IN THE PLATES CARRYING THE SLITS PROVIDE AN EASY MEANS OF MEASURING NEGATIVES FOR SHRINKAGE. THE CONSTRUCTION OF THE COLLIMATING MARK PLATE HAS BEEN ARRANGED TO FACILITATE CALIBRATION BY THE UNITED STATES BUREAU OF STANDARDS. ANOTHER POINT OF INTEREST IS THE METHOD USED TO MOUNT THE LENS. SO MUCH TROUBLE HAS BEEN EXPERIENCED IN THE PAST IN OBTAINING ACCURATELY FITTING THREADS ON LENS AND SHUTTER BARRELS THAT THIS FEATURE HAS BEEN ELIMINATED AND CENTERING IS OBTAINED WITH EXTREME ACCURACY BY MEANS OF A CYLINDRICAL SHOULDER ON THE FRONT AND REAR CELL ASSEMBLIES. THE LOWER PART OF THE CAMERA BODY IS PROVIDED WITH FLANGES AT THE PROPER DISTANCE APART TO SECURE THE NECESSARY SEPARATION OF THE TWO CELLS AND THESE FLANGES ARE BORED OUT SO AS TO BE PERFECTLY CONCENTRIC WITH THE MECHANICAL AXIS OF THE BODY. THE CYLINDRICAL SHOULDERS ON THE LENSES ARE TRUED UP BY TAKING A LIGHT CUT OFF THE LOCATING SURFACES AFTER THESE ELEMENTS HAVE BEEN OPTICALLY CENTERED BY WELL KNOWN MEANS. THE FRONT AND REAR ASSEMBLIES ARE HELD IN PLACE BY ORDINARY SCREWS PASSING THROUGH A FLANGE ADJACENT TO THE LOCATING DIAMETERS, THIS FLANGE BEING MACHINED SQUARE AT THE TIME OF TRUING UP.

THE SHUTTER MECHANISM IS CONTAINED IN A CAST ALUMINUM HOUSING INSERTED BETWEEN THE TWO FLANGES AT THE LOWER PART OF THE CAMERA BODY. THE HOUSING IS ATTACHED ONLY TO ONE OF THESE FLANGES AND IN SUCH A WAY AS TO PERMIT RADIAL EXPANSION OF THE DISSIMILAR MATERIALS WITHOUT DISTORTION BEING TRANSMITTED TO THE BODY FROM THIS CAUSE OR AS A RESULT OF SHOCKS INCIDENT TO THE OPERATION OF A HIGH SPEED SHUTTER, ETC. PROVISION IS MADE TO ACCOMMODATE THE USUAL LIGHT FILTERS ON BAYONET PINS ON THE LOWER FLANGE.

IN ORDER TO ELIMINATE THE POSSIBILITY OF STRAINS BEING APPLIED TO THE CAMERA BODY ABOVE MENTIONED, THE ENTIRE ASSEMBLY IS SUSPENDED BY MEANS OF A FLANGE NEAR ITS UPPER EXTREMITY INSIDE A SECONDARY CASING IN WHICH ALL REMAINING CAMERA MECHANISM IS ASSEMBLED. THIS MECHANISM CONSISTS OF THE WINDING MOTOR, SHUTTER RETARD AND DRIVE COUPLINGS, MAGAZINE DRIVE ASSEMBLY, ETC. SUITABLE BAFFLES ARE PROVIDED FOR THE EXCLUSION OF UNWANTED ILLUMINATION AND DIRT. A SPECIAL MAGAZINE CONTAINING ENOUGH FILM FOR 250 EXPOSURES FITS INTO A RECESS ON TOP OF THIS SECONDARY BODY IN SUCH A WAY THAT ITS MOVABLE VACUUM BACK WILL FUNCTION IN THE MANNER PREVIOUSLY DESCRIBED. THE MAGAZINE IS EASILY REMOVABLE AND THUS PERMITS THE USE OF AN EXTRA SUPPLY OF FILM WHENEVER DESIRED. THE OUTER BODY IS PROVIDED WITH FITTINGS TO PERMIT INSTALLATION IN STANDARD MAPPING MOUNTS. PROVISION IS ALSO MADE FOR THE ATTACHMENT OF THE TELESCOPIC VIEW FINDER MENTIONED EARLIER IN THIS ARTICLE SO THAT THE ENTIRE ASSEMBLY PROVIDES AND AERIAL PHOTOGRAMMETRY UNIT OF ADEQUATE ACCURACY AND HAVING THE NECESSARY ADVANTAGES OF FULLY AUTOMATIC OPERATION AND RUGGED DEPENDABILITY, FREE FROM DAMAGE DUE TO THE HANDLING TO WHICH AERIAL PHOTOGRAPHIC EQUIPMENT IS UNAVOIDABLY SUBJECTED.

THE BOULDER RESERVOIR SURVEY

BY
LEON T. ELIEL

(PAPER PRESENTED AT THE ANNUAL MEETING OF THE AMERICAN SOCIETY OF PHOTOGRAMMETRY JANUARY 18, 1937)

AT EIGHT O'CLOCK ONE SATURDAY MORNING, TELEGRAPHIC NOTIFICATION TO PROCEED WITH MAPPING LAKE MEAD (BOULDER RESERVOIR) WAS RECEIVED IN LOS ANGELES. THE CONTRACTOR WAS FURTHER INFORMED THAT WATER WAS BACKING UP BEHIND THE CLOSED GATES OF THE DAM AT THE RATE OF TWO MILES A DAY. IT WAS IMPERATIVE TO GET THE PICTURES TAKEN AND THE CONTROL IN BEFORE ANY SUBSTANTIAL AREA OF THE RESERVOIR WAS SUBMERGED. PICTURES OF THE CRITICAL AREA WERE SAFELY RECORDED ON THE AERIAL FILM FIVE HOURS AFTER RECEIVING NOTICE OF AWARD, NEEDLESS TO SAY THE PHOTOGRAPHIC CREW HAD BEEN HELD ON THEIR MARKS AND SET, READY FOR THE CRACK OF THE GUN -- "JUST IN CASE."

TO BEGIN WITH, THE RESERVOIR BACKED UP BETWEEN FAIRLY STEEP SLOPING BANKS, CONFINING THE GROWING LAKE SO THAT IT LENGTHENED WITHOUT GETTING VERY WIDE. FOR THIS REASON IT WAS POSSIBLE TO CONTROL THE PICTURES WHICH COVERED MUCH MORE THAN THE WIDTH OF THE RAPIDLY EXTENDING LAKE LONG AFTER THE RIBBON OF WATER EXTENDED ACROSS THEM. THUS ALL OF THE AREA WHICH WAS ABOVE THE FLOOD LINE AT THE TIME OF PHOTOGRAPHY WAS CONTROLLED AND MAPPED.

THE SOIL CONSERVATION SERVICE, FOR WHOM THE MAP WAS MADE, ARRANGED FOR THE

U. S. Coast and Geodetic Survey to make available rather extensive control, then being installed in the vicinity of Lake Mead. The splendid cooperation of that organization is responsible in no small measure for the success of this enterprise.

The contractor used the U. S. Coast and Geodetic Survey system as the origin of both horizontal and vertical control. The level circuits were in many instances modified to give elevations where the contractor needed them and several spur lines were run to provide elevations at various triangulation stations. From this origin, horizontal and vertical control was extended simultaneously by theodolites reading direct to one second.

Flying was done with the Four Couples Camera at an elevation of 13,000 feet above mean ground. This elevation was designed to give ten foot vertical accuracy of contours. This 1300 factor was selected rather than the usual 1500 factor for the stereoplanigraph because of the barren nature of much of the ground which is devoid of good stereoscopic detail.

Some experimental pictures were taken to determine how much could be seen in the shadows in steep canyons such as Black Canyon, Boulder Canyon, and the Grand Canyon proper. It was found the Black Canyon, true to its name, reflected insufficient light from its black walls to render any usable shadow detail, even at the slowest camera speeds and with the lightest filters. In Boulder Canyon, the rock is lighter in color. The walls are so steep that two flights were made,- one for each wall. Thus each wall was photographed well toward the side of a series of pictures, enabling the wall to be viewed obliquely in spite of the fact that the pictures were conventional "verticals", which, of course, only refers to the principal point. Since it was necessary to make a separate strip of pictures for each side of Boulder Canyon, a time of day was selected for each flight giving the best illumination. In this manner it was possible to contour Boulder Canyon without undue difficulty on the stereoplanigraph. Had a camera of narrower angle been used, it would have been necessary to take the pictures "obliquely". This would have involved an extremely difficult and impractical control problem as well as greatly increasing the "set up" time on the stereoplanigraph.

The formations of the Grand Canyon recorded usable detail in the shadows. It was surprising that the "sheer" Grand Canyon walls were mainly sheer in our imaginations and that while the Canyon is titanic, gigantic, colossal and all the other superlatives, it is less sheer than many other places in which we have worked. Our survey parties which daily scrambled up to the first bench about a thousand feet above the river might disagree with me. But they made it safely over a period of three months without resorting to any special climbing paraphernalia other than strong finger nails.

In a few instances, we made two sets of positive plates from the original air negatives, making one set very light for the shadows and the second set normal for the balance of the area.

Fortunately, we were not required to contour the worst part of Black Canyon. Had this been necessary, the pictures would have been deferred until mid-summer and the time of day selected for the best illumination of each wall. It might also have been necessary to employ a slow-moving blimp which could hover while longer exposures were made. We have done this on a number of occasions although the motive heretofore has usually been large scale pictures which would have blurred in a fast-moving airplane.

The aerial photography involved not only the securing of the necessary pictures to compile the map but also a considerable amount of reconnaissance photography used in studying the control problem. While the control of the entire area was unusually difficult, the Grand Canyon section was possible one of the most troublesome control problems in the entire history of photogrammetry. Here was a steep walled sinuous canyon, a mile deep, fifty miles long, with a roaring river in the bottom boiling through a continuous series of rapids. The mere problem of organizing to go through the Canyon was made easier by reason of the previous experience of the Geological Survey and other expeditions. However, it had never before been necessary to carry a survey through the Canyon of a higher order of accuracy than a stadia traverse. This additional precision brought many new complications, which will be discussed as we come to them.

The first problem was to break down the long narrow fifty-five mile arc of triangulation into shorter sections with closures into the U. S. Coast and Geodetic Survey system. First, a continuous set of stereoscopic high altitude verticals was taken from 25,000 feet above sea level. This gave an elevation of about 18,000 feet above the rim, and at this elevation the camera covers a gross width of about six miles. The south rim had been selected by an observation flight as the logical side from which to bring in control from the U. S. Coast and Geodetic Survey scheme. The pictures were taken to show the river and as much of the south rim as possible. On these pictures, it was possible to impose a stereoscopic hair line to determine visibility from the rim edge to the bottom of the Canyon. Next, a complete set of stereoscopic obliques was taken showing the south rim in the foreground and extending to the horizon. On these pictures, all of the Coast and Geodetic Survey stations could be identified. An index map was prepared correlating the verticals and obliques.

The verticals were studied first under the stereoscope and every section on the rim from which two stations could see a common point on the river was noted. Next, the obliques were studied to determine which of these rim sections could be most readily tied in to the Coast and Geodetic Survey system. In these studies, a hair line was again superimposed stereoscopically on the obliques and the problems of intervisibility, accessibility and strength of figure were practically solved at a glance.

The fifty-five miles from Diamond Creek to Pierce's Ferry readily broke down into three sections. One of about twenty miles from Diamont Creek to Spencer Canyon; a second of about fifteen miles from Spencer Canyon to New Water Canyon; and a final section of twenty miles from New Water Canyon to Pierce's Ferry.

Having settled this matter, the Coast and Geodetic Survey was requested to run levels to each of their triangulation stations in the Canyon section from which our survey would take off.

There was some question whether triangulation or traverse would be employed at Diamond Creek and Spencer Canyon. The triangulation appeared difficult. The traverse appeared equally difficult. The decision was left to a final ground inspection for the purpose of determining just how practical the traverse might be. In both cases, the decision was made in favor of triangulation. At New Water Canyon, triangulation was decided upon from the start.

The selected triangulation scheme was marked on the oblique photographs and the best route to reach each station was indicated. The selection of the route to the rim was particularly helpful at New Water Canyon where the approach across the mesa had to be made around tortuous side canyons which frequently could not have been seen until the party arrived at the impasse.

From the rim at New Water Canyon, a number of natural objects were identified on the river to which angles were turned. Later the river party occupied these stations. The several solutions checked each other for both position and elevation.

At the conclusion of the reconnaissance, the control problem was broken down into three areas. First, the Colorado River proper between Black Canyon and Pierce's Ferry was worked upstream. Secondly, the Virgin River area was entirely a land operation. Thirdly, the Grand Canyon section was to be an expedition from Diamond Creek down to Pierce's Ferry.

The first section was not unduly difficult. A reconnaissance was made by Engineer C. M. Cottrell and points were pricked on the pictures which were to be tied in by the triangulation parties. This job was so well organized that practically every point which was occupied was a necessary control point. There were very few extra points which were required for the triangulation net which were not also later essential for controlling the contour plotting. The triangulation parties moved around by truck, outboard motor boats, and water sled. The latter is a flat bottom shallow draft boat driven by an airplane engine and propeller. It was particularly useful going up through rapids and shallows, where its high speed and light draft got it through places which would have been unnavigable by conventional craft. Outboard propellers were in frequent trouble on account of the dirt carried by the water cutting out the propeller bearings, and the propellers themselves were ever striking submerged rocks and shearing drive pins.

In this section of the triangulation, as in the Virgin River section, the control distribution was such that the average sight was one to two miles long and rarely exceeded three miles, excepting lines which tied in to distant Coast and Geodetic Survey stations. Vertical angles were not used on the longer shots

AS COAST AND GEODETIC SURVEY LEVELS WERE ALWAYS USED AS THE ORIGIN OF THE VERTICAL SYSTEM.

ON THE VIRGIN RIVER AREA, TRANSPORTATION WAS CONVENTIONAL, EMPLOYING TRUCKS AND PACK ANIMALS. IN THIS SECTION, HORIZONTAL AND VERTICAL TIES WERE MADE TO BOTH COAST AND GEODETIC SURVEY AND BUREAU OF RECLAMATION WORK.

IT SHOULD BE KEPT IN MIND THAT THE TRIANGULATION AT ALL TIMES HAD TO BE CROWDED TO KEEP AHEAD OF POSSIBLE ABRUPT RISES OF WATER DUE TO FLOODS. THIS HAZARD WAS PARTICULARLY CRITICAL IN THE OCCASIONAL FLATTER AREAS WHERE A SLIGHT RISE MIGHT SUBMERGE CONSIDERABLE AREA BEFORE IT HAD BEEN OCCUPIED. UNTIL THE RUSH WORK WAS COMPLETED IN THE FLAT AREAS OF THE LOWER VIRGIN RIVER, THE COORDINATION OF THE PARTIES PROVED NO EASY MATTER. THE SURVEY WAS ON AN EMERGENCY BASIS. THERE HAD BEEN NO TIME FOR CAREFUL RECONNAISSANCE AND ORGANIZATION. ONLY THREE PARTIES COULD BE WORKED BECAUSE ONLY THREE INSTRUMENTS READING TO ONE SECOND VERTICALLY WERE AVAILABLE, AND BY THE TIME NEW INSTRUMENTS WERE ACQUIRED THE EMERGENCY WOULD HAVE BEEN OVER. CONSEQUENTLY, IT WAS NECESSARY TO ORGANIZE THE WORK AS IT PROGRESSED. THE PARTIES WERE EQUIPPED WITH SHORT WAVE RADIOS AS A MEDIUM FOR COORDINATING THEIR ACTIVITIES. UNFORTUNATELY, THESE DID NOT WORK AND WERE ABANDONED. COORDINATION WAS FINALLY ACCOMPLISHED BY HAVING EACH PARTY SET ON THE GROUND AT THEIR CAMP IN LARGE ROMAN NUMERALS AN ESTIMATE OF THE NUMBER OF DAYS' WORK REMAINING AT THAT LOCATION. EACH DAY AN AIRPLANE OBSERVED THESE SIGNALS AND REPORTED TO THE LOS ANGELES OFFICE. THE FOLLOWING DAY THE AIRPLANE DROPPED MESSAGES AT EACH CAMP, INSTRUCTING THEM, ARRANGING RENDEZVOUS, ETC. THE WORK PROGRESSED SMOOTHLY.

IN THE ORGANIZATION OF THE GORGE EXPEDITION, WE WERE FORTUNATE IN HAVING THE HELP OF E. C. LARUE, FORMERLY OF THE U. S. GEOLOGICAL SURVEY AND A VETERAN OF SEVERAL COLORADO RIVER TRIPS. HE WAS RESPONSIBLE FOR THE DESIGN OF THE FOUR BOATS WHICH WERE PRONOUNCED THE BEST EVER ON THE RIVER BY FRANK DODGE, HEAD BOATMAN, WHO TOOK OUR PARTY TWICE THROUGH THE CANYON WITHOUT THE SLIGHTEST MISHAP.

IN MANY WAYS OUR PROBLEMS DIFFERED FROM THOSE OF PREVIOUS EXPEDITIONS. THEY HAD GONE THROUGH AT THE RATE OF SEVERAL MILES PER DAY. THEY HAD AMPLE CHOICE, GENERALLY, OF A SAFE CAMP SITE. OUR PARTY ONLY MADE ABOUT A MILE A DAY AND CAMP HAD TO BE MADE WHEREVER THE DAY'S WORK ENDED. FURTHERMORE, OUR PARTY SPLIT INTO FOUR GROUPS EACH DAY. FIRST, THERE WAS THE COOK BOAT WHICH WENT AHEAD EACH MORNING AND SELECTED CAMP FOR THAT NIGHT. THEN THERE WERE THE THREE REMAINING BOATS WHICH STAYED BEHIND TO ASSIST IN CARRYING ON THE SOUNDING WORK UNDER THE DIRECTION OF E. A. SCHUCH, OF THE SOIL CONSERVATION SERVICE. THE TWO TRIANGULATION PARTIES CLIMBED THE WALLS TO THE FIRST BENCH ON EACH SIDE OF THE RIVER AND SCRAMBLED ALONG ON FOOT, HIGH ABOVE AND FREQUENTLY OUT OF SIGHT OF THE RIVER. THEY HAD TO BE ALERT NOT TO WORK PAST THE NIGHT'S CAMPSITE. TO PREVENT THIS, THE COOK, AT EXACTLY THREE O'CLOCK EVERY AFTERNOON, SENT UP A BOMB WHICH EXPLODED ABOUT 800 FEET IN THE AIR WITH A LOUD NOISE AND A PUFF OF SMOKE. AT THIS EXACT MINUTE EVERY MEMBER OF THE SPREAD-OUT EXPEDITION WOULD BE WATCHING FOR THIS SIGNAL SO EVERYONE KNEW WHERE DINNER WAS. IN THE TWO MONTHS OF THE SECOND TRIP NO ONE FAILED TO MAKE CAMP BY DARK.

EVERY MEMBER OF THE PARTY CARRIED A SUPPLY OF SMALL BOMBS TO USE IN SIGNALING OR TO ATTRACT ATTENTION. SIX HUNDRED OF THESE BOMBS PLAYED AN IMPORTANT PART IN SMOOTHING OUT THE DAY'S WORK.

RADIO PROVED INDISPENSIBLE. ON THIS EXPEDITION COMMUNICATION WAS CARRIED ON AT APPROXIMATELY 4000 K.C. WITH ENTIRE SUCCESS WHILE OUR EARLIER EFFORTS ON FIVE METERS HAD BEEN A COMPLETE FAILURE. A RADIO STATION WAS ESTABLISHED BY THE SOIL CONSERVATION SERVICE NEAR MILFORD, UTAH, AND IN PASADENA, CALIFORNIA CONTACT WAS FREQUENTLY MADE THROUGH AN AMATEUR STATION, PERMITTING DAILY PERSONAL CONTACT BETWEEN THE HOME OFFICE AND THE PARTY. FREQUENTLY THE RIVER PARTY FOUND THEMSELVES CAMPED IN PRECARIOUS SPOTS FROM THE STANDPOINT OF FLASH FLOODS IN THE NIGHT. BEFORE THEY WENT TO BED EACH NIGHT, THEY RECEIVED BY RADIO THE FOUR O'CLOCK RIVER GAUGING REPORT FROM THE U. S. GEOLOGICAL SURVEY STATION AT BRIGHT ANGEL, THIRTEEN HOURS AS THE WATER FLOWS ABOVE CAMP. THUS THERE WAS NO DANGER OF SURPRISE FLOODS AND CAMP COULD BE MADE IN SPOTS WHICH WOULD HAVE BEEN UNSAFE WITHOUT THIS WARNING.

ANOTHER IMPORTANT PART PLAYED BY THE RADIO WAS DAILY TRANSMITTING OF THE SURVEY NOTES FROM THE FIELD TO THE OFFICE IN LOS ANGELES. IN THIS WAY, QUICK CHECKS WERE MADE OF TRIANGLE CLOSURES, STRENGTH OF FIGURES, ETC. E. R. FRISBY, GEODESIST IN CHARGE OF THE COMPUTATIONS, WAS ABLE TO NOTIFY THE PARTY WHEN THEIR FIGURES WERE GETTING WEAK, WHEN IT WAS NECESSARY TO MEASURE A NEW BASE. THE radio thus kept the survey out of serious trouble, as with innumerable small figures it was not practical to do preliminary checking daily in camp.

Toward the end of the trip the Lake had backed several miles into the Grand Canyon. It was thus an easy matter to replenish the larder in reply to a radio S.O.S. (Sick of Soup).

It was indeed a modern miracle when the expedition which but for the radio had been isolated for more than sixty days made contact with the trucks from distant Kingman. The trucks pulled up to Pierce's Ferry and had scarcely dropped their tail gates when the boats, drifting in a leisurely current, appeared around a nearby bend.

This story of modern wizardry - of airplane and radio; of camera and theodolite; of the awesome stereoplanigraph - might not have been but for a grizzled Indian, a couple of lean-ribbed, hungry-looking horses, and a tumbled down, big-wheeled old derelict of a former lumber wagon. Without these, our ultra scientific expedition might still be stalled in Peach Springs Wash or Diamond Creek.

Altogether 758 triangulation stations were occupied to control 400 odd stereoscopic models. The survey involved 417 square miles which was drawn by the stereoplanigraph on forty-five metal mounted sheets at a scale of 1"=1000'. The contour interval was ten feet.

Control was distributed so that six points were available for each stereoscopic model. We have not found it practical to carry control forward with the stereoplanigraph. While we recognize that control could be carried forward to some extent at a sacrifice of accuracy, we have not so far found it economical.

It cannot be logically assumed that the vertical accuracy of contours will be the same with control carried through a number of models as when control is available in each model. For the sake of having a starting point for a hypothetical discussion, let us assume the accuracy will be 60% from the same altitude. Then to get the same vertical accuracy the area covered per model will be in the ratio of 1^2 to $.6^2$ or 1 to .36. If six points, for example, are required to fully control a model, the net number of control points required per model on a large area, after allowing for overlap, will be two. We now have two control points controlling one unit of area or .5 unit of area per control point. Now in carrying forward control on a comparable basis, we will require six points in one picture every so often. If we are to get the same control efficiency, six contol points must control 6 x .5 or three units of area. Thus we may establish control not more often than once per $\frac{3}{.36}$ or eight models. While this entire comparison is purely hypothetical, it illustrates that for a given specification there actually may not be any advantage in carrying control forward with present plotting equipment. For precision work, we see no advantage. We will let the military people answer as to rather obvious military advantages, where it is not a case of which is most efficient, but of getting the best possible results from an inadequate amount of control, which just <u>cannot</u> be increased.

To summarize: In cases where control is to be put in from beginning to end we believe there is little if any advantage in attempting to carry control forward. For any given vertical accuracy within the altitude range of the airplanes the increased area and more favorable distribution of control for every model may result in less cost per square mile than carrying control forward through pictures taken of necessity at a lower altitude to maintain the same vertical accuracy.

For these reasons, every model of the Lake Mead survey was fully controlled. The rate of progress through the stereoplanigraph averaged approximately .125 square miles per machine hour.

At the end of this paper a resume is given showing the vertical angle results. In other respects, aside from the difficulties encountered, the control survey was quite conventional.

The map is now in process of publication and will soon be available for general distribution.

The stereoplanigraph has been used on other projects ranging in scale from 1" = 30' to 2" = 1 mile. Vertical accuracy specifications have varied from 3/4 foot average for a 10,000 square foot area to 12.5'. The instrument has been found reliable to $\frac{1}{1500}$ altitude, plotting from four couple pictures with

CONTROL IN EVERY MODEL. THIS ACCURACY REFERS TO MAXIMUM ERROR OF CONTOURS AND SHOULD BE CAREFULLY DIFFERENTIATED FROM CONSISTENCY OF SETTING ON A GIVEN POINT WHICH MAY RUN AS HIGH AS $\frac{1}{12000}$ FOR A GOOD OPERATOR.

WITH SINGLE LENS CAMERAS NOW AVAILABLE WITH PRACTICALLY THE SAME ANGULAR COVERAGE AS THE FOUR COUPLE CAMERAS, THE EFFECTIVENESS OF THE STEREOPLANIGRAPH SHOULD BE IMPROVED AS THERE IS AN UNDENIABLE LOSS OF ACCURACY DUE TO THE SMALL RESIDUAL ERRORS OF A FOUR LENS SET UP.

VERTICAL SUMMARY

MAIN RESERVOIR AREA	NO. OF FIXED ELEVS.	LOOP CONDITIONS	DIFFS. OF ELEV.	NO. OF POINTS	MAX. CORRECT (CM)	PROB. ERROR (CM)
BOULDER DAM TO BOULDER CANYON	2	8	39	33	22	±1.23
BOULDER CANYON TO HUALPAI WASH						
BLOCK 1	3	10	36	29	27	±1.07
BLOCK 2	2	4	12	10	17	± 9.2
BLOCK 3	4	25	43	22	47	±17.4
HUALPAI WASH TO PIERCE'S FERRY	6	30	45	21	58	±13.9
VIRGIN RIVER						
BLOCK 1	4	24	37	17	23	± 9.6
BLOCK 2	5	22	37	20	28	± 9.3
BLOCK 3	9	24	42	27	19	± 7.3
BLOCK 4	6	31	50	24	30	± 8.2
BLOCK 5	4	24	41	21	38	±13.8
BLOCK 6	3	19	34	18	17	± 8.5
BLOCK 7	2	17	27	12	18	± 7.2
BLOCK 8	2	24	40	17	30	± 9.3
RIVER GORGE						
DIAMOND CREEK TO NEW WATER CANYON	3	FAILURE = 84 CM THROUGH 53 LINES = 1.6 CM PER LINE.				
NEW WATER CANYON TO PIERCE'S FERRY	2	FAILURE = 17 CM THROUGH 33 LINES = 0.5 CM PER LINE.				

OVERHEAD VERTICAL REFLECTING PROJECTOR

BY

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(PAPER PRESENTED AT THE ANNUAL MEETING OF THE AMERICAN SOCIETY OF PHOTOGRAMMETRY JANUARY 18, 1937)

DURING THE PROCESS OF CONSTRUCTING A PLANIMETRIC MAP FROM AERIAL PHOTOGRAPHS THE CONTACT PRINT IS THE BASIS OF A SYSTEM OF COMPILATION. THEREFORE, IT WAS MOST IMPORTANT TO DESIGN A PROJECTOR, SIMPLE OF OPERATION, BUT ONE THAT WOULD ACCURATELY PROJECT THE AERIAL PHOTOGRAPH AT VARIOUS PRECISE SCALES DIRECTLY TO THE FINAL OR BASIC MAP; ALSO TO BE ABLE TO CHANGE THE SIZE OF THE PROJECTED IMAGE TO FIT PREDETERMINED RADIAL CONTROL POSITIONS.

THE VERTICAL REFLECTING PROJECTOR IS DESIGNED AND CONSTRUCTED TO ACCURATELY PROJECT TEN INCH BY TEN INCH (10" x 10") AERIAL PHOTOGRAPHS, NINE INCH BY NINE INCH (9" x 9"), SEVEN AND ONE-EIGHTH BY NINE AND ONE-EIGHTH INCH (7-1/8" x 9-1/8") AERIAL CONTACT PHOTOGRAPHS ON TO A DRAWING BOARD. IT WAS ALSO ARRANGED THAT THIS