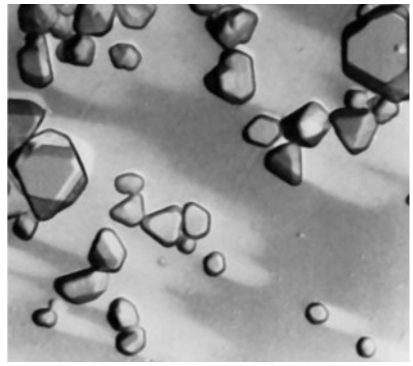
KODAK T-GRAIN® Emulsions

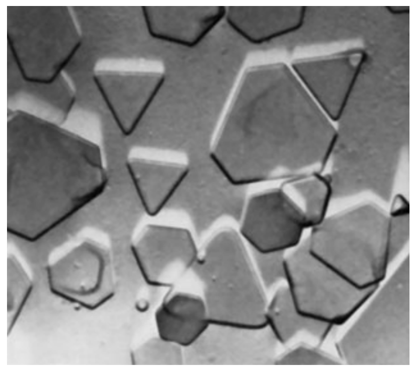
In recent years a new type of emulsion has been incorporated into some Kodak films. If we view conventional silver-halide grains (described above) under the scanning electron microscope, they appear as eight-surface solid cubes or irregularly shaped pebbles. The faster the film, the larger the grain—which gives the so-called "grainy" look. Kodak scientists have discovered that if the grain shape is changed to a flatter shape, the crystals intercept more light but the total amount of silver does not increase, allowing for an increase in speed with less noticeable grain. The new emulsions are called T-GRAIN Emulsions because of the flat, tabular shape of the grains. In 1991, Eastman Kodak Company's Motion Picture and Television Imaging received an Oscar from the Academy of Motion Picture Arts and Sciences for incorporating T-GRAIN Emulsion technology into motion picture films.

By incorporating T-GRAIN Emulsions into film structures, Kodak can achieve overall improvements in the film quality, not just speed and grain. Not all T-GRAIN Emulsions perform better than conventional ones. Therefore, some film emulsions are a combination of both conventional and T-GRAIN Emulsions.

If the uniform dot pattern of a conventional halftone is used to reproduce a scene, the eye accepts the image as a smooth, continuous-tone rendition. This happens because the dots are regularly spaced. However; when halftone dots are distributed randomly in an area to reproduce a changing scene the image looks "grainy." Graininess in the image is due, in part, to the random distribution of the individual elements which make up that moving image.



Conventional silver-halide crystals



KODAK T-GRAIN Emulsion crystals

Figure 16

Incorporating T-GRAIN Emulsions into a film improves film speed without sacrificing fine grain. The uniquely shaped grains align better than conventional silver crystals, absorbing and transmitting light more effectively.

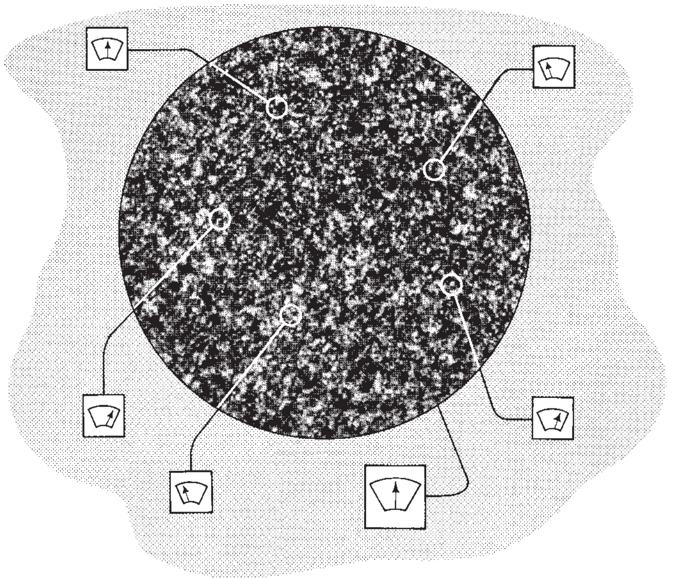


Figure 17

A large aperture "sees" a vast number of individual silver grains. Therefore, small local fluctuations have practically no effect on the density it records. Small apertures (about one-twentieth of the larger aperture diameter) detect random differences in grain distribution when they sample the large "uniform" area.

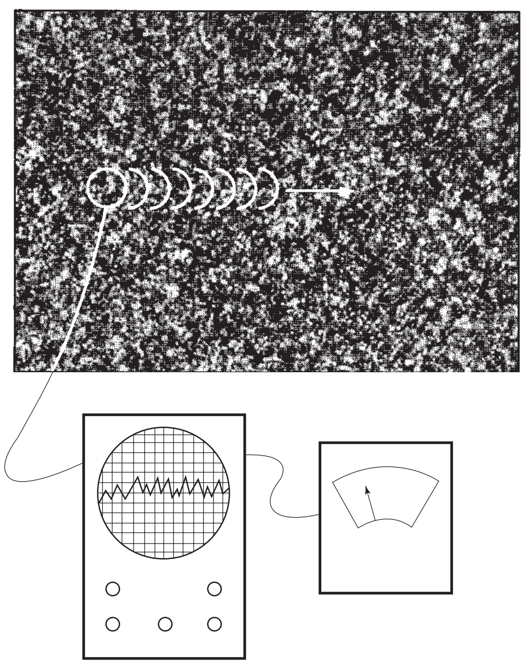


Figure 18

The signal from a continuous density scan of a grainy emulsion appears the same as random electrical noise when displayed on an oscilloscope. The rms voltmeter gives a direct readout of "noise level."

Measuring RMS Granularity. The attributes of the photographic image which cause the human eye to perceive graininess can also be measured (and simulated) by an electro-optical system in a microdensitometer. These measurements are analyzed statistically to provide numerical values that correlate to the visual impression of graininess. The two major advantages of objective measurement are that instruments can be devised to make rapid and precise measurements and that these measurements can be manipulated readily by mathematical means.

Ordinary densitometers measure density over areas much larger than those of individual silver particles. Since there are so many particles in the aperture area of an ordinary densitometer, small variations in the number of particles measured will not affect the reading (**Figure 17**).

Just as higher magnification increases the apparent graininess, a decrease in the aperture produces higher granularity values. When the aperture of the densitometer is considerably reduced, fewer particles are included and a small change in their number is recorded as a variation in density. Analysis of the magnitude of these variations gives a statistical measure of the granularity of a sample.

In practice, an area of *apparently uniform* density is continuously scanned by the small aperture usually 48 microns in diameter. The transmitted light registers on a photosensitive pickup; the current produced is then fed to a meter calibrated to read the standard deviation of the random-density fluctuations (see **Figure 18**).

Standard deviation describes the distribution of a group of values (in this case, variations in density) about their average. The square root (R) of the arithmetic mean (M) of the squares (S) of the density variations is calculated—hence, the term RMS granularity. For ease of comparison, this small decimal number is multiplied by a factor of 1,000, yielding a small whole number, typically between 5 and 50.

The RMS granularity instrument used at Kodak is calibrated to measure American National Standard Institute (ANSI/NAPM IT2.19-1994) diffuse visual density. The granularity values for Kodak black-and-white and color negative films are determined at a *net* visual density of 1.0, while the values for reversal and direct duplicating films, both black-and-white and color, are determined at a gross visual density of 1.0. KODAK Motion Picture Films are read with a circular aperture 48 microns in diameter. This aperture size gives meaningful readings over the widest range of film samples.

Factors That Affect Graininess

Different developers and different amounts of development affect the graininess of black-and-white films. The amount of exposure, which determines the densities of various areas, also affects the graininess of all films. Because the development processes of color films are rigidly fixed, the effect of development is rarely a factor in their graininess (however; force processing does cause an increase in graininess). Because many color films are made with emulsion layers of varying graininess levels, increasing the exposure (up to a point) places more of the density in the finer-grained layers, which actually reduces the overall graininess of the observed images.

Granularity and Color Materials.

One might expect a photographic image made up of cyan, magenta, and yellow dye clouds to appear more grainy than the corresponding silver image. In fact, close to its resolution limit, the eye sees only brightness differences and does not distinguish color in very small detail.

When color films are projected, the dye-cloud clusters form groups similar to silver-grain clusters in black-and-white films. At high magnifications, these clusters cause the appearance of graininess in the projected screen image.

The illustration of cyan layer dye clouds (**Figure 19**) shows how the dye clouds are formed around the developing silver grains and how the dye clouds visually associate into clumps when there are several development centers close to each other.

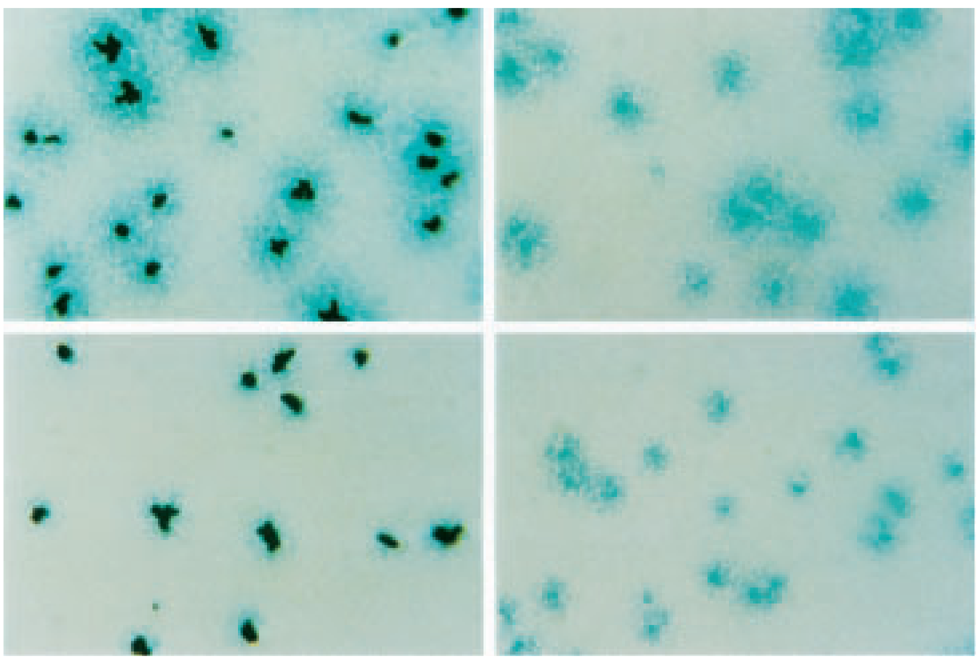


Figure 19

The above illustrations are 1200X photomicrographs of a special cyan color film layer with incorporated coupler made very thin to permit showing the structure. The upper left picture is the film after color development and shows the metallic silver grains surrounded by dye clouds. The upper right picture shows another area of the same film after bleaching and fixing with the grain removed. The lower two pictures show the same type of film developed with a color developer containing a completing coupler, which reduces the size of the dye clouds; hence, reducing the graininess.

Some Practical Effects of Graininess and Granularity

The photographer wants a fine-grain film but not at the expense of sensitivity or film speed. Faster films usually have larger grains because larger silver-halide crystals have a greater probability of being struck by light and made developable. Large silver-halide crystals normally develop to larger particles of metallic silver. Thus, the selection of a film is usually a compromise between available speed and tolerable grain. With today's Kodak films, grain size no longer seems to be a problem.

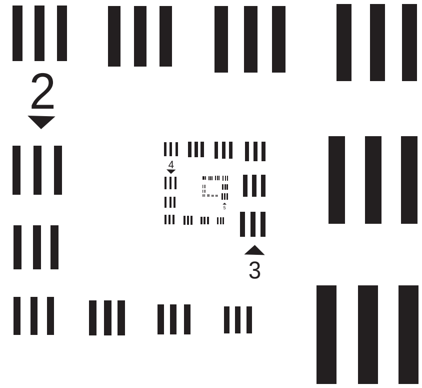
Kodak photographic scientists are constantly seeking more favorable speed-grain ratios. But the relationship of emulsion speed to the grain structure is also a vital concern to the photographer because the speed-grain relationship indicates whether the emulsion will detect light and, if detected, will form a recognizable image. If a biologist needs to record the life processes of an amoeba on film, the amount of allowable light is partly limited by the temperature tolerance of the amoeba. If fast film is used to compensate for limited light, the granularity must be low enough for the film to record the detail required by the application. Certainly the viewer should not have to wonder whether the movement on the screen is the amoeba's digestive process or "crawling" grain clusters. As you may recall from page 23, choosing a film with T-GRAIN Emulsions could be very beneficial in this type of photography.

Graininess is most evident in the midtones of a print (i.e., densities of about 0.6 to 0.9). The light tones of the print are on the toe of the characteristic curve where the slope is very much lower than unity. Hence, the contrast with which the graininess is reproduced is very low—decreasing its visibility. In dark tones, the eye is less able to distinguish graininess. The eye easily detects density differences as low as 0.02 in the average highlight density, but can detect density differences only on the order of 0.20 in the average shadow density. In the midtones, where the slope of the curve is constant, the print material has its maximum contrast and the eye can more readily distinguish small density differences; therefore, the granularity can be most easily detected by the eye as graininess.

Another factor in perceiving graininess is the amount of detail in a scene. Graininess is most apparent in large areas with fairly uniform densities and is much less evident in areas full of fine detail or motion.
It is difficult to predict the magnification at which projected print images will be viewed since both the projection magnification and the distance from the observer to the screen can vary. Both factors affect the picture magnification, and thus the sensation of graininess.

When a motion picture film is seen at great magnification (as from a front-row theatre seat), the viewer may be aware of grains "boiling" or "crawling" in uniform areas of the image. This sensation is caused by the frame-to-frame changes of grain positions, which make graininess, because of the motion, more noticeable in a motion picture than in a still photograph. Conversely, the moving image of the scene tends to distract the viewer's attention away from this sensation, and graininess is, therefore, usually noticed only in static scenes.

Resolving Power. The resolving power of a film emulsion refers to its ability to record fine detail. It is measured by photographing resolution charts or targets (see **Figure 20**) under exacting test conditions. The parallel lines on resolution charts are separated from each other by spaces the same width as the lines. The chart contains a series of graduated parallel-line



This drawing shows a standard resolving-power test object.

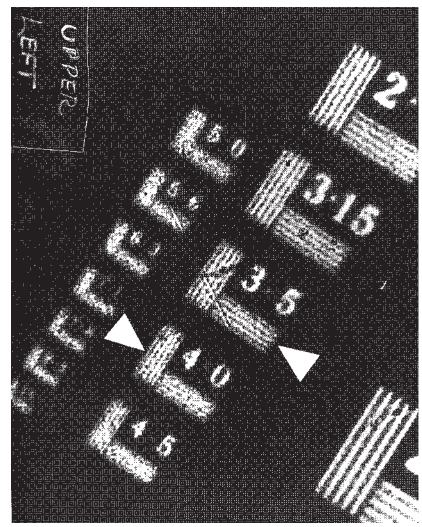


Figure 20

This is an enlarged view of the film images of a five-line resolving-power target imaged in the optical field by a photographic lens. Astigmatism causes the resolving power to be slightly lower in one direction than the other.

groups, each group differing from the next smaller or next larger by a constant factor. The targets are photographed at a great reduction in size and the processed image is viewed through a microscope. The resolution is measured by a visual estimate of the number of lines per millimetre that can be recognized as separate lines.

The measured resolving power depends on the exposure, the contrast of the test target, and the development of the film. The resolving power of a film is greatest at an intermediate exposure value, falling off greatly at high- and low-exposure values. Obviously, the loss in resolution that accompanies under- or overexposure is an important reason for observing the constraints of a particular film when making exposures.

Resolution also depends on the contrast of the image, hence, the contrast of the target. Test exposures usually made with both a high-contrast (luminance ratio 1000:1) and a low-contrast (1.6:1) target. A film resolves finer detail when the image contrast is higher. Both high- and low-contrast resolving-power values are determined according to a method similar to the one described in ISO 6328:1982, *Photography—Photographic Materials—Determination of ISO Resolving Power;* and ANSI/PIMA IT2.38-1998, *Method for Determining the Resolving Power of Photographic Materials*. The resolving power is based on film exposed and processed as recommended.

The maximum resolution obtainable in practical photographic work is limited both by the camera lens and by the film. The formula often used to predict the resolution of a camera original is:

$$\frac{1}{R_S^2} = \frac{1}{R_F^2} + \frac{1}{R_L^2}$$

R_S = Resolution of the system (lens + film)
R_F = Resolution of the film
R_L = Resolution of the lens

In practice, other external factors, such as camera movement, focus, aerial haze, etc., also decrease the resolution from the possible maximum.

Although resolving power provides an indication of the sharpness of a particular film stock to a specified test target, Modulation Transfer Function (MTF) is most often used to predict and model the sharpness of a film in an imaging system (see "Modulation Transfer Curve" on page 38).

Processing

General

Most Kodak color negative motion picture films are processed in Process ECN-2; color print films in Process ECP-2D; color reversal and B&W negative films in Process VNF-1 or RVNP. Kit chemicals are also available for Processes ECN-2 and ECP-2D. Additional information on processing and other laboratory operations begins on page 68.

Force Processing

Force processing is the technique of overdeveloping film that has been underexposed intentionally or not. This industry-wide practice is considered a normal working tool by many cinematographers.

Many commercial film laboratories offer force processing of both negative and reversal camera films. The following tips will make your use of force processing more successful:

- Discuss your needs (in advance of your assignment, when possible) with the customer service representative or the lab manager. A quick phone call usually gets an answer. Don't forget to ask about the cost involved.
- The lab may give filter recommendations. This helps to avoid unwanted color balance shifts that may occur due to the overdevelopment.
- Be aware of the limits of the process. Decide beforehand whether you can accept the loss in image quality that usually results from force processing. Consult the processing lab personnel.

Laboratory Aim Density (LAD) Control Method

To assure optimum quality and consistency in the final prints, the laboratory must carefully control the color timing, printing, and duplicating procedures. To aid in color timing and curve placement, time the negative originals relative to the Laboratory Aim Density (LAD)* Control Film. The LAD Control Film provides both objective sensitometric control and subjective verification of the duplicating procedures used by the laboratory. There are specific LAD values for each type of print or duplicating film onto which the original can be printed.

Film-to-Video Transfer

Transferring film from a negative directly to videotape is a universal process. For video release, transferring images produces excellent quality, while still maintaining an image originated on film (a worldwide standard), that can be used anywhere, including theatrical release. NTSC (National Television Systems Committee) video images are not conducive to producing the best transfer quality to systems (PAL, SECAM) other than the U.S. national standard, NTSC. There is a difference in frame rates as well as other factors.

When transferring film directly to video, typical flying spot scanners or solid-state imagers may be set up with the appropriate Telecine Analysis Film (TAF)†. This film is supplied by Eastman Kodak Company as a negative, intermediate, or print, and consists of a neutral-density scale and an eight-bar color test pattern with a LAD gray surround.

The TAF gray scale can provide the scanner operator (colorist) with an effective way to evaluate subcarrier balance and to center the telecine controls prior to timing and transferring a film. The TAF color bars are intended to provide the utility of electronic color bars. With proper color matrixing in the telecine for the film type being transferred, TAF color bars should closely match in phase, electronic color bars, but at a reduced chroma level. Use of TAF will help obtain optimum quality and consistency in the film-to-video transfer.

* The LAD control method is described in the paper "A Simplified Motion-Picture Laboratory Control Method for Improved Color Duplication," by John P. Pytlak and Alfred W. Fleischer in the *Journal of the SMPTE*. October 1976. Also refer to KODAK Publication No. H-61, *LAD—Laboratory Aim Density*.

† For more information on TAF and its features, see KODAK Publication No. H-822, *KODAK Telecine Analysis Film User's Guide.*