The Color Chemist's Handbook

The Color Chemist's Handbook:

Excelling in Paint and Coatings Lab Operations

By

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Cambridge Scholars Publishing

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This book first published 2024

Cambridge Scholars Publishing

Lady Stephenson Library, Newcastle upon Tyne, NE6 2PA, UK

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN: 978-1-0364-1217-3
ISBN (Ebook): 978-1-0364-1218-0

TABLE OF CONTENTS

FOREWORD

In this book, the author shares his valuable experience gained from working with three renowned multinational companies: 3M, Akzo Nobel, and Asianpaints in the paints & coatings laboratory. Having dedicated his career to research and development (R&D) from 2006 to 2021, the author delves into his involvement in the development of various paint & coating products and the management of laboratory operations. With Asianpaints, the author focused on industrial and floor coating programs, while at Akzo Nobel, he specialized in automotive specialty plastic (SP) coatings. His most extensive tenure was at 3M, spanning 12 years from 2009 to 2021, during which he contributed to numerous product development programs, from concept to tangible realization, requiring meticulous program management and comprehensive laboratory testing. The author's responsibility included the overall management of the coating laboratory, providing him with invaluable insights. By addressing the existing knowledge gap in the field, the author aims to assist college students studying surface coatings and paint technology, recent graduates entering paint laboratories, as well as professionals already working in this domain. Throughout the book, the author draws upon his practical experience in laboratory management during the development of various coating materials, making it relevant and beneficial to all individuals working or aspiring to work in paint and coating laboratories.

In this book, you will discover a comprehensive range of topics, including R&D and quality laboratories, best practices for paint and coatings laboratories, common instruments found in such laboratories, effective management of laboratory equipment, meticulous record-keeping, test methods and their interpretations, internal test methods (ITMs), testing standard operating procedures (SOPs) and result documentation, compliance with environmental, health, and safety (EHS) regulations, fire hazards and evacuation protocols, management of laboratory chemicals and raw materials, a brief overview of laboratory project management, and adherence to Good Laboratory Practices (GLPs).

SUMMARY

Why should you delve into the contents of this book? Allow me to elaborate further and provide an answer to this question. First and foremost, congratulations! By holding this book in your hands, it is evident that you are a dedicated professional eager to acquire effective paint laboratory management skills. Within these pages, you will gain a deep understanding of various aspects of paint laboratory management, ultimately transforming you from an ordinary laboratory worker into an efficient laboratory manager. You will learn about testing procedures, instrument management, test methods, as well as the organization and management of your testing protocols, instrument calibration, EHS compliance, and fire hazard prevention within the laboratory. Since the materials used in paints can pose hazards, a significant emphasis has been placed on labelling and compliance with health and safety standards. At the end of each chapter, practical exercise questions are provided to assess your knowledge and reinforce the concepts covered.

So, what are the benefits of acquiring knowledge in laboratory management? As a professional in the "paint and coatings" industry, it is crucial to efficiently and safely manage your laboratory, generate reliable and reproducible data, and maintain accurate records. Upon completing this book, you will possess the skills to prioritize, maintain, and align your laboratory with internationally accepted standards for laboratory management. A well-managed laboratory can lead to increased work efficiency, optimized resource utilization, and enhanced productivity, resulting in greater revenue for your organization. Additionally, an impeccably managed laboratory will elevate your company's brand value when customers visit and witness the reliability of your laboratory operations.

—Dr Mukesh Kumar Madhup

INTRODUCTION

"The Color Chemist's Handbook: Excelling in Paint and Coatings Lab Operations" is an invaluable resource for laboratory managers, chemists, and technicians in the paint and coatings industry. This comprehensive guide addresses every facet of laboratory management, from the management of raw materials to R&D and quality control, best practices, instruments and equipment management, record-keeping, test methods, compliance with EHS and regulatory requirements, and standard operating procedures.

Chapter 1: Paint Raw Materials Management

Chapter 1 delves into the management of paint raw materials, including inventory storage and labelling. It also provides a comprehensive overview of the commonly used raw materials in paint and coatings formulations.

The chapter also provides an overview of the four primary categories of raw materials used in paint laboratories: resins, additives, pigments, and solvents. Resins are further explored, highlighting their different chemistries such as epoxy, polyols, acrylics, alkyds, melamine, urea, and more. The chapter also delves into the various types of hardeners or curatives employed in conjunction with resin systems, such as polyamines, polyamides, isocyanates, and acid anhydrides.

Chapter 2: Research and Quality Laboratories

Focusing on R&D and quality control laboratories, Chapter 2 presents best practices for establishing and managing these critical laboratory environments. The chapter emphasizes the differences between R&D and quality laboratory and the roles & responsibilities of the two types of laboratory in paints and coatings.

Chapter 3: Best Practices inside a Paint and Coatings Laboratory

Chapter 3 outlines the best practices for efficiently managing a paint and coatings laboratory, covering topics such as sample preparation, testing procedures, and data management. The chapter also touches upon laboratory accreditation and certification, ensuring adherence to recognized industry standards.

Chapter 4: Common Instruments and Equipment inside a Paint and Coatings Laboratory

Providing an overview of the instruments and equipment commonly found in paint and coatings laboratories, Chapter 4 explores key tools such as spectrophotometers, rheometers, and viscometers etc. with their working principles and the test methods followed. In equipment, this chapter outlines the pilot batch processing machineries and their function in details. It also emphasizes the importance of instrument calibration and maintenance for accurate results.

Chapter 5: Cleaning, calibration and maintenance in laboratory

Chapter 5 hones in on laboratory instrument and equipment management, including calibration, maintenance protocols, new procurements and equipment replacement strategies. The chapter also addresses laboratory safety measures and risk management related to equipment handling.

Chapter 6: Record Keeping

The importance of meticulous record-keeping in paint and coatings laboratories is the focus of Chapter 6. It covers the types of records that should be maintained and provides best practices for effective record-keeping, ensuring traceability and compliance.

Chapter 7: Paint and Coating Testing, Test Method Interpretation and the Instruments

Chapter 7 offers an overview of the common test methods utilized in paint and coatings laboratories, including ASTM and ISO standards. Additionally, the chapter explores the development and validation of internal test methods tailored to specific laboratory needs.

Chapter 8: EHS and Regulatory Requirements

Compliance with environmental, health, and safety (EHS) considerations, as well as regulatory requirements, is explored in Chapter 8. Topics encompass hazardous waste management, proper chemical handling practices, and the importance of personal protective equipment (PPE).

Chapter 9: Reflecting on Effective Laboratory Management

This chapter provides a summary of the previous eight chapters, offering a comprehensive reflection on the key learnings presented throughout the book.

"Paint and Coatings Laboratory Management" serves as an indispensable guide for laboratory managers, chemists, and technicians. By following the guidelines and principles outlined in this book, laboratory professionals can ensure the efficient and effective operation of their paint and coatings laboratories, while upholding the highest standards of quality control and safety.

CHAPTER 1

RAW MATERIALS MANAGEMENT

Various Ingredients of paints and coatings

To effectively manage the raw materials within a paint laboratory, it is essential to understand the types of raw materials stored in such a facility. Paint laboratories typically handle four main categories of raw materials: Resin, Additives, Pigments, and Solvents. The finished paint or the coating is in general a mixture of resin, solvent, additives and pigments.

Fig. 1.1. Paint kept in a tin can [picture credit – Unsplash]

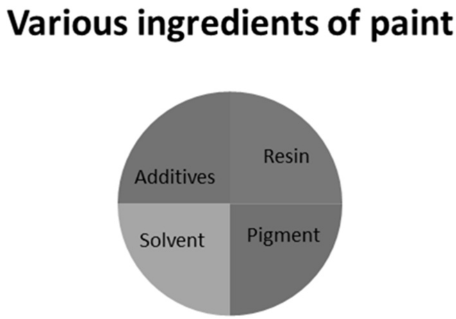

Fig. 1.2. various ingredients of a paint or coating

1. Resin

Resins play a pivotal role in the manufacturing of paints and coatings, serving as the fundamental component that binds the formulation together. These versatile materials are typically derived from natural sources such as plant exudates or synthesized through chemical processes. In the paint and coating production, resins function as the binder, adhering pigment particles to surfaces and providing the necessary adhesion, durability, and film-forming properties.

Various types of resins are utilized in paint and coating formulations, each offering unique characteristics and performance attributes. For example, acrylic resins are renowned for their excellent weatherability and colour retention, making them ideal for exterior applications. On the other hand, alkyd resins boast exceptional adhesion and are often used in high-performance coatings for metal substrates. Additionally, epoxy resins are prized for their superior chemical resistance and are commonly employed in industrial coatings for harsh environments.

The selection of the appropriate resin is crucial in determining the final properties of the paint or coating, including its durability, flexibility, gloss, and resistance to environmental factors such as moisture, UV radiation, and chemicals. Moreover, advancements in resin technology continue to drive innovation in the paint and coating industry, enabling the development of formulations tailored to meet specific performance requirements and sustainability goals.

In essence, resins serve as the backbone of paints and coatings, imparting structural integrity and performance characteristics that are essential for protecting and enhancing surfaces across various applications and industries.

So, Resin, also known as the binder, plays a crucial role in paint preparation. It binds together all the other ingredients in the paint and is responsible for adhesion to substrates. Resins are also classified based on their chemistries, such as Epoxy, various polyols, acrylics, alkyds, urea, melamine, and more. Some high-performance coating systems require a two-component (2K) reaction, where a separate resin system, known as a hardener or curative, needs to be mixed with the primary component before application. Various types of hardeners or curatives are used, including polyamines, polyamides, isocyanates, acid anhydrides, and others.

Fig. 1.3. Resin for paint. [Picture credit – Unsplash]

2. Pigment

Pigments and extenders are integral components in the formulation of paints and coatings, contributing to their color, opacity, and overall performance characteristics. Pigments are finely ground particles that provide color and hiding power, while extenders are inert materials added to enhance properties such as durability, texture, and cost-effectiveness.

Pigments are available in a wide range of natural and synthetic forms, each offering distinct color properties and performance attributes. Common types of pigments include titanium dioxide, iron oxides, carbon black, and phthalocyanine blues and greens. These pigments are selected based on factors such as desired color, opacity, light fastness, chemical resistance, and compatibility with other components in the formulation.

Extenders, also known as fillers or bulking agents, are typically mineral-based materials such as calcium carbonate, talc, silica, and clay. These materials are added to paint and coating formulations to improve their properties and reduce overall costs. Extenders help to enhance paint performance by improving viscosity, coverage, durability, and weather resistance. They also contribute to the formation of a smooth and uniform film on the substrate.

The careful selection and balance of pigments and extenders are critical in achieving the desired color, opacity, and performance characteristics of paints and coatings. Additionally, advancements in pigment and extender technology continue to drive innovation in the industry, enabling the development of high-performance formulations with improved durability, sustainability, and cost-effectiveness.

So, pigments and extenders are essential components in paint and coating formulations, playing key roles in determining their color, opacity, and performance properties. Their careful selection and incorporation are crucial for achieving the desired aesthetic and functional requirements of various applications and environments. Inorganic and organic pigments are used in paint formulations. Inorganic pigments include metal oxides like titanium dioxide, iron oxide, zinc oxide, while organic pigments comprise compounds like phthalocyanine green and phthalocyanine blue. Pigments can be naturally occurring or synthesized. Extenders or fillers are also utilized in paint and coatings compositions to reduce costs, enhance hiding properties, and provide specific functionalities. Recent advancements in research and development have led to the availability of functional extenders in the market.

3. Solvent

Solvents are vital components in the formulation of paints and coatings, serving multiple purposes in the application and drying processes. These volatile liquids are responsible for dissolving the resin and other additives to create a uniform mixture, which can be easily applied to surfaces. Additionally, solvents play a crucial role in controlling the viscosity of the paint or coating, ensuring proper flow and leveling during application.

Various types of solvents are used in paint and coating formulations, each with unique properties and applications. Common solvents include mineral spirits, toluene, xylene, acetone, and methyl ethyl ketone (MEK). The selection of solvent depends on factors such as the type of resin used, desired drying time, application method, and environmental regulations.

Solvents also facilitate the drying process by evaporating quickly after application, leaving behind a solid film of paint or coating on the surface. This rapid evaporation helps to speed up the drying time and allows for efficient handling of coated surfaces. Moreover, solvents contribute to the formation of a smooth and uniform film by promoting the flow and levelling of the coating.

However, it is important to note that solvents can have environmental and health implications due to their volatile nature and potential for emissions of volatile organic compounds (VOCs). As a result, there is a growing trend towards the use of low-VOC or solvent-free formulations in response to regulatory requirements and environmental concerns.

So, solvents are essential components in paint and coating formulations, playing critical roles in dissolving ingredients, controlling viscosity, facilitating application, and promoting drying. Their careful selection and management are crucial for achieving desired performance properties while minimizing environmental impact. Different types of solvents are used, selected based on factors like cutting power (power of reducing the viscosity of paint or resin), drying speed, compatibility with specific resin systems, and other requirements. Solvents can be true solvents or diluents. True solvents significantly reduce viscosity, while diluents primarily dilute the resin, resulting in a lesser reduction in viscosity compared to true solvents.

4. Additives

Additives are indispensable components in the formulation of paints and coatings, imbuing these materials with a wide range of performance-enhancing properties. These specialized substances are added in relatively small quantities to paint and coating formulations to improve various aspects of their application, appearance, durability, and functionality.

There exists a diverse array of additives tailored to meet specific requirements and address various challenges encountered in the formulation and application of paints and coatings. Some common types of additives include:

1. **Rheology modifiers**: These additives are used to control the flow and viscosity of the paint or coating during application, ensuring proper coverage and film formation. Examples include thickeners, dispersants, and anti-settling agents.
2. **Defoamers and surfactants**: These additives help to reduce foam formation during mixing and application, ensuring a smooth and uniform finish. They also assist in wetting and dispersing pigment particles evenly throughout the formulation.
3. **Biocides and preservatives**: These additives inhibit the growth of microorganisms such as bacteria, fungi, and algae, thereby extending the shelf life and preventing degradation of the paint or coating.
4. **UV stabilizers and antioxidants**: These additives provide protection against degradation caused by exposure to ultraviolet (UV) radiation and oxidative processes, enhancing the longevity and durability of the paint or coating.
5. **Crosslinkers and adhesion promoters**: These additives improve the adhesion of the paint or coating to various substrates, enhancing its durability and resistance to wear, abrasion, and chemical exposure.
6. **Matting agents and gloss modifiers**: These additives alter the surface texture and appearance of the paint or coating by controlling its gloss level and imparting desired matte or satin finishes.

7. **Drying and curing agents**: These additives accelerate the drying and curing processes of the paint or coating, enabling faster handling and recoating times.

The selection and incorporation of additives in paint and coating formulations are carefully optimized to achieve desired performance properties while ensuring compatibility and stability throughout the product's lifecycle. Additionally, advancements in additive technology continue to drive innovation in the industry, enabling the development of high-performance formulations tailored to meet evolving market demands and regulatory requirements.

So, Additives are incorporated in small quantities in paint and coatings to achieve specific effects within the system. These additives contribute to desired properties and functionalities.

Fig. 1.4. Additive for paint [Picture credit: Unsplash]

5. Other Materials within a Paint Laboratory

In addition to the primary raw materials like resins, additives, pigments, and solvents, paint laboratories are also equipped with a range of supplementary materials and tools essential for their operations. These additional materials serve various purposes, contributing to the efficiency, safety, and functionality of the laboratory environment.

Among the supplementary materials commonly stored in paint laboratories are acids and alkalis. These chemicals are utilized for pH adjustment and control during the formulation process, ensuring the desired chemical stability and performance characteristics of the final paint or coating product. Additionally, acids and alkalis may be employed in cleaning and maintenance procedures to ensure the cleanliness and functionality of equipment and laboratory surfaces.

Special chemicals are another category of materials often found in paint laboratories. These may include specialized additives, catalysts, or functional ingredients tailored to specific formulation requirements or performance enhancements. These chemicals play a crucial role in fine-tuning the properties of the paint or coating, such as adhesion, durability, and weather resistance.

Distilled water is a staple in paint laboratories, serving as a high-purity solvent for various applications. Distilled water is commonly used for dilution purposes, as well as for cleaning equipment and laboratory glassware to prevent contamination and ensure accurate measurements during formulation processes.

In addition to chemicals and solvents, paint laboratories also stock instrument repair tools necessary for maintaining and calibrating laboratory equipment. These tools include precision instruments for measurement and calibration, as well as repair kits and spare parts for essential laboratory equipment such as mixers, stirrers, and analytical instruments. Proper maintenance and calibration of laboratory equipment are essential for ensuring the accuracy and reliability of experimental results and formulation processes.

Overall, the diverse range of materials stored in paint laboratories, including acids, alkalis, special chemicals, distilled water, and instrument repair tools, collectively contribute to the smooth operation and functionality of these facilities. By maintaining a well-stocked inventory of supplementary materials and tools, paint laboratories can ensure efficient formulation processes, accurate experimentation, and the production of high-quality paints and coatings.

Storage Considerations

The storage conditions of raw materials in paint laboratories are of paramount importance to ensure their availability and maintain their chemical integrity and compatibility. Different raw materials, particularly those involved in reactive systems, must be stored separately to prevent unwanted reactions or premature gelation that could compromise the quality and performance of the final product.

One common example of the need for separate storage involves reactive systems that consist of two main components: a base and a hardener. In systems like epoxy-amine or polyol-isocyanate, the base (such as epoxy or polyol) and the hardener (such as amine or isocyanate) must be kept separate to avoid premature reactions that could lead to product degradation or even hazardous conditions.

For instance, in epoxy-amine systems, storing epoxy and amine together can result in undesired reactions, causing the mixture to gel prematurely and rendering it unusable. Similarly, in polyol-isocyanate systems, mixing polyol with isocyanates can lead to rapid polymerization, which may not only compromise the quality of the final product but also pose safety risks due to the release of heat and potentially harmful by-products.

To prevent such issues, paint laboratories typically adhere to strict segregation protocols, ensuring that reactive components are stored in separate designated areas or containers. This segregation minimizes the risk of cross-contamination and ensures that each component remains stable and ready for use when needed.

Furthermore, proper labeling and identification of storage containers are essential to prevent accidental mixing or confusion between different raw materials. Clear labeling indicating the contents of each container and any relevant storage instructions helps ensure that laboratory personnel handle the materials correctly and safely.

In summary, maintaining separate storage for different raw materials, particularly reactive components like bases and hardeners in paint laboratory settings, is critical to prevent unwanted reactions and ensure the integrity and compatibility of the materials. By adhering to stringent storage protocols and labeling practices, paint laboratories can mitigate risks and maintain a safe and efficient working environment.

So, it is crucial to store different raw materials separately to ensure availability and compatibility. Reactive systems often require separate storage for "BASE" and "HARDENERS" to prevent unwanted reactions or gelation due to leakage. For example, in epoxy-amine systems or polyol-isocyanate systems, epoxy should not be stored with amine, and polyol should not be stored with isocyanates.

Shelf Life and Hazard Labels

In paint laboratories, proper labeling of materials with accurate shelf-life information is a crucial aspect of maintaining quality and safety standards. Each raw material or chemical used in paint formulations has a finite shelf life, beyond which its effectiveness or stability may diminish. It is imperative for laboratory personnel to be aware of the shelf life of each material to ensure that only fresh and reliable components are used in formulations.

Expired materials pose risks such as reduced performance, compromised quality of the final product, or even safety hazards. Therefore, it is essential for laboratories to have clear procedures for identifying and disposing of expired materials promptly and safely. This may involve segregating expired materials, documenting their disposal following recommended procedures, and ensuring that they are handled and disposed of in accordance with regulatory requirements.

Hazard labeling is another critical aspect of ensuring safety in paint laboratories. Hazard labels provide vital information about the potential risks associated with handling or using specific materials. These labels typically indicate the classification of hazards based on criteria such as toxicity, flammability, reactivity, and environmental impact.

While detailed discussions about hazard classifications and their implications are typically covered in later chapters dedicated to environmental, health, and safety (EHS) considerations, hazard labels serve as immediate visual cues for laboratory personnel to recognize and mitigate potential risks associated with handling or storing specific materials.

By clearly labeling materials with their respective shelf-life information and hazard classifications, paint laboratories can effectively manage their inventory, maintain product quality, and ensure the safety of personnel and the surrounding environment. Additionally, ongoing training and awareness programs help reinforce the importance of proper labeling practices and ensure compliance with regulatory requirements related to material handling, storage, and disposal.

So, proper labelling of materials with their respective shelf-life information is essential. Expired materials should be promptly discarded following recommended disposal procedures. Hazard labels should indicate the classification of hazards, which will be covered in detail in later chapters concerning environmental, health, and safety (EHS) considerations.

Short Answer Questions

1. What are the key considerations when storing resin in a paint laboratory?
2. Name two common methods for storing pigments in a paint laboratory.
3. How can the storage of solvents be optimized to ensure safety in a paint laboratory?
4. Why is proper labelling essential for additives stored in a paint laboratory?
5. What measures should be taken to prevent contamination when storing materials in a paint laboratory?
6. Briefly explain the importance of temperature control in the storage of paint materials.
7. How can ventilation systems be utilized to maintain air quality in a paint laboratory?

8. What precautions should be taken when storing flammable materials like solvents in a paint laboratory?

9. Discuss the role of inventory management in the efficient storage of paint materials.

10. How often should storage containers for paint materials be inspected for damage or deterioration?

Long Answer Questions

1. Outline a comprehensive storage plan for resin in a paint laboratory, considering factors such as temperature control, container selection, and segregation from incompatible materials.

2. Discuss the challenges associated with storing pigment powders in a paint laboratory and propose strategies for minimizing dust contamination and ensuring accurate inventory management.

3. Explore the various safety considerations involved in the storage of solvents within a paint laboratory, including fire prevention measures and compatibility testing with storage containers.

4. Evaluate the benefits and drawbacks of different storage options for additives in a paint laboratory, such as shelving systems, cabinets, or dedicated storage rooms.

5. Describe the procedures for handling and storing hazardous additives in compliance with regulatory requirements, including proper labelling, secondary containment, and emergency response protocols.

6. Analyze the role of environmental controls, such as temperature and humidity monitoring, in maintaining the stability and integrity of paint materials during storage.

7. Propose guidelines for organizing storage areas within a paint laboratory to optimize accessibility, minimize clutter, and facilitate efficient inventory management.

8. Discuss the importance of employee training and awareness programs in promoting safe storage practices and preventing accidents or incidents related to paint materials.
9. Evaluate the use of digital inventory management systems in streamlining the tracking and replenishment of paint materials stored in a laboratory setting.
10. Develop a contingency plan for responding to emergencies, such as spills or leaks, involving paint materials stored in a laboratory, including containment procedures, evacuation protocols, and reporting requirements.

CHAPTER 2

RESEARCH AND QUALITY LABORATORIES

Types of laboratories in paint and coating industry

There are two different types of laboratory set up inside a paint company; it can be a product development laboratory which performs research (R&D) or a quality assurance (QA) laboratory which functions to control the produced goods on day to day basis.

Fig. 2.1. Microscopic study in the laboratory

Here is a comparison table highlighting the key differences between a Quality Control (QC) laboratory and a Research and Development (R&D) laboratory for paints and coatings:

Table. 2.1 Various aspects of quality control (QC) and Research & Development (R&D) Laboratory

Aspects	**Quality Control (QC) Laboratory**	**Research and Development (R&D) Laboratory**
Purpose	Ensuring product meets established standards	Developing new or improved products
Focus	Product testing and evaluation	Product development and innovation
Timeframe	Short-term	Long-term
Equipment	Standardized, routine testing equipment	Specialized, advanced testing and research tools
Testing	Standardized testing methods and protocols	Customized testing methods and protocols
Analytical techniques	Established analytical techniques	Advanced analytical techniques
Personnel	Trained technicians and analysts	Experienced scientists and engineers
Skillset	Attention to detail, adherence to protocols	Creativity, critical thinking, problem-solving
Documentation	Strict adherence to regulatory requirements	Flexible documentation to accommodate uncertainty
Collaboration with customers	Minimal	Close collaboration to identify customer needs
Risk Assessment	Limited	Detailed assessment of potential risks

In summary, a QC laboratory is focused on ensuring that products meet the established standards, using standardized testing equipment and methods, while an R&D laboratory is focused on developing new or improved products, using specialized research tools, advanced analytical techniques, and customized testing protocols. The personnel in an R&D laboratory typically have a broader skillset and collaborate closely with customers to identify their needs and develop innovative solutions. The documentation in an R&D laboratory is typically more flexible to accommodate the uncertainty and risks associated with developing new products.

Here are the detailed scopes of the two types of laboratories in paints and coatings companies.

R&D laboratory

There are different names given by different organizations to their research laboratories. The laboratories where new products and technologies are developed are named such as viz. “Research & Technology” (R&T) or Research & Development” (R&D) or “Research, Technology and Innovation” (RTI) laboratories etc. The research laboratories are meant for developing new formulation, generating long term test data and launching new products as per customer need. The research laboratories closely work with sales and marketing [S&MM] teams to understand the product modification need, trend in the technology and competition products.

The research laboratories broadly work on following types of programs:

a. Long term research for new technology introduction [NTI].

b. Long term research for new product development [NPD].

c. Short term product development [PD] programs for formula modification [for example change in shade [for existing products], new variants of existing products or minor modifications to meet a particular property]. These programs are actually line extensions or product engineering with existing products and formulations.