*Applied Photographic Techniques in High Definition Reproductions of Aerial Photography**

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THE material presented in this paper reflects our endeavor at ACIC, in the Photogrammetry Division, in applying photographic theory, instrumentation and data collecting techniques to our reproduction processes, to establish a quality control program. Through sensitometric and densitometric techniques, chemical analysis and precise photographic measurements, procedures and quality standards have been established in our phases of operation.

We began a scientific approach to a process capability study by using techniques and instruments specialized for the job. The results were expressed in units and terminology designed for this purpose.

Instruments such as the sensitometer, reflection and transmission densitometers, photometers, pH meters, spectrophotometers, and titrators are the tools by which we implemented controls and established product and process standards and procedures.

As these instruments require a high degree of reproducibility in measurement, they too are controlled through checks against certified buffers, National Bureau of Standards calibrated grey chips, color tiles and lamps. When reproducibility and accuracy were verified, we began to translate the desired quality of our photographic products into numerical values.

Studies were made on photographic equipment, materials and processing solutions. These studies considered the entire reproduction process from the original aerial negative to the final photographic product. Appropriate instruments were used to measure the processed images to determine their content and character in terms of density, contrast, definition and acutance. When these products met the significant requirements of the assignment, a study was made on variables

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and effective controls associated with the particular process.

Product and process standards were established in numerical values of contrast, density, definition, exposure and processing time to describe the quality desired in the end product.

Procedures were established to describe in detail the methods of reproduction to achieve these standards. In-process control checks were outlined to determine the reproducibility of the system and the methods of making required corrections in undesirable trends.

The use of control charts in both photographic and chemical control has reduced our production costs in our processes by improving the quality of and the time required to make decisions. Our control charts contain the basic data the photographer needs to know about his process, the results of his efforts and a standard for which to aim. We

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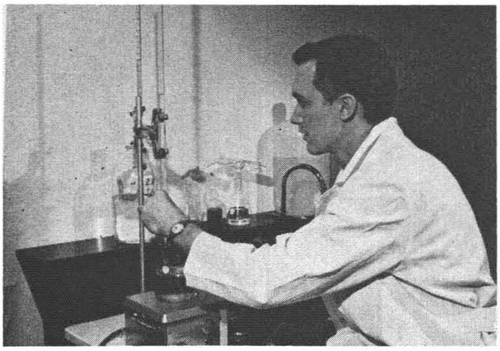

FIG. 1. Chemical titration of a photographic solution.

have noted a psychological effect in the use of control charts inasmuch as the photographer does a better job knowing that his work is being checked.

A chemical control facility (Figure 1) was established, primarily concerned with the formulation and maintenance of chemical concentrations in processing solutions which will yield photographic results within our desired control range. The chemical analysis required is dictated by two general categories.

1. Analysis of freshly prepared photographic solutions, and
2. The analysis of in-process solutions.

Each batch of freshly prepared photographic solution receives a thorough chemical analysis before it is distributed to the various photographic branches of ACIC. The analysis required will, of course, depend upon the individual type of solution. For instance, a typical developer solution is analyzed for the following: individual developing agents, sulfite, bromide, pH or total alkalinity and specific gravity. All results are reported in concentration units and must conform to established limits before a batch is released for use.

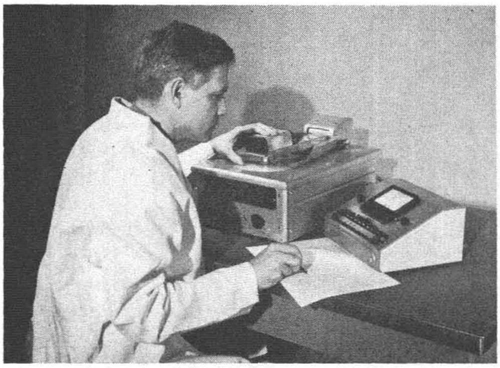

FIG. 2. Density measurements on a transmission densitometer.

The chemical analysis required for in-process solutions is limited to critical constituents which have been determined through sensitometric and chemical analyses, to be the limiting components to be controlled. All chemical limits are set according to the level required to achieve uniform photographic results. Once this was done it was possible to control the process through chemical analysis of the critical components.

If, for example, complete analysis showed that for a particular developer the critical components were the pH of the solution and the build-up in Sodium Bromide concentration, thereafter, control of the process could be maintained by regular analysis for these two components. Results can conveniently be plotted on a control chart which will tell in a glance if the process is within the established limits.

The techniques of sensitometry have been implemented into continuous processing operations to maintain the activity of the developing solutions to assure reproducible photographic results from day-to-day processing. Sensitometric exposures produced on a sensitometer are processed at random with the production run.

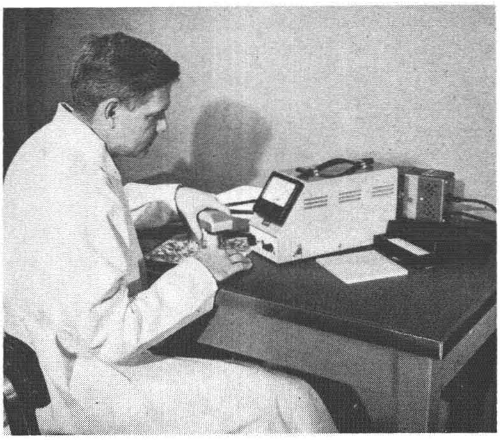

FIG. 3. Density measurements with a reflection densitometer.

The processed sensitometric exposures are measured, at selected steps, with a densitometer (Figure 2) and these densities are plotted on a statistical chart. When the plotted densities indicate a drift in either gamma or density, corrective action is taken to modify the replenishment rate or chemical formula before a significant loss in quality is encountered.

It is through this type of sensitometric and analytical control over processing that we

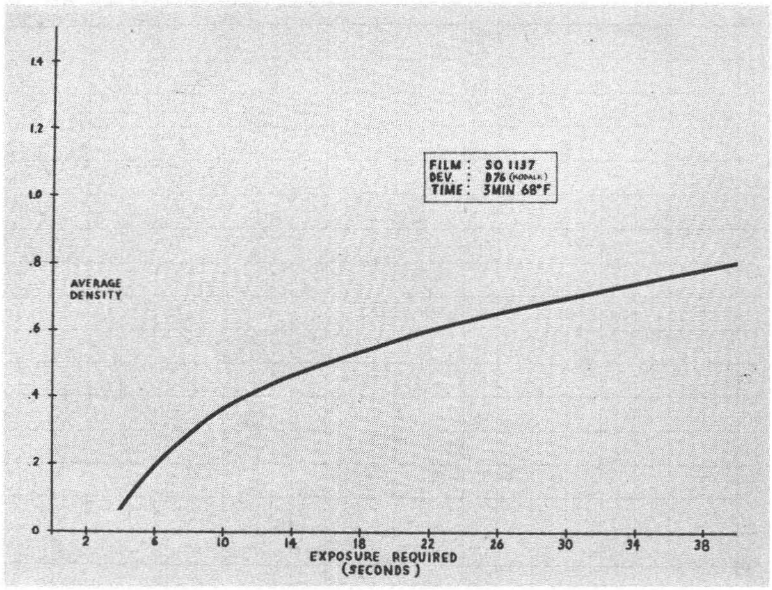

FIG. 4. Exposure determinant correlation chart.

were permitted to successfully process Lunar photography exposed at the Pic du Midi Observatory in the French Pyrenees and to apply controls to various reproduction processes.

Sensitometric techniques have enabled us to devise a method of predetermining the exposure required in camera reproductions of continuous tone copy through densitometric measurements.

Using a reflection densitometer (Figure 3), integrated maximum and minimum densities defining distinguishable detail in the prints, are measured and an average integrated density for this range is calculated.

A correlation was established (Figure 4) of actual exposure time required to the calculated average density, based on an exposure determinant to produce an integrated density of .85 above fog as required to yield maximum resolution at a specific gamma of development.

As each emulsion is individually calibrated to a particular camera system and developing process, we have been able to apply in-process controls to achieve a high degree of reproducibility. This method of exposure determination is successful for it considers the reciprocity failure of the emulsion, the spectral characteristics of the emulsion and the spectral output of the illuminant.

The benefits derived from the densitometric exposure determinant techniques and sensitometric controlled processing were threefold:

First, it had eliminated the variability associated with the trial and error guesswork of visual exposure evaluation.

Second, this technique provided reproducibility and uniformity in density and contrast never before achieved.

Third, the exposure is precisely determined by the individual density ranges of the original copy. The system is designed so as to reproduce the mid-tone density of this range on the center of the straight line portion of the characteristic curve, at a density of .85 plus fog, for a particular gamma of development. Where density differences are great in a copy, they are reduced in the reproduction; where such differences are small in the copy, they are increased. This was a tremendous break-through in continuous processing where the time of development remains the same but the contrast of individual reproductions needs to be corrected.

Along similar lines, to improve the quality of photographic negative products, we have devised a method of exposure predetermination for the Lunar project at the Pic du Midi Observatory, France, to eliminate the variability of techniques associated with the observer's visual evaluation of Lunar exposures.

Through sensitometric techniques and controlled processing we are compiling a sensitometric correlation of brightness range, exposure and density produced to more critically place the exposure to be most effective in detail retention, in our developing process.

A maximum brightness in foot candles will be measured for the 14 progressive ages of the Moon. The conditions of brightness, spectral characteristics and exposure duration will be

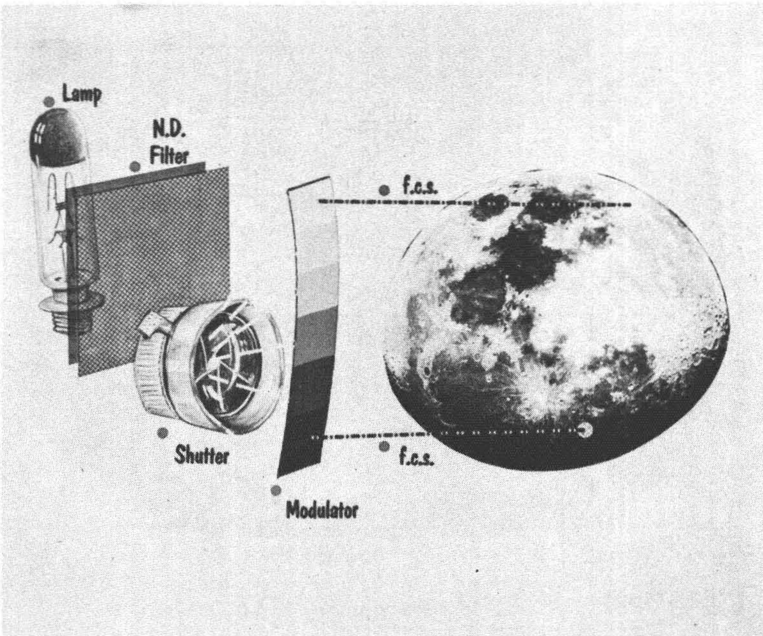

FIG. 5. Duplicating lunar characteristics into the sensitometric instrument.

duplicated into the sensitometric instrument (Figure 5).

Each of the 14 ages will be effectively modulated, from maximum brightness to shadow, in 21 steps decreasing in illumination by the square root of two. The densities

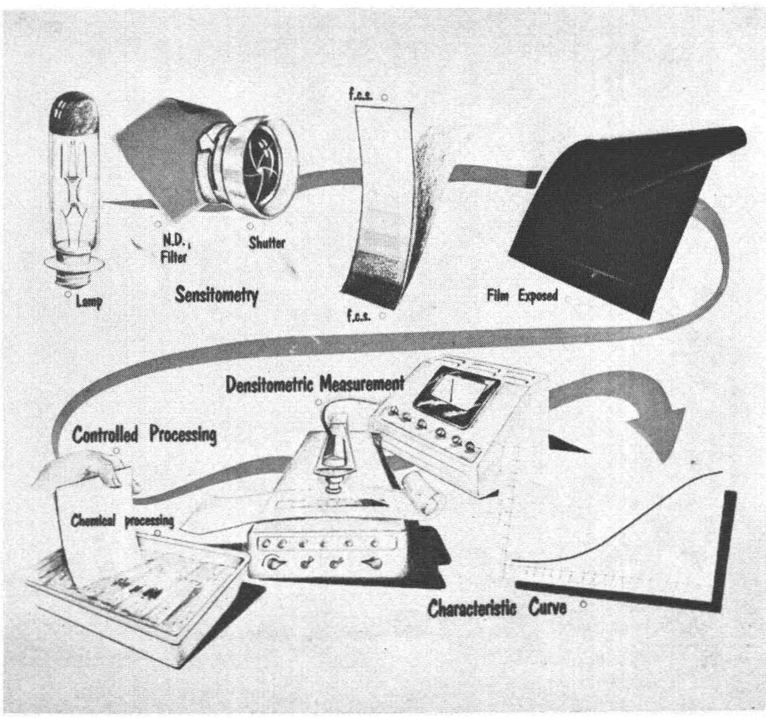

FIG. 6. Sensitometric processing and densitometric measurements to arrive at characteristic curve.

produced in our controlled processing will be measured and appropriately plotted against the exposure that produced them (Figure 6).

The 14 plots will be used at the Observatory to correlate photometric measurements taken at the film plane, to determine the exposure required to place the area of interest on the straight line portion of the curve (Figure 7). If, for example, the photometric measurements of highlight and shadow were .25 foot candle and 1.20 foot candle, an exposure of 1/10 second would produce exposure of .025 foot candle seconds and .12 foot candle seconds. This would place the Lunar imagery bracketed by these measurements on the straight line portion of our curve.

Similar calculations using exposures of 1/5 and 1/25 second would show these exposures unsatisfactory, as they would place the Lunar imagery on the shoulder and toe of our curve respectively.

been successful though, in establishing master prints, as visual aids, depicting the concept of contrast and tone required for various terrestrial areas to conform to our quality standards.

Our major problem in establishing controls has been the lack of reproducibility in photographic equipment. In many cases photographic exposing and processing equipment had to be modified to eliminate as many variables as possible. The ultimate goal of our program is the use of instruments to determine what photographic techniques are required, attain reproducibility in our processes and the use of instruments to ascertain conformance to quality standards.

In conclusion, I would like to summarize in this manner: To meet our quality requirements in photographic reproduction, the transition of photography from an art to a science was inevitable. We have just scratched

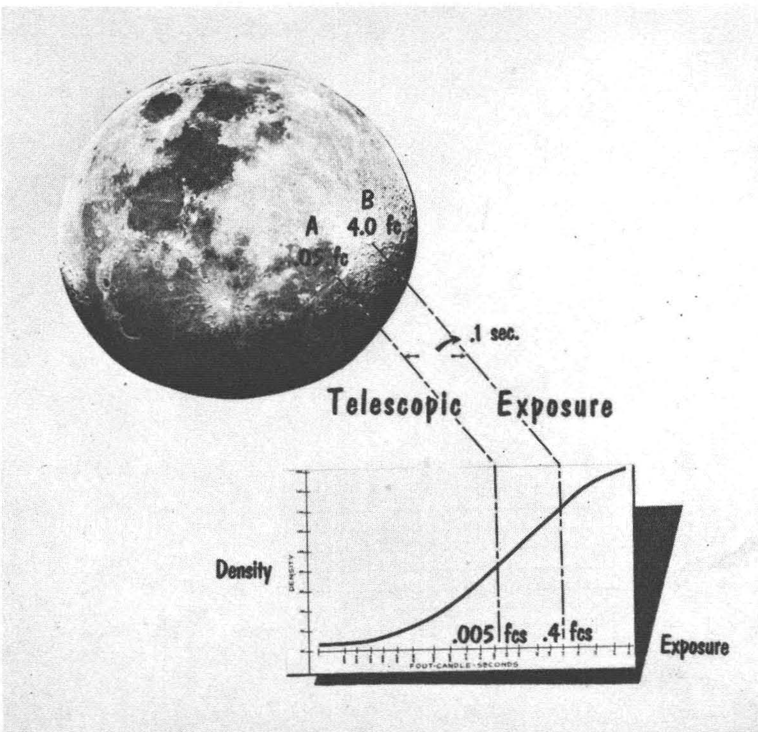

FIG. 7. Application of characteristic to arrive at lunar exposure.

We have incorporated nitrogen burst agitation systems, precise exposures and established controlled processing in our reproduction of diapositive glass plates to achieve our quality standards.

We are presently attempting to apply on-the-easel photometric measurements in our rectification processes to eliminate the visual evaluations of the exposure required. We have

the surface in resolving many of the complex problems affecting the quality of our photographic reproduction products. Our efforts to date have been rewarded with an improvement of quality and monetary savings in man-hours and materials. It will be a continuing effort to keep abreast with new developments in equipment, materials, and requirements.