driers
Cooling and Thinning
Cleansing
Storage
Oil-free Black Varnishes
Special Equipment

20. THE MANUFACTURE OF SPIRIT VARNISHES
Spirit Manila Varnishes
Shellac Varnishes
Accroides Varnishes
Oxidised Rosin Varnishes
Phenolic Resin Varnishes
Urea-formaldehyde Resin Varnishes
Hydrocarbon Base Varnishes

21. FLOOR PAINTS AND ENAMELS
Medium Tint Base Paint (Vinyl Acetate-Acrylic/Epoxy)
Gray Floor Paint (Acrylic)
Green Floor Paint (Vinyl Acetate-Acrylic/Epoxy)
Red Floor Paint (Vinyl Acetate-Acrylic/Epoxy)
Gray Floor Enamel (Acrylic/Alkyd)

22. INTERIOR CONCRETE PAINTS AND ENAMELS
Interior White Concrete Floor Paint (TT-P-0091D) (Styrene-Butadiene)
Interior Brown Concrete Enamel (Styrene-Butadiene)
Interior Battleship Gray Concrete Enamel (Styrene-Butadiene)
Interior Light Gray Concrete Enamel (Styrene-Butadiene)
Interior Olive Gray Concrete Enamel (Styrene-Butadiene)
Interior Silver Gray Concrete Enamel (Styrene-Butadiene)
Interior Dark Green Concrete Enamel (Styrene-Butadiene)
Interior Tile Red Concrete Enamel (Styrene-Butadiene)
Interior Yellow Concrete Enamel (Styrene-Butadiene)

23. EXTERIOR WHITE ENAMELS
Exterior Low Gloss White Low-Odor Enamel
(Two-Component, Epoxy-Polyester)
Exterior Low Gloss White Low-Odor Enamel
(A.P.A. Approved) (Two-Component, Epoxy-Polyester)
Exterior Low Gloss White Low-Odor Enamel
(A.P.A. Approved) (Two-Component, Epoxy-Polyester)
Exterior Low Gloss White Low-Odor Enamel
(TT-C-545D Type) (Two-Component, Epoxy-Polyester)
Exterior Semigloss White Enamel (Alkyd)
Exterior Semigloss White Enamel (TT-E-490B) (Alkyd)
Exterior Semigloss White Low-Odor Enamel
(Two-Component: Epoxy Polyester)
Exterior Semigloss White Low-Odor Enamel
(Two-Component: Epoxy-Polyester)
Exterior Semigloss White Enamel (Styrene-Acrylate)
Exterior Semigloss White Enamel (Styrene-Acrylate)
Exterior Gloss White Color-Retentive Enamel (Acrylic)
Exterior Gloss White Enamel (Alkyd)
Exterior Gloss White Fast-Drying Enamel (Alkyd)
Exterior Gloss White Fast-Drying Enamel (Alkyd)
Exterior Gloss White Odorless Enamel (Alkyd)
Exterior Gloss White Trim Enamel (Alkyd)
Exterior Gloss White Enamel
(Two-Component: Epoxy-Polyester)
Exterior Gloss White Low-Odor Enamel
(Two-Component: Epoxy-Polyester)
Exterior Gloss White Enamel (Oxazoline)
Exterior Gloss White Enamel (Styrene-Acrylate)
Exterior Gloss White Enamel (Styrene-Acrylate)
Exterior Gloss White Marine and General Purpose Low-Cost Enamel (Urethane)
Exterior White Rapid-Drying Enamel (Alkyd)
Exterior White Enamel (Urethane)
Exterior White Tile-Like Enamel
(Two-Component: Urethane-Catalyst)

24. EXTERIOR OR INTERIOR ENAMELS
Exterior or Interior Gloss White Enamel (Alkyd)
Exterior or Interior Gloss White Enamel (Alkyd)
Exterior or Interior Gloss Blue Enamel
(Alkyd/Hydrocarbon Resin)
Exterior or Interior Gloss Gray Enamel
(Alkyd/Hydrocarbon Resin)
Exterior or Interior Gloss Green Enamel
(Alkyd/Hydrocarbon Resin)
Exterior or Interior Gloss Yellow Enamel
(Hydrocarbon Resin)
25. VARNISHES, LACQUERS AND FLOOR FINISHES
Cold-Blend Spar Varnish – Metal
General-Purpose Utility Varnish
Crown Cap Varnish
Furniture Rubbing Varnish
Four-Hour Floor and Trim Varnish
Clear Floor Varnish
Flatted Alkyd Varnish
Alkyd Rubber Lacquer
Epoxy Clear Coating
Epoxy-Amine Clear Coating
Epoxy Clear Coating
Clear Flexible Epoxy-Amine Exterior Coating
Flatting Base
Clear Varnish
Gray Floor Enamel
MFMA Gym Floor Finish – 40% Solids
General Purpose Varnish – 50% Solids.
Marine Spar Varnish
Chemically Resistant Varnish
Overpaint Varnish
Porch and Deck Varnish
Venetian Blend Varnish
Clear Acrylic Lacquer
Directions for Use
Package
Precautions
Acryloid Acrylic Wood Lacquer
Protective Acrylic Coating for Copper Metal
Acrylic Lacquer
Clear Sanding Sealer
Varnish
Maroon Floor Varnish
(Phenolic Resin)
Shellac Primer Sealer
Furniture Lacquer
Cold-Blend Floor Varnish
Maroon Floor Paint
Vehicle
Gray Floor Enamel
Dull Finish Varnish
Flooring Primer
Green Floor Enamel
Red Floor Enamel

26. PIGMENTS - GENERAL CLASSIFICATION AND DESCRIPTION
Part A. Pigment Classification
Definition of Paint
The Functions of Pigments in Paint
Types of Pigments
Principles of Hiding Power
The Hiding Power of Paint
Part B. Supplemental Pigments
Definition
History
White Pigment Evaluation Methods
General Properties of Supplemental Pigments
Manufacture of Supplemental Pigments
The Major Supplemental Pigments
The Future of Supplemental Pigment Technology

27. WHITE PIGMENTS
Opacity
The Reactive White Pigments
Basic Carbonate White Lead

28. COLORED PIGMENTS
Chrome Yellows
Zinc Yellows
Strontium Yellow
Nickel Titanate Yellow
Nickel Azo Yellow
Cadmium Yellow
Yellow Iron Oxide
Hansa Yellows
Benzidine Yellows
Vat Yellows
Chrome Orange
Molybdate Orange
Cadmium Orange
“Mercadium” Orange
Benzidine Orange
Dinitraniline Orange
Vat Dye Oranges
Chrome Greens
Chromium Oxide
Hydrated Chromium Oxide
Copper Phthalocyanine Green
Organic Green Toners
Iron Blues
Copper Phthalocyanine Blues
Ultramarine Blue
Organic Blue Toners
Indanthrone Blue
Carbazole Dioxazine Violet
Organic Violet Toner
Mineral Violet
Quinacridone Violet
Lithols
Para Reds
Toluidine Reds
BON (-OxynaphthOic) Reds and Maroons
Lithol Rubine
Chlorinated Para Red
Quinacridone reds and maroons
Red Iron Oxide
Cadmium Red and Maroons
“Mercadium” Reds and Maroons
Red Lead
Thioindigo Reds and Maroons
Arylide Maroons
Siennas, Ochers and Umbers
Carbon Blacks, Lampblacks and Bone Blacks
Tinting Properties of Colored Pigments
Chrome Yellows
Zinc Yellows
Basic Zinc Chromate
Strontium Yellow
Nickel Titanate Yellow
Nickel Azo Yellow
Cadmium Yellow
Yellow Iron Oxide
Hansa Yellow
Benzidine Yellow
Vat Yellows
Chrome Orange
Molybdate Orange
Cadmium Orange
“Mercadium” Orange
Benzidine Orange
Dinitraniline Orange
Vat Dye Orange
Chrome Greens
Chromium Oxide
Hydrated Chromium Oxide
Copper Phthalocyanine Green

29. PIGMENT DISPERSION
Definition
Method
Equipment
Mill Base Formulation
Setting up a Laboratory Formula
Equipment Setups and Limitations
Tank Configuration
Premixers
Conclusions

30. ADDRESSES OF PLANT & MACHINERY SUPPLIERS

31. PLANT & MACHINERY PHOTOGRAPHS

Sample Chapter:
PAINT FORMULATION

Paint formulation is the art of scientifically compounding properly selected raw materials for efficient manufacture of a competitive product that satisfactorily meets performance requirements. Several terms are used in this definition of paint formulation and each term should be analyzed individually to give a better insight into the complexities of formulation.

ART

Art as the term is used here means a skill acquired by experience, study and observation, with emphasis on experience. Knowledge of the performance of the raw materials under the given conditions and in relation ship to each other is essential. This knowledge is largely dependent on experience. Many good formulators have had no formal technical training but develop excellent products based on years of practical experience. There are no precise scientific principles to apply that would insure a good formulation. Experience is an indispensable factor to the art.

SCIENCE

Though formulation is not a precise science, still scientific principles do apply. Several facets of paint formulation lend themselves to chemical and mathematical techniques. Pigment volume concentration is one such important approach. It will be discussed in some detail later in this chapter. With today's more sophisticated coatings such as epoxies, stoichiometric equivalents can be calculated to achieve proper balance between the resin and converter used to get maximum reactivity and eliminate trial-and-error methods. With the rapidly advancing technology of new vehicles and other raw materials, the scientific approach is gaining daily in importance.

RAW MATERIALS

The chemical industry is constantly introducing new compounds designed specifically or potentially for use in the paint industry. The alert formulator must keep abreast of these developments. He must know their properties as well as those of established materials. Proper selection of raw materials is essential. Small variations in properties between two otherwise comparable materials can mean the difference between a good or a poor finish. For example, two titanium dioxides may be identical in hiding power, whiteness, tinting strength and oil absorption, but can still result in vastly different performance. One of these may be surface treated to give it chalk resistance and tint retention and, hence, will produce an excellent exterior enamel. The other will chalk, lose its cleaness of tint and show rapid erosion. Knowledge of these small but important differences cannot be overemphasized for sound formulation.

MANUFACTURE

Efficient manufacture is always an important consideration in proper formulation. High-speed dispersion equipment, sand mills, attritors and other modern dispersing machinery are rapidly replacing the older roller, ball and pebble mills. This gives the formulator additional factors to consider: Particle size and particle size distribution of the pigment and the equipment to be used for dispersion now become problems for the formulator.

COST

The need for a competitive product is almost self-explanatory. If a product is over formulated, i.e., too good for its intended use, it may cost too much and no sales will result. Conversely, if it does not perform well, it will not be repurchased.

PERFORMANCE

With all these elements affecting the development of a good formulation, it becomes obvious that there is no unique answer for a specific formulation problem but rather that several equally good formulations can
The only real criterion for a formulation is its performance. For a proper start, these should be a clear definition of what is expected of the projected formulation. With these objectives defined, the selection of raw materials to achieve these objectives can begin. Frequently, a compromise may be necessary. Thorough knowledge of the characteristics of the ingredients and their interrelationship is necessary for a judicious selection.

**Table 1. Bulking Values of Typical Hiding Pigments**

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<thead>
<tr>
<th>Trademark</th>
<th>Producer</th>
<th>Specific Gravity</th>
<th>Wt./gal</th>
<th>Gal/lb</th>
<th>Type</th>
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<tr>
<td>Azo Dox-11</td>
<td>American Zinc Co.</td>
<td>5.6</td>
<td>46.65</td>
<td>0.02144</td>
<td>Zinc oxide</td>
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<td>XX 602</td>
<td>The New Jersey Zinc Co.</td>
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<td>46.7</td>
<td>0.0214</td>
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<td>EPA #506</td>
<td>The Eagle-Picher Co.</td>
<td>6.06</td>
<td>50.48</td>
<td>0.01981</td>
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<td>Ozlo 18 M</td>
<td>The Sherwin-Williams Co.</td>
<td>5.72</td>
<td>47.65</td>
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<td>St. Joe #911</td>
<td>St. Joe</td>
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<td>46.7</td>
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<td>Unitane 0 110</td>
<td>American Cyanamid Co.</td>
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<td>32.5</td>
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<td>Titanium Dioxide</td>
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<td>Ti-Pure L.W</td>
<td>E.I. du Pont de Nemours &amp; Co.</td>
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<td>32.4</td>
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<td>The Glidden Co.</td>
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**PRINCIPLES**

The basic prerequisite for good formulation is a broad knowledge of the properties of the raw materials used in coatings. Also essential for a good formulation is a full awareness of the limitations of the raw materials to be used, their interrelationship with the other materials employed in the formula and, of course, the economics of their use.

Many factors, in addition to the basic ingredients, must be considered for a good formulation. These must be clearly defined before the development of a formulation is even attempted. These factors are determined by the anticipated end use of the proposed product. This is often overlooked and can result in much
unnecessary laboratory work. The performance requirements, application properties, drying characteristics, color, gloss, hiding, production facilities, availability of raw materials, and selling costs are some of the factors that must be considered before development is begun.

With these requirements carefully outlined, selection of the proper raw materials based on a knowledge of their performance can be made, and the coating can be formulated to meet the stated objectives. Obviously this cannot be learned from a book but is dependent largely on a knowledge of the raw materials and the necessary experience to formulate a good competitive product. Although emphasis is placed on the necessity of thorough knowledge of raw materials, there are some basic mechanics common to all formulations.

If it is assumed that the proper selection of raw materials has been made the performance characteristics of these materials in a given formulation are significantly controlled by the relationship of pigment and vehicle, specifically their respective volumes. The pigment-vehicle volume relationship will determine gloss, drying, stain removal, brushing flow, boldout, viscosity and other properties.

**PIGMENT - VOLUME CONCENTRATION**

This relationship is known as the pigment volume concentration (PVC) or simply pigment volume (PV). It is a percentage expressed as a number and represents the pigment volume divided by the sum of the pigment volume and the vehicle solids volume, multiplied by 100. Thus,

\[
PVC = \frac{\text{Pigment Volume}}{\text{Pigment Volume} + \text{Vehicle Solids Volume}} \times 100
\]

The same relationship can be expressed as the pigment-binder ratio or P/B. In this case, the pigment volume is set equal to 1 and the vehicle volume is calculated to its proper value.

\[
P/B = \frac{\text{Pigment Volume}}{\text{Vehicle Volume}} = \frac{1}{x}
\]

Critical Pigment Volume Concentration.

Still another concept of this relationship is the critical pigment volume concentration (CPVC). This is the specific PVC at which the vehicle demand of the pigment is precisely satisfied; i.e., there are no voids among the pigment particles. There is no excess vehicle present. This concentration is critical because above or below this value the properties of a formulation change dramatically.

In the pigment volume relationship, the formulator has a tool by which can change the scrubbability, enamel holdout, stain removal, dry hiding, gloss and other properties by varying the PVC. As defined before, the CPVC is the specific PVC at which pigment is completely surrounded by the vehicle with no excess vehicle left and no pigment voids. If additional vehicle is added, free vehicle is immediately available to enhance the gloss, scrubbability, etc.

As a specific example, if two given latices are compared in a given formulation, one may have a CPVC higher than the other. The higher CPVC formulation would predictably have better stain and scrubbability characteristics than the lower. If more pigment were added to the latter formulation to raise its CPVC, this
would yield properties comparable to those of the first latex. Since pigment usually bulks at lower cost, comparable properties would result at a lower total cost.

It is quite apparent now that the pigment volume is important. Exactly low is pigment volume or bulk determined? Bulk simply means the volume occupied by a given weight of pigment. For pigments, it can be calculated by multiplying the specific gravity by 8.33, the weight of a gallon of water (specific gravity = 1.0). Thus, if a pigment has a specific gravity of 1.5, its bulk will be

\[
\text{Bulk} = 1.5 \times 8.33 = 12.495 \text{ lb/gal}
\]

or if expressed as the reciprocal

\[
1/12.495 = 0.08 \text{ gal/lb}
\]

This simply means that every 12.495 pounds of this pigment used in a formulation will yield 1 gallon, or for every pound used, .08 gallon results.

These values are usually expressed as bulk per 100 pounds for ready comparison with the bulk of other
Critical pigment volume concentration determinations are a bit more complex and in a routine formulation are seldom calculated precisely. Usually a series of coatings at various levels or ladders of PVC are made. An enamel holdout test is run, and the approximate CPVC is established. Enamel holdout is a simple test and is exactly what the name indicates. The coatings under consideration are used as a prime cost and the enamel is applied over it. The concentrations between which the gloss or holdout changes markedly would be the approximate CPVC.

For a detailed discussion of CPVC, the reader is referred to the original work by Asbeck and Van Loo and
their subsequent refinement, and also to the work reported by the New England Production Club.
Since the knowledge of raw materials has been stressed, we should now consider how their properties can affect the coating which is being formulated.

PIGMENTS
Prime pigments, i.e., those which provide the hiding or color, are of course essential because of their opacity or hiding power. The selection of a pigment for exterior application would be dictated by its durability. Will it chalk or not? How much will be required to get the proper hiding? For colored pigments, the lightfastness must be considered. From a viscosity standpoint, the oil or vehicle demand must be known. This property could affect the brushing, as well as leveling and gloss. The possible reactivity of the pigment with the proposed vehicle and its effect on package stability are important. Particle size and distribution may have an effect on the type of production equipment to be used in making the product. In general, the same factors must be considered for the inert pigments. Here, these properties contribute to hardness, mildew resistance, stain removal, viscosity and control of gloss, in fact the same as for the prime pigment selection with exception of hiding power.

VEHICLE
The nature of the vehicle will to a large extent determine the performance of the coating. The vehicle must be selected with continuous awareness of the requirements of the product listed in the original request. In selecting the best vehicle, the following factors must be considered: whether it will be used inside or outside, its own color particularly in whites, its color retention, oil length, drying characteristics, reactivity with the proposed pigments, viscosity, the solvent present and the driers needed. Again there is no easy route to a quick selection of a vehicle except thorough knowledge and experience in its use.

SOLVENTS AND DRIERS
Although solvents are an integral part of most vehicles, additional solvents are frequently added to the formulation to adjust the viscosity, brushing or spraying characteristics. Solvent strength, odor, color, flash point, evaporation time, flash off point and toxicity must all be considered to obtain the desired balance of properties. With driers, the proper combinations of top- and through-dry must be evaluated.

FORMULATION EXAMPLE
The following is an example of the calculations required for the formulation of a white house paint to give the desired characteristics. Heatbodied linseed oil is chosen as the vehicle. The pigment is made up of titanium dioxide, leaded zinc oxide and talc. The principal hiding pigment is titanium dioxide and the proper balance is made between anatase (chalking) and rutile (nonchalking). The leaded zinc oxide is included to give mildew resistance, and the talc prevents settling and reinforces the film, thereby aiding resistance to chalking.
WHITE HOUSE PAINT

Desired Characteristics

Appearance
1. Color
   White
2. Gloss
   Approximately 80 and 60° glossmeter.
3. Hiding
   Complete with one coat

Application
1. Viscosity
   80-90 K.U., generally applied at package consistency.
2. Flow
   Fair to good, must not sag.
3. Dry
   Overnight in air.

Durability
1. Adhesion
   Good to oil-type primers
2. Color retention
   Good—must resist mildew and chalk enough to remove dirt.
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NIIR PROJECT CONSULTANCY SERVICES
106-E, Kamla Nagar, New Delhi-110007, India.
Tel: 91-11-23843955, 23845654, 23845886, +918800733955
Mobile: +91-9811043595
Email: npcs.ei@gmail.com, info@entrepreneurindia.co
Website: www.entrepreneurIndia.co