A Review on Aqueous Film Coating Technology

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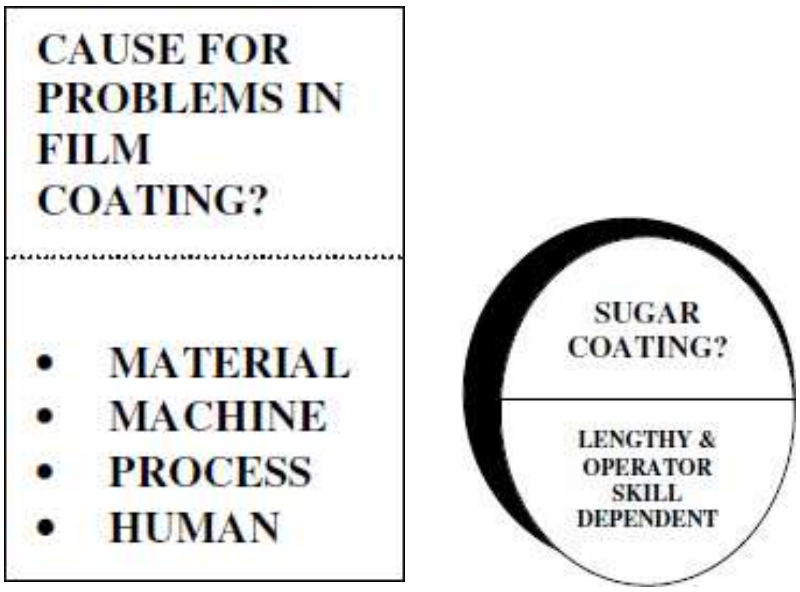
Introduction of Tablet Coating:

Since age's tablets/pills has been the most preferred dosage form to deliver any medically active substance to human body. These tablets /pills have to be coated for however, a number of product are now coated to provide some functional benefits like taste masking coating etc.

Until about 1950, sugar coating was the first choice as coating agent for pharmaceutical preparation and much time & efforts were spent in perfecting the sugar coating techniques. Nobody ever was concerned about the problems like material cost, toxic effect due to coating or pollution etc. because the solvent used was always water. However, sugar coating technique was time consuming, affecting the productivity & the quality of finished was dependent on the skills of operator.

The problems led to the development of film-coating technique, which has mainly based on solution of different polymers in various organic solvents, are toxic in nature. As the level of understanding regarding the toxic effect of these solvents is increasing industrial hygiene rules.

FDA regulation are being tightened world over, limiting the use of these solvent and exposure of workers to these solvents. Another area of concern is the cost of these solvents, which can only be expected to increase in coming times. Many a times the companies had to reschedule their production plans due to non-availability of skillful coating operator. Now a days there are some new invention takes place, which are helpful to the operator for success in their coating operations. The coating of any formulation is the additional step in pharmaceutical manufacturing so cost of the product is very important consideration because the cost of the final product is obviously increased after the coating.



In today's competitive business environment any cost saved will improve the market viability and success of any product. We are, therefore, left with no other choice but to eliminate the use of organic solvents and starts using water as the solvent system for tablet coating. Like any other system, aqueous film coating has some disadvantages. The main reason for using organic solvent was to avoid possible decomposition of active ingredients and many other process related problems such as over wetting, picking, sticking etc. which may occur with aqueous coating systems. However, reaches and experience of industry has indicated that the decomposition of active ingredients and possible coating difficulties are not so serious issues in actual applications and all such problems can be sorted out by scientific evaluation of the reasons for these problems.

Most of these problems could be categorized as:
(1) Material related problems
(2) Coating instrument related problems
(3) Coating process related problems

A large numbers of problems observed during conversion from organic solvent based coating to aqueous film coating are related to material selected for coating formulation. The problems related to the film adhesion, problem due to the coating solution viscosity and problem related to the non-uniform distribution of the coating solution may create the following problems.

Some of these problems could be:
(A) Poor film adhesion.
(B) Poor tablet finish due to high viscosity of coating solution.
(C) Uneven surface of finish product.
(D) Non-uniform color of finished product.

To, understand these coating problems, we will have to understand the properties and role of various material used in films coating formulation because they affect the coating cost also if wrong selection of the coating material is done so before selection of the coating material all the above problems are taken in to considerations (Pharma Times, Vol-35, Oct'03).

Objectives of tablets coating: -

The application of coating which is an additional step in manufacturing process, increase the cost of product, there for the decision to coat a tablet is usually based on one or more of following objectives and the additional step in manufacturing process if any manufacturer wants to develop the formulation from other then it is an additional step for development their formulation and all of the coating process an aqueous film coating is most widely used because of their following important advantages: -

- To mask the taste, odour or color of drug.
- To provide physical and chemical protection
- To control release of drug from tablet.
- To protect the drug from the gastric environment of stomach with an acid resistant enteric coating.
- Facilitate the swallowing of dosage form.
- Protect the drug from storage environment (Air, moisture and light)
- To incorporate another drug or formula adjuvant in the coating to avoid chemical incompatibilities.
- Improved esthetic qualities of product.
- Facilitating handling, particularly in high speed filling / packaging lines.
- Improve the appearance and provide product identity.
- Improve product stability.
- To improve the pharmaceutical elegance by use of special colors and contrasting printing (Leon Lachmann-Pharmaceutical Dosage forms: Tablets, Vol-3; Encyclopedia of Pharmaceutical tech., Vol-1).

Aqueous film coating demands according to the Myths:

- Consistent tablet hardness &
- Controlled spray rates.
- Controlled operating temperature &
- Controlled airflow rates for drying.
- Bad things can happen in seconds (Or you could end up with this).

Introduction of Aqueous Film Coating:

Aqueous film coating is applied as a thin polymeric film to the surface of a tablet. Film coating can protect the tablet from light, temperature and moisture, mask undesirable taste or odour, improves the appearance, provide tablet identity, facilitate swallowing control or modified the release of drug. Aqueous film of oral dosage forms has rapidly replaced solvent-based coating for safety, environmental and economic reasons. Since tablet may contain moisture sensitive drugs or excipients, the use of water raise concerns about the physical and chemical stability of the coated tablet.

Popular Myths about Tablet Coating:

- It is more art than science.
- Coating pan operators are “prima donnas.
- Water based coating is tricky.
- Coating solutions are just dyes in water and you can mix them anywhere’s About Tablet Coating” (Fred A. Rowley, 2005).

Fig. 1: Engineering for success: The aqueous film coating process

The process of the coating according the engineering success according to the Myths as seen above (Fig.1). Film coating of tablet is a multivalent process with many different factors, such as coating equipment, process conditions, composition of the core tablet and coating liquid, which affect the pharmaceutical quality of the final product. The side vented, perforated pan coater is the most commonly used coating device of tablets. Its airflow system through a perforated pan ensures rapid and continuous drying conditions. The low evaporation capacity of water requires high drying efficiency of aqueous film coating equipment.

Traditionally the level of instrumentation and automation of coating equipment has been low and subsequently, the coating process difficult to control. To improve the reproducibility and predictability of coating process and quality and safety of the final coated product, demand for instrumentation and automation of coating equipment in the pharmaceutical industry are increased. The reduction of the product costs has become an important factor a requirement for efficient production. An automated film coating process and a critical process parameter monitoring system would provide a useful tool for controlling

process and for understanding the phenomena during the process. High quality aqueous film coating must be smooth, uniform and adhere satisfactorily to the tablet surface and ensure chemical stability of a drug.

Critical process parameters such as inlet air flow rate, spraying air pressure, coating solution flow rate, pan air temperature and rotating speed of the pan, are quite well identified and can greatly affect the spreading, penetration and drying (i.e. water evaporation) of the cored liquid on the tablet surface, the quality of coated tablet. In the aqueous film coating process, tablets are exposed to wide temperature and humidity variations that may promote undesired water penetration into the tablet core during coating or storage. Entreated water can cause changes in the structure of the film core interface, core expansion and increase the risk of degradation of a moisture labile drug. Probably due to lack of effective instrumentation and automation systems, the effect of process condition on the properties of coated tablet is not very well understood.

In determining the effect of the film coating process and storage on the quality of the coated tablet, the relevant parameters are surface roughness, film core interface, i.e. water penetration into core, residual moisture content, degradation of moisture labile drug, dimensional changes of coated tablets and the effect of these changes on adhesion. The aqueous film coating process is an additional parameter and it is considered after completion of the compression of the tablet. According to the below (Fig.2) the aqueous film coating unit operation is understand very easy. First of all weight of the required active ingredients and excipients and screen them through appropriate sieve and then prepare the granules by wet or dry granulation method as per required after completion of the granulation blending them appropriately after addition of the lubricants and after that compress them by appropriate machine and after preparation of the tablet coating is considered and tablet go for printing if required (Fred A. Rowley, 2005).

Advantage of aqueous film coating: -

There are number of advantages for aqueous film coating some of them are described in the following.

- Minimized weight increased
- Reduction in processing times
- Increases process efficiency an output
- Increases flexibility in formulation
- A simplified process
- Ability to apply to wide range of pharmaceutical dosage forms (Tablets, Capsules, Powders, Granules, and Crystal of drugs).

Film formation mechanism:

Aqueous film coating application is either solutions or dispersions, depending on the water solubility of the film former polymers. Film formation from the polymer solution occurs through a series of phases. When the polymers solution is applied to the surface of tablet, cohesion forces from a bond between the coating polymer molecules .To obtain high cohesion, the cohesive strength of polymer molecules must be relatively high and continues surface of the film material must coalesce. Coalescence of adjacent polymer molecular layer or surfaces occurs through diffusion.

When most of the water evaporates, the viscosity of the solution increased (gelatin) and leaves the polymer chains in close proximity to each other and deposited over a previous polymer layer (Ghebre-Sellassie1987). If there is adequate cohesive attraction between the molecules and sufficient diffusion and coalescence upon the more complete evaporation of the residual water, the individual polymer chains align themselves to form a cohesive film. Film

formation from dispersion occurs when polymeric particle coalesces to form a continuous film. Making it more complex mechanism compared to film formation from solution (Obara, 1995). The coalescence of aqueous polymer dispersion deposited on the surfaces of a tablet into continuous film is initiated by water evaporation. As water evaporates, dispersed polymer particles are pushed into a closely packed, ordered array with water filling the voids. After the polymer particle comes into a contact with each other, they must deform and fuse in order to coalesce into film.

Coalescence will occur when the promoting forces are greater than the resistive forces of the particles. The forces promoting particle coalescence include capillary pressure (Water air interfacial tension) as well as particle air and particle water interfacial tension. Finally, the coalescence of the polymer particles is further complemented by inter-diffusion of polymer chains occurring through particle interfaces, making the film more homogeneous.

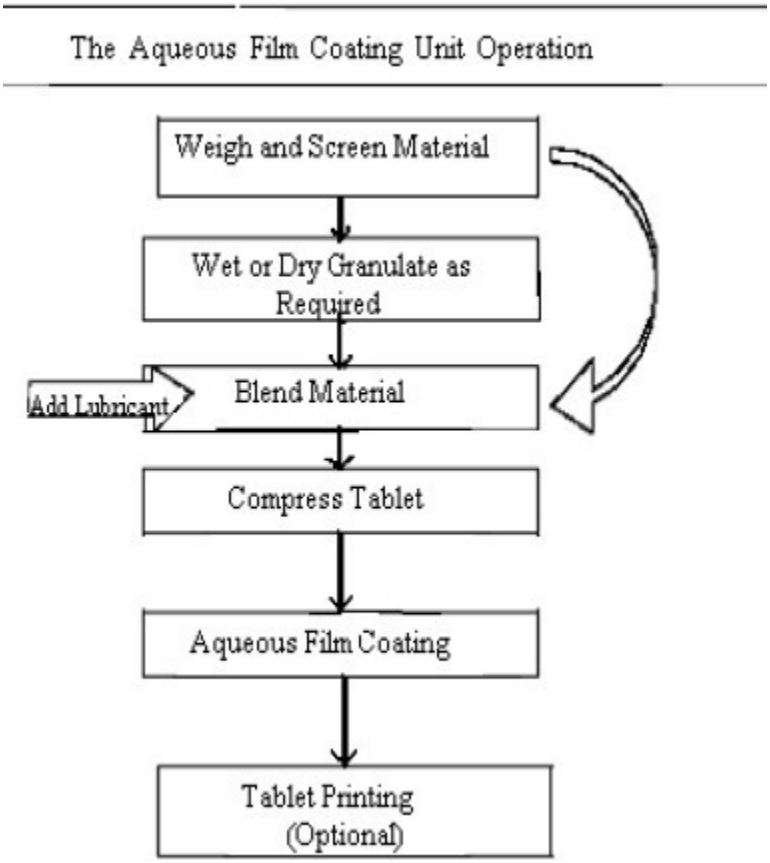


Fig. 2: Where aqueous coating fits into the big picture

Film formation, i.e. coalescence is complex process and dependent on coating and storage conditions, coating polymer molecular weight and particle size, coating liquid constituents and properties like viscosity and surface tension (Aulton, 1995; Dobler, 1996). In the aqueous film coating technology first of all droplets are formed and after wetting and spreading the coating material finally coalescence is takes place.

Since coalescence only occurs above a minimum film formation temperature (MFT) of coating polymer, temperature and water evaporation are considered to be major process related

factors affecting the properties of coatings (Obara, 1995). All the above mechanism is described and understands by the following (Fig.3), which indicates the schematic representation of the coating process in which how to form the droplet and how the complete the coating process are schematically described in the bellow figure there are mainly four to five steps droplet formation, film formation, wetting, spreading and coalescence.

Aqueous Film Coating Materials:

Film formers: -

The film former is major ingredient in a coating formulation. As no polymer has all of the physical and chemical properties, such as chemical stability, chemical inertness, strong tablet adherence, flexibility, and printability, to meet the various application needs, the coating compositions must be formulated with plasticized polymers or mixtures of polymers to achieve the desired tablet coating. The polymers can be divided into essentially two classes: aqueous soluble polymers and water-insoluble (sustained release) or pH-dependent (enteric) soluble polymers.

The most commonly used water-soluble coating polymers are hydroxypropylmethylcellulose (HPMC), other cellulose derivatives and polyvinylpyrrolidone (Dansereau, 1993; Fisher, 1976; Guo, 1998; Okhamafe, 1985; Heng, 1996). Recently, new rapid release coating material has been introduced, such as amylose starch (Krogars, 2002) and chitosan (Phaechamud, 2000). Water-soluble coating materials dissolve completely in the gastrointestinal tract and do not modify the drug release characteristics of the dosage. These polymers are usually applied as aqueous solutions.

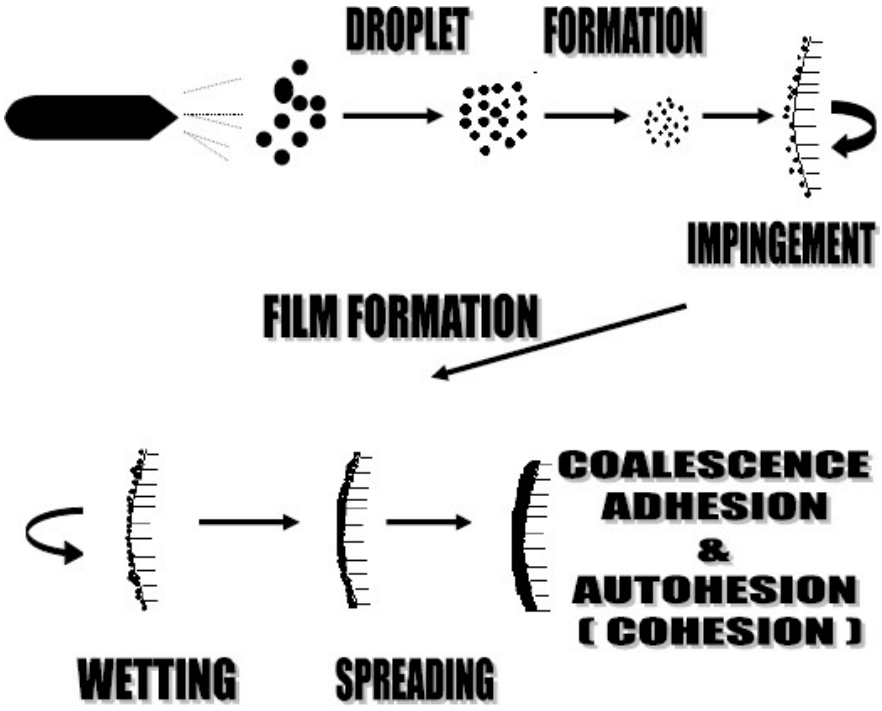


Fig. 3: Schematic representation of the aqueous film- coating process

The most commonly used aqueous- soluble polymers consist of: -

A. Acrylate copolymer: Eudragit E (cationic copolymer based on dimethyaminoethylmethacrylate and other neutral methacrylic acid Esters), Rohm Pharma GmbH, Darmstadt, West Germany.
B. Cellulosic polymers:
1. Carboxymethylcellulose sodium, USP
2. Hydroxypropylcellulose, NF
3. Hydroxypropylmethylcellulose, USP [HPMC]
4. Methylcellulose, USP
5. Polyethyleneglycols, NF
6. Povidone, USP.

Some of the most common insoluble polymer candidates are: -

A. Methacrylic acid copolymer, NF
B. Eudragit L and S®(anionic copolymers based on methacrylic acid and methacrylic acid methyl ester), Rohm pharma GmbH, Darmstadt, West Germany
C. Cellulose acetate phthalate, NF (CAP)
D. Hydraxypropyl methylcellulose phthalate, NF
E. Polyvinyl acetate phthalate, NF
F. Ethyl cellulose, NF

HPMC is a cellulose derivative in which some of hydroxyl groups are substituted with methyl and hydroxypropyl groups. HPMC has many of the desired coating polymer properties: it forms a transparent, tough and flexible film that protects fragile tablets, masks the unpleasant taste of drug and improves the appearance, tolerate the presence of colorants and other additives, and are resistant to abrasion. HPMC is a stable in the presence of heat, light, air and moisture in room conditions, although it is moderately hydroscopic (Nagai, 1997).

Films prepared with this polymer generally will another polymer or plastisizer to improve their binding to tablet surface and avoid the problem of bridging or filling of tablet intagliations. Aqueous film coating using HPMC has proven complex and more sensitive to changes in the process compared to those of organic solvent coating. In aqueous coating the water evaporation capacity is lower, which requires compensating adjustments to other coating parameter, such as air temperature, flow rate of coating solution and spraying air pressure. The increased use of aqueous based film coating has clearly increased the amount of coating defects.

If the coating conditions during aqueous film coating using HPMC were better characterized, these problems could be avoided. Most of the other polymers become tacky during their drying cycle. This may be ideal for the application of tablet subcoating to improve the adhesion of the primary coating to the tablet substrate, but generally appropriate additives must be incorporated to minimize the tackiness problem. Most water-soluble polymers, with the possible exception of povidone, significantly increase the viscosity of a coating composition at relatively low polymer concentrations. This limits the quantity of even the low-viscosity grades that can be used, as it is difficult to spray viscous compositions, and they do not spread adequately on the sprayed surface to produce a smooth coating.

High-viscosity grades generally provide better film than the low-viscosity grades. Yet, the lower-viscosity grades and their weaker film are used, as higher solid loading of the coating composition can be attained. The higher viscosity grades of HPMC thought provided film with good tensile strength but produces films having poor adhesion with the core surface and very often one can easily peel-off the film from the tablet surface. Enteric coating constitutes the major portion of the pH-dependent polymer. Adjusting the pH of the coating solution can solubilize these polymers, or they can be formulated to be suspended in the aqueous media and applied as insoluble polymer particles.

The water-soluble polymers used when an enteric coating or a special controlled-release delivery system is desired (Johnson, 1991; Heinamaki, 1994). The phthalate ester derivatives are used as enteric coating polymers. Cellulose acetate phthalate (CAP) was major enteric polymer for many years, but its films were brittle and they did not dissolve below pH 6.8. FMC Corporation, Philadelphia (Aulton, 1995), has developed a coating composition containing CAP as aquateric.

The enteric polymers, HPMC phthalate and polyvinyl acetate phthalate, are available in different grades that dissolve at lower pH values, namely 5.5 to 5.0. In addition, the polymers chemically most stable and form better films than CAP. The two most common HPMC phthalate are referred to as HP-50 and HP-55, corresponding to pH values of 5.0 and 5.5 at which the polymers dissolve. Polyvinyl acetate phthalate has also been formulated as a coating composition, Coateric by colorcon, West Point, Pennsylvania.

The acrylic resins Eudragit L ® and Eudragit S ® provide films that are resistant to gastric fluid, and they are soluble at pH6 and pH 7, respectively. Eudragit L is available as an aqueous dispersion. Ethylcellulose may be incorporated into enteric films to modify their solubility characteristics but films of ethylcellulose are not soluble in water over the physiological pH range. Two commercial coating compositions of ethyl cellulose have been formulated as aquacoat ® by FMC Corporation and Surelease ® by Colorcon. The molecular weights of the different polymers are also taken into consideration because the molecular weights of the polymers are affecting the coating properties of the perticulate formulation. When the same hydroxy methyl cellulose dissolve in water there number of risk which also take in to considerations (Encyclopedia of pharmaceutical tech., Vol-1).

The same HPMC when dissolved in water give rise to many other problems like: -

A. High solution viscosity.
B. Water is a poor solvent for HPMC as compared to organic solvents, therefore, solutionpreparation is difficult.
C. Water has much higher surface tension than organic solvents; material wetting is difficult resulting in poor film adhesion.
D. Film produced using water as solvent has poor mechanical properties like low tensilestrength, higher modulus of elasticity and low film adhesion.

Therefore, the selection of correct polymers system is very critical for the success of aqueous coating formulation. By selecting the lower viscosity polymers, the solid content in the coating formulation can be increased which will result in lesser amount of water required which in turn can increase the coating speed. However, the lower viscosity HPMC produced film with lower tensile strength. As described earlier film produced by HPMC using water as solvent system may have poor film adhesion resulting in easy peel-off from the tablet surface.

To overcome this problem some formulators have used the combination of HPMC and HPC. HPC provides better film adhesion to the substrate then HPMC, however, other mechanical properties of are not capable to HPMC, moreover, the cost of HPC is much higher that HPMC and thus make the economically non-viable. Various other polymers are also used in developing aqueous film coating formulations like sod. CMC, PVA, PVP, Sod. Alginate, PEG etc. either alone or in combination (Pharma Times, Vol-35, Oct'03).

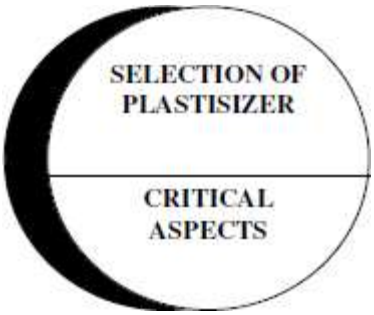
The enteric coating material today includes cellulose acetate phthalate (CAP), Cellulose acetate trimellitate (CAT), HPMC phthalate (HPMCP) (Baudoux, 1990; Thomaa, 1999) which persist in the stomach and only disintegrate in the higher pH environment of the intestinal fluid. The widely used water-insoluble polymers, ethyl cellulose and polymethacrylate copolymers (Ghebre, 1987; Gutierrez-Rocca, J.C. and McGinity, W.C., 1993). Control the rate of the drug release by swelling in water and firming a permeable membrane. Since polymers for enteric and sustained-release formulations are practically insoluble in water, they are usually

applied as aqueous dispersions. The selection of the appropriate polymer is necessary if wrong selection of the polymer is takes place then there should be create many problems in the final coated dosage form.

There are so many factors which are affect the properties like tensile strength, elastic modulus, film adhesion, solution viscosity and the film permeability The following table (Table:1) indicates that, what happened when the polymer molecular weight is increase

Table 1: Effect of polymer molecular weight on coating properties

Sr.No.	Property	Effect of increasing the molecular weight of the polymer
1	Tensile strength	Increase
2	Elastic modulus	Increase
3	Film adhesion	Decrease
4	Solution viscosity	Significantly increase
5	Film permeability	Typically unaffected, unless the structural properties improve as molecular weight of the polymer increase



The next most important component of the coating formulation is plastisizer. A wide range of plastisizers is available to the formulator such as:

A. Phthalate esters
B. Phosphate esters other esters like citrates, stearates, sebacate, oleate,adipate etc.
C. Oils, glycerol, glycols etc.

Films prepared from pure polymers frequently are brittle and crack on drying. To correct this deficiency, the polymer can be chemically modified or other ingredients can be added to make the film more pliable. Plastisizers can be classified into two categories:

(1) Internal politicizing involves the chemical modification of a basic polymer to alter the physical properties of the polymer. Changes in the degree of substitution, the type of substitution, and the polymer chain length influence the physical characteristic of the polymeric film. Generally, the formulator must work with the polymers that are available, and the film properties are altered by the addition of external plastisizers. The selection of the proper plastisizers is very necessary because it affect the final coating of the any pharmaceutical dosage forms.

(2) The external plastisizer can be another polymer, a nonvolatile liquid, or even the aqueous solvent. The plastisizer alters the polymer-polymer interactions to improve the flexibility of the film by relieving molecular rigidity. As a general rule, the film will become more flexible and more resistant to mechanical stress when a plastisizer is added to a coating composition. There is an optimal concentration of plastisizer to use for any film composition. The technique to establish the ideal concentration will be described later.

The water-insoluble polymer suspension formulation requires high concentrations of water-insoluble plastisizers. The plastisizers facilitate the transformation of the discrete polymer particles on the sprayed surface into a continuous film when heat is applied. Several of the insoluble plastisizers may be incorporated in combination with one or more water-soluble plastisizers for the water-soluble polymer compositions. Some of these ingredients are hygroscopic and retain water in the films. Water itself can be an effective plastisizer, but the concentration will vary depending on the environmental temperature and relative humidity. Similarly, the properties of the film will be affected by the changing storage conditions.

Typical Plastisizers are listed:

- Castor oil, USP
- Propylene glycol, USP
- Glycerin, USP
- Polyethylene glycols, NF, low molecular weight of the 200 and 400 series
- Surfactants

1. Polysorbates NF (Tweens)
2. Sorbitans NF (Spans), water insoluble, but can be used in combination with
3. Tweens, or in very low concentrations.

- Polyoxyl derivatives NF
- Phthalate esters [Diethyl phthalate]
- Acetylated monoglycerides
- Triacetin
- Dibutyl sebacate

The important factors to be considered here are: -

(A) Water solubility of the plastisizer: -
Hydrophobic plastisizer will create problems in solution preparation and can affect the D.T. and dissolution profile of the finished product.

(B) Water vapor transmission rate through the film: -
Higher concentration of plastisizer in the film generally tends to increase the water vapour permeability.

(C) Concentration in the coating formulation: -
Higher concentration of plastisizer reduces the modulus of elasticity (a desire effect) and thus reduces the possibility of logo bridging but also reduces the tensile strength of the film (undesired effect).

(D) Film adhesion: -
Tends to increase with increased concentration of plastisizer

(E) Higher concentration of plastisizer: -
It can lead to its bleeding (making the tablet surface feel oily). In most of cases presence of plastisizer improves the gloss level in the finished product (depending on the quality and concentration of plastisizer).

(F) Volatility of plastisizer: -
Aqueous coating generally needs higher drying capacity during the coating cycle due to Less volatility of water, if the plastisizer is more volatile e.g. propylene glycol, much of the plastisizer may get lost during the coating process.

Therefore, one needs to strike a balance between the desired and undesired effect of the

plastisizer and optimize its concentration in the coating formulation. Many times use of combination of plastisizer becomes necessary to achieve the most optimum results. The different properties like tensile strength, elastic modulus, film adhesion, glass transition temperature are affected when increasing the plastisizer concentrations and the permeability of the film and solution viscosity are also the properties of the film coating which are also affected by the plastisizer concentrations the following table (Table: 2) indicate the film coating property and effects when the concentration increases.

Table 2: Effect of plastisizer on the properties of film coatings

Sr.No.	Property	Effect of increasing plastisizer concentration during the coating
1	Tensile strength	Decreased
2	Elastic modulus	Decreased
3	Film adhesion	May be increased, but results often variable
4	Solution viscosity	Increased, and magnitude of effect dependent on compatibility with polymer
5	Film permeability	Can be increased or decreased, depending on compatibility with polymer
6	Glass-transition temperature	Decreased, but magnitude of effect dependent on compatibility with polymer

Opaquants and colorants: -

Often a distinctive color is desired to give the product a unique identity. The colorant can be either solubilized in the solvent system or suspended as insoluble particles. The addition of these materials provides distinctive color and "pharmaceutical" elegance to the coated tablet. Because the appearance of the product is the only product property a customer can assess, color uniformity and color stability are extremely important. The most brilliant colorants are provided by certified food, Drug and Cosmetic (FD&C) or Drug and cosmetic (D&C) dyes and lakes. These are synthetic colorants. Lakes are prepared from dyes by precipitating the colorant with alumina or talc carriers. Lakes are water-soluble and provide the most reproducible tablet colors. Commercially available lakes generally contain 10 to 30 %dye contents, but some lakes may contain up to 50 %.

Table 3: Colorants and opaquants

Sr.No.	Colorants	Opaquants
1	FD&C dyes	Silicates
2	FD&C lakes	Talc
3	Iron oxides	Aluminum silicate
4	Titanium dioxide	Magnesium carbonate
5	Natural colorants Like: Anthocyanins, Carmine, Annatto, Amaranth, Caramel, Carotenoids, Flavones & Turmeric	Calcium sulfate
6		Magnesium oxide
7		Aluminium hydroxide

Although the lakes are water-insoluble, the dye can be displaced from the carrier through the use of solvent systems that dissolve the dye. Simple time and temperature dependence equilibrium study to evaluate the potential for leaching the dye from the lake should be conducted if color variation is encountered. The inorganic colorant and opaquants

are chemically very stable. However, with the exception of white, they lake color intensity, so only pastel shades are possible with these materials. The nature colorant is for the most part less stable than the FD&C dyes and lakes. The most stable nature colorants are possibly caramel and carmine. Commercial color concentrates and film-coating concentrates are available. They are promoted as providing convenience and less lot-to-lot color variation.

To achieve reproducible colors, the insoluble colorant must be milled, and color matched with a color standard. Because the colorants are per se varying in their tinctorial strength, color matching required. The two commercial materials for aqueous film coating are Opaspray (an opaque color concentrate for film coating) and Opadry (a complete film coating concentrate), available from Colorcon. Food and drug cosmetics dyes and other important colorants and Opaquants are very important in identification. The different colorants and Opaquants are which are used in the aqueous film coating process are described in below (Table: 3), (Encyclopedia of pharmaceutical tech., Vol-1).

The concentration and the properties of each of these excipients can affect the quality of the resulting film, e.g.

- The commonly used colourant in sugar coating are water-soluble dyes. However, the overall color effect of these dyes depend on the dye concentration at a particular point, thickness of film at that point and the residual moisture content in the film at that point. As these parameters can differ from tablet to tablet, the colour difference among various tablets within the same batch may become very visible.
- The opacity of the film depends on the difference between the refractive index of the polymer and other component of the coating formulation. The lake colours used in filmcoating has refractive index similar to that of various polymers, thus the opacity of lake colours are very poor
- The most commonly used anti taking agent is talc, which if used in higher concentration tends to settle down from the coating suspension, thus affecting the composition of suspension during the coating process. Further, it is poor opacifier and tends to produce translucent films.
- As the aqueous film coating need higher drying capacity, the volatile matter in the flavor used may get lost, changing the nature of the flavor. These volatile matters may also interact with other components of the coating formulation and can affect their properties.
- One, therefore, need to use specific flavors and incorporate them in the coating formulation in a manner so that it does not affect the film quality. If, therefore, once again becomes a lot of balancing act while developing the optimized coating formulation. The following table indicates the effect of pigments.

Table 4: Effect of pigments on the properties of film coatings

Sr. No.	Property	Effect of increasing pigment concentration on coating
1	Tensile strength	Decreased
2	Elastic modulus	Increased
3	Film adhesion	little effect
4	Solution viscosity	Increased, but not substantially
5	Film permeability	Decreased, unless critical pigment volume concentration is exceeded
6	Hiding power	Increased, but magnitude of effect dependent on refractive index of pigment

Supplemental coating ingredients: -

Frequently adding other ingredients to a coating composition is necessary to stabilize or improve the product. The ingredients used in a film are generally tasteless, and flavors or sweeteners are added to enhance the esthetic properties of the product or to mask objectionable trace odors or tastes.
Surfactants were previously identified as possible plastisizer; they also serve to solubilize minor ingredients, to reduce the surface tension of the coating composition, and to facilitate faster dissolution of the film. The stability of some coloring system can be significantly improved by the addition of antioxidants such as ascorbic acid or alpha to copherol. Cellulosic coating solution can be particularly prone to microbial growth. Prolonged storage of aqueous-based coating preparations should be avoided, or antimicrobials should be incorporated in the formula. Antimicrobials that are routinely used in pharmaceuticals should be considered, including the parabens, sorbic acid, and benzoates

Typical aqueous-based coating composition includes: -

(A) Simple aqueous-based coating composition:

Hydroxypropyl methylcellulose 2910, 15 cps	6.0%
Propylene glycol	1.2%
Colorant / Opaquant	0.5%
Water q.s.	100.0%

(B) Mixed polymer system:

Hydroxypropyl methylcellulose 2910, 15 cps	5.0%
Hydroxyprppyl cellulose	1.0%
Polyethylene glycol	400 1.0%
Colorant / Opaquant	1.0%
Water q.s.	100.0%

(C) Cellulose acetate phthlate coating system:

Cellulose acetate phthalate pseudolatex (Aquateric, FMC)	10.8%
Triacetin	3.8%
Tween 80	0.1%
Colorant / Opaquant	0.6%
Water q.s.	100.0%

(D) Ethylcellulose coating system:

Aquacoat 30 % solid (Ethyl cellulose pseudolatex, FMC)	27.6%
Hydrooxypropyl methylcellulose, 6 cps.	8.3%

Dibutyl sebacate	1.7%
Tween 80	0.5%
Colorant / Opaquants	6.8 %
Water q.s.	100.0%

These examples show the higher solid loading attainable with aqueous-based polymer suspensions, Coating compositions containing dissolved polymer generally contain less than 10 % solids, whereas the pseudolatices can have over 20 % solids. Only half as much coating composition needs to be applied from polymer suspension system to achieve an equivalent film weight. Counteracting this advantage are the much higher cost of these commercial system and the special process conditions that must be used when the polymer suspension is applied in order to consolidate the polymer particles into a continuous film.

The important features like mechanical properties, permeability characteristics, the viscosity of the coating solution and hiding power, which affect on the aqueous film coating like the visual quality of the coating, barrier properties of the coating and spraying characteristics. These entire important feature are completely described in the below table, in visual quality of coating we can consider the resistance to damage on handling, barrier properties of coating, and drug release characteristic from modified release (Encyclopedia of pharmaceutical tech., Vol-1)

Table 5: Important feature of film coatings

Sr. No.	Feature	Has impact on the aqueous film coating
1	Mechanical properties	Visual quality of coating like : Resistance to damage on handling Barrier properties coating Drug-release characteristic from modified release product Taste masking efficiency
2	Permeability Characteristics	Barrier properties of coating like: Product stability Drug release characteristics from modified release products Taste masking efficiency
3	Coating solution Viscosity	Spraying characteristics like : Interaction with substrate Visual quality of coating
4	Hiding power	Visual quality like: Quantity of coating needed for uniform appearance Stability of photo-labile actives

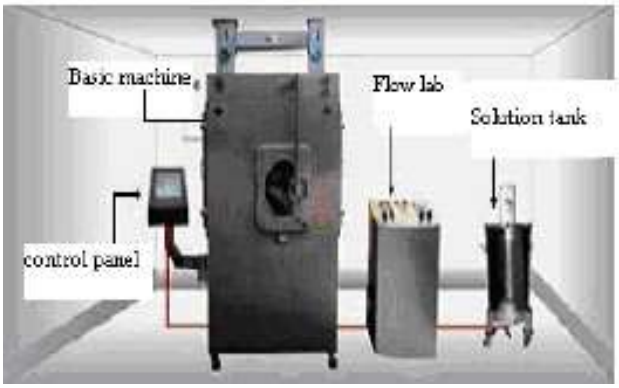
Equipment for Aqueous Film Coating:

Introduction to the coating room: -

Aqueous film coating requires equipment with high airflow and excellent control over

the coating process. Aqueous film coating needs tighter control of the coating process than organic solvent-based coating systems. The tablets are normally designed to disintegrate in water, so the rate of application of the coating composition is critical; too slow or too rapid application of the coating will cause the tablet to undergo excessive erosion and breakage.

View of a typical coating operation:



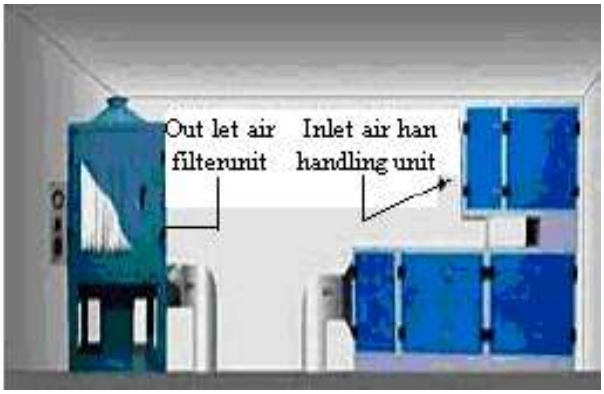


Fig.4: What the operator sees ***Fig.5: What the operator doesn't sees***

(A) What the operator sees:

- Coating Pan
- Suspension vessel
- Pumping System
- Spraying System

(B) What the operator doesn't sees:

- Inlet side of the pan:
- Inlet air turbine
- Inlet air filtration with paper& HEPA filters
- Air treatment packages:
- Air heating system
- Steam, high-pressure hot water, electricity (not recommended)
- Humidification and dehumidification systems
- Outlet side of the pan:
- Solvent recovery system (refrigeration, torch)
- Bag house (or scrubber)
- Outlet air turbine

The entire operation of the above is finally looks according to the below (Fig. 6) and the suspension spraying system is entirely looks like the (Fig. 7).

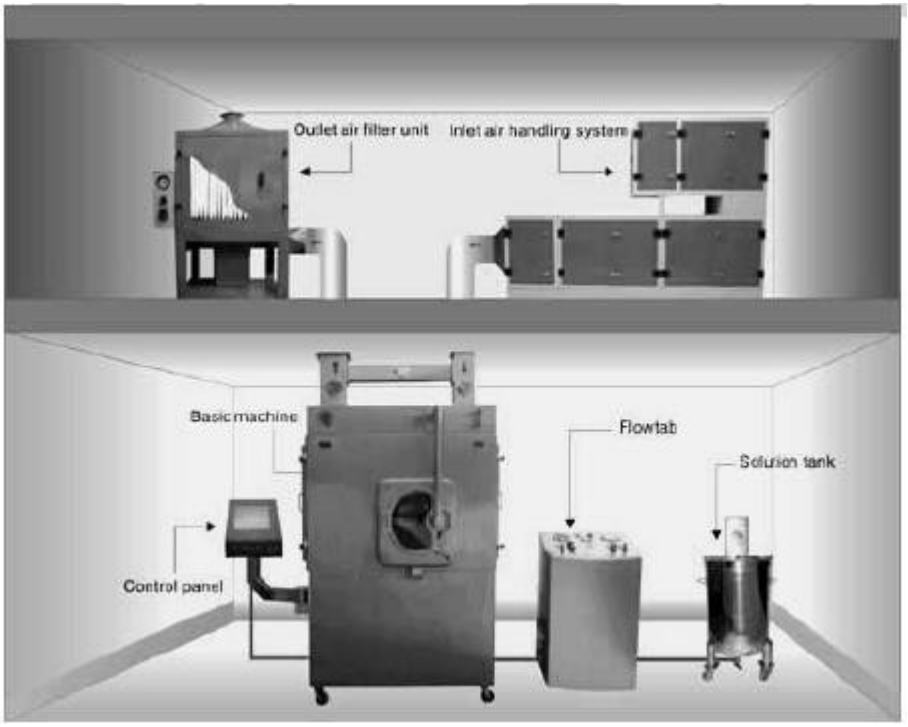


Fig. 6: The entire operation then looks like this

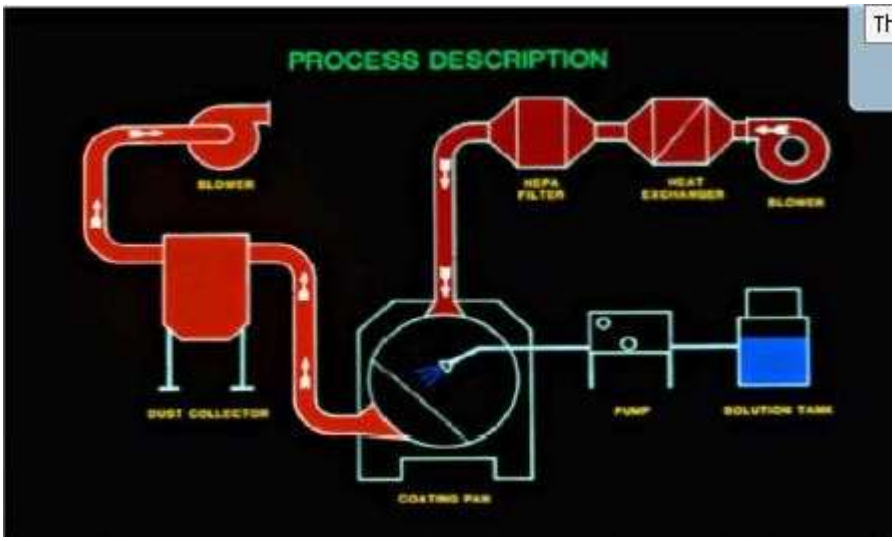


Fig. 7: The entire process also showing the suspension spraying system

The following coating pans can provide adequate airflow and control to be used for aqueous coating: -Two Basic Types of Perforated Coating Pans: Pliva Pharmaceuticals (Poland): The side vented and front-vented coating pan are as follows in which side vented is completely perforate and remaining is partially perforate (Fred A. Rowley, 2005).


Fig.8: Side vented (100%perforated) Fig.9: Front vented (Partially perforated)

E.g. of side vented perforated pan:
- O'Hara
- Accela Cota
- Driacoater
- Others

E.g. of front vented pan:
- Vector
- Freund
- Hi-coater
- Others

Accela Cota: This is an angular pan operating on a horizontal axis. Drying air is directed into the pan, through the tablet bed, and exhausted out the perforations in the periphery of the pan.

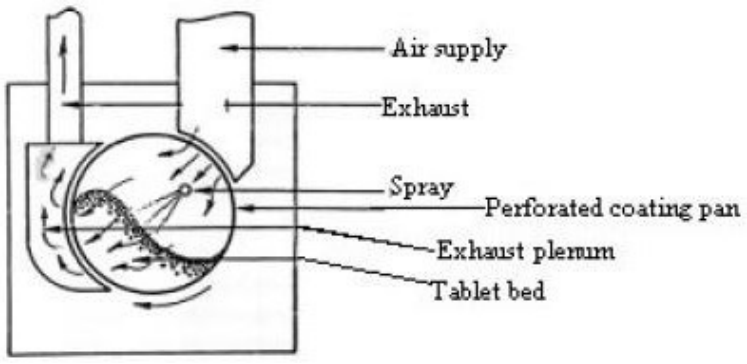


Fig. 10: Accela cota

Hi-Coater: This is similar to Accela Cota, but only a portion of the pan periphery has perforations. Like the Accela Cota, continuous venting of the exhaust air from the pan is still attained The Hi-coater in which Air in let, air outlet, sprayer and pan with perforated ribs all of these indicated in below (Fig. 12).

Driacoater: This introduces drying air through hollow, perforated ribs located on the inside periphery of the pan. As the pan rotates, the ribs pass under the tablet bed, and drying air can

fluidize the tablets. The exhaust air passes out the back of the pan. The following (Fig. 11) indicate the Driacoater.

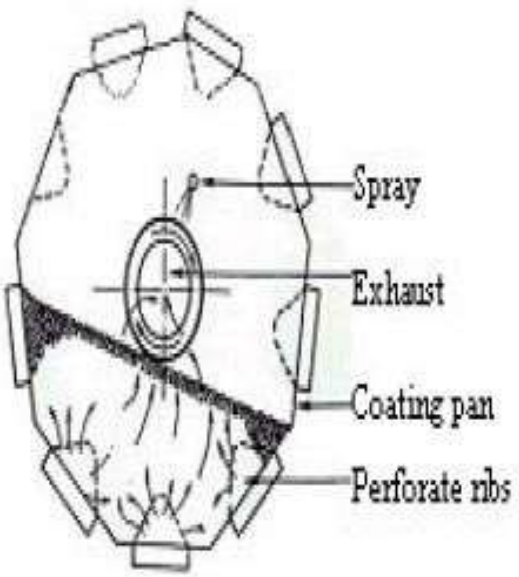


Fig. 11: Driacoater

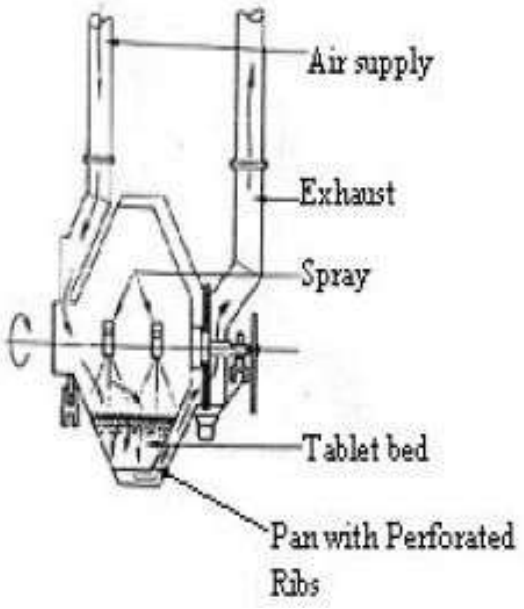


Fig. 12: Hi-Coater

Two techniques to spray coating composition onto tablets. Air spraying is the predominant method of applying an aqueous coating. Atomizing air is used to disperse the liquid coating into small droplets. Through the proper selection of spray heads, a wide range of

application rates and spray droplet size is attainable. In airless or pneumatic spraying, the

coating liquid is forced under high pressure through a small orifice that breaks up the liquid stream into fine droplets. This is a less flexible application system as a minimal pressure is needed to achieve atomization. The requires high-pressure spraying, in contrast to the low-pressure method above

Spray Guns: The coating of tablets in a coating pan involves spraying the coating composition through one or more spray guns onto a rotating bed of tablets. The spray gun is fixed and the tablets pass through the application zone.

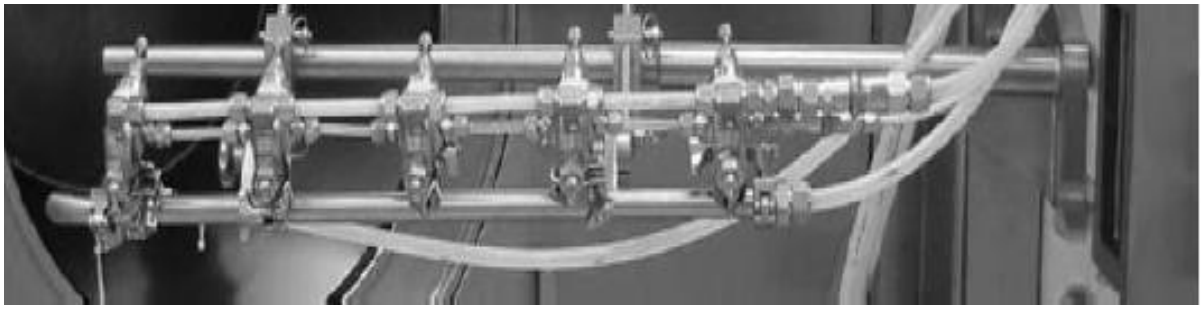


Fig.13: Spray guns

Nomenclature and Process:

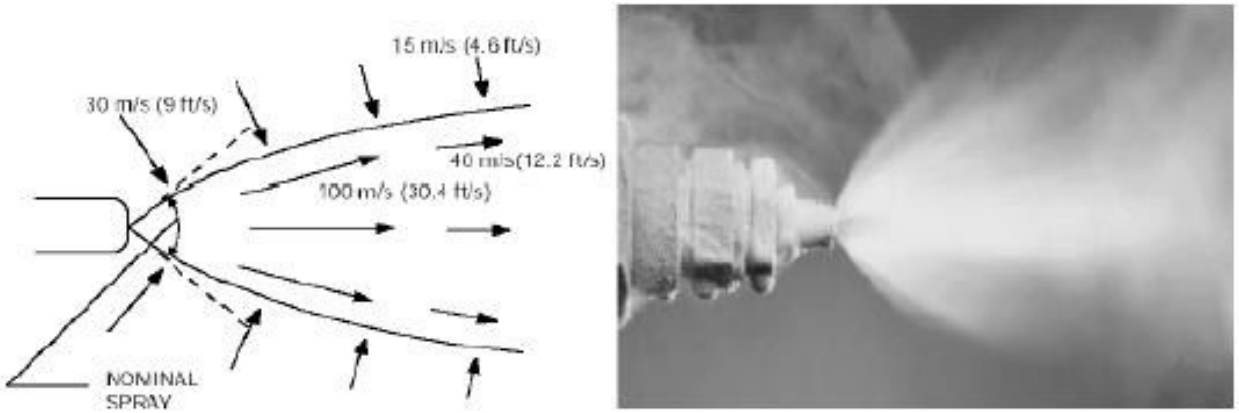


Fig.14: Spray pattern from an aqueous coating system

Outside of the pattern is slower than the inside; his may require some degree of overlapping of spray patterns. Most of the time the tumbling tablets are drying outside the application area. Thus, the coating process consists of the continuous application of coating liquids to a small portion of the tablets in the pan. The applied coating must dry before it touches the coating pan or receives its next application. As the tablets rotate in a pan, A portion of applied coating composition may be physically transferred from the coated tablet to adjacent ones (Fred A. Rowley, 2005).

Gun nomenclature:

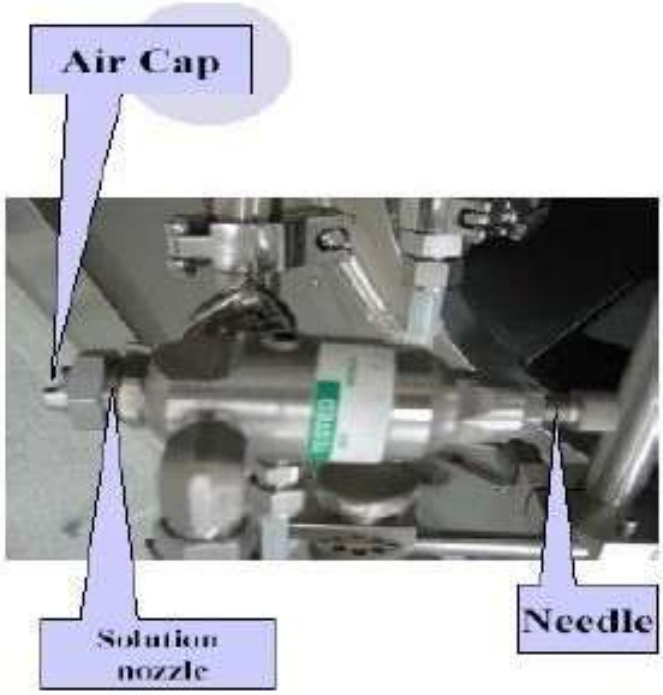


Fig.15: Air cap, solution nozzle and needle of the spray gun for film coating

- Air cap supplies atomizing and pattern air. Solution nozzle supplies coating suspension.
- Needle closes the suspension port. Manual setting adjusts both needle thrust and percent solution port opening.

Note: Air cap/suspension nozzle and needle come in matched sets.

To attain a continuous coating operation, the rate of water evaporation from the coated tablets must equal the rate of water applied in the coating liquid.

The input variable includes temperature and humidity of the drying air, rate of application of the coating liquids, and surface area of the tablets. The exhaust variables include the exhaust air (at a lower temperature due to evaporation of water), the capacity of the exhaust air to carry the evaporated water at that temperature, and the coated tablet surface area from which the water must evaporate. Psychometric charts provide a convenient means to determine the capacity of the exhaust air to carry the evaporated water. The coating composition is also a significant factor in establishing the tablet-coating rate.

Coating composition that is quite tacky during the drying phase must be applied at a slower rate to avoid tablets sticking to the pan surface or other tablets. Reiland and associates have accomplished by Stetsko and associates and Mathematical modeling of the aqueous coating process. These models have formed the basis for the automation of the aqueous coating system. To assess the actual coating efficiency, determine what portion of the applied coating is actually on the surface of the tablets after a particular coating operation. Ideally, 90 to 95 % of the applied film coating should be on the tablet surface.

The quality of the coated tablet can be determined by a series of specific tests:
Adhesion testing with a tensile-strength tester assesses the force require removing the film from the surface of the tablet. Diametral crushing tests are conducted, but this test is more comparison of the result before and after the tablets was coated. Generally, the addition of a

film coating increases the resistance of the tablet to crushing forces. Surface roughness can be measured, but the gloss of the coating is also an indication of the smoothness of the coating. The gloss of the coating improves, as the surface becomes smoother. Tablet disintegration and / or dissolution testing is vital to insure drug release is not adversely affected by the coating. Stability studied must be conducted, as some of the applied water will undoubtedly penetrate the tablet core. Moisture level studies on the coated tablet should be done to correlate with the stability results. Abrasion or hardness tests are special tests to evaluate the ability of the coated tablet to withstand the physical handling that occurs in the packaging of the tablets and when the coated tablets are used by the patients (Encyclopedia of pharmaceutical tech., Vol-1).

Factors Affecting Quality of Film Tablets:

There are many factors that affect the quality of the Film tablets so all the parameters should be considered before the operation going on, for success in the coating operation. There are some factors that affect the quality of the film tablets during the aqueous film coating process. The following tables are describing the full description of the factors, which are responsible for the change in the final coated tablet film after completion of the aqueous film coating process. So to solve the possible problems all the factors should be consider before the aqueous film coating process going on otherwise the final coated formulation create many problems.

Some important factors which affect the quality of the film tablets are:

1. Factor influencing interaction between substrate and coating.
2. Factor influencing the drying process.
3. Factor influencing uniformity of distribution of coating

Factor influencing interaction between substrate and coating: -

There are some factors, which are responsible for the interaction and affect the coating and property of the final coated tablet, granules or any other preparation. The interaction between substrate and coating are influenced by the many factors like tablet core. In this we can consider the sub factors like ingredients, porosity and surface roughness which are influence the wetting by coating liquid adhesion of dry film, adhesion of dry film wetting by coating liquid spreading of coating liquid across surface roughness of coating. Another factor which responsible for these interactions are described in the following table. Tablet core, coating liquid, drying process, and in the tablet core the ingredient of the coating solution, the porosity of the ingredient and surface roughness are to be consider which affect the factors in which are affect the wetting properties, adhesion mechanism and roughness of the coating, while in the coating liquid surface tension of the coating liquid or solution, the viscosity of the coating liquid or solution and the solid content of the coating solution or liquid which, are affect the roughness of the tablet, the coalescence property and the spreading of the coating liquid all are described in the below table (Table:6).

Table 6: Factor influencing interaction between substrate and coating

Sr. No.	Factor	Has influence on the aqueous film coating
1	Tablet core:	
	(1) Ingredient	Wetting by coating liquid adhesion of dry film
	(2) Porosity	Adhesion of dry film
	(3) Surface roughness	Wetting by coating liquid Spreading of coating liquid across surface Roughness of coating
2	Coating liquid:	
	(1) Solids content	Roughness of dry coating

		Coating liquid viscosity
	(2) Viscosity	Spreading of coating liquid across surface of substrate
		Coalescence of droplets of coating liquid into a continuous film
	(3) Surface tension	Wetting of surface substrate by coating liquid
		Spreading of coating liquid across surface of substrate
		Coalescence of droplets of coating liquid into a continuous film
3	Drying process:	
	1.Drying rate	Viscosity of coating liquid at time of contact with surface of substrate structure of dried coating
		Development of internal stress within film (Effect on adhesion and cohesion)
		Mechanical properties of coating

Factor influencing the drying process: -

There are some factors which are described in below table (Table: 7) are affect the drying process during the coating operation e.g. spray equipment, drying condition, spray rate and solid content of the coating liquid are the factors which influence the drying process. In this we consider the design of the nozzle, atomizing air and number of the gun used for the coating process. Inlet and out let airflow systems also play important role in the coating process and humidity is another consideration of the success. In this the drying process is also affected by the solid content of the coating and liquid also the solvent is necessary to remove after completion of the process.

Table 7: Factor influencing the drying process

Sr. No.	Factor	Has influence on
1	Spray equipment:	
	1.Nozzle design	Fineness of atomization of coating liquid (Thus evaporation rate of solvent
	2.Atomizing air	Fineness of atomization of coating liquid
	3.Number of spray guns used	Uniform distribution of coating liquid avoidance of localized over wetting
2	Drying condition:	
	1.Air flow,	Rate at which solvent / vehicle can be
	2.Temperature	Removed from coating liquid.
	3.Humidity	Product temperature
3	Spray rate:	
	1.Nozzle design	Rate at which solvent / vehicle needs to be removed from coating liquid.
	2.Number of spray guns	Product temperature.
	3.Pumping system	
4	Solid content of coating:	
	Liquid	Quantity of solvent / vehicle that must be removed from coating liquid

Factor influencing uniformity of distribution of coating: -

The following table describes the factor, which affect the distribution of coating.

Table 8: Factor influencing uniformity of distribution of coating

Sr. No.	Factor	Has influence on the aqueous film coating process
1	**Spray equipment:**	
	1.Nozzle design	Fineness of atomization of coating liquid area over which coating liquid is applied
	2.Atomizing air	Fineness of atomization of coating liquid
	3.Number of spray guns	Area over which coating liquid is applied length of coating process.
2	**Drying condition:**	
	Airflow, temp. & Humidity	Efficiency of coating process.
3	**Spray rate:**	Length of coating process.
		Amount coating liquid that is deposited on substrate at each pass through spray zone
4	Solid content of coating liquid	Length of coating process smoothness of dried coating
5	Pan speed or Fluidizing air velocity	Uniformity of mixing
		Amount of coating liquid that is deposited on substrate at each pass through spray zone
6	Baffles (in coating Pans)	Uniformity of mixing

Design of an Automation and Measurement System for a Tablet Pan Coater:

Film coating of tablet is a complex and multivariate process and, consequently, a rather sensitive manufacturing technique. Thus the pharmaceutical quality of the final film-coated product is difficult to control, which can influence the reproducibility of the batches.

In the pharmaceutical industry, aqueous-based film coating of the tablet is performed by using either an air-suspension (fluid-bed) coating apparatus or, today more often, by different kind of perforated pan. The side-vented perforated pan coating technique had been designed for rapid and efficient production of aqueous film coated tablets. In a side-vented pan coater the air current passes through a perforated pan to ensure continuous and consistent drying conditions. The constructions of the rotating pan ensure complete mixing of tablet.

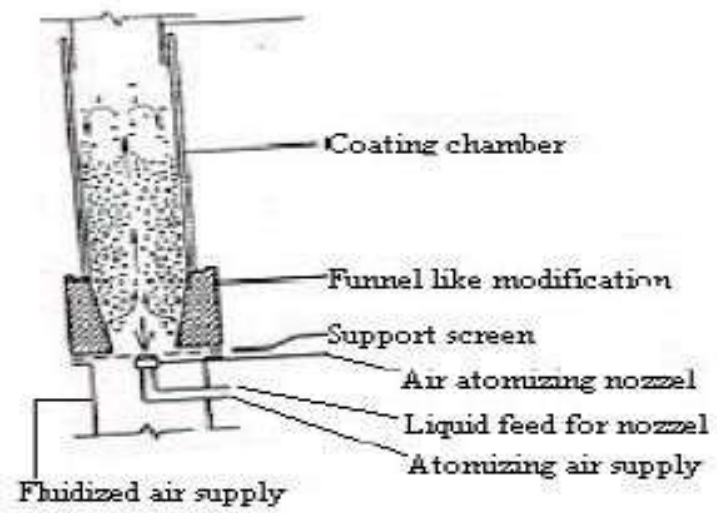


Fig.16: Fluidized bed coater

The aqueous coating liquid is commonly applied by pneumatic (air) spray systems, where the pressure of the spraying air disperses the coating liquid as appropriately sized droplets. The critical aqueous film coating process parameters of the pan coater are generally quite well identified. However, due to lack of effective instrumentation and automation systems, the effect on individual process variables on the coated tablet properties is not very well characterized and understood. So specialized coating equipment, controlled process conditions would be beneficial Instrumentation and automation includes measuring, monitoring and controlling critical process parameters such as properties of process air (temperature, humidity, flow rate), flow rate of coating liquid, spraying air pressure and rotating speed of pan.

With an instrumented & automated coater system, the desired conditions can be reliably maintained constant during coating, thus improving reproducibility & efficiency of the process & ensuring high quality & safety of final product. A critical process parameter monitoring system would provide a useful tool for controlling process & understanding phenomena during process.

Traditionally coating equipment has not been instrumented or automated, bur the demand for automated system has increased in pharmaceutical manufacturing during recent year. Development of computer capacity, supervisory control and data acquisition system enable monitoring & control of the measured coating parameter data is important for further observation and analysis and to meet high requirement for process control documentation of today.

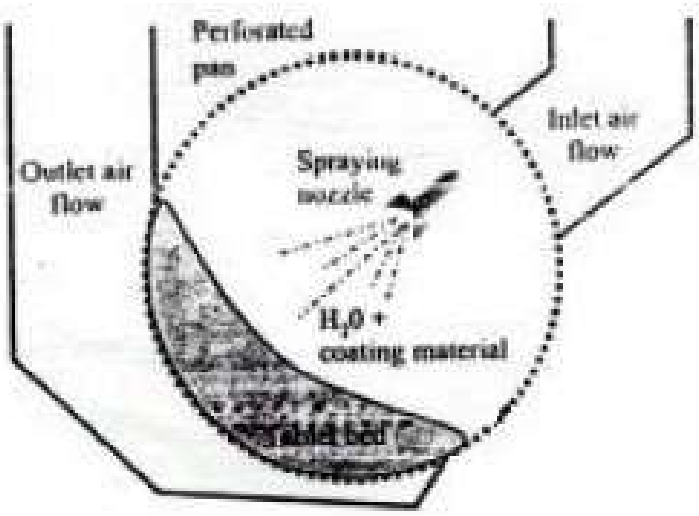


Fig.17: Side vented pan coater.

Production factors: Automation: -

The aqueous film coating process conducted in a modern pharmaceutical facility can be quite different from that done in a developmental laboratory. Because of the size of the equipment and the quantity of the tablets coated per coating pan, the manufacturing process must be as automated as possible so that much closer control of the coating process results. Automated coating system have been developed with appropriate moisture sensors and microprocessor interfaces to adjust and control the coating process, including the preheating of the tablets, controlling the incoming air, monitoring the spray rate, changing the coating compositions, if needed & linking the exhaust air temperature to the input component through appropriate microprocessors. An operator is relieved of need to monitor coating operation.

Process Parameters:

Many quality aspects of the final coated product are greatly influenced by the combined effect of process parameter values used in aqueous film coating. Coating process parameter affects the spreading, penetration and drying (i.e. evaporation of water) of the coating liquid on the tablet surface and subsequently, the surface roughness and the residual moisture of the coated tablets (Obara, 1995; Twitchell, 1995b). There are number of the process parameters which taken in to consideration for getting success in the final coated formulations during the aqueous film coating process

Some of the important process parameters in the coating process are as follows:

(1) Airflow rate.
(2) Absolute humidity of inlet air.
(3) Spraying air pressure.
(4) Flow rate of coating solution.
(5) Pan air temperature.
(6) Rotating speed of the pan.
(7) Inlet and Outlet Temperatures.
(8) Geometry of the spray guns.
(9) Adhesion of Particles to the Spray Guns.

Air flow rate: -

Although process air is an essential element in the manufacture of pharmaceutics, earlier studies of pan coater have not put much emphasis on the effects of airflow rate on the coating process. The flow rate of perforated pan coater, the airflow is reported to affect the drying efficiency of the coating unit and, the quality of the coated tablets (Cole1983). An increase of the inlet airflow rate causes a linear increase in the tablet bed temperature, increasing the evaporative capacity of the coating unit and eliminating over wetting problems of tablets. However, it does not find the inlet airflow to affect the content uniformity of the coating composition or coating efficiency. So the air flow rate is very important which affect the coating because there are two inlet and out let air therefore it is necessary to maintain the proper flow of the both inlet and outlet air throughout the coating process.

Absolute humidity of inlet air: -

The Absolute humidity of the coating process air is effect on the properties of the film coated tablet. It is obvious that the humidity of the coating process air is an important factor affecting the penetration and evaporation of water on the tablet surface. The water removal efficiency of the coating process is linearly correlated with the residual moisture content, tensile strength and porosity of the coated core tablet (Poukavoos, 1994).

Spraying air pressure: -

The spraying air pressure disperses the coating liquid into droplets and affects the droplet size distribution and the droplet spreading and penetration on the tablet surface. For the formation of an adequate and adhesive film coat, the atomized droplets have to spread completely over the surface of the tablet and only limitedly penetrate into the tablet core. Increasing the spraying air pressure to form smaller droplets and to increase the droplet velocity and momentum increases the extent of droplet spreading and therefore the rate of droplet drying and could thus reduce the degree of solution penetration into the substrate (Juslin, 1995; Khan, 2001; Twitcchell, 1995a).

In general, increasing the spraying air pressure decreases the surface roughness of coated tablets and produces denser and thinner film (Tobiska, 2003; Twitcchell, 1995a; Wilson, 1997). If spraying air pressure is excessive, the spray loss is great; the formed droplets are very

fine and could spray-dry before reaching the tablet bed, resulting in inadequate droplet spreading and coalescence (Tobiska, 2003).

If spraying air pressure is insufficient, the film thickness and thickness variation are greater possibly due to change in the film density and smaller spray loss. In addition, with low spraying air pressure big droplets could locally overwet the tablet surface and cause tablets to stick to each other. Wetting effect of spraying air pressure were found to have a minor effect on the adhesion of HPMC-film to the core tablet (Khan, 2001), because the interaction between film additives and tablet surface will become important only as the film coating dries. In the coating process the perforated pan in which there are spray nozzle is there which is responsible for supplying the coating solution which containing the water and other coating material so it is necessary to maintain the pressure of the spraying air.

Flow rate of coating solution: -

During a successful aqueous film coating process, the flow rate of the coating liquid is equal to the rate of water evaporation from the coated tablet's surface. Increasing the flow rate allows a greater number of droplets to be sprayed onto the tablet bed per time unit and increases the droplet size (Juslin, 1995). The flow rate is an important parameter since it impacts the moisture contents of the formed coating and, subsequently, the quality and uniformity of the film (Franz1983; Obara, 1995).

A low coating liquid flow rate causes incomplete coalescence of polymer due to insufficient wetting, which could result in brittle film (Obara, 1995). A high coating liquid flow rate may result in over wetting of the tablet surface and subsequent problems such as picking and sticking (Franz1983). If the flow rate is high and the tablet surface temperature is low, films are not formed during the spraying but the post drying phase, and rapid drying often produces cracks in the films (Obara, 1995).

Pan air temperature: -

It is an important that the Pan air temperature is monitored, because the spray tablet core interface is where problems manifest during aqueous film coating. The spray rate of coating solution, inlet airflow rate and inlet air temperature have significant effect on tablet bed surface temperature, whereas spraying air pressure and pan speed do not (Franz1983). During the coating process, the initiation of the spraying causes a rapid drop in the pan air temperature until equilibrium is attained. The pan air temperature affects the drying efficiency (i.e. water evaporation) of the coating pan and the uniformity of coating.

High inlet air temperature increases the drying efficiency of the aqueous film coating process and a decrease in the water penetration into the tablet core decrease the core tablet porosity, tensile strength and residual moisture content of coated tablet (Poukavoos, 1994, 1993a). Excessive air temperature increases the premature drying of the spray during application and, subsequently decreases the coating efficiency (Rege, 2002). Measuring the pan air temperature helps to control the optimum conditions during coating process, consequently, enables predicting possible drying or over wetting problems which may result in poor appearance of film or may have detrimental effects on the moisture & heat-sensitive tablet cores.

Rotating speed of the pan: -

It is well recognized that increasing the rotating speed of the pan improves the mixing of tablets. The pan speed affects the time the tablet spend on the spraying zone and the homogeneous distribution the coating solution on the surface of each tablet throughout the batch. Increasing the pan speed decreases the thickness variation and improves the uniformity of coatings (Tobiska, 2001). Too rapid a rotating speed of the pan will cause the tablet to undergo excessive attrition and breakage.

Fig.18: Anti-slide bars and pan baffles

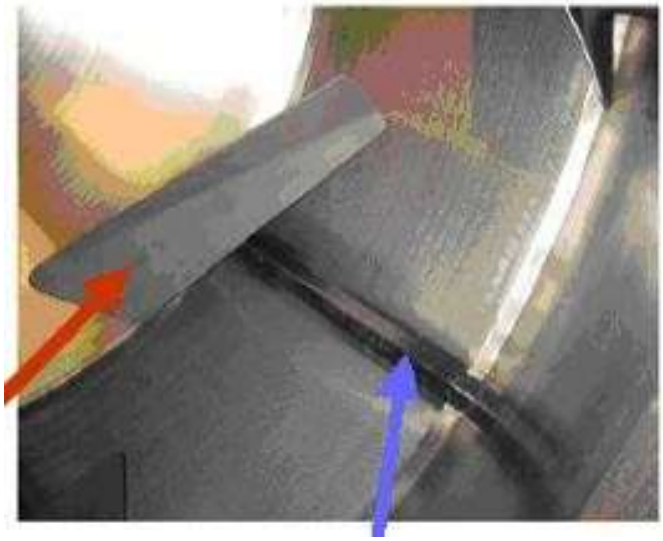


Fig.19: Anti-slide bars and baffles

A Frequently Overlooked Optimization opportunity for success.

- There is no single specific setting. This is a relative setting based on tablet size, shape and load.
- Experience and observation are the initial basis of good science.
- Two basic pan speeds for each product:

1) **Initial speed** to achieve a basic covering and then
2) **Steady state speed**.

(A) Anti-slide bars (Blue):

- Used to center the tablet bed in front of the outlet air plenum
- Not a mixing device.
- Almost mandatory

(B) Baffles (Red):

- Mixing device.
- More than one kind.

Inlet and outlet temperatures: -

- An alert organization keys on an ***outlet***air temperature target and let the inlet *vary within a range*.
- Outlet air target is usually between 45and 55 0C.
- Important Distinction!
- Inlet air temperature is a set point, whereas outlet air temperature is a function

1. Inlet air CFM + Inlet air Temp + Spray Rate+ Atomizing air = Outlet Temp.
2. Inlet temp is a set point, outlet temp is a function
3. Monitoring outlet air temperature helps us determine if any of the other factors have changed or shifted.

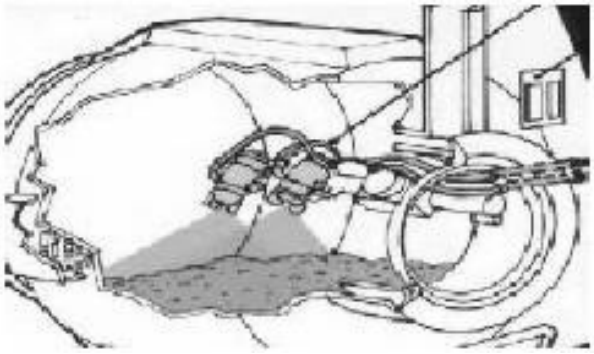


Fig.20: Inlet/outlet air temperature

Geometry of the spray guns: -

- Most common settings for aqueous coating are 8" or 10"from the bed, depending on the spray rate used.
- Always fixed, never use a range. Well understood and reported in the literature.
- Usually stated as a specification on the work seat.

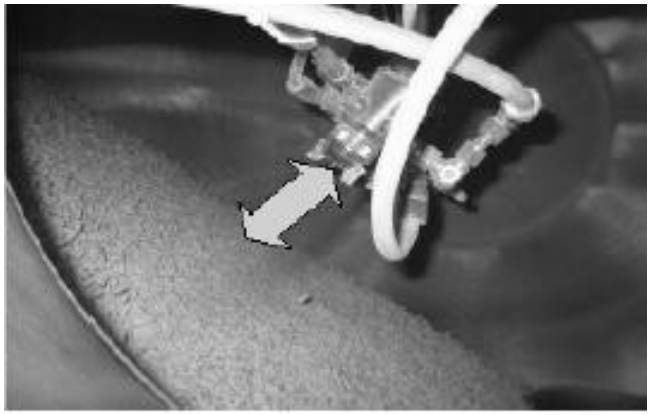


Fig.21: Gun to bed distance

- Widely accepted/assumed to be *fixed*…but this is false
- Not recognized as a variable in the literature.
- Usually not stated as a specification or set point on a worksheet. Setting is 5.5" or 6.0" gun tip to gun tip between guns.

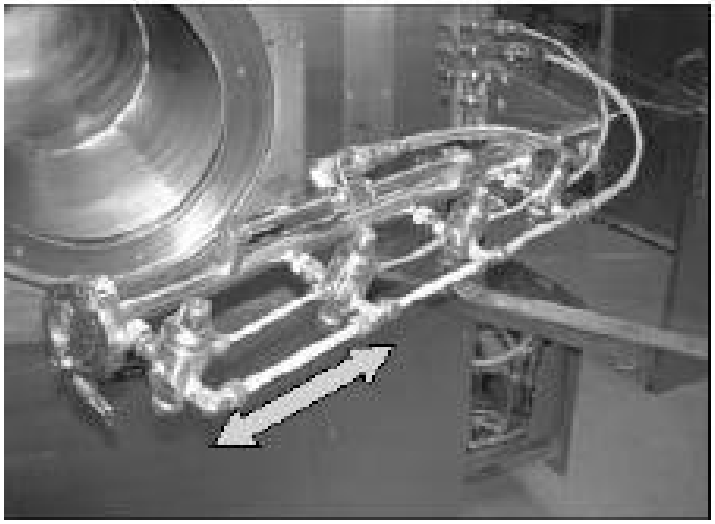


Fig.22: Gun-to-gun distance

Adhesion of particles to the spray guns: -

- One of critical parameters for success. Serious problem when left unattended.
- Solution: Leave atomizing air on, then:
- Stop spraying, Brush residue off
- Resume coating.
- So when we solve this problem we should follow the above points.

Fig.23: Adhesion of coating material to gun Fi

- Use a brush to remove the dry particle and use flashlight and pause if necessary and optimize the process in proper way.

Fig. 24: Flash light in the coating pan.

- Stop spraying.
- Keep atomizing air on.
- Brush the guns & assembly.
- Resume spraying & use a flashlight.
- Look for problems.
  So to stop the deficiency in the final coating periodically check is done during process.

Adhesion of Coating Polymer:

For aqueous film coating to be successful, the film must adhere satisfactorily to the tablet surface. When a polymeric solution is applied to tablet surface, an internal stress inevitably develops within the film coating. To understand the adhesion of coating polymer the following equation is helpful to us and it is necessary to consider before the process for our success.

The total internal stress within the film influenced by:

- The effect of the coating conditions on the shrinkage of the film due to evaporation of water
- Difference in the thermal expansion of the film and the tablet core
- Volumetric changes due to tablet core or polymer swelling during coating or storage

$$P = \frac{E}{3(1-v)}\left(\frac{\phi s - \phi r}{1-\phi r} + \Delta\alpha\,\Delta T + \frac{\Delta V}{V}\right) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where,

- P is the total internal stress in the film.
- E is the elastic modulus of the film.
- V is the polymer's Poisson ratio.
- Φs is the volume fraction of the solvent at the solidification point of the film.
- Φr is the volume fraction of the solvent remaining in the dry film at ambient conditions.

- $\Delta\alpha$ is the difference between the cubical coefficient of thermal expansion of the film coat and substrate.
- ΔT is the difference between the glass transition temperature of the polymer and the temperature of the film during manufacture and storage.
- ΔV is the volumetric change of the film tablet core.
- V is an original volume of the tablet core

Adhesion is influenced by the strength of interfacial bonds between the polymeric film and the surface of tablets and the internal stresses (Eq -1) with in the film coating (Felton, 1997). Poor adhesion may result in peeling of the coating from the tablet surface, which could significantly reduce the film functionality. Loss of adhesion may compromise the mechanical protection that the film coating provides to the tablet and may lead to an accumulation of the moisture at the film-tablet interface, affecting the stability of the moisture-labile drug (Felton, 1996; Fisher, 1976; Lehtola, 1995a; Lehtola, 1995b; Okhamafe, 1989; Skultely, 1988).

Several researchers have investigated variables such as composition of the tablet core, compression force of the tablet, i.e. surface roughness, coating formulation, coating condition and ageing, which influence the adhesion. In addition, changes in the tablet core will influence the internal stresses (Eq-1) with in the film of the final coated tablets, and may ultimately affect polymer adhesion (Nadkarni, 1975; Okutgen, 1995). However, the significance of dimensional changes occurring in the tablet core after coating and its effects on the film adhesion is not understood well enough.

Moisture Interaction with Core Tablet and Coating during Coating and Storage:

In aqueous film coating, tablets core may greatly interact with moisture during the spraying and drying phase of the film coating process and subsequent storage. Penetration of water into the outer layers of the tablet surface is inevitable. Although new approaches, such as the use of coating equipment with increased drying efficiency and optimized processes, have tended to increase the stability of sensitive tablet cores, answers to the moisture penetration from the applied coating solution into the tablet core remain speculative.

During coating, water penetration into the tablet core depends on a complex set of interacting factors related to the coating conditions, the formulation of the coating liquid (i.e. viscosity) and the tablet core, including pore structure and surface roughness. Moisture is very critical parameter because it affect the coated formulation so it necessary to maintain the product in proper environmental condition

Effect of moisture on the physical properties of tablets: -

In the aqueous film-coating process, tablets are exposed to wide temperature and humidity variations that may promote significance changes in the tablets. Water penetration into a tablet core directly linked to the hydrophilic nature of the excipients present in the tablet formulation. During aqueous film coating under normal coating conditions water penetrate from the film coating solution into tablets containing disintegrate and microcrystalline cellulose, and the penetration is not restricted to the tablet surface. The physical properties of the tablet like it smoothness and the uniformity of the color and its appearance is affected by the moisture so it should be controlled properly.

The penetration of the water promotes the hydration of the disintegrates, widening the pore structure of the coated core tablets and causing the tablet to swell and expand (Rowe, 1977). The penetration of the water during coating may result in significant changes in other

physical properties of coated tablets, such as residual water content, glass transition temperature and tensile strength. Residual water has significant effect on a variety of physical and chemical properties, such as chemical stability of solids, crystal structure, and polymer film permeability and dissolution (Ahlneck, 1988).

Effect of moisture on the chemical stability of a moisture-labile drug: -

Water in the tablet core increases the risk of undesirable degradation of a moisture-labile drug. However, very little is known about the effect of the aqueous film coating process on the activity and stability of moisture-labile drug. The degradation rate of acetylsalicylic acid (ASA) during storage at elevated conditions may be directly associated with the influence of formulation excipients due to their water adsorption characteristic.

Hydroscopic excipients may also enhance drug stability by binding moisture during manufacture or storage. The rate of ASA degradation is a slow process and accelerates with time. By controlling the coating conditions and selecting the excipients that is most resistant to moisture interaction it is possible to reduce the amount of adsorbed water and the degradation of a moisture-labile (Cunningham, 2001: Heidemann, J.D., Jarosz, P.J., 1991).

Effect of moisture on dimensional changes and coating structure: -

Moisture is also affecting the dimensional changes so it is necessary to consider during the coating. During a simulated coating process the nature of tablet excipients causes either contraction or expansion of the tablet. Exposure to different temperature and relative humilities were found to influence the magnitude and rate of these changes in tablets, due to water adsorption and evaporation. The most significant and important dimensional changes of tablet occur at the completion of the coating process and few hours later. Dimensional changes occurring in the tablet core create high internal stresses (Eq-1) within the film coat which consequently may cause major defects such as cracking or peeling of the film coat and may affect the film adhesion (Rowe, 1983).

However, there is insufficient understanding of the significance of tablet composition and compression force on the dimensional changes of coated tablets and their effect in the film adhesion. During storage at elevated humidity, adverse changes in the film structure have been reported to result from adsorbed water plasticizig the polymer and inducing increased polymer chain mobility, deformation, elasticity and flexibility. The swelling of the film and tablet core, as water penetrates during storage, cause the formation of new stresses within the film coating and weakens the film-core interface and results in a decrease of adhesion. The strength of the coated tablet decreases due to adsorbed moisture from the environment (Felton, 1997).

Characterization of Aqueous Film Coated Tablets:

Surface roughness and morphology: -

A rough coated tablet surface can be caused by almost any mistake in the coating process. If the drying rate is too fast and the spray droplets dry before they reach the tablet surface, the droplets do not have an opportunity to spreads adequately on the tablet surface. The spray-dried particles collect on the surface to yield a rough finish. Applying the coating composition at faster rate, reducing the incoming air temperature, or a moving the nozzles closer to the tablet bed all show the rate of drying and improve the coating smoothness. The roughness of tablet surface has been traditionally determined using a contacting stylus instrument that scans a line from which the roughness parameters are calculated (Nadkarni, 1975; Rowe, 1978a; Rowe, 1978b). A light section microscope was used to measure the roughness parameter (Twitchell, 1995b).

Non-contacting laser profilometry has been previously used to provide very accurate determination of the roughness parameters of the tablet. In this method, a line or an area of the tablet surf ace is evaluated to obtain a three-dimensional surface profile. During measurement the surface remains undamaged because the technique is non-contacting and repeat measurement can be made on the same surface. The surface roughness measurement of coated tablets is of great importance in the development of an optimal coating. The roughness parameters enable comparison of numerical values of the tablet surface, which are relevant and valuable for tablet surface texture and structure characterization. The roughness parameters are well standardizes and they have been used for a long time (Cielo, 1987). The most widely used parameter of surface roughness is the arithmetic average of the absolute values of all points of the profile (Ra):

$$Ra = \frac{1}{N} \sum_{i=1}^{n} |\gamma i|$$

Where,
Ra is the roughness average.
N is the number of measurement points.
$\gamma i1$ is the i point

The other surface roughness parameters used are the mean square of all values of all points of the profile (Rq), the maximum distance between the highest point and the mean line of the profile (Rp), the maximum distance between the highest and the lowest mean line of the profile (Rt) and the arithmetic average of the five highest profile points and five lowest profile valleys (Rz).

Scanning electron microscope (SEM) is a commonly used technique to examine the surface morphology of tablets and to visually support qualitative and quantitative results. Atomic force microscopy (AFM) is used to observe the surface topography and morphology of coating dispersions, and to measure film roughness, polymer particle deformation and the degree of coating flattening during film formation. Also environmental SEM (ESEM), cryogenic scanning electron microscopy and small-angle neutron scattering (SANS) have been used to study the polymer particle deformation mechanisms during film formation.

Film-core interactions: -

Coating liquid and core tablet interactions, such as droplet spreading, wetting and penetration tendencies, are commonly characterizes by contact angle. The contact angle is the angle of a tangent drawn along the edge of the drop from the point where solid, liquid and vapor contact. These tests provide fundamental information about film-core interactions (processing conditions aside), but do not reflect what may occur in practice when droplets of coating formulation impinge on a surface during the coating process.

Therefore, it would be important to clarity the behavior of the coating liquid at the filmcore interface during coating and find techniques for acquiring exact information of coating liquid penetration into the tablet core. Confocal laser scanning microscopy (CLSM) has been previously used to investigate the deformation of particles during compression, the drug permeability and release mechanisms with in controlled-release and enteric-coated pellets (Cutts, 1996). CLSM is a non-invasive technique producing high-resolution 2-D images, but also 3-D visualization of the surface or internal structure of the samples. In the characterization of the aqueous film coated tablet the film and core interactions is one of the important aspect to develop the good formulation, in this the coating liquid is directly contact

to the tablet surface so it is the important to maintain the proper flow of the coating solution, its composition and the spray rate.

Dimensional changes: -

A free-armature transducer rig measured dimensional changes of tablets, with the tablet placed underneath the rig. This method measures by contact and there is a risk that the surface of the tablet is damaged during the determination. As previously (Surface roughness and morphology), a non-contacting laser profilometer has used the surface roughness study of tablets, leaving the samples undamaged.

Adhesion: -

Adhesion measurements are useful during preformulation studies of film-coated tablets, as they provide information on the relationship of the polymeric coating formulation and composition of the tablet core to the strength of the film-core interfacial bond. Adhesion could be measured by several adhesion testing methods, for example with tensile strength tester, with a Lloyd LRX materials testing machine and with a chatillon digital force gauge. This method determines the force require to remove the entire film from the surface of the tablet.

Aqueous Film Coating Defects:

There are numbers of the limitations in aqueous film coating process if wrong selection of the coating composition and process parameters are selected so before process of the coating is going on the possible quality defects should be minimized by proper selection.

The following are the list of the aqueous film coating defects:

(1) Surface roughness
(2) Morphological defects
(3) Picking
(4) Color Variations:
(5) Bridging of the Logo
(6) Film peeling:
(7) Twins or Twinning:
(8) Logo Erosion

Surface roughness: - It is one the coating defects the problem and causes of these are as follows.

Problem: Spray drying of membrane.
Causes:

- Not enough vehicles.
- High atomizing air
- High CFM/inlet temp

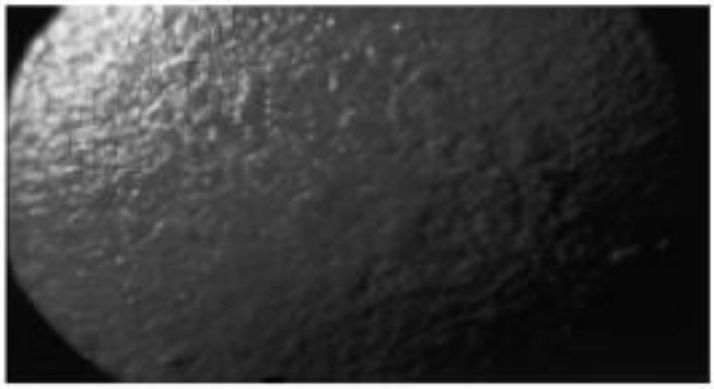


Fig.25: Rough/orange peel appearance

A rough coated tablet surface can be caused by almost any mistake in the coating process. If drying rate is too fast & spray droplets dry before they reach the tablet surface, droplets do not have an opportunity to spreads adequately on the tablet surface.

The spray-dried particles collect on the surface to yield a rough finish. Applying the coating composition at faster rate, reducing the incoming air temperature, or a moving the nozzles closer to the tablet bed all show the rate of drying and improve the coating smoothness. Orange peel appearance is a specific type of surface roughness, where the surface is bumpy like an orange. The drying of the coating composition causes it before it has adequately spread on the tablet surface. Slowing the drying rate, or reducing the viscosity of the coating composition by simply adding more water, can correct the situation in the film coating (Encyclopedia of pharmaceutical tech., Vol-1)

Morphological defects: -

For aqueous film coating to be successful, the film must be smooth and uniform. When the main function of the film coating is to control the drug release from the tablet and to protect the drug from moisture ingress or light degradation, uniformity of the coating is of primary importance. In addition, the appearance of the coating is very important to customers who usually identify and evaluate the tablet according to the coating quality. The coating liquid application conditions, like atomization and drying, roughness of core tablet and the properties of the coating formulation can affect the coating morphology and surface roughness (Aulton, 1995).

Smoother coating could be produced by increasing the spraying air pressure, decreasing the spray rate of the coating solution, decreasing the distance of the spray gun from tablet bed, or reducing the concentration of HPMC (i.e. viscosity) in the coating solution. If coating spray droplets dry prematurely due to too effective drying conditions or excessive atomization, the droplets subsequently become too viscous to spread on the tablet surface and coalescence of coating polymers shows and could penetrate into the core, resulting in a rough coating.

Over wetting and water penetration into the tablet core during the coating could affect the water-soluble components of the tablet core migrating to the film coating. The flow rate of the coating liquid and inlet air temperature (i.e. the rate of water evaporation) during the coating process affect the migration, whereas atomization air pressure does not. Therefore, by controlling the process conditions it is possible to control the core components' migration into the film coating. The migration of a tablet core component into the film coating could, for example, alter its adhesion properties and seriously interfere with the film formation mechanism, making the film less continuous and porous and increasing the drug release rate

of coated tablets.

In addition, over wetting of the tablet bed during the coating process may cause picking and sticking of tablets, which greatly affects the surface morphology (Obara, 1995). High internal stress (Eq-1) with in the film coating may cause many coating defects such as cracking, peeling, bridging and edge chipping. Shrinkage of the coating due to evaporation of water or different expansion characteristics of the core and coating cause stresses in the coating and may result in cracking of coatings. Also too rapid drying often produces cracks in the film. In addition, excessive amount of pigment in coating can promote crack initiation, which can lead to crack propagation.

The addition of plasticizer, use of higher molecular weight polymer and larger particle size pigment were found to alleviate the problems of cracking. Edge chipping or erosion of tablet can be caused by excessive rotating speed of the pan, low tablet hardness, low spray rate of the coating solution and low mechanical strength of the coating. These defects can be avoided by reducing the internal stresses in coating by decreasing the pan speed, improving the mechanical strength of the core by increasing the compression force, increasing the spray rate and polymer content of the coating liquid and improving the plasticizing characteristics of the coating liquid.

Picking: **-**The possible causes and the problems of this aqueous film-coating defect are as follows.

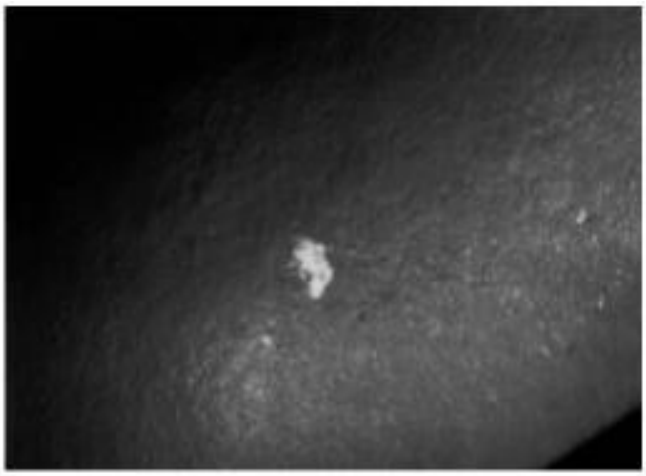


Fig.26: Tablet picking.

Problem: Tablets are too wet.
Possible Causes:

- Spray rate too high
- Guns too close together
- Insufficient atomizing air
- Pan speed too

The application of a coating composition at a rate that is a faster than the water can evaporate results in overwets tablets. Under these conditions the tablets adhere to the coating pan, as the pan surface or another tablet.

The loss of the small pieces of the film from the surface of the tablets gives the tablet its “picked” appearance, as small areas of the controlling the application rate and increasing the drying air temperature. Some polymers are quite tacky when their coating composition is drying. Using a mixture of polymers and the incorporation of the plastisizers or other film modifiers would improve the situation (Encyclopedia of pharmaceutical tech., Vol-1).

Color variations: -

Coating compositions usually contain suspended colorants or opaquants. If the coating composition is not kept agitated during the coating operation, the insoluble ingredient is settling. The initial coating is then different from subsequent coarings. This results in a color variation between coating runs. Color mottling occurs if soluble dyes, plastisizer, or other soluble ingredients are present and separate during the drying process.

If the plastisizer collect on the surface of the coating, it can be called a ***bloom***. This is a dulling of the coating due to the diffusion of some of the coating ingredient to the surface. Exposure of coated tablets to excessive temperature can also lead to blooming. Removal of the excess plastisizer or incompatible coaring ingredient is needed to correct it (Encyclopedia of pharmaceutical tech., Vol-1).

Bridging of the logo: -

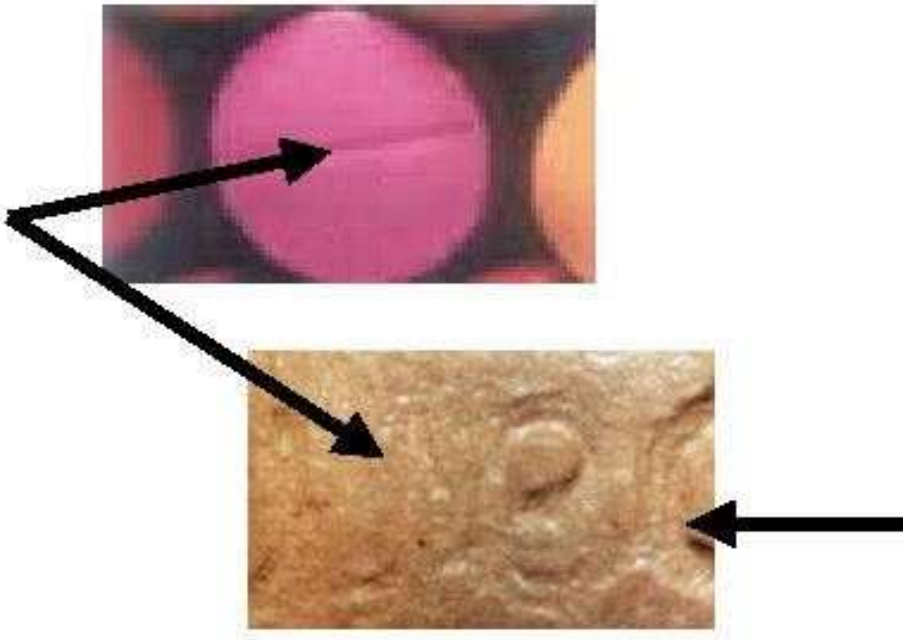


Fig.27: Bridging of the logo

It is one of the important quality defects, which are shown in the final coating the problem, and the causes of the bridging of the logo, by solving the causes that are responsible for problem we can correct the defects.

Problem: The letters and numbers fill in with dried suspension.
Causes:

- High spray rate coupled with high CFM (drying capacity).
- Inadequate atomizing air
- Poor tooling design

The ability to apply a coating to irregularly shaped tablets, occasionally; the surface detail disappears after the coating is applied The coating appears to have filled in the indentations on the tablet surfaces; however, close inspection of the coating shows the coating has “bridged” the surface depressions. This is primarily a formulation deficiency in which the polymer has stronger internal bonding than its bonding to the tablet. This is plastisizer or opaquants reduces the film strength and the tendency to bridge during the coating (Encyclopedia of pharmaceutical tech., Vol-1).

Film peeling: -

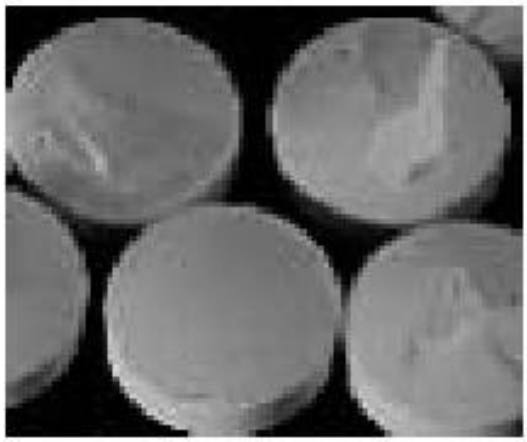


Fig.28: Film peeling

It is one of the serious critical defects, which is shown during the coating process.

Problem: - Tablets are baking and the coating ruptures
Causes:

- Very high spray rate,
- Low CFM
- Tacky coating material
- Lack of adhesion (nothing to stick to, the tablet is too hard)

Twins or twinning: -

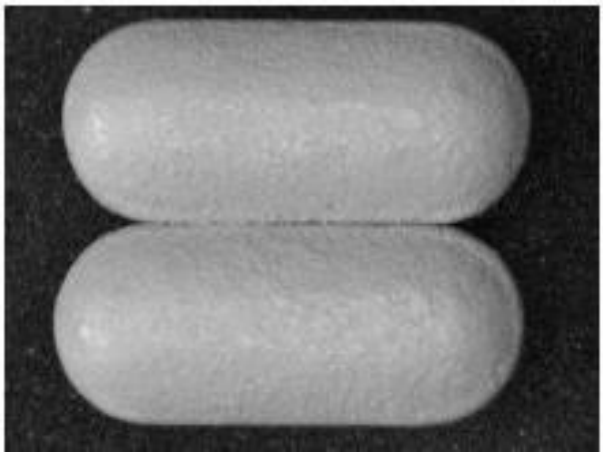


Fig. 29: Twings or twinning

It is one of the aqueous film coating defects

Problem: Tablets stick together
Causes:

- High spray rate,
- Inadequate-drying capacity
- Tablet shape/design,
- Bellyband too thick
- Tablet too long,
- One or more factors

***Logo erosion:* -** The possible problem and the causes of the aqueous film coating defect ofthese are as follows.

Fig.30: Erosion of the logo on the tablet

Problem: Tablet erodes before coating can adhere to the surface.
Causes:

- Spray rate too slow & Pan speed too fast
- Both, Soft tablets/combined with items shown above

***Cracking:* -**

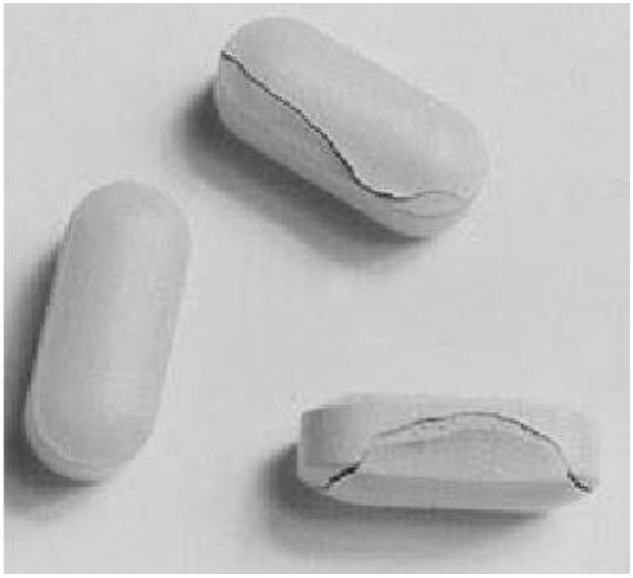


Fig. 31: Film cracking

Rather rare defect, Not seen often Happens when solution evaporates or is mixed too thick. This may be the most common film-coating flaw, and it may not be detected until several hours after the coating operation, when drying is completed and the tablets have cooled. This is a coating composition deficiency and indicates the film.

Stability issues: Physical changes in tablet appearance: -

Fig.32: Physical change in tablet appearance

Problem: Off color with (maybe) off odor tablets.
Causes:

- Microbial contamination
- Moisture sensitivity.
- Heat sensitivity & Film to tablet
- Incompatibility & Excipients to API.
- Both factors combine

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