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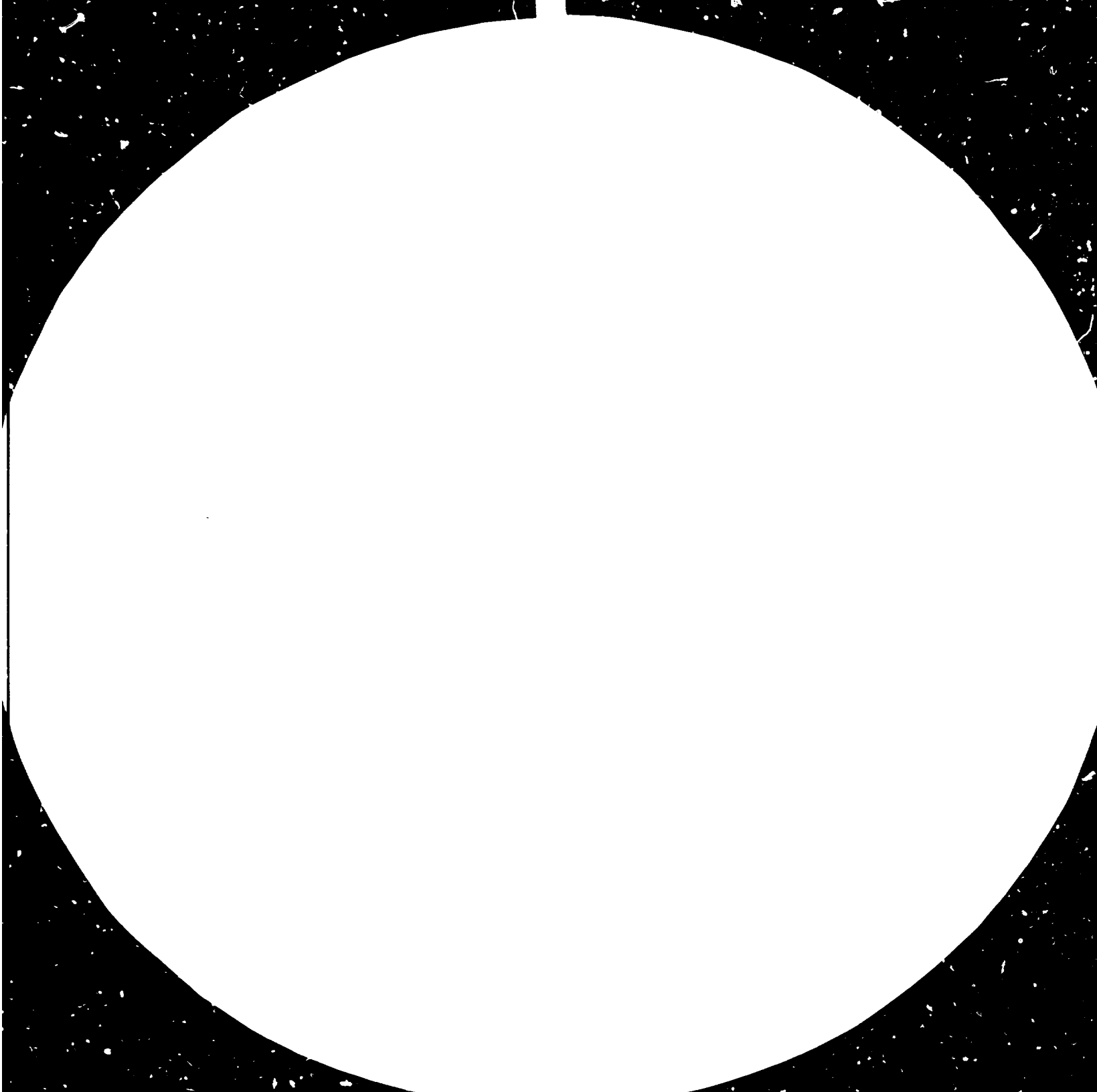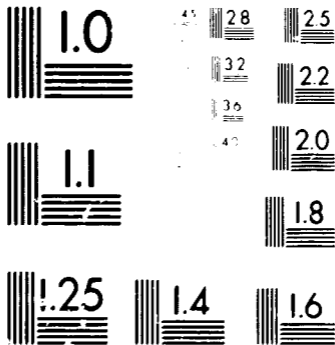
MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS

STANDARD REFERENCE MATERIAL 1010a

(ANSI and ISO TEST CHART No. 2)

13760

United Nations Industrial Development Organization

Seminar on Furniture and Joinery Industries

Réduit, Mauritius, 6 - 24 August 1984

FURNITURE FINISHING *

by

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J. Roüillard **

2376

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Introduction

The aim of any manufacturer is to make a profit.

These notes have been prepared to enable furniture makers to choose the right furniture finish (cost/quality compromise) and to use it in the right way to achieve a profit.

A few basic principles (theory) will be stated. Ignorance of these, negligence, short cuts, will result in substandard work, or even waste and unnecessary repairing, thus loss of money.

To make a profit, we must know, we must even be alert since all things (although inanimate) around us react, degrade, break down. We must know the properties of the substrates we are going to coat and the properties of the coating we are using and how to use these delicately formulated coatings efficiently.

We shall consider the following substrates (building materials):
- wood and derivatives (plywood, particle board)
- steel - black and galvanized and phosphated
- aluminium
- G.R.P. (glass reinforced polyester) also known as "fibreglass".

Wood

Since time immemorial wood has been a readily available and replenishable material. In the furniture "industry" solid wood has become a means of expression, a cultural affair with an important emotional aura. Certain pieces and certain sytles have even become collection items of high value.

A wide range of species is used for furniture manufacture, each sort of wood having different characteristics. Generally and approximately wood consists of the following:

A.   Cellulose and hemicellulose: 40-50 percent - fibrous structure of wood.

Lignin: 20-27 percent - Polymeric binding material.

Protein: 0.2 - 0.5 percent

Mineral matter and salt: 1.0-5.0 percent

Water: 25 - 35 percent

Colourants (flavones and quinones) less than 1 percent and tannins.

B.   Wood is a non uniform hygroscopic material, which shrinks and swells according to its water contents.

C.   Wood is susceptible to attack by various chemicals: eg. solutions of nitric acid, nitrates, chlorates, alkalis, phenol, calcium and zinc salts, salts of strong bases and weak acids, sulphoric acids, alkaline detergents and soaps.

     Wood is porous and even smooth surfaces are very irregular when viewed under magnification.

     Wood is attacked by fungi and insects.

     Wood is bleached by the U Via sunlight.

     Wood burns.

Moisture transfer

There are various methods of restricting the excessive transfer of moisture between the wood surface and the surroundings, and thus reducing excessive shrinking and swelling and even splitting. The method used in the furniture industry is application of a surface coating.

According to the exposure conditions and the type of wood the coating (whether a varnish or a paint) will have some flexibility to accomodate micro-movements in the wood, and will form a film that is supposed to resist various chemical and physical constraints. Depending on the requirements, a wide variety of coatings can be used (cost/quality).

The pores in the wood can also be filled with correctly formulated wood fillers or sealers, or putties for larger cracks and holes. Again depending on the requirements, a wide variety of materials can be used.

Wood degradation by fungi and insects can be retarded or stopped by a number of methods.

B.S.Standards relative to wood preservation

B.S. 144-1973: Coal tar creosote for the preservation of timber.

B.S. 913-197?: Wood preservation by means of pressure creosoting.

B.S.1282-1975: Guide to the choice used and application of wood preservatives.

B.S.3051-1972: Coal tar creosotes for wood preservation (other than creosotes to BS 144).

B.S.4072-1974:   Wood preservation by means of water borne copper/chrome/ arsenic compositions.

B.S. 3452 (1962): Copper/chrome, water borne, wood preservatives and their application.

B.S. 3453 1962 (1979): Fluoride/arsenate/chromate/dinitrophenol water borne, wood preservatives and their applications.

B.S. 5056 1974 (1979): Copper naphtenate wood preservatives.

B.S. 5707:   Solutions of wood preservatives in organic solvents.

Part I (1979):   Specification for solutions for general purpose applications including timber that is to be painted.

Part 2 (1979):   Specification for pentachlorophenol wood preservative solution for use on timber that is not required to be painted.

Part 3 (1980):   Methods of treatment.

Many are not suitable to the furniture industry. A few that are suitable are listed below.

(WB)   Waterborne preservatives: These are salt solutions used to impregnate dry wood under high pressure. They are generally colourless and odourless, they can be formulated to improve the fire resistance of wood. When dry they can be painted or varnished. However being water soluble, they are liable to be leached out of timber under wet conditions.

     Copper/chrome salts

     Tanalith process

     BM process

     Copper/chrome/zinc chloride process

(DS)   Preservatives carried by organic solvents: Zinc naphtenate, copper naphtenate, pentachlophenol.

Various high remanancy moder insecticides and fungicides (similar to those used in agriculture). Chlorinated naphtalenes and other chlorinated hydrocarbon. These are usually applied by brushing or cold dipping. They do not render the timber more inflammable than it originally was. Also there exist insecticidal paints and varnishes of various composition which, apart from protecting the wood from insect attach, kill by contact all insects which may walk on the surface. These products remain active for at least three years and should find application for interior coatings of furniture.

Fire

The resistance of wood to fire can be greatly improved in two ways:

1.   By incorporating salt such as ammonium phosphate in the pressure impregnation process used to render the wood resistant to insects and fungi using water borne preservatives.

2.   By using fire resisting and/or fire reacting intumescent paints and varnish. A number of brands are available on the international market.

The following standards, though they refer to tests on buildings and constructions, may also, if necessary, be used as guidelines if fire resistance of various pieces of furniture need to be assessed.

ANSI/ASTM E 119-76:   Standard Methods of fire tests of building construction and materials.

B.S. 476:   Fire tests on building materials and structures.

Also in the French Legislation, there are two books worth mentioning in respect of safety against fire.

Those are published by the "Journal Officiel de la République Française" 26, rue Desaix, 75727 Paris Cedex 15.

Their respective titles are:

Book I: Securité contre l'incendie - Etablissement recevant du public.

Book II: Securite contre l'incendie - Législation et reglementation générales - Immeubles de grande hauteur - bâtiments d'habitation - Etablissement industriels et commerciaux divers.

Steel

The backbone of today's world, available in so many alloys, is unfortunately a non renewable resource, which does not grow back like trees. It has got superb qualities but one main defect. It rusts, to achieve its original form of iron oxides and hydroxides.

For furniture, mils steel (of carbon content below 0.2%) is mainly used in the form of sheets and tubes of various sections.

These can be protected from rusting in different ways, a few of which are listed below:

1.   Galvanising

2.   Phosphating

3.   Application of surface coatings of a wide range of types
by a wide range of methods.

4.   Chrome plating.

Methods 1 and 3 as well as 2 and 3 above can be combined to achieve a
better protective/decorative aim.

As far as furniture is concerned, steel does not carry the same emo-
tional connotation as wood and it is mainly used for furniture of the office
type. In this context, and also because of its intrinsic structure, steel is
a material much more easy to coat and protect than wood, as long as one bears
in mind that the two main sources of corrosion are water and oxygen. Contact of
the unprotected steel with these two must be avoided. Under special conditions
steel furniture may be in contact with highly corrosive chemicals other than or in
addition to water and oxygen. Special coatings can be formulated to protect steel
under these specific conditions.

When steel (or iron) is placed in contact with water (containing dis-
solved salts) in the presence of another metal, an electrolytic cell is imme-
dicately formed. According to the electrode potential of the respective metals,
one will become the anode and the other the cathode. Electrons will flow (from
the anode to the cathode) and the anode will be corroded away.

In practice, the electrode potential of iron is -0,44 volt while that
of mild steel is +0,3 volt. This means that in the presence of an electrolyte,
an electrolytic corrosion cell will be formed whereby the iron will become the
anode and the mild steel the cathode (electron acceptor). Thus the iron will
corrode away to form various oxides and hydroxides (rust).

The electrochemical or electromotive series of element expresses the
electrode potential of various elements with respect to the hydrogen ion H+.
According to this classification when any two elements will be placed in an elec-
trolyte, the one element with the more negative electrode potential is the anode
and goes into solution (is corroded away).

Element (ion)	Normal Electrode potential
Mg ++ (Magnesium)	- 2,27
Al +++ (Aluminium)	- 1,76
Zn ++ (Zinc)	- 0,76
Cr ++ (Chromium)	- 0,60
Fe +++ (Iron)	- 0,44
Ni ++ (Nickel)	- 0,22
Pb +++ (Lead)	- 0,12
H + (Hydrogen)	0,00
Cu ++ (Copper)	+ 0,34
Ag + (Silver)	+ 0,80
Au + (Gold)	+ 1,50

However, the galvanic series reproduced below is a more practical way of determining which material will be corroded away when placed in contact with another material in an electrolyte.

Corroded end (anodic or least noble)

Magnesium

Magnesium alloys

Zinc

Aluminium

Cadmium

Steel and Iron

Cast Iron

Chromium Iron (active)*

18/8 Chromium/Nickel/Iron (active)

18/8/3 Chromium/Nickel/Molybdenum/Iron (active)

Lead/tin solders

Lead

Tin

Nickel (active)

Inconel (active)

Brasses

Copper

Bronzes

Copper/Nickel alloys

Monel metal

Silver Solder

Nickel (passive)**

Inconel (passive)

Chromium/Iron (passive)

18/8 Chromium/Nickel/Iron (passive)

18/8/3 Chromium/Nickel/Molybdenum/Iron (passive)

Silver

Graphite

Gold

Platinum

Protected end (Cathodic or most noble).

N.B.   * Activity (active)

A metal which has not received the above treatment.

** Passivity (passive)

A property shown by iron, chromium and related metals, involving loss of their normal chemical activity in an electrochemical system or in a corrosive environment after treatment with strong exidizing agents like nitric acid and when oxygen is evolved upon them during electrolysis, forming an oxide coating.

Galvanizing of steel

Galvanizing is a process whereby Zinc/metal is deposited on the cleaned steel surface.

Zinc is less noble (more electronegative) than iron or steel; when both metals are in contact with an electrolyte the zinc becomes the anode while the steel is the cathode. Thus zinc corrodes away instead of the steel which is thus "superficially" protected by the zinc.

The following British Standards refer to galvanizing of various steel articles:

B.S. 2989 - 1982: Specification for continuously hot dip-zinc coated and iron, zinc alloy coated steel; wide strip, sheet/place and slit wide strip.

B.S. 3083 - 1980: Specification for hot dip zinc coated corrugated steel sheets for general purposes.

B.S.   729 - 1971: Hot dip galvanized coatings on iron and steel articles.

B.S.   443 - 1982: Specifications for testing zinc coatings on steel wire and
                   for quality requirements.

B.S. 3034 - 1963: Galvanized hollow ware (withdrawn July 1979).

For additional protection, the galvanized surface is usually coated with a paint system consisting of a primer/undercoat and finish coat. Depending on the requirements, many sorts of coating (more or less durable) can be formulated. However, after degreasing, etching, and washing it is usual to apply a two pack etch primer (or wash primer) on the dry and clean surface to achieve good adhesion of the subsequent primer/finish coats.

Phosphating

The principle of phosphating is that the survace of a steel part becomes coated with a ferrous phosphate layer after immersion in a dilute phosphoric acid solution.

Of course,the chemistry and the practical application are much more involved. Depending on the type of steel used and tne end product required, a large number of process and different phosphating baths or solutions are available.

Generally, the phosphate coating has found two major applications:

1.   As a paint base to increase paint adhesion and light corrosion;
2.   To facilitate cold forming of metals (like a lubricating layer`.

Phosphating can usually be classified as "thin" or "thick" coat. These processes are described in the flow charts indicated in Fig. 1 and 2 hereunder.

The British Standard with reference to phosphating is:

B.S. 3189 - 1973: Phosphate treatment of iron and steel.
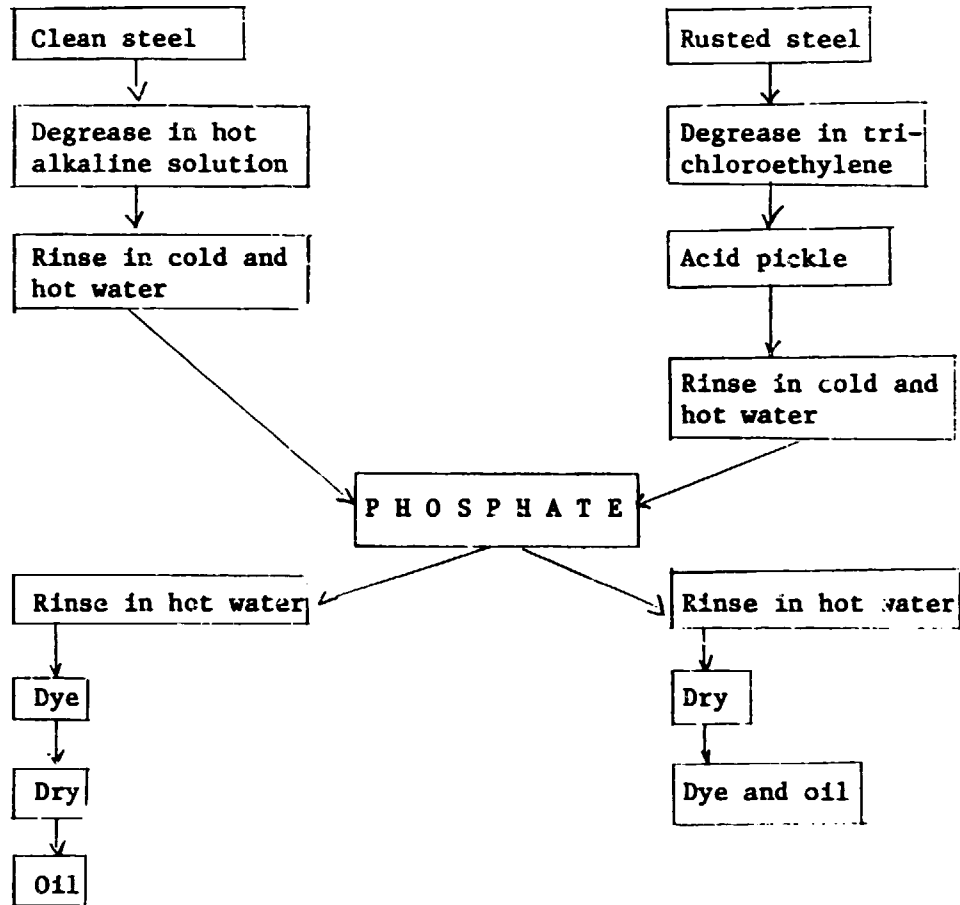
Fig. 1: Thick coat phosphating (not for overpainting)
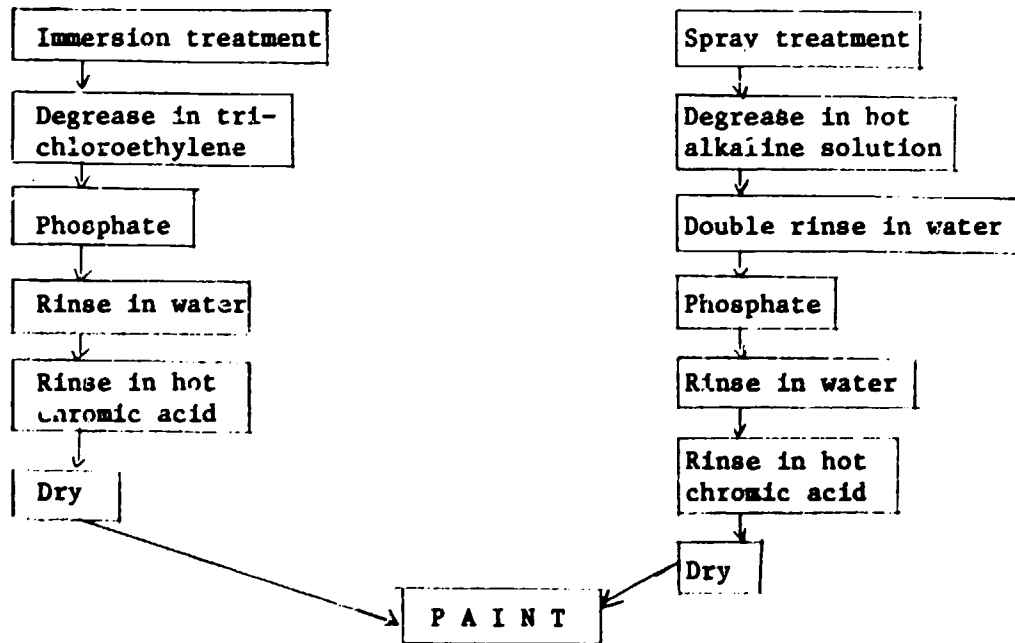
Fig. 2: Thin coat phosphating (suitable for overpainting

Aluminiur

One of the most widespread elements on earth (bur unfortunately not widely available in easily extractalle forms) is now available in a multitude of metallic alloys. Pure aluminium rapidly forms a protective aluminium oxide (Al_2O_3) layer under the action of oxygen.

Before application of a paint coating aluminium surfaces need to be cleaned. This is generally performed using chlorinated solvents such as methylene chloride or perchloroethylene. The surface can be etched with dilute sodium hydroxide solution, followed by acid neutralization and washing with water. Specific methods of degreasing and etching are recommended for specific alloys.

o achieve optimum adhesion, a two pack etch primer (or wash primer) is usually applied as a first, thin adhesion promoting coat. This is usually based on a polyvinyl butyral/phenolic resin blend with zinc tretraoxychromate as pigment and a phosphoric acid solution as catalyst. A wide variety of coatings can be applied on the cured primer. However, these coatings should be formulated to be somewhat flexible since the linear coefficient of thermal expansion of aluminium is of the order of 2.40×10^{-5} $^\circ C^{-1}$.

The coatings applied on the aluminium can be based on the following systems among others, thermosetting (convertible) or thermoplastic (non convertible) acrylic resins, polyurethanes, vinyls, alkyd/melamine combinations, alkyd/nitrocellulose combinations, chlorinated rubber.

Apart from application of a surface coating, aluminium surfaces can be anodized or electroplated.

Anodizing is a treatment iereby a relatively thick, hard, stronlgy adhering and protective coat of aluminium oxide is produced on the surface of the aluminium. The anodized aluminium can be overpainted if necessary.

Electroplating: Aluminium is sometimes plated with nickel or chromiums. This is usually carried out in five steps.

1. Degreasing
2. Electrolytic cleaning
3. Formation of undercoat
4. Electroplating
5. Polishing.

The following British Standards refer to aluminium and the various methods of protecting the metal:

B.S. 1615 - 1972: Anodic oxidation coatings on aluminium.

B.S. 3987 - 1974: Anodic oxide coatings on wrought aluminium for external architectural applications.

B.S. 5599 - 1978: Specifications for hard anodic oxide coatings on aluminium for engineering purposes.

B.S. 6161 - 1981/82 (parts 1 - 8): Methods of test for anodic oxidation coatings on aluminium and its allows.

Coating: General composition and main components with reference to the furniture industry

Now that we briefly examined the substrates to be coated (the materials used to manufacture various pieces of furniture) we shall have a quick look at what is: a paint, a lacquer, a varnish, a primer, an undercoat, a filler, a stopper, a putty, a sealer, a dye, a stain and a thinner.

We shall glance through their constituents and we shall explain the main characteristics of a coating such as: solid content, adhesion, flexibility, drying (or curing), hardness, gloss, opacity, colour, sandability, chemicals resistance, abrasion and impact resistance, resistance to weathering, compatibility amongst coatings systems.

Generally speaking, a coating consists of the following basic constituents:

Binders:

Also known as film formers, polymer resin, plastic material. These are the basic constituent of a coating and are responsible for adhesion, flexibility, gloss, imperviousness, resistance to all sorts of weathering contitions, see figs. 3, 4 and 5. Binders are available in solid and liquid form. They can be of natural or synthetic origin.

(i)   (ii)   (iii)   (iv)   (v)

Fig. 3

Legend: (i):   PVA/Acrylyc dispersion (emulsion) in water, with
               water white milky appearance. Used for water based
               paints.

         (ii) Raw soya oil, as used in manufacture of long oil
               alkyd resins by the alcoholysis process (semi drying
               oil).

         (iii) Boiled linseed oil (drying oil) - can be used in various
               oil based paints and primers manufacture - slow drying,
               soft film, which yellows.

         (iv) Long oil alkyd resin for primers manufacture

         (v)   Water colute melamine resin as used in acid catalysed
               varnishes or baking enamels.
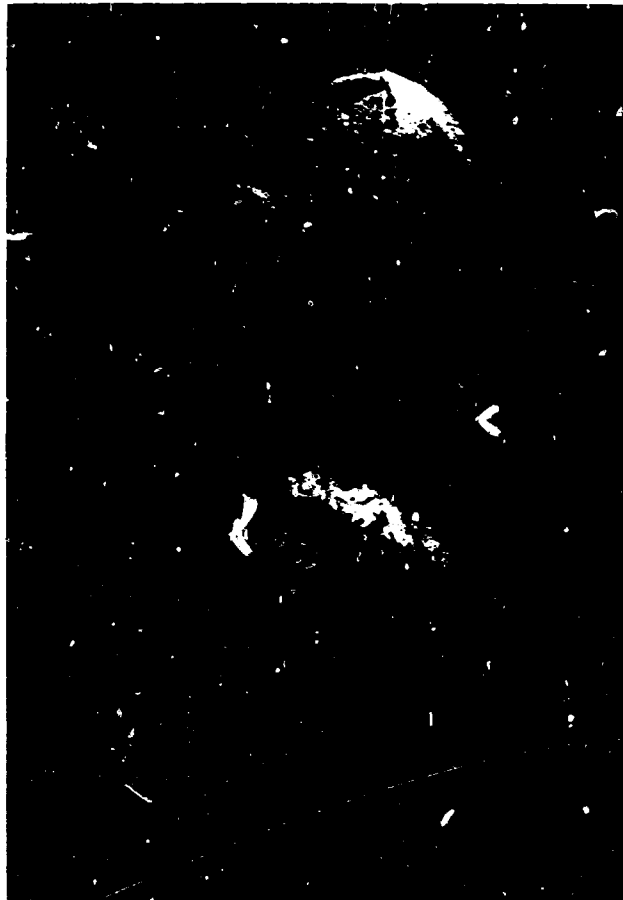
Fig. 4:   Some binders in solid form

Fig. 5:   Some binders in solid form

Plasticizers:

     These are flexible or soft binders used to modify the flexibility and adhesion, characteristics of a binder. They are available in either liquid or solid form.

Solvents:

     These are used to dissolve solid resins or to dilute (reduce the viscosity of) highly viscous liquid resins. They are usually considered as the volatile part of a coating. They are compatible with the binder and are specific to certain binders. Apart from water and a few chlorinated solvents such as methylene chloride all solvents are inflammable. Also they are usually more or less toxic being narcotic (central nervous system depressant) and benzene (C_6H6) has been classified as carcinogenic, see figs. 6, 7 and 8.

Fig. 6

PAINT X
+
SOLVENT B.
COMPLETE.
COMPATIBILITY.
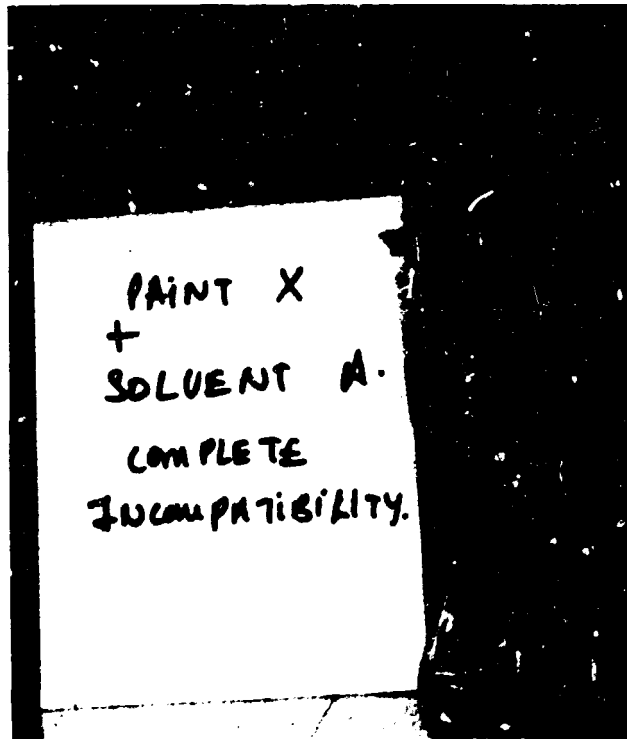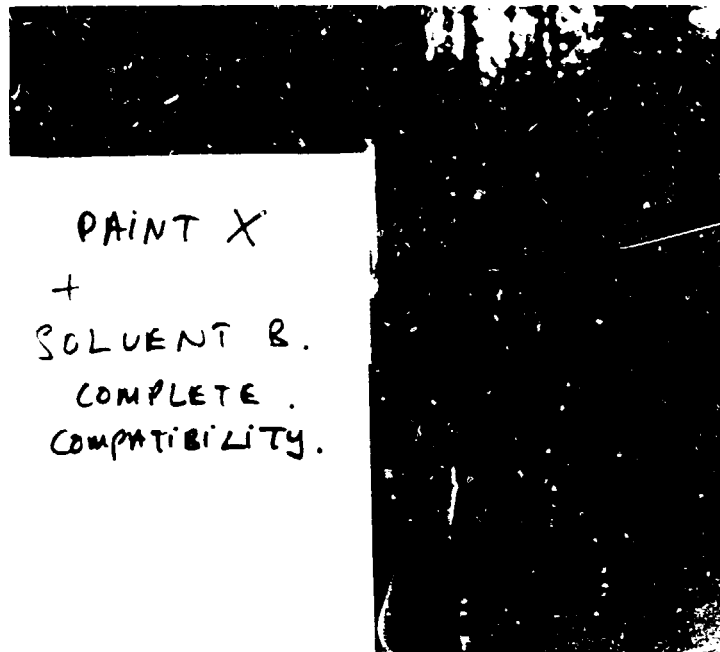
Fig. 7

Fig. 8

Pigments:

These are coloured powders and are designed to be insoluble
in the resin or resin/solvent solution in which they are dispersed
(not dissolved). They confer colour and opacity to coatings. They
tend to protect the resin component from the degradative influence of
ultra-violet radiation (from sunlight). They can also confer specific
properties to the coating example being the anticorrosive pigments.
See figs. 9 and 10.

Fig. 9

Fig. 10

Dyes:

These are coloured powders which are soluble in the resin or
resin/solvent or in water. Like the pigments they provide colour
and usually they are used for their high transparency to stain wood.
They also tend to protect the binder from degradation and influence of
ultra violet radiation.

Extenders:

These are powders which are insoluble in the resin or resin/
solvent solution in which they are dispersed. They provide very little
opacity to the system and they are used to modify certain properties
of the coatings or to reduce cost. They are usually whitish powders.

Additives:

These are special chemicals which, when added in small amounts,
(micro components),to a coating formulation have an important effect
on the coating characteristics.

Binders:

These consist of a wide range of chemical families and thus have a wide range of properties. Various binders of different chemical families are compatible with each other and blends are often formulated to obtain intermediate properties.

However, binders can be classified into two broad groups according to their curing (or drying) mechanism.

Group A - convertible binder (usually thermosetting)

These change in chemical composition when they cure. In the case of binders in solution, the curing mechanism renders them insoluble in their original solvent.

Examples are: two component epoxies, two component polyurethane, air drying alkyds , unsaturated polyester, urea, melamine and benzoguamine/formaldehyde in combination with various other resins such as epoxies and alkyds, various acrylics, drying oils such as linseed, fish, tung, one pack pojyurethane, epoxy esterts, modified alkyds.

Group B - non-convertible binders (usually thermoplastic)

These cure mainly by solvent evaporation and/or coalescence, without any chemical reaction taking place. Thus they keep their original chemical structure and remain soluble in their original solvent. They are said to dry physically. Head will speed the rate of solvent evaporation and will thus shorten the drying time.

Examples are: chlorinated rubber, nitrocellulose resins, cellulose acetate butyrate (C.A.B.), cellulose acetate proprionate (C.A.P.), vinyl resins, thermoplastic acrylics, bitumen and tars, thermoplastic emulsions or dispersions (which dry by water evaporation) and coalescence (eg. polivinyl acetate P.V.A. dispersions, P.V.A./ acrylic dispersions among others), waxes, shellac, coumarone resins, manillagum and damar.

Group A - Convertible binders (and thus convertible coatings of which they form
the basis

These can cure by a large number of methods depending on thier chemical
constitution. In fact the same binder can be cured by different methods to yield
the same end product, or a specific binder can be made to yield very different
end products by reacting with different reaction partners.

For a given binder (or coating) the curing method usually depends on
the rate of production and manufacturing method of a given object. The reaction
partner (thus formulation of the coatings) depends also 'n the rate of production
and manufacturing method but also on cost/quality compromise. Thus, various bin-
ders can be mixed or blended to formulate a coating adapted to the application
method, and having specific characteristics when cured. Thus, according to
their curing mechanism, (dictated by the production method) we shall draw an
arbitrary classification of convertible coating based on convertible binders.

N.B.   It should be noted that in certain cases a convertible binder
            can be blended with non-convertible binders to achieve certain desired
            properties. In these cases, the curing mechanism is both chemical
            (change of chemical structure) and physical (solvent evaporation.

General characteristics of each family

1.   Binders (coatings) which cure by reaction with a hardener (reaction partner

            Examples are:

            (i)   Two Pack Epoxies

                        A usual reaction is between the terminal opoxide groups
            (- CH - CH$_2$) in the epoxy resin and amine groups in polyamines
            and polyamido amides (R - NH) and occurs at room temperature.
            This reaction is speeded up by increasing the temperature.
            Solvent free and solvent containing epoxy coatings are available
            to cure at room temperature.

            (ii)   Two-pack Urethanes

                        A usual reaction is between the base resin which can be
            a polyalcohol which contains -OH groups and the hardener (a
            polyisocyanate) which contain isocyanate groups. The reaction
            occurs at room temperature and is accelerated by heating.

POLYURETHANE CURING REACTION

$$\underset{\text{Alcohol}}{\underline{Ho - R - OH}} \qquad + \qquad \underset{\text{Isocyanate}}{\underline{OCN - R' - NCO}}$$

$$Ho - R \qquad \left[\underset{\text{Urethane group}}{\underline{- O - C - N}}\right] \qquad - R' - NCO$$
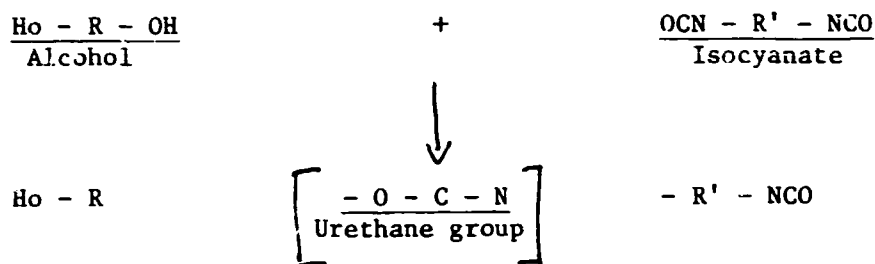
(iii)   **Two Pack Acrylics curing with isocyanates**

2.   Reaction accelerated by a catalyst.

(i)   **Acid Catalysed varnishes and Enamels**

These are based on Urea formaldehyde or melamine formaldehyde resin plasticised by short oil, non-drying castor oil or coconut oil alkyds. The reaction occurs at room temperature in the presense of an acid catalyst such as an alcoholic solution of hydrochloric acid, or paratoluene sulphonic acid. The reaction (which can also take place at elevated temperature without catalyst) usually occurs between the methylol groups of the amino resins and residual hydroxyl groups in the alkyd resin.

$$- Co - N - CH_2 - Co - N - CH_2 \qquad OH \qquad OH$$

$$+$$

$$\underbrace{CH_2 - OH \qquad CH_2 - OH}_{\text{From amino resin}} \qquad \underbrace{- R - R_1 - R_2 - R_1 - R}_{\text{From the alkyd resin}}$$

$$\left.\begin{array}{c} - CO - N - CH_2 - CO - N - CH_2 - \\ | \qquad\qquad | \\ CH_2 \qquad\qquad CH_2 \\ | \qquad\qquad | \\ O \qquad\qquad O \\ | \qquad\qquad | \\ - R - R_1 = R_2 - R_1 - R - \end{array}\right\}$$ Cross linked cured coating
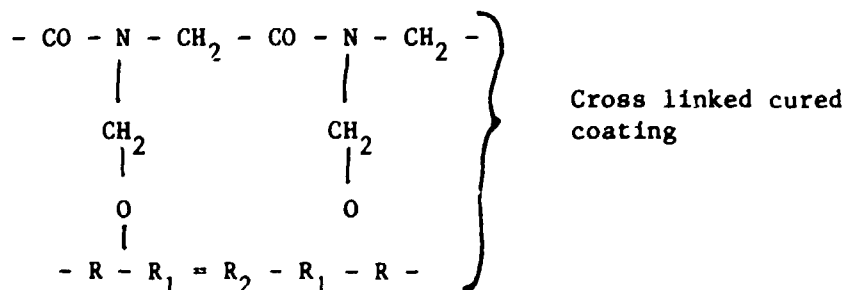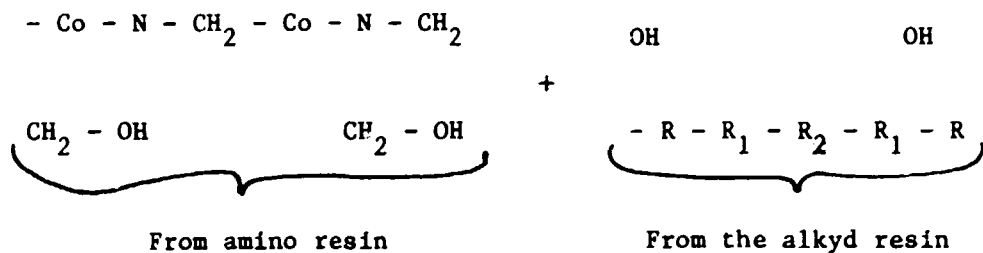
(ii) Unsaturated polyester fillers or coating

They are based on an unsaturated polyester resin which is the reaction product of unsaturated and saturated dibasic acids with polyols, they are supplied a solution in a monomer reactive diluant) such as styrene. The cross linking reaction can occur at room temperature when a catalyst (an initiator) and an accelerator are used. The reaction can also be carried out by ultra violet curing or electron beam curing.

The catalyst (an organic peroxide such as benzoyl peroxide or methyl ethyl ketone peroxide) initiate free radicals when heated to its critical temperature or when in contact with an accelerator such as cobalt napthenate.

The polyester then copolymenizes with the styrene moncmer to yield a cross linked structure as indicated below.

$$- OC - CH - CH - CO - CH_2 - CH (CH_3) - O -$$
$$\parallel \qquad\qquad \parallel$$
$$O \qquad\qquad\qquad O$$

$$\left[\begin{array}{c} CH_2 \\ | \\ C6\ H5 - CH \end{array} \right] \quad \text{From Styrene}$$
$$|$$

$$- OC - CH - CH - CO - CH_2 - CH (CH_3) - O -$$
$$\parallel \qquad\qquad \parallel$$
$$O \qquad\qquad\qquad O$$
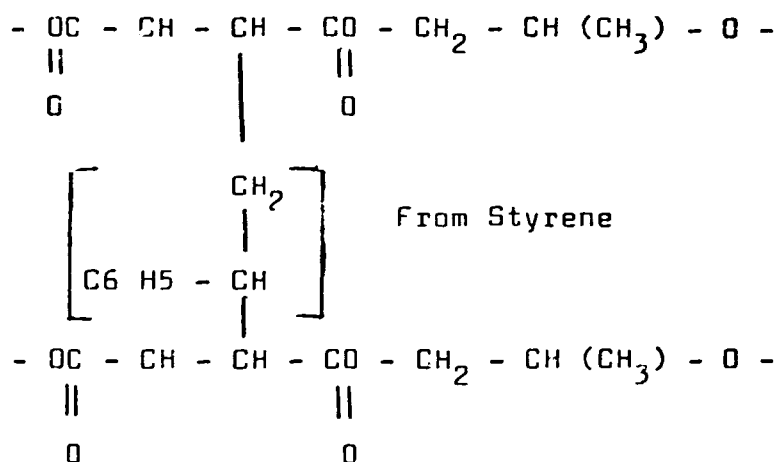
(iii) Two Pack Etch (wash) Primers

These are usually based on a blend of polyvinyl butural and resol phenolic resins together with appropriate pigments and solvents. The catalyst is a phospheric acid solution in various solvents.

Because of the methylol groups $(-CH_2\ OH)$ they contain resol resins can be catalysed by acid at room temperature to form polycondensates. These resols also polymerize when baked at 150 - 200°C.

3. Binders which cure by oxidation

(oxidative polymerization accelerated by catalyst usually called driers which are incorporated in the formulation and not mixed in prior to use).

(i) Drying oils such as linseed, tung end fish.

(ii) Long oil and medium oil alkyds based on drying oils or unsaturated fatty acids.

(iii) Modified alkyds such as styrenated alkyds, silicone modified alkyds.

(iv) One pack epoxy esters.

(v) One pack oxidation drying polyurethanes.

The drying (polymerization) mechanism is explained by the hydroperoxide theory and the formation of free radical in the unsaturated fatty acid (except for conjugated fatty acids whose curing mechanism is via peroxide formation).

BINDERS WHICH CURE BY REACTION WITH AMBIENT HUMIDITY

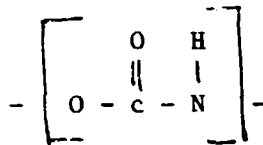These are usually moisture cured "polyurethane". They consist of urethane prepolymers containing residual (excess), isocyanate groups which pack with atmospheric humidity to cure and form polyurethanes containing the urethane group.

$$- \begin{bmatrix} & & O & & H \\ & & \| & & | \\ O & - & c & - & N \end{bmatrix} -$$

BINDERS WHICH CURE UNDER THE ACTION OF HEAT (INFRA RED RADIATION)

As we have seen heat speeds up the rate of chemical reaction and the rate of solvent evaporation. Thus most if not all coatings which cure at room temperature, would cure more rapidly if heated or warmed.

However, there are a few coatings which have been designed to cure only when heated. A few of these binder systems are listed below:

Amino/alkyd combinations

amino/epoxy/alkyd combination

phenolic (resol)/epoxy combination

epoxy/amino

epoxy/acrylics

amino/acrylic combination

Thermosetting powder coatings/epoxy based (with a variety of curing

agents such as cyanamides, acid anhydrides and both aromatic and aliphatic

amines, epoxy/polyester blends, polyester/polyisocyanate.

These coatings are used in industry where continuous flow production exists.

For example: amino/alkyds and amino/acrylic are used in car finishes. Epoxy phenolic are used in interior drum and can coatings. Epoxy/alkyd/amino used for domestic equipment and toys Acrylic/epoxy: domestic equipment and furniture Powder coatings: tubular funriture, industrial parts. These powders contain the base resin in the hardener already intermixed in each poder grain. It is only when the powder is heated above a certain temperature that the reaction and curing takes place.

We shall not consider the individual reaction involved, nor the individual characteristics of these binder blends since so many combinations are possible to yield coatings with similar properties.

ULTRA VIOLET AND ELECTRON BEAM CURING

These high energy radiations shorten the curing time of convertible coating considerably. Ultra violet is more common than electron beam curing.

Radiation of the order of 3000 - 4000 Angstrom is used to initiate free radical formation and thus polymerization in unsaturated polyester systems for wood coating. This UV-cured system is mainly used with curtain coating application.

Electron beam curing has been used for curing unsaturated polyester coatings. It is faster than UV curing and permits line speeds in curtain coating of the order of 600 metre/minute. Like UV curing the process does not heat the substrate so that it is suitable for materials such as wood or wood derivatives which are sensitive to heat. The depth of penetration of the electron beams depends on the potential difference in the apparatus. This is of the order of 300 kV (300,000 V) and can be varied as necessary.

The reaction mechanism of the polyester curing is the same as that of catalytical cure at room temperature.

Group B: non convertible binders

As we have seen these dry physically by solvent evaporation. Non convertible binders are often used in blend with convertible binders to achieve intermediate properties.

A few examples are :
====================

Nitrocellulose/drying alkyd blends for furniture finishes

Nitrocellulose/melamine/Alkyd blend for acid catalysed furniture finishes or air drying car repair finishes.

Chlorinated Rubber/drying Alkyd blend for industrial maintenance paints.

Epoxy/tar combination for industrial maintenance paints and marine coatings.

Plasticisers:
=============

Examples are :
=============

Various alkyds used to plasticize   melamine resin, chlorinated
rubber resins, nitrocellulose resins,

Chlorinated Paraffins used in conjunction with chlorinated rubber resins.

Various esters such as dibutyl phtalate tricresyl phosphate used in

conjunction with nitrocellulose.

MAIN GROUPS OF SOLVENTS USED IN COATINGS

Since solvents (thinners) are the only component (apart from hardeners and catalysts)
which the user or applicator of a coating can add to the coating before its application,
it is important that a few characteristics of more usual solvent be known, since adding
the wrong solvent to a coating can completely ruin the product itself or cause early
coating failure (breakdown).

Apart from its (1) compatibility with the binder system that is: ability to dissolve or
dilute a binder system (solvency), other basic properties of solvents which must be
known to users are : (2) evaporation rate , (3) flash point (4) toxicity.

An important tool for choosing solvents that are compatible with the binder system is
the solubility parameter concept, which is a numerical constant characteristic for each
solvent and film forming material. To be of practical use the solubility parameter is
linked to the degree of hydrogen bonding of the solvent and it has been found that a
third dimension of solubility which is polarity or dipole moment (μ) helps to explain
the solubility of a few more systems.

According to their hydrogen bonding solvents can be grossly classified into the three
following groups :

(1) Poorly hydrogen bonded include aliphatic, aromatic, chlorinated and nitro hydro-
carbons.

(2) Moderately hydrogen bonded include: esters, ketones, ethers, and either alcohols.

(3) Strongly hydrogen bonded includes : alcohol, aminos, and acids.

Solubility parameters represent the force by which molecule of a solvent or a resin
attract each other. Resins are dissolved by solvents whose solubility parameter are
similar to their own, while they remain insoluble in solvents which have very different
solubility parameters from their own.

Also substances that differ widely with respect to hydrogen bonding are immisible.

Finally it has been found that solubility parameters and hydrogen bonding properties
of mixtures of solvents are approximately proportional to the volume average of the
components.

The following table is a summary of the basic solvents properties mentioned. However,
since coating manufacturer specifies special "thinners" for their coatings the user should
follow the respective manufacturer recommendation and not try and prepare his own
"magic" solvent blend.

ALCOHOLS

Methanol

Ethanol

Propanol

Butanol

Diacetone Alcohol

ESTERS

Ethyl Acetate

Butyl Acetate

KETONES

Acetone

Methyl Ethyl Ketone

Methyl I.B.K.

Cyclohexanone

Isopharone

CHLORINATED SOLVENTS

Methylene Chloride

Perchloroethylene

AROMATIC HYDROCARBONS

Toluol

Xylol

Styrene

HYDROCARBON SOLVENT BLENDS (both aromatic and aliphatic)

Various White Spirits

    "   Shellsols

    "   Pegasol

    "   Solvesso

    "   Aromalsols

As determined by their boiling range. For eliphatic hydrocarbons their percentage of aromatics is stated.

CYCLOALIPHATIC HYDROCARBONS

Cyclohexane

MISCELLANEOUS SOLVENTS

Turpentine

Dipentine

Cellosolve

Cellosolve Acetate

Polysolvan O

Texanol

Mono Ethylene Glycol

Butyl Diglycol

TESTS ON SOLVENTS

1. Boiling range (Distillation range)

2. Refractive Index

3. Flash point

4. G.L.C. Analysis (Gas/liquid chromatograph analysis)

5. Aromatic content (for hydrocarbon solvents)

6. Water content (Determination of water Karl Fischer method BS 2511-1970)

7. Specific gravity

8. Evaporation rate

9. Viscosity reduction power. Refers to the capacity of a solvent to dissolve various resins. For a given resin, at a given solution concentration and temperature the solvent which produces the lowest viscosity is the better solvent for that resin.

10. Copper corrosion test (to detect presence of sulphur in hydrocarbon solvents).

PIGMENTS

They are an enormously large group of compounds with a wide range of composition and a wide range of characteristics. They are classified in the "Colour Index" published by the Society of Dyers and Colourist and the American Association of textile chemists and colourists.

For our use we should know that pigments can be simply classified as organic and inorganic.

Organic pigments are always synthetic, while inorganic pigments can be obtained from natural origin (although nowadays they are mostly synthetic).

Apart from their desired properties of colour, opacity and weather fastness, we should know that some pigments are toxic and that their use is restricted. Examples of toxic pigments are : those containing lead such as the Lead Chromates, White Lead (basic lead carbonate), Red Lead (lead oxide) and Calcium Plumbate, the two last being used as anticorrosive pigments for metals.

Lead compound when ingested accumulate in human beings and finally produce conditions known as "peripheral neuropathy", whence the motor nerves of arms or legs are affected.

A few Inorganic pigments of common use in paints are :

Titanium dioxide (white)
Lead Chromates (lemon yellow, chrome yellow, oranges, yellowish red).
Iron Oxides (brown, red, black)
Chrome Oxides (dirty greyish green)
Molybdated Lead Chromates – solid solutions of lead molybdate, lead chromate and lead sulphate, molybdate orange (orange).
Cadmium pigments (yellow, orange, red to marroon)
(Cadmium Sulphide, Cadmium Sulphoselenide, Cadmiun Mercurysulphide)
Various Carbon blacks (various shades of black)
Micacious Iron Oxide

A few Organic pigments of common use in paints are :

Azo Yellow, Red and violet of various shades, also a few blue, greens and browns.
Phthalocyamine Blues and Greens

Apart from pigment containing lead, others such as antimony trioxide, and pigments containing heavy metal (eg. chrome) such as Zinc chromate are also considered as toxic.

The purpose of mentioning the toxicity of pigments is that, for example : children furniture should be coated wiht "non-toxic" coatings so that in the event that part of the furniture be chewed and part of the coating swallowed no cumulative, irreversible deleterious effect will be observed. It should be noted that all colours and shades are available with non-toxic pigments in non-toxic binders.

The British "Toy (Safety)" Regulations of 1974 specifies the following maximum level of various heavy metals per million parts (ppm) of the dry paint film.

METAL	PPM
Arsenic (soluble)	100
Lead (total)	2500 (0.25%)
Mercury (soluble)	100
Cadmium (soluble)	100
Chromium (soluble)	250
Antimony (soluble)	250
Barium (soluble)	500

The following pigments could be classified in either of the above two families but because of their specific use, we shall list them according to their uses :

Anticorrosive pigments: (which actively take part in corrosion protection.
1. Red Lead (for iron and steel)
2. Calcium Plumbate (for iron and steel) including galvanised surfaces
3. Zinc Chromate   "   "   "   "   "
4. Zinc Phosphate   "   "   "   "   "
5. Metallic Zinc Dust   "   "   "   "   "

<u>Metallic Pigments</u> : (used for deccrative effects such as metallic finishes)

Aluminium powder and flakes of various grades
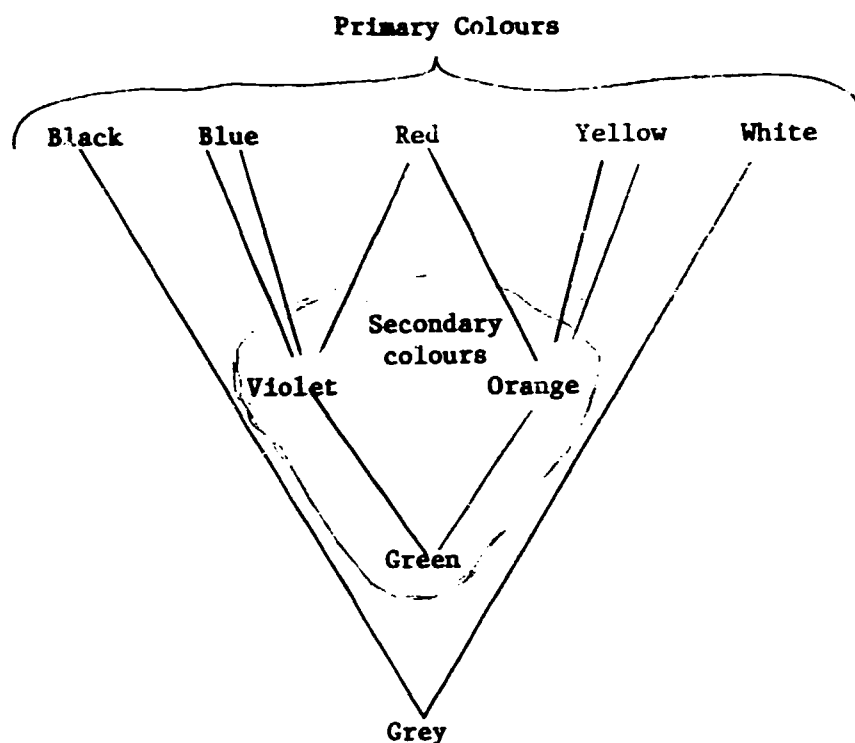Bronze powder and flakes of various grades

N.B.

It is to be noted that aluminium flakes has many uses apart from its incorporation in metallic finishes of various shades - e.g. Its flaking properties make it usefull in formulation for knot sealer for resinous woods..

Now that we have had a quick look at binders and pigments,we should state that a paint is basically a more or less stable system in which a pigment has been dispersed, i.e. intimately ground with the binder, so as to achieve the best cost quality compromise in terms of storage stability (of the unused product) and durability (service life) of the applied product.

However, pigments and binders may react together (example : Red Lead which is an amphoteric oxide reacts with an acidic resin - such as a long oil alkyd - to form insoluble lead salts) and the product may gel in the can during storage. Also according to "Stokes Law" pigments will tend to separate out and settle on the bottom of the can during paint storage. This is specially true of heavy (high density) pigments such as Red Lead, Calcium Plumbate, Zinc Dust, Titanium dioxide, among others.

Furthermore for colour matching purposes, pigments of very different families will have to be mixed and these may not be compatible with each other, hence the phenomenon of pigment floation or seperation of colours on application of a coating.

Now let us have a quick look on the principles of colour mixing. Using five basic "colour" , namely Black, White, blue, yellow, red, we can prepare a large number of "shades".

Primary Colours

Black   Blue   Red   Yellow   White

Secondary colours

Violet   Orange

Green

Grey

This is what happens in practice in colour mixing or colour matching procedures. By mixing equal parts of a primary colour and a secondary colour, a tertiary colour is obtained (six tertiary colours are obtained). When two or more tertiary colours are mixed together the result is a colour grey.

NOTES ON ORGANIC PIGMENTS

Before we list some of the main organic pigments used in the paint industry, it is necessary to have a few definitions.

Organic pigments can be classified into :-

Pigment dyestuffs: are entirely organic compounds which leave no ash on ignition and contain no salt-forming groups. They are a large class and include pigments with good lightfastness.

<u>Toners</u> : are salts produced from :

                  a) soluble or partly soluble acid dyestuffs by
                     precipitation with a heavy metal^{ion},

    and from:

                  b) basic dyestuffs by precipitation with acids.

<u>Lakes</u> : are formed by precipitation of a toner in the presence of a "base" such as blanc fixe, alumina/blanc fixe, or alumina/china clay.

The colour producing group in an organic pigment is called the CHROMOPHORE.

The most important Chromophores are :

    $N = N -$ AZO group

    $N = O$,   Nitroso group

    $N O_2$ Nitro group

Acid and basic dyes also contain salt forming groups known as Auxochromes, which are a radical or group of atoms, whose presence is essential in enabling a colored organic substance to be retained on fibers.

<u>Acids</u>   <u>Base</u>

   - COO H   - NH_2

   - SO_3 H   - NHR

   - OH   - NR_2

A molecule containing a chromophore but no auxochrome is known as a "chromogen".

<u>A ZO Group</u> :- Azo pigments consist the largest group of organic pigments used in the paint industry. The various pigments containing Azo groups range in hue from yellow (all shades), red (all shades), violet (all shades) to a few blues, greens and browns.

                  Thus there are a large number of pigments structures which contain the Azo group, with more or less good fastness and good resistance properties. The Azo group is divided into monoazo, diazo, triazo and tetrazo according to the number of - N = N - groups in the molecule.

<u>Phthalocyamines</u>

Another important group of organic pigments is the phthalocyamines.

EXTENDERS

Some Usual extenders are :

Calcium Carbonate (various grades)
Talc
Barytes (Barium Sulphate)
Mica
China Clays
Diatomaceous earths
Silica Sands
Barium Metaborate

Extenders are cheaper than pigments and are often used to decrease the raw material cost of coatings, without reducing the solid content of the product. With reference to solid content, it is quite dicy (apart from cost consideration) to increase the proportion of pigment above a certain pigment-binder ratio. Organic pigments (Azo yellow for example) have higher oil absorption than calcium carbonate (for example) and too much pigment will result in a stiff paste, which is difficult to apply and will have poor weathering characteristics, whereas addition of the same mass of the extender will not have the same adverse effects and will increase the solid content to the same proportion.

A few other uses of extenders are as matting agents, as agents to assist in sandability of sealers, stoppers and putties, to increase hardness of coatings, as antiskid agents to increase the compressive strength of putties, to prevent deposition (and caking) of heavy pigments when products are stored, to provide certain flow properties to coatings putties, fillers or stoppers, to aid in fire resistance properties of coatings, to improve fungus resistance, as PH stabilizers in certain emulsion system.

ADDITIVES

We have seen be large "macro" constituent of coatings and putties (resins, plasticines, solvent, pgiments, extenders). These can be mixed together, dispersed, ground and adjusted to viscosity with the appropriate solvents. However, sometimes, things go wrong or special effects are required.

Examples are:

Oil paint and varnishes form a skin in the pot.
Colours separate (pigment floatation)
A coating sags on application
Pigment settle on storage
Certain coatings may foam on application
Fungus grows on the coating
To solve these problems certain chemicals (additives are added in small amounts (1 percent and less) to the coating, at the manufacturing stage.
They can be antiskinning agents, (prevent skinning), dispersing agents (prevent pigment floatation) and improve "wetting" of pigment by binder. If Rheology agents which provide "false body" and prevent sagging, anti-setting agents, antifoam, fungicides and bactericides. Again these are a very wide range of products available for each particular use.

Some importants characteristics common to all paints, putties and varnishes

1. Solid percent by volume and by mass
2. Pigment volume concentration (P.V.C.)
3. Opacity
4. Coverage
5. Appearance of cured coating (glossy, matt)
6. Viscosity (consist ncy)
7. Drying time (touch dry and hard dry)
8. Various application cured characteristics (as agreed between supplier and purchaser or as per specific standards).

The finished product that is purchased by the applicator has certain designed characteristics. Generally these are given, these are mentioned to the customer via data or product specification sheets.

We shall now explain the meaning of these various characteristics.

The type of binder and the pigment are usually specified. (We have lareday seen those).

Then the solid content of the liquid product by mass and by volume is specified. The solid content by mass simply means that in 100 kg of product say 60 kg are solid matter and remain in the film after 40 kg of volatile constituents (solvents) have evaporated to the environement. Thus it is better (for a given viscosity)to purchase the coating which has more solid material.

However this concept can be misleading; for example, if we use high density pigments in the formulation then the solid by mass is bound to be high, although the volume of solids percent can be low.

When we considered coating protection properties, these are dependant on the dry film thickness of the coating, the higher the film thickness the better the protection provided.

Also when we purchase a can of paint we need to know what areawe can cover with this paint.

Film thickness and area covered brings us to the concept of volume (area $\times$ thickness).

Thus when we purchase a can of paint we need to know the volume of solids in the paint so that we can calculate (within experimental error) what area we can cover and what average dry film thickness we are going to obtain with the paint we have used.

When we need to choose between different brands of paint; the same type, with all other characteristic constant we should purchase the one with the higher volume of solids.

The volume solid is specified on product specification. It is directly related to the practical figure of coverage at specified average film thickness on a specified substrate. (Coverage is specified in terms of area covered per coat at a specified film thickness.

Diagramatically we can represent volume solids as in the figure below:

A = total area covered
T = wet film thickness
A x T = Volume of wet paint
TV = thickness of volatile
TV x A = volume of volatile FILM.
TS = thickness of solids
TS x A = volume of solids
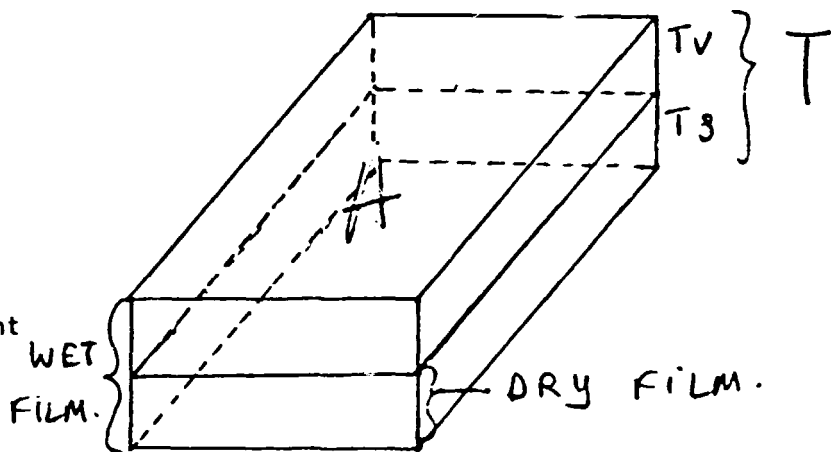
When the solvents evaporates the film shrinks and we are left with TS which is the thickness of solids and with the volume of solids which is (TS x A)

N.B. Since solvents are toxic, dangerous, inflammable, non renewable, polluting ,more and more expensive and contain lots of calorific energy, which cannot be wasted, the trend is to formulate coatings with high solids or with water as the thinner.

High solids coatings are usually:

1. Two Pack polyamine cured epoxies
2. Two Pack polyurethanes
3. Unsaturated polyester (since the solvent styrene copolymers with the
    polyester resin during curing).
4. Thermosetting (epoxies, polyester) powder coatings,
5. Thermoplastic powder coatings based on polyethylene and nylon.

Water based coatings can be divided into two groups?

-   Emulsion binder - in which the resin is in a state of dispersion (not
    solution) in water - this involves the uses of emulsifier and stabilizers,
    since the binder and water are not compatible.
    Common example: "Emulsion" binders use to manufacture decorating paings
    for buildings
    Many coatings are now available in emulsion form and are based on the
    following resin for example:

    Polivinyl acetate emulsion

    Polivinyl acetate/acrylic emulsion

    Acrylic/acrylic copolymer emulsion

    Styrene/butadiene emulsion

    Styrene/acrylic emulsion

    It is also possible to emulsify two pack epoxy systems and

-   Solution binders

    in which the binder have been modified to render then in completely or
    partly soluble in water or just water dilutable:
    These include:

    Modified drying alkyds - for gloss paints and clear varnishes;
    also metal primers

    Saturated polyester - for stoving enamels (in combination with
    melamine)

    Thermosetting acrylics: for spraying and dipping, stoving
    enamels. (in combination with melamine).

Pigments volume concentration P.V.C. (of dry film)

This characteristics of a coating is a ratio of the volume of pigments to the total volume of solids in the dry coating; it is expressed as a percentage. P.V.C. (not to confuse with polivinyl chloride) can be related to coating properties such as abrasion resistance, gloss, chalking resistance, stain resistance, flow among others.

Opacity

This is the ability of a coating to obliterate the surface on which it is applied. It is directly dependent on the amount of pigment present in the formulation and to the type of pigment use. It can be measured under certain condition and is expressed as contrast ration at a certain dry film thickness between the reading observed on standard white and black surfaces. A contrast ratio of 100% means complete opacity under the specified conditions.

Appearance of coating surface (glosses, satin or matt)

On a standard smooth surface such as gloss the appearance of the dry coating depends cn the ratio between pigment extenders and binders.

The following diagrams illustrate the point :-

| Gloss paint | Satin finish | Matt finish |

Proportion of pigment to binder increases

| (10-20) Low P. V. C. mirror like finish which reflects incidnet light rays in an orderly fashion. A clear image of an object can be formed | (subdued gloss) P.V.C.(21-40) satin like finish incident light rays are reflected in a somewhat disorderly fashion such that an image of an object cannot be formed | P.V.C. (41 or more) Dull and completely non reflective finish. Incident light rays are partly absorbed and or reflected in a disorderly fashion. No image of an object can be formed. |

N.B. Each type of binder has a range of P.V.C. for which it is gloss, satin or matt - some binders in clear films may form mroe glossy finish than others - i.e. not all binders are equal in their ability to form glossy films. Gloss (reflection) at various angles of incident light can be measured using a glossmeter.

Viscosity :

Viscosity (consistency) is related to the flow of various fluids (more of less thick).
Fluids can be grossly classified into Newtonian (ideal fluids) approximation of
which are water and certain oils – (Long oil, alkyd resins and many other binder
in solution fall under this category)
For Newtanian fluids : Stress = constant strain which is viscosity :
These sort of fluids are said to have laminar flow : whereas the fluid in motion
is considered to have an infinite number of planes which slide upon each other
in an orderly fashion when a force (stress) cuts upon them, and the flow (strain)
is produced.

There are two conditions for a Newtanian fluid.

1. flow is proportional to force.

2. the least possible force produces same flow.

The units   of $\frac{\text{stress}}{\text{strain}}$ = viscosity is the poise an absolute unit of
1 gram per centimeter per seconds.

Another unit of viscosity the stokes is used when the density of the
fluid needs to be taken into account.

$$\text{Stokes} = \frac{\text{Poise}}{\text{Density}}$$

Practically for Newtonian fluids a graph of strain (y axis) and
stress (x axis) is represented by a straight line going through
the origin.
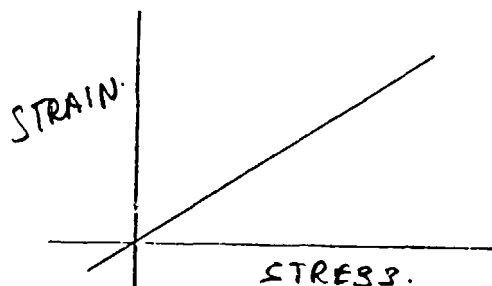
A simple way of measuring "viscosity" or more rightly efflux time
of newtonian fluids is using a efflux cup such as Ford cup No. 4
or various Zahn cups.

N.B. Viscosity changes with tempetature. Thus temperature must be
     stated whenever viscosity reading are taken.

Many fluids are not Newtonian fluids. They include solution of high molecular weight materials such as rubber and proteins and suspension of solid in liquids (emulsion type binders, and paint system where the properties of the binder solution is affected by the incorporation of various pigments, extenders and additives which all interact).

Example of non newtonian fluids

Birghem Bodies

STRAIN

STRESS

x
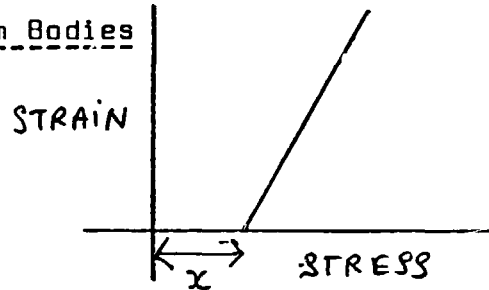
The intercept X means that below a certain limiting stress no flow takes place. This limiting stress is called the "yield value". Above it stress is proportional to stain. Materials exhibiting this behaviour are called "Birgham Bodies" and they are said to exhibit "plastic viscosity"

Pseudoplastic Materials

They have some degree of in built structure in the fluid so that at first viscosity is high, but eventually decrease above a certain rate of shear and the graph straitens to that corresponding to Newtonian flow. When the shear is removed they immediately resume their original structure. This is the case of many paints and coating which are designed to have in built structure which they lose when applied (shear from brushing action from spraying) but immediately resume once the shear is stopped. This property is in built in "high build" coat systems to prevent their sagging tendency.

Newtonian Flow

Strain

Stress
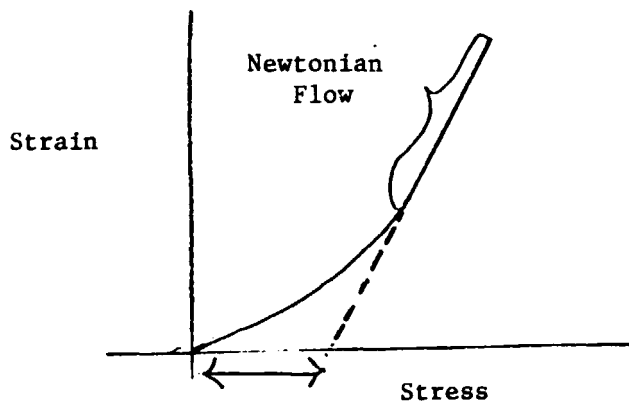
Thixotropy

Some fluids possess structures which in contrast to pseudoplastic material cannot be broken down and resumed immediately. i.e. they possess a certain resistance to the breaking down of their structure, under shear and when the shear is stopped or decreased they take a substantial time before resuming their original structure.

This can be the case of certain coatings which although they seam to posses pseudoplastic properties, do not resumed their original structure immediately after the shear is stopped. They resume same structure and are called "thixotropic materials".
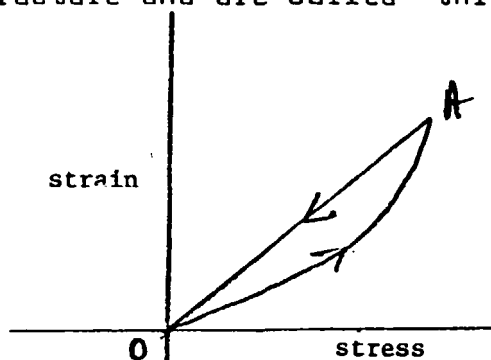
The rate of shear is increased gradually to obtain constant flow at each level until point A is reached. Then the rate of shear is suddenly decreased. It will be observed that the fluid requires a lower value of stress to shear it into constant flow. Thus the downward line with lower values of stress for equal values of strain can be drawn. An hysteris loop (hysteresis from the greek lay behind) characteristic of thixotropic materials is thus formed.

Various apparatus have been designed to measure the viscosity of the various structured materials at a constant flow - equilibrium point - when the graph becomes a straight line and $\frac{stress}{strain}$ = a constant.

Examples are: the stormer paddle, the viscometer, the I.E.I. cone and the plate viscometer.

There exist another condition of fluid flow called dilatancy.

In this case viscosity increases with increasing rate of shear. i.e. stain diminishes with increasing stress. This condition can occur in highly pigmented systems. (A common example is "corn flour" solution).

As can be seen viscosity is a very important property of coatings. Viscosity (apart from shear) is temperature dependant. Normally, increasing temperature decreases viscosity. Addition of the right solvent will reduce the viscosity of a coating. Viscosity is thus extremely important with reference to how a coating is to be applied.

Drying time. In product specifications, it is usual to specific touch dry time, overcoating interval and hard dry time, under specific condition. There exist standard methods to determine (and check) these properties. To the user drying time (and curing schedule) are very important, since they are directly related to production rate. In furniture manufacture quick drying coatings (one coat) are to be prefered since the increase output. Also quick drying sustems have less chance of being soiled by environemental dirt; thus requiring further polishing – drying time , as we have seen, is usually shortened by increasing ambient temperature.

Other Coatings Characteristics, these include :

- storage stability – (of unsued product)
- Pot life – (of base/hardener mix in the case of two pack systems and of catalysed system) (again increasing temperature increase the rate of reaction).

flexibilitv
Adhesion
Impact Resistance
Abrasion Resistance   of cured systems
Hardness
Weathering resistance
Colour fastness

Resistance to various chemicals

Electrical Characteristics (insulating or conducting ,water and water vapour absorbtion and transmission.)

Resistance to wet and dry heat –

Coatings characteristic oan be made tailor made to suit agreement (cost/quality) between manufacturer and purchases or made according to certain official standards.

PAINT MANUFACTURING PRINCIPLES

Purpose:

To produce an homogeneous and stable, more or less fluid paste, which posesses drying and film forming properties, to protect and decorate a wide variety of substrates.

Pigments and extenders are mixed and "dispersed" in the chosen binder (resin) or binder blend (various resins mixed together), adequate additives are added (see additives) and the viscosity (consistency) is finally ajusted with the appropriate solvent or solvent blend.

Depending on the type of pigment used (see pigments), the volatility of the solvents for the binder system, the degree of dispersion required, various paints manufacturing equipments are used.

Also various equipments can be used to manufacture the same end product. In this case the "mill base" formulation is adapted to the equipment.

N.B.   The "mill base" is that part of the total paint formulation which contains some resins, additives, solvents and all the pigment to be dispersed. It is usually thicker and more viscous than the finished paint. It is more economical to process a small mass of mill base than the complete larger paint batch.

The second part of the paint formulation to be added to the mill base is called the "let down". It consist of additional resin in solution (varnish) with various additives, and solvents as necessary.

General Paint Formulation for a Long Oil Alkyd Enamel to be Dispersed on a Tripple Roll Mill

75% Long Oil Alkyd	9.0)	
White Pigment	29.0)	Mill Base
Dispersing Agent	0.5)	
Solvent	6.0)	
75% Long Oil Alkyd	41.0)	
Mixed Driers	1,0)	Let Down
Antiskining Agent	0.1)	
Fungicide	0.4)	
Solvent	13.0)	
	100.0	

Manufacturing Equipments Used :-   Cowles type disperser/dissolver, Tripple Roll Mill.

Procedure

Weigh the resin and dispersing agent into the manufacturing vessel and start stirring add the pigment and solvent to adjust the consistency and mix for about half an hour until a smooth paste is obtained. Scrape the side of the manufacturing vessel to ensure that all the pigment is mixed in.

After ½ hour mixing the temperature of the paste may rise to 40 - 50°C.

Transfer the paste to the tripple roll mill and proceed with the

dispersion (see tripple roll mill operation).

Check the dispersion with a grind gauge if the grind
is O.K. transfer the mill base into another manufacturing vessel
containing the let down, and mix with a spatula.

When dispersion is complete, fully homogenise the mill base/let down
blend under cowles.

Check the viscosity and adjust with appropriate
solvent if necessary. Since viscosity is temperature dependent, it
should be checked at a specified temperature say 25^0C. For an alkyd
enamel as per enclosed formulation, a Ford cup No. 4 is used to deter-
mine the "efflux time".

Proceed to full quality control before packing the paint.

In the case of a long oil alkyd enamel, apart from dispersion and
viscosity, routine quality control should include:specific gravity
control, drying time v/s standard
        opacity   v/s standard
        gloss   v/s standard
        film   v/s standard

Flexibility, adhesion and resistance to various exposure conditions
should only be derttermined occasionally.

Various Paint Manufacturing Equipments

Cowles type high speed dissolver/disperser

This is the basic paint manufacturing equipment and it use is widespeed

It is usually sufficient to achieve a reasonable dispersion for white
emulsion based paints and various solvent based primers. It is not
adequate to obtain a good gloss enamel or good dispersion of various
pigments in water based or solvent based media.

In theory, the various parameters to make optimum use of a high speed
Cowles type dissolver/disperser are reported below
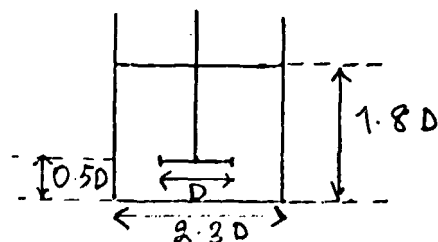
Peripheral speed of Impeller
        1000 - 1300 m/min.

D = Diameter of Impeller

A normal belt driven high speed Cowles dissolver/disperser is not suited
to blend high viscosity paste such as offset inks or polyester fillers.

To improve dispersion and mixing various "impeller" type have been
designed e.g. :-

    Silverson type (cage) emulsifiers/disperser (see Fig. 11)

    Star disperser/dissolver (Drais)

Twin Shaft disperser/dissolver (Myers)

Variable Impeller Diameter (Vary Shear)

To handle thicker pastes hydraulic drive dispersers fitted with either "cowles" or "trifoil" blades have been devised

- Other Paint, Paste Mixing Equipments include :

Planetary Mixers which handle very thick pastes (see fig. 12)

Dough Mixers which handle medium to thick pastes (see fig. 13)

Z Blade Mixer for very thick pastes (putty) also produces good dispersion (see fig. 14)

Dispersion Equipments include :

Tripple roll mills with mechanical or hydraylic setting. (see fig.15)

Perl and Sand Mills (see fig. 16)

Attritor Mills

Colloid Mills

Ball Mills

Tripple Roll Mill : Handle thick pastes with slow evaporating solvents. Mill bases containing fast evaporating solvents cannot be used on tripple roll mills as the solvent will evaporate and the paste will dry out on the mil

Sand and Perl Mill : Handle thinner pastes (that can be pumped) with slow or fast evaporating solvent.

Attritor Mill : Process paste with similar viscosity to Perl and sand mills.

Colloid Mill : Useful for small runs of water based dispersion.

Ball Mill : Process pastes of similar consistencies to sand mill.

Fig.11: Silverson type emulsifier/disperser

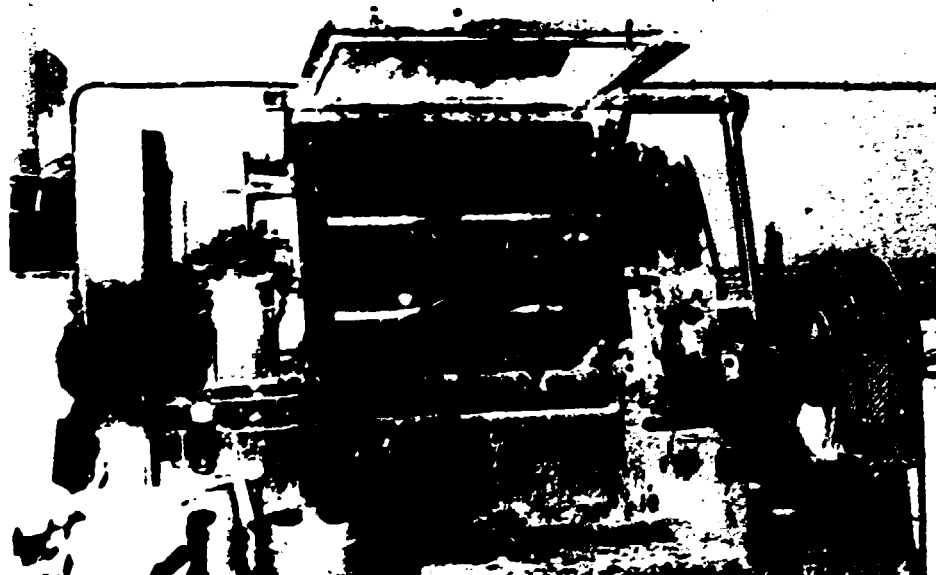Fig.12: Planetary mixer

Fig. 13:   Dough mixer

Fig. 14:   Z blade mixer
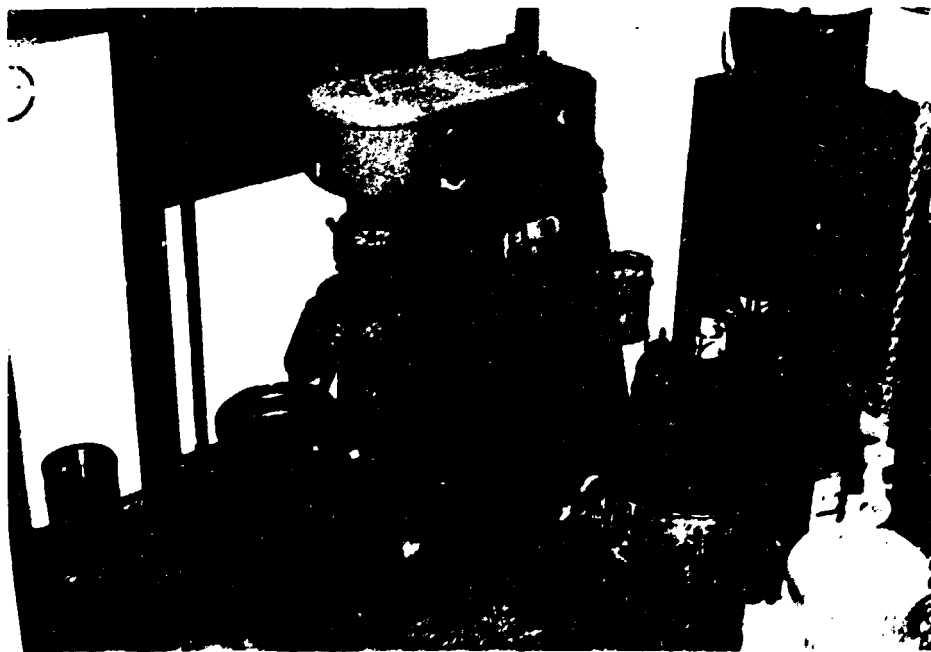
Fig. 15: Tripple roll mix

Fig. 16: Perl and sand mills

NOTES ON PAINT FACTORY SAFETY PRINCIPLES

1. Building and factory layout should comply to local safety regulations.

2. Adequate ventilation and air renewal should be provided by allowing air entries fitted with dust arrestors and forced air exits using flame-proof extractor fans.

3. Adequate fire extinguishers and fire fighting facilities should be made available - according to local legislation.

4. No smoking should be allowed in the factory.

5. All electric motors, fittings, lighting and wires should be flame and explosion proof.

6. All manufacturing equipment should be properly grounded (electrically earthed) to prevent static electricity sparking in dry weather conditions which could initiate a fire or explosion. This is particularly important when using a Cowles dissolver/disperser to dissolve nitrocellulose resin in volatile esters and ketone solvent and low boiling aromatic diluents such as toluol. Sparking due to static build up may occur between a sharp edge on the rotating shaft and the metallic manufacturing vessels thus both the Cowles mixer and the manufacturing vessel should be properly grounded (earthed).

7. Adequate safety equipment should be provided to the work force.

    eg. (a) Respiratory masks when spray paint (see fig. 18) and handling toxic pigments (see paragraph on pigments).

    (b) Protective goggles, aprons, gloves and boots should be worn when handling corrosive or poisonous liquids.

    (c) Protective (industrial) boots should be worn at all times in the factory.

    (d) No loose clothes, belts, ties, hair hat, should be allowed on workers operating machinery.

8. The factory floor should always be kept clean, dry and not slippery.

9. No moving parts, gear, flywheels, etc. should be left without a proper guard.

10. All waste (washing water) should be safely disposed of, since inflammable solvent and paint residue may be present.

11. When using Cowles or trifoil, all manufacturing vessels must be properly secured before starting the mixer.

PAINT APPLICATION

Paint and varnishes can be applied in a large number of ways, depending on the end product required, the output required and the final characteristics of the cured coating.

The usual coating application methods are listed below:

Hand powered
{
Brush
Roller
Knife filling and stopping
French polishing
Waxing
}

Air Spray

Pressure fed air spray (hot/cold)
Airless spray
Hot airless spray
Electrostatic spraying (of liquid paints)
Automatic spraying (of any one of the above methods)
Spray application of two component materials
Dip coating
Barelling
Flow coating
Roller coating
Curtain coating
Powder coating (fluidised bed and electrostatic spraying)
Electrodeposition

BRUSH APPLICATION

The paints brush is made of natural (animal) bristles (pig or horse) or of synthetic bristles such as nylon.

The paint is taken up in between the bristle when the brush is dipped into the paint. In fact each bristle is somewhat fibrous and paint droplets are also taken by the bristle themselves.

When the brush is pressed on the surface paint is forced out from the brush onto the surface.

The brushing action has the advantage of improved wetting of the surface by the paint which results in improved adhesion and paint protection.

Beautiful "lacquered" finishes can be obtained by correct use of a good paint brush and judicious thinning of long oil alkyd enamels (for example: which has a near Newtonian flow).

The important thing with a brush is that the paint flows after the brushing action. Quick drying paints and paint having pseudoplastic characteristics (see viscosity) do not produce beautiful smooth and glossy finishes with brush application since they do not level out properly once the brushing action (shear) is stopped.

Brush application is cheap in material investement but time consuming (slow) and labour intensive. It is not suited for in line high rate production of furniture items for example.

ROLLER APPLICATION

A roller can be considered as a cylindrical brush, but it has less "brushing action"than a proper brush.

Roller application seldom achieves the quality finish that can be obtained with good brushing practice.

Roller application is much more rapid than brush application and is suited for application of decorative coatings for interior and exterior of buildings, and or protective coatings of ships hulls ·and various other large surfaces.

Various sorts of rollers with long and short (hairs) or bristles, of natural (lambs wool) or synthetic origin (agrylic or nylon) are available. There are also "sponge and rubber rollers" with various designs in relief on the surface. Each sort or roller is suited to a specific purpose, the sponge rollers being used for the application of textured coating on buildings while the "rubber stamp" rollers can print various design on a surface.

Certain rollers are made to be resistant to various strong solvent which are present in certain coatings.

A roller is used with a tray (to pick up the paint). Rollers can be fitted with "man helps" of various length. These are light poles fitted to the handle of the roller. They give access to high surfaces without the use of expensive scaffolding.

KNIFE FILLING AND STOPPING

This is the use of the various "painters knife" to apply various putties and fillers into holes, cracks and various imperfection found in surfaces to be coated.

A large spatula can also be used to apply a high solids filler paste on porous wood or concrete surfaces. This minimises the use of many coats of primer and undercoats. High solid filler paste can be formulated to be quick (air drying) and possessing excellent dry sanding characteristics (i.e. they do not require water for sanding down, and the dust produced in sanding does not dog the sand paper).

These fillers are useful for "one a piece" or short series production of lacquered wood, plywood or particle board furniture. Their dry sanding characteristics avoid wetting of the wood, they dry quickly and if used correctly can be directly overcoated with the finish coat.

Putties and fillers for the furniture industry consist of :

Adhesives/wood dust mix :-(These are usually prepared on site by mixing the appropriate wood dust with the adhesive such as Polivinyl acetate (white glue), urea formaldehyde glue, various animal glues, two pack epoxy glues. Resorcinol/formaldehyde glues are dark coloured and cannot be tinted and filled with wood dust to make a filler composition, moreover they are too expensive for this use.

Two Pack Polyester Fillers:- (Catalysed with a peroxide and accelarated if necessary with a metal salt such as cobalt napthenate).

These are solvent free and contract very slightly on using (maximum 2%), thus they can be applied in thick coats without the risk of "crater" formation or cracking when fully cured. They are available off the shelf pretinted to match various commonly used woods.

They are usually quite cheap since they are heavily filled with extenders. They have good dry sanding characteristics and are compatible (are not softened) with most (if not all) usual top coats when cured.

They are also available for use on metallic furniture where they exhibit good adhesion. Depending on the formulation, they also support baking procedures. They can be formulated to have a certain degree of flexibility.

They are very suitable for filling imperfection on G.R.P. (glass reinforced polyester)surfaces. Depending on the resin used in their manufacture, unmixed polyester fillers can gell on long storage in tropical conditions.

Two Pack Epoxies Fillers :- These are quite expensive but possess excellent anticorrosive characteristics coupled with great chemicals inertness and excellent adhesion to various substrates.

When cured they can be machined, (turned, polished) to very smooth surfaces).

Their use is tricky since the recommended hardner/base mixing ratio should be strictly observed. This often necessitates the use of a scale (balance), Also the "pot life" of the base/hardener mix is usually quite short (of the order of a few minutes for 100 g of mix at 25^oC). Longer pot life can be obtained by choosing different base/hardener combinations, but this implies longer curing time.

Epoxy fillers are solvent free (100% solids) and exhibit practically no contraction in volume when curing. The curing reaction is exothermic (dissipates heat) and if a certain amount (say 1 kg) of unused base/hardner mix is left it will react and heat up. For high reactive clear resin/hardner mix, the mixture may even start boiling. However in filler composition due to the presence of various extenders the heat dissipation is less. Unmixed epoxy base/hardner are usually very stable on storage. Two Pack epoxies can be baked to temperature up to 140^oC for a few minutes.

One Pack Quick Drying Nitroputties :- These are based on a blend of Nitrocellulose alkyd resins. Other resins and plasticisers are also incorporated. The finished products usually contain 75 - 85% solids, and are available in various shades to match usual woods. They must not be applied in thick film in excess of one milimetre, since they will crack and craze on drying due to reduction in volume resulting from solvent loss. When dry (overnight) they can be overcoated with most usual furniture finishes. However some coatings containing strong solvents may soften these nitro putties (so better check with supplier).

These products are also formulated for application to metallic surfaces and G.R.P. surfaces. However they have the same limitation as those for wood surfaces.

They can be formulated to have as good dry sanding characteristics as polyester or epoxy fillers.

They are not recommended for baking conditions in excess of 100°C. If the subsequent finish needs to be "low baked" it should be ensured that the putty is hard dry to prevents bubble formation from entrapped solvent.

Miscellaneous Fillers Compositions: Apart from mixing wood dust with adhesive, fillers are also sometimes prepared by mixing various paints and varnishes and drying oils with wood dust, whiting, iron oxide or pigments available on the retail hardware market. Depending on the finishing system he is using, each tradesman has his own filler "recipe" apart from those ready made we have just mentioned.

These personal "recipes" are mostly used in the wood, plywood, or particle board trade, not for metallic furnitures. Usually they are not suited to industrial serial production or to baking proceedures.

FRENCH POLISHING

This old time and effort consumming finishing method is based on the use of alcohol soluble she lac varnish. The varnish is easily prepared by dissolving the shellac in alcohol (methylated spirits). Various grades of shellac (more or less refined) are available.

The process consists of applying with a dabber a large number of successive coats of the varnish .

The dabber consists of cotton wool enclosed in a fluff free cotton cloth. The wool is soaked with varnish and a circular motion of the hand is used to apply the varnish.

To seal the pores of the wood, powder pumcice stone or talc or fine silica is usually incorporated in the varnish or sprinkled and rubbed on the varnished surface. Excess is wiped and/or sanded off before applying further varnish   Too much powder will cause unsightly whitish streaks and spots, in the finished job. (Apart from their sealing proporties these various powders also produce a polishing action when rubbed on the varnish surface).

To give the final luster, the fully dry varnish system is wiped with a clean dabber moistened with alcohol (methylated spirits).

French polishing provides a good wetting of the wood surface and a superb finish having "depth". It is suited to the restoration of antiques, or the finishing of imitation antiques.

It is coupled with various process of dying and colouring the wood. Also various dyes colourants or pigments can be incorporated to the varnish to achieve desired shades.

Tradesman use various iron oxides and lamp black. They sometime obtain their lamp black by collecting the soot produced from the incomplete combustion of oil, kerosene or candles.

WAXING

Some furniture styles and some woods do not lend themselves to varnishing or lacquering. The finishing method used in this case is waxing which may be used in conjunction with a clear or tinted sealer coat. The wood can be bleached or tinted before the sealer coat. The wax can be used clear or tinted.

The sealer coat is usually based on a drying oil such as boiled linseed oil or a long oil alkyd or air drying polyurethane oil (quicker drying) containing various extenders to make it mat and increase its solid content thus improving its sealing properties. These solvents are formulated to have good dry sanding properties.

Waxes generally used are :-

Beeswax: which is available in various grades (bleached or raw). Melting range 62 - 65°C, and is slightly soluble in alcohol and soluble in oil among others.

Ozocerites:which are a mineral waxes of fossil origin Grades vary from yellow brown to black green. They are soluble in Kerosene and turpentine among others (melting range 55 - 110°C).

Ceresins: which are purified ozocerites.

Carnabua: which is the hardest most expensive commercial wax available. It is in the form of yellow to greenhish brown lumps. It is produced by the leaves of a Brazillan tree (Copernica cerifera). It is soluble in broiling alcohol among other solvents. (Melting range 84 - 86°C.)

Paraffin Wax: White translucent, tasteless and odourless solid derived from crude petroleum cracking. They are soluble in benzene (C_6 H_6), warm alcohol and turpentine. Melting range 45 - 65°C).

Depending on the formulation the waxes (or wax polishes) can be applied hot in the molten form, dissolved in an appropriate solvent or in emulsion.

Wax based finishes can be modified with various compatible resins or drying oil to yield products with intermediate characteristics.

Waxing is not suited to mass production and furnitures coated in this way need to be regularly maintained by polishing (with an adequate polish compositior) to maintain their original lustre.

AIR SPRAY

The principle of air spraying is when a fast flow of air passes over a capillary tube filled with a liquid a vacuum is produced on top of the capillary tube which causes the liquid to be sucked up and vaporize (atomize) in the air flow.

An air spray gun is an improved version of this atomization principle.

According to the way in which the paint is fed to the atomization area, air spray guns can be classified as:

- Suction fed
- Gravity fed
- Pressure fed

Depending on the way in which the paint is atomized at the tip (air cap) of the spray gun, two types of air caps are available namely:

- internal mix air caps used only with pressure feed guns
- external mix air caps used with suction feed guns.

Fig.17 illustrates the working principle of a suction feed spray gun with an external mix air cap.

Figs. 18 to 20 show a few spray guns available.

Considerable details on air spray gun construction, operation and characteristics are available in the trade literature.

Prices for "similar" spray guns can vary enormously but one usually gets what one pays for.

Apart from the spray gun itself, the following pieces of equipment are essential for spray painting:

- air compressor
- air transformer
- air lines
- pressure regulator.

SAFETY MEASURES

Since air spray painting produces air pollution and involves highly volatile, toxic and inflammable materials, a number of safety measures need to be taken.

Painters need to wear an appropriate respiratory mask and even goggles in certain instances. Painting is best performed in spray booths or chambers which must be provided with flame and explosion proof electrical fittings, with flame proof extractor fans and with fibre glass (or other materials)

air filter unit (dust arestors) to minimize air pollution.

Also no smoking should be allowed when and where spray painting is being performed.   Apart from the fire hazard, the heat of the cigarette may decompose various solvent and paints into toxic products, which will then be inhaled.   Fire extinguishers should be present.   (Appendix II gives a list of British Standards, some of which refer to safety conditions).

FIG.17

HOOK TO HANG SPRAY GUN

A

SPRAY HEAD

AIR

B

PAINT

FLUID NEEDLE

PAINT

AIR + PAINT ARE MIXED AT EXTERIOR OF AIR CAP

WINGS OR HORNS

TRIGGER

FLUID TIP

PAINT FLOW

AIR VENT

PAINT CONTAINER

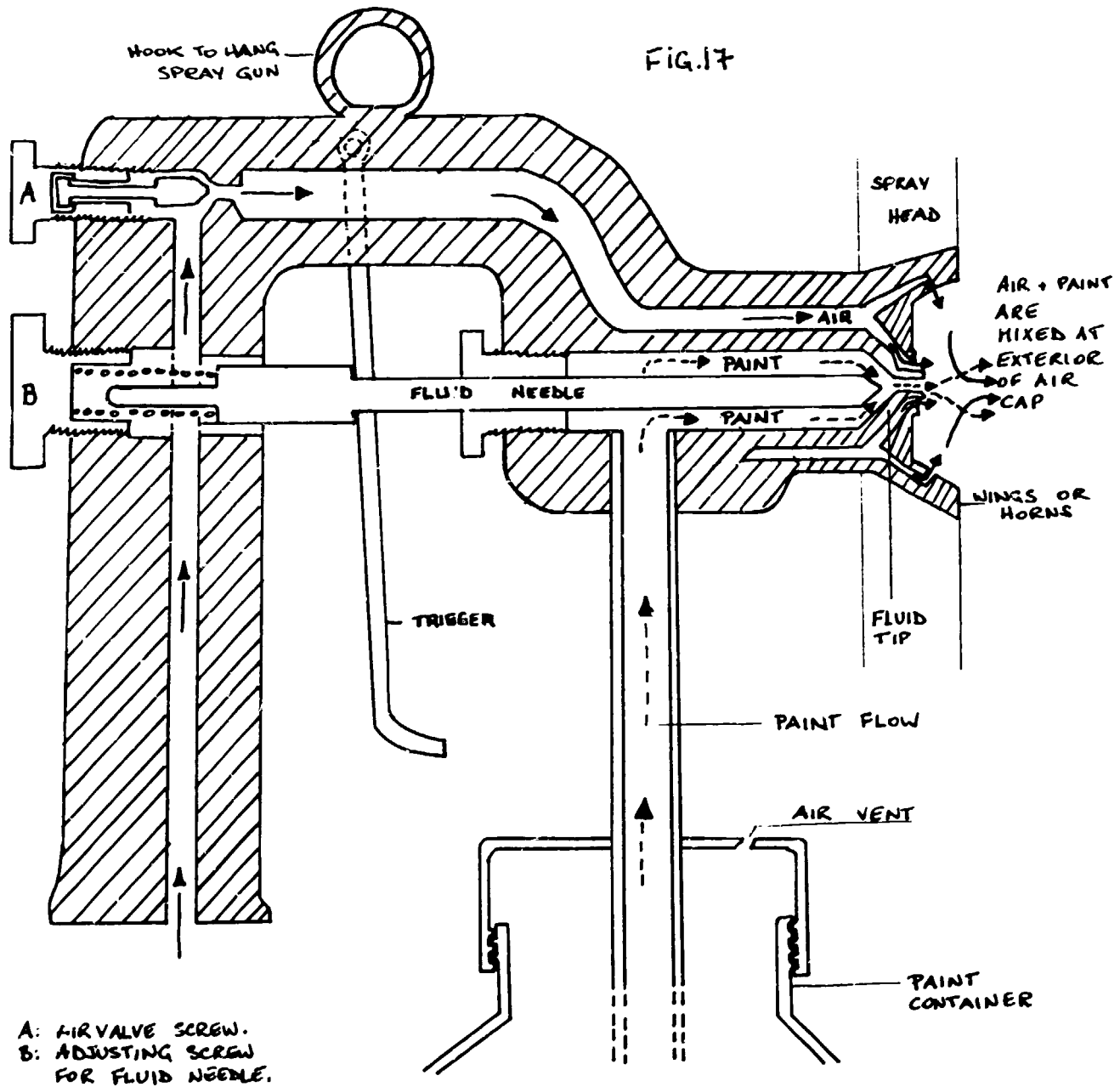A: AIR VALVE SCREW.
B: ADJUSTING SCREW FOR FLUID NEEDLE.

Fig. 18
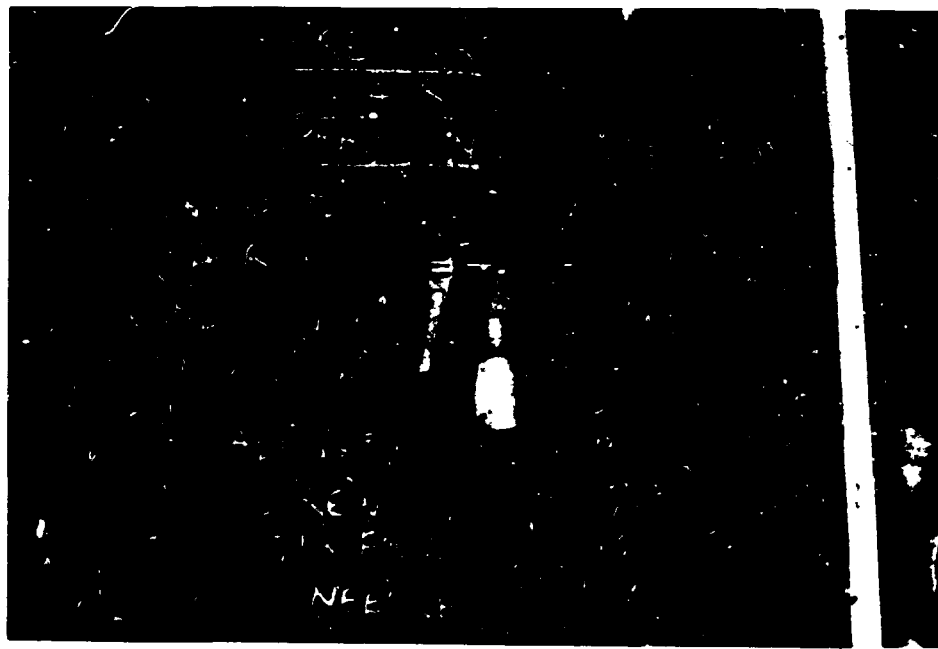
Fig. 19
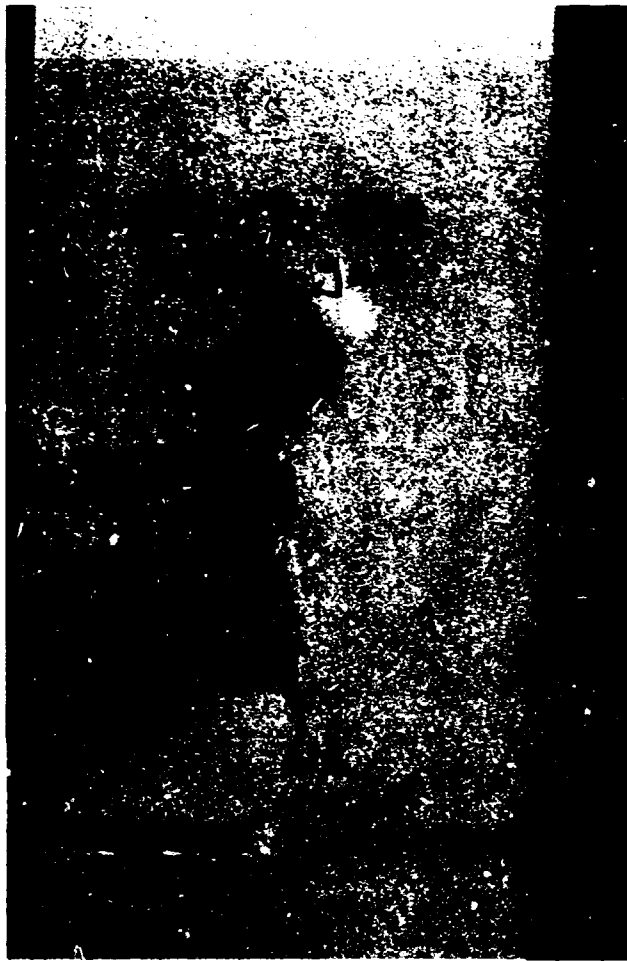
Fig. 20

AIR COMPRESSORS

A large number of makes and a large number of types of air compressors are available, some are huge fixed machines for continuous industrial operation; others can be rolled around,some can be transported at arm length and still others are suitable to the do-it-yourself - amateur market are available as accessory to "powertool" hand drilling machines.

Principle of operation

Two main types of compressors exist: pistom compressors and centrigugal compressors (rotary).

Both types need to be driven wither by an electric motor or by an enormous internal combustion engine (two or four strokes, gasoline, diesel or even kerosene fired).

Piston type compressors

These are the ones most commonly encountered for spray painting. They are available as single stage with or without compressed air storage tanks and multi-stage with compressed air storage tanks. For multi-stage, high capacity and high pressure compressors, a water or air cooled heat exchanger is fitted to the compressor since compressing air produces heat which must be removed before the compressed air is stored or utilized.

The compressed air, from the compressor needs to be supplied to the spray gun at a specified pressure, thus a pressure regulator need to be fitted between the compressor and the spray gun, to step down to the utilizable level and a manometer needs also to be fitted after the regulator to be able to determine (read) the actual air pressure air being supplied.

The "low pressure" compressed air from the pressure regulator is not "clean air". It contains various contaminants such as oil fromthe compressor and water from the moisture in the air. These are mixed with the paint when sprayed and will cause various paint defects.

Thus, an air transformer is fitted (see fig.) on the air line before the spray gun. This equipment fileters the air and separates out any moisture present which can then be bleeded off. Various designs of air transformers are available, some are fitted with air regulators and one or two manometers to be able to determine the air pressure before entering and after leaving the air transformer. Such an air filter without manometers and regulator is called an air condenser.

From the compressor to the air transformer, there is usually a metallic non flexible, fixed air line.

From the air transformer to the spray gun, the compressed air is carried by a flexible line or variable length and variable cross section.

The longer and the smaller the internal diameter of the air line the higher will be the pressure drop from the air transformer to the spray gun, due to increased resistance to air flow encountered in long tubes of small internal cross section.

AIR SPRAYING TECHNIQUES

Spray gun settings

It is assumed that the compressed air reaching the spray gun is free from moisture and oil, that the paint is of the correct viscosity (as can be checked

with a Ford cup No. 4 for example) and that the compressed air pressure is
constant.

Referring to fig.   (suction feed air spray gun) it can be seen that
there are at least four settings that can be varried in this type of spray
gun.

1.   The air valve screw A can be opened more or less to allow more
or less compressed air in per unit time.

2.   The fluid needle adjusting screw B which controls the maximum
movement allowed to the fluid needle and thus control the volume of
paint allowed in or atomised per unit time.

3.   The trigger movement which controls the actual movement of
the fluid needle and thus at any moment in time the volume of paint
that passes through the fluid tip and is atomized in the air cap.

4.   The direction of air cap i.e. whether the two "horns" at
either side of the air cap are directed in a vertical or horizontal
plane with respect to the fluid needle axis.

Direction and patterns of spray fan

In actual spray guns, the air cap and fluid tip are not cast as one
piece but are separate parts fitted (screwed) to the core of the spray
gun. Thus the air cap and its two "horns" (in an external mix air cap)
can be swivelled around the axis of the fluid needle to provide various
spray patterns, thus changing the direction of the spray fan. Thus, when the
operator holds the spray gun so that the spray head points away from him,
if the air horns of the air cap are in vertical plane, the spray pattern is
horizontal (see fig.21), whilst if the air horns are in a horizontal plane,
the spray pattern is in a vertical plane (see fig.22.).

In the first case (vertical air horns and horizontal spray pattern) the
painting motion is in a vertical plane, while for the second case (horizontal
air horns and vertical spray pattern) the painting motion is in a horizontal
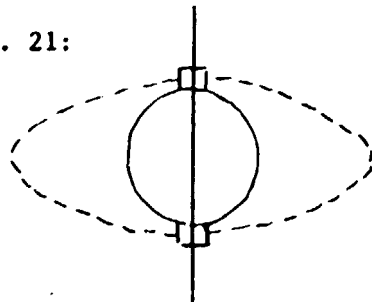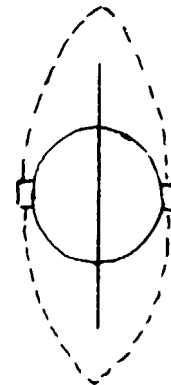plane.

Fig. 21:   Fig. 22

Effect of direction of air horns
with respect to spray pattern.

Various spray patterns defects are shown in fig.   (a, b, c, d, e and f).
They may result from problems such as clogging of one or more of the various
air vents on the air cap horns or clogging of various parts of the fluid tip
and fluid needle. (see fig. 23 below)
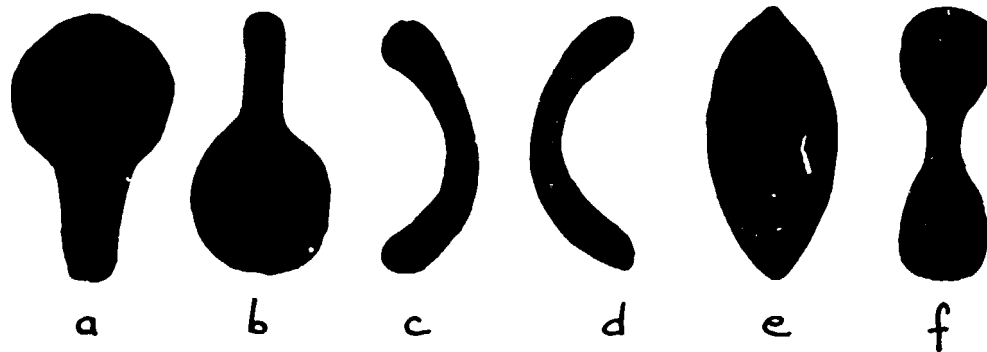
Fig. 23: Legend:
a) top heavy; b) bottom heavy; c) heavy rightside;
d) heavy left side; e) heavy center; f) split-spray.

Apart from the four settings mentioned above, a specific spray gun can
be fitted with different air caps, fluid tips and fluid needles to suit a
variety of uses.

As a general rule, to minimize overspray and paint dust formation,
paint should be sprayed at the lowest aire pressure possible (other factors
remaining constant).

Tables of data concerning the air pressure drop along air line of
various cross section are a useful aid to estimate actual air pressure
at the spray gun. A few indicative figures are reported in table 1.

Table 1: Indicative figures for spray gun operation.

| Inside Diameter | Air-Pressure Drop at Spray Gun, psi | | | | | |
	5-ft length	10-ft length	15-ft length	20-ft length	25-ft length	50-ft length
¼ in.						
At 40 psi	6	8	9½	11	12 3/4	24
At 50 psi	7½	10	12	14	16	28
At 60 psi	9	12½	14½	16 3/4	19	31
At 70 psi	10 3/4	14½	17	19½	22½	34
At 80 psi	12¼	16½	19½	22½	25½	37
At 90 psi	14	18 3/4	22	25¼	29	39½
5/16 in.						
At 40 psi	2¼	2 3/4	3¼	3½	4	8½
At 50 psi	3	3½	4	4½	5	10
At 60 psi	3 3/4	4½	5	5½	6	11½
At 70 psi	4½	5¼	6	6 3/4	7¼	13
At 80 psi	5½	6¼	7	8	8 3/4	14½
At 90 psi	6½	7½	8½	9½	10½	16

PAINT CHARACTERISTICS FOR AIR SPRAYING

The paint viscosity must be such that it can be sucked up (in a suction feed spray gun) that it can flow down (in a gravity feed spray gun) and can be pressed into (in a pressure feed system) the adequate spray gun.

Gravity feed and suction feed spray guns can atomize paint of lower viscosity than pressure feed spray guns. Since the paint, primer, sealer or varnish is usually supplied at a viscosity higher than what is required, the apint has to be diluted with adequate thinners before use. Thus some means of measuring the extent of dilution or the effect of adding thinners on the viscosity of the paint is needed. Since at spraying viscosity many paints have a near newtonian flow a Ford cup or sometimes a Zahn cup (both are efflux cups) are used to measure the viscosity at a specific temperature (since viscosity decreases with increase in temperature up to a point). See fig.24 for use of a Ford cup No. 4.
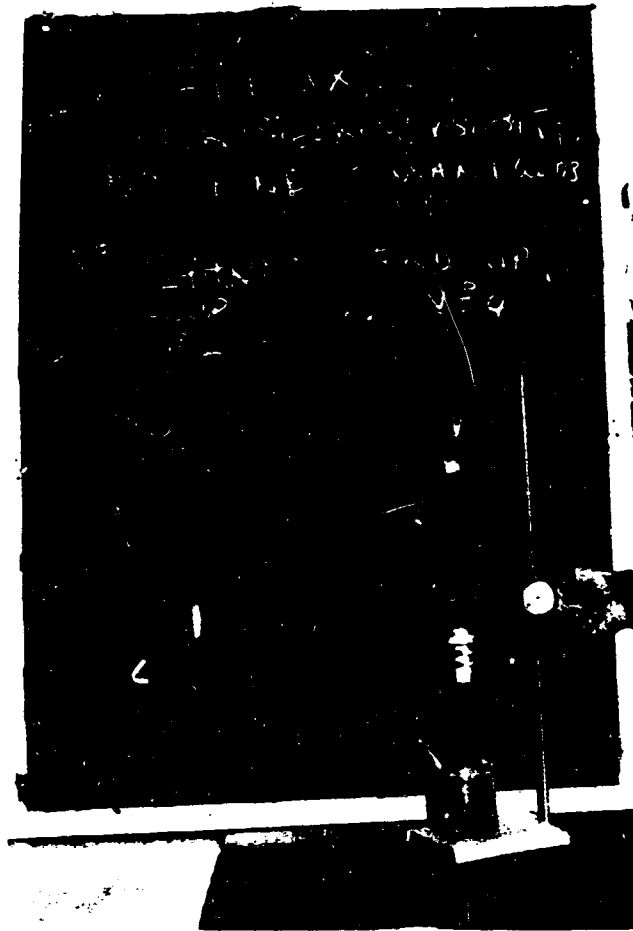
Fig. 24

    Drying time: Very fast drying paints (containing very fast evaporating
solvents) cannot be sprayed since they may form "spider webs" from the spray
gun or they will not have enough time to flow evenly on the surface after
spraying and thus cause "dry spray".

    In very humid conditions, when sprayed on metallic surfaces, some fast
drying paints may exhibit the phenomenon of blushing or blooming. This
can be explained when we know that solvents (thinners) in the liquid state
need to obtain the latent heat of evaporation from the substrate and surroun-
dings to evaporate. Quick evaporating solvents on metallic surfaces take
their heat of evaporation quickly from the metallic surface (which is good
a good conductor of heat). This cools the metallic surfaces and the paint
below dew point for the ambient humidity conditions. Thus moistures
condenses on the paint film (which acts as a barrier between the metal and
the surroundings) and the result is a whitish discoloration of the paint
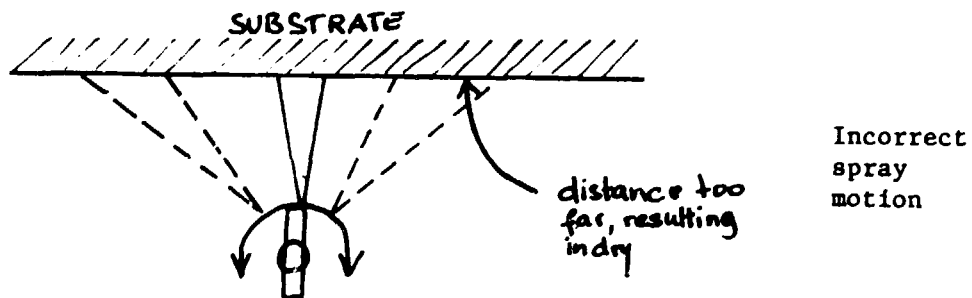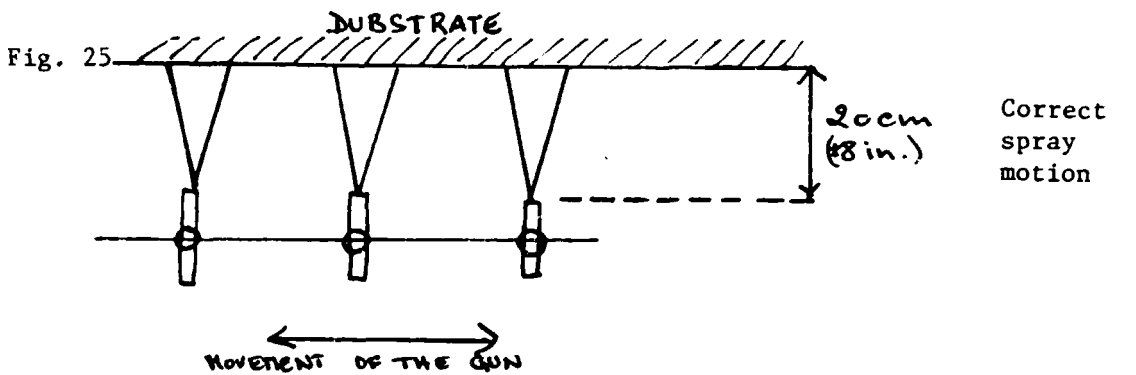film due to precipitation of the birer (known as blooming or blushing).

This phenomenon can be prevented by using slower evaporating thinner (retarder) when spraying in very humid conditions, or by warming up the surface to be painted using for example infra-red lamps.

SPRAYING DISTANCE AND A FEW TRICKS OF THE TRADE

The spray gun should be held at a certain distance, usually twenty centimeters (about eight inches) from the tip of the spray gun to the surface being painted. Furthermore, the axis of spray gun (along the fluid needle) should be kept at an angle of ninety degrees (both in the horizontal and vertical planes) to the surface being painted.

If the spray gun is held too far from the surface the paint will be deposited in droplets and in a "close to dry" stage, thus flow on the surface and adhesion (in extreme cases) will be impaired. This defect is referred to as "dry spray" (the same effect may be observed when the pressure of the compressed air is too high or when too fast evaporating thinners are used).

If the spray gun is held too close from the surface, too much paint in a very "wet" stage will be deposited on the surface and sagging or weeping of the paint will result.

Fig. 25

SUBSTRATE

20 cm (8 in.) — Correct spray motion

MOVEMENT OF THE GUN

SUBSTRATE

distance too far, resulting in dry — Incorrect spray motion

PRESSURE FED SPRAY GUNS

Their advantage is that paints of higher viscosities can be used, and thus savings are achieved both on solvents and the number of coats of paint to be applied.

Solvents are toxic, inflamable, expensive, a source of pollution and are lost when they evaporate from the coating.

When paints need to be diluted for application with an air spray their solid content are reduced, the film deposited is thus thin, this necessitating a larger number of coats thus increased labour cost and longer production time.

The disadvantage of pressure fed spraying compared to air spraying is that the initial capital outlay for equipment is usually more expensive.

Principle of Operation

Apart from the air cap, (pressure fed gun have internal mix air caps) the spray gun itself is similar to non pressure fed air spray gun.

If the paint container is attached to the spray gun, then it is completely air tight as compared to the paint container of non pressure fed guns which have an air vent so that the paint may be sucked up.

A certain maximum air pressure is specified for pressure fed guns with paint container attached. Exceeding this pressure will tend to blow or inflate the paint container.

For continuous in line production the paint container of pressure fed guns is separated from the gun itself.

This container usually has a capacity in the range of five to twenty five litres as compared to the one litre capacity normally available when the paint container is attached to the spray gun.

The remote container is available with a stirrer usually air driven, if there is a tendency for certain heavy pigments to settle out from the paint, such as zinc powder in zinc rich primer, or aluminium and bronze powders or flakes in certain metallic or hammer finish paint formulations.

Figrue 17 represents a pressure fed spray gun with container attached It is rated to work at a maximum pressure of 50 p.s.i. As can be observed from the photograph this pressure has been exceeded since the paint container is swollen.

To achieve an air light seal this container is screwed to its cover whereas for non pressure fed spray gun the container is of the clamp nn type.

HOT AIR SPRAYING (PRESSURE FED)

Increasing the temperature of a paint (up to a certain limiting
temperature Lower part of the curve) reduces its viscosity.

Viscosity
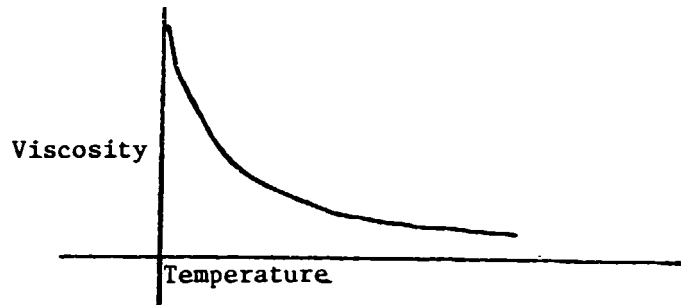
Temperature

Instead of reducing the viscosity of a paint by diluting it with
adequate thinners the paint can be warmed or heated to a specific
temperature.

Some advantages of hot air spraying are:

- No need for thinners with all their disadvantages (already mentioned).

- Less coats of paint (since the heated paint is sprayed at higher solid
  content).

- No blushing on cold metallic surfaces in conditions of high ambient
  humidity (since there is less thinners and the thinners which are
  present have higher boiling points and the paint itself warms the surface so
  that dew point is not reached).

- Better flow of paint and reduced "orange peel" and dry spray. It is
  high temperature and not thinners that is responsible for the flow
  of paint. When fast evaporating thinners are used the paint sometimes
  reaches the surface as dry spray (if the air pressure is too high, or
  there is too much air for atomization, or the spray gun is held too
  far from the surface)   and thus does not flow.

- Quicker setting of the paint when it hits the cool surface, thus
  reducing sagging and weeping tendencies when thick films are applied.

- Constant paint temperature keeps spraying viscosity constant.

Principle of Operation

A paint heater is incorporated between the storage tank and the
spray gun. From the heater to the spray gun the paint is carried in
a special lagged line to reduced heat loses.

The paint is usually heated by passing through a heat exchanger that
itself contain circulating hot water that is heated electrically
in another heating tank.

This process ensures that the paint itself is not in direct contact
with heating elements, thus reducing risks of localised overheating
of the paint and also fire risks.

ELECTROSTATIC SPRAYING

This method of spraying can be used to apply both certain "powder coatings and specially formulated liquid paints.

The principle resides in the fact that particles with similar electric charges repel, and that these same particles can be attracted to an object bearing an opposite electrical charge.

Thus by providing an electrical charge to atomized liquid paint particle (as those produced in normal air spray) and providing an opposite charge to the object to be sprayed, the paint particles will ideally be attracted to the oppositely charge object and will be deposited in a uniform film.

A number of methods of charging the atomized paint particles either in air or airless spraying or the powdered paint have been devised for both automatic and manual spray guns.

The Ransburg No. 1 process developped before the second world war was the original application of the electrostatic principle.

Basically it consisted of a conventional air spray gun, automatically triggered and spraying a mist of paint droplets into a powerful electro-static field produced by charging a grid (or series of wires) arranged on each side of an earthed conveyor carrying the object to be painted. The static potential then produced was of the order of 100,000 to 130,000 volts.

In this process the paint is atomized at a minimum air pressure   the velocity of the paint particles is kept as low as possible. The object to be painted could be rotated while passing through the charge paint mist.

In the Ransburg No. 2 process compressed air and conventional spray gun are eliminated.

Paints diluted to about 15 seconds Ford cup No. 4 is carefully metered (pumped) into the spray gun whose tip consists of a rotating metal bell whose outer sharp edge is charged to a potential of 90,000 to 100,000 volts. The bell is rotated by an electric motor to speeds of the order of 1,000 r.p.m.   This rotation cause the paint to spread centrifugally towards the charge tip, where it is charged and atomized to a fine mist. With the bell the spray pattern obtained is in the form of an annulus.

Based on the above principle many devices have been produced by spray equipment manufacturers. Each manufacturer claims to combine specific advantages with minimum disadvantages.

A few advantages usually attributed to electrostatic spraying compared to concentional spraying methods (air spray, pressure fed, airless) are:

Great paint savings due to the "wrap around" effect of the charged paint mist which deposits itself on the earthed object, instead of being wasted due to overspray specially important for objects like expanded metal tubular steel work.

Better coverage, more uniform deposition of the paint on the object being painted.

AIRLESS SPRAYING

In the search for applying high solids coatings, quickly to increase
output an improved spraying method was designed.

This spraying method is not based on the air atomization principle.
No air is required and the thick paint is pumped directly from the
container through a strainer and into the spray gun at a pressure of
the order of 3,000 p.s.i. where the paint is atomized through a
specially designed tungsten carbide tip.

Since no air was required this system was called airless spraying.

It is well suited for mass production to apply a wide variety of
coatings at thick film thickness, (one coat high build systems) on a
wide variety of substrates.

Since the atomization pressure is very high, paint particles impinge
on the surface with high energy which favours good wetting of surfaces
being painted.

Airless sprays can be fitted with pole guns of up to six feet in length.
These allow painting of ceilings or inaccessible surfaces without the
use of expensive and cumbersome scaffoldings.

A few limitations and disadvantages of electrostatic spraying are :

High Static charge which may be dangerous or cause inconvenience to operators.

Unsatisfactory coating of inside surfaces or recesses, and holes of surfaces due to Faraday cage effect implying that "no electrostatic charge can exist inside a hollow conductor, the charge immediately passing to the outside of the conductor".

Up to now electrostatic spraying of metallic (electrically conductive) objects have been considered. However non conducting material such as wood, plastic and glass can be sprayed, In that case, the surface is rendered conductive by a thin film of moisture.

Paint suitable for electrostatic spraying

Most paints are suitable or can be rendered adequate for electrostatic spraying. Although no hard and fast rate applies, the resistance of the paint should lie between 100,000 to 1,000,000 ohms. Resistance of paints can be adjusted using appropriate solvents. Addition of polar solvents such as methyl iso butyl ketone (M.I.B.K.), butanol, di acetone alcohol reduces the resistance of the paint.

There exist in the trade "paint resistance meters" which provide direct reading of the resistance of a given paint by immersing a electrode into the paint.

Apart from its resistance, characteristics the paint such as viscosity and evaporation rate of the solvents are important for spraying performance.

ELECTROSTATIC POWDER SPRAYING

Similarly to liquid paint spraying, the aerated powder is fed to the spray gun where the powder is charged by various means and carried towards the earthed article to be painted. According to the type of powder being used, a positive or negative charge potential can be used. Epoxy based powder generally give better results with a negative potential, while thermoplastic powders such as nylon give a better result with a positive potential difference.

The article to be coated can either by warmed (hot) or cold. Hot articles will result in a thicker final film, all other parameters being constant.

APPENDIX I

LIST OF BRITISH STANDARDS TEST METHODS FOR VARIOUS COATINGS

BS 3900 : Methods of test for paints

Group A : Tests on liquid paints (excluding chemical tests).

3900 - Part A1 (1970) Sampling

3900 - A2 (1970) Examination and preparation of samples for testing.

3900 - A3 (1970) Standard panels for paint testing.

3900 - A4 (1979) Notes for guidance on paint application.

3900 - A5 (1968) Large scale brushing test.

3900 - A6 (1971) Determination of flow time.

3900 - A7 (1968) Determination of the viscosity of paint at a high rate of shear.

3900 - A8 (1976) Determination of the danger classification by flash point (closed cup method).

3900 - A9 (1973) Determination of flashpoint (closed cup method).

3900 - A10(1976) Determination of volume of dry coating (non-volatile matter) obtained from a given volume of liquid coating.

3900 - A11(1979) Small scale test for combustibility.

3900 - A12(1975) Determination of density.

3900 - A13(1978) Rapid test for determination of danger classification by flash point.

3900 - A14(1978) Rapid test for determination of flash point.

3900 - A15(1976) Determination of the quantity of material in a container.

Group B : Tests involving chemical examination of liquid paints and dried paint films.

3900 - Part B1 (1965) Determination of water by the Dean and Stark method.

3900 - Part B2 (1970) Determination of volatile matter and non-volatile matter.

3900 - Part B3 (1965) Determination of 'soluble lead'.

3900 - Part B4 (1967) Determination of lead in low-lead paints and similar materials.

Group C : Tests associated with paint film formation

3900 - Part C1 (1965) Wet edge time.

3900 - Part C2 (1971) Surface-drying test (Ballotini method).

3900 - Part C3 (1971) Hard-drying time.

3900 - Part C4 (1965) Freedom from residual tack.

3900 - Part C5 (1975) Determination of film thickness.

3900 - Part C6 (1970) Determination of fineness-of-grind.

3900 - Part C7 (1974) Pressure test.

3900 - Part C8 (1978) Print free test.

Group D : Optical tests on paint films

3900 - Part D1 (1978) Visual comparison of the colour of paints.

3900 - Part D2 (1967) Gloss specular reflection (withdrawn June 1982
                    superseded by Part D5).

3900 - Part D3 (1975) Assessment of sheen.

3900 - Part D4 (1974) (1979) Comparison of contrast ratio (hiding power)
                            of paints of the same type and colour.

3900 - Part D5 (1980) Measurement of specular gloss of non-metallic
                    paint films at 20°, 60° and 85°.

Group E : Mechanical tests on paint films

3900 - Part E1 (1970) Bend test (cylindrical mandrel).

3900 - Part E2 (1970) Scratch test.

3900 - Part E3 (1973) (1979) Impact (falling weight) resistance.

3900 - Part E4 (1976) Cupping test.

3900 - Part E5 (1973) (1979) Pendulum damping test.

3900 - Part E6 (1974) (1979) Cross-cut test.

3900 - Part E7 (1974) Resistance to impact (falling ball test).

3900 - Part E8 (1974) (1979) Resistance to impact (pendulum test).

3900 - Part E9 (1976) Buchhloz indentation test.

3900 - Part E10 (1979) Pull-off test for adhesion.

Group F : Durability tests on paint films

3900 - Part F1 (1966) Alkali resistance of plaster primer-sealer.

3900 - Part F2 (1973) (1979) Determination of resistance to humidity
                            under condensation conditions.

3900 - Part F3 Addendum No. 1 : (1978) Notes for guidance on the
            operation of artificial weathering apparatus to BS3900 :
                                            Part F3 : 1971

3900 - Part F4 (1968) Resistance to continuous salt spray.

3900 - Part F5 (1972) Determination of light fastness of paints for interior use exposed to artificial light sources.

3900 - Part F6 (1976) Notes for guidance on the conduct of natural weathering tests.

3900 - Part F7 (1973) (1979) Determination of resistance to water (water immersion method).

3900 - Part F8 (1976) Determination of resistance to humid atmospheres containing sulphur dioxide.

Group G : Environmental tests on paint films (including tests for resistance to corrosion and chemicals).

3900 - Part G4 (1967) (1979) Resistance to hot fats.

3900 - Part G5 (1976) Determination of resistance to liquids.

3900 - Part G7 (1976) Determination of the effect of heat.

Group H : Evaluation of paint and varnish defects.

3900 - Part H1 (1980) Designation of quantity and size of common types of defect: general principles and pictorial scales for blistering and rusting.

BS AU : 148 - <u>Methods of test for Motor vehicle paints</u>

<u>Part 1</u> (1969) - Visual colour matching. (Withdraw October 1982, superseded by 6S 3900 Part 1).

<u>Part 2</u> (1969) - Resistance to continuous salt spray.

<u>Part 3</u> (1969) - Flexibility and adhesion.

<u>Part 4</u> (1969) - Resistance to abrasion.

<u>Part 5</u> (1969) - Gloss measurement.

<u>Part 6</u> (1969) - Hardness.

<u>Part 7</u> (1969) - Hiding power (withdrawn October 1982, superseded by BS 3900 Part D4).

<u>Part 8</u> (1969) - Measurement of paint film thickness (withdrawn October 82 superseded by BS 3900 Part C5).

<u>Part 9</u> (1969) - Resistance to dry heat.

<u>Part 10</u> (1969) - Resistance to heat and corrosion.

<u>Part 11</u> (1969) - Resistance to blistering.

<u>Part 12</u> (1969) - Resistance to accelerated weathering.

<u>Part 13</u> (1969) - Resistance to deterioration by contact with other materials.

<u>Part 14</u> (1969) - Resistance to outdoor exposure.

<u>Part 15</u> (1969) - Resistance to chipping.

BS 3962 - <u>Methods of test for finishes for wooden furniture</u>

<u>Part 1</u> (1980) - Assesment of low angle glare by measurement of specular gloss at 85°

<u>Part 2</u> (1980) - Assesment of surface resistance to wet heat.

<u>Part 3</u> (1980) - Assesment of surface resistance to dry heat.

<u>Part 4</u> (1980) - Assesment of surface resistance to cold liquids.

<u>Part 5</u> (1980) - Assesment of surface resistance to cold oils and fats.

Part 6 (1980) - Assesment of resistance to mechanical damage.

BS : 5910 - <u>Methods of test for surface finishes for furniture</u>

<u>Part 1</u> (1980) - Assesment of surface resistance to cold liquids.

APPENDIX II

A few British Standard relating to fire extinguishers and safety
of electrical equipment for explosive atmospheres

BS : 889 - 1965 (1982) - flame proof electric lighting and fittings.

BS : 5306 - Code of practice for fire extinguishing installations and
equipment on premises.

    5306: Part 1(1976)- Hydrant systems, hose reels and foam inlets.

        Part 2(1979)- Sprinkler systems.

        Part 3(1980)- Portable fire extinguishers.

        Part 4(1979)- Carbon dioxide systems.

        Part 5 section 5.1 (1982) - Halen 1301 total flooding
systems.

BS : 5423 - (1980) - Specifications for portable fire extinguishers.

BS : 229 - (1957) + (Various amendments)   - Flame proof enclosure of
electrical apparatus.

BS : 4683 - Electrical apparatus for explosive atmospheres.

        Part 1 (1971) - Classification of maximum surface
temperature.

        Part 2 (1971) - The construction and testing of flameproof
enclosures of electrical apparatus.

        Part 3 (1972) - Type of protection N.

        Part 4 (1973) (1979) - Type of protection "e".

BS : 1259 (1958) (With various amendments)   - Intrinsically safe
electrical apparatus and circuits for use in explosive
atmospheres.

BS : 5345 - Code of Practice for the selection, installation and
Maintenance of electrical apparatus for use in potentially
explosive atmospheres (other than mining applications or
explosive processing and manufacture).

        Part 1 (1976) - Basic requirements for all parts of the code.

        Part 3 (1979) - Installation and maintenance requirements
for electrical apparatus with type of
protection "d" flame proof enclosure.

        Part 4 (1977) - Installation and maintenance requirements
for electrical apparatus with type of
protection "i". Intrinsically safe
electrical apparatus and systems.

Part 6 (1978) - Installation and maintenance requirements for electrical apparatus with type of protection "e" increased safety.

Part 7 (1979) - Installation and maintenance requirements for electrical apparatus with type of protection N.

Part 8 (1980) - Installation and maintenance requirements for electrical apparatus with type of protection "s". Special protection.

BS : 5501 - Electrical Apparatus for Potentially Explosive atmospheres.

Part 1 (1977) - General requirements.

Part 2 (1977) - Oil immersion "o".

Part 3 (1977) - Pressurised apparatus "p".

Part 4 (1977) - Powder filling "q".

Part 5 (1977) - Flame proof enclosure "d".

Part 6 (1977) - Increased safety "e".

Part 7 (1977) - Intrinsic safety "i".

Part 9 (1982) - Intrinsically safe electrical systems "i".

BS : 3116 - Automatic fire alarm systems in buildings.

BS : 5445 - Specification for components of automatic fire dection systems.

Part 1 (1977) - Introduction.

Part 5 (1977) - Heat sensitive detectors. Point detectors containing a static element.

CODE PRACTICE - CP 1003

Electrical apparatus and associated equipment for use in explosive atmospheres of gas or vapour other than mining application.

Part 1 (1964) - (With various amendments)

Choice, installation and maintenance of flame proof and intrinsically - safe equipment.

Part 2 (1966) - Methods of meeting the explosion hazard other than by the use of flame proof or intrinsically safe electrical equipment. (Deals with the following methods of meeting the explosion hazard, segregation, ventilation and pressurisation.

Part 3 (1967) - Division 2 areas. Considerations affecting
the choice, use and installation of apparatus
in Division 2 areas (i.e. areas in which
flammable and explosive substances are so well
under conditions of control that a hazard is
likely only under abnormal conditions).

PUBLIC AUTHORITY STANDARDS

PAS : 7 (1972) - Carbon dioxide fire extinguishers - hand protable types.

BS : 6016 (1980) - Specification for filtering face piece dust respirators.

APPENDIX III

CLASSIFICATION OF ABRASIVE CLOTH

	Standard Rating	Emery Scale
VERY FINE	600	12/0
	500	11/0
	400	10/0
	360	
	320	9/0
	280	8/0
	240	7/0
	220	6/0
FINE	180	5/0
	150	4/0
	120	3/0
MEDIUM	100	2/0
	80	1/0
	60	1/2
COARSE	50	1
	40	1 ½
	36	2
VERY COARSE	30	2 ½
	24	3
	20	3 ½
	16	4
	12	4 ½

BS 871 (1981) Specifications for abrasive papers and cloths.

BS 2992 (1970) Painters and decorators brushes for local authorities and public institutions (excluding quality of fillings).