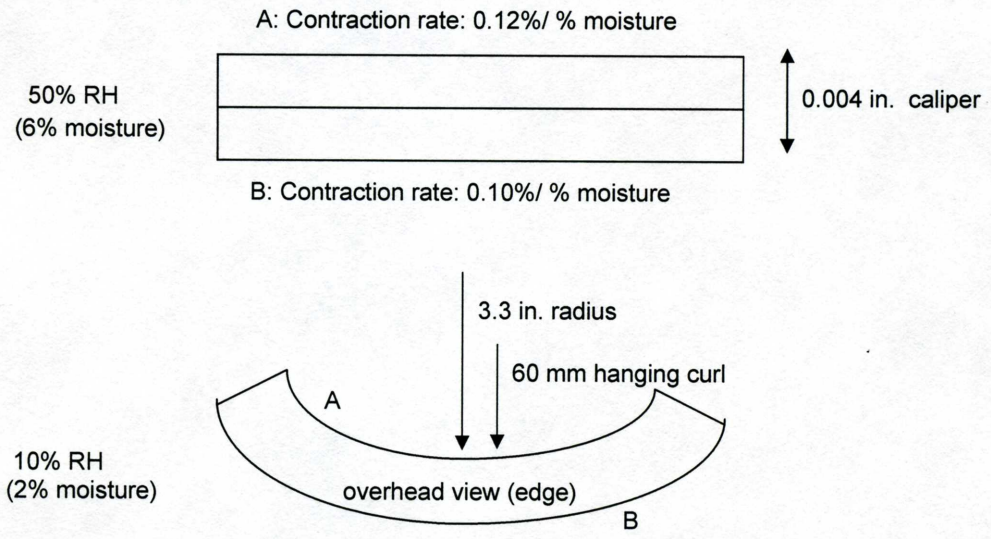
Basically curl occurs when layers within a sheet expand or contract unevenly when they originally started out at equal length. Uneven shrinkage (or expansion) produces a bending moment because of uneven shear forces. The simplest situation is that a sheet is made up of two layers of equal thickness. In fig. 1 there is a layer A, which contracts at the rate of 0.12% for each percent of moisture loss. Layer B contracts at the rate of 0.1% for each percent moisture loss. In losing 4% moisture, surface A contracts 0.48%, while surface B contracts 0.4%. Without applying an opposing bending moment, the sheet will curl toward surface A. In this case the curl radius formed is about 3.3 inches. (Some assumptions are that there are no other outside forces such as gravity and the elastic modulus of both layers are nearly the same.)

Figure 1. Curl from humidity changes (edge view)



CAUSES OF DIFFERENTIAL CONTRACTION (OR EXPANSION)

Differential contractions can result from

1. A difference in fiber orientation between the two layers.
2. A difference in composition. For example, fines, filler and coatings.
3. Bending a sheet about a small radius.
4. Passing a sheet through a xerographic copy machine fuser

Sometimes several of these are combined to produce curl. The first three can affect copy machine curl also.

DIFFERENTIAL FIBER ORIENTATION

Perhaps the most frequently encountered problem is that of differential fiber orientation. A difference in orientation develops as the result of velocity differences between the forming fabric and the slurry forming the paper. To improve curl we can adjust "jet" speed in small increments of 10-20fpm, at the same wire speed. After an adjustment is made, curl is measured. This procedure is repeated to obtain a jet speed that produces minimum curl (whatever curl measurement is used). *A more fundamental approach would be to measure coefficient of moisture expansion (CME) or tensile stiffness index (TSI) of sheets that have been split in thickness* (appendix A).

A characteristic of differential fiber orientation is the "dual" curl behavior that may be seen in these papers. Such a behavior is illustrated in fig. 2. *MD axis curl to the wire side would occur when fibers are more oriented on the wire side.*