OPTICAL AND SENSITOMETRIC DEVELOPMENTS*

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ABSTRACT

Recent advances in methods of photographic image evaluation are outlined, along with a brief description of the new instruments and equipment designed especially for the U. S. Air Force in carrying on this work. These improvements have resulted in MIL-STD-150, a document which standardizes most photographic test procedures. The use of electronic computers for developing ray trace data is shown to be highly desirable. New optical and sensitometric developments are discussed and improvements in film processing for night photography are mentioned. The use of electronic and electrostatic image forming devices for aerial photography is described briefly, offering savings in the requirements for film and equipment weight in aircraft.

The work is primarily under the direction of the Physics Branch of the Photo Reconnaissance Laboratory.

FIGURE 1 is a photograph of what, in the final analysis, has been the subject of a great deal of controversy and study in recent years. It may not be readily recognized as being a photograph of a star image; i.e., an enlarged picture of an off-axis image of an extremely small point object—the building block of optical images. Although this star image can tell a story to the expert about chromatic aberrations, coma, astigmatism, etc., it can not be conveniently used for making measurements of performance or writing specifications.

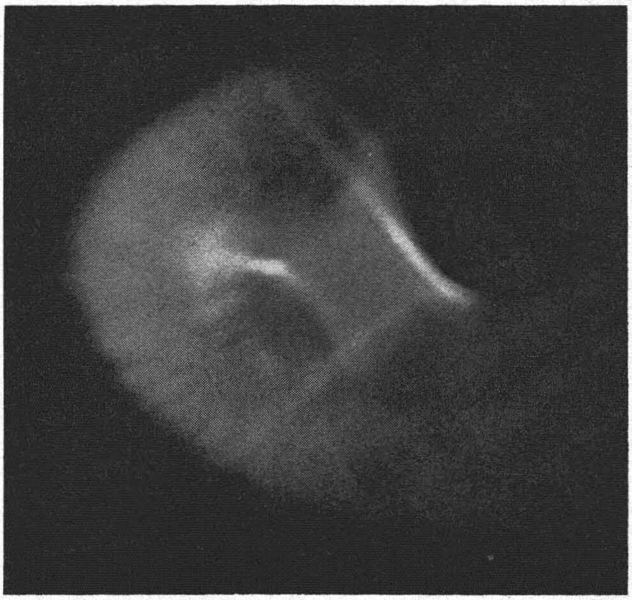

FIG. 1. Photograph of star image.

Much work has been done recently in image evaluation and improvement, as well as in studying the sensitized material on which the image is recorded. For many purposes, the resolving power target is a useful device with which to

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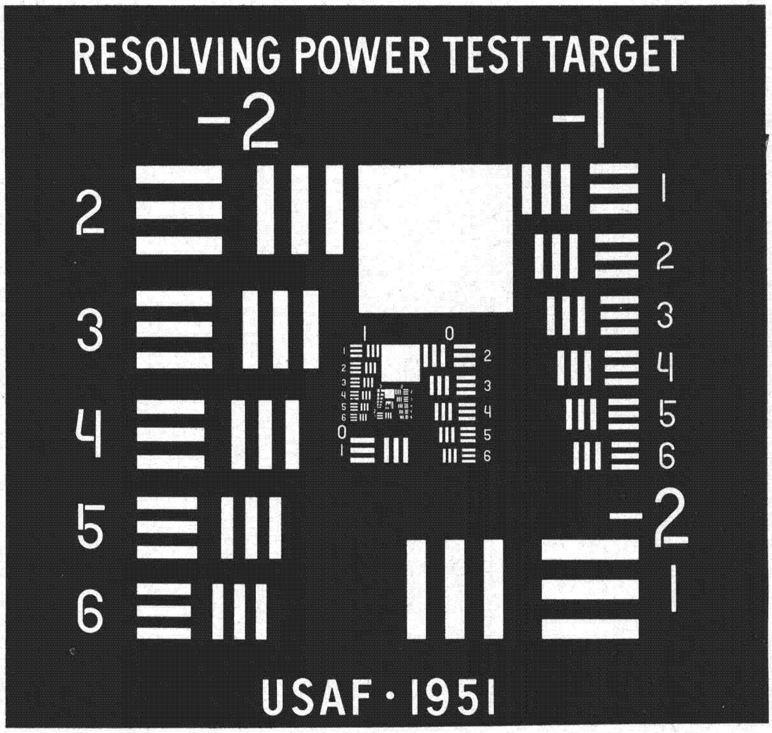

FIG. 2. Latest U. S. Air Force Target.

evaluate this work. Figure 2 is the latest U. S. Air Force target, manufactured by the Buckbee Mears Company. It is a modification of the standard three line, high contrast target which has been used in laboratory tests for approximately 14 years.

Consideration should also be given to some of the photographic test equipment recently acquired by the Air Force. In Figure 3 is pictured the visual test bench and one of the 16 inch diameter 14 foot Fecker collimators. The lens holder on this bench was designed for rather large aerial lenses and has 6 degrees of freedom. The collimator is a Wright-Schmidt design, with the target placed on axis by means of a beam splitter plate, so that no occulting area exists in the collimator beam.

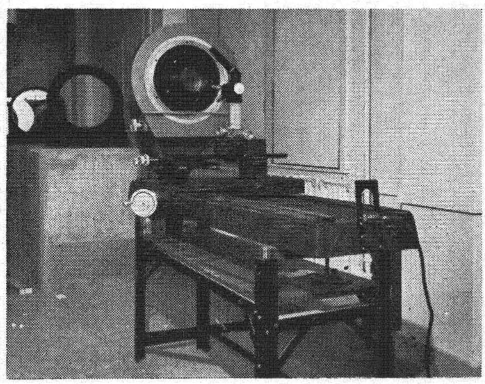

FIG. 3. Visual test bench and a 16 inch diameter 14 foot Fecker collimator.

Figure 4 shows the medium size lens test camera. The collimator tube is to the right. This camera was manufactured by the Jam Handy Corporation and has all the necessary adjustments for making through-focus exposures at any field angle out to 45 degrees in increments of $1\frac{1}{4}$ degrees. The angles are being calibrated for distortion measurements. The standard plate holders take either film or plates 2 inches by 14 inches and, with a special adapter, lenses covering a

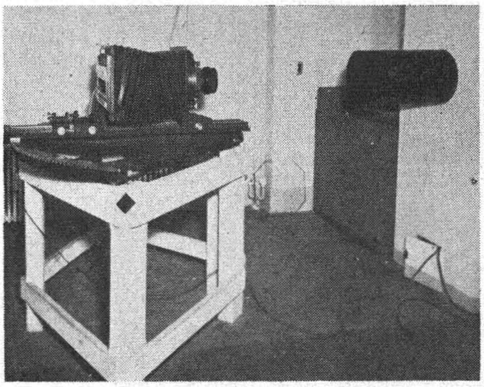

FIG. 4. Medium size lens test camera.

9 inch by 18 inch picture area can be tested.

The large test camera, shown in Figure 5, was manufactured by Consolidated Photo Engravers, Equipment Company, and was designed primarily for testing special long focal length reconnaissance and spotting lenses. It is over 20 feet tall and will accommodate lenses up to 100 inches in focal length and 16 inches in diameter. The collimator for this camera is placed on a swinging mount in an 8 foot deep pit under the camera. The operator rides in the small elevator on the left.

Figure 6 shows the folded collimator which is mounted in the pit. The angular positions of this collimator can be set by remote control from the operator's elevator. The collimator is shown without its cover. This arrangement makes possible testing these heavy lenses in a vertical position, and large cameras in any oblique position. Considerable time and expense of flying large aircraft has been reduced by means of this apparatus.

Figure 7 is a picture of the plate holder carriage and control panel. For focusing, the plate holder carriage is moved by a slow-motion electric drive. Focus positions are read to the nearest .1 mm. from a scale mounted on the rear of the camera. A magnified view of the scale and vernier is projected for convenient reading by the operator. This camera will accommodate either plates or film up to 40 inches in length.

All the testing in the laboratory is done in accordance with MIL-STD-150. This document may be of considerable interest. It can be obtained from the U. S. Government Printing Office. Instead of being the work of any one organization, it represents the combined thinking of many leaders in the field of photographic optics such as Dr. Gardner, Dr. Pestrecov, Dr. Baker, Dr. Washer, Dr. Hopkins, Dr. Scott, Mr. Cox, Paul Foote, Mr. Kingslake and many others. It was very pleasing to work with these men in the preparation of this document which has already proved its value in preparing specifications and standardizing test procedures for aerial lenses. It is hoped that the recently adopted specification of Commission I of the International Society of Photogrammetry will prove

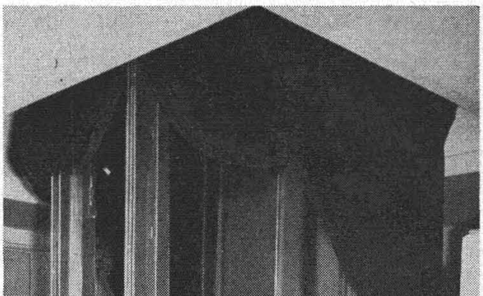

FIG. 5. Large test camera designed primarily for testing special long focal length reconnaissance and spotting lenses.

to be equally useful, and that the Commission's work in this direction will be continued.

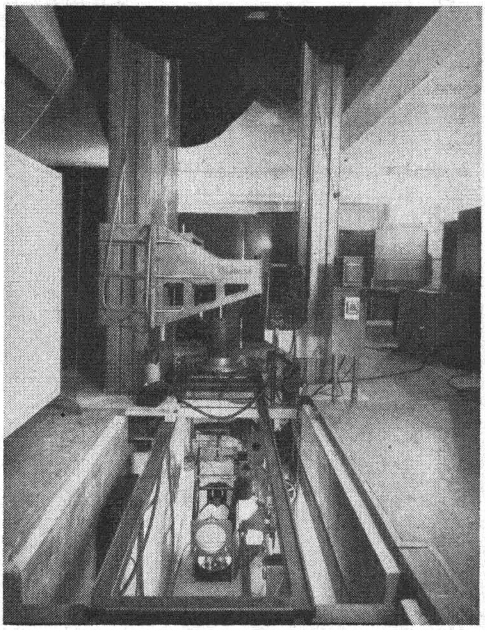

FIG. 6. The folded collimator which is mounted in the pit.

Figure 8 is a histogram of a group of 36 inch f/8 lenses. High contrast, slow, fine grain, spectroscopic plates were used on these tests and the Area Weighted Average Resolution was determined for each. As a quality control technique, Bell & Howell plotted the number of lenses having approximately the same AWAR against the AWAR for each month's production. This figure represents a summation of the data. Through use of such data can be prepared truly meaningful production specifications. The specifications merely require that a certain percentage shall have resolutions better than a specified quality level. Another percentage is allowed to fall to another quality level, and finally all must be better than the minimum quality level.

Later on there may be available a system of measuring lens performance that does not involve the much-discussed and controversial problems of photographic evaluation. Perhaps an electronic photometric method of lens evaluation will be evolved that will eliminate the inconsistencies of reading targets visually, and that will handle satisfactorily such problems as type of target, contrast of target, type of sensitized material, and processing techniques. The Bureau of Standards, Boston University, the University of Rochester, and Eastman Kodak Company, to mention only a few, are working closely with the Air Force on this problem.

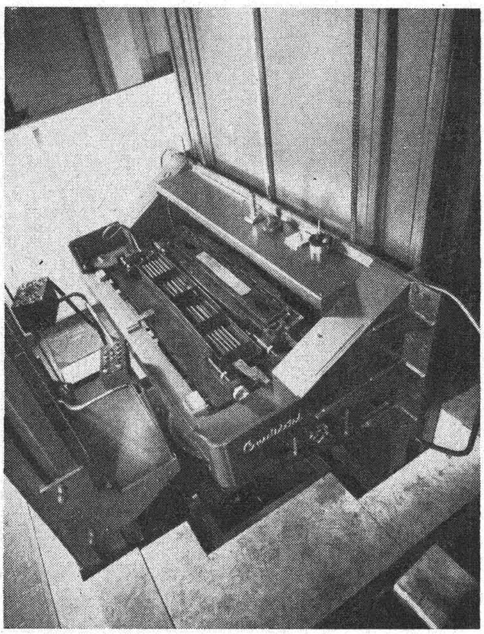

FIG. 7. Plate holder carriage and control panel.

Figure 9 portrays the large T-stop calibrator. It can accommodate lenses up to 100 inches EFL and has proved to be of considerable value in evaluating night lenses and measuring image illumination.

The small T-stop calibrator is shown in Figure 10. It utilizes the collimator type of system as compared to the extended source method of the previous picture. Both methods are included in MIL-STD-150, and have been approved by the

Society of Motion Picture and Television Engineers Committee on T-stop calibration.

One of the new Air Force night lenses, a 24 inch f/3.5 for 9 inch by 18 inch coverage is illustrated in Figure 11. This lens resolves 40 lines/mm. on-axis with high speed panchromatic film, and has an AWAR of 23 lines/mm. The focusing dial is located near the body mating surface, and incorporates a slide rule type of computer to correct for focus effects due to target distance, pressure, temperature, and also for whether the film is I.R. or panchromatic. This lens, designed by Dr. James E. Baker, is only one of about 20 lenses designed for the USAF by him and others; on these all reproduction rights are the property of the government. The Bureau of Standards checks the formulas for these lenses by ray tracing on I.B.M. card programmed digital computers. Much valuable design information is obtained. It is hoped that it will be possible to present this ray trace data in the form of curves showing expected photographic performance integrating all aberrations instead of the usual 3rd order and 5th order aberration curves. The Bureau of Standards is not alone in exploring the possibilities of the electronic computers. Dr. Baker is making extensive use of these computers, as are Mr. Cox of Bell & Howell and Dr. Pestrecov of Bausch & Lomb. It is amazing how much faster these machines do ray tracing. Lens designs can be obtained in a matter of days rather than months, and the work is more thorough. Detail tolerance analysis of a lens formula is also possible, and this is being done on USAF lenses now going into production.

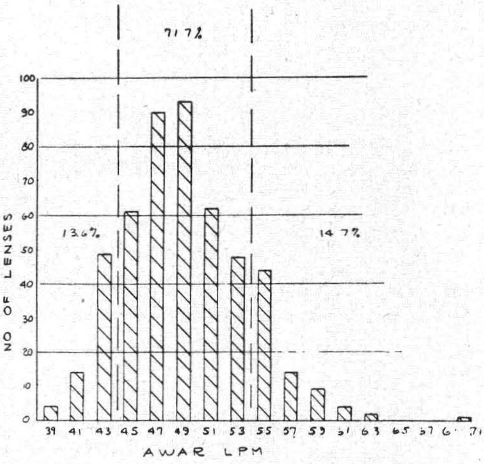

FIG. 8. A histogram of a group of 36 inch f/8 lenses.

Figure 12 is a picture of the famous Planigon or Cartogon lens. It is the result of a discovery by Russell Bean of the American Society of Photogrammetry while in Germany after V.E. Day. Bausch & Lomb under contract to the U.S.A.F. made the first American prototypes using American glasses. More recently, two other companies—C. P. Goerz American Optical Company and Curtis Color Laboratories—have started manufacturing this lens. The most remarkable thing about this lens is its extremely small distortion, this being less

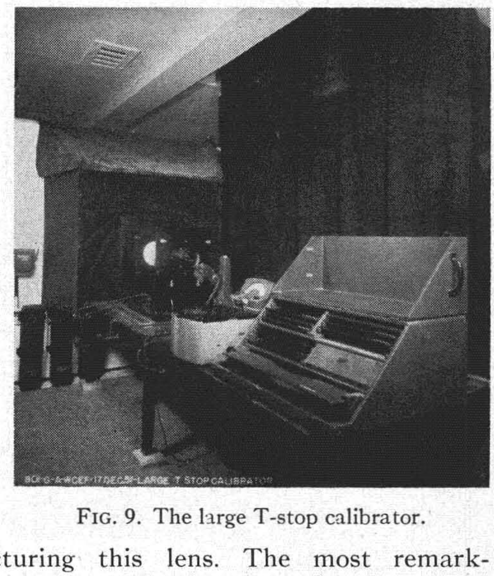

FIG. 9. The large T-stop calibrator.

than 15 microns. And 15 microns radial distortion for those who have not tried to measure it, can be an elusive quantity. Work is continually being done on better methods of measuring distortion. The photographic method, with the lens mounted in the mapping camera, is still favored in spite of some attractive features about the goniometer method. Search is also being made for an even better lens to replace the Planigon. The WILD (AVIOGON) lens has not yet been tested by the Laboratory.

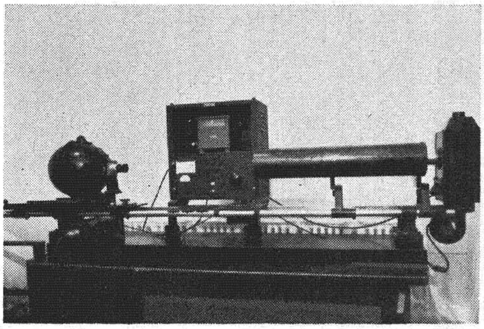

FIG. 10. The small T stop calibrator.

The activities of the USAF in the field of sensitometric materials will be briefly described. Figure 13 shows three curves which are useful in the sensitometric studies. Curve A is the standard H&D curve. Curve B is the gradient curve, or a plot of the first derivative of Curve A. Curve C is the resolving power curve. It is only natural that there be interest in high resolution, contrast rendition, and high emulsion speed, particularly for night photography. The speed of the material is represented by the positions of these curves with respect to the log E axis; the further to the left, the faster the material. Usually there is interest in an image brightness range of about 1:10, as represented by the solid line on the log E axis. The position of this line indicates the exposure where one would expect to obtain the best results. In practice it is found, however, that the exposure is much further down on the toe of the H&D curve, particularly in night photography.

These and other sensitometric aspects of aerial photography are due for much more study. There is particular interest in increasing film speed for night photography. The most promising results to date have been achieved with hydrazine compounds where true increases of exposure index have been attained that exceed a factor of 3 with high speed materials.

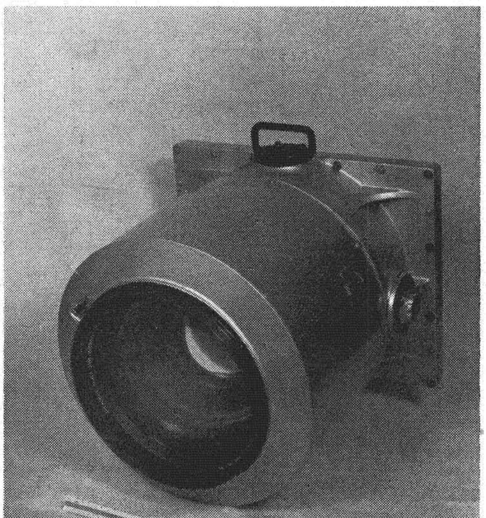

FIG. 11. A new Air Force night lens—24 inch f/3.5 for 9 inch by 18 inch coverage.

The resolving power camera used in the laboratory in studying photographic film is shown in Figure 14. It is actually a special sensitometer of the intensity scale type which projects a reduced picture of a resolving power target through a miscroscope lens on to the film, and varies the exposure in graded steps. It is largely automatic, requiring only that the operator move a modulating filter slide and press a button which positions and holds the film and controls exposure.

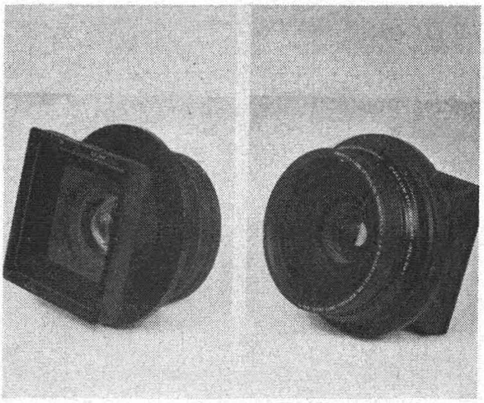

FIG. 12. The Planigon or Cartogon lens.

The dimensional stability and brittleness test apparatus is shown in Figure 15. The air in the plastic chamber can be maintained constant at any relative humidity in the range from 5 to 95%. Humidity amplitude is measured with a pin gauge placed in this chamber (Figure 17). With this apparatus process shrinkage is also measured by comparison measurements before and after processing. Furthermore, brittleness tests can be made in this chamber by placing in it the vise, as illustrated in Figure 16, which closes on conditioned loops of film. The film is placed in the jaws of the vise by means of a magnetic probe. The film loops are held together with paper staples. The jaws of the vise are closed by means of a small electric motor. The separation of the jaws, in thousandths of an inch at the point where the film breaks, is a measure of the film's brittleness.

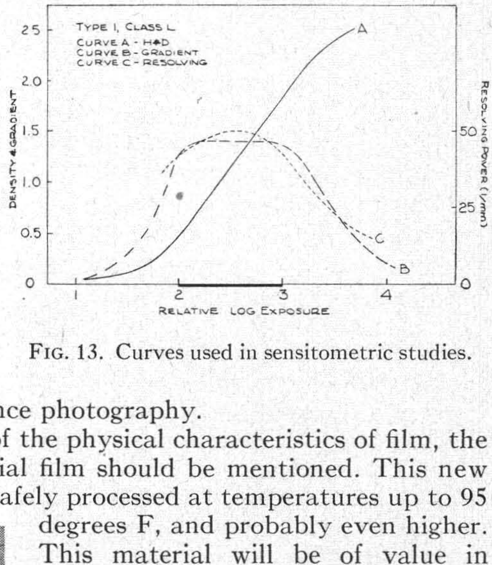

FIG. 13. Curves used in sensitometric studies.

Tests have recently been made of a new film base, developed by DuPont, which has remarkable brittleness characteristics even at low temperature and low relative humidity. It is related chemically to the fiber Dacron. It also has very good dimensional stability, although to date tests made on a laboratory scale show that the samples tested are not quite good enough for mapping photography; much better results are expected soon from the pilot plant. In its present form, however, it has great possibilities as a film base for reconnaissance photography.

In connection with this discussion of the physical characteristics of film, the new Eastman Kodak prehardened aerial film should be mentioned. This new film, soon to become standard, can be safely processed at temperatures up to 95 degrees F, and probably even higher. This material will be of value in meeting requirements for rapid processing, when suitable processing machines can be built. But of more immediate interest is its drying rate, which is approximately 75% greater than for regular Aero Super XX.

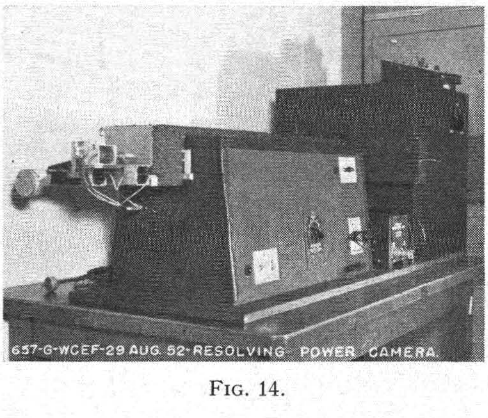

FIG. 14.

There is also interest in photo sensitive processes that are not, strictly speaking, photographic, being different from the conventional silver-halide process. Figure 18 is a reproduction of a sample photograph

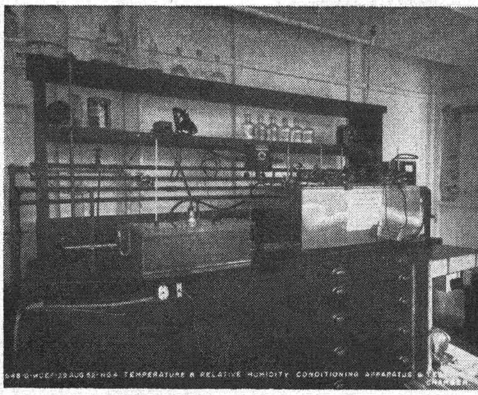

FIG. 15. Dimensional stability and brittleness test apparatus.

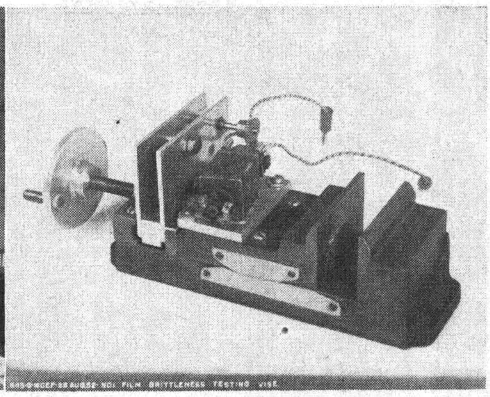

FIG. 16. Film brittleness testing vise.

produced by the xerography process, or more correctly, the electrostatic electrophotographic process. Xerography was originally developed by the Haloid Company in the form of a quick-delivery document reproduction process, which is now commercially available. The Air Force and U. S. Army Signal Corps are jointly sponsoring research to make Xerography a continuous-tone photographic process as well. The Xerographic plate, which can be used over and over, uses static electricity and is light sensitive. Electrically charged black powder is used to develop the plate; this accounts for the fast processing possibilities of Xerography and also for a great eventual economy in reducing the requirements for light sensitized film and paper.

This is not the only way of utilizing electricity in a photosensitive process. Many other systems, similar to the snooperscope and T.V. principles, have been suggested and are being worked on, Here is a whole field of electro image formation or image amplification that is just waiting for a few clever inventions. The USAF is considerably interested at present in the possibility of increasing sensitivity by a factor of 10 or 100, thus greatly reducing the speed and complexity required of lenses, and thereby decreasing the weight of photographic installations. The substitution of an electric impulse for the shutter is desired obtaining thereby extremely short exposures. Maybe some day such a process can be developed.

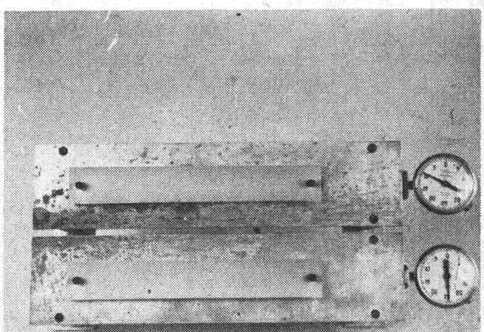

FIG. 17. Pin gauges for film dimension testing.

What is being done today in color photography would have sounded as fantastic 20 or 35 years ago as the previous remarks on electrophotography. Color photography is easily accomplished from low altitude in fast flying aircraft and Aerial Ektachrome has produced outstanding pictures from 42,000 feet. Work is also being done on negative positive color processes with Eastman Kodak Company and Ansco; this looks very promising. They will have greater ease of reproducibility, greater latitude, and better resolution.

There is interest not only in natural color process but also in special effects

FIG. 18. Photograph produced by Xerography process.

for special purposes. Camouflage detection film is an example. One layer is infrared sensitive and dyed in one color; the other layer or layers is sensitive in the visual region and dyed in another color. Any green non-chlorophyl material which is not highly I.R. reflective appears as green against a red background.

As a summary of the activities in terms of present objectives the goals are:

1. To develop practical methods of increasing photo-sensitivity chemically or electronically.

2. To increase the interpretability of aerial photography by improving the resolution or the contrast rendition. That is, increase the information content of photographic message.

3. To bring combat performance of the photographic process closer to the laboratory performance.

4. To provide more efficient, cheaper, lighter weight, more dependable, photographic equipment.

5. To develop better and cheaper methods of manufacturing and testing photo materials and supplies.