tion stations will be needed than in regular Shoran controlled surveys. This, however, need not be a disadvantage, because the restrictions imposed on present Shoran station locations are greatly reduced. The tri-lateration network obtained in this manner will be used in all future survey projects which will certainly follow a small-scale Doppler controlled mapping program.

Pure Doppler flights can be used to determine the geographic positions of flight-line intersections within an accuracy obtainable by usual astro field methods. This procedure was used by Aero Service on a recent magnetometer survey over the Libyan Desert. The flight path was photographed on strip film from 1,500 feet above ground. At 4 km. intervals, a fiducial mark was exposed on the film triggered by the Doppler computer. Flight-line intersections were then determined from the strip film interpolating the interval for distance. The strip film intersections were then transferred onto existing 9″×9″ photographs and a radial photo templet-laydown was made, using the astro positions as basic control. The Doppler distances were compared with the astro controlled templet distances resulting in an average distance error of 0.22%. However, this test cannot be considered as conclusive for the attainable accuracy. The distance comparison is based on astros in an area which is known to have large deflections of the vertical and is lacking ideal identifiable terrain features. This leaves too much to unaccountable facts.

It would be highly desirable to perform a test over well-mapped territory with the Doppler lines flown in such a manner that enough redundant measurements are available, and where errors due to the insufficient reference data are eliminated.

Since the azimuth of the flight line is determined by reference to a compass aboard the aircraft, the accuracy and dependability of this compass become matters of great importance. We use a Kearfott J-4 compass, either as a high-precision magnetic compass, or in free mode, as a low-drift inertial reference. Its operation has been satisfactory, but the magnetic compensation of the aircraft has not yet been carried out to the limit we desire.

We realize that the feasibility of the ideas presented here depend on further investigation of the capability of the Doppler system for photogrammetric purposes. It has proven its value as a navigation device, and it seems to us, based on the short experience gained with the instrument, that its use for small-scale mapping is well within its range. At present there are at least four different Doppler systems commercially available: the Decca, the Marconi, the Laboratory for Electronics and the Radan. Each of these makes has different characteristics, advantages and disadvantages.

Aero Service will welcome the opportunity of keeping the Society advised of future experience gained by the Company with its Radan equipment.

*ACIC Objectives for Photographic Quality Control**

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(*Abstract is on next page*)

A RECENT magazine article stated that science and technology have been expanding at an annual rate of 5 to 7 per cent. Such a rate of expansion means a doubling in about 15 years.[1] How the photographic industry would rate under such a system is not definitely known, but from a user standpoint the author would be inclined to place it at or near the top.

A part of the mission of the Aeronautical

* Presented at the Society's 25th Annual Meeting, Hotel Shoreham, Washington, D. C., March 8 to 11, 1950.

[1] Foote, P. D., Industrial and Engineering Chemistry, Vol. 51, No. 2, p. 91A (1959).

ARNOLD F. TRACHSEL

Chart and Information Center is to process and print any type of aerial photography, prepare duplicate positives or negatives, enlargements, rectified prints, etc., necessary for producing charting materials for the Air Force. A great many types of aerial photography, such as wide-angle, oblique, tri-met, convergent, long focal-length, etc., are being successfully used to accomplish this mission.

One factor common to all of this photography is a low resolution of approximately 20 lines per millimeter. In spite of this low resolution, such photography is quite adequate for chart compilations and revisions, intelligence studies, etc., because the general definition is good, and the scale is large enough to permit identification of most of the detail required for control or for portrayal on the chart. Normal processing and reproduction of this photography are adequate because of these factors:

1. The resolution capabilities of emulsions and processing equipment used either provide for or exceed the resolution required.
2. The scale of the photography is large enough so that a great magnification is not normally required for compilation use.
3. The end prints are still adequate for the graphics being prepared even though 30 to 40 per cent of the resolution may be lost in the various reproduction stages. Although the resolution may thus be reduced to 8 to 10 lines per millimeter, such resolution appears adequate to the average human eye at normal viewing distance if the definition is good.

Photographic quality standards used in the past at ACIC have utilized every means available to maintain the quality. Information obtained from photographic materials manufacturers has been used to set up gamma charts and time and temperature charts for developers, to serve as guidelines or standards for processing films or papers. Variations from the charts were made for processing high or low-contrast films or papers. Chemical and manual dodging techniques and the use of different contrast papers provided evenness of tone and maximum detail in high-light and shadow areas. Quality controls vary with the intended use. Prints which will be used for indexing, planning, tilt computations, etc., do not require the same high quality as prints which are used for interpretation purposes. It is readily apparent that a great reliance was placed upon operator skill, experience and judgment.

ABSTRACT: *High-resolution small-scale photography is supplementing large-scale photography as photographic source material for the compilation of aeronautical charts and graphics. This new photography has created a requirement for precise quality controls in photographic reproductions. The facilities, equipment, operation, etc., necessary to achieve such precision at ACIC will be discussed.*

The trend toward both higher altitudes of the camera and smaller format photography has created a requirement for higher acuity photography in order to maintain present qualities of the end products. It would appear reasonable to assume that if the camera altitude is doubled and the photographic format and focal-length are reduced to one-half, the resolution of the photography must be increased four-fold in order to maintain the resolution. The fallacy of this assumption was pointed out by Mr. Macdonald in his speech "Resolution as a Measure of Interpretability" presented at the Society's Semi-Annual Convention in St. Louis on October 3, 1957. He stated: "High resolution systems require more resolution lines per object in order to detect the image at the limit of the system than do low resolution systems. Resolution and scale are not interchangeable at parity." The requirements for graphics produced have also changed. Aerial mosaics are now produced at 1:50,000 instead of at 1:25,000 scale. Smaller-scale photography can be effectively utilized for such compilations if the quality of the photography is such that all of the required information can be interpreted.

Recent advances in aerial cameras, lenses and negatives emulsions have made great increases of the quality of aerial photography possible. Quality control methods must be improved in proportion to the increases of photographic qualities. Such controls, applied to photographic reproductions, will provide a yardstick for measuring deviations from the established standard. Just as a part for a precision instrument might be machined to within a tolerance of plus or minus 0.002 of an inch, so can photographic reproductions be made within prescribed limits. However, in aerial photographic reproductions, these limits are much more difficult to define. For example, prints made from a roll of aerial film can be processed under set conditions to a prescribed density within a small tolerance. Such prints can also be printed in such a manner that a certain resolution is maintained. The resulting prints, however, may not have the high quality desired since other factors, such as acuteness and granularity, also determine the quality and cannot be easily defined by a single number or value.

A number of factors which are extremely critical for the reproduction of high-acuity photography without a great loss of detail are vibrations, air and water impurities, precise focusing, film flatness, and stringent temperature and processing controls. The acquisition of equipment which is capable of reproducing high-acuity photography to the desired quality level is not in itself a guarantee that this quality will normally be maintained in production. The manner and environment in which equipment is used is as important as the equipment itself and any one of the above factors will set a limit on the maximum quality obtainable. In addition, each item of equipment used for processing or reproducing photography has its own characteristics which determine the quality of reproductions obtainable.

The quality of photographic reproductions cannot be defined by resolution alone. Higgins and Wolfe, Eastman Kodak Co. Research Laboratories, pointed out in the February 1955 *Journal of the Optical Society of America*, that the definition of a photo image is a composite of several factors such as resolution, sharpness, graininess and tone reproduction. Numerous investigations have been made and articles written of the factors which affect the quality of photographic reproduction. Mr. Robert S. Barrows, Eastman Kodak Company Research Laboratories, states in the July 1957 issue of *Photographic Science and Engineering* "the information-transfer capacity of a system is its ability to retain in all essential respects the identity of the object which it reproduces." Herein lies the interest of ACIC in photographic quality controls. Many uses of aerial photography do not require good "picture quality" which appears pleasing or sharp to the eye. The total information which can be obtained from the photography for use in the compilation of the graphics produced is of the utmost importance.

A limited investigation of the capabilities of projection printing equipment in ACIC was conducted to determine the resolution obtainable. A standard AF resolution test target of maximum contrast was projected and printed on high contrast paper at several magnifications and with various lenses and light sources. Figure 1 shows the test target. It was realized that such tests would provide only a relative measure of the capabilities of the equipment. Table 1 shows some of the results obtained. The resolutions shown in Table 1 are the number of lines on the negative resolved. As may have been predicted, the best resolution was obtained with the narrower angle lens and the greater magnification.

ACIC will be using high-acuity photography in various phases of its operation. Common sense and good economics dictate that this photography must be utilized in such a manner that the maximum information possible is transferred in reproducing this photography. To insure the maximum quality, photographic quality-standards laboratory-techniques are being established in ACIC. Such quality controls will provide a practicable range of limits or standards for each reproduction stage. We are establishing a quality control system calling for built-in controls to eliminate defects in the end products by establishing tolerances for each step.

Methods of photographic quality control have long been used by the photographic industry which has developed the equipment, standards and tolerances for accomplishing such controls. Photographic quality stand-

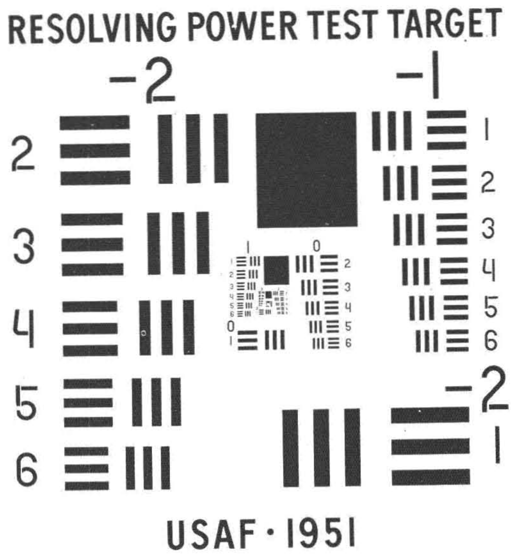

FIG. 1. Resolving power test target.

TABLE 1

PROJECTION PRINTING RESOLUTION TESTS

Lens	*Focal Length*	*Magnification*	*On Axis Resolution of Negative Lines/mm.*
Metrogon	5.5″	1×	29
Metrogon	5.5″	2×	57
Metrogon	5.5″	3.3×	80
Artar	9½″	1×	24
Artar	9½″	4×	64
Artar	9½″	6×	90
Raptor	135 mm.	1×	51
Raptor	135 mm.	2×	80
Raptor	135 mm.	3.3×	101

ards laboratory techniques will provide ACIC with the equipment and the means to utilize such available information by giving absolute values to the qualities which often are determined by operator skill, experience and judgment.

ACIC is taking the following specific action to achieve a high standard for processing and reproducing high acuity photography:

1. Establish a quality standard and control laboratory to accomplish the following:
   a. Determine the means for measuring parameters of resolution loss in each step of photographic reproduction.
   b. Establish a means of quality control in present and future processes.
   c. Determine the operational suitability of films, photo papers and optical systems.
   d. Take random samples of production work to examine the quality.
   e. Develop sensitometric techniques to be applied to production.
   f. Furnish guidance to production segments to enable them to meet the established standards.
2. Acquire and test new equipment to be used in photographic reproductions. Improvements desired in this phase are:
   a. Semi-automatic step and repeat printing with automatic dodging and contrast controls, developing, drying, cutting and packaging.
   b. Improved resolution and definition characteristics for rectifying equipment.
   c. Semi-automatic means of enlarging reduced negatives of source materials.
   d. Improve various photo-mechanical steps associated with proofs and offset plate making.

Steps are being taken to acquire equipment required to accomplish the above objectives. Many items are currently available. Others will need to be developed or modified from present equipment. Several photographic engineers with experience in photographic processing and quality control methods will be required for the quality control laboratory.

The end result which ACIC hopes to achieve is to increase the present photographic qualities obtainable by a factor of two to five times. Such an increase in quality will affect nearly every operation in photogrammetry with a primary emphasis on photographic reproduction activities. Methods and procedures which have been entirely satisfactory in the past will no longer suffice. Less reliance will be placed upon the photographic technician's judgment and experience although it will still be of great importance. New skills will need to be acquired by personnel to properly utilize equipment secured. Compilation personnel will need to use viewers, enlarging device, etc., to utilize the information available. The present "state of the art" has opened a gap between what can be accomplished and what is generally accomplished in production. ACIC intends to help close this gap through Photographic Quality Controls.