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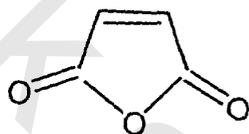
2.1 RAW MATERIALS

2.1.1 Acids and Acid Anhydrides

a- Maleic anhydride (MA)

Systematic name: cis-butenedioic anhydride

Formula:



This dibasic acid obtained from Aldrich Chemical Co. Ltd. (UK). It is a white powder, having molecular weight 98.06 g/mol, melting point 54-56°C and boiling point 200°C.

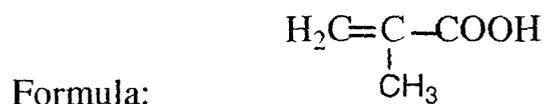
b- Acrylic Acid (AA)

Formula:



It is obtained from Aldrich Chemical Co. Ltd. (UK) with the following specifications: molecular mass 72.06 g/mol, boiling point 139°C, melting point 13°C, and density 1.051g/cm³.

c- Methacrylic Acid (MA)

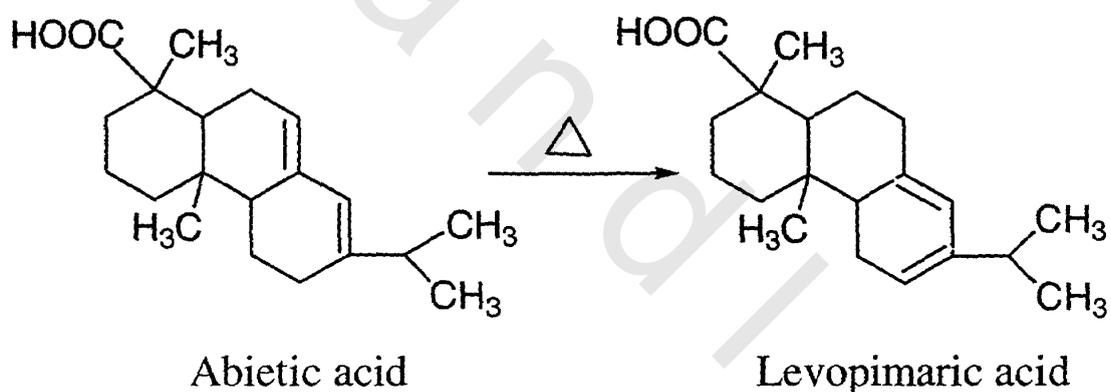


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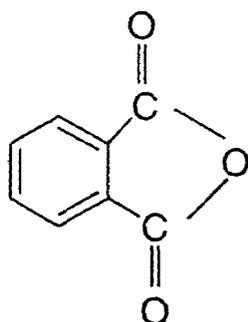
It is purchased from Aldrich Chemical Co. Ltd. (UK) with the following specification: Molecular mass 86.09 g/mol, boiling point 163°C, melting point 16°C, and density 1.015g/cm³.

d-Rosin Acids

Rosin is a solid resinous material obtained naturally from pine trees. Rosin is composed of approximately 90 % rosin acids (abietic and pimaric acids) and 10 % non acidic materials. Rosin was heated at 150°C for 4 hr then heated at 200 °C at 0.5 hr in nitrogen atmosphere to isomerize to leveopimaric acid, then it was separated by crystallization from the cold acetone solution of commercial rosin. [23]



e) Phthalic anhydride



It was obtained from Aldrich Chemical Co. ltd (UK) and it is a white crystalline solid have the following specifications:
M.wt:148.12 g/mol M.p131 - 134 °C B.p: 284 °C

f) Adipic acid (hexane – 1, 6 –dioic acid)

Formula: $\text{HOOC}(\text{CH}_2)_4\text{COOH}$

It is crystalline solid material, it was obtained from ADWIC Company and has the following specifications:

M.wt: 146.14 g/mol M.p: 152 °C B.p: 265 °C

2.1.2 Glycols

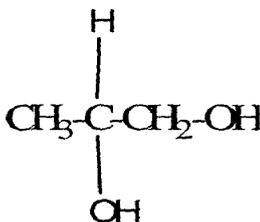
a- Ethylene glycol (EG)

Systematic name: 1, 2-dihydroxy ethane.



EG was obtained from Aldrich Chemical Co. Ltd. (UK). It is a colorless, liquid, miscible with water and having molecular mass 62.07 g/mol, density 1.113 g/cm³, melting point -13°C, boiling point 196-198°C.

b) Propylene glycol (1, 2 – propanediol)

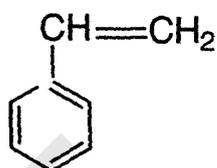


It was obtained from ADWIC Laboratory Chemicals. It has the following specifications: M.wt: 76.1 g/mol B. p : 186 – 188 °C

d : 1.04 g/cm³

2.1.3 Reagents

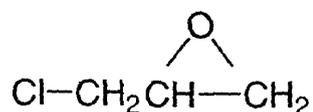
a) Styrene



It is a colorless, liquid, containing hydroquinone as an inhibitor. It is immiscible with water but miscible with benzene, toluene and carbon tetrachloride. Quoted specifications of styrene monomer, which was obtained from SIR Company. It has molecular mass 104.15 g/mol,

m. p. -310°C, b. p. 145°C, and n_D^{20} 1.5458.

b) Epichlorohydrine (EC)

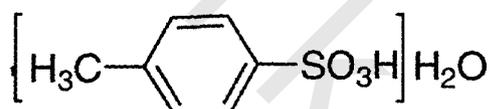


It was obtained from Aldrich Chemical Co. Ltd. (UK) with molecular weight 92.53 g/mol. m. p. -57°C, b. p. 115-117°C and density 1.183 g/cm³.

2.1.4 Catalysts, inhibitor, Activator and Initiator

A) Catalyst

1) p- Toluene sulphonic acid monohydrate (PTSA)



It was obtained from Aldrich Chemical Co. ltd (USA) with the following specifications :

M.wt: 190.2 g/mol M.p : 103 - 106 °C

2) Sodium hydroxide

It was purchased from ADWIC Laboratory Chemicals, packed and distributed by EL- NASR Company for Pharmaceutical Chemicals.

3) Triphenyl Phosphite (Ph₃P)

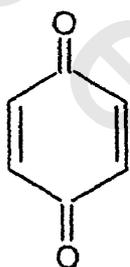
Formula:



It was obtained from Aldrich Chemical Co. Ltd. (UK) with the molecular mass 310.29 g/mol. melting point 22-24°C, boiling point 360°C and density 1.184 g/cm³.

B- Inhibitor

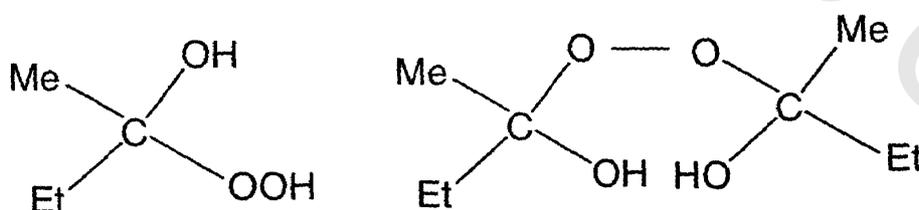
Hydroquinone (HQ)



It is a white solid crystal obtained from Aldrich Chemical Co. Ltd. (UK) with the molecular mass 326.44 g/mol., melting point 173-175. HQ was used as an inhibitor to stop the polymerizable unsaturated polyester obtained.

C- Initiator

Methyl Ethyl Ketone Peroxide (MEKP)



It is a colorless liquid obtained from SIR Company. MEKP was used as initiator for curing of unsaturated polyester. MEKP was supplied as a 50% paste in dimethyl phthalate.

D- Activator***Cobalt Octoate (Co)***

It is a violet liquid obtained from SIR Company. It is a 10% solution of cobalt octoate in styrene and used as an activator for curing of unsaturated polyester.

2-1-5. Solvents

High purity grade toluene, ethanol, acetone, pyridine, acetic acid & its anhydride, and methylene chloride (purchased from Aldrich) were used as received.

The following solvents were used:

Solvent	Source	B .p (°C)
Acetone	Aldrich Chemical Co. Ltd (USA)	56
Toluene	Aldrich Chemical Co. Ltd (USA)	111
Xylene	Aldrich Chemical Co. Ltd (USA)	138
Methanol	Aldrich Chemical Co. Ltd (USA)	64
Benzene	Aldrich Chemical Co. Ltd (USA)	80-81
Chloroform	Aldrich Chemical Co. Ltd (USA)	60.4

2-2 PROCEDURES

2-2-1 Synthesis of the Rosin Diels – Alder Adducts^[147,148]

A) Synthesis of maleopimaric acid MPA

Maleopimaric acid (MPA) was synthesized according to following method: 90 g (0.298 mol) of levopimaric acid and 29.5 g (0.3 mol) of MA were melted and reacted at 150°C for 2 hr under N₂. The cooled solid mass was dissolved in diethyl ether and slowly poured into hexane to give crude MPA (m.p:220°C), washed with ice-cold glacial acetic acid and dried under vacuum at 130-140°C for 5 hr (m.p: 229°C, yield 57%).

B) Synthesis of acrylopimaric acid (APA)

Ten g rosin and 2.4g acrylic acid containing 0.5% hydroquinone were heated under N₂ at 140 °C for 2 hr, 160 °C for 2 hr and finally at 175 °C for 1 hr. The solid mass was then cooled and washed thoroughly and repeatedly with water to remove unreacted acrylic acid. The adduct was finally purified by reprecipitation with petroleum ether from diethyl ether solution.

2.2.2 Synthesis of MPA/EG ester

A mixture of freshly distilled EG (2.2 mole), MPA (1 mole), PTSA (1 %) based on total weight of reactants and 20 ml xylene were placed in 0.5 L round-flask fitted with Dean Stark apparatus. The mixture was

allowed to reflux by heating mantle until (2 mole; 3.6 ml) of water was collected. Xylene was distilled off from the reaction product by rotary evaporator under reduced pressure.

2.2.3 Preparation of polyester resins:

There are many potential starting materials available for making polyester resins one or more of a variety glycols can be used. The UP resin was prepared by reacting the APA or MPA products with glycol EG or PG with MA. Maleic anhydride, phthalic anhydride and saturated acid (adipic acid) are suitable to modify the structure of the prepared polyester.

Apparatus: A 1.0 L four necked flask is equipped with a mechanical stirrer, thermometer, nitrogen inlet and a side arm joined to a Dean and stark receiver equipped with normal water cooled lei big condenser used for initial refluxing period, **figure (2.1)** and the position of the condenser can be changed when it is necessary to distill off the water of the reaction. Nitrogen gas was used as inert atmosphere to prevent darkening also it serves the added functions of agitation and of expediting the removal of water formed by reaction. Exclusion of oxygen is desirable not only because it causes discoloration, but also it tends to produce premature polymerization at the used elevated temperature.

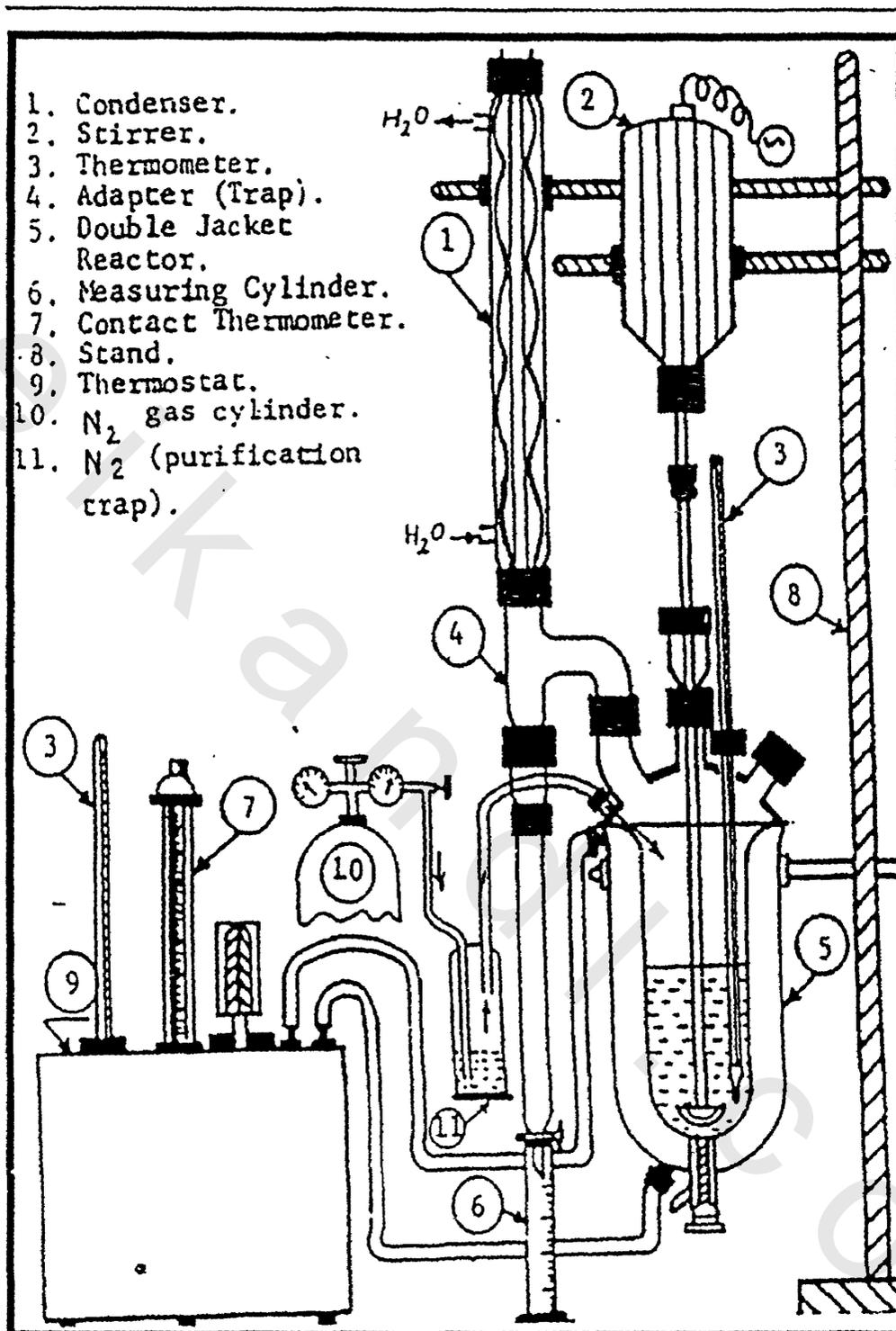


Figure (2.1): Esterification Reaction Flask.

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Procedure: The unsaturated polyester (UP) having different chemical structure was obtained. MA was added at the ratio of OH/COOH 1.1/1 (mol/mol). The reactions were carried out in an esterification reactor (as represented in **Figure (2.1)**) equipped with stirrer, thermometer, Dean-Stark side arm, and nitrogen inlet. The UP resins were prepared by reacting 1.1 mole of glycols, such as EG, PG or glycol of Rosin acid adduct of MA and AA, 0.5 mole of MA and 0.5 mole of saturated aromatic and aliphatic acids, such as adipic acid and phthalic anhydride, in the resin kettle **Figure (2.1)** the polyesterification reactions were carried out under a slow stream of dry nitrogen gas. The reactants were heated from room temperature to 180 °C in about 1.5hr. The temperature was then persevered at 180 °C for about 3hr and finally raised to 200°C and maintained till the expected water quantity was removed. The extent of reaction was followed by monitoring the water volume as a cool under nitrogen to 60°C or just below. About 1000 ppm of hydroquinone is added as inhibitor to avoid the polymerization of the product.

The unsaturated polyester resin (UP) was dissolved in adequate amount of CH₂Cl₂ and then an equal volume of distilled water was added to reaction products. The mixture was shaken by means of a flask shaker for half an hour and it was then left to separate. The organic layer was separated and the solvent was evaporated by means of a rotary evaporator. The purified samples were placed in a vacuum oven and weighed at intervals of time until constant weight was attained for the sample. The polyester was viscous liquids having dark yellow to pale brownish color was diluted by a sufficient quantity of styrene monomer to give 60% solution of polyester.

Table (2.1): Composition of Different Formulae of Unsaturated Polyester Resins.

Designation	Glycol composition (mole)		Acid composition (mole)				
	EG	PG	APA	MPA	MA	PA	AdA
APAUP1	1.1	—	0.5	—	0.5	—	—
APAUP2	1.1	—	0.34	—	0.34	0.34	—
APAUP3	1.1	—	0.34	—	0.34	—	0.34
APAUP4	—	1.1	0.5	—	0.5	—	—
APAUP5	—	1.1	0.34	—	0.34	0.34	—
APAUP6	—	1.1	0.34	—	0.34	—	0.34
MPAUP1	1.1	—	—	0.5	0.5	—	—
MPAUP2	1.1	—	—	0.34	0.34	0.34	—
MPAUP3	1.1	—	—	0.34	0.34	—	0.34
MPAUP4	—	1.1	—	0.5	0.5	—	—
MPAUP5	—	1.1	—	0.34	0.34	0.34	—
MPAUP6	—	1.1	—	0.34	0.34	—	0.34

The composition and mole ratio of reactants were listed in **Table (2.1)**. The designations of the UP resins with MPA and APA were also listed in this table.

2-2-4: Synthesis of Vinyl Ester of Rosin

A. Synthesis of Glycidyl Ether of MPA /EG

In humidity –protected 1L glass reactor equipped with a mechanical stirrer ,dropping funnel and condenser, (49.0 g, 0.1 mole) MPA /EG and 1% of $\text{BF}_3(\text{OC}_2\text{H}_5)_2$ were placed and heated at 40 °C then (92.5 g, 1 mole) epichlorohydrine was added drop wise during 2hr. The reaction mixture was heated at 60 °C for 0.5 hr and then cool to 40 °C after that 1 mole of NaOH 50% aqueous solution was added drop wise, the mixture washed at 80 °C for 0.5 hr and after cooling the mixture was neutralized with 50 % acetic acid. Then 200 ml Toluene was added and the resulting mixture filtered NaCl salt washed with 50 ml of toluene. The filtrate was washed four times with hot water and toluene which removed by distillation under reduced pressure.

B. Synthesis of Acrylate and Methacrylate Vinyl Esters of Rosin

MPA/ EG epoxy resin (0.11 mol) was mixed with (0.2 mol) of acrylic acid, AA or methacrylic acid, MA, 1% of triphenyl phosphite, 0.5% of hydroquinone and diluted with 5% of toluene into reaction flask (**figure 2.1**). The reaction temperature rose up to 95°C and the reaction was preceded until 0.2 mol of water was separated using Dean–Stark separator. The synthesized acrylate and methacrylate resins of MPA/ EG were purified by extraction with ethanol, distilling off the solvent under

reduced pressure. The viscous products were washed with sodium bicarbonate, NaHCO_3 aqueous solution to remove unreacted acid until the washings become neutral. The products were dried over anhydrous sodium sulphate, $\text{Na}_2\text{SO}_4 \cdot 2\text{H}_2\text{O}$, filtered and vacuum-distilled. They had a yellow oily liquid appearance.

The diacrylate and dimethacrylate oligomers of MPA/ EG are designated here as AVEMPR and MAVEMPR, respectively.

2.3 CHARACTERIZATION OF THE OBTAINED PRODUCTS.

2.3.1 ^1H NMR-Spectroscopy

The prepared compounds were dissolved in CDCl_3 and analyzed using Varian ^1H NMR spectrometer model JNM-EX (300 MHz) for determining their chemical structures.

2.3.2 IR-SPECTROSCOPY

The chemical structures of the prepared compounds were characterized by FTIR-spectroscopy using FTIR-spectrophotometer type [Mattson-Infinity series bench to P 961]. The wave number and intensities of IR bands of the different types of the function groups were determined a between of $500\text{-}4000\text{ cm}^{-1}$.

2.3.3 DETERMINATION OF MOLECULAR MASS OF UP RESIN

The molecular weight of the prepared unsaturated polyester resin (UP) was determined by the end-group analysis. UP was analyzed for both acid number (A) and hydroxyl value (B) in (mg KOH/g of resin).

The hydroxyl value is determined by take a 2.0 g of UP is weighed to the nearest milligram into a 100 ml round –bottom flask. To dissolve the

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sample, 25 ml of a mixture of (5 ml acetic anhydride and 25 ml pyridine) is added by pipit. The solution is refluxed for 1h, the condenser is then washed out by the addition of 5 ml water through the top, and the heating is continued for 5 min. The heat is then removed and the condenser tube and tip washed with 25 ml methanol. When the mixture has cooled to room temperature, it is titrated with approximately 0.5N standard potassium hydroxide solution to phenolphthalein end-point. This is value "S", taken as mg KOH/g. A blank is then run on a mixture of the same volumes used above of acetic anhydride-pyridine reagent and water, this value is "b". [112]

$$\text{OH}_{\text{no.}} = \frac{b + (wa/c) - S}{w} \times N \times 56.1 \quad (2.1)$$

Where : **a** ml of KOH solution required for the acidity titration.

b :ml of KOH solution required for blank titration.

c : weight of sample used in acid value determination in gram.

s : ml of KOH solution required for titration of acetylated sample.

w : weight of sample used for the acetylation in gram .

N : normality of alcoholic KOH.

The acid value was determined by titrating the solution of the weighted quantity of resin in acetone, with a standard alcoholic KOH solution ($\approx 0.5N$) using phenolphthalein as an indicator [113].

$$\text{COOH}_{\text{no.}} = \frac{N \times V \times 56.1}{w} \quad (2.2)$$

The number average molecular weight M_n was then, calculated from the following equation [114]

$$\langle Mn \rangle = \frac{2 \times 56.1 \times 1000}{B} \quad (2.3)$$

$$\langle M_n \rangle = \frac{2 \times 56.1 \times 1000}{A + B} \quad (2.4)$$

2.3.4 DETERMINATION OF PEAK EXOTHERM OF CURING

The curing exotherm of unsaturated polyesters and the prepared vinyl ester resins with styrene and cross-linkers were measured by Digitron digital differential thermometer, type K, model 3202 with a resolution 0.1°C, as described in the previous work [101, 102]. The reaction mixture of (UP & cross-linkers) was thermostated at (35, 45, 55 °C) for about 5min. Then the appropriate amount of accelerator and initiator were added successively and mixed thoroughly for 1 min in case of UP. The reaction mixture was poured into a test tube and a glass bottle of 5 ml. To achieve the reproducibility of the measurements and affording a comparative study, the volume and the shape of the curing glass bottles, used in all experiments were kept constant. The curing zero time was considered of the moment at which the initiator is added to the reaction mixture of UP. The maximum curing temperature (T_{max}) was taken as the highest value in the temperature / time curve, whereas t_{max} is the time required acquiring T_{max} . The concentration of methyl ethyl keton peroxide, MEKP (initiator) and cobalt octoate, Co (accelerator) was kept constant all over the curing reactions as 2 and 0.2 (wt %), respectively. The concentration of vinyl ester resins was varied from 5 to 20 (wt %) based on weight of UP and styrene mixtures.

2.4 TESTING OF THE COATINGS

• **Preparation of steel panels for testing** ^[115]

Before blast cleaning and application of the coating system, the panel shall be free of all surface contaminants. Oil, grease, and other contaminants shall be removed by suitable solvent, detergent or potable water. The treatment involved the following steps:

- Remove the rust by hand tool cleaning (wire brush or sanding paper) to achieve the requirements of St2, SIS 05590 and BS 7079.
- The rust free panels wiped vigorously on both sides with a cloth wet with methanol.
- The panels were allowed to dry at room temperature (15 minutes). Then rubbed briskly with clean, lint less cloth to remove any adhering dirt.
- Then, the panels were dipped in phosphoric acid (1:1) at 25°C for one minute and rinsed immediately by distilled water for a minimum 15sec.
- The panels were dried at a temperature between 50°–100°C and coated immediately or stored in desiccators for future use.
- The panels should not be touched with the fingers during the process of preparation.
- The coated panels should be scribed to bare steel; the scribe line was approximately 10cm.

2.4.1 Measurements of film thickness ^[116]

- Measuring DFT directly with non-destructive test is the most widely used method: The instrument used for measuring the dry film thickness (DFT) was the "*Minitest microprocessor coating thickness gauge, Model 2100*", manufactured by ELECTRO – PHYSIK Germany.

2.4.2 Pull – Off strength of coating using portable adhesion testers ^[117]

This test method covers a procedure for evaluating the pull – off strength (commonly referred to as adhesion). Generally, there are two field tests for the adhesion of coatings, the first is pull – off adhesion and the second is Hydraulic adhesion test, which is carried out as follow:

- Sand rough the dollies and area of the painted surface with a sandpaper
- Degrease the dollies and the painted surface using a suitable solvent and dry them before use.
- Mix the 2 pack solvent less epoxy in the correct ratio before applying it on to the dollies, press the dollies to the surface and turn them 360° in order to ensure that most of the glue is squeezed out.
- Before the pull – off test is accomplished cut through the cured adhesive and the paint coating to the substrate , round the circumference of the test cylinder using a cutting device , extreme care is required to prevent micro – cracking in the

coating, since such crack may cause failure at diminished strengths.

- The instrument measures the force in Kg / cm² , PSI or MPa

2.4.3 Flexibility (BEND) test ^[118]

The test was performed to determine the adhesion power of the varnish to the substrate by the bending apparatus. 5x15 cm tin panel was coated by the varnish, and dried. The panel was placed into the bending apparatus (0.3 cm diameter) in such away that the surface of the panel was directed out side. The apparatus was then opened and the panel was examined carefully to find out any cracking or dislodging of the film as criterion of loss of consistency of the film. The varnish was considered satisfactory if no marks for cracking or dislodging are observed after bending.

2.4.4 Resistance to mechanical damage (IMPACT RESISTANCE) ^[119]

The impact resistance of the coating on the steel panels shall be tested by means of dropped steel ball of two pounds (890 gm) from a 1,00m height. After impact, no cracks shall be visible by a magnification of ten times. When the area of the impact and the area of 5mm around the impressed area shows flakes after scratching with a sharp needle the coating failed.

2.4.5 CHEMICAL RESISTANCE TESTING

- *HOT WATER RESISTANCE* [120]

The coated panels were placed in a beaker containing about 7cm (2.5in) of distilled water at room temperature and allowed to remain in the water for 24 hours or other suitable period. The edges of the panels were sealed by paraffin wax. The panel was then removed from the water, wiped carefully and allowed to dry at room temperature. The panel was tested for any change. For longer testing period, the test liquid was changed at least every 72 hours to avoid contamination. To accelerate the test, the same procedure was applied with the exception that water was gently boiled throughout the immersion period, which may be from 15 minutes to several hours. The panels were removed and examined. The films were considered not affected when no film defects were observed after 24 hours immersing or 15 minutes in boiling water.

The procedures used to evaluate the hot water resistance of the coatings were as follows:

- The test panels were immersed in hot water (85°C) for 48h then; removed from the water, rinsed and lightly brushed in warm tap water.
- The test panels were cooled to room temperature (25°C).
- The coat was cut to bare steel with a razor blade as follow:
 - i) Two parallel cuts have 1.3 cm long, were made 0.6cm a part.
 - ii) One cut has 0.6cm long, was made between two adjacent ends of the parallel cuts.
 - Attempts were made to lift the coating, between the parallel cuts, from the test panel with a dull knife blade. The coating

failed the hot water resistance test if the coating could be lifted from the test panel and passed the test if the coating could not be lifted from the test panel ^[119].

- *SOLVENT RESISTANCE TEST* ^[122]

- *Immersion Testing*

The coated panels were immersed in benzene / mineral turpentine solvent mixture (1:3 by volume) for 15 minutes at room temperature. The panels were removed from the test solvent followed by drying in vertical position for one hour. The panels were then tested for any defects.

The coated panels were immersed in diesel fuel and the changes were observed periodically. Visual inspection is made to determine softening of the film or separation from the substrate, which may take the form of wrinkling or blistering. Results are rated by number, with 10 indicating virtually no effect, and 0 indicating complete failure. In-between scores are subjective ^[123]

- ***Acetone Rub Test***

A cotton tissue was drained with acetone and then rubbed 100 times forwards and backwards over one spot of cured coating. A complete cross-linked polymer should show no changes on the film surfaces after this treatment ^[124].

- **ACID AND ALKALI RESISTANCE TESTS** ^[121].

The acid and alkali resistance of coated panels with cured UP resins were determined after immersion in 10% HCl and 5% NaOH aqueous solutions using distilled water. The period of test was 90 days at 38°C. The tested panels were examined to determine the degree of adhesion and visual

- **The resistance to the corrosive environments was assessed using the procedure outlined in** ^[125].

The cured materials were cut into cubic shape and immersed in the corrosive media (hydrochloric acid 32 wt%, sulphuric acid 25 wt%, sodium hydroxide 5 wt% solutions, and uncut Kerosene), in large glass bottles and placed in an oven at 25°C. The concentrated hydrochloric acid medium was replaced every 6 weeks. The sulphuric acid and sodium hydroxide were replaced at each withdrawal. Cubic cured materials were withdrawn for testing at 3 monthly intervals. The materials were passed the test when their color and weight are not changed.

2. 4.6 CORROSION RESISTANCES

The coated steel panels to be tested were exposed to salt spray (Fog) corrosion cabinet, manufactured by Sheen Instruments LTD. England,

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for a period of 700 hours. This cabinet is used to measure the corrosion resistance of materials and components. This cabinet is designed to expose test pieces to aggressive environments that simulate prolonged exposure in natural environment. It gives better correlation between accelerated laboratory tests and “real-world” exposure. The salt solution is pumped to the atomizer via a variable speed peristaltic pump. This ensures accurate control and monitoring of the salt fog out rates ^[126].

- ✓ **Salt Solution:** The salt solution prepared by dissolving 5 ± 1 parts by weight of sodium chloride in 95 parts of water.
- ✓ **Position of Specimens During Test**

The position of the specimens in the salt spray chamber during the test shall be supported or suspended between 15 and 30° from the vertical and preferable to the principal direction of horizontal flow of fog through the chamber.

- ✓ **Air Supply**

The air supply to the nozzle for atomizing the salt solution shall be free of oil and dirt and maintained between 69 and 172 KN/m² (10 and 25 psi)

- ✓ **PERIOD OF TEST**

The test method does not prescribe the type of the test specimen or exposure periods to be used for a specific product. The period of test shall be as designated by the specifications covering the material or product being tested, but exposure periods of multiples of 24 h are suggested. The films were examined for any defects such as blistering and rusting.

✓ **Evaluation of Painted Specimens Subjected to Environments (SCRIBE FAILURE) ^[127]**

This test method covers the treatment of previously painted or coated specimens for accelerated and atmospheric exposure tests and their subsequent evaluation in respect to corrosion and blistering associated with corrosion, loss of adhesion at scribe mark and other film failure. Painted or coated specimens subjected to a corrosive environment are evaluated by record the average (mean) maximum and minimum creep age from the scribe mark. Record creep values in millimeters, inches, or rating numbers as represented in *table (2.2)*.

Table (2.2): Rating of Failure at Scribe

Millimeters	Inches (Approximate)	Rating Number
Zero	0	10
Over 0 to 0.5	0 to 1/64	9
Over 0.5 to 1	1/64 to 1/32	8
Over 1 to 2	1/32 to 1/16	7
Over 2 to 3	1/16 to 1/8	6
Over 3 to 5	1/8 to 3/16	5
Over 5 to 7	3/16 to 1/4	4
Over 7 to 10	1/4 to 3/8	3
Over 10 to 13	3/8 to 1/2	2
Over 13 to 16	1/2 to 5/8	1
Over 16 to more	5/8 to more	0