

Chapter 4

The Proposed FMEA Technique

4. The Proposed FMEA Technique

In order to reduce the amount color adjustment (correction time) and improve productivity in terms of cycle time in tinting section, it is imperative to identify and eliminate the potential problems in the systematic way. The failure mode and effect analysis (FMEA) is an engineering technique used to define, identify and eliminate potential failures that impact to tint for tinted alkyd products. Moreover, the cause and effect diagram is also applied in the FMEA process as a supplement to identify root causes.

4.1 Problem Analysis by means of the FMEA and The Cause and Effect Diagram

As stated in Chapter 3 (Table 3.2 : Problem identification in tinted alkyd paint in terms of quality and color adjustment), the potential failure mode causes will be analyzed and executed. So The Failure Mode and Effect Analysis (FMEA) and The Cause and Effect Diagram have been introduced in the ABC Company.

4.1.1 The FMEA Types Selection

There are four types of FMEA : system, design, process, and service. The tinting process in tinted alkyd products in ABC Company use only the process FMEA because it relates with analysis in manufacturing process. It focuses on failure modes caused by process deficiencies.

4.1.2 The FMEA Team Selection

The FMEA concept is a team function, not individually. The team must be cross-functional and the team members must be willing to contribute the project. The team must be set up as properly for specific project. It can not serve as the company FMEA team. Therefore, the team for tackle the problem in tinted alkyd products has been establishes based on education qualification or extensive experience in paint manufacturing. The FMEA team in this project consists of 7 persons with multi functional backgrounds, and 2 color specialists from headquarter to suggest and comment all of problem identification. Team includes the members as following :

1. Process Engineer

He graduated from a university in Textile Chemical Engineering with the second class honor since 1993. He has joined with ABC Company more than five years. He has been trained about paint processing and quality control techniques from headquarter in Norway, Malaysia, and Singapore. He also joined projects with specialists from headquarter to develop the production process and optimize the process for manufacturing line. He takes responsible for paint process design, troubleshooting in production line both of water base and solvent base.

2. Color Engineer

She graduated from a university in Chemical Engineering since 1993. She has joined with ABC Company more than six years. She has been trained about color technology and processing by Asia Pacific Regional Laboratory in Malaysia. She also works with color specialist to develop the color processing in ABC Company. She takes responsible for tinting processing, color development in production line both of water base and solvent base.

3. Quality Control Chemist

She graduated from a university in Chemistry Science since 1998. She has joined with ABC Company more than two years. She has been trained about paint technology and quality control technique in paint manufacturing by Asia Pacific Regional Laboratory in Malaysia. She takes responsible for quality control both of raw material and finished goods.

4. Solvent Base Supervisor

He graduated from a university in Textile Chemical Engineering since 1993. He has joined with ABC Company more than six years. He has been trained about paint production and processing from specialist from headquarter. He also visited and trained some course in terms of production management in Singapore and Malaysia. He takes responsible for production line management in solvent base.

5. Specialist Engineer

He graduated from a university in Technology Electronic since 1983. He has joined with the ABC Company more than 10 years. He has been trained about engineering system and plant design in many countries in the ABC groups. He also the member of the design engineer team for new factory in the ABC Company. He is the expert in plant design, automation and control system, electronic system.

6. Solvent Base Foreman

He received the diploma from Technical School in Electronic and Power Control in 1992. He has joined with the ABC Company more than 3 years. He takes responsible for assist the production supervisor in solvent base to manage and supervise in grinding and tinting section in solvent base.

7. Raw Material Foreman

He received the diploma from Technical School in Industrial Technical in 1992. Before he joined with the ABC Company, he worked as the production planning and supervisor in truck manufacturing. He has joined with the ABC Company more than 3 years. Before he worked as production planning and control system in chemical industry. He supervises in section of raw material preparation, and raw material handling.

Moreover, one color specialist from the headquarter that comment for this is

1. Head of Color Development Chemist

He received the degree in Chemistry from the Norwegian Institute of Technology since 1983. He worked at ABC Company as the Color Development Chemist at Pigment Laboratory for 12 years, and promoted to Senior Color Development Chemist. Until now, he works as the Head of Color Development Chemist. His responsible includes research and development the tinter formulation, color formulation etc. He is the one of expertise in the ABC Company in the field of color both of water base and solvent base.

4.1.3 The Process of Conducting the FMEA

After FMEA team is established the flowchart of four processes in tinting section of alkyd products is briefed and explained to all of team members. This is to make sure that everyone understands the process as the same direction. The team started to collect the data of failures and categorized them appropriately. Problem identification will be done firstly. It shown as the Table 3.2 : Problem identification in tinted alkyd paint in terms of quality and color adjustment in Chapter 3. All of them is sent to color specialist at headquarter of the ABC Company to approve and comment.

The failure in each process is brainstormed by means of using the caused and effect diagram technique. They are shown in the Appendix I. The information from this analysis will be used to fill in the columns of the FMEA form in relationship to the effects of the failure, existing controls. The score of severity, occurrence, and detection will be rated base on team judgement.

The ranking of each criterion in severity, occurrence, and detection of process FMEA is modified from Table 2.8 : the example of evaluation criteria for the Process FMEA that uses for QS 9000. They are summarized as the following :

Severity (s) Evaluation Criteria

Effect	Criteria	Score
Hazardous Effect	Hazardous Effect. Safety-related—sudden failure in process production. Non compliance with government regulation.	10
Serious Effect	Potential hazardous effect. Able to stop product without mishap; safety-related ; time dependent failure. Disruption to subsequent process operations. Compliance with government regulation is in jeopardy.	9
Extreme Effect	Extreme effect on quality of products, tinting process; equipment damaged. Product can not achieve their specification but safe. They are treated as waste.	8
Major Effect	Extreme effect on quality of products, color adjustment, rework/repair on product necessary. Product/process performance severely affected but functionable and safe.	7
Significant Effect	Product/process performance degraded, but operable and safe.	6
Moderate Effect	Moderate effect on product/process performance in terms of quality and color adjustment. Product needs perform color adjustment > 1 time with minor quality adjustment.	5
Minor Effect	Minor effect on product/process performance. Product needs perform color adjustment > 1 time without quality adjustment.	4
Slight Effect	Slight effect on product or process performance. Product needs perform color adjustment only 1 time with minor quality adjustment.	3
Very slightly effect	Very slightly effect on product/process performance. Product needs perform color adjustment only 1 time without quality adjustment.	2
No Effect	No effect on product or subsequent processes.	1

Detection (D) Evaluation Criteria

Effect	Criteria	Score
Almost impossible	No known controls available to detect the failure.	10
Remote	Remote likelihood current work instruction and controls will detect the failure.	9
Very slight	The current work instruction and control are not applicable to detect the failure.	8
Slight	The current work instruction and control are applicable, but not effective to detect the failure. (Slight likelihood current controls will detect the failure)	7
Low	The current work instruction and control are applicable and effectiveness, but lack of training to user. (Low likelihood current controls will detect the failure)	6
Medium	The current work instruction and control are applicable and effectiveness. They are trained to users, but they are not fully clear and understanding. (Medium likelihood current controls will detect the failure)	5
Moderately high	The current work instruction and control are applicable and effectiveness. They are trained to users, but they might be don't follow instruction strictly. (Moderately high likelihood current controls will detect the failure)	4
High	The current work instruction and control are applicable and effectiveness. They are trained to users, but they perform with low skill. (Good likelihood current controls will detect the failure.)	3
Very high	The current work instruction and control are applicable and effectiveness. They are generated in form of controlled document and are trained to users. The users understand and perform as the instruction with high skill. (Very high likelihood current controls will detect the failure.)	2
Almost Certain	The current work instruction and control are applicable and effectiveness. They are generated in form of controlled document and are trained to users. The users understand and perform as the instruction strictly. (Current controls almost always will detect the failure. Reliable detection controls are known and used in similar processes)	1

Occurrence (O) Evaluation Criteria

Effect	Criteria	Score
Almost certain	Failure almost certain. It is inevitable. History of failures exists from previous or similar design	10
Very high	Very high number of failure likely (80-90%)	9
High	High number of failure likely (70-79%)	8
Moderately high	Frequent high number of failure likely (60-69%)	7
Medium	Moderate number of failure likely (50-59%)	6
Low	Occasional number of failure likely (30-49%)	5
Slight	Few failures likely (20-29%)	4
Very slight	Very few failures likely (10-19%)	3
Remote	Rare number of failures likely (1-9%)	2
Almost never	Failure unlikely. History shows no failures.	1

Table 4.1 : Evaluation Criteria Table for the Process FMEA

The rank of 1 to 10 is mostly used because it provides ease of interpretation, accuracy, and precision in the quantification of the ranking (Stamatis, 1995 : 35).

All of criteria that we use for ranking the score of severity, occurrence and detection in this research were generated by FMEA members, and final revised and approved by corporate pigment and color specialist team at headquarter in June 2002.

After FMEA team quantify the severity, occurrence, and detection in process FMEA. The priority of the failure is then articulated via the RPN (Risk Priority Number). It is the outcome of the Severity (S), Occurrence (O), and Detection (D) ranking. The relationship shown as below :

$$RPN = (S) * (O) * (D)$$

The RPN is the value by itself that use only for ranking and concerning in the process of tinting section in alkyd products. The RPN will be between '1' and '1000'. All RPNs have no other value or meaning (Stamatis, 1995 : 35) The

result of quantification the severity, occurrence, detection, and RPN are summarized in Appendix II.

The FMEA team agree to pursue failures or problems based on a 90 percent confidence and a 1 to 10 guideline scale. It means that 90 percent of all failure must be addressed for a very critical process. Since the maximum score possible for the RPN is 1000 ($10 \times 10 \times 10$ from severity, occurrence, and detection). Ninety percent of 1000 is 900. Now subtract $1000 - 900 = 100$. Therefore, the threshold of examining the failures would be anything equal to or greater than a 1000 RPN. It means that the RPN of failure that is higher score than 100 must be addressed.

Concept of addressing the failure is the failure with high RPN will be stated first. In case of there are more than two failures with the same RPN, the first address is failure that has high severity, and then detection respectively. Severity is approached first, because it impact directly to failure, while detection is used over the occurrence, because it is customer dependent, which is more important than the frequencies of the failure (Stamatis, 1995 : 40)

4.1.4 The way to quantify the Severity, Occurrence, and Detection of each process

The FMEA team has ranked the score of severity, occurrence, and detection of each process in tinted alkyd products based on table 4.1 : Evaluation Criteria Table for the Process FMEA. There are many failure modes in four process for tinted alkyd products, only three of them will be explained the way to rank the score of severity, occurrence, and detection in the process being discussed.

4.1.4.1 Raw Material Preparation Process

In the raw material preparation process, one of main critical failure mode is uncontrolled color strength of white base. It was found that color strength of

white base impact directly to color deviation. The higher color strength of white base, more impact to color deviation of tinted shade. Therefore, the severity is ranked at score 7 (major effect). It can not rate at score 8, because it does not impact to paint quality that leads to be waste. In addition, it also can not be ranked as level 9 or 10, because it does not concern with the government regulation and safety related. In terms of occurrence and detection, they are rated at level 9 because there is no formal procedure to control or detect the failure from reoccurring, only Process Engineer or Color Engineer who understand the problem can investigate. As the result, the RPN score is $7*9*9 = 567$, which is the highest RPN because it leads to color adjustment for many times.

4.1.4.2 Mixing Process

In mixing process, level of the impeller of tinting machine impacts to color deviation. It can create the homogenous paint. This leads to incorrect color shade during color measurement. Consequently, it needs to perform color adjustment for many times to achieve the target. That is the reason why the score of severity is equal 7. It does not affect to paint quality, government regulation, and safety-related. So score at level 8,9,10 is not appropriate. At the present, the ABC Company has the work instruction to set up the maximum and minimum level of paint in each container (pot, tank). It is the preventive action for this problem. Consequently, the score of occurrence is only 2 (Remote). The score of detection is equal to 4 (Moderately high) because the current work instruction and control are applicable and effectiveness to detect the failure, but sometime users doesn't follow the instruction strictly. As the result, the $RPN = 7*2*4 = 96$. It means that the existing procedure can prevent the failure effectively.

When compare the RPN of example in raw material preparation (Uncontrolled color strength of white base) with mixing process (level of impeller), it was found that the RPN of first failure cause is much higher than the second failure cause. This is because first mode does not have controlling system for preventing the

problem. Consequently, score of occurrence and detection are high. That is the reason why the first failure mode is higher than the second.

4.1.4.3 Color Panel Preparation Process

In color panel preparation process, The potential mode is wrinkle film on paper panel. This is the one of problem that impacts to color deviation till to rework. So the score of severity is 7 (major effect). It can not rate at score 8, because it does not impact to paint quality that leads to be waste. In addition, it also can not be ranked as level 9 or 10, because it does not concern with the government regulation and safety related.. The cause of problem is paint film is thicker than standard. It maybe caused by inaccuracy of paint film applicator. Normally, this problem rarely occurs (less than 9%). So the score of the occurrence is equal to 2. At the present, the existing process control is not implemented yet. Therefore, the detection is ranked to high score. It is level 9. As the result, the RPN is $7*2*9 = 126$.

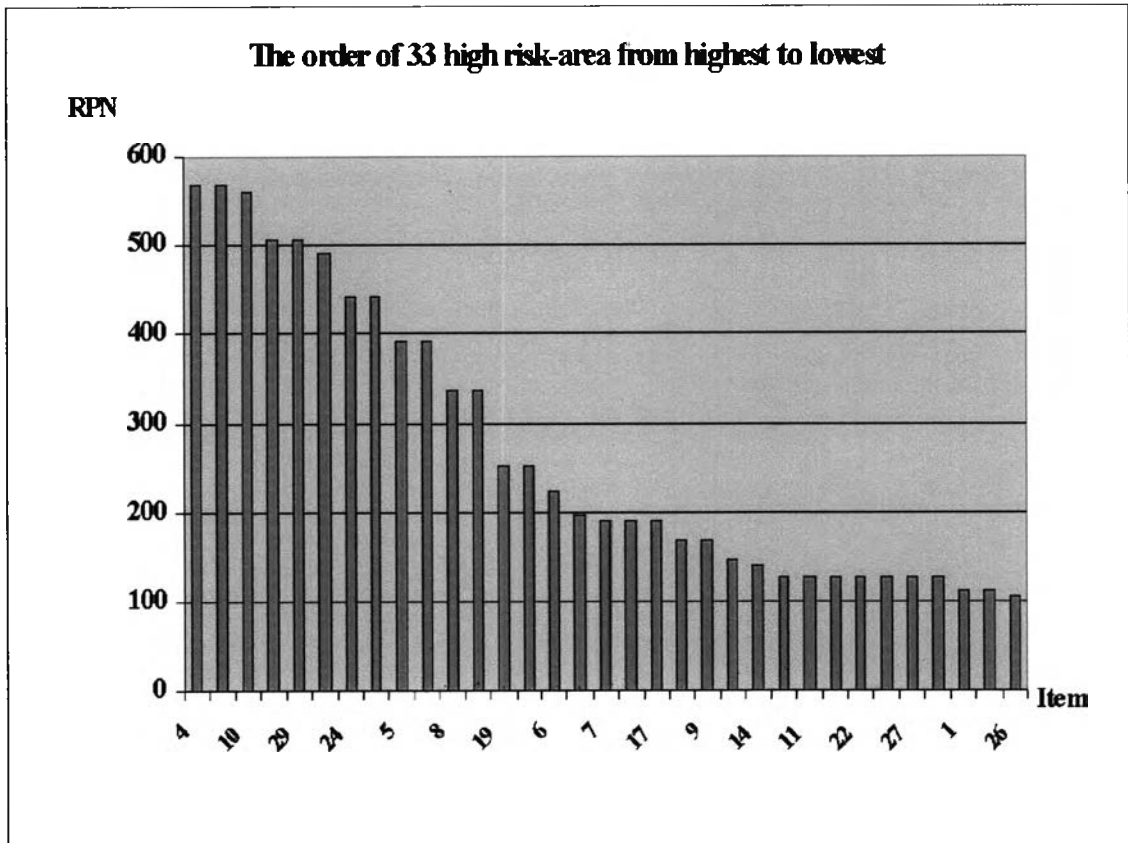
4.1.5 Results of Conducting the Process FMEA

The results of conducting the FMEA are expressed in Appendix II. Moreover, The cause and effect diagram is used for identification the root causes of each failure are also shown in Appendix I. The outcome of identification are recorded into the process FMEA form for evaluating the severity, occurrence, detection to calculate the RPN score. The critical failure mode that the RPN is higher than 100 (90% confidence) must be addressed to take the action. All of them shown as the following :

Table 4.2 : Summary the process FMEA that RPN is higher than 100 (90% confidence)

Item	Potential Failure Mode	Potential cause(s) of Failure	RPN
1	White base/ Neutral base preparation	Quality of TiO ₂	112
2	White base/ Neutral base preparation	Weight of each TiO ₂ packing	126
3	White base/ Neutral base preparation	Dust form suction dust in dissolver	168
4	White base/ Neutral base preparation	No color strength control for white base	567
5	White base/ Neutral base preparation	Quality of binder in terms of drying time	392
6	White base/ Neutral base preparation	Inaccuracy of cube applicator	224
7	White base/ Neutral base preparation	Inaccuracy of drying time recorder	189
8	White base/ Neutral base preparation	Ventilation system in drying cabinet is low efficiency	336
9	White base/ Neutral base preparation	No re inspection after drying time adjustment	168
10	Tinter preparation	Color strength of tinter are board (+/- 10%)	560
11	White base/ Neutral base preparation	Closing system for storage tank is low efficiency	126
12	White base/ Neutral base preparation	Leakage of lid seal in storage tank	112
13	Tinter storage in tinter tank	Tinter level is lower than stirring blade	189
14	Tinter storage in tinter tank	Circulation time in tinter tank is not suitable	140
15	Tinter storage in tinter tank	Stirring system is not good enough to stir the tinter	490
16	Tinter storage in pale	Operator does not stir the tinter in pale before use	126
17	Tinter storage in pale	Level of tinter is the same of level of stirring blade	189
18	Tinter storage in pale	Circulation pipe in tinter tank is too high	504
19	Tinter storage in pale	Tinter tank is dirty from dry skinning of tinter	252
20	Tinting formulation	Tinting formulation is not precision	567
21	Tinter Weighing	Accuracy of dispenser in Full machine	392
22	Uncleanness of tinting tank	Brush that use for cleaning is not suitable	126
23	Inhomogeneous paint in mixing stage	Stirring time is not suitable	147
24	High bubble in paint film	Film is too thick	441
25	Low hiding power on paint film	Inaccuracy of applicator	126
26	Low hiding power on paint film	Low skill tinting operators	105
27	Wrinkle film color panel during draw down	Inaccuracy of applicator	126
28	Dust on paint film in drying cabinet	Cleanness of drying cabinet	441
29	Dust on paint film in drying cabinet	Ventilation system does not have the filter	504
30	Long drying time of color panel	Ventilation system in drying cabinet is low efficiency	336
31	Film is not fully cure during keep in oven	Inaccuracy of temperature in oven	252
32	Film is not fully cure during keep in oven	Amount color panel in oven is too much	196
33	Wrinkle film in during curing in oven	Temperature in oven is higher set point	126

Figure 4.1 : The RPN of the High-Risk Area Ranked in Order



PROCESS FMEA (Potential Failure Mode and Effect Analysis in process)

Process Name : **Raw material preparation**
 Product Name : **Alkyd**
 Responsible person : **Process Engineer**
 Approved by : **Lab Manager**
 Team : **Piyawat R., Watcharin S., Surin P., Sawitree L., Sukanya P., Wiroteh S., Chokchai N.**

Supplied by : **Grinding section**
 Received by : **Tinting section**
 Documented by : **Piyawat R.**
 Approved date : **6/7/2002**

PFMEA Number : **02/001**
 FMEA Date (Orig.) : **5/4/2002**
 FMEA Date (Rev.) : _____
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Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential cause(s)/ Mechanism(s) of Failure	O	Current process controls	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Result				
											Action	S	O	D	RPN
White base preparation	Color strength of white base is deviation from batch to batch	Color deviation	7	Quality of TiO ₂ (%TiO ₂ , Purity whiteness)	4	Only check COA from supplier (This raw material was specified as our specification)	4	112	Revise formulation by using only TiO ₂ TR 92	Process Eng. (13/9/02)					
			7	Weight of each TiO ₂ packaging	2	No inspection but it was guarantee by Supplier	9	126	Random checking	Raw Material (10/9/02)					
			7	Dust from dust suction	3	Visual inspection	8	168	Set PM plan in dust suction pipe	Maintenance (10/9/02)					
			7	No color strength control for white base	9	No control	9	567	Set up work instruction for color strength control Specific color strength of white base in 20-25%	QC (10/9/02) Process Eng. (10/9/02)					
Score				S= Severity		O= Occurrence		D= Detection		RPN= SxOxD					

PROCESS FMEA (Potential Failure Mode and Effect Analysis in process)

Process Name : **Raw material preparation** Supplied by : **Grinding section** PFMEA Number : **02/001**
 Product Name : **Alkyd** Received by : **Tinting section** FMEA Date (Orig.) : **5/4/2002**
 Responsible person : **Process Engineer** Documented by : **Piyawat R.** FMEA Date (Rev.) : _____
 Approved by : **Lab Manager** Approved date : **6/7/2002** Page 2 of 9
 Team : **Piyawat R., Watcharin S., Surin P., Sawitree L., Sukanya P., Wiroth S., Chokchai N.**

Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential cause(s)/ Mechanism(s) of Failure	O	Current process controls	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Result					
											Action	S	O	D	RPN	
White base preparation	Long drying time of white base	Color deviation	7	Quality of binder (long drying time of binder)	7	No control	8	392	Set up work instruction to investigate before using	QC (10/9/02)						
			7	Inaccuracy of cube applicator	6	No calibration	8	224	Set up work instruction for calibration	Process Eng. (10/9/02)						
										Set up cal. schedule	Process Eng. (10/9/02)					
			7	Inaccuracy of drying time recorder	3	No calibration	9	189	1. Set up work instruction for calibration 2. Set up calibration schedule	Process Eng. (13/9/02) Process Eng. (13/9/02)						
			7	Ventilation system in drying cabinet is not good	6	No inspection and control	8	336	1. Check flow rate 2. Set PM for ventilation	Maintenance (13/9/02)						
Score				S= Severity		O= Occurrence		D= Detection		RPN= SxOxD						

PROCESS FMEA (Potential Failure Mode and Effect Analysis in process)

Process Name : **Raw material preparation** Supplied by : **Grinding section** PFMEA Number : **02/001**
 Product Name : **Alkyd** Received by : **Tinting section** FMEA Date (Orig.) : **5/4/2002**
 Responsible person : **Process Engineer** Documented by : **Piyawat R.** FMEA Date (Rev.) : _____
 Approved by : **Lab Manager** Approved date : **6/7/2002** Page 3 of 9
 Team : **Piyawat R., Watcharin S., Surin P., Sawitree L., Sukanya P., Wiroteh S., Chokchai N.**

Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential cause(s)/ Mechanism(s) of Failure	O	Current process controls	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Result				
											Action	S	O	D	RPN
White base preparation	Long drying time of white base	Color deviation	7	No checking the RH in the lab	6	No control	8	336	Install the RH controller in the laboratory	Maintenance (13/9/02)					
			7	No re inspection after adjusting drying time	6	Specify in work instruction	4	168	Set training Course	QC (10/9/02)					
Tinter preparation	Color strength of Tinters are too board (±10%)	Color deviation	7	Specification of color strength control are too board	10	Control by formulation	8	560	Revise specification for controlling from +/- 10% to ±5%	Process Eng. (13/9/02)					
White base and neutral base storage	Skinning of white and neutral base	Quality of Paint in terms of fineness	7	Closing system for storage tank is low efficiency	2	No control	9	126	1. Set up preventive maintenance	Production (13/9/02)					
									2. Training	Production (13/9/02)					
Score				S= Severity		O= Occurrence		D= Detection		RPN= SxOxD					

PROCESS FMEA (Potential Failure Mode and Effect Analysis in process)

Process Name : **Raw material preparation** Supplied by : **Grinding section** PFMEA Number : **02/001**
 Product Name : **Alkyd** Received by : **Tinting section** FMEA Date (Orig.) : **5/4/2002**
 Responsible person : **Process Engineer** Documented by : **Piyawat R.** FMEA Date (Rev.) : _____
 Approved by : **Lab Manager** Approved date : **6/7/2002** Page 4 of 9
 Team : **Piyawat R., Watcharin S., Surin P., Sawitree L., Sukanya P., Wiroth S., Chokchai N.**

Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential cause(s)/ Mechanism(s) of Failure	O	Current process controls	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Result				
											Action	S	O	D	RPN
White base and neutral base storage	Skinning of white and neutral base	Quality of Paint in terms of fineness	7	Leakage of seal of the lid	2	No control	8	112	1. Set up preventive maintenance	Production (13/9/02)					
									2. Training	Production (13/9/02)					
Tinter storage -Buffer tank -Tinter tank	Settling of tinter	Color deviation	7	Tinter level is lower than level of impeller	3	No control	9	189	Set up the min. level of tinter in buffer tank	Process Eng (13/9/02)					
				Circulation time of tinter is not suitable	5	Set up and control at PLC	4	140	Revise to Stirring every 20 min	Maintenance (13/9/02)					
				Stirring system is not good enough to stir tinter	7	No control	10	490	Set up Max and Min of tinter	Process Eng. (13/9/02)					
Tinter storage -Pail	Settling of tinter	Color deviation	7	Operator does not stir before using	2	No control	9	126	Set up the work instruction	Production (10/9/02)					
Score				S= Severity		O= Occurrence		D= Detection		RPN= SxOxD					

PROCESS FMEA (Potential Failure Mode and Effect Analysis in process)

Process Name : **Raw material preparation**
 Product Name : **Alkyd**
 Responsible person : **Process Engineer**
 Approved by : **Lab Manager**
 Team : **Piyawat R., Watcharin S., Surin P., Sawitree L., Sukanya P., Wiroth S., Chokchai N.**

Supplied by : **Grinding section**
 Received by : **Tinting section**
 Documented by : **Piyawat R.**
 Approved date : **6/7/2002**

PFMEA Number : **02/001**
 FMEA Date (Orig.) : **5/4/2002**
 FMEA Date (Rev.) : _____
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Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential cause(s)/ Mechanism(s) of Failure	O	Current process controls	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Result				
											Action	S	O	D	RPN
Tinter storage Buffer tank Tinter tank	Skinning of tinter	Color deviation and quality of Paint in terms of fineness	7	Level of tinter is nearly the same level of impeller	3	Set up minimum stock of tinter at PLC	9	189	Set up the min level of tinter in buffer tank	Process Eng (13/9/02)					
			7	Circulation pipe is too high	9	No control	8	504	1. Modify pipe pipe extension 2. Set new min. stock	Maintenance Process Eng. (13/9/02)					
			7	Tank is dirty from dry skin of tinter	4	No control	9	252	Set up cleaning procedure Set up cleaning schedule	Production (13/9/02) Production (13/9/02)					
Tinter weighing	Error of tinter weigh	Color deviation	7	Accuracy of dispenser in Full machine	7	No control	8	392	Create short form for calibration during loading Tinter into tank	Process (13/9/02)					
Tinting formulation	Starting formulation is not good	CIE of color is high	7	No verification before implement in production	9	No control	9	567	Revise new formulation sheet with verification	Color Eng. (13/9/02)					
Score				S= Severity		O= Occurrence		D= Detection		RPN= SxOxD					

PROCESS FMEA (Potential Failure Mode and Effect Analysis in process)

Process Name : **Color panel preparation**
 Product Name : **Alkyd**
 Responsible person : **Process Engineer**
 Approved by : **Lab Manager**
 Team : **Piyawat R., Watcharin S., Surin P., Sawitree L., Sukanya P., Wiroteh S., Chokchai N.**

Supplied by : **Grinding section**
 Received by : **Tinting section**
 Documented by : **Piyawat R.**
 Approved date : **6/7/2002**

PFMEA Number : **02/001**
 FMEA Date (Orig.) : **5/4/2002**
 FMEA Date (Rev.) : _____
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Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential cause(s)/ Mechanism(s) of Failure	O	Current process controls	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Result				
											Action	S	O	D	RPN
Keep it into drying cabinet	Dust on paint film	Color deviation	7	Cleanness of drying cabinet	7	No Control	9	441	Set up schedule for cleaning	Color Eng. (10/09/02)					
			7	Ventilation fan without filter	6	No control	9	504	Install the new ventilation fan with filter	Maintenance (13/09/02)					
	Long drying time of panel	Color deviation	7	Ventilation system in drying cabinet is not good	6	No inspection and control	8	336	1. Check flow rate 2. Set PM for ventilation	Maintenance (13/09/02)					
Curing film in oven	Film is not fully cure	Color deviation	7	In accuracy temperature in oven	4	No control	9	252	1. Set up work instruction for calibration 2. Set up calibration schedule	Process Eng. (13/9/02) Process Eng. (13/9/02)					
			7	Amount paper panel in oven is too much	4	Internal inform	7	196	Internal training	Color Eng. (13/9/02)					
Score				S= Severity		O= Occurrence		D= Detection		RPN= SxOxD					

PROCESS FMEA (Potential Failure Mode and Effect Analysis in process)															
Process Name : Color panel preparation			Supplied by : Grinding section			PFMEA Number : 02/001									
Product Name : Alkyd			Received by : Tinting section			FMEA Date (Orig.) : 5/4/2002									
Responsible person : Process Engineer			Documented by : Piyawat R.			FMEA Date (Rev.) : _____									
Approved by : Lab Manager			Approved date : 6/7/2002			Page 9 of 9									
Team : Piyawat R., Watcharin S., Surin P., Sawitree L., Sukanya P., Wiroth S., Chokchai N.															
Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential cause(s)/ Mechanism(s) of Failure	O	Current process controls	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Result				
											Action	S	O	D	RPN
Curing film in oven	Wrinkle film	Color deviation	7	Temperature in oven is higher than standard	2	No control	9	126	1. Set up work instruction for calibration	Process Eng. (13/9/02)					
									2. Set up calibration schedule	Process Eng. (13/9/02)					
Curing film in oven	Film yellowing	Color deviation	7	Temperature in oven is higher than standard	2	No control	9	126	1. Set up work instruction for calibration	Process Eng. (13/9/02)					
									2. Set up calibration schedule	Process Eng. (13/9/02)					
Score			S= Severity			O= Occurrence			D= Detection			RPN= SxOxD			

Table 4.3 : Summary the process FMEA that RPN is higher than 100 (90% confidence) in detail

Based on analysis, it was found that there are 33 high-risk area must be addressed. The next step is that all of RPN are ranked from the highest to lowest to set up the priority of action. It has shown as the table 4.3.

It was found that the raw material preparation process in terms of color strength (No control) and starting tinting formula (high CIE) show highest score. So they should be taken the action first because it impact directly to color adjustment. Otherwise, the tinting process in tinting section is also needed to adjust and create to the standard to reduce the RPN.

PROCESS FMEA (Potential Failure Mode and Effect Analysis in process)

Process Name : Raw material preparation	Supplied by : Grinding section	PFMEA Number : 02/001
Product Name : Alkyd	Received by : Tinting section	FMEA Date (Orig.) : 5/4/2002
Responsible person : Process Engineer	Documented by : Piyawat R.	FMEA Date (Rev.) : _____
Approved by : Lab Manager	Approved date : 6/7/2002	Page 1 of 23
Team : Piyawat R., Watcharin S., Surin P., Sawitree L., Sukanya P., Wiroteh S., Chokchai N.		

Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential cause(s)/ Mechanism(s) of Failure	O	Current process controls	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Result				
											Action	S	O	D	RPN
White base preparation	White base that color strength deviate from standard	Color deviation	7	No color strength control for white base	9	No control	9	567	1. Set up work instruction for color strength control 2. Specific color strength of white base in 20-25%	QC (10/9/02) Process Eng. (10/9/02)					
Tinting formulation	Starting formulation is not good	CIE of color is high	7	No verification before implement in production	9	No control	9	567	Revise new formulation Sheet with verification	Color Eng. (13/9/02)					
Tinter preparation	Color strength of Tinters are too board (±10%)	Color deviation	7	Specification of color strength control are too board	10	Control by formulation	8	560	Revise specification for controlling from +/-10% to ±5%	Process Eng. (13/9/02)					
Tinter Storage -Buffer tank -Tinter tank	Skinning of tinter	Color deviation and fineness of paint	7	Circulation pipe is too high	9	No control	8	504	1. Modify pipe Pipe extension 2. Set new min. stock	Maintenance Process Eng. (13/9/02)					
Score				S= Severity		O= Occurrence		D= Detection		RPN= SxOxD					

PROCESS FMEA (Potential Failure Mode and Effect Analysis in process)

Process Name : **Raw material preparation** Supplied by : **Grinding section** PFMEA Number : **02/001**
 Product Name : **Alkyd** Received by : **Tinting section** FMEA Date (Orig.) : **5/4/2002**
 Responsible person : **Process Engineer** Documented by : **Piyawat R.** FMEA Date (Rev.) : _____
 Approved by : **Lab Manager** Approved date : **6/7/2002** Page 1 of 23
 Team : **Piyawat R., Watcharin S., Surin P., Sawitree L., Sukanya P., Wiroth S., Chokchai N.**

Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential cause(s)/ Mechanism(s) of Failure	O	Current process controls	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Result			
Keep it into drying cabinet	Dust on paint film	Color deviation	7	Ventilation fan without filter	6	No control	9	504	Install the new ventilation fan with filter	Maintenance (13/09/02)				
Tinter Storage -Buffer tank -Tinter tank	Settling of tinter	Color deviation	7	Stirring system is not good enough to stir tinter	7	No control	10	490	Set up Max and Min of tinter	Process Eng. (13/9/02)				
Making draw down panel as following specification	Bubble on paint film	Color deviation	7	Film is too thick	7	WI does not suit with paint system	9	441	Revise WI	Color Eng. (13/9/02)				
Keep it into drying cabinet	Dust on paint film	Color deviation	7	Cleanness of drying cabinet	7	No Control	9	441	Set up schedule for cleaning	Color Eng. (10/09/02)				
White base preparation	Long drying time of white base	Color deviation	7	Quality of binder (long drying time of binder)	7	No control	8	392	Set up work instruction to investigate before using	QC (10/9/02)				
Score				S= Severity		O= Occurrence		D= Detection		RPN= SxOxD				

PROCESS FMEA (Potential Failure Mode and Effect Analysis in process)

Process Name : **Raw material preparation**
 Product Name : **Alkyd**
 Responsible person : **Process Engineer**
 Approved by : **Lab Manager**
 Team : **Piyawat R., Watcharin S., Surin P., Sawitree L., Sukanya P., Wiroth S., Chokchai N.**

Supplied by : **Grinding section**
 Received by : **Tinting section**
 Documented by : **Piyawat R.**
 Approved date : **6/7/2002**

PFMEA Number : **02/001**
 FMEA Date (Orig.) : **5/4/2002**
 FMEA Date (Rev.) : _____
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Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential cause(s)/ Mechanism(s) of Failure	O	Current process controls	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Result				
											Action	S	O	D	RPN
Tinter weighing	Error of tinter weigh	Color deviation	7	Accuracy of dispenser in Full machine	7	No control	8	392	Create short form for calibration during loading Tinter into tank	Process (13/9/02)					
White base preparation	Long drying time of white base	Color deviation	7	No checking the RH in the lab	6	No control	8	336	Install the RH controller In the laboratory	Maintenance (13/9/02)					
Keep it into drying cabinet	Long drying time of panel	Color deviation	7	Ventilation system in drying cabinet is not good	6	No inspection and control	8	336	1. Check flow rate 2. Set PM for ventilation	Maintenance (13/9/02)					
Keep it into drying cabinet	Long drying time of panel	Color deviation	7	Ventilation system in drying cabinet is not good	6	No inspection and control	8	336	1. Check flow rate 2. Set PM for ventilation	Maintenance (13/09/02)					
Curing film in oven	Film is not fully cure	Color deviation	7	In accuracy temperature in oven	4	No control	9	252	1. Set up work instruction for calibration 2. Set up calibration schedule	Process Eng. (13/9/02) Process Eng. (13/9/02)					
Score				S= Severity		O= Occurrence		D= Detection		RPN= SxOxD					

PROCESS FMEA (Potential Failure Mode and Effect Analysis in process)

Process Name : **Raw material preparation** Supplied by : **Grinding section** PFMEA Number : **02/001**
 Product Name : **Alkyd** Received by : **Tinting section** FMEA Date (Orig.) : **5/4/2002**
 Responsible person : **Process Engineer** Documented by : **Piyawat R.** FMEA Date (Rev.) : _____
 Approved by : **Lab Manager** Approved date : **6/7/2002** Page 3 of 23
 Team : **Piyawat R., Watcharin S., Surin P., Sawitree L., Sukanya P., Wiroteh S., Chokchai N.**

Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential cause(s)/ Mechanism(s) of Failure	O	Current process controls	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Result				
											Action	S	O	D	RPN
Tinter Storage -Buffer tank -Tinter tank	Skinning of tinter	Color deviation and quality of paint in terms of fineness	7	Tank is dirty from dry skin of tinter	4	No control	9	252	Set up cleaning procedure Set up cleaning schedule	Production (13/9/02) Production (13/9/02)	As the recommend				
White base preparation	Long drying time of white base	Color deviation	7	Inaccuracy of cube applicator	6	No calibration	8	224	1. Set up work instruction for calibration 2. Set up calibration schedule	Process Eng. (10/9/02) Process Eng. (10/9/02)	As the recommend As the recommend				
Curing film in oven	Film is not fully cure	Color deviation	7	Amount paper panel in oven is too much	4	Internal inform	7	196	Internal training	Color Eng. (13/9/02)	As the recommend				
White base preparation	Long drying time of white base	Color deviation	7	Inaccuracy of drying time recorder	3	No calibration	9	189	1. Set up work instruction for calibration 2. Set up calibration schedule	Process Eng. (10/9/02) Process Eng. (10/9/02)	As the recommend As the recommend				
Score				S= Severity		O= Occurrence		D= Detection	RPN= SxOxD						

PROCESS FMEA (Potential Failure Mode and Effect Analysis in process)

Process Name : Raw material preparation	Supplied by : Grinding section	PFMEA Number : 02/001
Product Name : Alkyd	Received by : Tinting section	FMEA Date (Orig.) : 5/4/2002
Responsible person : Process Engineer	Documented by : Piyawat R.	FMEA Date (Rev.) : _____
Approved by : Lab Manager	Approved date : 6/7/2002	Page 5 of 23
Team : Piyawat R., Watcharin S., Surin P., Sawitree L., Sukanya P., Wirotth S., Chokchai N.		

Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential cause(s)/ Mechanism(s) of Failure	O	Current process controls	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Result				
											Action	S	O	D	RPN
Tinter storage -Buffer tank -Tinter tank	Settling of tinter	Color deviation	7	Tinter level is lower than level of impeller	3	No control	9	189	Set up the min. level of tinter in buffer tank	Process Eng (13/9/02)	As the recommend				
Tinter storage Buffer tank Tinter tank	Skinning of tinter	Color deviation and quality of Paint in terms of fineness	7	Level of tinter is nearly the same level of impeller	3	Set up minimum stock of tinter at PLC	9	189	Set up the min level of tinter in buffer tank	Process Eng (13/9/02)	As the recommend				
White base preparation	White base that color strength deviate from standard	Color deviation	7	Dust from dust suction	3	Visual inspection	8	168	Set PM plan in dust suction pipe	Maintenance (10/9/02)	As the recommend				
White base preparation	Long drying time of white base	Color deviation	7	No re inspection after adjusting drying time	6	Specify in work instruction	4	168	Set training Course	QC (10/9/02)	As the recommend				
Mixing	Inhomogeneous paint in mixing stage	Color deviation	7	Stirring time does not suitable	3	Specify into the formulation	7	147	Create short form	Color Eng. (13/9/02)	As the recommend				
Score				S= Severity		O= Occurrence		D= Detection		RPN= SxOxD					

PROCESS FMEA (Potential Failure Mode and Effect Analysis in process)

Process Name : **Color panel preparation** Supplied by : **Grinding section** PFMEA Number : **02/001**
 Product Name : **Alkyd** Received by : **Tinting section** FMEA Date (Orig.) : **5/4/2002**
 Responsible person : **Process Engineer** Documented by : **Piyawat R.** FMEA Date (Rev.) : _____
 Approved by : **Lab Manager** Approved date : **6/7/2002** Page 7 of 23
 Team : **Piyawat R., Watcharin S., Surin P., Sawitree L., Sukanya P., Wiroth S., Chokchai N.**

Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential cause(s)/ Mechanism(s) of Failure	O	Current process controls	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Result				
											Action	S	O	D	RPN
White base and neutral base storage	Skinning of white and neutral base	Quality of Paint in terms of fineness	7	Closing system for storage tank is low efficiency	2	No control	9	126	1. Set up preventive maintenance	Production (13/9/02)	As the recommend				
									2. Training	Production (13/9/02)	As the recommend				
Tinter Storage -Pail	Settling of tinter	Color deviation	7	Operator does not stir before using	2	No control	9	126	Set up the work Instruction Training tinting operators	Production (9/10/02) Process Eng.	As the recommend				
Tinting m/c container preparation	Uncleanness of tinting m/c	Color deviation	7	Brush for cleaning is not suitable	6	-Visual inspection	3	126	Modify the equipment to match with cleaning	Production (13/9/02)	As the recommend				
White base preparation	Color strength of white base is deviate from batch to batch		7	Weight of each TiO ₂ packaging	2	No inspection but it was guarantee by supplier	9	126	Random checking	Raw Material (10/9/02)	Set up WI and random checking				
			Score	S= Severity		O= Occurrence		D= Detection		RPN= SxOxD					

PROCESS FMEA (Potential Failure Mode and Effect Analysis in process)																
Process Name : Color panel preparation			Supplied by : Grinding section			PFMEA Number : 02/001										
Product Name : Alkyd			Received by : Tinting section			FMEA Date (Orig.) : 5/4/2002										
Responsible person : Process Engineer			Documented by : Piyawat R.			FMEA Date (Rev.) : _____										
Approved by : Lab Manager			Approved date : 6/7/2002			Page 8 of 23										
Team : Piyawat R., Watcharin S., Surin P., Sawitree L., Sukanya P., Wiroth S., Chokchai N.																
Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential cause(s)/ Mechanism(s) of Failure	O	Current process controls	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Result					
											Action	S	O	D	RPN	
Curing film in oven	Film yellowing	Color deviation	7	Temperature in oven is higher than standard	2	No control	9	126	1. Set up work instruction for calibration	Process Eng. (13/9/02)	As the recommend					
									2. Set up calibration schedule	Process Eng. (13/9/02)	As the recommend					
White base and neutral base storage	Skinning of white and neutral base	Quality of Paint in terms of fineness	7	Leakage of seal of the lid	2	No control	8	112	Set up preventive maintenace	Production (13/9/02)	As the recommend					
Making panel as the following specification	Low hiding power of paint film	Color deviation	7	Low skill operator	3	Training	5	105	Set up training	Color Eng. (13/10/02)	As the recommend					
Score			S= Severity			O= Occurrence			D= Detection			RPN= SxOxD				

Table 4.4 : The RPN summary that rank from highest score to lowest score at 90% confidence

The FMEA team have meeting to generate the recommendation and action plan to reduce for each failure in process FMEA. It can conclude as following :

Table 4.5 : The summary Action for FMEA Project

Production :

Topic	Due Date	Remark
1. Create preventive maintenance plan (PM Plan)		
• Closing system for storage tank (Base and Holding Tank)	13/9/02	To prevent the base skinning
• Leakage of seal of storage tank lid (Base and Holding Tank)	13/9/02	To prevent the base skinning
• Untight close of storage tank lid (Tinter Tank)	13/9/02	To prevent the tinter skinning
2. Set up work instruction		
• Cleaning procedure for tinter tank/ cleaning schedule	23/9/02	To reduce risk of dry skinning of tinter tank
• Cleaning procedure for buffer tank/ cleaning schedule	23/9/02	To reduce risk of dry skinning of tinter tank
• Operator does not stirring the tinter in pail before using (Tinter pail handleing)	10/9/02	To prevent the settling of tinter
4. Training		
• Pot scale instruction	23/9/02	
• Full machine instruction	23/9/02	
• Cleaning procedure for tinter tank/ cleaning schedule	23/9/02	
• Cleaning procedure for buffer tank/ cleaning schedule	23/9/02	

Maintenance :

Topic	Due Date	Remark
1. Create preventive maintenance plan (PM Plan)		
• Set up PM plan for dust suction pipe for dissolver	10/9/02	To prevent the contaminate of dust suction pipe with the batch
• Study the feasibility to modify the stirring system in tinter tank	10/9/02	Coordinate with Process Eng. Improve homogenous of tinter, and prevent settling
• Set up PM plan for ventilation system in drying cabinet	13/9/02	To ensure the ventilation system in drying cabinet
2. Miscellaneous		
• Revise stirring time in tinter tank from every 30 min to 20 min	13/9/02	To prevent the tinter setting
• Set the schedule of printing the record of PLC in terms of re circulation of buffer tank	13/9/02	To ensure that re circulation is working
• Install new ventilation fan with filter	13/9/02	To reduce dust on paint film.
• Install the Relative Humidity Controller	13/9/02	To control the drying time of white base and neutral base

Raw material :

Topic	Due Date	Remark
1. Create check sheet (Short form)		
• Create short form for raw material weight checking plan	10/9/02	To ensure the weight of TiO ₂

QC :

Topic	Due Date	Remark
1. Set up Work Instruction		
• Quality of binder in terms of drying time	10/9/02	To ensure quality of binder in terms of drying time
• Work Instruction for color strength control in white base	13/9/02	To control the color strength of white base before releasing into tinting section
2. Training		
• Draw down paint on drying time panel and re inspect after drying time adjustment	23/9/02	To ensure the drying time of white base and neutral base before release to tinting section
• Color strength control for white base	23/9/02	Coordinate with Process Engineer
• Color strength control for tinter	23/9/02	Coordinate with Color Engineer

Color Engineer :

Topic	Due Date	Remark
1. Set up Work Instruction		
• Scaling instruction of paint in each container	13/9/02	To prevent unsuitable volume with tank
• Create short form of speed, stirring time of paint	13/9/02	To ensure that paint is homogenous
• Revise work instruction of color panel preparation	13/9/02	Reduce error in color panel preparation
• Revise the formulation sheet for new color (CIE, Verify)	13/9/02	Reduce correction time
2. Miscellaneous		
• Set up the schedule for drying cabinet cleaning	13/9/02	To prevent the dust on paint film panel
3. Training		
• Basic for tinting	23/9/02	
• Speed and stirring time for each batch size	23/9/02	
• Color panel preparation	23/9/02	

Process Engineer :

Topic	Due Date	Remark
1. Revise formulation		
• Specify the TiO ₂ TR-92 for Alkyd White Base	13/9/02	To control quality of paint
• Specify the color strength for Alkyd White base at 20-25% to control the color quality	03/9/02	To control quality of paint
• Revise the specification of tinters for controlling the color strength from $\pm 10\%$ to $\pm 5\%$	13/9/02	To control quality of tinter
• Confirm the formulation for trial	23/9/02	To ensure the formulation before releasing in the production
2. Set up Work Instruction		
• Calibration for Full machine after loading the new tinter into tank	13/9/02	To ensure the accuracy of tinter weigh during weighing
• Calibration of applicator/ Set up the calibration schedule	10/9/02	To ensure the precision of applicator
• Calibration of drying time recorder/ Set up the calibration schedule	13/9/02	To ensure the precision of drying time recorder

Topic	Due Date	Remark
2. Set up Work Instruction		
<ul style="list-style-type: none"> Set up the minimum and maximum level of tinter in tinter tank and buffer tank 	13/9/02	To reduce the skinning problem and create homogenous of SI tinter
<ul style="list-style-type: none"> Calibration thermometer for production line/ Set up the calibration schedule 	13/9/02	To ensure the precision of thermometer
<ul style="list-style-type: none"> Calibration the temperature in oven/ Set up the calibration schedule 	13/9/02	To ensure the precision of temperature in oven
3. Training		
<ul style="list-style-type: none"> Basic of paint processing 	23/9/02	

After action plan is done, the FMEA team implements the FMEA in tinting section in October 2002. We collect the data of amount correction times and process time in tinting section compare with before implement the FMEA.