Image analysis standardization

Charles S. Moss

ABSTRACT: With the routine use of image analysis, there is a definite need for standardization in the pulp and paper industry. Since image analysis uses basic concepts, creation of a standardization package should be easy. This paper discusses what to expect from standardization, how it might occur, and the variables that interfere or affect standardization. There is a specific proposal for standardization with concomitant questions.

KEYWORDS: Accuracy, bibliographies, calibration, image analysis, measuring instruments, standards.

A thousand points of light

Is there a need for another good image analyzer? The paper industry now has a multitude of image analyzers that produce voluminous data that operators manipulate for their specific purposes. Operators may gather a thousand points of light or, rather, a thousand points of nonlight. Image analysis' main concern, however, must be the calibration of these points. The equipment configurations usually provide reasonable data. Nevertheless, equipment manufacturers scurry from one laboratory image analyzer to another hoping to achieve consistent results. In the end, they only find frustration with the realization that such an image analyzer does not exist.

Paper manufacturers are writing specifications for new equipment, processes, and entire systems using data from their image analyzers. No equipment manufacturer or consulting firm can relate to these specifications from image analysis without using means which are less than exact.

All systems are equal

There is no need for variations in measurements with image analyzers. All image analyzers in existence have several things in common that should make standardization simple. They all rely on detection of gray levels. **Figure 1** depicts gray level detection. These gray levels are the shade variations which the imaging system differentiates between pure white and pure black. Gray level detection is the ability of the imaging tube to sense an image lighter or darker than the surrounding background according to the intensity of the gray level output of the image. An analyzer with more gray levels can differentiate more sensitively. It is common to have units with more than 250 gray levels.

As an example, an image analyzer should be able to distinguish a colored or black speck on a background of white fiber or vice versa. It should also be able to detect a dark brown shive on a light brown background. All image analyzers have this capability, and almost all can vary their sensitivity. This is the fundamental concept that makes them image analyzers.

Another common denominator for all image analyzers is that they detect images on a pixel basis. A pixel is a picture element. One scan line is one pixel high. One may consider a phosphor dot as one picture element. A minimum of 2 pixels is necessary for repeatable linear detection. Some investigators argue that the square of this minimum, 4, is the minimum resolution necessary for area measurement. Earlier work has shown that it is possible to detect an image that has less than 2-pixel resolution at anywhere from 2 pixels to 9 pixels *(1)*. In addition, the finer calibration levels provide significantly better repeatability. **Figures 2 and 3** provide examples of detection limitations.

There is one more common trait in all image analyzers. They use a sensing device that records an image through a focusing system. This focusing system is generally a photographic lens or a microscope.

It is this latter feature which makes standardization difficult. Images can vary due to changing apertures and focal lengths, sensitivity of the camera, lighting intensity and angle, and the lens-mounting system. Aperture settings within the arbitrary system are a factor only when there is no standardization of gray levels.

It is possible to set all the above factors to measure a specific standard particle size with a given gray level background to report a specific standard area in square pixels. When this happens, there is standardization. **Fig-**

Moss is manager, research and development for Celleco Hedemora, Inc., 1000 Laval Blvd., Lawrenceville, GA 30243.

ure 4 shows that the absence of proper gray level standardization causes area counts which can vary by huge factors.

Too many variables spoil the broth

The type of material within a slurry undergoing processing for debris analysis is phenomenal in its range of size and type. Nevertheless, there is a standardization based on the weight of material corresponding to a given slot size. The debris collection equipment operates in a specific way, uses specific plates, and runs for a specific time. These factors produce a standardized report. With consistency with standardized slot sizes and the slurry for processing the debris through a fractionator, any laboratory can measure the material and obtain comparable results. Although there may be variations in pulsing similar to detection settings, similar results will occur provided the slot sizes are accurate.

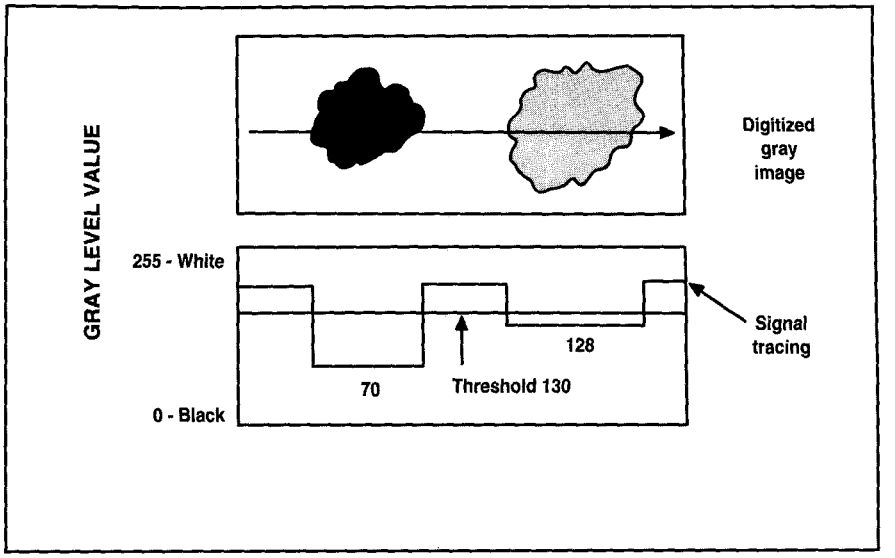
TAPPI Test Methods T 214 and T 436 as well as CPPA Method D 36 P have existed for many years for the measurement of visual dirt and are the accepted standard for dirt reporting *(2-4)*. This visual count standard is the basis that almost everyone uses for image analysis standards. **Figure 5** shows a standard dirt comparison card. The observer matches each dirt speck with one of the printed specks on the edge of the card.

One invariably reports image analysis as ppm larger than 0.04 mm^2. This is the smallest speck size acceptable for visual counting in the TAPPI method. The question arises, however, whether this size should remain as the standard threshold for equipment operation.

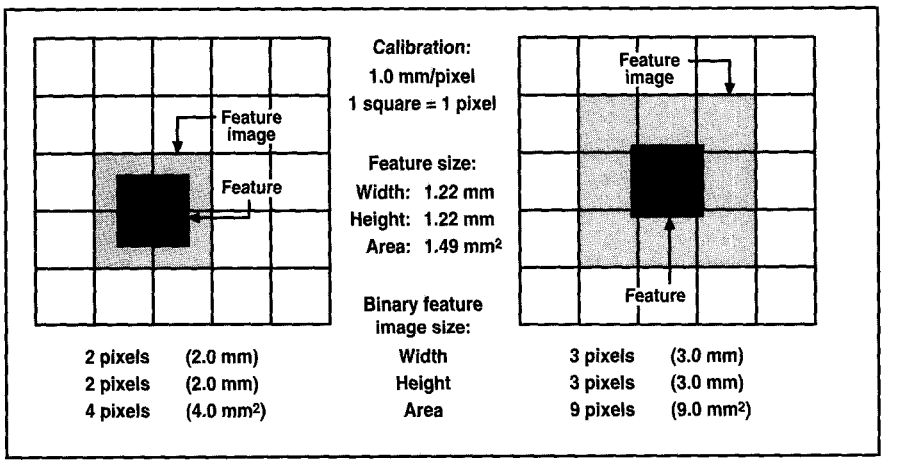
Standardization is only a word

Standardization is the acceptance of the application of a procedure to all similar test equipment to produce comparable results. Standardization for image analysis would mean that results for a sample measured at any

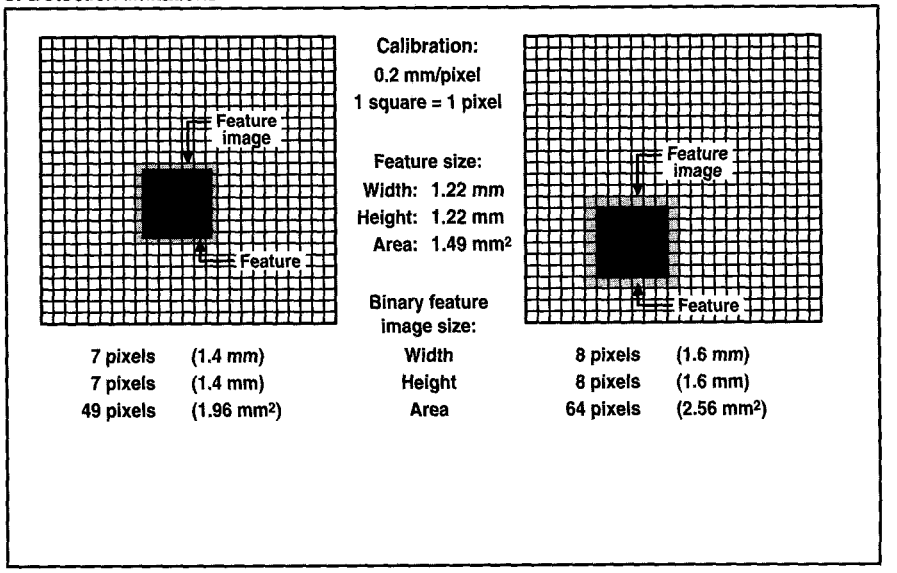
1. Gray level detection



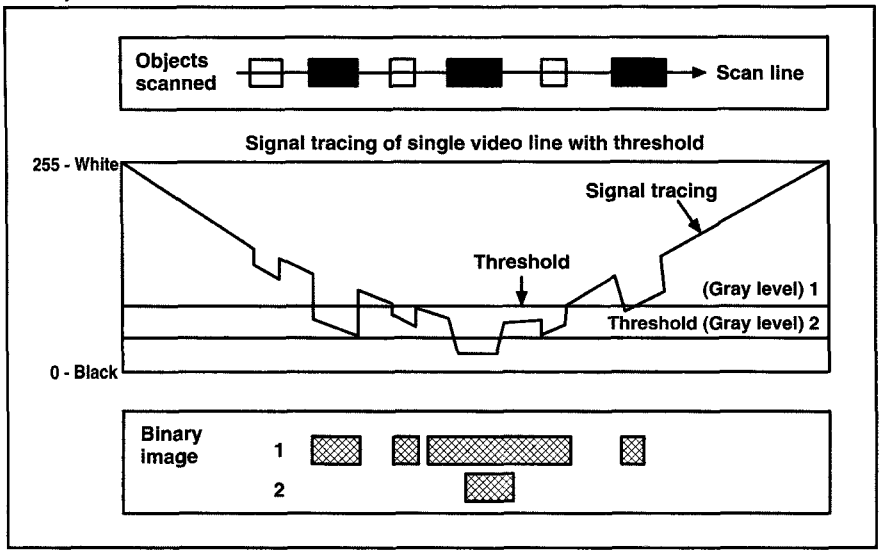
2. Detection limitations



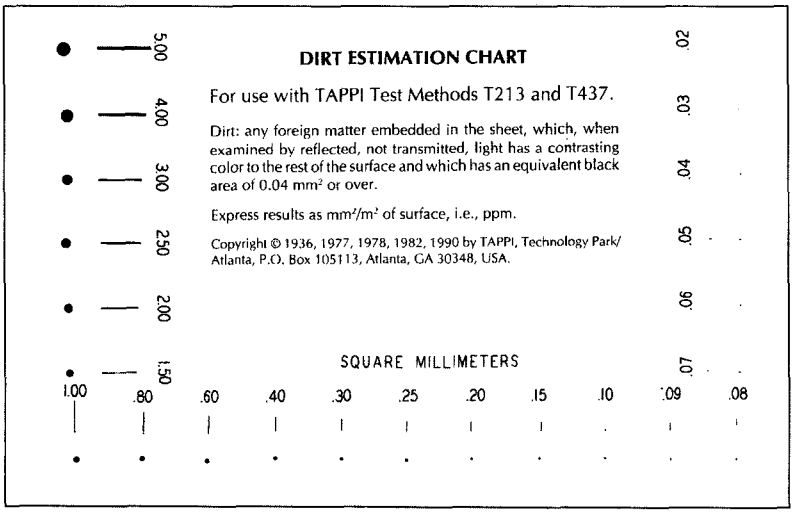
3. Detection limitations



4. Gray level detection variances



5. A standard dirt comparison card



The TAPPI Dirt Estimation Chart as shown here is a reduced copy of the actual Dirt Chart. The size of the spots and rectangles printed here are, therefore, not the proper size as indicated on the scale. Reproduced copies of the TAPPI Dirt Chart, as printed here or in any other printed material, whether printed full size or to scale, are not acceptable substitutes for the photographically printed Dirt Charts referenced in TAPPI Test Methods T 213 and T 437. Individuals who wish to use these methods and the Dirt Estimation Charts for estimating dirt in paper or pulp should use only the photographically printed charts, which are available from TAPPI PRESS.

test facility would agree within ± 10% of the value from any other image analyzer.

Although image analyzers have the common elements noted above, they also have many things that vary. The electronic versatility of the analyzers can vary just as much as the variations in electron microscopes can vary their output. The size of the image at a given magnification does not change from microscope to microscope, however. This is the item that can produce standardization.

Numbers never lie

Let us examine why results vary. One must select a specific amount of detection at a specific gray level background to achieve a specific pixel output. An accurate image representation without shadowing is also necessary. Image analysis operators are not able to do this. A standard lighting arrangement and several standard templates are necessary. Each template should have a gray level background to simulate a specific color range or a certain pulp type: bleached pulp, unbleached pulp, groundwood, semibleached pulp, or recycled newsprint. Each template should have standard area images from 70 μm diameter (0.0038 mm²) to 100.67 μm² as **Fig. 6** indicates. There should be a benchmark of 0.04 mm² for pulp and paper cleanliness. This level is standard for all papermakers and equipment manufacturers alike for quality and guarantees.

There should likewise be another standard for research purposes from 1–70 μm diameters as **Fig. 7** depicts on similar gray level backgrounds with a benchmark at 20 μm. This is the size at which smaller specks disappear within a matrix of fibers. Counts of ink pockets make individual particle counts impossible with more than a single layer of fibers within paper and pulp handsheet samples.

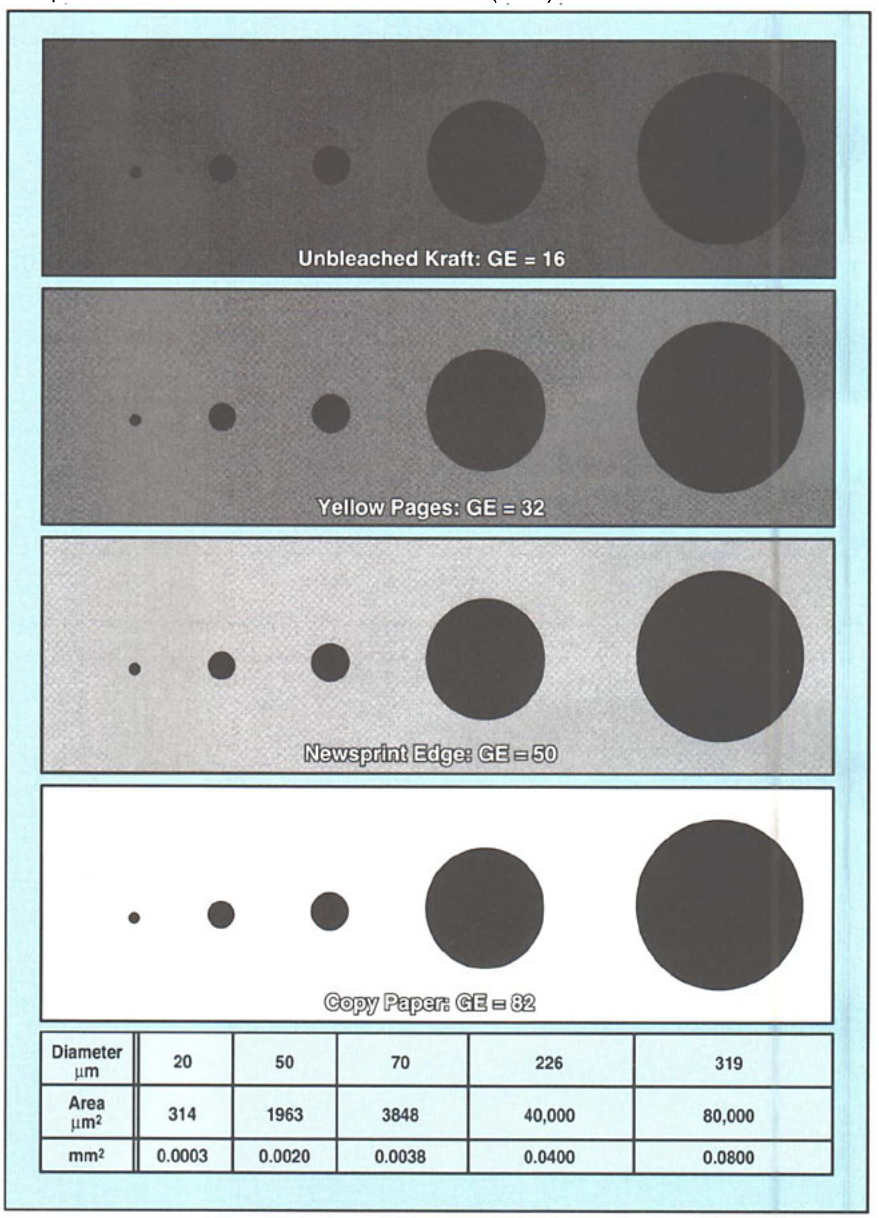
One need only place the standard for test purposes under the optical system and adjust the analyzer gray level, magnification, and sensitivity so the benchmark particle measures a 3-pixel

diameter (7.07 pixel^2). This provides standardization. It is certainly not difficult. Only scanners with immovable optics will present a problem. These instruments find general use for quality control and comparative results, however, rather than for communication of specifications between companies. There is equipment that "virtualizes" images with mathematical transforms to the impact visualized by the human eye. This is a complex feat, but it is not necessary to virtualize the image when you already have an accurate image. Using only area and not effective black area provides straight-forward imaging.

Seeing light through the looking glass badly

Lighting of sample sheets is critical. One must take care to ensure there are no shadows enlarging particle size. The opposite is true as well. Excessively bright or direct light must not minimize the image or cause a reflection. Previous work has shown that diffuse (fluorescent) light situated at 45° on two sides of the imaged area produces the most accurate image. Note that this eliminates the use of transmitted light. One should only use this method for internal testing. Any image analyzer with a movable light source will have no trouble with this technique.

6. Proposed visible standards with micro benchmark (130X)



Diameter µm	20	50	70	226	319
Area µm^2	314	1963	3848	40,000	80,000
mm^2	0.0003	0.0020	0.0038	0.0400	0.0800

Color problems

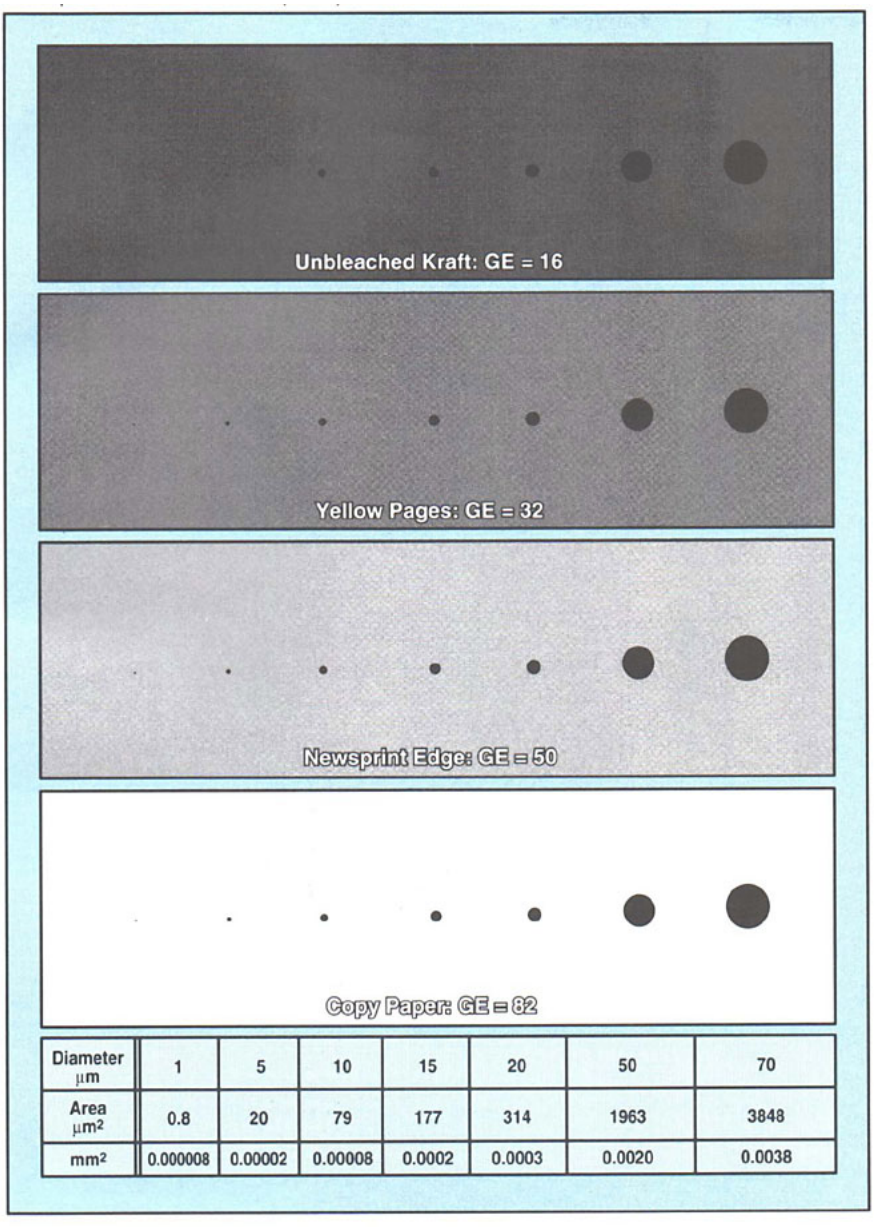
How can one use gray level standards to read colored inks or black inks on colored paper? Does gray level mean anything when referring to color? Yes, it does.

Reading a standardized brightness produces a result. Placing a gray level standard on the same instrument provides a result from a standardized instrument. One should use the closest gray level standard to the compared sheet brightness and continue with it. Any report should reference that standard. Obviously this is a simple technique.

The processing of repulped magazines includes white coating and inks of all colors. Standardizing on gray level and particle size only, one cannot count yellow and black ink at the same time. Where is standardization now? This is the toughest of all problems.

Inks are not just black. They are yellow, red, and a wide variety of colors. I suggest using a color filter over the optical system to change bright colors to a specific green of 550-nm wavelength. This will change pastels, yellows, etc., to dark green (a darker shade of gray). Black is still black. Although there will be no count of green specks, few in many are a small sacrifice. One should standardize with both the filter and gray level standard in such instances. Then one should count as without the filter but always report its use! Benchmark standardization works.

7. Proposed micro standards (130X)



Diameter µm	1	5	10	15	20	50	70
Area µm²	0.8	20	79	177	314	1963	3848
mm²	0.000008	0.00002	0.00008	0.0002	0.0003	0.0020	0.0038

Researching the specks or methods of reporting

Counting handsheets

Unfortunately, standards do not have short cuts. One must generate counts from a minimum number of fields to achieve a certain degree of statistically correct accuracy. With the universal goal for cleaner pulp, this accuracy becomes more difficult.

There are only four types of samples to analyze in the real process world of pulp and paper: inlet, accept or final product, heavy reject, and light reject. Do all require the same manner of handling? Yes, there are no short cuts. I propose counting 55% (minimum of 65% is possible) of a standard British sheet using a square scan of each side (top and bottom) for a total of five sheets. This will equal a counted area of 0.01 m^2. This requires multiplication by 100 to obtain ppm. It does not matter if the tabulated area contains size groups or bins for presentation purposes. Such counts, however, must also be in ppm. The comparison must be to total ppm which must also be in the report.

Micro counts

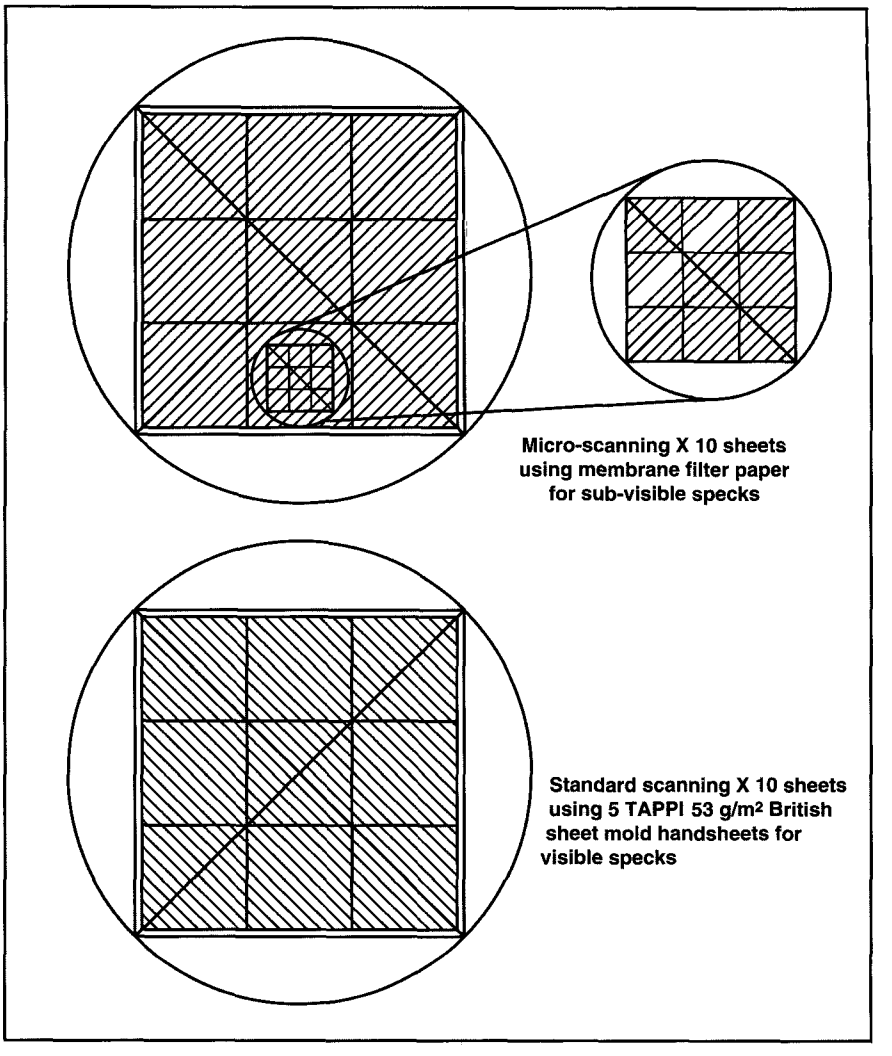
It would be impossible to count the areas mentioned above when using the sub-visible standard scale suggested. The easier and more statistically correct method would be to report μm^2 on a ppm basis. The information above would reduce by a factor of 10^6. Now mm^2 becomes μm^2, and m^2 becomes mm^2. The same relative scan areas will apply but on a µm basis. If one used 9 scans per side before, one would use the same number of scans now as indicated in **Fig.** 8.

There is a problem, however. Micro counts cannot accurately count specks in a matrix greater than one layer of fibers. There must be a serial dilution to deposit fibers of a density no greater than 1 mg/m^2. Micro formation access is on the top side only. There is no bottom side, and again there is no short cut. Ten individual samples are necessary with counting of 55% of each sample formation. This relates to the benchmark of 20 µm equalizing 3 pixels in diameter. Although researchers may use smaller benchmarks, the ratio of scan to area would not be "standard." Although such information may be very valuable for demonstrating equipment performance or product quality, one must not use it as a quality or performance guarantee. Since the end product is a web or matrix of fibers, basing such information on sizing less than 20 µm will cause trouble. One must always adhere to standardization.

Conclusion

I am proposing this type of standardization out of frustration—research frustration. When someone reports 80% efficiency of 20 µm particle removal, I want it to be truthful according to a TAPPI test method. I want to report my results accurately for system efficiency, equipment removals, quote guarantees, and comparative buyer's guide benchmarks. I am not attempting to stifle any inventiveness for new research techniques. It is possible to base speck size in internal re-

8. Visible and sub-visible scan areas



ports on "jackrabbits squared," if one wishes, but industry information and comparisons cannot continue to work that way. There are too many jackrabbits out there already. Why square them? ◧

Literature cited

1. Scott, D. and Bliss, T. L., *TAPPI 1991 Pulping Conference Proceedings*, TAPPI PRESS, Atlanta, p. 997.
2. TAPPI T 213 om-85, "Dirt in Pulp."
3. TAPPI T 437 om-85, "Dirt in Paper and Paperboard."
4. CPPA D 36 P, "Dirt in Paper."

Received for review May 25, 1993.

Accepted May 28, 1993.

Presented at the TAPPI 1993 Process and Product Quality Conference.