error of closure in the ground surveyed position of these points, if necessary, to each control survey station the Electrotape has occupied. The elevation of vertical control points near the corner of each stereomodel, and elsewhere as required, will be determined in the usual survey manner on the ground.

The District offices perform a field check and test profile analysis of the topographic maps as prints of the maps are delivered and inform the Photogrammetry Section of the results.

Maps Compiled by Photogrammetric Firms

In the event a highway project survey is to be developed by contract, proposals are requested from photogrammetric firms which have been prequalified by the State as to their abilities and facilities. The request is accompanied by a set of standard specifications pertaining to the acceptable quality of photogrammetric work in general and a set of special specifications setting forth conditions and standards applicable to the particular project.

The contractor is responsible for the photography, all compilation products, and the field control. The Photogrammetry Section checks the manuscripts on a stereoscopic plotter while the District field offices conduct a separate on-the-ground evaluation as delivery is made. The District field office is informed as to the results of the stereoscopic plotter checking and either returns the map sheets to the contractor for correction or accepts them as meeting the requirements of the specifications.

Special Projects

A procedure has been established in obtaining detailed right-of-way information from maps compiled photogrammetrically at the large scale of 20 ft to 1 in.¹

Research is being conducted into the possibility of utilizing a six-projector Kelsh stereoscopic plotter instrument in bridging horizontal control. The recent delivery of a three-projector Kelsh instrument should facilitate this research.

A system of reducing the aerial photographic image to 35-mm strip film and the projection of a three-dimensional image on a screen through the use of two projectors remotely controlled from a single source is being studied both for design use and for demonstrations at public hearings.

Color photography has been examined to a limited extent for feasibility in differentiating soil conditions, geological formations, types of ground cover, etc. No definite program for its general use has been established.

An attempt is presently being made to design an image projecting machine, manually operated, that will determine the azimuth and degree of tilt, scale, and crab of a photograph through the use of opaque templates.

PHOTOGRAMMETRY IN ARIZONA HIGHWAY DEPARTMENT

The Photogrammetric Division of the Arizona Highway Department was inaugurated in October 1957 with a staff of six men selected from existing personnel with varying experience in utilization of photogrammetric methods. Equipment consisted of a KEK plotter, two vertical sketchmasters, a slotted template cutter and an assortment of used drafting tables. The initial purpose of the new division was revision and modernization of the small-scale county maps which had been made a number of years previously and were incomplete and inadequate.

¹Henry, H. A., "Development of Photogrammetric Methods for Right-of-Way Operations in Texas." HRB Bull. 283, pp. 39-48 (1961).

Existing aerial photographs secured through the Army Map Service, augmented where necessary by new photography secured through contract, were used in preparing map manuscripts for the revisions. By radial line plot, originating and closing on existing U. S. Coast and Geodetic Survey, Forest Service, and Government Land Office established basic control, supplemental horizontal control was established for mapping with the aid of vertical sketchmasters and the KEK plotter.

Three of the existing 13 counties within the State have been mapped, comprising some 15, 227 sq mi. Work on the remaining counties is in various stages of completion. Maps are lithographed in three colors at a nominal scale of 0.5 mi to 1 in. Selected areas with more detail are shown at a larger scale.

As county mapping progressed and additional funds became available, the scope of the work of the Photogrammetric Division expanded to include larger scale topographic mapping for highway reconnaissance surveys and for highway location, which now forms the greater part of the work. Two standard two-projector Kelsh stereoscopic plotters were purchased and in 1960 an additional three-projector model was added. Until recently all photography was secured by contract with outside firms. Ground control has been developed, placing targets on markers of control points before the aerial photography is taken, by cut-and-try methods. Wild T-2 theodolites, Zeiss self-leveling levels, subtense bars, steel tapes, and related equipment were used.

The Photogrammetric Division has five ground control survey crews working under control survey engineers. Present personnel total 64, including 5 map compilers working two shifts on the three Kelsh instruments. Both Tellurometer and Model 4 Geodimeter are now part of the ground control surveying equipment. The Tellurometer is used for measuring distances of more than 0.5 mi, and the Geodimeter for the short measurements and for positioning from the maps the designed centerline of each highway on the ground. Targets for marking control points are generally constructed of Firestone Velon plastic sheeting 0.003 in. thick, available in 36-in. wide rolls. This material shows up well in the photography and is easily placed using lath, stakes, and large spikes. White traffic-line paint is used to pre-mark targets on existing paved roadways where necessary. Whitewash and cement mixtures have too short a life for use on Arizona highways under modern traffic conditions.

Maps, both planimetric and topographic, are generally compiled at a scale of from 50 ft to 1 in., with a contour interval of 2 ft, to a scale of 1,000 ft to 1 in., with a contour interval of 25 ft. The larger scale maps are used in detailed design of interchanges and bridges and the smaller scale maps are for reconnaissance purposes to determine and compare route alternatives and to select a route for preliminary survey and design. Generally a scale of 100 ft to 1 in. with a contour interval of 5 ft is used for designing the highway location, and a scale of 400 ft to 1 in. with a contour interval of 10 or 20 ft for the reconnaissance work, although highway locations are sometimes established by use of the smaller scale maps.

Wherever possible, basic control is originated and closed on station markers in the State plane coordinate system of the U. S. Coast and Geodetic Survey. This procedure not only serves to position stereoscopic models for the mapping but is a positive check on the accuracy of the work performed. Map compilation is done on Stabilene or similar material, and each manuscript map is printed directly for use in highway design and preparation of detailed construction plans. Computations for the ground survey control and its adjustment are done by a Univac Solid State 90 Computer in the Computing Section.

After the highway centerline has been established in the design processes, the plane coordinate computed position of essential points, such as PI and intermediate P.O.T., are established on the ground with the Geodimeter from the previously established horizontal control points, and the elevation of these points is measured by use of spirit levels. The designed centerline has been accurately plotted on the topographic maps using plane coordinate computed points, stationing determined, and, after resetting the photographic glass plates in the Kelsh stereoscopic plotter, cross-sections are measured and digital dimensions thereof are used in the electronic computer for ascertaining grading quantities. Later, the centerline is staked on the ground and permanent bench marks are established. At the present time, no attempt has been made to use photogram metric techniques for determining construction pay quantities. A Cessna 185 airplane was recently purchased, and a Kargl converted K17 camera is being installed. It is expected all aerial photography in the future will be taken by and processed within the Department, thus making the Photogrammetric Division selfcontained.

USE OF PHOTOGRAMMETRIC AND ELECTRONIC PROCESSES BY THE INDIANA STATE HIGHWAY COMMISSION

In November 1959, approval was given for the organization of the Bureau of Photogrammetric and Electronic Processes within the Construction Division of the State Highway Department of Indiana. An aerial photographic laboratory had already been set up in 1956. The new Bureau had as its responsibility the performance or supervision of the following:

1. All aerial photography, either vertical or oblique, and requisite laboratory work of processing, printing, enlargement, mosaic preparation, and graphic arts reproduction associated therewith;

2. Any ground photography of a special nature requested by personnel of the Central Office, wherein the nature of the assignment justifies the services of a qualified photographer and the use of professional equipment;

3. The performance of any graphic arts, photostat or photographic copy work possible within the scope of the equipment and facilities of the photographic laboratory;

4. The preparation by photogrammetric methods of any topographic or planimetric reconnaissance or design maps using the Kelsh stereoscopic plotters;

5. Preparation, development, utilization, or modification of computer programs, and their application and processing in the IBM 650 computing equipment, for use in the design and construction of roads and bridges, traffic studies, route location, etc.

6. The maintenance of a complete file of the latest available aerial photographic coverage of the 92 counties of the State, as acquired from the Agricultural Stabilization and Conservation Service (ASCS) of the U. S. Department of Agriculture.

Equipment

The Bureau maintains a 1956 Piper Apache PA-23 (5 place, twin engine) modified for vertical camera equipment and oxygen equipped. Among the cameras are one each of a K-17C 6-in. Metrogon f/6.3; a K-17B 12-in. Aerostigmat f/5.0; a F-56 $8\frac{1}{4}$ in. B&L Altimar f/4.0; a Speed Graphic 4 by 5 162-mm Optar f/4.5, 90-mm Raptar wide angle f/6.8; and Calumet view 4 by 5 135-mm Schneider Symmar f/5, 90-mm Schneider Super-Angulon f/8. Darkroom equipment includes cut-film dryers, various printers and enlargers, and a camera test bench. Sinks and tanks are, wherever possible, stainless steel to minimize corrosion. The three darkrooms are equipped with Kodak Utility Model Safelights and appropriate filters.

Laboratory Personnel

In early 1957 an engineer of Photogrammetry was engaged to direct procurement of equipment and supplies and to initiate operation of the photographic laboratory. Subsequently, four highway technicians and a photographic laboratory supervisor were hired. The maximum number of employees was reached in early 1961 when the laboratory employed a total of 13.

Outline of Procedures

1. A single strip reconnaissance flight at a 1,600 ft to 1-in. scale will give a 14,400-ft width of coverage, and 3 sidelapped flights at an 800 ft to 1-in. scale will give