PROJECT REPORT

ON

'WIRE ENAMELLING'

SUBMITTED

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BY

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V. M. KUTTAN.

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CHAPTER - I

*** INTRODUCTION ***

INTRODUCTION

The subject for my project work is 'W I R E E N A - M E L LI N G'. The aim of the work is to have a detailed study on the subject. Since Premier Cable Company is the only biggest Company producing enamelled wires in Ernakulam district, I selected this company for my project work.

The Premier Cable Company Limited, producing PVC insulated cables of various sizes and various uses, winding wires, overhead conductors as per the ISI standards is situated on the NH 47 at Karukutty in Ernakulam District. The company started its production in 1964 with the technical collaboration of'VEB Cables works' BERLIN. Each of the sections here are headed by experienced experts in the field.

Enamelling as a whole can be described in one sentence - coating Aluminium or Copper conductors with certain electrically insulative enamels - Commonly used enamels are based of poly vinyl acetals and Poly ethylene Terepthalate. Poly vinyl acetals finds its use in normally 60% of the total requirement of the enamels for enamelling.

Enamel coated wires are called enamelled wires where in enamel acts as insulation and wire as conductor, which can be either Copper or Aluminium. The properties which enamelled wire posses by virtue of this layer of insulation over the conductor are Numerous. It offers good resistance to moisture, chemical solvents and other such compounds which erode the insulating elements . The insulating enamel coating being of flexible nature enables the conductor to be wound in any shape. Besides the enamels can withstand the temp. effects on the conductor under operating conditions, without loosing its insulation properties.

Enamelled wires have formed wider applications in electric and electronic industries and are used extensively for winding. Some of the important fields where enamelled wires find their use are (1) Electrical motor winding (2) Transformer coils (3) Electrical coils used for electromagnetic contactors (4) Solinoid valve coils (5) Brake coils (6) Control transformers (7) Instrument coils.etc..,

In Kerala there are only very few units producing enamel insulated wires, of which 'Premier Cables' is the biggest unit. Here they concentrate on wires having thicker guages. But for thinner guages we mostly depend on other states. So there is tremendous scope for a factory producing thinner guage insulated wires.

In short the enamelled wires have contributed greatly to the developments in electrical and electronic industries. Its application in electrical equipment have resulted in significant upgrading of performance and considerable reduction in the cost of manufacture.

CHAPTER - II

*** LITERATURE SURVEY ***

LITERATURE SURVEY

The following literature which are most relevent to my project were referred.

I The National Productivity Council's book 'Cable Industry in Japan & USA' gives a good coverage of the various metals, insulative materials and the process used for winding wires.

II D.J. Debensd's book 'Wire Coatings' gives a good coverage of the various types of enamels that can be used for winding wires.

III The Encyclopedia of polymerscience and technology, Vol. 9 gives some details about the application of wires enamelled with various types of resins.

IV The ISI - 4800 gives a good coverage of the tests that should be conducted for different types and different sized enamelled wires. A brief summary of the above references is included in the following part.

[redacted]

Of all the metals silver has the highest electrical conductivity, but its general use as a conductor is naturally precluded by economic considerations. Of the commercially available metals, copper has the highest conductivity section for section, while Aluminium has the highest mass conductivity. Both economic and technical factors have to be taken account in choosing between Aluminium and Copper.

History

Till the beginning of the 20th century all technology in electric conductor manufacture was based on the use of copper. Copper wire was first used for carrying electricity as early as 1840, but high purity electrolytic copper of proper conductivity and tensile strength was developed only towards 1877.

Aluminium wire was first used for electrical applications for a telephone line in Chicago Stockyards in 1897, and use of insulated aluminium started only 1898.

RELATIVE ELECTRICAL CONDUCTIVITY OF VARIOUS METALS

Metal	Specific gravity (lbs./cubic ft.)	Relative electrical conductivity	
		Section to Section	Mass to mass
Silver	652	106	89.0
Copper	550	100	100.0
Aluminium	167	62	204.0
Zinc	428	29	37.2
Tin	455	15	18.1
Lead	709	8	6.3

Aluminium is the most widespread metal found in earths crest & now ranks second in volumetric production.

PROPERTIES OF ALUMINIUM AND COPPER

Aluminium conductor has greater bulk than a copper conductor of the same resistance. In short conductivity of the Aluminium is lesser than that of copper.

For conductors of equal resistance the current carrying capacity of Aluminium will be greater than that of copper, because of the increased size and hence the greater rate of heat dissipation. Aluminium conductor of the same current carrying capacity as its equivalent copper section weighs only 42% of the copper conductor.

Short Circuit Currents in Aluminium & Copper Conductors.

Comparison of specific heat, density and resistivity of Aluminium and copper shows that the short circuit rating of an aluminium conductor is approximately 66% of that copper conductor of equal area. However for conductors of equal current carrying capacity the rating is 92% and for conductors of equal resistance it is one hundred and eight percent.

Comparison of Copper and Aluminium Conductors

	Copper	Aluminium
1. For equal resistance		
area ratio	1	1.61
diameter ratio (round conductor)	1	1.27
weight ratio	1	0.48
2. For equal current & temperature rise		
area ratio	1	1.39
diamete r ratio	1	1.18
weight ratio	1	0.42

	Copper	Aluminium
3. For equal diameter		
resistance ratio	1	1.61
current carrying capacity	1	0.78

Properties of Aluminium and Copper used as conductors

	Copper-high conductivity Annealed.	Aluminium 99.5% Annealed wire
Density at 20°C	8.890	2.703
cofft. of linear expansion °C x 10^6	17.000	23.000
Melting point(°C)	1,083.000	659.000
Specifit heat (Cal/gm)	0.092	0.230
Thermal conductivity (Cal./cm./sec./°C)	0.920	0.540
Resistivity at 20°C (micohm - cm.)	1.724	2.800
Temp. cofft. of resistance at 20°C	0.0039	0.004

Copper Winding Wires (Magnet Wires)

These could be divided broadly into two groups:-

(a) those with fibrous coverings and

(b) those with non-fibrous coverings.

The first group include coverings with organic material such as cotton, silk, rayon and paper & inorganic materials like glass, asbestos etc., The second group consists of wire insulated with enamel either of the conventional oil-based type or the synthetic type.

The principal short coming of those organic fibrous coverings is their inability to withstand high temperatures. The inorganic fibrous coverings like asbestoes and fibre glass yarns inpregnated with an insulating varnish have an advantage of being able to withstand high temperatures but the space factor is poor. But for higher temperatures of the order of 180°C the fibre glass covering inpregnated with a silcone varnish still holds the market.

In comparison with fibrous covered wires, enamelled wires have a definite advantage in regard to space factor.

Enamelled Aluminium Wires

The quality of enamelxxxxxx insulationon the Aluminium conductors is close to the quality of the enamel on copper conductors, where the same resins are used. The behaviour of the aluminium wire is more stable at high temp. in comparison with copper which becomes coated relatively faster with a layer of copper oxide at temp. over 225 degree centigrade. Neverthless the electrical resistively of copper also starts to rise appreciably. The presence of a layer of Aluminium oxide on aluminium wires has a stabilising influence on the enamel insulation and thus the heat resistance.

Anodized Aluminium Winding Wires.

By the use of anodizing techniques the microscopically thin layer of aluminium oxide that exists to some extent on all aluminium is expanded into a hard, in elastic and highly insulated film in the order of three/ten thousands of an inch thick. This film is desirable in may applications because of its hardness, abrasion resistance and high break down potential for a given thickness.

Applications

Anodized aluminium strip conductors find increasing applications in dry type transformers, lift magnets, DC magnet brakes and welding transformers. Major advantages pointed out are:

1. Ease of winding
2. Reduction of voids and thickness of insulation.
3. Better heat transfer characteristics, simpler insulation system with lower material and labour costs.

Materials for insulation

INSULATION: The prime object of electrical insulation is to restrict the flow of electricity to the correct channel. Any fault in the insulation may have dire results such as the complete destruction of the equipment or appliance. Choice of the insulating mterials depends upon the service conditions, insulation conditions, availability and economy.

The first insulated cable consisted of a copper wire covered with cotton or silk threads saturated with wax. Enamels of mineral origin were used extensively for winding wires till 1938, when synthetic varnishes came into the market.

Wire Enamels

Oil-based enamelled wires introduced about 7 decades ago were a great advance on the other types of winding wires obtaining them. Even though they have high dieelectric strength, they are not resistant to any abrasion encountered in coil winding and assembly and to any undue heat.

The development of synthetic resin based enamels marked an important step in the field of winding wires. Apart from the multi purpose enamelled wires, enamels for special

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applications such as self bonding wires, solderable wires and wires to withstand temperatures in the range of 250 to 650°C (required in high flex nuclear radiation areas) have beendeveloped. Some of the more popular synthetic resins that are in use on enamelled wires today are:

1. Vinyl based polymers
2. Polyamids (Nylon)
3. Epoxy polyesters
4. Terephalic polyesters
5. Terephalic polyester silcones.
6. Polyurathanes.

CHARACTERISTICS OF WINDING WIRE INSULATION

Type of covering		Notes
Cotton, silk or rayon	:	Now used only where additional safeguard is required against the possibility of a pinhole in an enamel covering. Can be used at 105°C imprignated with some resins or oil immersed.
Oleo-reionous enamel	:	Gives good space factor and high dieelectric strength. Some amount of oil persists on the surface of the processed wire. This slippery nature of oil makes one layer to the some other layer very constant. Used upto 110°C.
Polyamide resin based enamel	:	High abresion resistance comparable to vinyl acetal coverings. Used upto 120°C.

Polyester Terethalate based enamel	:	good thermal properties-heat shock, ability to withstand high operation temperature . Used upto 155 degree centigrade.
Epoxy Based Enamel	:	Abresion resistance, intermediate between oleo resinous and vinyl acetal enamels. Self stripping and flexing at 450 degree centigrade. Used upto 150 degree centigrade.
Polyvinyl acetal based enamel	:	Preferred to oleo resinous covering on account of its improved behaviour at higher temps., increased chemical and high abresion resistance. Used upto 130 degree centigrade
Polyurathne based enamel	:	Abresion resistance approaches that of vinyl acetals and has better chemical resistance than epoxy covering. Self stripping and self bonding at 360 degree centigrade. ie., it can be soldered without removing the coated enamel. used upto 150 degree centigrade.
Silcone Enamel	:	Flexibility and abresion resistance is intermediate between vinyl and other synthetic based enamels. Used upto 180 degree centigrade.
P T F E	:	Wire coverings are deposited from a liquid dispersion and when used in conjunction with an inorganic primary insulant and nickel or mercury plated conductor. Operating temp. is 250 degree centigrade.

Method of Manufacture

Pickling: Pickling for copper is conducted in hot sulphuric Acid pickling solution of 5 to 10% nominal strength. The procedure involves straight line pickling tanks, spray washing at pressures upto 180lbs/sq.inch followed by soap solution dip tanks.

Drawing: Drawing of the copper wire to required size is done in a mxxx wire drawing machine having multiple number of dies. Soap solution is used as a lubricant for drawing.

Wire Enamelling: The enamel coating process consists essentially of passing the conductor of high conductivity annealed copper through a trough of enamel and hen through a heating or baken oven for drying and baking. Several coats are necessary to obtain the required build up of enamel on the wire. Both horizontal and vertical types of oven are in vogue, the former is more suitable for thin wires usually below 33 SWG, and latter for thicker sizes. The baking oven may be gas or electrically heated. For thinner size wires, single heating tubes are employed for each wire enabling better flexibility control of temp. and speed.

The winding equipment for enamelling should incorporate the following features:

1. Control of wire tension
2. capacity to take on pay off the maximum weights of wire.
3. Wide range of speed variations with maximum sensityvity in torque control at the spindle.

Considering these aspects the thicker sizes are wound on large type take up units having a common driven spindle.

Method of Application

The methods commonly used for round wires are :

1. Split floating dies of phosphor Bonze for wire sizes down to 33 SWG (with vertical ovens)
2. Rollers with or without grooves(Vertical ovens)
3. Roller type dies for thin wires(with horizontal ovens)

Feeding of lacquer and control of lacquer thickness are done by different methods. Lacquer feeding is done by suction of by rollers or by injection on to the wire directly.

The build up of each coat of enamel and its concentricity is controlled in various ways depending upon the size of the wire conductor and the type of enamel.

The enamelling of aluminium wire can be carried out in the same plants as are used for copper wires. But in view of lower mechanical strength of aluminium suitable measures should be taken to reduce the tension of the wire. This is particularly importantfor the enamelling of aluminium wires of diameter 0.7 mm. and below.

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PART II

The good insulating properties of many thermoplastic and thermosetting polymers make them particularly suitable for coating wires to be used as conductors in electrical aparatus. Other properties of the materials which make them desirable as wire coatings include abrasion resistance, inpact strength, flexibility, solvent resistance and stability at high temperature.

The most important polymers used in coating are acrylics, epoxies, fluorinated resins, polycarbonates, polyesters, polyimides, polyurethanes, polyvinyl acetals, silicones etc...,

EPOXY RESINS : Epoxy resins are characterised by the pxpx epoxide group. Simplest type of epoxy resin is produced by reacting Bisphenol A with Epichlorohydrin. By controlling operating conditions and varying theratic of Bisphenol A and Epichlorohydrin, epoxies having different molecular weight can be produced.

100% solid epoxy composition containing rigid and flexible resins can be used to prepare magnet wire. The coated wire is cured at a temp. higher than the flashing point of epoxy resins for a duration less than required for the degradation of the coating.

Epoxy coated magnet wires re produced by solution coating techniques. The solution coatings employ a solvent system containing about 30 to 50% epoxy resin. The solvent acts as a fluid carrier for the resin enabling convenient deposition of a smooth continious film on the surface of the wire. In order to provide the necessary build up, hence the dielectric strength of the enamel coating 4 to 6 coatings are generally required. The solvent is evaporated and is seldom recovered for further use. Due to the multiple coating required a slow baking schedule is employed which can be provide escape of the solvent from the coatings, thus eliminating pinhole failures in the coated film. The slow baking shedule combined with the large amount of solvent loses add considerably to the cost of producing this type of magnet wire.

A solvent free or 100% solid based on the liquid epoxy resins, eventhough can be used, found to be unsuccessful in shock test.

Another type of solvent free composition containing a rigid epoxy resin, a flexible epoxy resin and Boron-trifluride organic complex curing agent can be used. Such type of magnet wire exhibits flexibility, good adhesion to the metallic conductor, high thermoplastic flow temperature, excellant dielectric strength, solvent resistance, good abrasion resistance.

The rigid epoxy resins are characterised by the presence of repeating change of a relatively large number of aromatic rings in the resinous molecule. The flexible epoxy resin is characterised by the presence of long aliphatic change, which provide the flexibility to the chain.

The ratio of rigid to the flexible epoxy resins in the resinous composition of the process can be varied considerably depending on the properties desired in the final product. The relative amount of flexible epoxy resin in the composition influences the flexibility of the final coating.

The baking temperature depends on the exact resinous composition, the curing agent, thickness....etc. The baking temperature in between 310 to 750 degree centigrade The time required depends on the baking temperature, exhaust etc. When the enamel coating is baked with the temperature range above, the curing time is in the range from 6 seconds to 25 seconds.

Part III - Magnet Wire

The diversity of the products discribed as "wiring and cable" can be subdivided as follows:
Magnet wire, hook_up-wire, building wire and cabele, communications cable, and power cable.

Magnet wire is manufactured by the immersion coating process. The filament (wire) is drawn through a liquid and some of the liquid adheres to the filament. When this dries through the evaporation of volatile constituents, a layer of insulating material is formed on the outside of the filament. The process can be repeated to build the thickness to the desired level. In practice, the coated wire is normally passed through an oven to hasten the evaporation of solvents and/or Quiring of the insulation.

Insulating materilas for magnet wire

Material	Important properties	Major use
1. Acrilic resin (co-polymer of acrilo nitrile and an acrylate together with phenolic resin)	Resistance to solvents and refregerants	Hermetically sealed motors when refrigerant contacts the wire.
2. Solderable acrylic resin	Solders easily at 450 degree centigrade by melting film	Motor windings and as replacements for a variety of other enamels.
3. Epoxy resins(high epoxide equivalent with urea-formaldhyde modyfying resins		Oil filled transformers
4. Poly (hexamethylene adipamide)	Excellent windability	General magnet wire when moisture is not a problem

PART IV

Description of the Test	Poly vinyl Acetal Based	Polyester Based	Polyurathane Based	Oleoresins Based.
Range of sizes - Copper (in mm.)	0.02 to 5.00	0.02 to 5.00	0.05 to 1.60	0.02 to 1.00
- Al.	0.02 to 2.50	0.20 to 2.50	.....	0.02 to 1.00
Over all diameter	All sizes	All sizes	All sizes	All sizes
Bare Wire diameter	Nominal conductor dia. over & including 0.71 mm.	Nominal conductor dia. over & including 0.71 mm.	Nominal conductor dia. over & including 0.71 mm.	Nominal conductor dia. over & including 0.71mm.
Increase in diameter	All sizes	All sizes	All sizes	All sizes.
Resistance	Dia. upto & including 1 mm.	Dia. upto & including 1 mm.	Dia. upto & including 1 mm.	Dia. upto & including 1 mm.
Elongation	All sizes	All sizes	All sizes	All sizes
Abrasion Resistance (size in mm.)	0.25 to 2.50	0.25 to 2.50	0.25 to 1.60	Not applicable
Breakdown voltage	All sizes	All sizes	All sizes	All sizes
Heat Shock Test	All sizes	All sizes	All sizes	All sizes
Cure Test	All sizes	Not Applicable	Not Applicable	Not applicable
Cut Through Test	All sizes	All sizes	All sizes	All sizes
Jerk Test - Copper	upto 1.00 mm.	upto 1.00 mm.	upto 1.00mm.	upto 1.00 mm.
- Al.	All sizes	All sizes	Not applicable	Not applicable
Springness Test (size in mm.)	0.05 to 1.60	0.05 to 1.60	All sizes	0.05 to 1.00

CHAPTER - III

*** P R O C E S S   D E T A I L S ***

PROCESS DETAILS

The manufacture of enamelled wire is a controlled process requiring close attention at various stages of production with regard to size and quality. Enamelling plants can be of two types.

i) Vertical Type

ii) Horizontal Type

Vertical Type machines are used for coating finer thicker guage wires, while horizontal type is used for coating finer guage wires. The Project is proposed to start with the horizontal type machines. Particulars of the machine are the following.

The machine consists of a Pay off, baking furnace, exhaust and take up. The furnace in this type of machine is placed horizontally. No seperate pre-annelar is necessary as in the vertical type plant. Pre-annealing can be done by the dry passing of the wire to be processed through the furnace once. In some cases seperate furnaces are used for different wires so that control of temperature and speed will be easy. Common furnace is more economical. The furnace length cannot be more than 3 feet.

Processing of wire in horizontal type machine is almost same as that in a vertical type. Only difference is that pre-annealing is not done in a seperate pre-annealer.

Discription of the vertical type plant and process used in Premier Cables is given below.

The important parts of the vertical type enamelling plant (ER-10) are 1. Pay off 3. Baking furnace
2. Pre-annealer 4. Take up.

Pay off:-

Vertical pay offs are used. The pay off consists of 500 m.m. spools, V - shaped grooved pulleys having a diameter of about 8 inches and pulleys having a diameter of about 10 inches.

Pre-annealar:-

The pre-annealar is made of miled steel having a bricklining inside. Heaters are arranged in between the bricklining and surface of the annealar. In between the brick surfaces there are 10 stainless steel tubes running from one end to the other. Each has a diameter of about 12 m.m.

The capacity of the pre-annealar is 18 k.w. The supply is 3 face. The maximum temperature that can be attained is 800°C. Muffle type heaters are used for heating the pre-annealar. Each heater has a capacity of 2 k.w. Just after the pre-annealar there is a water tank containing water at about 50 to 60 degree centigrade. The water tank is provided with level maintaining system. It is also provided with a drainage system. The water is heated electrically.

In the tank there are 10 Bronze pulleys connected together on a central shaft. Each has a diameter of about 10 inches. It also contain another set of 10 pulleys each having a diameter of about 10 inches, fitted on the oven. Besides this there are 60 guide rolls each having a diameter of about 14 inches. Resin is taken in the applicator. The resin is first stored in a collecting tank, from where it is pumped to an overhead tank provided with a suctional and delivery system. The excess resin in the applicator flows back to the collecting tank, from where it is again pumped and operations repeated.

The next important section is the baking furnace which is made of heat resistant stainless steel. The furnace of

ER-10 consists of two zones, Zone I & Zone II. The capacity of the oven is 80 k.w. Tubular heating elements are used for heating. Each has a capacity of about .5 k.w. The maximum temperature that can be attained is 500°C. Zone I and Zone II temperatures are controlled by using PID Electronic temperature controllers. For sensing the temperature we have thermocouples Fe/constant. Control components, contactors, relays, fuses, instrumentation systems are housed in an electrical console.

In the first and second zonethere is a permanent thermo couple TZ_1 and TZ_2 respectively. Three thermo couples (T_1, T_2, T_3) are also attached to the zone I. But in the case of Zone II only two thermo couples T_4 & T_5 are attached.

The speciality of the baking furnace used in the enamelling plant is that the temperature of the oven increases slowly from the bottom and reaches a maximum at about 3/4 of its height and then again decreases. The total height of the oven is about 144 inch. Studies are made on the oven temperature and temperature readings in the oven at different heights are found as follows.

	Temperature	Ht. in inches
TZ_1 (fixed thermo couple in Zone I)	430°c	50
TZ_2 (fixed thermo couple in Zone II)	480°c	112
T_1 (Thermo couple in Zone I)	30°c	12
T_2 (--- do ---)	270°c	33
T_3 (--- do ---)	320°c	70

[redacted]

T_4 (thermo couple in Zone II)	$500^{\circ}c$	102
T_5 (- - - - do - - - - -)	$480^{\circ}c$	133

From the above readings it is clear that maximum temperature attainable is $500^{\circ}c$ and it is at about 3/4 ht. of the oven.

The last section of the enamelling plant is take up. The take up includes Capstan which pulls the wire, there by controls the speed and, also a number of spindles - depending upon the number of wires that can be enamelled at a time, on which the reels for packing the enamelled wire, is fixed.

The take up has two induction motors one on each side. Each motor has a capacity of 2.2 k.w. The supply is 3phase. It is coupelled to a reduction gear which is connected to various spindles. For transverse a 3 phase 1.1.k.w. induction motor with conepulley is used.

For pumping enamel from the collecting tank to the overhead tank an induction motor of 1.1. k.w. is used. Also machine has got an exhaust. For the function of the exhaust an induction motor of capacity 2.2 k.w. is used. In addition to this the room in which the enamelling unit is installed has an exhaust. The room in which it is installed should be dust-free .

Process:-

500 m.m. spools containing copper wife of required guage is fixed on the pay off. Tension can be adjusted by break system. Then the wire is subjected to felt application. This is done for wiping the wire and thus serves

as a surface cleaner. Then pass through a guide-roll. Then again passed between two pieces of felt placed close together so that wire can be passed in between it. This is to givem tension to the wire. Then it enters the pre-annealer through a pulley. The pre-annealar is usually maintained at a temperature of about 600 to 700 degree centigrade. Pre-annealing is done to make the wire short soft, so that coating will be uniform. Also it helps in attaining a smooth surface finish. For different guage wires, the speed is varied keeping the temperature almost constant. The hot wire is then subjected sudden cooling. This is done by water in the tank placed just after the pre-annealar. The pre-annealar is placed in an inclined position. Since water will maintain the level some water enters inside the tube. As soon as it enters the tube, it becomes converted to steem and steem is forced to go out by the entry side of the copper wire. This is done to prevent the formation of copper oxide layer which is dangerous to the insulation. Reaction of the hot wire with oxygen will be very high. Further the steem serves as a cleaning medium. The cooling is given to minimise the temperature. Since copper is a non-ferrous metal sudden cooling after heating the wire wont make it hard. But in the case of ferrous metals it becomes hard on cooling. The wire after cooling is passed througha a enamel taken in the applicator. In order to get uni-f form coating for the wires certain dies are used. After getting coated the wire is passed through a baking furnace where the enamells gets cured. The solvent in the enamel evaporates and is thrown away by means of exhaust. The curing takes place at the point of maximum temperature in the Oven. In order to get the necessary thickness of insulation, the wire is passed 7 times through the resin. At each time, after dipping, the coated enamel gets cured in the oven. After the required number of dips the wires are wound up on a wooden reel.

Thicker guages cannot be processed in a horizontal type machine. The reasons are the following:-

1. If thicker wires are used, sagging will take place.
2. More number of passes will be required for the thicker wires so as to have the necessary build up.
3. To maintain the speed also will be difficult.

The important factors to be considered in enamelling are speed, temperature and exhaust. The exhaust is used to remove the vapours of the solvent, present in the upper part of the baking furnace. If the exhaust is more, the temp. inside the oven changes, thereby creating problem in curing. Similarly if the exhaust is less the vapours of the solvent will remain in the oven thereby creating variation in temp. So it should be optimum.

Temperature is another factor. If the temperature is more, the speed has to be increased to prevent overcure. But increase in speed than the optimum will lead to wire vibrations and thus causes roughness in the insulated wire. Now we shall see why the wire cannot be processed in one dip. The reasons are the following:-

1. Maintaining the heat curve for apt cross-linking will be difficult.
2. Maintaining the build up will be difficult.
3. Difficulties in maintaining an effective exhaust.

PVA coated wires are usually preferred because of its attractive golden yellow colour.

DIES FOR ENAMELLING

Commonly used dies are of three types. They are solid dies split dies and felt dies.

Solid dies has the advantage that the non uniformity of coating is avoided. Non uniformity in coating can adheresly affect the quality in many ways. But the disadvantage of solid dies is that in consumes more time in changing the die. Also it leads to some wastage. The diehole depend on the solid content of the resin and ba-rewire diameter. For seven coatings seven dies are used. The first die will be having a diameter about 50 microns more than the bare wire diameter. From second die onwards an increase of 25 microns only is needed. The above die series is in the case of PVA. An eg. of the die series is given below:-

Bare wire diameter	-	0.825	mm.
First die	-	0.875	"
Second die	-	0.900	"
Third die	-	0.925	"
Fourth die	-	0.950	"
Fifth die	-	0.975	"
Sixth die	-	1.000	"
Seventh die	-	1.025	"

In the case of poly ester having more solid content, then PVA, only lesser die hole is needed. In this case an increase of 50 microns is given for first die. Then only 20 microns increase are given for sucessive dies.

Split dies made of Brass can also be used. In this case a small tension will widen the space thereby causing eccentricity to the wire. Also it leads to wire breakage. In this case dies can be changed at the time of processing itself without stopping the machine.

Felts can also be used for enamelling. For thicker guages, Felts are not usually used because thicker guage wires when coated by using Felts, ovality is produced.

The important thing to be considered in∠any die is that the ∠using wire should be adjusted in such a way that it can move freely without touching the sides. That can create roughness in the wire.

RESINS USED FOR ENAMELLING

Nowadays only two types of Synthetic enamels are used in enamelling. They are (i) based on poly vinyl acetals and (ii) based on poly ethlene terethalate. About 95 % of the enamelled wires produced in India are based on the above two enamells. Some amount of enamelled wire are manufactured by using polyurathane based enamel also. Polyesterimide is also used in some cases.

Even though we are getting the reddymade enamel from the Company producing enamels, it will be good to have an idea about the preparation of the commonly used wire enamels. A brief discription about the preparation is given below.

Polyvinyl Acetals

Treatment of polyvinyl alcohol with aldehydes results in the formation of polyvinyl(Acetals). Among the polyvinyl (Acetals), Polyvinyl formal and polyvinyl Butral are the predominent members. Among these two polyvinyl formal can be used in enamelling purposes.

Polyvinyl Formal

Generally produced from polyvinyl Acetate. In a typical process polyvinyl Acetate is dissolved in Acetic Acid and then formalin & a small amount of Sulphuric Acid catalyst are added. Heated to 70 degree centigrade for about 24 hrs. What Water is added to the product with rapid agitation and polyvinyl formal is precipitated as granules. Washed with alkali and dried. The polyvinyl formal can be obtained in two grades as follows.

	Grade I	Grade II
Hydroxycontent	5 - 7	5 - 6

Acetate content	40 - 50	10 - 13
Formal content	50	83
Mol. Wt.	21,000	34,000

For enamel preparation the resin of the second grade is used in compination with resole - phenolic resin. Cwosslinking occurs with the formation of ether links by condensation of Methylol groups in the resol and hyderoxy groups in the poly-vynyl formal.

Method of preparation of Enamel

100 parts of the grade ii polymer, 60 parts of polyurathane, along with 10 parts of Melamine-formaldehyde condensate resin added as a 67% solution in Butanol, are added to a solvent mixture containing 440 parts of Naptha and 255 parts of Creselic Acid. The resin addition is made in a suitable container at room temperature with moderate agitation. A resin having a solid content of approximately 18% and a viscosity of 70 poises at 25 degree centigrade is obtained. The use of titanium esters increases the curing efficiency.

Polyester Wire Enamel

Polyester resins are prepared from Dimethyl Terepthalate, Ethylene G lycol and glycerol. Glycerol is added for getting resins having branched structures.

D.M.T. is preferred than acid, since acid is difficult to purify due to its sublimation tendency at 300 degree centigrade and is rather insoluble.But ester can be purified easily by distillation. In addition the lower melting point and greater solubility in the glycol make it more convenient. A typical formulation for the resin is given below.

D.MT.	-	46	parts
Ethylene glycol	-	31	"
Glycerol	-	23	"

Preparation of Wire Enamel

The above reaction product (100 parts) is melted in a heat- stainless steel round bottomed flask fitted with a heat- ing mandle, stirrer and a thermometer. The temperature of the resin during melting was held below 180° C. in order to prevent gelation.

When all the resin is melted temperature is reduced to 145°C., further heating discontinued. At this time 2.5 parts of ditkiethamol Amine di-isopropyl titanate as curing catalist is added. The catalist is added as 80% solution in isopropyl alcohol. It should be addedat the lowest possible temperature to prevent the possibility of gelation. Solvent is added so as to get a solid content of about 32-35 percent. Usually used solvents are para-metacresol, xylenol, naptha...etc.

Even though PVA and Polyester based enameels are used for enamelling only polyester based enamel is used for enamelling thinner guagee wires. This is because the viscosity of PVA will be of PVA is very high. Since felts are used as the dies for enamelling thinner guage wires, the roughness will be there if we use PVA. Above all thinner guage wires itself are flexible. For thinner guage wires more importance is given for thermal properties than mechanical properties. Thermally polyester based enamel is having better properties than PVA. So polyester based enamel is preferred for enamelling thinner guages.

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QUALITY CONTROL

The enamelled wires should be produced strictly on as per the ISI specification. The specifications required for enamelled wires and their methods of testing are given in ISI - 4800, Part I, II, III & IV. The various tests conducted on enamelled wires are

1. Conductor Diameter
2. Overall Diameter
3. Electrical Resistance
4. Elongation of the wire
5. Springness
6. Flexibility & Adherence
7. Jerk Test
8. Peel Test
9. Resistance to abrasion
10. Heat shock Test
11. Cut through Test
12. Cure Test
13. Solvent Test
14. Breakdown Voltage

But all the above tests are not done on all types of enamelled wires. The table given in the literature survey part will givem an idea about the necessary test that should be conducted for different sizes and different types.

Methods of Testing

General Test Condition:- Unless otherwise specified all the tests should be carried out within a range of 10 _ 40 degree centigrade and a relative humidity not greater than 85%.

2. The wire to be tested shall be removed from the packaging in such a way that the wire will not be subjected to tension.

3. Before each test, make sure that the sample does not contain any damaged wire.

<u>TESTS</u>

Diameter : 1) Bare conductor diameter
2) Overall diameter.
3) Increase in diameter.

The diameters are measured by 'Micrometer'. Usually measured at 6 positions and average is taken.

<u>Electrical Resistance</u>: For wires having small diameter, diameter is measured by measuring the electrical resistance.

If the resistance R_t is measured at a temperature t^o other than 20^oC, the resistance R_{20} at 20^oC shall be calculated by the formulae

$$R_{20} = R_t / 1 + (t-20)$$

t = actual temperature in °C during measurement.
= temperature coefficent, which is 0.00393 for Copper and 0.004 for Aluminium.

<u>Elongation</u>: Elongation is measured with a tensile testing machine. The testing length shall be between 200 to 250 mm. The wire is streched @ 300mm/minute for Copper & 100mm/min. for Aluminium. Three measurements are made and mean value is taken.

<u>Resistance to Abrasion</u>: The test is performed by repeatedly scraping the surface of the wire with the side of a loaded

steel sewing needle of 0.400mm. dia. which is held horizontally at right angles to the wire.

The sample to be tested is firmly fixed between two clamps in the apparatus. The needle is fixed on the holder. The needle is driven by an eccentric, so that it oscillates through a distance of approximately 10mm. The apparatus is also equipped with an electrical circuit so arranged as when the needle wears through the enamel, an electrical contact is made between the needle and the conductor and the device stops when a current approximately 5mA passes from the needle to the conductor for 0.1 second at a potential difference of 12volts dc. The needle is also loaded by placing weights on the weight carrier, depending on the diameter of the wire.

The number of strokes required to cause failure of the enamel is noted. Number of strokes required varies with type of enamels.

<u>Heat Shock</u> : A sample of wire is wound for 10 turns round a polished metal mandrel of diameter depending upon the bare wire diameter and placed into a hot, electrically heated oven for 30 minutes. The temperature depends up the type of enamel. After removal from the ovan the samples arecooled to room temp. and examined for cracks under a magnification of 10 to 15 times.

Enamel	Temperature
Polyester	180°C
PVA	160°C
Polyurathane	125°C
Oleoresins	175°C

<u>Cut through Test</u> : Two pieces of the wire are placed in the apparatus preheated to a specified temp. depending upon the type of enamel used for coating, so that they cross each other at right angles.

After some time-time required for the sample to attain the temp. of the apparatus- a load is applied on the crossing point. An alternating voltage is applied between the wires to indicate conťact of the conductors. During the period for which the voltage is applied, no cut through should occur due to the thermoplasticity of the enamel at the particular tèmperature.

Enamel-Temperature

Polyester	-	240°C for 2 minutes
PVA	-	170°C " " "
Polyeurathane	-	170°C " " "
Test voltage applied	-	100 ± 10 volts.

Cure Test : A sample of wire not less than 100mm. length contitioned at 130± 2°C for 10 minutes is immersed in a boiling mixture containing 30% Tolvene and 70% Ethyl alcohol for a period of 5minutes. Any effect on the film is noticed.

Continuvity of Covering (Pinhole Test) : This is an important test in the case of thinner guage wires. The test is carried out by passing a sample of enamelled wire through a bath containing mercury. Before entering the bath, the enamel passes over a freely running, highly polished v-grooved metal wheel, having a dia. of 25 mm. at the bottom of the groove. The groove has radious at the bottom of 0.35mm. During the test the wire runs in the bottom of the groove without coming into contact with sides of the 'v'. The length of the wire immersed in the Mercury is approximately 60mm.

A sample of 50 metres of enamelled wire is subjected the following test.
Test speed of the wire through the mercury is 0.30 metres per second. Care should be taken not to stretch the wire during the test. A potential difference of 24 Vdc for wires upto &

including 0.040mm. and 50 Vdc for wires over 0.040 mm. is maintained across a circuit consisting of the enamelled wire, mercury in bath, and a sensitive magnetic relay, connected in series in such a way that a fault in the insulation of the is indicated.

The number of faults in a 50 meter length of wire will be indicated in the counter. It should not exceed the maximum number of faults specified.

Breakdown voltage:- Test for sizes upto and including0.040mm.

A specimen of enamelled wire from which the enamel has been removed at one end is enameled to the high voltage terminal and wound once round the cylender of 25 mm. diameter mounted with its axis horizontal and is connected electrically to the earth terminal of the voltage test apparatus. The voltage is applied at a increased uniform rate of approximately 100V per second until breakdown occurs. The voltage at which breakdown occurs is noted.

Test for sizes over 0.040 mm. upto and including 2.500 mm.
A peice of wire approximately 400 mm. in length shall be twisted together for a distance of 125 mm. The test voltage is applied at a increased uniform rate of approximately 200V PER SECOND between the conductors until breakdown occurs. Five samples are tested.

The minimum breakdown voltages specified for conductors of different diameter are given below:

Nominal conductor dia.	Breakdown voltages (min.volts.)		
	Fine	Medium	Thick
0.025	60	120	—
0.032	70	150	—
0.040	100	200	—
0.040 to 0.050	300	700	—
0.100 to 0.125	700	1,300	1,800

The usual defects found in the Enamelled wire are BDV fail and roughness.

BDV fail can be due to :

1. under cure
2. Over cure
3. Low insulation dia.
3. Eccentricity in Id.
5. Bare wire defects.
6. Improper exhaust.
7. Enamel defects.

Roughness can be due to:

1. Speed
2. Temperature variations
3. Bare wire defects.

Abrasion fail can be due to:

1. Improper curing
2. Low I.d. and eccentricity

Failure in heat shock test is due to:

1. Improper curing

Flexibility fail can be due to:

1. Improper curing.

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CHAPTER - IV

ECONOMIC EVALUATION

ECONOMIC EVALUVATION OF A ENAMELLING UNIT HAVING THE CAPACITY TO PRODUCE 22.5 TONNES OF INSULATED WIRE PER ANNUM.

MARKET ANALYSIS

The enamelled wires are used in electronic and electrical industries both. Among various sizes poly-vinyl type find its use in nearly 55 to 60% requirement. Polyester type constitute about 35% of the total requirement. The shares of other types are limited.

Demand trend is studied on the basis of production of units registered with DGTD. Reliable details of production of units in the small scale sector are not available. Production of the DGTD units are given below.

VALUES IN METRIC TONES

Year	1975	1976	1977	1978	1979
Production	12,330	10,687	12,098	15,685	14,062

In the absence of production details of small scale sector, the above quantity may be considered as an indication of the trend in the country. Based on the trend analysis of production of DGTD units, it is estimated that the demand will increase to 30,000 MT by 1981.

MARKET PROSPECTS IN KERALA

In Kerala enamelled wires are consumed for end products manufactured by units namely KELTRON (Kerala State Electronic Development Corporation), Kerala Electrical and Allied Engineering Company Ltd., Kundra, Indian Telephone Industries, Switch gear Division of Alind-Mannar, United Electricals-Quilon, Eddy Current Controls-Chalakudy, O/E/N India Ltd., Mulanthuruthy, Anand Lamp Ballast - South Kalamassery Industrial Estate.

The consumption requirements of units for repair and maintenance of electrical installation, instruments, motors etc., were studied by a dealer level survey. Accordingly it is considered that an average of 40 to 50 MT/year of enamelled wires are consumed for repair and maintenance purposes. In addition, Electrical and Automobile workshops also require these wires for repair and maintenance purposes. Dealer level study indicates that the demand from such end uses is about 35 to 40 MT per year.

MARKET PROSPECTS OF THE PROPOSED UNIT

The product capacity of the proposed unit is only 22.5 Tonnes per year. The production will be 18 Tonnes at 80% of capacity utilization.

PRODUCT AND PRODUCT MIX

Product : Enamelled wires are identified,

(1) By the size of the wire specified by standard wire guage (SWG)

(2) By the type of enamel used.

(3) By the enamel covering specified as fine, medium and thick.

The main criteria on the selection of the enamelled wires is the temperature to which it can withstand under normal operating conditions. Broadly it is classified into 7 catogories depending upon the temperature as given below:

Class	Temperature
Y or O	90°C
A	105°C
E	120°C
B	130°C
F	155°C
H	180°C
G	above 180°C

The limited market study conducted has revealed the fact that the manufacturing capacity for thinner guages is limited in the country and has not kept pace with the increase in demand. Considering the gap in the demand and the supply prevailing, it is proposed to manufacture enamelled copped wires in the range of 36 SWG to 47 SWG in the proposed project. The unit is envisaged to work in 3 shifts for 300 days per year. However the capacity utilisation is assumed at 50%, 60% and 80% in the first 3 years of operation and 80% thereafter.

EQUIPMENTS & MACHINERY

Two small wire drawing machines.
Enamelling Plant - pay off, baking furnace, Exhaust, take up.
Abrasion Testing equipment
Pinhole testing equipment
High voltage breakdown testing equipment
Spring back testing equipment
Resistance Bridge
Viscosity tester, Micrometer etc.,

RAW MATERIALS

Copper wire of 21 SWG

Synthetic Enamels

For the production programme envisaged in the project viz., 75 kg. of enamelled wires per day, the annual requirement of copper omc;idomg sp,e /rpcess - waste estimated at 6% will amount to 21.6 Tonnes.

LOCATION, BUILDING AND LAY OUT

The project is proposed to be located in 50 cents of land, where facilities like transport, water, power, skilled personnels etc., are available. The cost of land including compound wall and gate at the rate of 580/cent comes about Rs.29,000.

BUILDING

The total covered area required for housing the various sections of the unit is estimated at 2,400 sq.ft. as per the details given below:

	Sections	Area in Sq.ft.
a)	Office	400
b)	Wire Drawing	350
c)	Enamelling	750
d)	Inspection	200
e)	Stores	600
f)	Toilet	100
	T o t a l:	2,400

The Cost of building @ Rs.45 per Sq.ft. comes about 1,08,000.00.

PRODUCT MIX AND ANNUAL SALES REALISATION

Basis: 1) 100% Capacity utilisation.
2) 3 Shifts working per day.
3) 300 days working in a year.

Sl.No.	Product Description	SWG	Quantity per day (kg.)	Per Annum (Kg)	Rate (Rs.)	Total Sales (Rs.)
1	Enamelled Copper wire thick or medium	40	25	7,500	80	6,00,000
2	Enamelled Copper wire thick or medium	44	50	15,000	105	15,75,000
	T o t a l:	..	75	22,500	...	21,75,000
	Add income from returned scrap	..	5	1,500	20	30,000
	Grand Total:	..	80	24,000	..	22,05,000

Anticipated sales in the first year at 50% Capacity utilisation .. .. .. } 11,02,500

- do - in the 2nd year at 60% - do - 13,23,000

- do - in the 3rd year at 80% - do - 17,64,000

ANNUAL RAW MATERIAL REQUIREMENTS

Basis : 100% Capacity Utilization

Sl. No.	Material Description	Qntty.per Annum (kg.)	Rate/kg. (Rs.)	Total Rs.
1.	Copper Wire (21 SWG)	21,600	50.00	10,80,000.00
2.	Enamel	6,480	30.00	1,94,400.00
3.	Lubricant for Wire Drawing (Soap solution)	4,200	2.50	10,500.00
4.	Plastic reels (1 kg. of enamelled wire/reel)	20,000	1.00	20,000.00
5.	Wire Drawing dies	.....	.....	2,500.00
	T O T A L :	.....	.....	13,07,400.00

Cost of raw material in the 1st year at 50% capacity untilisation .. .. } Rs.6,53,700.00

Cost of raw material in the 2nd year at 60% capacity utilisation . . . . . } Rs.7,84,440.00

Cost of raw material in the 3rd year at 80% capacity utilization .. .. .. } Rs.10,45,920.00

LIST OF MACHINERY & PRICES

Sl. No.	Machinery description	Qty.	Rate	Cost in Rs.
1.	Fine Wire Drawing Machine for drawing copper from 21 to 47 SWG	2	21,000	42,000
2.	<u>Enamelling Section</u> Wire enamelling plant (Horizontal type)	1	1,25,000	1,25,000
3.	<u>Testing Section</u>			
a)	Abrasion Testing equipment	1	3,200	3,200
b)	Pinhole testing equipment	1	6,000	6,000
c)	High voltage breakdown testing equipment	1	2,500	2,500
d)	Spring back testing m/c	1	2,400	2,400
e)	Resistance bridge	1	6,500	6,500
f)	Viscosity tester, micro meter, etc.	1 each	2,000(totally)	2,000
4.	Metal Reels	30	100	3,000
5.	Diamond dies	50	250	12,500
	Total:	..	......	2,05,100
	Cost towards C.S.T @4%		Rs. 8,204	
	Packing forwarding, insurance etc @3%		Rs. 6,153	
	Transportation		Rs. 7,000	21,357
	Errection and commissioning			7,000
	Wiring and Electrical fittings			7,500
	Enamel ~~xxxxxxx~~ initial/charger ..			5,000
	GRAND TOTAL:			2,45,957

Say : Rs.2,46,000.00

ANNUAL REQUIREMENT OF POWER

Basis : (1) 3 shifts per day.
(2) 300 days in a year.

Sl. No.	Machine	HP	K.W.	Shift working	KWH per Day.
1	Winding Wire/xxx Enamelling Plant and (Wire Drawing)	30	22.50	3	540
2.	Testing Equipments	5	3.75	1	30
3.	Lighting and Fans	-8	5.00	2	80
	Total:	...	31.25	..	650

Connected load = 31.25 KW

Fixed charges @ Rs.5/-kw per month	-	Rs. 156.25
Energy charges @ Rs.0.17 per kwh per month (80% capacity utilization)	-	Rs. 2,210.00
Total:	-	Rs. 2,366.25
Excise duty at 10%		Rs. 237.00
Total:	-	Rs. 2,603.25

Say 2,600/-

Annual energy charges in the 1st year	-	Rs.19,500.00
-do- -do- 2nd year	-	Rs.23,400.00
-do- -do- 3rd year	-	Rs.33,200.00

MAN POWER REQUIREMENT WITH RENUMERATION

Basis (1) Factory will work in 3 shift
(2) Administration in 1 shift.

ADMINISTRATION		Renumeration per month (Rs.)	Total Rs.
Managing Director	1	1,250	1,250
Accountant	1	500	500
Asst.cum Typist	1	300	300
Peon	1	175	175
TOTAL	4	....	2,225

FACTORY			
Works Manager	1	750	750
Fine W/D M/c.oprs	6	300	1,800
Enamelling m/c oprs	3	300	900
Inspector	1	300	300
Helpers	3	175	525
Watchman	2	175	350
Total:	16	.....	4,625
Grand Total:	20	....	6,850

Estimated wages/Annum	82,200
Add 25% for employees benefit like P.F., ESI, Bonus etc.,	20,500
Grand Total	1,02,700

CALCULATION OF WORKING CAPITAL REQUIREMENT AND MARGIN MONEY

Basis : 1 Month

		Rs. in lakhs.	Bank finance	Margin
Raw material	- 30 days	0.65	0.455	0.195
Working expense	- 30 days	0.15	0.0000	0.150
Receivable	- 30 days	1.10	0.880	0.320
* Finished goods	- 15 days	0.40	0.280	0.120
	Total:	2.30	1.610	0.780
Working capital inthe IInd year for one month		2.76	1.930	0.830
-do- in the IIIrdd year for one month		3.66	2.580	1.100

* Finished goods :

Raw material	: Rs.65,370	
Wages	: Rs. 8,558	
Power & fuel	: Rs. 3,120	
Total	:Rs. 77,048	-Rs.77,000(say)
Contigency 5%	:	Rs. 3,850
	Total:(1month)	Rs.80,898

for 15 days Rs.40,449.00

Say .40lakhs

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CALCULATION OF PROJECT COST

Land	:	Rs. 29,000	
Building	:	Rs.1,08,000	
Machinery & Equipment	:	Rs.2,46,000	
Miscellaneous Assets	:	Rs. 10,000	
Preliminary and pre-operative expenses (Salary during construction, interest during construction, Travelling Expenses etc.,)	:	Rs. 30,000	
Margin money for working Capital	:	Rs. 78,000	
Contigency	:	Rs 20,000	
Total	:	Rs.5,21,000	say Rs.5,20,000

FINANCING

Kerala Financial Corporation (85% ofland, building, m/c, miscellaneous assets, contigency)	:	Rs.3,51,000
State Bank of India (10% subsidy for land, machinery, buildingetc.)	:	Rs. 38,000
Share Capital	:	Rs.1,31,000
TOTAL	:	Rs.5,20,000

CALCULATION OF COST OF PRODUCTION AND PROFITABILITY

	operating years 1	2	3
Number of working days	300.00	300.00	300.00
Number of shifts	3.00	3.00	3.00
Installed capacity (MT)	22.50	22.50	22.50
Production (MT)	11.25	13.50	18.00
Capacity utilisation (%)	50.00	60.00	80.00
A. Sales	Rs.11,02,500.00	13,23,000.00	17,64,000.00
B. Cost of Production			
Raw materials	6,53,700.00	7,84,400.00	10,46,000.00
Power	19,500.00	23,400.00	31,200.00
Wages including Benefits	70,000.00	70,000.00	70,000.00
Repairs and Maintenance	7,000.00	7,000.00	7,000.00
Insurance	3,000.00	3,000.00	3,000.00
Depreciation (5% for building & 10% for machinery-straight line method)	30,000.00	30,000.00	30,000.00
Contigency (5% of the 1st 3 in B)	37,000.00	43, 800.00	57,300.00
TOTAL:	8,20,200.00	9,61,600.00	12,44 500.00
C. Administrative &Selling Expenses			
Salary including benefits	34,000.00	34,000.00	34,000.00
Selling expenses (3%)	33,000.00	39,000.00	53,000.00
Other Administrative exp.	20,000.00	20,000.00	20,000.00
Total:	87,000.00	93,000.00	1,07,000.00
D. Financial expenses			
Interest on Term loan(11.87%)	41,663.00	41,663.00	39,206.00
Interest on working capital (16.5%)	26,565.00	31,845.00	42,570.00
Total:	68,228.00	73,508.00	81,776.00
E. Grand Total: (B+C+D) = E	9,75,428.00	11,28,108.00	14,33,276.00
Operating Profit(A = E)	1,27,072.00	1,94,992.00	3,30,724.00

BREAK EVEN ANALYSIS

Basis : 80% capacity utilisation

Variable Cost

Raw materials	Rs. 10,46,000
Power	Rs. 31,000
Repairs and maintenance (2% of the m/c & bldg.cost)	Rs. 7,000
Selling expense (3% of the total sales)	Rs. 53,000
Contigency (3% of raw material, Power, and repairs and maintenance)	Rs. 54,000
Total:	Rs.11, 91,000

Fixed and Semi-variable Cost

Direct Labour, factory supervision and overheads	Rs. 70,000
Administrative Expenses (salary of Administrative staff and other administrative exp.)	Rs. 54,000
Contigencies (5% of wages including benefit and insurance)	Rs. 5,300
Insurance (1% of land, building, machinery and miscellaneous assets)	Rx
Depreciation	Rs. 30,000
Financial expenses	Rs. 82,000
GRAND TOTAL:	Rs. 2,41,300

Selling prise	=	Rs. 17,64,000
Variable cost	=	Rs. 11,91,000
Difference	=	Rs. 5,73,000

Break even point = $\frac{\text{fixed and semi variable cost} \times 100}{\text{Difference in selling prise \& variable cost}}$ X Capac

= 33.647%

[redacted]

RAW MATERIAL SUPPLIERS

ENAMEL	- Dr.Beck Co., Poona & Parik Monopol Co., Maharashtra.
COPPER WIRE	- Minerals & Metals Trading Corpn, Bombay.
INDUSTRIAL SOAP	- Shamli Agencies, Alwaye.
DIOMOND DIES FOR WIRE DRAWING MACHINE	- Electrical die Corpn, Calcutta & Sudarsan Diamond Dies, Bangalore.