There are many different procedures to choose from, each of which has particular value according to the specific highway engineering job, and depending on the availability of photogrammetric equipment as well as equipment operators.

I feel that the highway engineer can do well to become better acquainted with the wonderful progress that photogrammetry has made and the great advantages to be gained by using a modern method of obtaining information and factual data essential for the solution of his problems.

PRESIDENT SANDERS: Thank you very much, Mr. Pryor.

I am very pleased to welcome to our meeting as a speaker a representative from the National Geographic Society. We have always felt very close to that Society, although there has not been as much interchange between us as there should be, but perhaps we are correcting that situation when today we have one of their representatives with us, Mr. Newman Bumstead.

Mr. Bumstead has been instrumental in the invention and development of a photocomposing process which makes possible the mass production of hand lettering for a map copy, and he has also been instrumental in many other technological improvements connected with map printing. He is going to talk to us about a new method of map compilation for color printing. I am pleased to present Mr. Bumstead.

MR. NEWMAN BUMSTEAD: Compared to flying and the making of aerial photographs, the drafting of map copy for the lithographer is a pretty drab and unromantic procedure. It is, nonetheless, an important and highly critical link in the complicated chain that connects aerial mapping with the printing press.

Efforts to obtain extreme accuracy in the many phases of photogrammetry, each one of which is a little science in itself, may be largely in vain if the resulting map drawings are not adequately prepared for precision press work.

We in the National Geographic Society's Cartographic Section, with the aid of the Ozalid Division of General Aniline and Film Corporation, have recently developed a map compilation technique that renders more certain the preparation of adequate copy for precision printing. It is also faster and more efficient than the method we formerly employed.

The need for such a technique in the preparation of multi-color maps is easily appreciated when one stops to realize that for each color on the final map there is a separate printing plate. For each of these printing plates there is a separate negative, and for each negative, a separate drawing.

For example, all the place names, railways, parallels, and meridians, which will appear in black on the finished map, are drawn on one piece of paper. Drainage, rivers, shorelines, lakes, etc., to appear in blue are drafted on a second piece. Highways, to be printed in red, are done on a third, and mountains or relief shading, to be printed in brown, are drawn on a fourth piece of paper. Obviously, the relationship of these drawings to each other is extremely critical. Whenever we place a line on any one of them, we must know exactly what relationship it will bear to the lines on all of the other drawings. For instance, when a railroad is being drawn which parallels a river and perhaps runs between the river and highway, it must be placed exactly right with reference to the river and the highway, or on the final map we shall have an obvious misfit, or lack of register.

How then can we be sure that we get this fit between these various types of detail? One procedure that is often used is to prepare a compilation drawing entirely on one piece of paper, regardless of the color in which the various types of detail will appear on the finished map. The photo-engraver, or lithographer, makes a number of negatives of this, and by tedious painting out and negative

cutting, he is able to eliminate on each of the several negatives all but one class of information, thus obtaining a set of color separation negatives.

A big objection to this procedure is that the final drafting, if this negative work can be so called, is often done not by the map people who laid out and planned the job, but by the lithographer who may not have full knowledge or appreciation of the job's requirements. Under such circumstances the final result is almost certain to suffer.

Another method, the one we formerly used, also employs a compilation drawing which contains all detail regardless of its color on the finished map. From a negative of this drawing, blue-line prints are made by the ferrocyanide process or by lithography. Color separation drawings are then produced by inking a single class of information on each of these blue-line prints. This is better than the first method in that the lithographer obtains his color separation negatives by direct photography of our drawings. In fact this method would be quite satisfactory except that perfect register cannot be held on ferrocyanide or lithographic blue-line prints.

Let's look at the disadvantages of the ferrocyanide process. First, it calls for a negative, which requires a camera step. It is seldom possible to make a large copy negative without some slight error in scale. Sometimes, if the camera is not in perfect adjustment, we also get errors of shape.

Second, the ferrocyanide process requires the wetting of the drawing paper stock, once when it is sensitized, and again when it is developed. This double wetting has a ruinous effect on the drawing paper. The finest drawing paper-stocks are finished under heat and pressure to obtain a smooth and slightly toothy surface. This important step in drawing paper manufacture is cancelled out by wetting, and the firm, smooth finish gives way to a loose, fibrous surface which remotely suggests that of blotting paper.

The shrinking and stretching that occur with this double wetting make accurate register exceedingly difficult. This objection can be overcome by mounting the drawing paper on stiff boards. There are, however, obvious disadvantages to working on drawing paper mounted in this fashion.

Making prints by lithography has in common with the ferrocyanide process the disadvantage of requiring a camera and negative step. In addition, if the transfer roller of the lithographic press happens to be of a slightly different diameter from that of the pressure roller, and this frequently is the case, the slippage that takes place between them will change the shape of the impression, either shortening or lengthening it. A further objection to the lithographic blue-line print is its greasy ink which often makes drafting extremely difficult.

Our new compilation procedure gets around all these objections and difficulties very nicely. The drafting is done under the direction of the people who laid out and planned the job. No drafting whatsoever is left to the lithographer. Blue-line prints are used but they are not subjected to wetting as in the case of the ferrocyanide process. Neither are they subjected to the greasy ink and slippage of the litho press. Last but not least, the blue-line prints are made directly from the compilation drawing by dry contact printing. No camera step is required. Never is final accurate register in doubt.

Taking for example The Society's recently published map, the SOUTH CENTRAL UNITED STATES, we have in the vicinity of Little Rock, Arkansas, the Arkansas River paralleled on both sides by railroads and highways. The river is printed in blue. The railroads which parallel it are printed in black. The highways which parallel the railroads are printed in red. Bearing in mind that each one of these types of detail is printed in a separate color, that the relation-

ship between them is extremely critical, and that the drawing for each one of them is prepared on a separate piece of paper, one can further appreciate the need for a precise compilation technique.

Each year The Society publishes four full-color wall maps. Of each map at least 1,700,000 copies are printed. On each copy there are seven press impressions. This adds up to 47,000,000 press impressions per year. And on any one of them a register error of 1/100 of an inch or less would violate The Society's rigid standards of accuracy. I give you these figures to show how essential to us is a sure-fire method of copy preparation.

The first step in our new procedure is to plot a projection accurately on Di-Noc. This plastic material is transparent. It has an excellent tooth for pencil and ink line work, and most important of all, it has a high degree of dimensional stability. To this projection is fitted and adjusted all map detail.

The drainage is drawn in blue ink. The highways are drawn in orange and yellow—orange for federal highways and yellow for state roads. Railroads are inked in green. Town spots are inked in red in several symbols which indicate populations. Place names are not lettered in. To do so would obscure the other more essential information.

This colorful drawing is regarded as one of maximum accuracy if perhaps of somewhat rough appearance. The colored inks used are carefully selected for opacity.

The next step is making by the Ozalid process several non-photographic blue-line prints of this colored compilation drawing which serves here as a contact positive. Hence the need for opaque inks. A vacuum frame is used to insure perfect contact. Exposure is by carbon arcs. Enough prints are made on sensitized high quality drawing paper so that one may be assigned to each basic color that will appear on the finished map.

Development of these prints is simply a matter of feeding them into a machine which passes them over hot ammonia fumes. Any one of the standard Ozalid printing machines may be used.

The time required for printing and development is only a few minutes, and the prints are immediately ready for final drafting. They have none of the disadvantages that are common to ferrocyanide and lithographic blue-line prints which I described earlier. The fine drawing surface of this paper has not been disturbed, nor has its dimensional stability been affected.

Care must be taken in making these prints to have the grain of the paper running always in the same direction. They must be made at the same time in order to assure uniform atmospheric conditions. Subsequent humidity changes may have some effect on them, but it will be a uniform effect, and the several prints will continue to fit one another. Exact scale adjustment, if necessary, is obtained by the lithographer when final negatives are made.

Final drafting is done entirely in black ink. On each one of the several prints, only that detail is drafted which will appear in the basic color to which the print has been assigned.

The compilation drawing is kept at hand so that the draftsman may refer to its color in identifying the particular detail he is working up with black ink on one of the blue-line prints.

For small-scale maps such as the one referred to (1:2,500,000), we do not as a rule make provision on the compilation drawing for mountain detail. The draftsman uses the river system and accurately plotted elevations as a basis for his relief drawing.

When the lithographer photographs these final drawings preparatory to

making his printing plates, the color-blind negatives which he employs pick up only the black lines. The blue un-inked lines of each print which serve as a guide to the draftsman are invisible to his color-blind negatives and therefore drop out.

Summing up, from a primary compilation drawing, a number of blue-line contact prints, true and undistorted, are obtained by the Ozalid process. A print is assigned to each color that will appear on the finished map, and on it is inked in black the particular detail to be printed in that color.

From these drawings the lithographer makes his color separation negatives by direct photography. Thus are eliminated many of the pitfalls formerly encountered in platemaking. The lithographer's cameraman and platemaker are not required to adjust poorly matched copy. Exact register is, as it should be, solely a matter of careful work in the press room.

In short, this method offers a consistent means of obtaining accuracy, always a primary objective in the work of the National Geographic Society.

PRESIDENT SANDERS: Mr. Bumstead, we all thank you for such an excellently prepared paper and which was so well delivered. The material was excellent. We will now adjourn for the morning session, and I think we can proceed to the luncheon.