CONTRAST MEASUREMENT OF BLACK AND WHITE NEGATIVE MATERIALS

The appearance in Britain of Contrast Index as a method of specifying the contrast to which a photographic negative material has been processed has revived interest in a subject which has not, in recent years, been the topic of a great deal of discussion.

Interest has so far centred on the comparison of Contrast Index with earlier measurement systems and on the practical value of contrast measurement to the various branches of photography. The notes which follow are intended to provide an objective view of Contrast Index and earlier methods of measuring contrast.

Contrast measurements provide a practical guide to the photographer by enabling him to choose a development time for a given film in a given developer which will produce a negative suitable for his particular enlarger on his preferred paper grade.

There are two basic ways of assessing contrast:

1. By measuring the slope of the 'straight line' portion of the characteristic curve (gamma) and
2. By measuring the average slope of the part of the characteristic curve that is most likely to be used in practice (various average gradient systems).

Gamma:

Gamma is defined as the slope of the straight line portion of the characteristic curve and is expressed as the value of the tangent of the angle that this makes with the log E axis (see Figure 1).

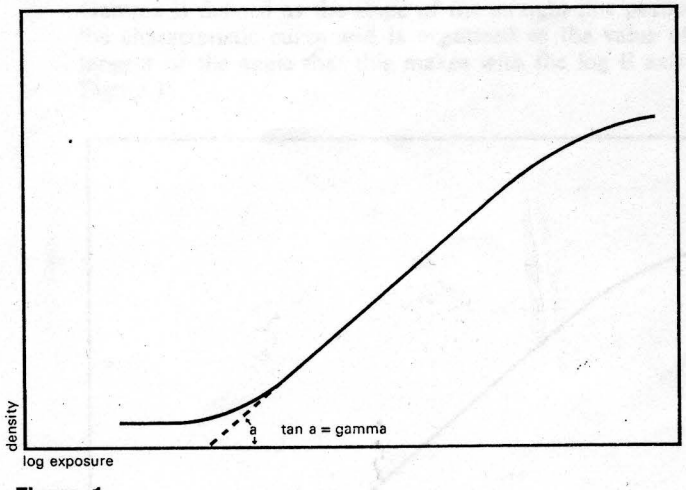

Figure 1.

If all emulsions produced characteristic curves of the same shape, with a long straight mid-section, and if all exposures were made on the straight line portion of the curve, gamma would be a perfect measure of contrast. A curve showing how gamma varies with development time would then provide a reliable guide as to how a particular emulsion should be developed in a particular solution to achieve a given overall negative contrast.

Unfortunately many modern emulsions do not have long straight line characteristics. Some modern emulsions have a short 'foot' whilst others have a long sweeping foot. In order to achieve optimum sharpness and graininess and to prevent excessively long exposures during printing, part of the exposure should be made on the foot of the curve and it is thus obvious that simply to measure the slope of the straight line portion of the curve will give no indication of the overall negative contrast (Figure 2).

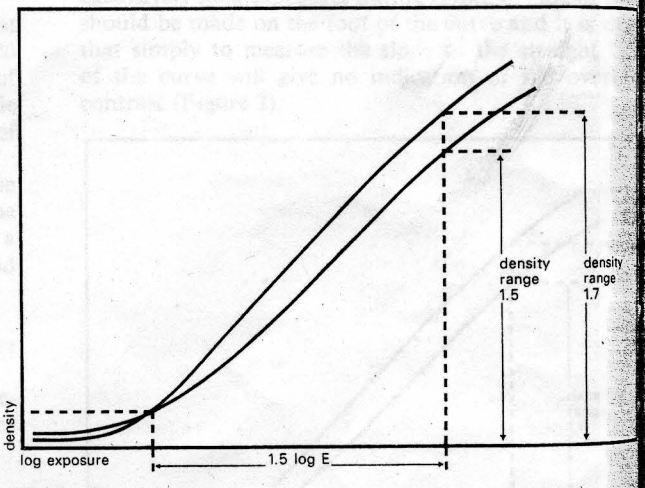

Figure 2.

Additionally many modern emulsions produce a 'bent leg' curve, that is a curve in which the slope at higher densities is lower than the slope at lower densities. With such a material it is impossible to measure gamma, which cannot then be used to predict the density range of the negative produced and does not give a reliable indication of the amount of development that the material requires.

Although gamma is of little use as a means of measuring negative contrast in general purpose photography, it is still sometimes used in certain specialised applications. In these cases correct tone reproduction in the photographic material is achieved by exposing in such a way that the exposure falls on the straight line portion of the characteristic curve, as for example in the production of duplicate negatives. In these circumstances gamma is clearly a satisfactory way of describing contrast.

Average Gradient Systems:
Ilford $\overline{G}$

The inadequacies of gamma for describing the contrast of general purpose monochrome materials were realised many years ago and led to the introduction of average gradient systems. As long ago as 1912 an article appeared in *The British Journal of Photography* by Renwick (1) where the point was made that the 'under-exposure' region of the characteristic curve is used in practice. But it was not until Loyd A. Jones carried out his work in America that any serious attempt was made to take this into account when expressing negative

contrast. Jones measured the brightness range and took photographs of many scenes and found that the average significant brightness range was 128:1, which was reduced by flare to 32:1 (i.e. 1·5 log E units) after passing through the camera lens. Statistical examination of many negatives showed that the minimum exposure which would produce an excellent print placed the deepest significant shadow at the point on the foot of the characteristic curve where the slope was 0·3 times the average gradient over a log exposure range of 1·5.

It was proposed that the slope of the line joining these two points should be taken as a measure of negative contrast. This system of contrast measurement was adopted by the American Standards Association on a basis for specifying the speed of general purpose photographic emulsions, and was used in ASA PH 2·5—1954. This method of obtaining the lower point in the curve was very difficult to work in practice and so the lower point was taken as being 0·1 density units above fog. This point was somewhat higher on the characteristic curve than that specified by Jones and consequently the log E range covered was reduced from 1·5 log E to 1·3 log E units in American Standard ASA PH 2·5—1960.

Ilford Limited have used an average gradient method for measuring contrast since the early part of the last war, when they adopted it to express the contrast of aerial film. This system was adapted for general purpose materials in the mid 1950's, and has appeared in Ilford Limited publications from that time.

The system currently in use by Ilford Limited for general purpose films defines the average gradient ($\overline{G}$) as being the slope of the line joining two points on the characteristic curve, one of which is 0·1 above fog and the other at 1·5 log E units greater exposure (Figure 3). Practical work has shown that

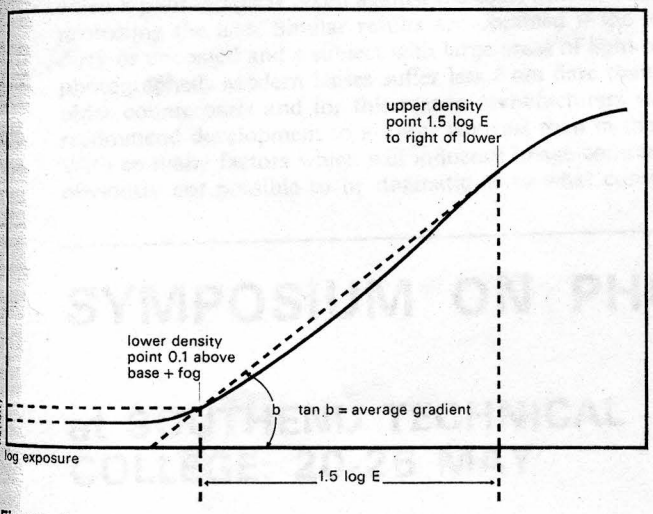

Figure 3.

with this system it is possible to produce similar prints on the same grade of paper from any of the general purpose films currently available. ($\overline{G}$ is referred to as *Gee-bar*.)

Contrast Index:

Contrast Index was introduced by Eastman Kodak (Rochester) in the early part of 1966, and is intended to supersede gamma which Kodak had used previously to determine development recommendations.

Like $\overline{G}$, Contrast Index is an average gradient system, but the two points are obtained in a different way from that used for $\overline{G}$. The lower point is found by describing an arc of 0·2 density (or log E) units radius whose centre is on the base plus fog axis. The upper point is obtained by describing the arc of 2·2 log E (or density) units using the same centre. The points where these two arcs intersect the characteristic curve give the lower

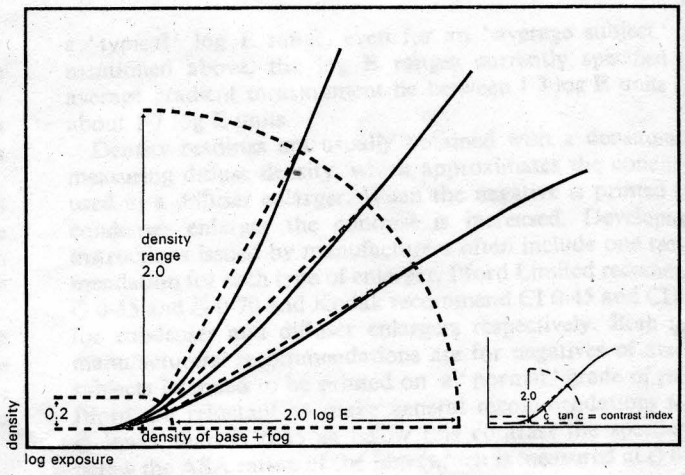

Figure 4.

and upper points. The centre of these arcs is positioned along the base plus fog axis in such a way that an imaginary straight line originating from the centre passes through both the upper and lower points simultaneously. With Contrast Index, as with $\overline{G}$, the value of the tangent this line makes with the log E axis is taken as the measure of contrast. It can be seen from Figure 4 that when the contrast of the material increases so the density of the lower point rises and the log E range covered becomes shorter. The maximum value for the minimum density point is 0·2 density units, which would be obtained if the contrast of a material with infinite contrast were being measured.

Comparison of $\overline{G}$ and Contrast Index:

As will be seen from the diagrams Contrast Index and $\overline{G}$ are both average gradient systems. The two systems yield numerically similar results on a wide variety of characteristic curves for various general purpose film and developer combinations.

Because the position of the lower point varies according to the slope of the curve being measured, it is most difficult to make accurate Contrast Index measurements without the use of a special meter. It is comparatively simple to make accurate $\overline{G}$ measurements from a curve without the use of such aids, as the positions of the two points are fixed.

Contrast Index differs from $\overline{G}$ in two details. $\overline{G}$ measures the average gradient between two points, one of which is a fixed density above fog (0·1) and a second point which is derived from a fixed log E range (1·5 log E unit). In Contrast Index the position of the lower point will vary according to the contrast of the curve measured, the maximum being, of course, at a density of 0·2 above base plus fog. The log E range covered will also vary according to the slope of the curve being measured: the higher the contrast the shorter the log E range covered.

When most general purpose materials are developed normally to a CI 0·5–0·6 the log E range covered is about 1·7 log E units, with a minimum density point at about 0·1 above base plus fog. This compares with the 1·5 log E range used by Ilford Limited in $\overline{G}$ and the 1·3 log E range used by the American Standards Association in their standard for film speed determination ASA PH 2·5—1960. Both of these systems specify a minimum density point of 0·1 above fog.

Contrast Index has an advantage over $\overline{G}$ when measuring higher contrast materials. In this class of work the minimum density used is usually 0·3–0·4 density units above base plus fog. For this type of material the minimum density point when using Contrast Index is about 0·15 density units and this goes some way towards meeting the practical requirements of the situation. Also the density range covered is usually lower than

with films for general purpose photography and again Contrast Index goes towards meeting this requirement. It should be mentioned that it is, of course, possible to alter the parameters employed for $\overline{G}$ measurements, and in fact Ilford Limited do this when measuring the contrast of such specialised materials as micro-film and aerial films.

Other organisations such as NATO also use a $\overline{G}$ system which is modified to suit the type of material in use. An example of this is NATO Specification Stanag. No. 3188, for aerial film which specifies the contrast as the average gradient between two points one of which is 0·4 density units above base plus fog and the other 1·0 log E units away. It is thus possible with $\overline{G}$ to specify precisely the limits which have been found to be the most useful in practice, whereas with Contrast Index the limits are clearly defined and cannot be so readily adapted to suit specific needs.

Some Practical Considerations of Contrast Measurements:

The systems in current use for contrast measurements have been briefly discussed above; these methods aim in general at describing the printing contrast of a negative and it may be worthwhile considering a few of the factors that influence the contrast of the final result.

Average subject brightness range is generally taken to be 128:1 which is reduced by flare in the camera considerably. The amount of contrast loss in the image will be influenced by such factors as the type of subject being photographed, the type of lens, the condition of the lens and light scatter within the camera body.

We are all familiar with the effect of overall flare produced when a photograph is taken against the light with no lenshood protecting the lens. Similar results are obtained if the lens is dirty or uncoated and a subject with large areas of light tone is photographed. Modern lenses suffer less from flare than their older counterparts and for this reason manufacturers tend to recommend development to a lower contrast than in the past. With so many factors which will influence image contrast it is obviously not possible to be dogmatic as to what constitutes a 'typical' log E range, even for an 'average subject.' As mentioned above, the log E ranges currently specified for average gradient measurement lie between 1·3 log E units and about 1·7 log E units.

Density readings are usually obtained with a densitometer measuring diffuse density, which approximates the conditions used in a diffuser enlarger. When the negative is printed in a condenser enlarger the contrast is increased. Development instructions issued by manufacturers often include one recommendation for each type of enlarger. Ilford Limited recommend $\overline{G}$ 0·55 and $\overline{G}$ 0·70 and Kodak recommend CI 0·45 and CI 0·56 for condenser and diffuser enlargers respectively. Both these manufacturers' recommendations are for negatives of average subjects intended to be printed on a 'normal' grade of paper. Ilford are reluctant to make general recommendations for a $\overline{G}$ lower than $\overline{G}$ 0·55 as below this contrast the speed-drop below the ASA rating of the film (which is measured at $\overline{G}$ 0·62) becomes significant.

Negatives processed to the Ilford Limited recommendations therefore tend to need a softer grade of paper than negatives processed to Kodak recommendations.

The wide acceptance of average gradient systems by the photographic manufacturers will, in time, dispel the confusion which has arisen over the term 'contrast.' Photographers will in future be able to achieve the same overall contrast from different films by developing to the same $\overline{G}$ or Contrast Index value.

In the past photographers may have chosen a film because it was 'more contrasty' or 'less contrasty' than another. It has been shown that by developing to the manufacturers' recommendations, it should be possible to obtain the same contrast with any general purpose film irrespective of speed or manufacturer.

References:

(1) The Under-Exposure Period of the Characteristic Curve. By: F. F. Renwick.
The British Journal of Photography—12 April 1912. 59, 2710, 289-290.