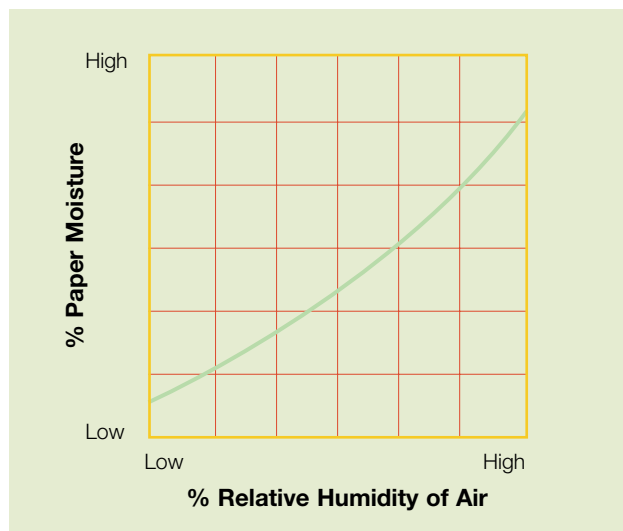


## Paper

### Moisture and Relative Humidity

The major component of paper, cellulose fiber, is hygroscopic in nature. A material that is hygroscopic will absorb moisture from a damp atmosphere or release moisture to a dry atmosphere and, after sufficient exposure time, will come into equilibrium (balance) with its atmospheric environment.

**Figure 1. Typical relationship between the moisture content of cellulose-based paper and ambient relative humidity**



All paper encountered in normal situations contains some moisture since it is composed of cellulose fibers. This normal moisture content will generally range between 2% and 10% depending on the type of paper, its past moisture history and the atmospheric conditions to which it is exposed. When subjected to extreme conditions the moisture content of a paper may range from as low as 0.5% to as high as 13%. Many basic properties of paper are greatly affected by its moisture content. Paper dimensions, flatness, conductivity, strength and fold are among

the more significant properties influenced by its moisture content. These paper properties can be very critical to the proper performance of paper and therefore, effective control of paper moisture level and moisture uniformity is essential for efficient printing and converting operations.

#### **PAPER MOISTURE CONTENT AND RELATIVE HUMIDITY: DEFINITIONS**

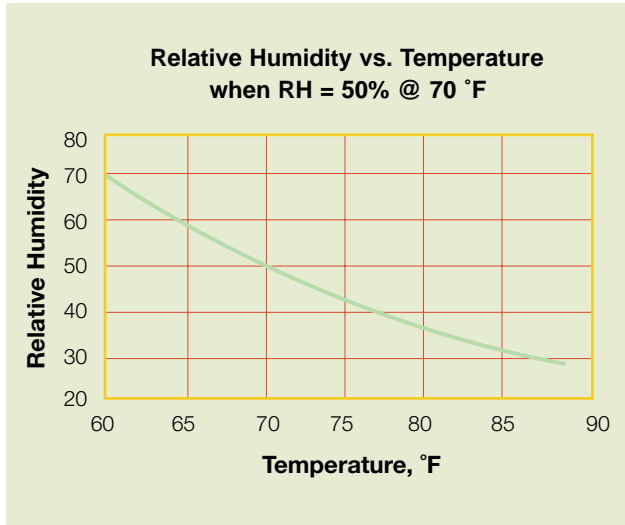
**Moisture content** of paper is the percentage of the total paper weight, which is moisture. Moisture content of paper is determined by weighing a paper sample and, after oven drying, weighing it again. The difference in the two weights is calculated and expressed as a percentage of the original weight. It is the level of moisture in a particular paper that influences stability of the critical properties of dimensions, flatness, conductivity and strength of that paper.

Paper, since it is hygroscopic, will exchange moisture with its environment until equilibrium with that environment is achieved. The moisture level of paper is routinely referred to in relation to the moisture level of the environment with which the paper is in equilibrium (**Figure 1**). The moisture level of an environment can be measured in two ways: absolute humidity and relative humidity (RH).

**Absolute humidity** is a measure of the number of grains of water per pound of dry air (7,000 grains equals one pound). Absolute humidity is independent of air temperature.

**Relative humidity (RH)** is a measure of the amount of water in the air, at a specific air temperature, expressed as a percentage of the maximum amount of water the air can hold at that temperature.

**Figure 2. Relationship between relative humidity versus temperature for a fixed absolute humidity**



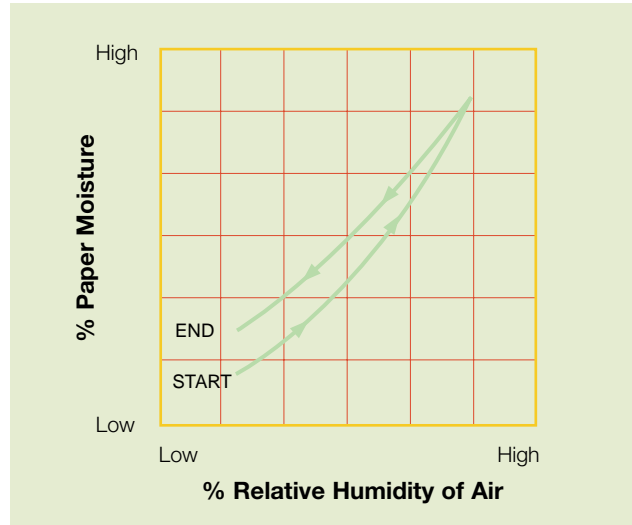
As the temperature of the air increases, its ability to hold moisture increases. Air, when heated, will retain the same absolute humidity, but its relative humidity will be lowered (**Figure 2**). Conversely, as the temperature of air decreases, its ability to hold moisture is reduced. Air when cooled therefore, also will retain the same absolute humidity, but its relative humidity will be increased.

The relative humidity of the paper’s environment is the primary atmospheric factor that affects the paper’s moisture content. When the relative humidity of the surrounding air is high, hygroscopic materials such as paper gain moisture from it. Paper, exposed to conditions of low relative humidity, will lose moisture to the air. Therefore, it is the relative humidity of surrounding air that controls the actual moisture content of hygroscopic materials such as paper. It is also the relative humidity of air surrounding exposed paper which affects those properties of paper that vary as its moisture content changes.

**Dew Point** is the temperature at which moisture in the air will condense on to surfaces.

Charts and tables are available for the conversion of relative humidity to absolute humidity and absolute

**Figure 3. The hysteresis effect and its impact on paper moisture as the relative humidity changes**



humidity to relative humidity. The absolute humidity value is sometimes needed for various calculations and measurements. However, it is not of great importance in its influence on paper moisture content.

**PAPER RELATIVE HUMIDITY**

Relative humidity, since it is the major factor that influences the moisture content of exposed paper, is the environmental moisture level measurement used in reference to paper moisture level. Paper, therefore, is commonly referred to as having a relative humidity (RH).

**Paper relative humidity (paper RH)** is defined as the relative humidity of the air with which that paper is in moisture equilibrium (**Figure 1**). In other words, the relative humidity of an environment in which the paper will neither give off nor take on moisture.

The “ideal” relative humidity of paper as supplied from the paper manufacturer has often been debated. The relative humidity of pressrooms and binderies in the United States has a known range each year from as low as about 10% to as high as 90%. This fact, together with the differences in average relative humidity in various geographic areas, is largely responsible for the “difference of opinion” regarding paper relative humidity.

Paper manufacturers cannot produce papers with RH levels that will allow a given paper to function ideally under all conditions. Therefore, the RH produced by the papermaker will be a compromise, selected to accommodate the majority of all environments in which the paper will be processed. Additional factors influencing the RH selected by the paper manufacturer for a particular paper are characteristics desired in the finished product and limitations that exist within the papermaking process.

Printing papers cannot be manufactured consistently at moisture levels which would generate values above 50% RH in the paper. Appearance characteristics are significantly deteriorated at elevated moisture levels. This high level of moisture in paper during certain processing operations causes both brightness and opacity to decrease and shade to vary. Appearance characteristics are more easily controlled and maintained during these processing operations when paper RH is approximately 40%.

The desired characteristics of the finished product and technological limitations of the papermaking process result in practical paper moisture levels allowing paper to be produced with relative humidity ranging from about 25% to 50%. It has been determined that a moisture level generating an RH range of 38% to 45% is generally satisfactory for uncoated papers and that a slightly higher range, 40% to 45%, is satisfactory for coated paper which is produced in sheets. Coated papers produced for use in heatset printing operations are commonly manufactured to have an RH of approximately 30% to aid in the prevention of blister problems during the processing of the paper on such equipment.

Naturally, if paper is exposed to an environment which is significantly above or below the RH of the manufactured product, problems may occur—depending on the time and conditions of exposure, requirements of the particular job, etc.

### **PROPER PAPER MOISTURE CONTENT DEPENDS ON PAPER CONSTRUCTION**

Paper should be in moisture equilibrium with an atmosphere that has a relative humidity of 40-50% at 72 degrees Fahrenheit. However, the actual moisture content of various papers will differ under these conditions depending on the individual construction of each paper. Similar papers may be encountered which, when in equilibrium with the same relative humidity environment, have a considerable difference in their moisture content. The actual moisture present in a particular paper (at a specified RH) is determined by the following: fiber (type, purity and quantity), filler (type and quantity), adhesives/binders (quantity and nature), manufacturing techniques (degree of fiber treatment), and the past moisture history of the particular paper (**Figure 3**).

Paper is routinely manufactured to a moisture content specification since the measurement of moisture content is more accurate, reliable, and convenient as a means of production control. However, the relationship between moisture content and relative humidity of the particular paper must be established in order to produce the finished product at the proper relative humidity. This relationship is determined by allowing the paper to reach equilibrium in a series of different relative humidity environments and, in each situation, measuring the moisture content of the paper after equilibrium has been established. Graphs produced using the data points obtained are referred to as moisture equilibrium curves. Once the proper moisture equilibrium curve has been developed for a particular paper, that paper can be manufactured to be in equilibrium with a specified relative humidity by controlling the moisture content of the final product.

Most paper manufacturers have automatic online monitoring/controlling devices to ensure proper and uniform moisture content as their products are produced on paper machines and coating equipment. The paper is processed in areas that are monitored and/or controlled and then packaged using materials that protect the product from its environment during shipping and warehousing. Paper produced today is

more consistent and uniform with respect to moisture content than ever before in the history of paper manufacturing. When properly packaged and stored, paper will retain a stable moisture content for well over two years.

**PRECAUTIONS SHOULD BE TAKEN TO PROTECT PAPER MOISTURE CONTENT**

Certain routine precautions should be taken to minimize the opportunity for paper to exchange moisture with an environment—where the relative humidity of the paper and the environment may differ—thus reducing the possibility of problems related to paper moisture:

1. Paper removed from a truck, rail car, or an unconditioned warehouse should be allowed to reach the temperature of the area where it is to be processed before being unwrapped.
2. Paper should not be stored near any type of heating or cooling unit, in an air stream of heated or cooled air, or in the path of a humidifying stream of air.
3. Paper should remain in wrappers until immediately prior to being processed (this applies to rolls, skids, cartons and reams).
4. Paper being held between processing steps should be protected by vapor-proof wrappers while awaiting additional processing operations.

For heatset printing the oven-dried paper can be left unwrapped for several days, allowing the paper to regain lost moisture.

**CRITICAL PAPER PROPERTIES ARE ALTERED AS MOISTURE CONTENT OF PAPER CHANGES**

The most significant paper properties affected by change in moisture level or the development of a non-uniform moisture level within the paper, as stated earlier, are: dimensions, flatness, conductivity, strength and fold.

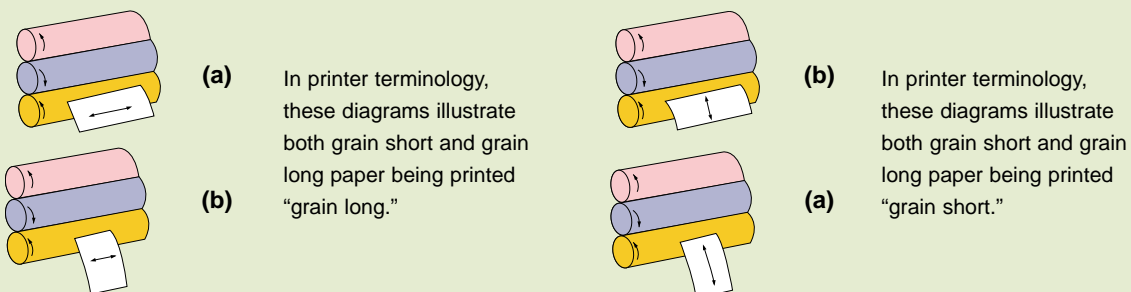
**MOISTURE AND PAPER DIMENSIONS**

Paper dimensions increase with higher moisture content and decrease with lower moisture content.

Individual cellulose fibers will change in dimension as their moisture content changes. As the moisture content of the cellulose fiber increases, the fiber will increase in dimension and as the moisture content of the fiber decreases, the fiber will decrease in dimension. As the cellulose fibers change in dimension due to changing moisture content, the diameter (width) of the individual fibers will change 2-5 times more than their length (their width changes significantly more than their length). These individual fiber dimension changes communicate themselves to the sheet as a whole and depending on the reactivity of each particular paper, the paper will change in dimension.

**Figure 4. Nomenclature used in printing and paper manufacturing**

**In papermaker terminology, paper in diagrams (a) are “grain long” paper and paper in diagrams (b) are “grain short” paper**

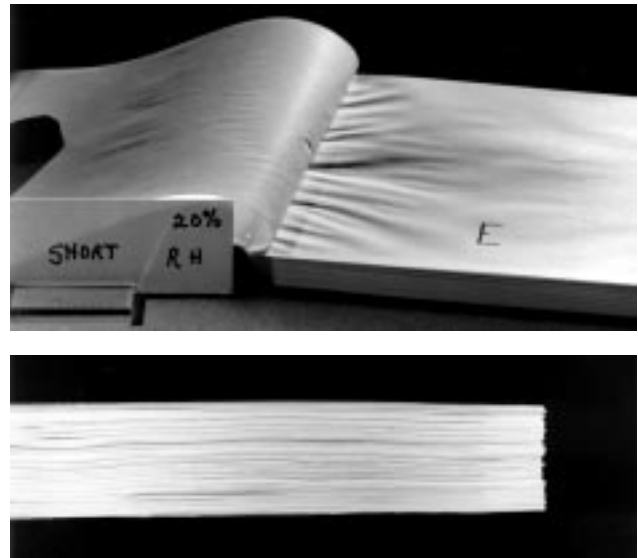


Since a majority of fibers in paper are aligned parallel to the machine direction, it follows that the greatest change in dimension due to moisture change will be in the “across grain” dimension. The dimensional change will normally range from 1.5 to 2.5 times more in the across grain direction than in the direction parallel to the paper grain.

It is for this reason that sheetfed printing papers should be processed during printing with the paper grain direction parallel to press cylinder axis (**Figure 4**). Any change that occurs in paper dimension will then correspond to the direction of travel through the printing press, and cylinder packing can be adjusted to obtain print register. Little, if anything, can be done on press to accommodate a paper dimensional change that occurs in the across press dimension. As a result of these factors, printing papers are normally not guaranteed to perform with respect to freedom from register and wrinkling difficulties **unless** the paper grain direction is parallel to press cylinder axis during the printing operation.

Dimensional changes in paper, especially when they occur during and/or between processing steps can be very critical—and in other instances can affect the quality of the finished product when they occur after the job has been completed. When paper dimensional changes occur between press passes during multicolor printing, misregister can result. Dimensional changes in signatures after binding into books can create undesirable appearance and/or quality defects known as either “starts” or “buckles” depending on whether the paper is bound parallel or perpendicular to the grain direction (**Figure 5**).

**Note:** All papers do not possess the same reactivity to changing moisture content. Papers will react differently as their moisture content changes depending primarily on the total percentage of hygroscopic material (fiber) present in a particular paper and the degree of bonding that exists within the paper structure. It is possible to have two different papers in the same atmosphere that have either a high or a low relative humidity, and observe that one paper has changed more in size than the other paper after



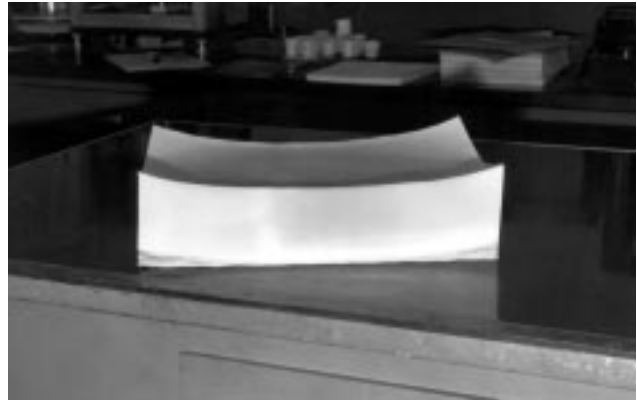
**Figure 5.** “Buckles” and “starts” occur with moisture changes in paper. “Buckles” shown on the top occur when paper is bound perpendicular to the grain; “starts” occur when bound parallel to the grain (bottom photo).

moisture equilibrium has been established. All papers do not react to the same degree as their moisture content changes! Therefore, in the same environment, it is possible to have one paper changing in size, developing distortions, etc., while yet another paper remains apparently unchanged.

#### **MOISTURE AND PAPER FLATNESS**

Flatness of paper may be altered if paper is exposed to an environment in such a manner that a non-uniform moisture content develops. A lift of paper when exposed for a sufficient period of time to an environment that has a significantly different RH from that of the paper will absorb or release moisture in the exposed portions—around the perimeter of the lift or skid. The result will be that each sheet in the lift or skid will have a higher (or lower depending on the RH of the environment) moisture content around the perimeter than in the remainder of the sheet.

If the lift or skid has been exposed to a high RH atmosphere, for a period of time, the increase in moisture around the perimeter will cause the sheet to increase in dimension where the moisture has been absorbed—around the edges. The increase in dimension in this instance develops as waviness around the outside edges of each individual sheet. Non-flatness



**Figure 6.** “Wavy” edges and “tight” edges are caused when the edges of the paper expand or contract relative to the middle of the sheet.

(distortion) that develops in this manner is referred to as wavy edges.

The reverse will occur, however, if the skid or lift has been exposed, again for a sufficient time period, to a low RH atmosphere. In a low RH atmosphere, the exposed areas of the paper (the edges) will release moisture to the drier air. As the sheets release moisture, they will decrease in dimension in the areas where moisture has been released around the edges. In this case, the perimeter of the individual sheets will become smaller. This condition is referred to as tight edges or shrunken edges. A lift of paper which has developed tight edges will generally have the corners drawn up and appear “dished” or “cupped” – such paper is frequently described as “baggy” in the center.

**Note:** A moisture content change as little as .25% around the perimeter of sheet paper is sufficient to cause either wavy or tight edges to develop.

Paper that has become distorted as the result of tight edges or wavy edges can create very difficult processing problems (**Figure 6**). Those that seem to be most common are misregister, doubling, slurring and wrinkling during printing and wrinkling during folding and/or binding operations.

### CONDUCTIVITY

Electrical conductivity of paper is related to its moisture content. Although paper is generally considered to be a non-conductor of electricity, some degree of conductivity does exist, and is dramatically influenced

by moisture present in the paper. As the paper moisture content decreases, conductivity also decreases.

Static (frictional electricity) is always generated when a non-conductor like paper is moved across another surface. If these static charges dissipate or leak away as they develop, they create no difficulty and are not noticed. If, however, these static charges do not dissipate, they build up and can create considerable difficulty in the moving and handling of sheets of paper. Static charges on the surface of paper may cause sheets to cling together and/or to machinery mechanisms, thus affecting the smooth movement of paper through the equipment and often creating jam-ups.

Efficient paper processing operations require that sufficient moisture be present in the environment and in the paper to prevent buildup of static electricity in the paper. When the relative humidity of the environment or the paper (or both) is 35% or lower, the static charges generated may not dissipate readily. In such an instance, unless some outside influence dissipates the static charges, they can build up and may create the mechanical difficulties of double feeding, jamming, poor jogging, etc. The best precaution to prevent static is to keep the relative humidity of both the paper and its environment above 35%.

### STRENGTH AND PAPER MOISTURE CONTENT

Although several types of paper strength are affected by moisture level, probably the most significant of these to a user of paper are strength properties that relate to the folding of paper. Folding strength is the



ability of paper to withstand repeated folding without breaking and falling apart. Fold quality is the ability of the paper to be folded without exhibiting objectionable cracking on the outside of the fold line. Once the paper has been produced, fiber pliability, which is heavily dependent on fiber moisture content, is the major factor affecting both fold strength and fold quality. A paper that has been exposed to excessive heat, as in a heatset press dryer, or to low humidity in a heated pressroom or bindery will commonly be low in moisture content. It may then exhibit one or both of these undesirable fold characteristics since the dry fibers are stiff and brittle and tend to break rather than bend when forced to conform to a fold line (**Figure 7**).

#### **COMMON CAUSES OF MOISTURE VARIATION IN PAPER**

The paper manufacturer makes a constant effort to ship paper which has the proper moisture content—and has sophisticated tools today that allow better monitoring and control of final paper moisture content than ever before. When the user exercises the previously mentioned precautions, problems directly related to paper moisture are very rarely encountered. Problems related to moisture variation in paper generally occur when proper precautions are not taken to protect the paper after it has been received by the user.

#### **IMPROPER MOISTURE CONDITIONING OF PRESSROOM/BINDERY ENVIRONMENT**

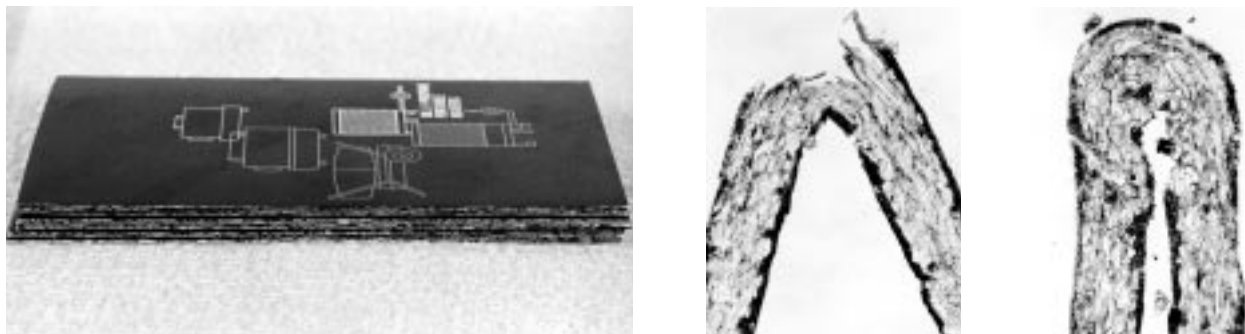
The most common and most obvious effect of unbalanced relative humidity between paper and

its environment are those of wavy or shrunken (tight) edges. Paper exposed in a high RH atmosphere will develop wavy edges, and paper exposed in a low RH atmosphere will develop tight edges.

While any extreme of humidity is harmful and to be avoided, the low range generally presents the most severe situations. Wavy edge problems are more common, but tight edge problems are normally more difficult and expensive. It is at low atmospheric humidities of the paper's environment that tight edges occur. The edges shrink and buckle the paper producing a baggy center in the sheet. It is virtually impossible to process tight edged sheets without encountering misregister and/or wrinkling.

Care should be exercised to ensure that equipment that has been installed to control humidity in a particular environment is properly maintained and performs this function consistently. Additionally, it should be noted that even in humid areas, when air conditioning equipment is operating during hot weather, moisture removed from the air via the air conditioning unit can reduce the relative humidity of the environment to as low as 30-35%.

An overall change in paper dimensions as a result of either increasing or decreasing paper moisture content rarely causes problems today when sheet paper is involved. Sheet paper is normally exposed in a somewhat uniform fashion as it is being processed through equipment (i.e., a sheetfed-offset press). Today, most multicolor, close register printing is accomplished on multicolor presses, and while some



**Figure 7.** Fold cracking may occur when the paper is too dry. The moisture content of the sample in the center example was 20% RH; that on the right 50% RH.

slight sheet growth may occur between press passes, the images printed on each pass can be registered without difficulty. However, this can still create problems today as it has in past years when multicolor, close register printing is accomplished on single and two-color equipment. A uniform increase or decrease in paper moisture may alter paper dimensions slightly but will generally do so without creating severe distortions in the paper.

### **HIGH HUMIDITY ENVIRONMENT**

Paper that is properly temperature conditioned (70-75 degrees Fahrenheit) will absorb moisture when exposed to a high relative humidity atmosphere. The absorbed moisture causes the paper to develop wavy edges. Paper will absorb moisture very rapidly from a humid atmosphere – approximately 65% of all moisture that will be picked up in one hour is picked up in the first 30 seconds of exposure while no more than 10% would be lost during the same 30 second time interval – and wavy edges may develop shortly after exposure begins. In a high RH pressroom, wavy edges will begin to develop immediately and quite often will begin to create difficulty on the first pass through a sheetfed operation. In other words, high pressroom relative humidity will quite often create problems on the initial processing of the paper. If properly identified, a minimum of loss is encountered.

High humidity environments are most commonly encountered in geographic regions that inherently have a lot of rain and thus high humidity and/or during the humid summer months.

### **LOW HUMIDITY ENVIRONMENT**

Paper that is properly temperature conditioned (70-75 degrees Fahrenheit) will release moisture to the atmosphere in a low relative humidity environment. The release of moisture results in a decrease in paper dimension around the perimeter, and tight edges are the result. Tight edges due to low relative humidity of the atmosphere are often accompanied by static. Paper releases moisture to a dry atmosphere much more slowly than it will absorb moisture from a damp atmosphere. Tight edges, therefore, develop much

more slowly than do wavy edges. This is one reason that tight edges in paper are generally a more severe, more costly problem than wavy edges. Properly conditioned paper, when unwrapped in a dry environment does not develop tight edges immediately. In a dry pressroom, paper when unwrapped and put on press, may perform in an excellent fashion with good press performance, excellent register, no wrinkling, etc., during the first pass through the press. Quite often, as a result of such performance, all pressroom/paper parameters are assumed to be in perfect balance, and the paper, which has been printed on one side, is not rewrapped and protected from the dry pressroom environment. Tight edges then develop before the paper is put on press for the back-up (or a subsequent color or varnish). Depending on the exposure time of each skid of paper to the dry atmosphere, mild to very severe problems may be encountered during this second pass through the press. These difficulties generally consist of one or more (or even all) of the following: slurring, doubling, misregister and wrinkling. Situations of this type are usually severe, since considerable time is generally spent trying to salvage a portion of the partially printed job. Additionally, it is quite often the case that much (if not all) of the job is lost and must be reprinted.

Low humidity environments are commonly encountered in geographic regions that inherently have low humidity and/or during the winter months or cool weather. Cool/cold air, when heated indoors to the comfort zone, will decrease in relative humidity—in some instances to 10% and possibly even lower, unless some provision has been made to stabilize the humidity of such an environment.

### **IMPROPER TEMPERATURE CONDITIONING OF PAPER**

Paper should be temperature conditioned to the environment where it will be processed, prior to removing the moisture barrier wrappings. Although either cold or hot paper could conceivably cause the following indicated difficulties, problems with hot paper are very rare.



**Table 1. Time, in hours, necessary for paper to come into temperature equilibrium with its environment**

**Cubic feet = length X width X height (in inches) divided by 1728**

Temperature Difference degrees Fahrenheit	10°	15°	20°	25°	30°	40°	50°	60°
<b>12 cubic ft.</b>	8	14	18	22	27	38	51	78
<b>24 cubic ft.</b>	11	16	23	28	35	48	67	100
<b>48 cubic ft.</b>	14	19	26	32	39	54	75	109
<b>96 cubic ft.</b>	15	20	27	34	41	57	79	115

Chart values indicate the number of hours the indicated volumes of paper should stand unopened in order for it to come into temperature balance with the new environment's temperature.

#### **COLD PAPER**

During shipment and storage in the winter months, paper is often exposed to temperatures that are more than 50 degrees Fahrenheit below normal room temperature. Paper, when received under these conditions, should be allowed to reach room temperature while still wrapped in the moisture barrier packaging. The temperature-conditioning chart above can be used to determine the minimum time required to raise a specific volume of paper to room temperature (**Table 1**). By following these procedures, moisture problems can be minimized.

If cold paper is not allowed to reach temperature equilibrium with the pressroom or bindery, the following series of events may occur. The cold paper, when unwrapped, will immediately cool the air adjacent to it and cause the relative humidity of that air to increase. The paper will then absorb moisture from the higher RH air, and wavy edges will begin to develop. In a moisture-controlled pressroom, with an extreme difference in temperature, just as with a glass of ice water in the same environment, moisture can actually condense on the paper (see "*Dewpoint*"). The resulting wavy edges, which will develop in a relatively short time period, can create difficulties in the processing of the paper. Continued exposure of

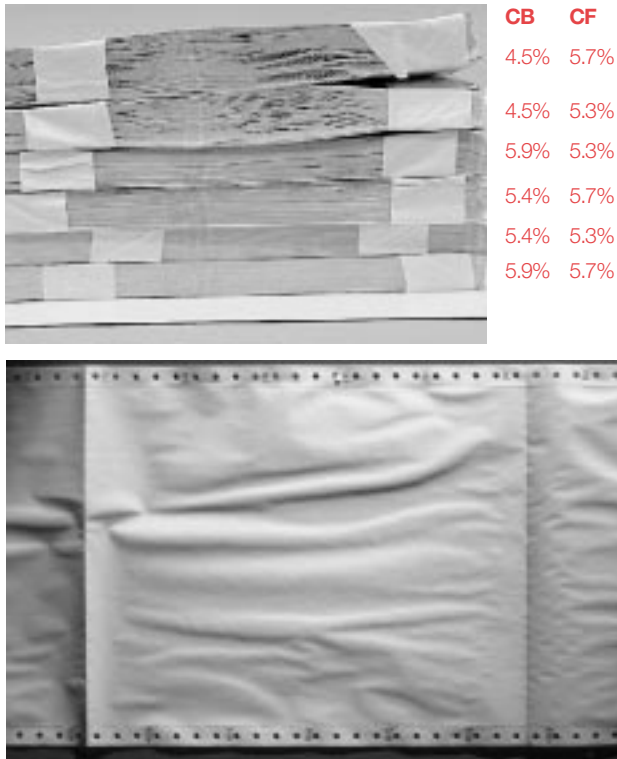
this paper will allow it to begin releasing moisture, especially if the room RH is low, and, in time, tight edges will begin to develop. It is virtually impossible to salvage paper that has developed wavy edges and has then been allowed to develop tight edges.

Paper in roll form is less likely to exchange moisture with its environment. However, temperature conditioning should also be a routine practice with roll paper. Cold web offset paper would certainly be susceptible to certain runnability, ink transfer and ink drying problems. Cold web offset paper has been documented to create splicing problems, possibly due to moisture condensation on splicing adhesive, or by the cold temperature having reduced the "tack" of the splicing adhesive.

#### **HOT PAPER**

During shipment and storage in the summer months, paper may be exposed to temperature 30 degrees higher than the normal 70-75 degree room temperature. Paper received under these conditions should be allowed to reach room temperature while still protected in the moisture barrier packaging. The temperature-conditioning chart can be used to determine the time required.

Hot paper, when not allowed to reach temperature equilibrium with its environment prior to unwrapping,



**Figure 8.** Effects of varying moisture levels on paper. On the top, 2-ply carbonless forms with varying moisture contents were bound together. On the bottom is an example of dimensional wrinkles.

could initially begin to develop tight edges. However, since tight edges are slow to develop, the paper will generally reach temperature equilibrium in exposed areas before they occur. Wavy edges are more likely to be encountered during warm weather in non-humidity controlled environments.

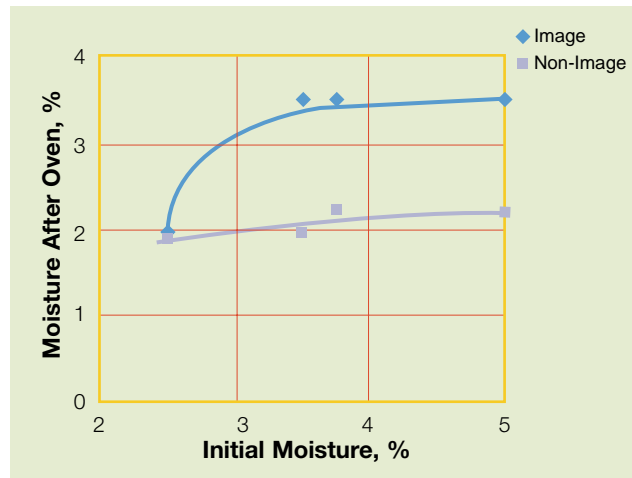
**PAPER MOISTURE CONTENT AND BUSINESS FORMS**

The relative humidity of paper is very important in the manufacture of multi-part business forms. All necessary precautions must be taken to ensure that proper moisture content is present in the paper at the time of manufacture and that it remains consistent and uniform during storage, processing and imaging of the business form.

Sheet papers, having a different relative humidity, when collated together into a multi-part form, will later come into equilibrium with each other and with their environment. Dimensional variations that occur in the different plies of the form set can create register variations when the form is imaged.

One of the more serious problems occurs when papers having different relative humidities are collated into a continuous, multi-part form that is bound on one or both edges by gluing—and to a lesser degree when crimped (**Figure 8**). When such a situation is encountered, one (or more) of the different plies can change in size as they come into equilibrium with each other and with their environment. The result is wrinkles running parallel with the paper grain direction. These wrinkles are referred to as dimensional wrinkles and develop after the forms have been manufactured, but before they are imaged. The dimension wrinkles create additional stiffness in the form set and may interfere with either the feeding of the forms through imaging equipment or the refolding after imaging—or both. In instances where the forms have been crimped rather than glued, some slight movement is possible as dimensional changes take place in the plies of the form set, and dimensional wrinkles are less likely to develop. If the moisture content of any (or all) of the papers, which will later become the various plies of a continuous, multi-part form, changes dramatically between printing and collating operations, collating may be impossible due to line hole misalignment between the plies and/or misalignment with collator pins. The misalignment develops when changes in moisture content cause significant dimensional changes after

**Figure 9. How moisture varies in the non-image and image areas of a print when paper, of varying moisture content, is passed through a heatset oven**



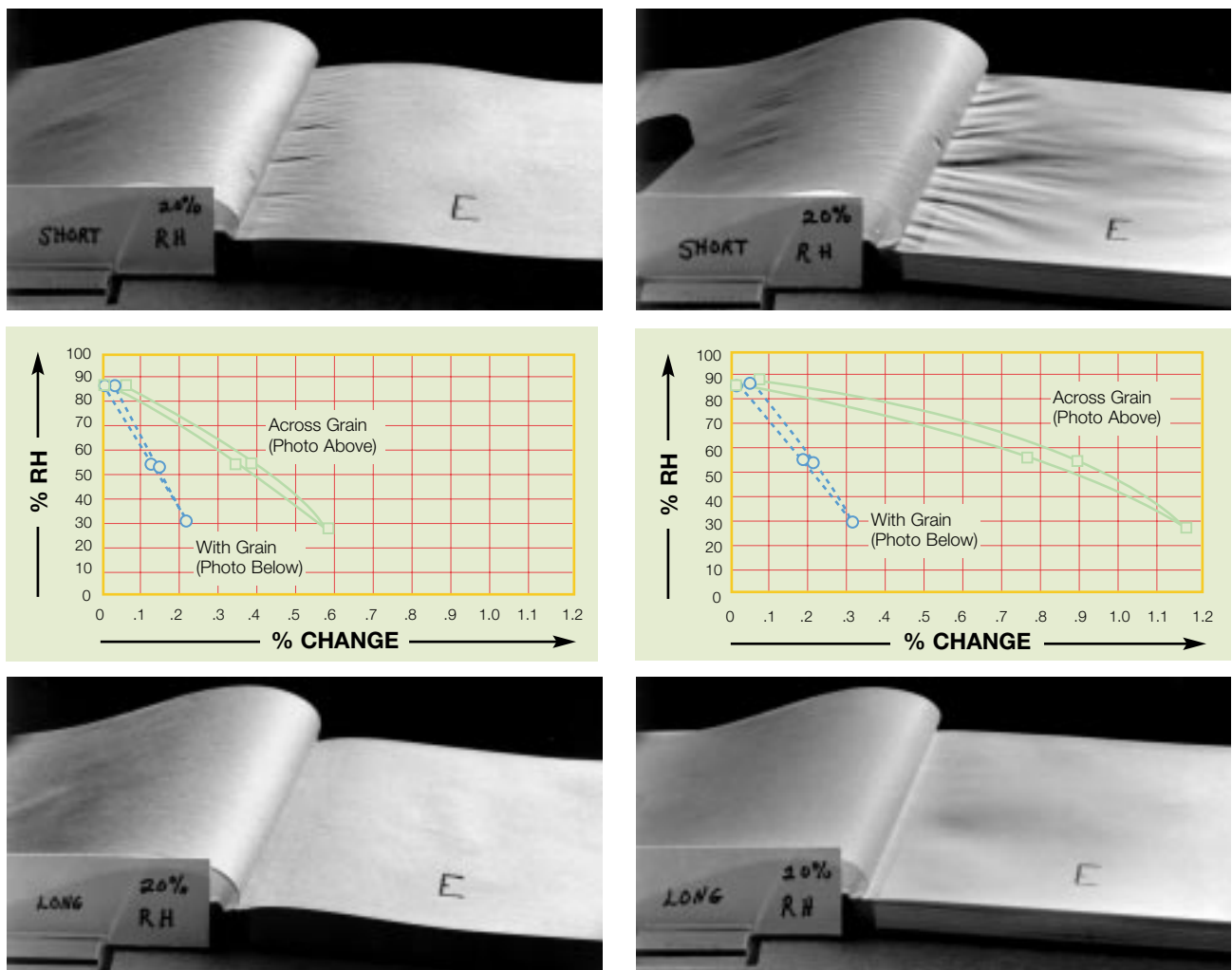
the line holes have been punched and before the collating operations are initiated.

#### PAPER MOISTURE CONTENT AND WEB PRINTING

Paper moisture content can be drastically reduced as it passes through the heatset web offset press dryer (Figure 9). The paper is subjected to elevated temperature as solvent is evaporated from the printed ink films. As solvent is evaporated from the ink, moisture is also evaporated from the paper. The paper, after exiting from the press dryer, has a reduced level of moisture and is very likely to be smaller in size and exhibit both poor fold quality and poor fold strength. It is also very susceptible

to a later increase in size as it absorbs moisture from its environment.

It is quite common today for the inline folding systems on web offset presses to rewet the paper along the intended fold lines just prior to folding to enhance both fold quality and fold strength. This in itself may create problems during and/or after binding since the paper now has nonuniform moisture content. The moisture content along the fold lines is higher, and waviness may be present in the final bound product along these edges where moisture was applied. This waviness is referred to by using terms such as moisture welts and buckles (Figure 10).



**Figure 10.** Paper in all four books was at 20% RH at the time of binding. Paper on left is newsprint, and paper on right is coated but not calendered (Matte paper). Books at top were bound perpendicular to paper grain (across grain edge), while books on the bottom were bound parallel to paper grain direction. Graphs in center are “hygroexpansivity” graphs showing percentage of size change at different RH equilibrium points for each paper.

Also, water will more readily penetrate the areas where there is no printing; a solid ink film is an effective moisture barrier.

Printed signatures that are very dry, when bound into a book or magazine, will take on moisture, after binding, until they reach equilibrium with the surrounding atmosphere. The bound edge of the paper cannot move as freely as the unbound edge. This difference in movement of the paper as it increases in dimension is manifested by waves in the paper. The waves that develop in the paper radiating outward from the bound edge are commonly referred to as buckles. Buckles in bound books not only affect the appearance of the product, but also tend to stiffen the pages near the bound edge, and thus as the book is forced to open and lie flat, the stress exerted on the binding shortens the life of the book. Buckles are more likely to occur when the bound edge is perpendicular to the paper grain direction.

Signatures, having different relative humidities, when bound together into books or magazines, will all come into equilibrium with each other and with the surrounding atmosphere. As this happens, the dry papers will take on moisture and grow while the high moisture papers will give up moisture and shrink. Such a dimensional change in the bound, trimmed product will cause the finished edges to become uneven and unsightly. This condition is referred to in the trade as "starts." Starts are more likely to occur when signatures are bound parallel to the paper grain **(Figure 5)**.

### SUMMARY

An understanding of paper, the interactions that occur between paper and its environment and its reaction to changing moisture content, is critical for those who are in the business of printing and processing paper.

Certain key factors should also be kept in mind to ensure that problems with paper due to moisture imbalance are minimized. Probably the most important of these is to monitor the relative humidity of the environment in which paper is processed. This can be accomplished very simply and at very little cost by using a sling psychrometer. Although more sophisticated instruments are available, none are more accurate than the sling psychrometer.

Extreme conditions of relative humidity are harmful and are to be avoided. In practice, troubles are more commonly encountered when the relative humidity of the processing environment gets below 35% or above 55%-60%. Of these two extremes, low relative humidity of the processing environment (below 35%) is generally more serious and costly.

Assuming the printer or converter receives paper in the 40%-45% relative humidity range, which is probably the best all-around level for sheetfed operations, the best way to prevent problems is to control the relative humidity of the processing environment to this same range, 40%-45%. If this is not possible, the extremes above 55%-60% and below 35% should be eliminated or at least minimized. Although it can be quite costly to lower high humidity levels below the 55%-60% range, the most troublesome extreme, below 35%, can be corrected with minimum expense by using inexpensive devices to spray water and/or steam into the air. In the central and northern portions of the United States, this simply requires the use of such devices (water and/or steam sprays) during the winter months—when the inside air is heated. However, for the Southwestern United States and the higher elevations of the Western United States, the use of these spray, moisture-addition devices may be necessary throughout the year.