not established a maximum flight height for this type of work at this time, I feel that the C factor for such work will be found to be much larger than those currently used for smaller contour intervals. I certainly would not state that the Multiplex equipment is perfect and entirely satisfactory for this type of work; nor do I know of any equipment which I consider to be entirely satisfactory. However, the Multiplex is doing an acceptable job of producing this type of map which after thorough testing has been found to meet the requirements of the specifications.

Large-scale small-contour interval mapping today in my opinion is in about the position that the 20′ contour map at a scale of 1″ = 1 mile was some fifteen to twenty years ago. When this type of map was made some fifteen years ago it was considered to be a good map, while by today's standards it is considered "lousy" and the area needs to be completely remapped.

We now have a request to produce a map at a scale of 1″ = 20′ showing 6″ contours. At the moment I am of the opinion that the easiest way to do this job is to load it on a wagon and haul it into the customer's office.

We feel that the camera and instrument manufacturers have a big job ahead of them. To do the job required for map users at a cost they can justify, we operators need more efficient equipment than any manufactured at this time.

Moderator Sharp: Mr. Quinn will now read his paper.

REPORT FROM AERO SERVICE CORPORATION

A. O. Quinn, Aero Service Corporation

AERO SERVICE CORPORATION has used and is now using a stereoscopic mapping method which has been referred to as both primitive and archaic by critics who have failed to recognize the basis for this very successful mapping method. The Brock process which utilizes a series of highly precise instruments was designed to answer the following mapping fundamentals:

1. In making topographic maps from aerial photographs, some operations can be performed without the use of a machine and those operations performed on machines do not require the same amount of time. Therefore, a single machine performing all operations would not be economically successful, as its output would be limited by the operation requiring the most time.
2. Because of possibility of relatively large errors introduced by angular displacement of optics, due to lost motion and deflection of supporting members, non-movable optical systems should be used where possible.
3. That until film free of non-uniform shrinkage or expansion is available, aerial photographs should be made on glass plates, for accurate determination of contours.

I am not going to take the time to describe in detail each of the component parts of the Brock equipment. These instruments have been very well described in the "MANUAL OF PHOTOGRAMMETRY" and various articles which have appeared in "PHOTOGRAMMETRIC ENGINEERING." Also, many of you have visited our offices in Philadelphia. The equipment consists of an aerial camera, which is on exhibit for this meeting, a measuring stereoscope, a correction printer which is used in the solution of the tilt problem and also to produce rectified photographs, a scale equalizer and a precise projection camera.

Basically the Brock process requires: the exposure of a glass plate negative, the determination of tilt of each exposure, the horizontalization of each photograph, contouring, scale equalization, and the assembling of individual photographic data into a final map.

It is true that the Brock equipment is unique, and that under present conditions, it defies duplications. The instruments were built by precision craftsmen and no expense was spared in achieving accurate results. The lenses, grid plates, and machine parts used in the original construction could be replaced today only at a tremendous cost.

Is the Brock process conceived and built in the 1920's an obsolete mapping method? We at Aero think not, and I am inclined to believe that some of our competitors are of the same opinion. Can the Brock equipment be used to prepare as accurate topographic maps as other mapping systems? The answer to this question is yes, and proof may be found in the thousands of square miles of topographic maps which have been prepared using the Brock equipment, and in the fact that these jobs were obtained through competitive bidding against other equipment. Map accuracy tests have proven that maps prepared by Brock equipment meet and in most cases far exceed standard map accuracy requirements. Data on such tests have been published by such clients as the City of Cleveland and the consulting engineers for the Pennsylvania Turnpike.

Because Aero Service also uses Kelsh Plotters for the production of topographic maps, a discussion concerning these plotters and the Brock equipment may be of interest. I will not use valuable time in a detailed description of the Kelsh Plotter as I am sure that the construction details and principles of operation are well known to this group.

A rapid comparison of the two instruments can be obtained from the most excellent chart "Major Functional Properties of Stereoscopic Instruments" prepared by Messers. Sharp and Sparling and published in the September 1948 issue of "PHOTOGRAMMETRIC ENGINEERING." The major differences may be resolved into the following: the Brock uses glass plate photography, but requires a 2 diameter enlargement: the Kelsh uses a glass diapositive which can be made from either film or glass plate photography. The Brock Stereometer employs a direct binocular telescope viewing system while the Kelsh model is obtained from projected light. This difference gives rise to the most interesting discussion advanced by Mr. Cottrell of the Fairchild Company in his paper* given at the 1949 Annual meeting in which he reviewed the relative merits of "sharp sighted" and "dull sighted" instruments. At that time Mr. Cottrell stated,

> "The clarity with which the operator views the image is a function of definition and magnifications. The Stereoplanigraph and Wild A-5 are 'sharp sighted' machines. The image quality is good and magnification is at optimum value. The Multiplex and Kelsh Plotters have excellent definition only at one elevation, and the definition falls off as the terrain departs from flatness. Their magnification is of a lower order. Thus they are 'dull sighted' instruments."

Without meaning to reopen Mr. Cottrell's arguments, or to prove or disprove his definitions of "sharp sighted" and so called "dull sighted" instruments, I feel that the model observed in the Brock viewing instrument may be called "sharp sighted" in comparison with that of the Kelsh Plotter. Many of our operators have done considerable work on both instruments, and they are unanimous in their opinion that the model presented in the Brock is far clearer, and that readings made on this model are more accurate than corresponding readings on the Kelsh Models. In fact one man who has done some work with

* Cottrell, C. M., "Operations and Comparison of the Stereoplanigraph," PHOTOGRAMMETRIC ENGINEERING, Vol. XV, No. 1, p. 103.

the Stereoplanigraph and A-5 states that the Brock model is far clearer than either of these instruments. The Brock viewing telescope permits magnification of two, three and four diameters of the already two-diameter enlarged glass plates. The Kelsh projects an image which is enlarged five times when using the 6″ metrogon assembly and four times when the $8\frac{1}{4}''$ lens cone is used. The added clarity of the Brock model is a most important factor.

Another major difference is in the solution of the inevitable tilt problem. The Brock method is analytical and is supplemented with prepared charts and tables to speed up the computations. The tilts for a pair of photographs are determined through the use of the parallax values read at several points whose elevations are known, and measurements on the Correction Printer afford an immediate check upon the tilt solution and a positive position of the nadir point. For best operation, it is usually desirable to secure more field elevations than are normally required by the Kelsh Plotter. The orientation of the Kelsh model, and this is the solution of the tilt of each photograph, is accomplished by visually clearing the parallax at a series of points. The eventual solution is a function of the ocular acuity of the operator which may or may not correspond to the solution obtained by another observer.

After the Brock pictures are horizontalized, they are placed in the stereometer where all contours and other details may be drawn on a transparent sheet superimposed on one of the pictures. The pictures are aligned and set at proper separations, corresponding to the parallax of any contour, and the parallax slide is fastened. Parallax values may be set and read on a dial to .001 of an inch with interpolation to a tenth of a thousandth. Our operators are confident that they can duplicate measurements to .001 of an inch. By means of coordinate hand wheels, all parts of the photographs may be brought into the view of the optics. We like the coordinate motion afforded by the hand wheels, and there is a definite advantage to this type of movement.

The Kelsh plotting table contains a single floating dot, whereas the Brock instrument has two very fine lines intersecting at right angles. These lines are respectively parallel to the motions of the coordinate slides. When viewed through the eye pieces, the two reticules blend into one pair of intersecting lines, and give the sensation of establishing a horizontal plane.

Critics of the Brock have stated that a big disadvantage of the Brock equipment is reflected in the necessity of changing the contours as drawn on the overlay from a conic to an orthographic projection. The stereometer could be designed to plot directly, but the added accuracy gained from hand drafting each contour makes the need for such a change debatable. The Kelsh instrument plots contours and planimetry directly on an orthographic projection.

The Brock process lends itself to production line methods. Many people are required to handle the various operations and each person becomes a specialist in one phase of the total operation.

We have found that each mapping job rates special consideration, and it is on this basis that decision is made as to whether Kelsh or Brock methods are to be used. By comparison, a higher C factor, the ratio between the flying height and the contour interval, can be used in the Brock process, and this must be weighed against a slight increase in control and materials cost when figuring a specific mapping problem.

Both the Kelsh and Brock equipment are well suited to large scale mapping work. Because of the greater image stability, and model clarity, we prefer to handle mapping jobs which require a contour interval of less than two feet, on the Brock equipment. We agree with Dr. Lyle Trorey who states in his book, "Handbook of Aerial Mapping and Photogrammetry," "the whole operation, including the aerial photography, is on glass, and the Brock process is capable of work of great accuracy, approaching or exceeding the accuracy of the better automatic instruments."

We have a high regard for the Kelsh Plotter and find that it too fits into our needs in topographic mapping work. We have not explored the full range of flying height—contour interval ratios for various types of mapping areas with this instrument. We see the need for slight modifications, improvements and expansions of the basic Kelsh ideas, and we look with interest upon the instruments which have been displayed at this meeting.

Moderator Sharp: The next speaker is Mr. Robert E. Altenhofen.

ACCURACY AND ADAPTABILITY OF STEREOPLOTTING INSTRUMENTS AS REVEALED BY U. S. GEOLOGICAL SURVEY PRACTICE

Robert E. Altenhofen

THE U. S. Geological Survey utilizes a variety of stereophotogrammetric plotting instruments in its topographic mapping program. This agency practices a policy of combined production and research in the field of photogrammetry. Long experience in topographic mapping has proved the wisdom of such a course. Photogrammetric research creates the tools for map production which in turn proves the efficacy of research. This reciprocity of benefits has led specifically to the development and improvement of certain stereoplotting instruments, and generally to the production of better maps at lower costs.

The map production methods practiced by the U. S. Geological Survey have a direct bearing on the subject under discussion by this panel. The plotting instruments used by the Survey in order of increasing accuracy as revealed by experience are the Multiplex, Kelsh, Wild Autograph A-6, Autograph A-5, and the Stereoplanigraph.

It is prudent to preface this discussion by admitting the controversial character of the subject of instrument accuracy. Comparisons of accuracy inevitably lead to heated discussion which frequently descends to argument. Pride seems to be the cause of much debate. Pride of invention and ownership, national pride, or just plain bias often lead to overenthusiastic claims for a specific instrument.

We of the Survey can only say, in the vein of the late Will Rogers, that all we know relative to the performance of stereoplotting instruments is what the photogrammetrist reads on the height counter of the plotter, or what the engineer finds in his field check of the topographic map. The performances of these instruments have been determined by the practical procedure of checking their end product, the map. Thus, all operational components of the photogrammetric process are considered in the appraisal of an instrument. Inherent instrumental accuracy as a function of design and manufacturing skill is the principal component; but we find other factors combined with it, perhaps detrimentally, when facing the realities of map production. Some of these components are instrument calibration, quality of the aerial photography, ease of operation, skill of the average operator, and work schedules. Therefore, from a production standpoint, instrument accuracy and adaptability are most comprehensively determined by weighing all factors in the photogrammetric process.