Surface characterisation of paper and printability

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ABSTRACT

Experience of various problems by the Printer and Convertors necessitated study to analyse the characteristics of paper and paper board in relation to different process of printing and binding operations involved. Usage of raw materials, such as, paper and ink need to strike a balance between these two to achieve required results in terms of availability of these. Such a study becomes obvious to analyse physical, structural, mechanical and chemical properties to pin-point the various characteristics affecting "Printability" and "Print Quality". A detailed study of manufacture of paper is not very much relevant to our study but necessary to look into raw material and additives used in the process of paper making, which in turn governs various surface and structural properties of paper. The criteria is to manufacture the paper of specific grade with requisite properties for the end use and within economical cost level.

The detail and analytical study of characteristics of paper required to study in relation of various properties their effect in printing operation. Testing methods are available to establish the optimum result of all its properties by producers for specific usage. The well controlled properties of paper affects the "Printability" to achieve the desired "Print Quality". A reference on this area is made in the Annual TAPPI, Graphic Arts Conference held in 1969.

INTRODUCTION

"Paper is a material made in thin sheets as an aqueous deposit from linen rags, exparto, wood-pulp, or other form of cellulose, used for writing, printing, wrapping and other purposes". The word "paper" had been derived from "Papyrus".

Paper making is an ancient art. It was known in China as early as 105 AD but not until the 15th century did it become generally practical in Europe. Paper is made from fibres of selected nature which is cellulose. The basic requirements in manufacturing paper are cellulose and water. Requirement of water is tremendous, so to speak, as an old thumb rule—that is, about 300 kgs of water will be required to manufacture one kilogram of paper. The interaction between fibres and water assume various modes as the suspension turns into a web and it moves down the machine. Water may thus be regarded as the "anniotic fluid of paper." Printing papers may be evaluated by actual printing press during operation and end result.

A knowledge and awareness of the numerous interrelationships among paper properties are necessary during papermaking and also essential for a basic understanding of paper, its proper application and the problems that exist during printing, converting and end-use. Improvement in one property may be beneficial or detrimental to other properties. The requirements of paper and paper boards are governed not only by the printing process used, but also by operations subsequent to printing and end use of the printed product. A printed product may be produced by one

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or more of the principal of printing processes such as Letter Press, Lithography, Gravure, Flexography, Screen Printing and Ink Jet Printing.

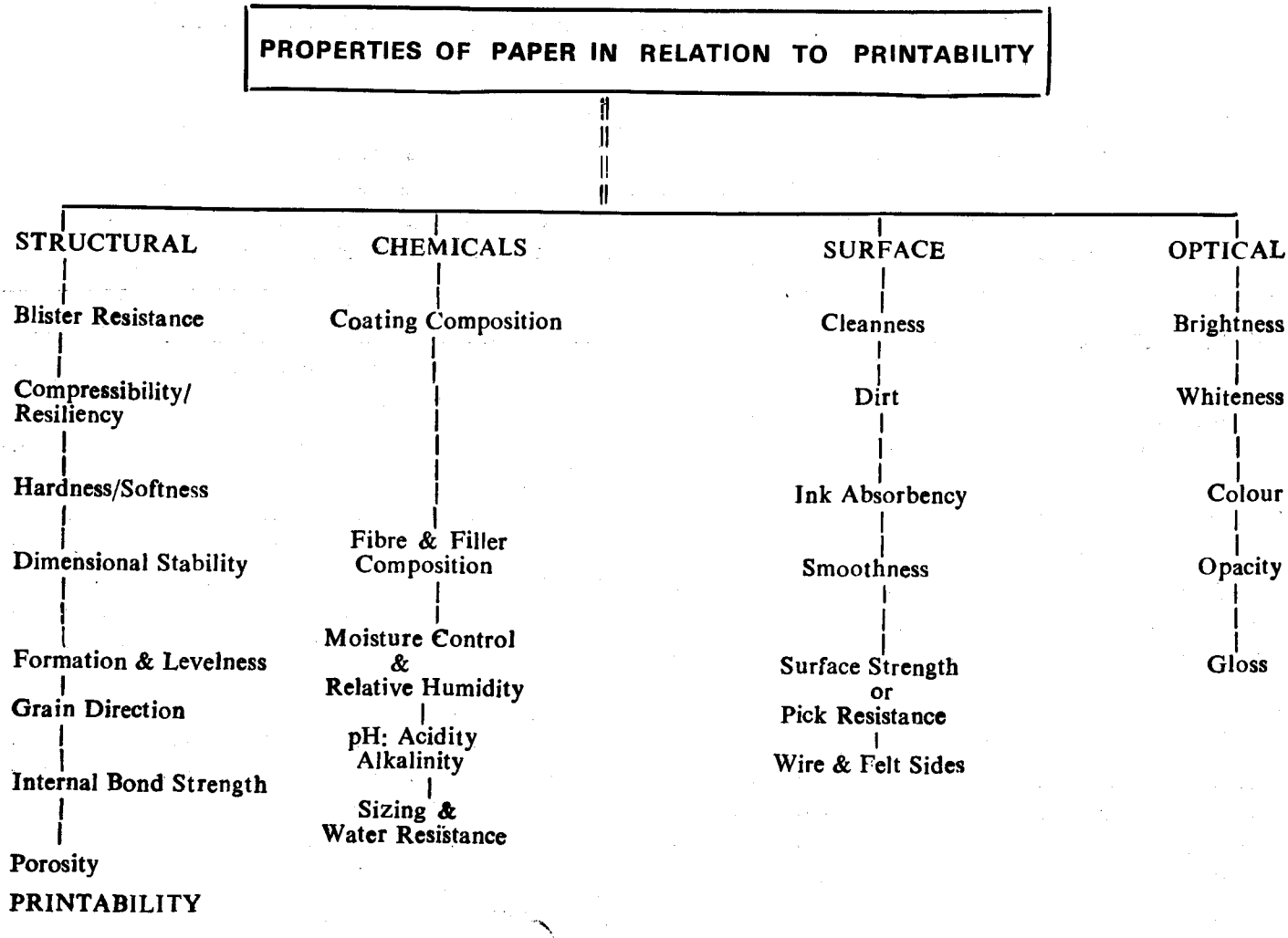
CHARACTERISTICS OF PAPER

The most obvious characteristics of paper are thickness, strength, and surface quality, but there are other characteristics of primary importance to the lithographer which depend on its structure. These are, grain, two sidedness, density and hygroscopic properties. Generally speaking, paper is a more of less porus and its structure is determind by the particular materials that are used and the forces that enter into the paper making operations.

PROPERTIES OF PAPER IN RELATION TO PRINTABILITY :

It is significant to discuss main properties of paper under suitable headings to highlight factors govern mainly printability in relation to printing procedures and "print quality". The properties have been grouped mainly as (a) Structural, (b) Chemicals (c) Surface and (d) Optical.

Lot of work had been done in respect of ascertaining the inter-relation of properties and to quantify the figures of each properties of paper. The detailed experiment by the aid of different instruments have found the end-use and rationalised the optimum result. Some of the experiments could be carried out in actual environment of the press room in printing machine. But lot of experiments need to be carried out in Laboratories in order to get correct sequence of results.



STRUCTURAL PROPERTIES

BLISTER RESISTANCE

It is a phenomena usually happen on coated stock. The surface of the paper have tiny blisters created while coated-web runs through heatset chamber during printing operation and when large volume of water cannot escape quickly through paper's surface which generate excessive pressure causing blisters.

To avoid blister on coated paper it is necessary to balance its moisture content, basic weight, internal bond strength and porosity of the coating while manufacturing. The main criteria that moisture vapour should escape during heatset operation of printed web of coated paper as otherwise due to excessive pressure the same could cause unwanted blisters. It is the common practice all over the world to make use of coated paper for heatset web with less moisture content than are made for other ink drying systems.

There is a tendency to increrse the blisters if the basic weight of paper is increased. Internal bonding strength must be adequate to avoid delamination of the fibres and which will withstand the excessive forces of water and also the vapour to escape in to atmosphere (humidity). Porosity of the coating must be mainatained to a minimum balanced level so as to allow the moisture vapour to escape.

Fibre puffing--i.e. the tiny bundle of fibres in coated paper, as is known the worldover, could sometime explode when passing through the drier in the web machine. This could be limited by controlling the temperature of the drier. Blister resistance of coated paper could be measured as described in TAPPI standard T-526.

COMPRESSIBILITY AND HARDNESS

The thickness of paper gets reduced under impressional force is normally referred to as the compressibility of paper. This property affects the capacity of the paper to alter its surface contour and conform to, and achieve correct contact with printing plates on blanket during printing. The concept of smoothness of paper at the time of printing is called as "printing smoothness".

While acertaining the compressibility of paper it is also essential to consider the hardness and the existence of moisture vapour within the fibres of paper. It has been found that paper tends to be more compressible at higher R.H and moisture content.

Resiliency is the quality of paper to regain its original thickness and surface contour after release of impressional force. The characteristics of paper has also specify the hardness and also its degree. Amount of indentation on paper have during printing depend on its degree of softness. This also in turn result in resistance of indentation due to the inherent hardness of paper where the impressional force also plays its role towards the same.

The printability of paper is very important especially in Letterpress and Gravure printing by interrelationship of compressibility, resiliency and softness and printing condition. These elements help to achieve good transfer of ink in above printing processes. Compressibility and resiliency are not essential for offset and Flexographic printing since the rubber blanket and plate provide some degree of resiliency.

Papers need to be hard for handling and folding and must have adequate strength, durability, erasability and pick resistance. Offset printing papers are harder than these for letterpress and gravure process to withstand the force of rubber blanket. To obtain the required compressibility, resiliency and softness, it is necessary to find a balance or compromise among the various properties of paper.

Calendering reduces the compressibility of paper. Hard paper offers Pick resistance to avoid the removal of coating of paper.

Density of paper substance refers to the relative hardness and impermeability. Density can be measured directly as apparent specific gravity or weight per unit valume. For practical purposes it is calculated from the sheet thickness and weight per ream.

DIMENSIONAL STABILITY

It is an important and essential property of paper. The paper should be able to maintain constant dimension under the environment conditions and also forces applied during printing and converting processes.

No absolute assurance on dimensional stability of any paper. The Paper of any kind are likely to expand or shrink with changes in the environmental and atmospheric variation. But the degree of changes will depend on the type of paper. It is possible that the dimensional stability of paper could be changed with changes in the properties involved in the manufacture of paper.

The paper would undergo little dimensional change if the fibres in a sheet of paper are free to expand or shrink individually and no restraining influences on each fiore. These internal changes in individual dimensions are transferred into external change in paper dimension. The paper will expand or shrink less for a given change in moisture content if the paper is less refined and higher its porosity. Less refined paper will produce a linty, loosely bonded structure with low pick strength so adding fillers in to the paper improves dimensional stability. Sufficient internal bonding, refineness of fibres are necessary for offset paper to withstand from the stress printing without any picking, blistering, splitting or delamination.

Printing paper should have maximum dimensional stability and consistency with other properties required for printing process. For example-Continuous Stationery paper should have high degree of dimensional stability as it has to go through the various stages of operations required for maximum handling. The optimum result of dimensional stability of paper could be envisaged in an environment of 35-50% R.H. (Relative Humidity).

The expansivity of paper is expressed as a percentage and the amount of dimensional change that could take place for each 15% change in relative humidity as measured by hygroscopic method to ascertain the quality of paper is of great significance to the printer as it passes in multiple times through printing during multi-colour jobs. Hygroscopic material tend to absorb moisture accompanied with dimensional changes to accelerate curling, distortion and misregister in printing operation. The hygro-expansivity of paper means the percentage of elongation or shrinkage of a paper, caused by a given change in its surrounding R.H. or its moisture contents.

All paper will stretch and change their dimension under tensile strength. Paper is visco-elastic, so it stretches upto a point and returns to its original size. If paper stretches beyond its limit, it deforms and lose its shape. If stretching of sheets are all same then it helps in achieving good registration of printing jobs towards the length of printed impression by adjusting packing in plate or in blanket cylinders.

Embossing is caused by permanent mechanical stretching or deformation of sheet of paper. But this problem is seldom faced during web offset printing. The direction of paper running through a web press is always in its grain direction, which resist embossing. To avoid mechanical stretch in sheetfed offset printing, a paper should have good strength in cross-grain direction.

The vertical structure, however is that paper is layered, and the importance of the layered structure in combination of mechanical and other properties was summarised by Rodravan at the Fundamental Research Symposia, Cambridge in 1973.

"For printing, it offers a compact, smooth surface but poor procuring strength and opacity. For packaging, good puncture resistance and easy erasibility of board, but poor folding endurance".

There is an useful study by TAPPI in Method Nr. 549 measuring dimensional stability in relation to Relative Humidity.

FORMATION

In early days the term "formation" was often to indicate the level of small scale variation in areal density-but after studying the underlaying Statistical Geometry, it is more rational to use the term as "distribution of mass density". The basis weight or grammage is the Coefficient of Variation of areal density zones of appropriate size. For printing purposes the variation of properties over millimeter zone is probably important. Areal density is a fundamental quality and could be measured. The Importance of areal density variations for mechanical properties is obvious.

Formation is a combination of physical or appearance property. It denotes the structure and the mannar in which its fibres are interwoven, uniformity

and distribution. Formation could vary from one paper to another, it considers as relative property. Formation could be judged by the degree of uniformity of light transmission seen when we see a paper backed by light.

The property of formation influences other properties of paper, viz. smoothness and uniformity of surface The process of calendering smooth out unevenness of the surface of the paper but it produces non-uniform density and ink absorbency. The appearance of this will be often mottled on print especially on solid prints. If the formation of paper is bad then it could cause greater variation in opacity, show-through, especially in light basis-weight paper.

The paper for Letterpress and gravure printing need good formation to attain a good surface smoothness. For Offset printing, the surface smoothness is not that acute because the prints obtained from resilient rubber blankets. It is important that degree of formation is uniformly maintained as otherwise it could affect the strength of paper. Good formation is equally important with paper board to avoid mottling prints. In printing the fracture between fibres are dominating factors. It might surprise that, for a given pulp, the degree of interfibre bonding would be influenced by the manner of drying the web. The detection of fibre to fibre bond failures while carrying out the experiment of tensile strength but it has been found that in concentrated fracture zone the fibres themselves were never seen to break. Formation is the visible result of the uneven horizontal structure of paper.

The distribution of fibre in the formation of paper is never pefectly uniform. Fundamentally, formatiom relates to the print to print variance on the basis weight-called as "Print Function". Formation is almost judged visually by examining the sheet which is held between a light source and the observer's eyes. Mechanical properties of paper could be described in three main directions, viz. bonding, fibrous structure and fractur. "In early thirties, W.B. Campbell formulated that the role of surface tension is bringing to their fibres during bonding, and also ascertain that water is also required as swelling agent."

Formation is difficult to judge subjectively. Instruments have been devised for the purpose, TAPPI Method 432.

GRAIN DIRECTION

In the process of paper making, the fibres move into the paper machine wire and adjust themselves towards the direction of their flow and the moving wire. The web gradually gets dried during its travel towards the direction of machine and start having tension and strength. The direction the fibre travels into the paper machine is called the "Machine Direction" which is termed as "Grain Direction". The direction which is perpendicular to grain direction is called as "Cross Direction". The grain direction is called as long grain which is parallel to machine direction. The short grain paper has its shorter dimension parallel to the machine direction.

The grain direction of a paper be found out in one or two ways which may be carried out by the printer themselves. In the laboratory, the bursting test will indicate grain direction and also tensile strength.

The important aspects are to look into the adverse effect resulted by variation of moisture content in connection of grain direction by changing the dimension and stability of the paper.

For Offset printing, it is always recommended to have long grain, that is the grain should be parallel to the axis of the press cylinder. Short grain paper give stretching problem while passing through machine of many printing units and therefore short grain paper is usually avoided in offset printing.

When the sheet passes through the press number of times for multi-colour jobs, long grain paper will minimise the overall dimensional change whereas short grain paper will maximise dimensional change.

Short grain paper is sometimes used for black and white or single colour work-requiring economical layout, and also for automatic label pasting machine and also bindery consideration in which case misregistration and wrinkling do not pose too much problem. Short grain sometime used in multi-colour presses where image areas required are all over the plates. The short grain should have a lesser tendency to acquire tail end curl, embossing etc. of the sheet.

The Bursting Test and Tensile Strength respectively are described in TAPPI Standard T-403 and T-404 in detail indicating the grain direction of paper.

INTERNAL BOND STRENGTH

"The strength of paper and paper boards is usually considered in two directions within the phase of the sheet, these are in the grain and cross directions. Two axis of X and Y represents two directions respectively than the strength is Z-direction which is called as the internal bond strength (Vertical). Internal bond strength is defined as the transverse force required to delaminate a unit area of paper."

Internal bond strength of coated paper must be such that it does not blister especially when web passes through heatset chamber. The paper also should not delaminate while using tacky ink during printing, for heavy solid areas. The Z-directional force affects both sides of the paper simultaneously in blanket to blanket web presses.

POROSITY

This property need careful study and analysis to ascertain all the relevant aspects as it has basic influence on other properties of paper such as hardness, compressibility, resiliency, absorbency of ink, oil fluid and water. The components like fibres, sizing, fillers and coating are only part of total volume of paper. The porus structure of paper consists of :

(1) Air spaces from paper surface to its interior

(2) Inter fibre air spaces, and

(3) Pores extends completely through the paper thickness

Coated paper are normally found to be lesser degree of non-porous than uncoated printing paper. Long and short fibres control the porosity level of paper such as long fibers create more porosity than the short fibre. The effort of paper maker is such that to reduce the interfiller spaces while manufacturing paper to reduce porosity of paper. Therefore they do refine the fiber which helps to create interfibre bonding and filler and which reduces the spaces between the fibres.

The closer the interfiber structure is the lesser the porosity and darkness of the paper. Paper makers also give surface sizing to reduce airspace between fibres and filling-up tiny pores. Calendering also helps to reduce porosity. There is another advantage of using Coated Paper which reduces porosity of sheet thus minimizing so many intermittent problem faced by pressmen.

Paper with coating base of printing paper have porus structure of two faces, viz. "too much or too little", which could adversely affect the conversion processes and utility of end product. There is a constant effort by paper makers to minimise the porosity of paper which are to be used for printing and packaging.

"Porosity"--the quality or fact of having pores". The porus structure of paper made by spaces between and within fibers. Porosity can be calculated from the density of the volume and density of the fibres.

The penetration of liquids into paper has also been used to arrive at a desired pore size for distribution. The term "Surface porosity is used for the roughness or generally for the topographical structure of the paper surface". Lot of fundamental work in this area were carried out by research scientists on problems of printing and printability.

The show through problem, the pigment penetration and the vehicle separation components, each of which is related to a particular structural feature of paper, the porus structure being responsible for these components. Some experiments had been carried out on samples of offset paper and these results show that there is little correlation between print-through and porosity but are found to have very high correlation to opacity.

The surface porosity or roughness was found to have a major influence on the print result and all investigators focussed on an "emperical' correlations between paper properties and printability".

Packaging papers are the most important group fall in low porosity range. There are lot of work being carried out with regard to printability of paper, surface structure of paper, roughness or smoothness of paper etc. The investigations and the method used are aimed at such phenomena to ascertain ink acceptance and absorption qualities which are difficult to ascertain clearly in the point of view of porosity phenomena.

Coated paper with high hold out of ink than uncoated stock due to lower porosity of the coating surface. Printers have expressed that setting of printing ink depends largely on the porosity of the surface of paper.

The useful method of measuring porosity has been explained in detail in TAPPI Method 524.

CHEMICAL PROPERTIES

COATING COMPOSITION

This is formulated for the need of the printing method and the paper's end use, such as Letter Press and gravure process which do not need water resistant coating binder but offset process do require water. The degree of water resistance required determines the type of coating binder the paper maker will choose. The percentage of binder is the coating, whereas the coating pigments used are controlled by the kind of printing process, the ink drying system, required gloss level and the type and grade of paper on which printing is to be done.

Offset coated papers should have a higher pick resistance than that of Letterpress or Gravure paper. Because of their different ink drying systems and to avoid blistering during heat-set drying, the coating composition for sheetfed and web fed printing also differ. Web offset paper for their running faster through the press require less moisture resistance than sheetfed paper.

The coating adhesive must be fairly water resistant as otherwise the coating pigment will gradually transfer to the blanket and result in build-up of adhesive film causing scumming. Coating paper are often liable for scumming and could cause printing trouble. It is usual practice therefore to investigate the final water solubility, chemical action, metal plates and surface activity or its ability to emulsify ink so that trouble free printing is obtained.

An informative two-part survey on the interaction between the base paper and the coating mix was published in 1975 by Berger and Reinhardt. Reference is also made in the Annual TAPPI Coating Conference held in 1949.

FIBRES AND FILLER COMPOSITION

The Composition of fibres affect paper characteristics. Cotton and linen fabrics are important fibres which are different from wood fibres. Chemical wood pulps have different paper making characterics-namely, ground woods give high opacity, good printing cushion and high ink absorbency but low brightness and strength.

Various kinds and amount of fillers are used to increase the opacity, brightness and smoothness to improve printing surface and simultaneously also reduce ink see-through and decrease fibre harshness. As the loading of filler is increased, the capillaries are reduced in size. The smaller the capillaries, the greater the force they exert on ink which contact the paper.

Increase in filler content results in the paper becoming more ink absorbent *although* the capacity to hold the ink gets decreased. But a coated sheet absorbs the vehicle or solvent from the ink more quickly than it is on uncoated sheet.

Filler helps to reduce reaction on changes in moisture content during atmospheric change in moisture, thus improving dimensional stability of paper. Usually uncoated paper have about 15% high fillers in their composition. Technically, the content of filler is termed as "Ash Content". The ash content is the composition of particular kind of paper that could be analytically expressed by laboratory testing method.

MOISTURE CONTENT & RELATIVE HUMIDITY

The basic and fundamental relationship of cellulose fibres and water are the important factors in processing and finishing stages of paper. manufacture The original moisture content of paper and its capacity to absorb moisture for surrounding atmosphere influences greatly its electrical and mechanical properties, and surface dimensional stability.

As paper is hygroscopic since its cellulose fibres attract water molecules the fibres increases in size when they absorb water and contract in size after giving-up water. These changes affect the fibre diameter than the fibre length. This phenomena affects the dimensional change in cross-grain direction of paper.

Dimensional change due to change in moisture content do primarily cause misregistration, curling and distortion during printing. The degree of dimensional change of any particular paper is an important aspect to printers as the same reveals the composition of refining and the kind of paper being used for printing. The main focus being given to the exact time of manufacture of paper is to minimise dimensional instability in its physical properties.

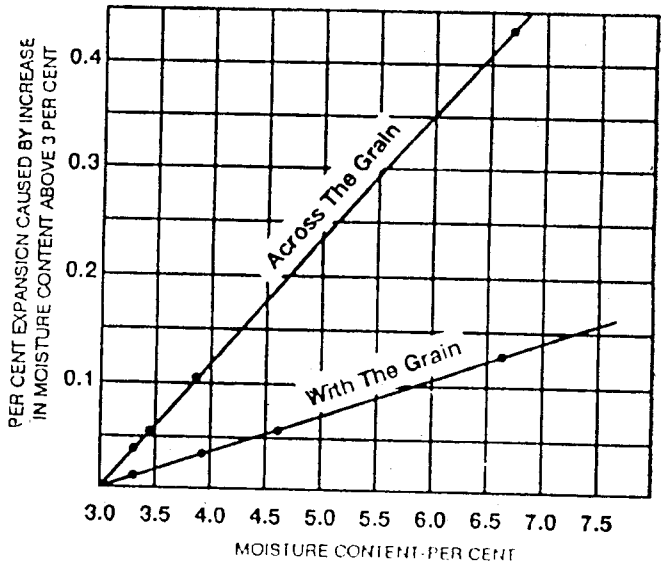
The tendency of curling of paper normally is towards the wire side (due to loss of moisture) and with the grain due to greater fibre alignment than the felt side. With gain of moisture, paper tends to curl towards the felt side. These curling effects could be minimised by reducing the two-sideness of the sheet.

Problems like misregister, doubling of printed images are due to wavy or curl paper during the uniform squeeze of an offset paper- and any excessive unevenness of flat surface of paper will cause wrinkling.

The requirement for offset paper is that the paper be in equilibrium with respect to relative humidity of the press room. In multi-colour printing, if the printed sheet passes separately through the machine, and in case the moisture content is higher than standard figures required in equilibrium condition of controlled pressroom naturally reduces the dimensional changes of paper during the complete operation. Tests so far carried out reveal that dimensional changes is two to four times more across the grain than with the grain. Following diagram will explain this clearly :

From the experience it has been found that-ideal condition of the Pressroom is about 45% R.H. and 75-80°F. The paper exposed on this condition sufficiently, assuming the paper has the best combination of strength characteristics for resisting mechanical distor: tion, and is fairly free from curl, then it does not give any trouble in view of static electricity but if there is any change in R.H. from this condition then it could affect very little on the dimensional stability.

The moisture content of paper under equilibrium conditions bears a direct relationship to the R.H. of



surrounding air. The paper tends to be equilibrium if the Pressroom has 45° R.H.

Too much low moisture content produces hard brittled paper and also reduces its resiliency, printing cushion and smoothnees under impressional force. Higher moisture of paper will increase its resiliency and thus make the printing paper to be better, lie flatten and conform to the printing surface under printing stages. It is preferable to have higher moisture of paper—so using such paper for copper engraving work will bring out finer detail in the contour of the work due to paper's resiliency quality. Brittling causes web-breaks and cracking at the fold. High moisture helps runnability of uncoated paper stock.

During heat-set drying, the coated paper is likely to blister due to the high moisture content. We, very often consider bringing the paper to equilibrium moisture content condition but since the same depends on fibres and non-fibre composition of paper, the R.H. condition and the Pressroom and other environmental conditions, it may not be possible to achieve the same. This is largely due to the high attraction of fibres towards moisture than fillers and coating. Therefore, high quality of fillers composition in paper are desirable,

The relationship of paper and water is controlled during manufacturing and printing in web form but for sheet fed printing and for converting operations, the

equilibrium R.H. at a particular temperature is more important. Equilibrium of relative humidity denotes that the paper do not gain or loss moisture in the atmospheric R.H. of any specific area where the paper have been kept. So the moisture content of the paper become balanced with its surrounding R.H. which is called as "Equilibrium Moisture Content". It has been found, as an example that in the range of 20-65% R.H. usually a 10% change in R.H. will earn about 1% change of equilibrium moisture content of paper. Only changes in temperature will have little effect on the equilibrium moisture content for a constant R.H.

If the pressroom is not humidity controlled, then possibly the R.H. can vary to a larger extent from a very high humid weather to a very dry cold weather. It is a difficult task for paper manufacturers to produce paper with correct R.H. content as there is no prior information available with respect to R.H. condition of the pressroom. However, paper makers do try to manufacture papers keeping in mind average R.H. prevailing in standard condition.

It is commonly experienced that sheet fed paper is more critical with respect to moisture content than web offset paper.

pH : ACIDITY AND ALKALINITY

The chemical status of paper during manufacturing and printing have significant role while we are studying the problems experienced during printing operation, especially for Offset Presses. As far as possible, it is recommended to look in to the value of acidity and alkalinity of paper and also specially water fountain solution. The term used in pH is to highlight the potential of the hydrogen ion (H^+). It is understood that a positively charged hydrogen ion (H^+) produces acidity and whereas negatively charged hydroxyl ion (OH^-) gives alkalinity.

Ionisation of pure water is neutral, that is neither acid nor alkali. But this water changes the status, i e. if an acid or alkaline substance is added then water changes towards acidity at the first stage and alkalinity in the next stage. These can be expressed in pH value, for which a scale is used marked from 0 to 14. These represents logarithm or exponent which is mathematically expressed as the concentration of hydrogen ions. When the pH number of a substance or solution is exactly 7, it will have equal concentration of hydrogen and hydroxyl ions. It is chemically natural when the concentration of hydrogen ion is more than hydroxyl ions then it will be acidic, so pH number changes. Here the less the pH number the maximum the substance acidic and for alkaline solution the strength also expresses from pH 7 to max of pH 14. The term pH indicates the intensity and not the quantity of an acid and alkali, measured by a temperature scale that denotes the intensity of coldness or hotness.

Considering the pH value in the whole manufacturing process of paper are important and necessary, low pH affects the aging of paper and reduces its life. Permanent paper having long life are somewhat at pH 7.

The pH value is less significant for Letter Press, Flexographic and Gravure printing. The pH value of paper does not affect the drying of heatset inks. But pH value of offset presses need paper which are controlled and maintained. It is necessary to follow the recommended pH value to avoid all kinds of problems in end-use. For example, paper with low pH value, in the fountain solution is likely to retard or prevent the drying of ink, causing chalking. Also on the other hand ink drying problems also is associated with low pH of fountain solution. But high moisture content in the paper, or excessive moisture in presses and a high R H. will considerably influence the low pH or ink drying capacity. But higher pH naturally helps in achieving smoothness of operation.

In many cases, ink drying trouble cannot be considered as a fault of paper. The fountain solution should not be low in pH. Drying of ink on printed coated sheet does retard if coating of paper is too acidic, especially when R. H. is high. Most offset inks dry by a combination of setting (penetration) and hardening (polymerisation). Drying of ink or ink on paper stock in correct manner within certain period needs constant check and control by pressman who should be aware of all other connecting factors required to achieve the best results, as an example - absorbency of paper is also an important property of paper in relation to "Printability" and "Print Quality".

pH Meter is necessary to measure the pH value of the fountain solution in the Offset Press so as to strike

a correct and steady balance of intensity of acidity and alkalinity to avoid all kinds of problems faced by pressmen.

SIZING AND WATER RESISTANCE

The main criteria for sizing the paper is to make it water or fluid repellent. There are two kinds of internal sizing, viz. "Stock Sized" and "Hard Sized", which depends upon the degree of sizing.

The internal sizing is added in paper making operation prior to the fibres run through the paper making machine. The internal sizing gives the paper a resistance towards water penetration and is effective throughout the fibres network.

Hard sized paper minimises water absorption from repeated exposure to the press dampening system (Offset Press). Too much absorption of water by paper evolves problems such as picking, surface becoming weak and undergo changes in dimension and finally it also creates curls. Curling of paper which is encountered in Offset printing by changes in dimension of paper are - (1) Inherent Curl due to improper manufacture or handling, (2) Moisture curl due to non-uniform moisture distribution in the sheet, and (3) Structural curl - change in structure of paper due to printing and finishing operations.

External or surface sizing differs from internal sizing. Surface sizing normally consists of heated starch solution applied to the partially dried web. Sizing is forced into the two sides of the paper. Surface sizing penetrates below the paper's surface to some extent. It has got little water resistant property. The surface sizing increases the surface strength of paper and imparts greater ink hold-out by stopping many surface capillaries of the paper. The surface sizing contributes the following properties—stiffness, improved erasibility, scuff resistance, bursting strength, tensile strength and folding capacity.

Uncoated offset printing paper have internal and surface sizing. Letter Press printing does not require hard sized paper. The degree of internal and surface sizing varies among many different paper/boards; depending upon the individual requirements for their converting and end-use. The sizing of paper enhances the resistance to water and other fluids.

SURFACE PROPERTIES

SURFACE CLEANNESS OF PAPER

Cleanness is an important requirement in offset printing. The trends are towards heavier ink coverage, faster press speeds, higher gloss are the more serious consequences in terms of costs and loss of print quality when presses are stopped for wash-ups too frequently.

Contaminating materials, which detract from surface cleanliness and which originate during paper manufacturing, can be classified into two types. One kind is superficial, loosely attached particles existing on the paper surface. The other is contaminating material that detracts from paper cleanliness originate in various foreign inclusion that are embedded in paper's surface and which gets lifted out of paper by the rubber blanket and its internal areas.

Printing papers can be checked for cleanliness by sampling sheets from paper production and printing them with heavily inked solids on an offset press, which will reveal both debris and pickouts.

DIRT

It has a special meaning to the paper maker. It consists of any embedded foreign matter or spikes that have a colour contrasting to the paper. Dirt may or may not interfere with the print quality, depending upon whether it can be lifted from the paper and transferred to a printing plate or rubber blanket.

Freedom from dirt is specially important with papers to be used in optical character recognition applications, when a speckle or dirt can cause a false reading.

INK ABSORBENCY

It is the property that determines on what rate and what amount the ink penetrates the paper, after the printing plates or blanket deposits it. Penetration is primarily that of the ink vehicle into the voids, capillaries and pores of the paper.

The film thickness of offset printing is considerably less than that of Letterpress printing. Consequently, the absorbency of a paper's surface plays an important part in ink drying and related problems.

Typical ink film thickness (wet, full strength solid on smooth paper)

Type of Ink	μm	Mils(1 Mil=0.001(In)
Offset Lithography	2	0.08
Letter press	3	0.12
Gravure	12	0.5
Screen	66	2.5

Courtesy : GATF

These experiments have been carried out on sheet-fed machine using drying oils and drying by processes of setting and polymerisation.

An interesting study in respect of oil into paper, in connection to printability was done by Laraque. He found that "the penetration rate for a given paper was proportional to the quotient surface/viscosity of the oil and that increasing the temperature rate in proportion to the decreasing viscosity of the oil. The penetration rate to be directly proportional to the applied pressure'. Messrs. Voit & Brand had also confirmed that "the proportionality between the penetration rate and the fludity (i. e reciprocal viscosity) of the inks". The emprical nature is also very much a feature of absorbency tests which could be carried out in actual printing machine. Excessive penetration may cause problem like as show through or less opaque.

The complete mechanism, once the film of ink gets transferred on to the surface of paper, the mechanism of setting the film on the surface goes under two distinctive stages. Firstly the ink should set on the surface of paper to avoid set-off. Setting occurs when a part of the vehicle penetrates into the paper surface. Secondly, drying of ink film on the surface occur by oxidation-polymerisation which takes approximately two to four hours.

The absorptivity of the paper involves a fine balance between high absorptivity which is desired to prevent set off and low absorptivity for high ink hold out and gloss.

In commercial printing where all types of papers are used, ink often requires to be adjusted for individual purpose. The important aspect for the printer is to have a uniform absorbency from sheet to sheet within a given supply of the same batch of production of paper manufacturing machine.

The set-off problem in heat-set web printing which lacks absorbency of ink do not pose a problem but quick absorption of ink may affect the gloss of the print. Inks for newsprint practically do not dry but the penetration vehicle let the pigment trapped by the surface of the paper Fibres and filler composition for uncoated paper, controls ink absorbency.

Surface properties of paper greatly influences ink absorbency, viz. smooth paper and calendered surface decreases ink absorbency. Surface sizing decreases ink absorptivity and increase ink hold-out thereby reducing vehicle penetration. The degree of surface-sizing can be varied within limits to control ink absorbency.

The ink absorbency of a coated paper is controlled by its coating composition and calendering and is dependent upon the process by which it will be printed.

The test of ink absorbency on different kinds of paper is explained in detail in TAPPI Useful Method 519.

SMOOTHNESS

Smoothness characterises "the dimensional distribution of the surface irregularities of paper".

It is a very important characteristics of paper as it influences both functional and appearance purposes. From the printability point of view, it refers to suitable contour and the degree to which the surface levelness approaches an optical place, viz. smooth gloss.

The application of coating and super calendering increases the smoothness significantly. The Bendstan Smoothness Tester is useful to indicate rapidly smoothness at the rate of air leakage over the paper's surface.

The faithful reproduction of printed job largely depends on correct transfer of ink with all detail from printing plates to paper stock. The result mainly indicates smoothness of paper and also its softness.

Surface irregularities of paper affects the printability of gravure printing as there is very less pressure used in time of printing as ink transfer due to capillary phenomena. Completeness of image transfer is greatly influenced by the printing smoothness of paper. The extent to which a paper surface contour will change under printing pressure to contact ink from the printing plate more completely is unknown as its "Conformability".

Mr. Klu Ghardt discusses the relationship between gloss and smoothness and his theories, "that the smoothness is determined only by the orientation of surface clarity." Where gloss is in addition influenced by the clear and refractive index of these elements"

SURFACE STRENGTH OR PICK RESISTANCE

The surface strength or pick resistance of paper enables its surface to withstand the applied force during printing, to avoid picking and rupturing the ink film. Picking occurs when the force or splitting on ink film are greater during ink transfer.

Picking can occur in various ways such as partial or complete removal of coating fragments from the surface, as a partial delamination of the paper substrate below the printed surfaces, producing a disturbance resembling a blister, or as a rupture consisting of a continuous removal of the paper surface.

Dry picking and wet picking occurs in the absence of water during printing. Wet picking also occurs due to loss of surface strength during dampening and weakening of the surface bonding strength prior to printing impressions.

Pick resistance is an important consideration for Letterpress and Offset printing. The IGT Printability Tester is used to measure surface strength. Surface strength of Offset papers is best predicted by printing variables of the offset printing process such as inks, blankets, rollers, plates and operating conditions and when controlled continuously within the prescribed limits.

WIRE AND FELT SIDES

The wire side is the side which is in contact with the wire of the paper machine, the opposite or top side is termed as felt side.

The wire side gives the impression of the wire-mesh on the surface. The impression is called as "Wire Mark". The wire mark could be greatly reduced by using wires made by different material such as plastic in the machine.

When the water is suspended from the paper making machine, it furnishes fibres, fillers, sizing and other additives flows on to the water. Water is first drained away by gravity and then by suction. The greater percentage of fibres will be aligned in the machine direction on the wire side, since they are quickly fixed into this position during initial drainage. The wire and felt sides of paper made on a single-wire machine differ in their composition and structure. The wire sides has a more pronounced grain, less fines and fillers and more open structure.

Coating greatly reduces the printing differences between the wire and felt sides.

OPTICAL PROPERTIES

The most important subjective optical characteristics are Brightness, Colour, Opacity and Transparency.

Individual judgement on optical properties depends on the eye, mind and experience. This exercise brings complex by the interactions between light, paper and observers. The optical properties most obviously relates to the geometric categories of the paper struc ure, such as—Formation, Horizontal Structure, Transparency, Vertical Structure and the Gloss-Surface Structure.

BRIGHTNESS

"When optical property of paper and its principle light-scattering components—Pulp and Pigments—is of specialised reflectance are known in the industry as "Brightness". It does not directly relate to appearance. Brightness is an optical property that controls the potential whiteness of the product. The blue reflectance (brightness) of a pulp is vital to the potential whiteness of final product. The brightness is a very important intra-industry control property.

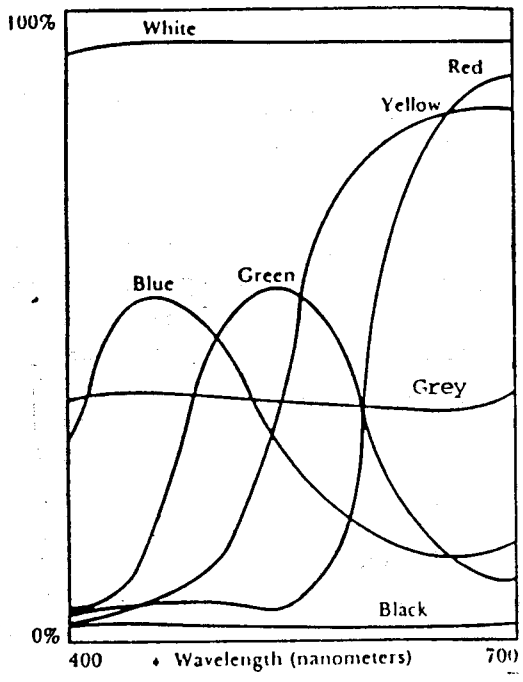
Brightness reflects standard wave length in "White" which creates the balance of colour and high reflectance. A grey paper though it has low reflectancy but reflects

all band of wave length equally. A printing paper thus gets selected on the basis of this criteria other than its reflectancy values.

It is usually wrong to consider "Brightness" as whiteness and to avoid such errors the newsprint surface has been measured with blue-green wave length--which is called as "Visual Efficiency". Human eyes are more suspectable and sensitive in colour range than other wave length. High brightness of paper may not always be the better choice but the choice depends upon the printing requirements, cost and end-use.

Higher contrast prints require higher brightness of paper considering cost factor. For printing books, it is always recommended to use low brightness paper to reduce the reflectance of paper brightness to readers' eyes.

TAPPI G-E Brightness Tester is a good instrument which is sensitive to surface characteristics.



Typical reflectance Characteristics of Black, Grey, white & Colour Objects—"The Measurement of Appearance—1975."

"Reflects of colour for the paper is due to its absorbency in certain wave length. Adding of dyes or pigments in white paper creates the absorbency of certain wave length of light. So the combination of remaining wave length reflected by the paper is called as "Colour".

Detailed and lengthy work had been done in this field but yet to learn about the physiology and psychophysics of colour vision quantitative colour measurement is not possible by eye and therefore it necessitated an instrument for this purpose. The most commonly used instrument for colour measurement is the so called "Colorimeter". It is always useful for people in printing industry to discuss and study the interaction between light and paper and to understand the optical properties, viz. Reflectance & Transmittance.

TAPPI Standard T44L gives detailed information on Spectrophotometric Measurement.

OPACITY

"Show Through" is perceived when a sheet of paper is laid upon a printed page, is governed by the so called Opacity of the Paper. This is an important aspect of paper, although it is also regarded as an optical property of technical significance.

The classical definition of capacity is "the logarithm of the reciprocal of transmittance". Opacity is not commonly measured in the paper industry but opacity is defined as contrast "Ratio" of the reflectance of a sheet over white and black backgrounds. Translucency and transparency are associated with the passage of light through a sheet of material.

Mr. Davis proposed, "a contrast ratio in which the white body would be an opaque file of the white paper". This theory became more realistic as white which is commonly used paper, often tends to lie upon zones of white and black printed characters, which is called as "Printing Opacity".

There is an another important theory to understand, viz. paper makers while compressing to lessen the tensile strength to meet the opacity specifications, should ensure proper and sufficient pigments are used to obtain good quality papers for use by end-users. Pigments such as clay, calcium carbonate and titanium dioxide opacify paper through their contributions to the overall scattering power of the paper when acting as either or both fillers and coating pigments. Opacity of white paper results primarily from the scattering of light by both fibre and pigments.

From printing terminology—the opacity of paper is its capacity to hide the printing on its reverse side. For pinting industry, the opacity means the difference in reflectance observed as show through. Show through is also somewhat depends on the composition of printed matters.

During manufacture of paper, adding more filler and after calendars, the opacity of paper gets increased. This has been found that if the basis weight is less, the opacity also simultaneously gets reduced. It has been observed that printing paper mostly looks like translucent substance.

The degree of opacity of printing paper depends on composition, brightness, colour, weight, c st and end-use of any paper. It is important to note that the surface of printing paper transmit light in two ways--parallel rays non-scattering type and diffused rays. It has been observed that yellow tinted paper has less opacity than blue-white paper.

The method of measuring opacity is given in detail in TAPPI Standard T-519.

GLOSS

This is another important physical property of paper in relation to its apperance. Gloss is an related factor with other optical state and which has been considered as valuable surface characteristics called "Surface Texture".

If each eye look at the paper from s ightly different angles, gloss is then seen. It is as little as physical property of paper or any other object such as Colour Formation, Brightness and other perceptive phenomena.

Gloss offers shiny or lustrous surface of the paper. It is measured as the ratio of its reflection to its incident light for a specified equal angle.

Gloss is related to smoothness but there is no simple co-relation. High gloss increases gloss of printed ink film and improve the brightness and colour intensity of prints. As gloss is somewhat depend on ink film, so ink absorbency hold out are more important consideration. Therefore, glossness of paper should be maintained to achieve uniform print quality.

PRINTABILITY

It is the characteristics of paper surface to determine the degree it can produce the desired quality and quantity in relation with printing inks and press combinations.

Printability of a paper's surface can be explained by the quality- "as the degree to which its surface (papers) enhances the production of high quality prints by a particular printing process". Printability of a paper surface is influenced by other properties of paper as well. The most important property which influences the printability are - Smoothness, Uniformity, Ink Transfer and Ink Absorption. All these properties have been explained in detail in this article.

Differences in ink acceptance and absorptivity from print to print in paper's surface can be caused by a deficiency in printing smoothness, non-uniform formation or an insufficient coverage of the fibres for coated paper.

Uneven ink penetration from print to print in the surface produces a mottle gloss appearance in heaviiy inked areas.

The colour density and gloss in printed areas which are s rongly influenced by the ink hold out and gloss of the paper's surface. Paper gloss predominantly infiuences printed ink gloss. The combined effect of paper's gloss and ink hold out also influences the colour density of the print. High printed gloss may or may not be desirable, depending upon the end-use of the printed product.

Printability could be measured by measuring of various properties of paper. The results indicate the testing methods of different properties of the printability of paper Methods used to measure, control and predict the printability includes procedures to have the best co—relation with printability observed during field experience IGT Printability Tester and Printing Processes are often used to evaluate printability.

Printability has been accepted by subjective method though so many efforts have been made as a "Single Number". To quantify printability is a difficult task

as it is completely related to all the relevant and important properties of paper surface but requirement of these properties will depend on the type of job and paper that needs to be used. But enlightening the printers and the technical personnel in the printing industry would be a very positive step towards achieving excellence in print quality.

To summarise some of the important factors influencing printability, especially in two major printing processes, the following points should be noted :

LETTERPRESS PRINTING

Problems affecting printability are :

(a) Varying degree of ink hold out
(b) Non-uniformity of paper gloss
(c) Ink absorptivity
(d) Variation of smoothness
(e) Lack of hardness

These properties should be controlled to achieve best results and minimise faults mentioned hereunder :

(a) Show Through Printing
(b) Dimensional Stability
(c) Good Registration
(d) Pickout and Picking
(e) Blistering of the prints
(f) Curling
(g) Lack of flatness of sheet in the machine

GRAVURE PRINTING

Problems affecting printability are :

(a) Lack of contrast between the minute individual cells of the gravure cylinder and the paper
(b) Skips
(c) Snow or spickles
(d) Irregularities of the surface resulting in missing dots.

Softness, absorbency and compressibility are the important factors for uncoated paper. Electro static assists ink release techniques have helped to reduce skips. Correct tensile strength and elongation of paper web are also important qualities.

"Print Quality" is an abstract concept for a printer or viewer as this could be judged subjectively but rational approach shall be to evaluate this property to compare the end result with its original. Keeping in mind the operational process, type of paper and above all Pre-Press work are carried out in a most technical manner to achieve the desired result. Printability does co-ordinate many properties of substrates and demand the correct technology with high resolution.

CONCLUSION

The basic and fundamental approach to this subject reveals that it is necessary to minimise and rectify (if possible), faults encountered in printing operation. As printing has been shifted from artistic expositions to hi-tech exposure so it has become imperative to improve the raw material such as paper, board, and ink in accordance with printability of paper surface and print quality with finished result.

The choice of any stock should be in accordance with quality of ink and type of process that will be employed for any job beforehand. Sometimes, it is necessary to take proof on right paper with standard quality of ink prior to bulk production so as to avoid controversial end products.

Mainly properties of paper play a vital role to achieve best results in printing and subsequently end operations.

The paper manufacturer should have free dialogue with their users and study all kinds of "Effects" produced due to properties of paper to avoid wastage, labour and delay in printing which will all be the added up cost of any particular job. The good quality raw material used by the paper manufacturers claim to minimise problems for printers, high productivity and standard quality the key factors for the printer to determine their market share.

Quality print jobs are in demand so the paper used should be balanced with all the requisite properties. The judgement of quality of stock were defined as subjective but to-day quality is analysed quantitatively and producing paper in terms of their usage.

The intervening of hi-tech paper manufacturing processes contributing to standardise the finished paper upto an extent that end users expect trouble free stock and in turn to produce high quality products. Printers and converters are still in struggling front to compromise and adjust the techniques of production and other raw material to achieve standard quality and quantity.

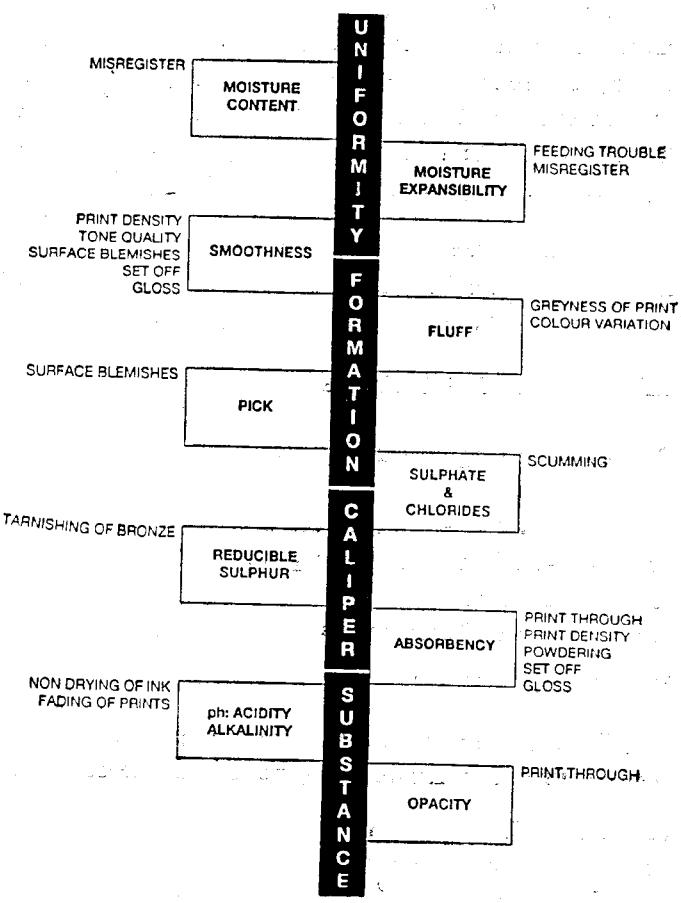
The cost of paper is also an important aspect for the end-users as high quality of paper demand high price which influences manufacturer's end products. The proper balance between the final price of paper and the quality of paper are most essential points in discussion.

The ideal condition of pressman for proper production technique for printing is also very important and should be considered in terms of productivity and cost of production in printing jobs.

We should put our effort trying to adjust techniques, carry trial with new kind of material and also producing standard originals for printers will be a continuous effort. The introduction of hi-tech techniques in eaeh stage of production in printing industries will help to standardise the technique for production in accordance with raw material to maintain high standard of finished products.

Enclosure- 1

DEFECTS CO-RELATED WITH PAPER PROPERTIES IN PRINTING OPERATION



EFFECTIVENESS OF VARIOUS RESULTS OF PAPER PROPERTIES

PROPERTY & DESCRIPTION	EFFECT
Abrasiveness	
The capacity of the paper for scratching other surfaces	If a paper is abrasive it may cause premature wear of printing plates. It does not follow that, if premature wear occurs, the paper is necessarily the cause
Absorption	
Lithographic inks depend for part of their drying on being absorbed by the paper. Papers differ in their absorbency. It is important to remember that absorbency to ink is not the same as absorbency to water	If the paper is too absorbent the inks may not dry because they powder or the ink may penetrate and be visible from the back of the sheet. If the paper is non-absorbent there may be difficulty from set-off and sticking in the pile, and in extreme cases from the ink failing to key to the paper
Acidity	
Acid materials are of necessity introduced into paper during its making. One source is paper makers' alum. The activity of these acid materials is usually expressed as the pH value. pH is a logarithmic scale measuring acidity and alkalinity. pH7 denotes neutrality; decreasing pH corresponds with increasing acidity and increasing pH corresponds with increasing alkalinity	Papers that are strongly acid or strongly alkaline, particularly under damp conditions, may cause chemical fading of certain colours, particularly with light tints. Acid papers may also cause delayed drying of inks and have considerable bearing on tarnishing and corrosion
Colour	
The colour of paper is controlled by the extent of bleaching of the fibres and by pigments used in the loading or coating. Many near-white papers contain fluorescent bleaching agents which absorb ultra-violet radiation and re-emit it as blue light. This counteracts the natural yellowness of the paper. The 'whiteness' of fluorescent papers will depend on the ultra-violet content of the light under which they are viewed	Neutral white paper should be used for colour reproduction. The higher the reflectance of the paper (the whiter the paper) the longer will be the tonal range of the print. Very white paper is not necessary for text and may impair readability with some type faces
Curl	
Some papers differ in moisture expansibility on the two sides of the sheet. Exposure to changed r.h. induces curl	Feeding and delivery difficulties. Collating troubles.
Delamination	
Separation of the liner from the base board	Occasionally the adhesion between the liner and the base board is too weak to resist the pull of the ink during printing
Fluffing (Dusting : Linting)	
The presence of loose material on the surface, or of constituents of the sheet so loosely bound that they are removed from the sheet during printing	Build up on blanket causing impaired ink transfer and frequent wash-ups. White specks on the print ink contamination
Folding of carton board	
Creases have a resistance to folding related to the press settings used	The performances of cartons on packing lines are influenced by the folding of the creases. Carton bowing depends also on board stiffness
Formation	
The uniformity of distribution of fibres in a sheet of paper	Paper with a poor formation is difficult to print uniformly because impression and absorption of ink may be uneven and mottle results
Gloss	
The extent to which a paper appears to reflect light directly, rather than diffusely	High gloss paper should be avoided for text printing, as it gives rise to glare which impairs readability. The gloss of paper to be used for illustrations is a matter of personal preference
Grain direction	
Two main directions are usually distinguished in a sheet of paper—(1) the direction parallel to the direction of travel of the paper making machine wire (machine direction). (2) the direction at right angles to the machine direction (cross direction). The grain direction is the machine direction	The physical properties of the paper differ with and across the grain. For example, paper is more rigid in the grain direction than across it. Stretch and moisture expansibility are usually greater in the cross grain direction. Papers for close register work should be cut long grain
Hardness or compressibility	
Hard papers with uneven surface require excessive pressure to bottom the grain	In direct lithography the excessive pressures required to print hard papers may cause plate damage. Many hard papers are non-absorbent and set-off troubles may result

PROPERTY & DESCRIPTION	EFFECT
Mechanical stretch Paper subjected to tension increases in length. It extends more in the cross direction than in the machine direction	In printing the paper is subject to tension and will stretch. This is particularly true when heavy solids are printed
Moisture content The moisture content of printing papers usually lies between 4 and 10%	Papers of low moisture content are prone to static, curl, cracking on folding and web breaks. If the moisture content is not in equilibrium with the r.h. of the pressroom, sheet distortions, creasing and misregister may occur
Moisture expansibility Paper changes size when exposed to humidity changes: this change is much greater across the grain than with the grain, except for M. G. Papers	Wavy or tight edges on stacks or reels Misregister
Opacity The property of a paper which controls the extent to which printed characters can be seen through the sheet	A certain amount of showthrough and strikethrough can be tolerated when reading text, but both are objectionable when viewing illustrations. The PATRA Opacity Indicator gives a demonstration of showthrough with papers of different opacities. Showthrough refers to the visibility of characters printed on the sheet below the sheet being viewed, e.g. on the next page of the book and depends only on the opacity. Strikethrough refers to characters printed on the reverse side of the sheet being viewed and depends also on other properties including absorption of the paper
Pick resistance Coated papers have a mineral layer attached to the base sheet by means of an adhesive. The pick resistance describes the ease of removal of the coating	A high pick resistance is desirable since this will permit high printing speeds and concentrated inks to be used
Sizing There are three main methods of sizing paper— (a) Engine sizing in which the size (usually rosin) is added to the beater, (b) Size press application in which the size is applied to the web on the paper machine, (c) Tub-sizing in which the size is applied to the paper after the sheet has been made	Engine-sizing probably has little or no effect on the printing qualities of paper when using oil-based inks. Tub-sizing retards ink penetration. Surface sizing reduces fluffing
Smoothness A measure of the levelness of the surface of the paper	For sharp printing and good halftone illustrations a smooth paper is desirable
Two-sidedness The side of the sheet which was formed in contact with the paper making wire is the wire side; the other side is the top or felt side. The properties of the two sides may differ and the sheet is then said to show 'two-sidedness'. Papers made on double wire machines have two top sides and no wire side	A paper with pronounced 'two-sidedness' may be difficult to print and adjustments to ink and make-ready may be necessary to accommodate differences in paper quality

Courtesy: PATRA