MR. VICTOR ELLIS: I am from Montclair, New Jersey and am a retired commercial photographer who knows very little about aerial photography. Would it not pay our Government to produce just one airplane of the type described by Mr. Miller?

MR. MILLER: Our Government, at least within the military corps, has produced a great many. However, in commercial mapping, we can't always take advantage of what's been produced through the military.

MR. REVERE SANDERS (Aeroflex Corp.): Some years ago Ted Abrams designed and constructed an airplane that was primarily designed for use in aerial photography. I'm sure that he was disappointed that no one seemed much interested in an airplane designed strictly for aerial photography.

MR. MILLER: Mr. Abrams for many years has been ahead of others in some aspects of mapping and photogrammetry, as we are all aware. His airplane was developed as a visionary venture, probably long before cameras, lenses, films, specifications and general mapping techniques evidenced the need for better negatives; and definitely prior to the time that photogrammetrists and their photogrammetric equipment were capable of utilizing better negatives. All of us in actual field operation regard with much reverence the airplane he developed, because it was very nearly the ideal design.

*The Influence of Atmospheric Haze on the Quality of Aerial Photographs**

J. L. TUPPER, *Research Laboratories, Eastman Kodak Company*

ABSTRACT: *An ideal aerial photograph is one in which the brightness and dimensional relationships of terrestrial details are reproduced without degradation or distortion. The problems involved in achieving this objective are numerous, not the least of which is that introduced by atmospheric haze. The visibility of an object is related to the brightness contrast between the object and its background, its size, structure, and the spatial gradients at its boundaries. The magnitude of the brightness ratio at the limit of visibility depends upon all of these factors. The superimposed brightness of the atmosphere, by increasing the brightness level without affecting the brightness differences, reduces the ratio, and hence, the visibility. Various methods for improving the visibility of details in aerial photographs are suggested by tone-reproduction theory.*

ATMOSPHERIC haze is as variable and, in many respects, is less predictable than the weather. Like the weather, much is said about it, but unlike the weather, something can be done about it, photographically speaking. Although there is much more to be learned about the nature of the phenomenon that gives rise to haze in the atmosphere, present knowledge provides a basis for practical measures by which the loss in contrast attributable to atmospheric haze can be effectively minimized. An obvious practical solution to the problem is to increase the gamma of the negative material, or to make the prints on a harder grade of paper whenever the photographs are taken on a hazy day. This straightforward measure has

* Presented at the 22nd Annual Meeting of the Society, Hotel Shoreham, Washington, D. C., March 23, 1956.

been generally adopted as an operational procedure with varying degrees of success. The reason that it is not more successful is the subject of the following discussion.

First, the degrading effect of haze is not uniform throughout the brightness scale of the scene. The compression of subject-brightness ratios is greater in the shadow regions than in the upper middletones and highlights. This effect is illustrated graphically in Figure 1.

Along the horizontal axis are shown the log luminance values of *2* for the extreme shadow (*s*), and *4* for the extreme highlight (*h*) of the aerial scene, as measured near the ground, so that the effect of haze is negligible. The shadow area (s') has approximately twice the luminance of the shadow area (*s*). The luminance of the haze is assumed to be 10 per cent of maximum luminance. Adding this luminance to the luminances of all the ground objects and plotting the result on a logarithmic scale (log *I* camera image) as a function of the luminance of the ground objects results in the curve shown in the figure. It is seen that the large difference, ss', in the subject is reduced to a small difference, *ab*, in the image, and that this reduction in the shadow region is much greater than it is for equal luminance differences in the highlight region. Obviously, no corrective measure, such as higher gamma or harder paper, which increases the contrast throughout the scale, will restore the shadow gradients without producing excessive contrast in the highlight region of the negative and blocking of the highlights in the print.

In Figure 2 is shown a graphic analysis of the tone reproduction obtained in prints made on two grades of paper. In the lower right-hand quadrant is placed the camera-image curve for 10-per cent haze. The log *I* values of the camera image plus the logarithm of the exposure time determine the log *E* values for the *D*-log *E* curve of a typical aerial negative material shown in the lower left-hand quadrant. If the negative is contact-printed on the photographic paper, the diffuse density values of the negative are linearly related to the log *E* values for the paper *D*-log *E* curves, given in the upper left-hand quadrant. Two paper curves are shown; one for a Grade 1 and the other for a Grade 3 paper. The final tone-reproduction curves are shown in the upper right-hand quadrant. These curves illustrate the loss in highlight reproduction which accompanies a slight improvement in shadow gradient with the use of the harder grade of paper. It follows that optimum compensation for the degrading effect of haze can only be achieved if certain non-linearities are deliberately introduced in the photographic phase of the reproduction cycle.

There are several ways in which non-linearities in the reproduction process can be accomplished. Some achieve only partial compensation, others may provide the full amount of correction required. Some are operationally feasible, others are not. Some are now in use, others await further development. All are of interest, however, since they indicate where refinements in operational practices may be expected to lead to improvements in the over-all quality of aerial photographs.

Area dodging, which is widely used in the printing operation, may be thought of as a device for producing a kind of pseudo-non-linearity into the reproduction system. If, by means of dodging, it were possible to reduce the printing exposure in all the shadow areas, instead of the large shadow areas only, a result more closely approaching the ideal could be realized.

Flying-spot printers, working with very small scanning areas and with non-linear feedback, could be expected to achieve the type of compensation desired. This type of printer with a large scanning spot produces an effect similar to area dodging and therefore does not achieve the degree of correction required.

Masking for contrast control has been used successfully in many photographic applications. Both shadow masks and highlight masks introduce non-linearities of the type required in the reproduction process. Although this technique is not practical for run-of-the-mill aerial photography, it might be applicable in certain isolated cases where the value of the photograph is such that the extra effort is justified.

Tone-reproduction studies have suggested the possibility of introducing non-linearities of the desired kind in the characteristics of the sensitive materials themselves. The *D*-log *E* curves which are required by tone-reproduction theory to give optimum compensation are quite unconventional in shape. The computed curve for the negative material is shown in

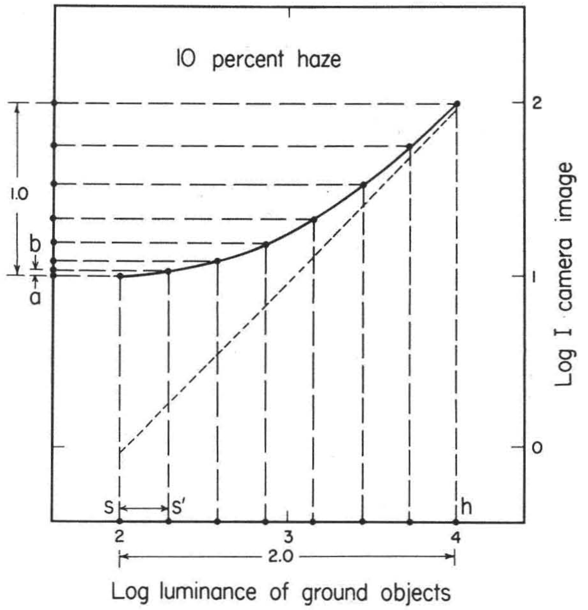

FIG. 1. The effect of 10 per cent haze on the log luminance differences in the camera image.

Figure 3. This curve represents a hypothetical negative material which would give the desired tone reproduction, provided that the optimum grade of paper were chosen for printing negatives made under different haze conditions, and that the camera exposures were adjusted so that the negative densities for the extreme shadow areas (*s*) were approximately the same for all scenes. Thus, for a large amount of haze,

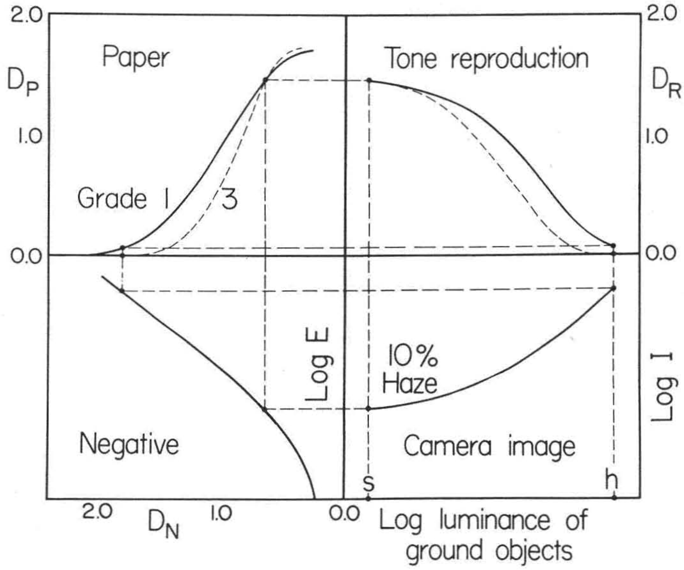

FIG. 2. Graphic analysis of the tone reproduction obtained in prints made on two grades of paper.

the negative densities generally would extend from s to about h, while for a small amount of haze, the densities might extend from s to h''. It might be possible to approximate this characteristic by the proper choice of emulsion and development. But such a negative material has extremely short exposure latitude, and, unless the camera exposure is exactly right, the tone reproduction may become worse than it would be using a negative material having a simple straight-line characteristic. It is believed, therefore, that this idea is of very limited practical value. However, the situation is more promising if we examine the curve of the positive material computed to give correct tone reproduction. A curve of the type shown at *A* in Figure 4 is required. Curve *B* is an actual curve of an experimental photographic paper. It is seen that it matches the hypothetical curve quite closely. Trial prints made on this paper with a number of aerial negatives show significant improvement over prints made on conventional papers.

In most of these modifications in procedure which have been suggested, it is assumed that the brightness gradients lost in the haze can be restored by merely increasing the gradients at the right place in the reproduction process. But, unfortunately, this is true only within certain limits imposed by graininess in the final print. Unless the subject detail is large compared to the grain structure of the negative material, increasing the contrast in the positive will not necessarily make these details more readily visible, since the grain structure will be emphasized along with the contrast in the subject itself. In this event, the subject will appear to be submerged in the pattern produced by the grains. This observation leads to the interesting conclusion that, for maximum haze penetration, one should use a long-focal-length lens and a fine-grain film.

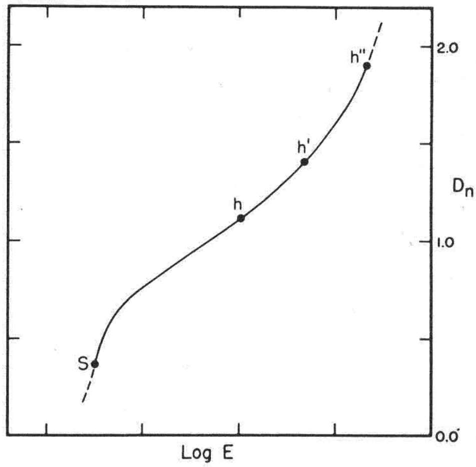

FIG. 3. The computed D-log E curve for a negative material required to give the desired tone reproduction if the grade of paper is varied with the amount of haze.

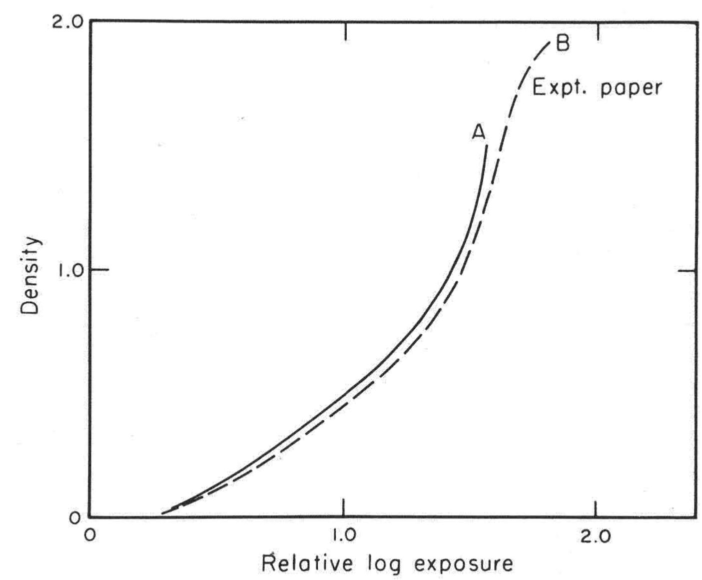

FIG. 4. The computed D-log E curve of a paper required to give desired tone reproduction (Curve A) and an actual curve of an experimental paper (Curve B).

And, for the best tonal separation throughout the full scale of the photograph, it is desirable to introduce, by one of the devices which have been suggested, the required amount and the right kind of nonlinearity in the reproduction process.

Discussion of Mr. Tupper's Paper

MR. HARMAN: Does anyone desire to ask Mr. Tupper a question or to comment on the paper?

MR. LAYLANDER (Photogeologist): Have you tested with color film, the changes due to haze?

MR. TUPPER: We have done about what one does with black and white film when a yellow filter is used. The contrast of the blue sensitive layer is very much higher than in normal color materials. That is about the extent of what can be done to compensate in some small measure for the effect of haze. A practice has been developed for changing the filters to de-emphasize the bluishness associated with haze. But in the color reproduction system, we haven't the contrast variable as well under control as we have in the black and white.

CAPTAIN READING: What is the availability of the fine grain negative material? Would it be useful in haze conditions? Its speed? Also the availability of the high-contrast paper?

MR. TUPPER: The paper that we have and that I discussed, is now experimental and is in the testing stage. If our preliminary results are confirmed by the practical tests, and if the demand exists the paper might well be procurable.

I am riding a bit of hobbyhorse on the fine-grain film. Its use would be much more general if it weren't so difficult to get enough light on the film to get an adequate exposure. The film speed that I demonstrated is about the equivalent of a speed of 6, on a scale on which super-XX is 100. It may be possible some day, when the platform is sufficiently well stabilized and the image motion has been well compensated, to use fine-grain films by permitting longer exposure times. In full sunlight, under favorable lighting conditions—not in the absence of haze, but on hazy days when the sun is high and there is adequate light incident on haze—it should be possible to get pictures with a film of this speed, with wide-open apertures and moderate shutter speeds. However, the opinion in regard to this fine-grain film is in advance of the machinery for implementing it. I feel, however, that in the future availability and use are almost certain because of the requirements, particularly of reconnaissance work, for increasing the length of the airpaths through which the photography must be done.

MR. MIDDLETON (Fairchild Camera & Instrument Corp.): Will you comment on what seems to be a contrast restoration with respect to the PI and his photographic interpretation aids?

MR. TUPPER: I believe you mean the viewing devices that the PI has at his disposal. Certainly, in stereo, your effective contrast is apparently improved due to the depth perception. Aside from that, the interpreter has to work and learn to work with very flat grey pictures. It is really surprising how much information can be extracted from such pictures through experience. A picture that looks attractive esthetically is frequently not satisfactory in the light of present techniques for aerial interpretation, simply because of the limitations of the system.

MR. TIBBILS (Eastman Kodak Co.): Can you mention possibly our first forward step in getting through haze, before we have all of these papers?

MR. TUPPER: We are actively working in the photographic industry to improve photographic emulsions. Along with developments in emulsion technology—related to some other films that are available in commercial photographic applications, i.e. ground photography—we can look forward relatively soon to improvements in the basic old favorites, super-XX, toward high resolution, better sharpness and finer grain, and higher available maximum gamma.

There's also the possibility of doing something about spectral sensitivity of these materials so that one can work farther into the long wave-length region where haze effects are at their minimum. The whole problem is so intimately associated with all of the factors in the reproduction system, that anything that can be done to produce a sharper image—through better stabilization, shorter exposure times, better control of exposure and development—will help in the penetration of atmospheric haze.