Digitizing Stereoplotter Output for Preliminary Design and Construction

The Auto-trol Scaler, an analog-digital converter developed for the Federal Highway Projects Office, Region 9, Denver, Colorado, is one answer to the problem of cross-sectioning with the Kelsh stereoplotter. Actual development of this instrument was begun in October 1959 and completed in March 1960. The impetus for this definite step forward was the need for a modern and applicable instrument designed to extract accurate, basic terrain data necessary for highway design by photogrammetric methods.

This instrument compiles the information in a conventional manner acceptable to the highway engineer and at the same time prepares the information in a form acceptable for electronic processing.

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● TO ASSIST the engineer in extracting basic information for highway design by photogrammetric methods, a number of electronic readout devices have been developed. These devices, like many electronic computer programs, have been designed by electronic engineers without the benefit of highway design experience. In order to take advantage of these new methods, it has been necessary for the highway engineer to change his design procedure. This situation has led to considerable controversy over accuracy of measurements and adequacy of design.

The Federal Highway Projects Office in Region 9 of the Bureau of Public Roads has taken a different approach to the use of these new tools. Electronics should work for the user in the design procedure elected for use. With this in mind, the office has developed instruments, revised computer programs, and written new ones to produce a complete highway design in an acceptable format.

About 95 percent of its highway location and design is accomplished through the effective use of photogrammetric and electronic methods. The basic terrain information extracted by commercial electronic readout devices was not completely satisfactory. The terrain data were not entirely acceptable because the many errors in mispunched cards caused expensive computer stops. To correct this situation, it was decided to have an electronic scaler constructed, tailored to the needs of the highway engineer.

AUTO-TROL SCALER

The Auto-trol Scaler, an analog-digital converter developed for the Federal Highway Projects Office and described in Appendix A, is an answer to the problem of cross-sectioning with the Kelsh stereoplotter. The actual development of this instrument was begun in October 1959 and completed in March 1960. As previously stated, the impetus for this definite step forward was the need for a modern and applicable instrument designed to extract accurately by photogrammetric methods basic terrain data necessary for highway design. This instrument compiles the information in a conventional manner

acceptable to the highway engineer and at the same time prepares the information in a form acceptable for electronic processing.

The scaler, which converts horizontal and elevation measurements into digital data, can be adapted for use with practically any stereoplotter equipment. In cross-sectioning, when the photogrammetric instrument operator is satisfied that he has placed the measuring dot at a break in the ground slope on the stereomodel, he then presses the record button at which time the distance and elevation are recorded on the output device. The internal programming hardware makes it unnecessary for the operator to trouble himself with such things as end-of-card hesitation and typewriter control. In the case of cards, the identification, station number, H.I. elevation, card code, and card number are all automatically punched on the cards under the direction of console programing. There is an automatic interlock on the readout so that readings can be taken on the run. When the readout button (record) is pressed, the console automatically places the horizontal and vertical readings in memory and begins the readout cycle. This means that there is no waiting period necessary. The operator is free to move on to the next measurement point.

The horizontal and vertical scaling device may be attached to the tracing table of the stereoplotter in approximately 5 min. Cross-section measurements for any normal distance each side of the designed centerline or any station interval may be speedily made for any map scale. The cross-sectioning rate of the scaler is about two times faster than that of some similar instruments because of ease of operation. An average stereoinstrument operator can measure about 30 to 35 cross-sections an hour. Considering an average time of one hour to orient each stereomodel, one instrument operator can normally be expected to complete 1 to 1½ mi of cross-sections during an 8-hour period scaling on a 100-ft-to1-in. scale map manuscript and measuring the cross-sections at a 50-ft interval on the highway centerline for a distance of 200 ft each side of that centerline.

The results from this instrument have been reasonably satisfying. Considerable "down time" was originally experienced due to malfunctions of various components. Numerous changes in counters and circuits have been made since the scaler was first put into operation. It now appears that most of the "bugs" have been eliminated. Its ease of operation, versatility, and handy recording methods, which eliminate a great deal of the lost motion prevalent on other scalers, lead to high productivity and lower highway survey and design expenditures.

The Federal Highway Projects Office has developed and assembled a "package" electronic computer program that extends the use of the output from the new electronic scaler and readout device, originally used only for preliminary design, through the construction engineering phase. To be specific, photogrammetry and electronics have been put to work for the highway engineer to its best advantage.

Because the office performs all the basic control for topographic mapping by photogrammetric methods, regardless of whether the mapping is done by the office or contracted to commercial firms, a traverse program for immediate checking of the field control survey work is extremely valuable. This provides a quick method of checking such field work before the control survey crew leaves the project. This program along with many others, some original and some borrowed, are at the disposal of the automatic data processing section for step-by-step electronic control from preliminary reconnaissance through completion of highway construction.

The program for computing basic control for highway location and all mapping done by photogrammetric methods is original with Region 9 and has been used since January 1960. The program computes the control traverse and tabulates the plane coordinates of the horizontal control and elevations of vertical control to be used in the mapping by stereophotogrammetric methods. This program has several options:

1. Given azimuth and distance, output is sine and cosine functions, latitude and departure, and the plane coordinates of all traverse stations.
2. Given azimuth, distance, or subtended subtense bar angle and vertical angle to foresights or backsights, output is the same plus elevations of all stations by trigonometric level computation.

3. Given subtended subtense bar angle and vertical angle to elevation control points of the aerial photographs, output is distance from control station to each vertical control point and its elevation.

After the topographic mapping has been completed in manuscript form by photogrammetric methods, the proposed highway alignment is plotted on the manuscript by means of the plane coordinates calculated by conventional methods. The azimuth program mentioned previously, or the State of California traverse program were the directions are expressed in bearings, checks the plane coordinates computed by conventional methods. Such a procedure saves manual checking, which is both tedious and time consuming.

PROFILE GRADE AND EARTHWORK PROGRAM

As to the design of earthwork quantities program, the automatic data processing section utilizes the Colorado Department of Highway's profile grade and earthwork program. Several changes made in Region 9 have better adapted this program to the Region's work. Two short supplemental programs written in this Region have reduced appreciably electronic computer time in revising the original profile or alignment.

Design criteria for each project are listed on a permanent form and include the following:

1. Design speed,
2. Type section expressed in punched-card form,
3. Slope selections used by electronic computer for cuts and fills,
4. Superelevations used,
5. Swell or shrink factors,
6. Widening used on curves, and
7. Widening for guardrails and guide posts.

The results of preliminary earthwork computations are in the form of three tabulations:

1. Grade elevation for each station,
2. Earthwork quantities and end areas for each station, and
3. Slope staking details.

From this preliminary computation, all slopes that are 2:1 or steeper on fills are selected to be widened for guardrail or guide posts. A grade revision is usually necessary in order to bring excavation and embankment quantities into desirable balance. Generally, the design is completed with the third computer run, provided an optimum in earthwork balances has been reached.

Modifications of the Colorado Department of Highway's profile grade program can now handle the prorating of the superelevation on compound curves. Guardrail and guide post widening can be prorated independently on the right or left side of the roadway. A program revision has been made to edit the profile input. This revision should save many time-consuming computer stops and reruns of the profile computations.

Revisions of the Colorado Department of Highway's program by Region 9 include the following:

1. Output of grade elevations on staking details corrected for superelevation on all curves.
2. Rotation of a typical section template from low shoulder point on all curves, whereas previously rotation was made from shoulder plus widening point.

A supplemental program to earthwork computations is used when only a portion of the original quantities is recalculated due to grade change or slope revisions. Formerly, because the earthwork quantity punched cards carried the mass ordinate, the entire design had to be rerun through the complete program to reflect the corrections in the mass diagram ordinate from a recomputed partial section. This was costly in

machine time and necessary before this supplemental program was written. Now, the last quantity card in the project, beyond which there are no further end area changes, is used as the first data card for initial input into a program that runs at a punch-speed rate and reads in the remaining quantity cards. This operation adjusts the mass diagram ordinates to the corrected figure and punches out new quantity cards with corrected mass ordinates.

Since many computer stops were experienced because of faulty terrain cards punched through Benson-Lehner's Terrain Data Translator and the Auto-trol Scaler, a terrain note-editing program has been instituted. Cards are run through the IBM 650 at the speed of 250 cards per min, and among the items checked for are the following:

1. Blank columns and double-punched columns,
2. Centerline vertical difference between stations exceeding a 25-ft limit,
3. Cross-section vertical distance between ground slope breaks exceeding 50 ft difference in elevation, and
4. Station numbers.

At the same time that the editing is done, the IBM 650 reads centerline elevations and interpolates the 25-ft interval between stations and punches out a card that is used to tabulate the actual ground elevation at centerline. This profile can be plotted on the IBM 407 Accounting Machine in the same manner as the mass diagram ordinates are plotted and is to a horizontal scale of 100-ft-to-1-in. and vertical scale of 20-ft-to-1-in.

Work is under way to program for reduction of construction project cut and fill notes for use with the present earthwork program. At present when the cross-sections obtained by photogrammetric methods do not match actual ground, the project engineer, during slope-staking, records the actual ground cross-section by cut and fill notation with respect to the highway cross-section. These notes are reduced to elevations before submitting to the computer; and, with the cut and fill program addition, this note reduction can be done by the electronic computer. Catch slope points will be introduced into all original terrain notes for construction engineering computations later.

COMPUTATION OF RIGHT-OF-WAY

A new and original right-of-way program is in use for electronic computation of plane coordinates to locate parcels of full ownership. These are plotted onto the map manuscripts compiled by photogrammetric methods. This phase is considered to be the first third of a group of complete right-of-way programs. To date, this program accepts a series of twenty ownerships with a maximum of 6 ground ties and not exceeding 3 ties per ownership. By designating the principal tie, the program will output 6 different computations or one with each principal tie. Input can be either bearing or azimuth, and distances can be in any units; e.g., feet, chairs, or rods generally found on older plats. The program outputs errors of closure from plat descriptions and lists errors to given ties. The program will handle a traverse of 99 courses from a section corner to the centerline of the proposed highway or to a tied corner or a parcel, using options of either bearings or azimuths. The program will output the plane coordinates of all intermediate points or only point of origin and tie. The corners of each ownership are located by plane coordinates.

The California traverse program is still used in computing parcel areas, and a Colorado Department of Highway arc segment area program is used to compute the area of parcels lying withing highway curves.

A metes and bounds traverse program has recently been completed. This program takes tangent bearing and distance, curve information (including transitions), width of right-of-way on the right and left, and computes bearing and distance of each course to be used for input of California traverse program.

CONSTRUCTION ENGINEERING

Because of the detail required to present properly the subject of construction engineering and its computer application, only a summary of its current status will be

considered. This phase of computer application presents an almost unlimited field. The Federal Highway Projects Office has not presented this work officially to the field project engineers but is developing construction control methods on two current projects.

The project engineer uses electronic tabulation of the staking details developed in the project design for an accurate guide in slope-staking. About 10 percent of the slope selections require field changes and approximately 15 to 20 percent of the electronically scaled cross-sections from the Kelsh stereoplotter model do not match the actual ground cross-sections. After slope-staking the project, the field engineer submits new terrain cross-sections to replace the following:

1. Areas of daylighting,
2. Catch basin locations,
3. Areas where different slopes are fixed,
4. Widened shoulders or ditch cross-sections, and
5. Areas that do not match catch points within the desired accuracy.

Setting up the files and terrain cards for construction engineering is a rather time-consuming task. Once this has been done, however, there is an exact digital duplication of the project as staked on the ground. From this point on, or after the first construction program computer run, as the project progresses, a field engineer can have his project recomputed for earth work quantities with only a telephone call or letter indicating grade changes, slope changes, or shrink or swell factor revisions. After the first construction run on one of our test projects with actual slopes fixed, catch basins inserted, shoulders widened on transitions, daylights added, etc., the computed quantities were 3,000 cu yd over the design quantities of 220,000 cu yd, or within 1.5 percent. Later, when a single grade change was made, the new computation showed a savings of 12,000 cu yd. Furthermore, this project was recomputed and completely rebalanced twice within 7 days.

The program to recompute a corrected mass diagram ordinate is also used to good advantage for construction engineering earthwork revisions. Another supplemental program is used for recomputing earthwork quantities when the only change is the shrink factor. This program reads the previous output cards, removes the quantity previously added or subtracted for shrink or swell respectively, and recomputes new volumes using the new shrink factor. The program also punches new output cards with the corrected mass diagram ordinate and volumes. This supplemental program will recompute an average project for a revised shrink or swell factor in about 15 min of computer time.

Not mentioned earlier, but used in design, is the Colorado Department of Highway's plotting of the mass diagram ordinates. This enables the design engineer and the project engineer to visualize earthwork quantities. The mass diagram ordinates can be plotted after each quantity run in 5 min. This allows for an over-all solution to correcting a quantity balance; i.e., a single grade change over a small section can serve to bring the entire project into a balance.

We have an addition to the staking detail tabulation whereby the actual ground elevation as well as corrected grade elevation will be calculated.

DESIGN CONTROL

The Federal Highway Projects Office in Region 9 has instituted a progress of design program whereby the data processing section tabulates weekly the progress of each design phase—from setting photographic targets along photography flight strips, mapping, projecting, surveying materials and drainage, computing grades and quantities, staking centerline, drafting plans and writing special provisions, to finally assembling plans for contract. This program is not computed on the IBM 650 electronic computer but is accomplished entirely by peripheral equipment; e.g., sorters, collators, interpreters, and the IBM 407 accounting machine. The weekly tabulation is on the desks of the federal highway projects engineer, the supervisory design engineer, and the supervisory contracting engineer each Tuesday morning, showing current status of all projects in the process of location or design. This program could have a far-

reaching effect and has been set up with an eye for future implementation with actual expenditures for accurate and up-to-date determination of design costs. This system could be used by State highway departments to ascertain detailed design cost records. The report shows man-hours of design time actually expended in each phase of the work, and these phases are broken down into 30 separate operations.

DATA PROCESSING ACCOUNTING

Federal projects data processing has been set up under a separate account. Beginning in August 1960, this account was disbursed by machine accounting. The tabulations will show work distribution of section personnel, computer and peripheral equipment rental, and prorated charges; e.g., programing, debugging, and board wiring. The tabulations will indicate account balance after charges are made for the month, the rate at which account is expended, and a projected rate to show future expenses, if the current average monthly rate is maintained.

FUTURE REVISIONS

The Federal Highway Projects Office has produced construction staking details tabulated on printed forms that serve as the project engineer's field notebooks when bound. These books have a self-duplicating paper that does not require carbons and will provide the automatic data processing section with any field changes from the original design. A contemplated revision to the present earthwork program for use on a 4,000-word IBM 650 will automatically reduce cut and fill notes to elevations and will allow these figures, when punched into cards, to be used interchangeably with terrain notes using elevations.

Most changes that have been made in the earthwork program must be handled on a 4,000-word IBM 650, which is commercially available. The reason for this is that there is no available space for instruction storage in the earthwork program, when using an IBM 650 computer with a 2,000-word drum.

It is expected that, within the next two years with the use of magnetic tape electronic computers, it will be possible to combine the grade program and the earthwork program into a single linear type of program. This will enable the engineer to give grade parameters; e.g., maximum, minimum, and fixed grades, and the distances within earthwork balances that are to be optimized. With this type of operation, the electronic computer can put data from punched cards onto tape and compute the quantities to the point where earthwork balance is desired. If it has not been attained at this point, the answer tape would be erased, the data tape would be reversed, and the machine would automatically adjust grades within the program parameters. This will give optimum earthwork quantities with the use of grade alignment only. Later program changes could incorporate horizontal alignment changes for further optimization and develop along the lines of curvilinear (spline line) alignment rather than solely by means of tangents, circular curves, and transitions. Furthermore, additional computer applications will include evaluation of materials with respect to estimated costs and estimations, such as low-price, intermediate, and costly excavation, and land values in addition to alignment features.

ECONOMICS

In the Federal Highway Projects Office of Region 9, it is estimated there is a possible $500,000 savings yearly for each $10,000,000 in the construction budget through the effective use of photogrammetry and electronic processing for design and construction. Formerly, survey, design, and materials investigated cost an average of about $5,000 per mi, but with electronic processing and photogrammetry the cost has been reduced substantially. Half of this saving is attributed to photogrammetry and the other half to electronic processing. Currently, engineering costs on construction projects are considered too high. With rapid recomputation of earthwork quantities and savings in staking time, about 10 percent of these costs can be saved. With mag-

netic tape and linear programing and with machine-optimized earthwork quantities, there is a further possible savings of 2.5 percent, due to a more efficient earthwork design. More savings are possible through the application of drainage, right-of-way, and structure programs. Furthermore, if organizations would purchase electronic computers outright rather than rent, the cost of these facilities would be less than half of current rental prices.

CONCLUSION

The Federal Highway Projects Office in Region 9 believes that photogrammetry and electronic processing will eventually make possible a savings of 5 percent on an average construction budget. This means that with full electronic data processing in operation, Federal projects could have one additional project annually, in addition to a more efficient operation in design, construction, and administration.

Appendix A

AUTO-TROL SCALER: DETAILED INFORMATION

The Auto-trol Scaler, is a precise electronic instrument with many technical applications possible. The present unit, which is designed as an aid in gathering basic information for calculating end areas and volumes of earthen structures, is accurate to 1 part in 2,000 over its entire scale. The Auto-trol Scaler is an analog-digital converter. It takes analog data from maps, aerial photographs, aerial photogrammetric plotters, graphs, etc., and converts them to standard digital form. It then tabulates these data on a typewriter and at the same time punches them on a card or paper tape in any format desired.

The following application is for the highway engineering field. Reference is made from time to time to the alphabetic characters in Figures 1, 2, 3, and 4 denoting various parts on the scaler and aerial photogrammetric plotter.

Step 1. As shown in Figures 1 and 2, the scaling bar (F) of the horizontal unit (M) is connected to the tracing table (P) by slipping the neck of the scaling bar over the pencil lead holder of the tracing table (this fit is machined to 1/10,000 in.). The vertical end coder (R) is attached to the vertical counter of the tracing table by means of a small chuck and two thumb screws. The record actuation device (Q) is clipped to the tracing table, left or right side, or can be left free of the tracing table and conveniently placed elsewhere.

Step 2. The horizontal unit (M) is now oriented on a line previously drawn at right angles to centerline (or base line). This orientation is accomplished by setting the pointer (E) of its scaling unit (M) and the pointer (D) of the tracing table (P) on the line. It will be noted that the tracing table is completely free to swing on an arc limited only by the arms (S) of the photogrammetric plotter itself. This allows the instrument operator to scale easily a centerline drawn in any position on the manuscripts.

Step 3. The station of the centerline (the y coordinate of an x, y, z coordinate system) is set on the 8 rotary dials (J) of the console (Figure 3).

Step 4. The elevation of the counter on the tracing table (P) is set in the console with the 6 elevation set buttons (T). This is done only when the elevation counter of the tracing table is indexed, usually once per set-up of the stereoplotting instrument.

Step 5. The set button (record button) (B) is pressed either on the console (Figure 3) or on the record actuation device (Q). This causes the typewriter to tabulate and the punch unit to punch the station, the H.I. (if any), the computer code, and the card number if cards are used. It records all information required for each station that is preparatory to the actual cross-sectioning.

Step 6. The tracing table pointer (D) is moved to rest on centerline. At this time the zero "x" button (C) is pressed. This sets the console horizontal counter (the x coordinate) (I) to zero, thus indexing the horizontal counter to centerline.

Step 7. The first break in ground slope is found by moving the table out left or right of centerline any desired distance and visually picking the change in slope of the ground

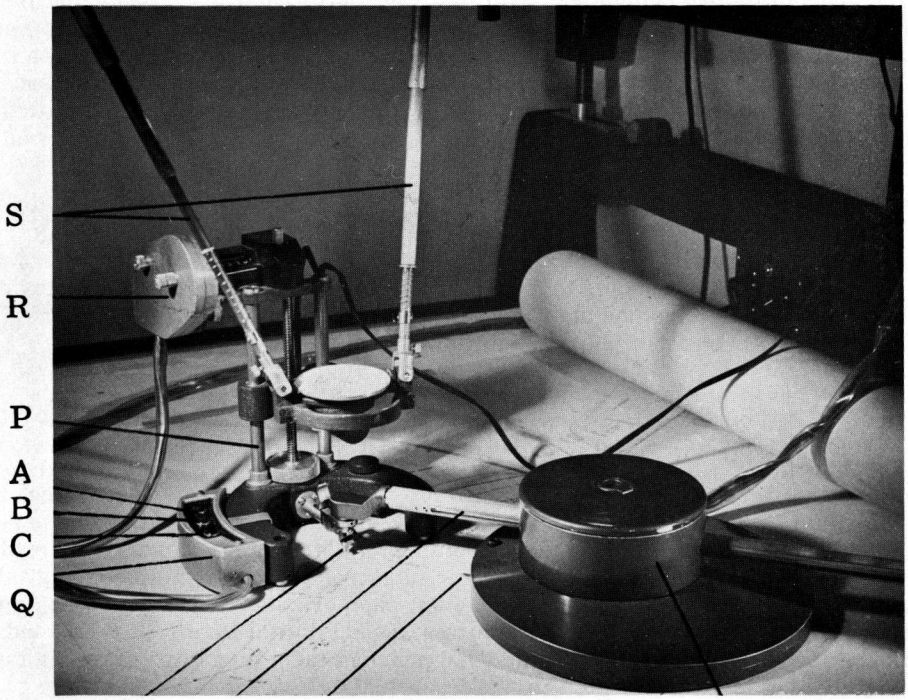


Figure 1.

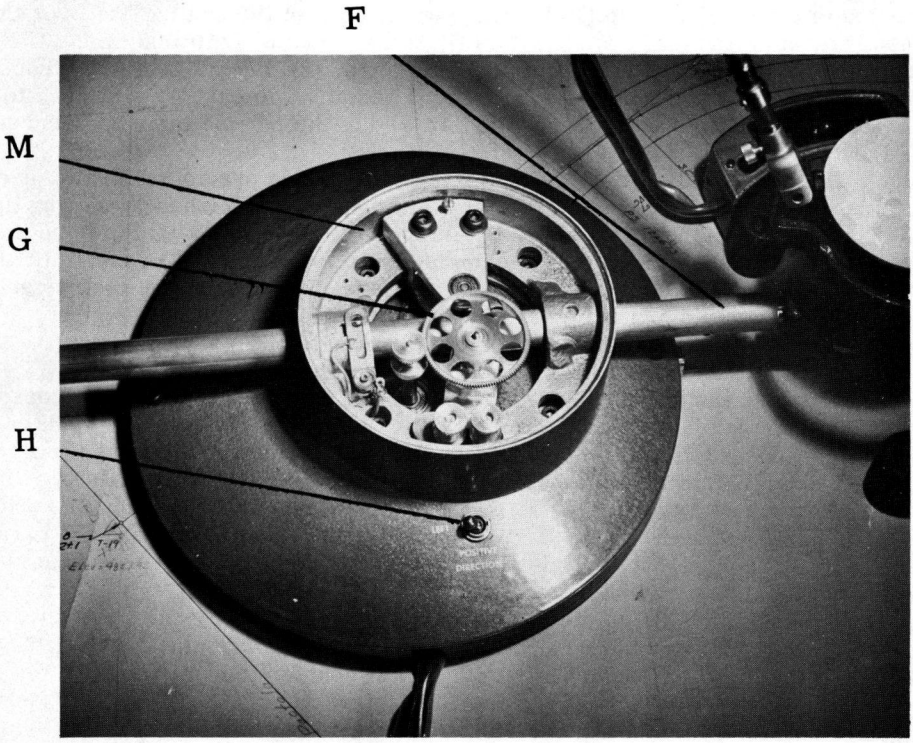


Figure 2.

line. The tracing table is kept on a straight line path at right angle to centerline by the horizontal unit (M). When the break in slope is found, the record button (B) is pressed. This causes the distance displayed on the horizontal counter (I) and the elevation on the elevation counter (T) to be recorded on the output devices previously mentioned. The alphabetic character "L" for left or "R" for right can be recorded on the tabulation. The positive horizontal direction is controlled by the switch (H) on the horizontal unit (M). When the switch is set on left, the counter will add going from right to left; and when set on right, it will add from left to right. The operator does not need to wait for the apparatus to finish its record cycle before moving the tracing table in search of the next break. The console puts the last reading in memory and keeps it there until it finishes recording the reading through the output units. This is true even when, in the case of punch cards, the card unit is going through the process of feeding another card. The record button (B) can be pressed during this cycle.

Step 8. The operator continues recording breaks in ground slope as they are found. When the operator reaches the centerline, he presses the zero "x" button (C) and the record button (B) simultaneously. This insures an exact zero recording for centerline and not a 000.1 recording. This is due to the fact that the operator will have difficulty in coming back to the exact point from which he started as the scaler is dividing each inch into 1,000 parts.

Step 9. He follows the procedure of recording the measurements at breaks in ground slope as he finds them until the last break of the cross-section at this particular station is reached. At this time the final record button (A) is pressed. This causes the console to reset and prepare itself for the next station. It causes such things as the card punch to skip to a new card, the card counter (L) automatically to reset to one, and the typewriter to return carriage and space down one line. The operator now continues making the cross-section measurements at stereomodel scale by repeating Steps 2, 3, 5, 6, 7, 8, and 9. This is done on the stereoplotter until all cross-sections on one stereomodel have been measured.

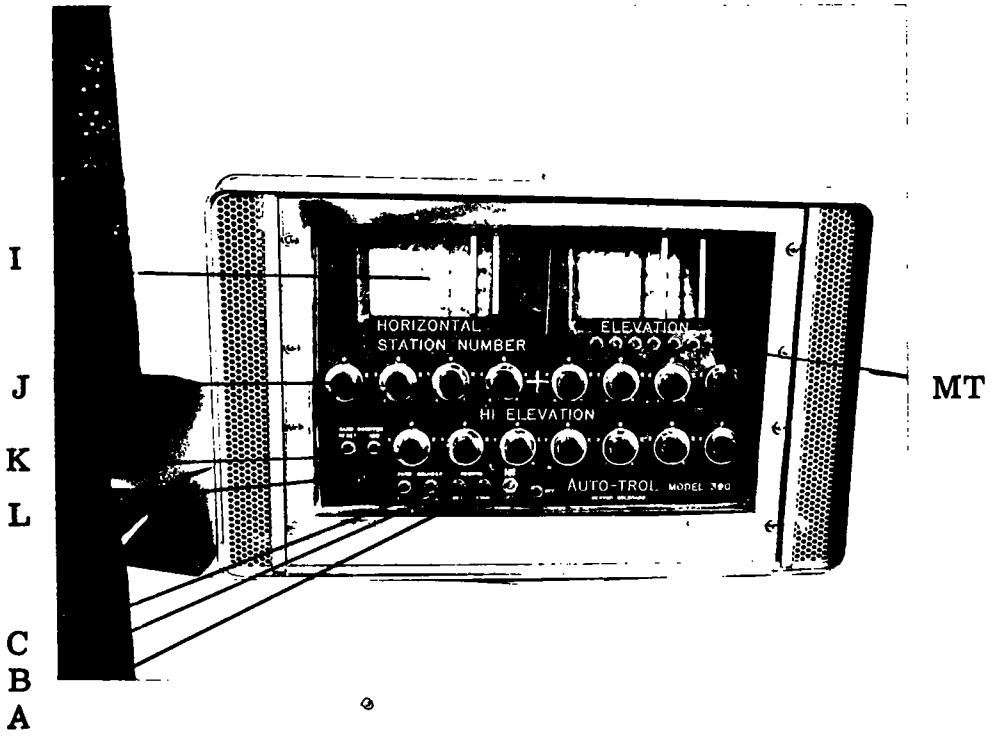


Figure 3.

The seven Height of Instrument (H. I.) dials (K) of the console are used in the following way. If it is desired to have the separate measurements of all breaks in ground slope on each cross-section in reference to a given elevation (H. I.), the elevation is set on the H. I. dials (K). The elevation counter (T) is set at zero. Now all elevations recorded will be plus or minus, up or down from the given reference (H. I.) elevation.

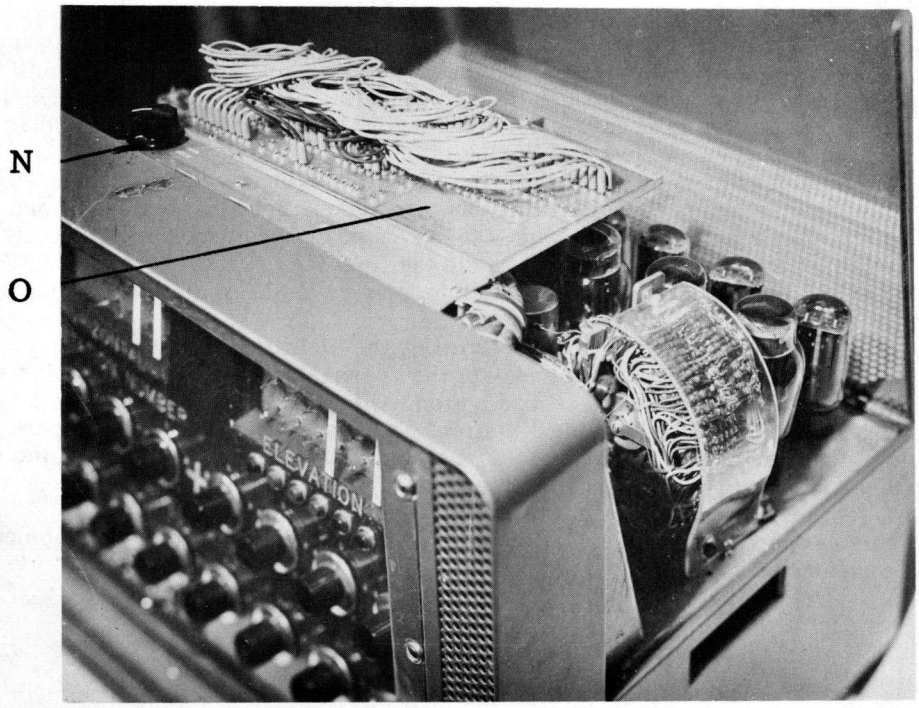


Figure 4.

Pictured in Figure 4 (O) is the console control board (patch board). This board is used to program the console and its supporting output devices. It is through this board that complete versatility is obtained in variable formats, counter control, the emitting of fill in digits, and so forth. This is very necessary as this allows the cross-section scaler to output its information in any desired form, thus making it possible to suit the needs of any customer who wishes to use his own computer program.

The intensity of the panel lights may be varied by the dimmer control (N) in Figure 4.

Appendix B

EXAMPLES OF FORMS USED

Forms used in electronic processing of the photogrammetric data are shown on the following pages.

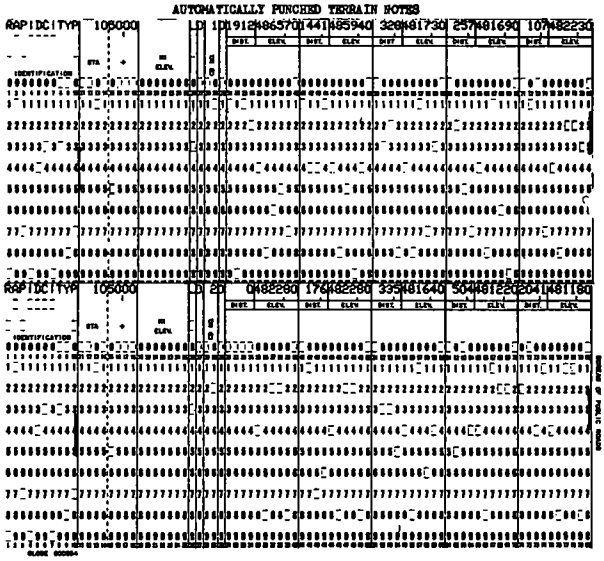
PROBLEM 1 GIVEN: Azimuth, Angle on Bar, Bar Length
" 2 " : Azimuth, Distance

TRIG LEVELS 1 - No Trig Level Computation
" 2 - Traverse with Trig Levels
" 3 - Wing Point Computation

TRAVERSE COMPUTATIONS

JOB	PROBLEM TRIG LEVELS P	T	TRAVERSE NO. GROUP TN	G	CRSE	DIST	AZIMUTH	COS	SIN	NS DIST	EW DIST	NS COORD	EW COORD
TESTPROBLM	1	1	1	1								10000.000	10000.000
	1	1	1	1	1	100.000	210 00 00.0	0.866025406	0.499999991	86.602	49.999	10086.602	10049.999
	1	1	1	1	2	100.000	300 00 00.0	0.499999994	0.866025401	49.999-	86.602	10036.603	10136.601
	1	1	1	1	3	100.000	000 00 05.8	1.000000000		100.000-	0.000	9936.603	10136.601
	1	1	1	1	4	100.000	359 59 54.2	1.000000000		100.000-	0.000	9836.603	10136.601
	1	1	1	1	5	100.000	089 59 54.2		1.000000000	0.000	100.000-	9836.603	10036.601
	1	1	1	1	6	100.000	090 00 05.8		1.000000000	0.000	100.000-	9836.603	9936.601
	1	1	1	1	7	100.000	179 59 54.2	1.000000000		100.000	0.000	9936.603	9936.601
	1	1	1	1	8	100.000	180 00 05.8	1.000000000		100.000	0.000	10036.603	9936.601
	1	1	1	1	9	100.000	269 59 54.2		1.000000000	0.000	100.000	10036.603	10036.601
	1	1	1	1	10	100.000	270 00 05.8		1.000000000	0.000	100.000	10036.603	10136.601
	1	1	1	1	11	100.000	000 00 58.0	1.000000000	0.000281190	100.000-	0.028-	9936.603	10136.573
	1	1	1	1	12	100.000	359 59 02.0	1.000000000	0.000281197	100.000-	0.028	9836.603	10136.601
	1	1	1	1	13	100.000	089 59 02.0	0.000281197	1.000000000	0.028-	100.000-	9836.575	10036.601
	1	1	1	1	14	100.000	090 00 58.0	0.000281183	1.000000000	0.028	100.000-	9836.603	9936.601
	1	1	1	1	15	100.000	179 59 02.0	1.000000000	0.000281192	100.000	0.028-	9936.603	9936.573
	1	1	1	1	16	100.000	180 00 58.0	1.000000000	0.000281186	100.000	0.028	10036.603	9936.601

AUTOMATICALLY PUNCHED TERRAIN NOTES



TERRAIN DATA

JOB	STATION	NO.	DIST.	ELEV.	DIST.	ELEV.	DIST.	ELEV.	DIST.	ELEV.	DIST.	ELEV.
RAPIDCITYP	10-50.00	1	191.2	4865.70	144.1	4859.40	32.8	4817.30	25.7	4816.90	10.7	4822.30
RAPIDCITYP	10-50.00	2	00.0	4822.80	17.6	4822.80	33.5	4816.40	50.4	4812.20	204.1	4811.80
RAPIDCITYP	11-00.00	1	189.9	4857.10	136.6	4848.40	63.2	4830.50	39.3	4819.60	13.0	4821.70
RAPIDCITYP	11-00.00	2	00.0	4821.70	22.2	4821.60	40.9	4811.60	232.8	4811.30		
RAPIDCITYP	11-50.00	1	192.2	4850.50	114.7	4830.90	55.7	4819.90	12.7	4821.30	00.0	4822.20
RAPIDCITYP	11-50.00	2	19.9	4821.20	39.7	4812.80	219.2	4812.80				
RAPIDCITYP	12-00.00	1	212.2	4846.90	182.1	4839.30	78.4	4819.60	30.5	4814.90	09.1	4821.00
RAPIDCITYP	12-00.00	2	00.0	4822.00	21.9	4821.40	45.6	4811.80	229.1	4811.80		
RAPIDCITYP	12-50.00	1	240.8	4836.60	136.0	4819.20	114.4	4819.20	51.1	4811.50	37.1	4812.60
RAPIDCITYP	12-50.00	2	06.4	4821.50	00.0	4822.60	20.7	4822.00	54.0	4806.20	67.7	4806.20
RAPIDCITYP	12-50.00	3	100.3	4813.40	114.4	4813.40	122.4	4812.50	185.1	4812.50		
RAPIDCITYP	13-00.00	1	231.8	4828.30	181.6	4819.20	157.9	4819.20	54.4	4809.70	44.3	4809.70
RAPIDCITYP	13-00.00	2	10.0	4821.90	00.0	4821.90	20.4	4821.90	54.6	4805.60	142.6	4803.70
RAPIDCITYP	13-00.00	3	176.3	4805.80	201.8	4812.10						
RAPIDCITYP	13-50.00	1	192.8	4817.70	46.5	4807.80	41.3	4808.50	05.9	4821.10	00.0	4821.90
RAPIDCITYP	13-50.00	2	20.6	4821.30	53.1	4803.10	138.4	4803.10	189.7	4798.60		
RAPIDCITYP	14-00.00	1	198.3	4811.60	95.2	4805.30	48.6	4804.20	10.1	4820.70	00.0	4820.70
RAPIDCITYP	14-00.00	2	20.5	4820.50	59.1	4801.30	100.1	4804.30	186.9	4849.80		
RAPIDCITYP	14-50.00	1	196.0	4807.00	110.0	4803.20	49.1	4803.20	07.2	4822.10	00.0	4822.10
RAPIDCITYP	14-50.00	2	20.0	4820.90	58.4	4803.00	88.8	4804.00	168.8	4843.10	198.0	4857.40
RAPIDCITYP	15-00.00	1	183.6	4803.10	52.5	4801.60	05.7	4822.10	00.0	4822.10	20.1	4821.20
RAPIDCITYP	15-00.00	2	52.6	4807.10	63.9	4805.80	191.4	4858.30				
RAPIDCITYP	15-50.00	1	270.8	4798.30	172.9	4798.30	156.4	4801.00	90.7	4801.00	52.4	4799.00
RAPIDCITYP	15-50.00	2	05.6	4821.60	00.0	4822.10	23.3	4820.80	44.2	4817.60	82.5	4869.30

EARTHWORK EDITING PROGRAM. . . DESCRIPTION OF ERROR CODES. .

KEY PUNCH ERRORS. INVALID PUNCHING HAS BEEN SENSED IF COLUMN 80 CONTAINS A 2 OR 3.

THE FOLLOWING CODE INDICATES THE CARD WAS NOT PROCESSED BEYOND THE ERROR. IF THIS SHOULD BE A VALID CARD, SEVERAL OTHER ERROR INDICATIONS WILL BE PRODUCED--FOR EXAMPLE, THE CARD NUMBER WILL BE WRONG.

IDENT PCH STATION NUMBER, 11 18, OR CARD NUMBER AND HEIGHT OF INSTRUMENT, 27 29 AND 20 25, WERE MISKEYPUNCHED.

THE FOLLOWING CODES INDICATE THE ENTIRE CARD WAS READ. A VALIDITY CHECK OF THE STATION WAS MADE ONLY IF IT WAS LATER RESTARTED BY A NEW CARD 1.

DATA1 PCH COLUMNS 31 40 MISKEYPUNCHED.
DATA2 . PCH COLUMNS 41 50 MISKEYPUNCHED.
DATA3 PCH COLUMNS 51 60 MISKEYPUNCHED.
DATA4 PCH COLUMNS 61 70 MISKEYPUNCHED.
DATA5 PCH COLUMNS 71 80 MISKEYPUNCHED.
28 32 PCH COLUMNS 28 32 MISKEYPUNCHED.

THE VALIDITY ERRORS NOT INVOLVING KEYPUNCHING CONTAIN A 1 IN COLUMN 80.

ONE OF THESE ERRORS BYPASSES OTHER VALIDITY CHECKS.

WD1 MISSN WORD 1 OF DATA ON CARD 1 WAS ZERO. IT IS ASSUMED THIS CARD WAS LEFT IN BY MISTAKE, AND IT IS NOT PROCESSED FURTHER.

CERTAIN ERRORS BYPASS THE CREATION OF A CENTERLINE ELEVATION PLOT.

STAT ORDER	STATIONS ARE NOT IN ASCENDING SEQUENCE. CENTERLINE PLOT WILL BE RESUMED ONLY WHEN STATIONS IN ASCENDING SEQUENCE FROM THE LAST PLOTTED POINT ARE AGAIN ENCOUNTERED.
NO CLINE	NO CENTERLINE, THEREFORE NOT USED IN PLOTTING.
STAT FAR	STATIONS ARE TOO FAR APART. TENATIVELY THIS DISTANCE HAS BEEN SET AT 500 FEET.
H I WRONG	IF DIGIT 7 OF CONSOLE IS 9 HI IS NOT EQUAL TO ZERO. THE PROGRAM SETS IT TO ZERO AND PROCEEDS WITH A NORMAL CENTERLINE CALCULATION. IF DIGIT 7 OF CONSOLE IS 8 HI IS EQUAL TO ZERO. SINCE THIS IS AN ERROR, THIS POINT WILL BE SKIPPED IN THE CENTERLINE CALCULATIONS.

MOST COMMON ERRORS DO NOT AFFECT THE CREATION OF A CENTERLINE PLOT. SOME OF THESE MAY CREATE OTHER FALSE ERRORS.

CARD ORDER	CARD NUMBER DOES NOT START WITH 1 AND INCREASE 1 EACH CARD FOR THIS STATION.
STAT REPTD	STATION RESTARTS WITH CARD 1 AFTER AN ERRONEOUS OR CORRECT START.
PTLY BLANK	A CARD IS BLANK OR ZERO IN A DATA WORD, YET ANOTHER CARD OR MORE DATA FOLLOWS. THIS CAN EASILY GENERATE A NUMBER OF FALSE ERROR CARDS.
CD1 MISSN	THE FIRST CARD OF A STATION IS NOT THE 1 CARD.
NO PT LEFT	NO POINTS TO LEFT OF CENTERLINE.
NO PT RIGT	NO POINTS TO RIGHT OF CENTERLINE. NO CENTERLINE WILL CREATE THIS ERROR ALSO.
TWO CLINE	TWO OBSERVATIONS AT CENTERLINE.

HORIZ SAME	TWO ADJACENT OBSERVATIONS ARE THE SAME DISTANCE FROM CENTERLINE.
HORIZ INVR	TWO ADJACENT OBSERVATIONS SHOW AN INVERSION IN DISTANCE FROM CENTERLINE. NORMALLY NO CENTERLINE WILL PRODUCE THIS ERROR ALSO.
NOT L CARD	CARD DOES NOT HAVE L IN COLUMN 26.
NAME DIFF	THE NAME IN COLUMNS ONE TO TEN DIFFERS FROM THAT ON THE FIRST CARD OF THE JOB.

TWO CHECKS OF REASONABLENESS ARE MADE.

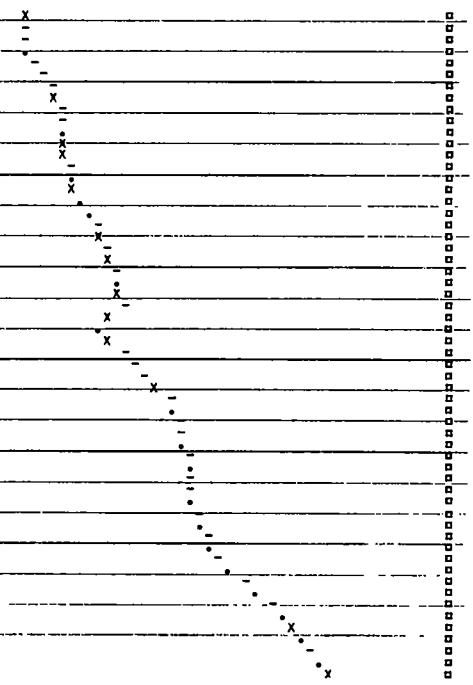
CRSVT NG	TWO ADJACENT OBSERVATIONS ON A CROSS SECTION DIFFER BY MORE THAN A MAXIMUM. AT PRESENT THIS MAXIMUM IS 50 FEET. THIS RESULTS IN A FEW FALSE WARNINGS IN AN AREA OF CLIFFS, BUT THESE SEEM WORTHWHILE.
CLVRT NG	TWO ADJACENT CENTERLINE READINGS DIFFER BY MORE THAN A MAXIMUM. AT PRESENT THIS MAXIMUM IS 25 FEET.

TERRAIN DATA

JOB	STATION	NO.	DIST.	ELEV.	DIST.	ELEV.	DIST.	ELEV.	DIST.	ELEV.	DIST.	ELEV.
DINOSAURNM	13-50.00	2	10.0	5970.00	00.0	5967.40	10.0	5965.00	25.0	5960.00	42.0	5955.00
DINOSAURNM	13-50.00	3	70.0	5950.00	* 0		* 0		* 0		* 0	
CRSVT NG ERROR												
DINOSAURNM	14-5		0		0		0		0		0	
DINOSAURNM	14-00.00	1	90.0	6030.00	68.0	6010.00	55.0	6000.00	43.0	5990.00	28.0	5980.00
DINOSAURNM	14-00.00	2	15.0	5975.00	00.0	5970.00	25.0	5965.00	40.0	5960.00	62.0	5955.00
DINOSAURNM	14-00.00	3	120.0	5950.00	* 0		* 0		* 0		* 0	
DINOSAURNM	14-50.00	1	80.0	6025.00	62.0	5915.00	42.0	6000.00	34.0	5995.00	22.0	5985.00
DINOSAURNM	14-50.00	2	12.0	5980.00	00.0	5975.60	10.0	5970.00	35.0	5965.00	60.0	5960.00
DINOSAURNM	14-50.00	3	80.0	5955.00	* 0		* 0		* 0		* 0	
DATA3 PCH ERROR Cols 51-60 Invalidly Punched												
DINOSAURNM	15-00.00	1	70.0	6025.00	62.0	6020.00	500.0		* 0		* 0	
DINOSAURNM	15-00.00	1	70.0	6025.00	62.0	6020.00	50.0	6015.00	35.0	6005.00	30.0	6000.00
DINOSAURNM	15-00.00	2	18.0	5990.00	08.0	5985.00	00.0	5982.40	35.0	5970.00	50.0	5965.00
DINOSAURNM	15-00.00	3	80.0	5960.00	* 0		* 0		* 0		* 0	
DINOSAURNM	15-50.00	1	70.0	6035.00	54.0	6025.00	50.0	6020.00	40.0	6015.00	28.0	6005.00
DINOSAURNM	15-50.00	2	12.0	6000.00	00.0	5992.00	10.0	5985.00	38.0	5975.00	53.0	5970.00
DINOSAURNM	15-50.00	3	70.0	5965.00	* 0		* 0		* 0		* 0	
DINOSAURNM	16-00.00	1	70.0	6035.00	50.0	6025.00	35.0	6020.00	05.0	6000.00	00.0	5997.00
DINOSAURNM	16-00.00	2	06.0	5995.00	12.0	5990.00	35.0	5985.00	60.0	5975.00	74.0	5970.00
DINOSAURNM	16-50.00	1	76.0	6040.00	58.0	6035.00	40.0	6025.00	30.0	6020.00	18.0	6010.00
DINOSAURNM	16-50.00	2	00.0	6005.00	08.0	6000.00	20.0	5995.00	30.0	5990.00	55.0	5985.00
DINOSAURNM	16-50.00	3	70.0	5980.00	* 0		* 0		* 0		* 0	
STAT REPTD ERROR & 28-32 PCH ERROR												
DINOSAURNM	17-00.00	7	0		0		0		0		0	
DINOSAURNM	17-00.00	1	70.0	6035.00	58.0	6030.00	50.0	6027.00	44.0	6025.00	28.0	6020.00
DINOSAURNM	17-00.00	2	20.0	6015.00	10.0	6010.00	00.0	6005.00	12.0	6000.00	18.0	5995.00
DINOSAURNM	17-00.00	3	23.0	5990.00	30.0	5985.00	38.0	5980.00	80.0	5975.00	* 0	

GROUND PROFILE PLOTTED FROM TERRAIN NOTES — SCALES - HORIZONTAL 1" to 200' VERTICAL 1" to 20'

625.00	590954
650.00	590858
675.00	590847
1600.00	590894
1625.00	591043
1650.00	591222
1675.00	591401
2600.00	591580
2625.00	591620
2650.00	591660
2675.00	591700
3600.00	591740
3625.00	591793
3650.00	591845
3675.00	591898
4600.00	591950
4625.00	592110
4650.00	592270
4675.00	592430
5600.00	592590
5625.00	592668
5650.00	592745
5675.00	592823
6600.00	592900
6625.00	592960
6650.00	593020
6675.00	592760
7600.00	592500
7625.00	592770
7650.00	593040
7675.00	593250
8600.00	593460
8625.00	593730
8650.00	594000
8675.00	594110
9600.00	594220
9625.00	594250
9650.00	594280
9675.00	594400
10600.00	594520
10625.00	594460
10650.00	594400
10675.00	594510
11600.00	594620
11625.00	594710
11650.00	594800
11675.00	594920
12600.00	595040
12625.00	595320
12650.00	595600
12675.00	595925
13600.00	596250
13625.00	596495
13650.00	596740
13675.00	596870
14600.00	597000
14625.00	597280
14650.00	597560

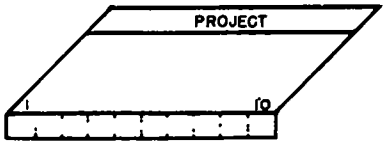


FORM PDP 104
AUG 1960

	PUNCHED
	VERIFIED

DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS

GRADE DATA



CARD CODES

0 Compute-Gen Mode
1 P I Station
2 Horiz Equation
3 Odd Station
4 Vert Equation
5 Chg Interval
6 Tfr to Terr Mode
7 Tfr to Gen Mode
8 Compute-Terr Mode
9 Reset
J Begin Max Super
K End Max Super
L Center Line Shift
M Widening

FROM _____

ADDRESS _____

DATE _____ SHEET ____ OF ____

	11 18	19 25	26	29 32	33 40	41 45
	NUMERIC CODES					
	P I STATION OR STATION BACK	STATION ELEVATION	CODE	LENGTH OF VC OR V DIFF	STATION AHEAD OR INTERVAL	DESCRIPTION OR TEMPLATE
	ALPHABETIC CODES					
	P I STATION OR STATION BACK	WIDENING NORMAL SLOPE OR SHIFTING	CODE	LENGTH OF TRANSITION	MAXIMUM SUPER ELEVATION	
1	+					
2	+					
3	+					
4	+					
5	+					
6	+					
7	+					
8	+					
9	+					
10	+					
11	+					
12	+					
13	+					
14	+					
15	+					
16	+					
17	+					
18	+					
19	+					
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21	+					
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26	+					
27	+					
28	+					
29	+					
30	+					

GPO 840177

FORM PDP 103
AUG 1960

PUNCHED
VERIFIED

INITIAL RUN
CORRECTED RUN

DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS

EARTHWORK DATA SHEET

CARD CODES

- U RESET
- R END OF JOB
- S FACTOR & GRADE COR SINGLE LANE
- A EQUATION
- B ZERO AREA
- W ADDED QUANTITIES
- F FIX SLOPES
- J TOTAL SHIFT
- Q QUIT TEMPLATE
- C BRIDGE
- T NOTE MAJOR AND MINOR TEMPLATES
- K TEMPLATE
- E CUT SLOPE SELECTION
- G DITCH SLOPE SELECTION
- H COMPLEX 1 (CUT)
- I COMPLEX 2 (FILL)
- Y FILL SLOPE SELECTION

PROJECT

SHEET NO. ___ OF ___ SHEETS

LINE	TEMPLATE / SLOPE / ETC.	LT SLOPE	RT SLOPE	CODE	TEMP	C	S	C	LAST STATION / FACTOR	ΔY 1	SLOPE 1	LAST STATION	C	ΔY 2	SLOPE 2	C	ΔY 3	SLOPE 3	C	ΔY 4	SLOPE 4 LT. FIXED	C	ΔY 5	SLOPE 5 RT FIXED
1																								
2																								
3																								
4																								
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GPO 846177

GRADE TABULATION

BUREAU OF PUBLIC ROADS

FORM PDP 107

PROJECT	STATION	DESCRIPTION	GRADE* ELEVATION	GRADE — %	TANGENT ELEVATION	SHIFT	SUPER	WIDENING LEFT	WIDENING RIGHT
RAPIDCITYP	13.00	WIDE A	4858.93	1.0690-					
RAPIDCITYP	20.00	PC X	4858.86	1.0690-				3.00	3.00
RAPIDCITYP	50.00	A	4858.36		4858.53			3.00	3.00
RAPIDCITYP	1 00.00	PI A	4856.81		4858.00			3.00	3.00
RAPIDCITYP	1 50.00	A	4854.33		4854.50			3.00	3.00
RAPIDCITYP	1 80.00	PT X	4852.40		4852.40			3.00	3.00
RAPIDCITYP	2 00.00	A	4851.00	7.0000-				3.00	3.00
RAPIDCITYP	2 50.00	A	4847.50	7.0000-				3.00	3.00
RAPIDCITYP	3 00.00	PC A	4844.00	7.0000-				3.00	3.00
RAPIDCITYP	3 50.00	A	4840.64		4840.50			3.00	3.00
RAPIDCITYP	4 00.00	A	4837.55		4837.00			3.00	3.00
RAPIDCITYP	4 50.00	A	4834.74		4833.50			3.00	3.00
RAPIDCITYP	5 00.00	A	4832.20		4830.00			3.00	3.00
RAPIDCITYP	5 50.00	A	4829.94		4826.50			3.00	3.00
RAPIDCITYP	6 00.00	PI A	4827.95		4823.00			3.00	3.00
RAPIDCITYP	6 50.00	WIDE A	4826.24		4822.80			3.00	3.00
RAPIDCITYP	7 00.00	A	4824.80		4822.60			1.50	1.50
RAPIDCITYP	7 50.00	A	4823.64		4822.40				
RAPIDCITYP	8 00.00	A	4822.75		4822.20				
RAPIDCITYP	8 50.00	A	4822.14		4822.00				
RAPIDCITYP	9 00.00	PT A	4821.80		4821.80				
RAPIDCITYP	9 50.00	A	4821.60	0.4000-					
FAPIDCITYP	10 00.00	A	4821.40	0.4000-					
RAPIDCITYP	10 50.00	A	4821.20	0.4000-					
RAPIDCITYP	11 00.00	A	4821.00	0.4000-					
RAPIDCITYP	11 50.00	A	4820.80	0.4000-					
RAPIDCITYP	12 00.00	WIDE A	4820.60	0.4000-					
RAPIDCITYP	12 50.00	A	4820.40	0.4000-				1.50	0.00
RAPIDCITYP	12 67.30	TS X	4820.33	0.4000-				2.02	0.00
RAPIDCITYP	13 00.00	A	4820.20	0.4000-			SR.010.000	3.00	0.00
RAPIDCITYP	13 50.00	A	4820.00	0.4000-			SR.025.000	3.00	0.00
RAPIDCITYP	14 00.00	A	4819.80	0.4000-			SR.040.000	3.00	0.00
RAPIDCITYP	14 50.00	A	4819.60	0.4000-			SR.055.000	3.00	0.00
RAPIDCITYP	14 67.30	SC X	4819.53	0.4000-			SR.060.000	3.00	0.00
RAPIDCITYP	15 00.00	PC A	4819.40	0.4000-			SR.060.000	3.00	0.00
RAPIDCITYP	15 50.00	A	4819.15		4819.20		SR.060.000	3.00	0.00
RAPIDCITYP	16 00.00	WIDE A	4818.80		4819.00		SR.060.000	3.00	0.00
RAPIDCITYP	16 50.00	A	4818.35		4818.80		SR.060.000	1.50	0.00
RAPIDCITYP	17 00.00	A	4817.80		4818.60		SR.060.000		
RAPIDCITYP	17 50.00	A	4817.15		4818.40		SR.060.000		

* ALL GRADES ARE NOT CORRECTED FOR SUPER ELEVATION

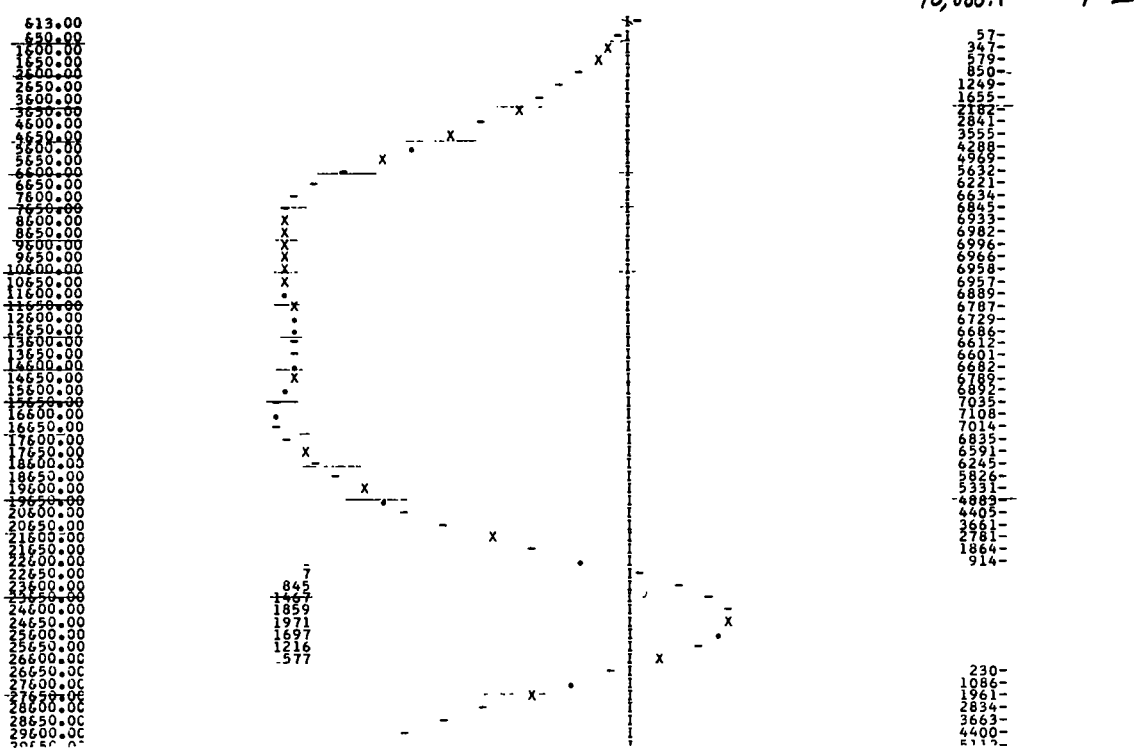
EARTHWORK QUANTITIES - BUREAU OF PUBLIC ROADS

FORM PPP 126

PROJECT	STATION	FACTOR	EXTRAPOLATION LEFT	EXTRAPOLATION RIGHT	MASS ORDINATE	ADDED QUANTITIES (MASS TEMP) EXCAVATION	ADDED QUANTITIES (MASS TEMP) EMBANKMENT	COMPUTED QUANTITIES (MASS TEMP) EXCAVATION AREA S.F	EXCAVATION VOLUME C.Y	EMBANKMENT AREA S.F	EMBANKMENT VOLUME C.Y
RAPIDCITYP	0-13.00	0.008	000	000				62			
RAPIDCITYP	0-50.00	1.108	000	000	57-				42	131	99
RAPIDCITYP	1-00.00	1.108	000	000	347-				42*	154	290
RAPIDCITYP	1-50.00	1.108	000	040	579-			118	109	181	341
RAPIDCITYP	2-00.00	1.108	000	000	850-				109	192	380
RAPIDCITYP	2-50.00	1.108	000	000	1249-				218*	200	399
RAPIDCITYP	3-00.00	1.108	000	000	1655-					198	406
RAPIDCITYP	3-50.00	1.108	040	000	2182-					320	527
RAPIDCITYP	4-00.00	1.108	040	000	2841-					327	659
RAPIDCITYP	4-50.00	1.108	040	000	3555-					374	714
RAPIDCITYP	5-00.00	1.108	000	000	4288-					345	733
RAPIDCITYP	5-50.00	1.108	000	000	4969-					323	681
RAPIDCITYP	6-00.00	1.108	000	000	5632-					329	663
RAPIDCITYP	6-50.00	1.108	040	000	6221-					249	589
RAPIDCITYP	7-00.00	1.108	000	000	6634-					156	413
RAPIDCITYP	7-50.00	1.108	000	000	6845-			2	2	54	213
RAPIDCITYP	8-00.00	1.108	000	000	6933-			7	9	41	97
RAPIDCITYP	8-50.00	1.108	120	000	6982-			34	38	44	87
RAPIDCITYP	9-00.00	1.108	040	000	6996-			22	51	19	65
RAPIDCITYP	9-50.00	1.108	040	000	6966-			48	65	16	35
RAPIDCITYP	10-00.00	1.108	000	000	6958-			27	70	45	62
RAPIDCITYP	10-50.00	1.108	000	000	6957-			57	78	31	77
RAPIDCITYP	11-00.00	1.108	000	000	6889-			51	100		32
RAPIDCITYP	11-50.00	1.108	000	000	6787-			58	102		7562*
RAPIDCITYP	12-00.00	1.108	000	000	6729-			46	97	38	39
RAPIDCITYP	12-50.00	1.108	000	000	6686-			67	105	23	62
RAPIDCITYP	13-00.00	1.108	000	000	6612-			69	126	28	52
RAPIDCITYP	13-50.00	1.108	000	000	6601-			51	111	70	100
RAPIDCITYP	14-00.00	1.108	000	000	6682-			25	70	78	151
RAPIDCITYP	14-50.00	1.108	000	000	6789-			57	76	101	183
RAPIDCITYP	15-00.00	1.108	000	000	6892-			68	116	114	215
RAPIDCITYP	15-50.00	1.108	000	000	7035-			95	151	174	294
RAPIDCITYP	16-00.00	1.108	000	000	7108-			64	148	43	221
RAPIDCITYP	16-50.00	1.108	000	000	7014-			96	148	10	54
RAPIDCITYP	17-00.00	1.108	000	000	6835-			115	196	7	17
RAPIDCITYP	17-50.00	1.108	000	000	6591-			156	251		7
RAPIDCITYP	18-00.00	1.108	000	000	6245-			217	346		1399*
RAPIDCITYP	18-50.00	1.108	000	000	5826-			235	419		
RAPIDCITYP	19-00.00	1.108	000	000	5331-			300	495		
RAPIDCITYP	19-50.00	1.108	000	040	4883-			184	448		

MASS ORDINATE PLOT

Rapid City
10,000:1 9-29



FORM PDP 109

BUREAU OF PUBLIC ROADS

STAKING DETAIL

* TO SHOULDER POINT OR BOTTOM OF DITCH

△ MINUS INDICATES FILL SLOPE
NO SIGN INDICATES CUT SLOPE

REV. 9-29-66
REVISED 10/66

PROJECT	STATION	TEMPLATE	LEFT SLOPE STAKE				ADJUSTED GRADE	RIGHT SLOPE STAKE			
			SLOPE △	ELEVATION	DISTANCE	CUT OR FILL *		CUT OR FILL *	DISTANCE	ELEVATION	SLOPE △
RAPIDCITYP	13.00	A	3.00	4857.9	29.4 L	C 0.80	4858.93	C 3.50	37.5 R	4860.5	3.00
RAPIDCITYP	50.00	A	2.00-	4847.7	41.6 L	F 10.30	4858.36	F 4.80	30.6 R	4853.2	2.00-
RAPIDCITYP	1 00.00	A	2.00-	4845.5	42.8 L	F 10.90	4856.81	F 11.30	43.6 R	4845.1	2.00-
RAPIDCITYP	1 50.00	A	1.50-	4835.6	48.5 L	F 18.30	4854.33	C 11.90	47.9 R	4864.3	1.50
RAPIDCITYP	2 00.00	A	1.50-	4831.3	50.0 L	F 19.30	4851.00	F 10.50	36.8 R	4840.1	1.50-
RAPIDCITYP	2 50.00	A	1.50-	4826.3	52.1 L	F 20.70	4847.50	F 10.50	36.8 R	4836.6	1.50-
RAPIDCITYP	3 00.00	A	1.50-	4832.5	37.7 L	F 11.10	4844.00	F 13.50	41.3 R	4830.1	1.50-
RAPIDCITYP	3 50.00	A	1.50-	4825.6	43.1 L	F 14.70	4840.64	F 11.10	37.7 R	4829.1	1.50-
RAPIDCITYP	4 00.00	A	2.00-	4826.1	43.2 L	F 11.10	4837.55	F 12.40	39.6 R	4824.7	1.50-
RAPIDCITYP	4 50.00	A	2.00-	4825.3	39.2 L	F 9.10	4834.74	F 10.80	42.6 R	4823.5	2.00-
RAPIDCITYP	5 00.00	A	2.00-	4823.4	37.8 L	F 8.40	4832.20	F 9.40	39.8 R	4822.4	2.00-
RAPIDCITYP	5 50.00	A	2.00-	4822.5	35.0 L	F 7.00	4829.94	F 8.70	38.4 R	4820.9	2.00-
RAPIDCITYP	6 00.00	A	2.00-	4819.7	36.6 L	F 7.80	4827.95	F 7.30	35.6 R	4820.2	2.00-
RAPIDCITYP	6 50.00	A	2.00-	4818.6	35.6 L	F 7.30	4826.24	F 7.30	35.6 R	4818.5	2.00-
RAPIDCITYP	7 00.00	A	4.00-	4820.0	37.1 L	F 4.40	4824.80	F 3.50	33.5 R	4820.9	4.00-
RAPIDCITYP	7 50.00	A	4.00-	4819.5	33.2 L	F 3.80	4823.64	F 4.40	35.6 R	4818.9	4.00-
RAPIDCITYP	8 00.00	A	6.00-	4819.6	34.8 L	F 2.80	4822.75	F 0.20	18.8 R	4822.2	4.00-
RAPIDCITYP	8 50.00	A	4.00-	4816.1	40.8 L	F 5.70	4822.14	C 0.00	27.0 R	4820.3	3.00
RAPIDCITYP	9 00.00	A	6.00-	4819.3	31.2 L	F 2.20	4821.80	C 0.10	27.3 R	4820.0	3.00
RAPIDCITYP	9 50.00	A	6.00-	4818.9	31.8 L	F 2.30	4821.60	F 1.30	25.8 R	4819.9	6.00-
RAPIDCITYP	10 00.00	A	6.00-	4818.7	32.4 L	F 2.40	4821.40	C 1.00	30.0 R	4820.5	3.00
RAPIDCITYP	10 50.00	A	6.00-	4818.0	34.8 L	F 2.80	4821.20	F 1.30	25.8 R	4819.6	6.00-
RAPIDCITYP	11 00.00	A	3.00	4820.3	30.6 L	C 1.20	4821.00	F 1.50	27.0 R	4819.2	6.00-
RAPIDCITYP	11 50.00	A	3.00	4820.7	32.1 L	C 1.70	4820.80	F 1.00	24.0 R	4819.4	6.00-
RAPIDCITYP	12 00.00	A	4.00-	4815.5	36.8 L	F 4.70	4820.60	C 0.30	27.9 R	4819.0	3.00
RAPIDCITYP	12 50.00	A	2.00-	4814.5	30.5 L	F 5.50	4820.40	C 0.20	27.6 R	4818.7	3.00
RAPIDCITYP	13 00.00	A	2.00-	4812.0	37.8 L	F 8.40	4820.20	C 0.20	27.6 R	4818.5	3.00
RAPIDCITYP	13 50.00	A	1.50-	4810.1	36.8 L	F 10.50	4820.09	F 1.30	25.8 R	4818.3	6.00-
RAPIDCITYP	14 00.00	A	1.50-	4807.1	41.9 L	F 13.90	4820.16	F 1.20	25.2 R	4818.3	6.00-
RAPIDCITYP	14 50.00	A	1.50-	4804.3	46.7 L	F 17.10	4820.23	F 1.50	27.0 R	4817.8	6.00-
RAPIDCITYP	15 00.00	A	1.50-	4803.9	47.3 L	F 17.50	4820.12	F 1.90	29.4 R	4817.1	6.00-
RAPIDCITYP	15 50.00	A	1.50-	4799.1	54.2 L	F 22.10	4819.87	C 2.00	36.0 R	4818.8	3.00
RAPIDCITYP	16 00.00	A	1.50-	4810.5	36.5 L	F 10.30	4819.52	C 1.90	35.7 R	4818.3	3.00
RAPIDCITYP	16 50.00	A	3.00	4820.0	32.1 L	C 1.20	4819.07	C 2.30	34.6 R	4818.2	2.00
RAPIDCITYP	17 00.00	A	3.00	4819.6	31.5 L	C 1.50	4818.52	C 4.00	42.0 R	4819.4	3.00
RAPIDCITYP	17 50.00	A	3.00	4818.2	29.1 L	C 0.70	4817.87	C 19.90	49.9 R	4834.7	1.00
RAPIDCITYP	18 00.00	A	3.00	4819.0	33.9 L	C 2.30	4817.12	C 3.10	33.1 R	4817.1	1.00
RAPIDCITYP	18 50.00	A	2.00	4820.1	35.6 L	C 4.30	4816.27	C 7.40	37.4 R	4820.6	1.00
RAPIDCITYP	19 00.00	A	1.50	4822.9	39.0 L	C 8.00	4815.32	C 7.70	41.6 R	4820.0	1.50
RAPIDCITYP	19 50.00	A	6.00-	4814.6	22.8 L	F 0.80	4814.27	C 7.00	44.0 R	4818.2	2.00

SLOPE STAKE BOOK MADE ON IBM 407 FROM EARTHWORK OUTPUT CARDS

PAGE 47 BUREAU OF PUBLIC ROADS FORM PDP 109

COMPUTER STAKING DETAIL OR EARTHWORK COMPUTATIONS

STATION	ACTUAL PROFILE	GRADE AND PROFILE	TEMPLATE	AREA EXC SLOPE	AREA EMB ELEV OF STAKE	VOLUME EXC DIST FROM CL	VOLUME EMB CUT OR FILL
				2094 SF	SF		
WARRENPEAK		76.4 GN	060 SL 060	1.00 C	5477.8	51.9 LT	C 29.9
		5450.38GR	16.0 13.0	1.00 C	5479.0	48.4 RT	C 29.4
129+75.00				1957 SF	SF	1875 CY	CY
+							
		75.2 GN	055 SL 055	1.00 C	5474.5	47.8 LT	C 26.0
		5450.80GR	15.8 13.0	1.00 C	5479.4	48.3 RT	C 29.3
130+00.00				1771 SF	SF	1726 CY	CY
+							
		71.0 GN	040 SL 040	1.00 C	5468.2	39.6 LT	C 18.6
		5451.46GR	15.0 13.0	1.00 C	5474.3	42.6 RT	C 23.6
130+50.00				1232 SF	SF	2780 CY	CY
				PAGE	TOTAL	6381 CY	CY
				BOOK	TOTAL	40151 CY	28484 CY
+				JOB	TOTAL	40151 CY	28484 CY

SLOPE LEFT	SECTION LEFT	CENTER	SECTION RIGHT	SLOPE RIGHT

FORM PDP 108

GPO 841800

COORDINATES OF RIGHT-OF-WAY OWNERSHIPS FROM ORIGINAL PLAT DESCRIPTIONS

JOB	PARCEL	CRNER	OWNERSHIP NS CO ORD	OWNERSHIP EW CO ORD
HOLMANTAOS	HES 317	1	53,890.72	75,302.70
HOLMANTAOS	HES 317	2	53,721.40	75,251.53
HOLMANTAOS	HES 317	3	53,642.24	75,218.44
HOLMANTAOS	HES 317	4	53,541.72	75,175.36
HOLMANTAOS	HES 317	5	53,641.44	74,935.20
HOLMANTAOS	HES 317	6	53,765.13	74,423.93
HOLMANTAOS	HES 317	7	54,068.73	73,842.37
HOLMANTAOS	HES 317	8	54,177.70	73,936.32
HOLMANTAOS	HES 317	9	53,955.91	75,053.01

ERRORS

HOLMANTAOS	HES 317	1.36	0.31	53,640.88	75,218.75

FORM C D H 220 REV FEB. 1960

Dayton - Kane ROW Parcel No 2

COLORADO DEPARTMENT OF HIGHWAYS

TRAVERSE COMPUTATIONS

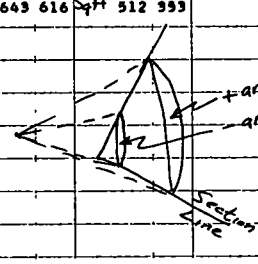
1. ALL SIDES AND BEARINGS KNOWN
2. TWO SIDES UNKNOWN
3. ONE SIDE & ONE BEARING UNKNOWN
4. TYPE 1 WITH AREA
5. ONE SIDE & IT'S BEARING
7. TYPE 3 WITH AREA
8. TYPE 4 WITH AREA
9. TYPE 6 WITH AREA
6. TWO BEARINGS UNKNOWN

PROBLEM TYPE: 4

PROBLEM TYPE	GROUP	BACK OR COURSE	TRAV NO.	AREA IN SQUARE FEET OR DISTANCE	BEARING	COSINE	SINE	LATITUDE OR AREA IN ACRES	DEPARTURE OR SINE OF DELTA	COORDINATES NORTH	COORDINATES EAST	REMARKS
								ERROR OF CLOSURE		PROGRESSIVE TOTALS		
4	E	1	2							100000 000	100000 000	
		1		133 990	S 89 10 00 E	0 014543896	0 999894230	S 1 949	E 133 976	99998 051	100133 976	
		2		450 420	S 43 14 30 W	0 728470613	0 685077041	S 328 118	W 308 572	99669 933	99825 404	
		3		132 260	N 00 24 00 E	0 999975626	0 006981255	N 132 257	E 923	99802 190	99826 327	
		4		263 250	N 41 17 00 E	0 751456085	0 659783102	N 197 821	E 173 688	100000 011	100000 015	
		99						011	015			
		Area		33.674 Sq Ft				Area 773	Acres			
				33 674				773				
							Plus Arc Area	467				
								Parcel Area 1.240	Acres			

PROBLEM TYPE	GROUP	BACK OR COURSE	TRAV NO	AREA IN SQUARE FEET OR DISTANCE	BEARING	COSINE	SINE	LATITUDE OR AREA IN ACRES	DEPARTURE OR SINE OF DELTA	COORDINATES NORTH	COORDINATES EAST	REMARKS
								ERROR OF CLOSURE		PROGRESSIVE TOTALS		
2		4		263.248	S 41 16 60 W	CHORD	CALC	Acres = 0.282	- 12292 192	Sq Ft 306 258		
2		2		450 416	S 43 14 30 W	CHORD	CALC	Acres = 0.749	+ 32643 616	Sq Ft 512 393		
								Net Area 0.467 +				

RIGHT OF WAY PARCEL COMPUTATION



DESIGN PROGRESS CONTROL FORM

001 JOB CEDAREDGE-MESA 13 E C 10 3 60

OPERATION MATERIALS SURVEY LINE

ROBERT BOHMAN	7-29-60	ORIG							95%
ROBERT BOHMAN	8-12-60	ORIG							95%
ROBERT BOHMAN	9-02-60	ORIG							95%

OPERATION CROSS SECTION LINE

DAVID WAGNER	7-22-60	ORIG	8	790 00	962 50			HAND	80%
DAVID WAGNER	7-23-60	ORIG	8	790 00	962 50			HAND	70%
DAVID WAGNER	7-24-60	ORIG	8	790 00	962 50			HAND	90%
RICHARD BRAUNLICH	8-11-60	REV-01	8	790 00	960 00	845 00	945 00	HAND	40%
RICHARD BRAUNLICH	8-12-60	REV-01	8	790 00	960 00	845 00	945 00	HAND	85%
RICHARD BRAUNLICH	8-15-60	REV-01	4	790 00	962 50	845 00	945 00	HAND	100%
			44*						

OPERATION CALCULATE GRADE

RICHARD BRAUNLICH	8-09-60	REV-01	4	790 00	960 00	845 00	945 00	HAND	30%
RICHARD BRAUNLICH	8-10-60	REV-01	8	790 00	960 00	845 00	945 00	HAND	100%
			12*						

OPERATION MINOR DRAINAGE

CHARLES POWELL	8-23-60	REV-01	8	790 00	962 50	790 00	962 50	HAND	50%
CHARLES POWELL	8-24-60	REV-01	8	790 00	962 50	790 00	962 50	HAND	100%
			16*						

OPERATION DRAFT PLANS

JOHN HARPER	7-26-60	ORIG	1	790 00	962 50	790 00	962 50	HAND	98%
JAMES ERICKSON	7-26-60	REV-06	2	790 00	962 50	790 00	962 50	HAND	100%
JUNIOR CUBBAGE	8-26-60	REV-07	4	790 00	962 50	790 00	962 50	HAND	100%
JUNIOR CUBBAGE	8-30-60	REV-07	4	790 00	962 50	790 00	962 50	HAND	
			11*						

II. Ohio Department of Highways

E. S. PRESTON, Director, Ohio Department of Highways

● OHIO'S PLANS for digitizing stereoplotter output were outlined to the Conference on Improved Engineering Methods and Procedures sponsored by the Illinois Highway Department and the AASHO at Chicago, March 6, 1956.

In reporting at that meeting on the role of photogrammetry in highway location and design, the advantages of taking cross-sections directly from a stereoplotter rather than from a contour map were pointed out. It was stated that automatic recording would eliminate human errors in transcribing notes and would provide an output that would be immediately available for use in electronic computers performing highway design computations.

Afterwards, the development of such a system was discussed with individuals within the Ohio Department of Highways. On August 15, 1956, the Department began work on a system that would accurately follow the movements of a Kelsh plotter tracing table, give an indication of the horizontal and vertical distances measured by the Kelsh plotter, and automatically record on punched cards these distances whenever a record button was pushed.

THE KELSH PLOTTER

Components

The system developed by the Ohio Department of Highways is an analog-to-digital converter. The development consisted of modifying and interconnecting various standard devices and designing the necessary circuitry to enable them to operate as a unit. The basic components of the system are the following:

1. The Kelsh plotter modification (Figure 1).

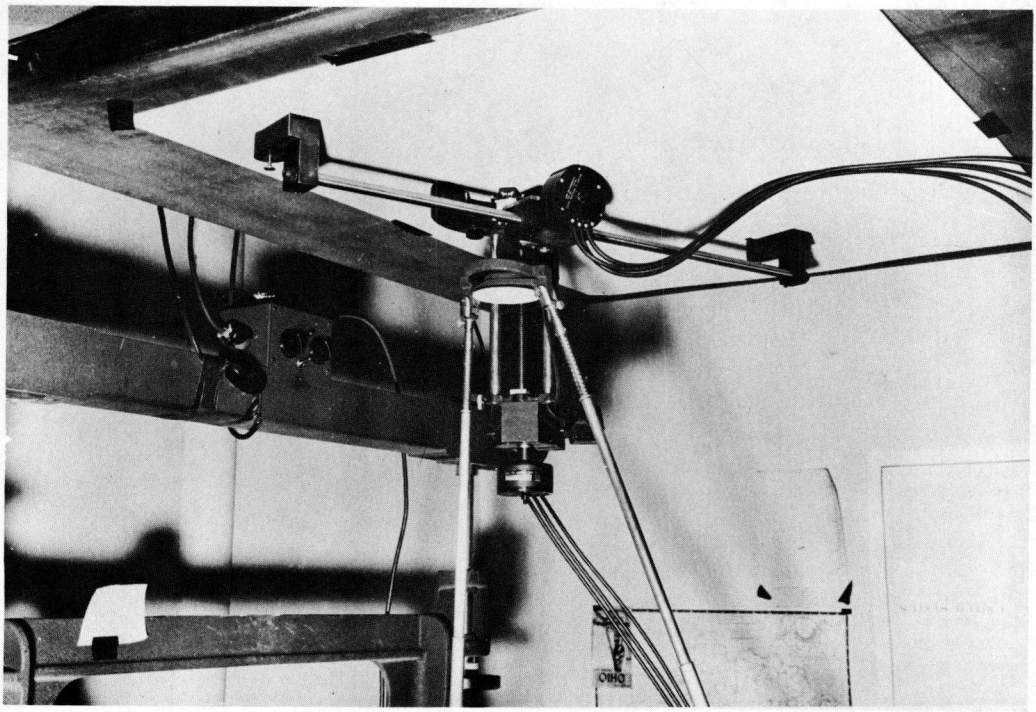


Figure 1. Ohio Department of Highways' Kelsh plotter modification.

2. Analog-to-digital conversion circuits purchased from the Telecomputing Corporation and consisting of (a) horizontal and vertical quantizers, (b) demodulator unit, and (c) input units (Figure 2),
3. Electronic Counters purchased from Beckman Instruments, Inc.,
4. Readout circuits, and
5. IBM 526 printing summary punch.

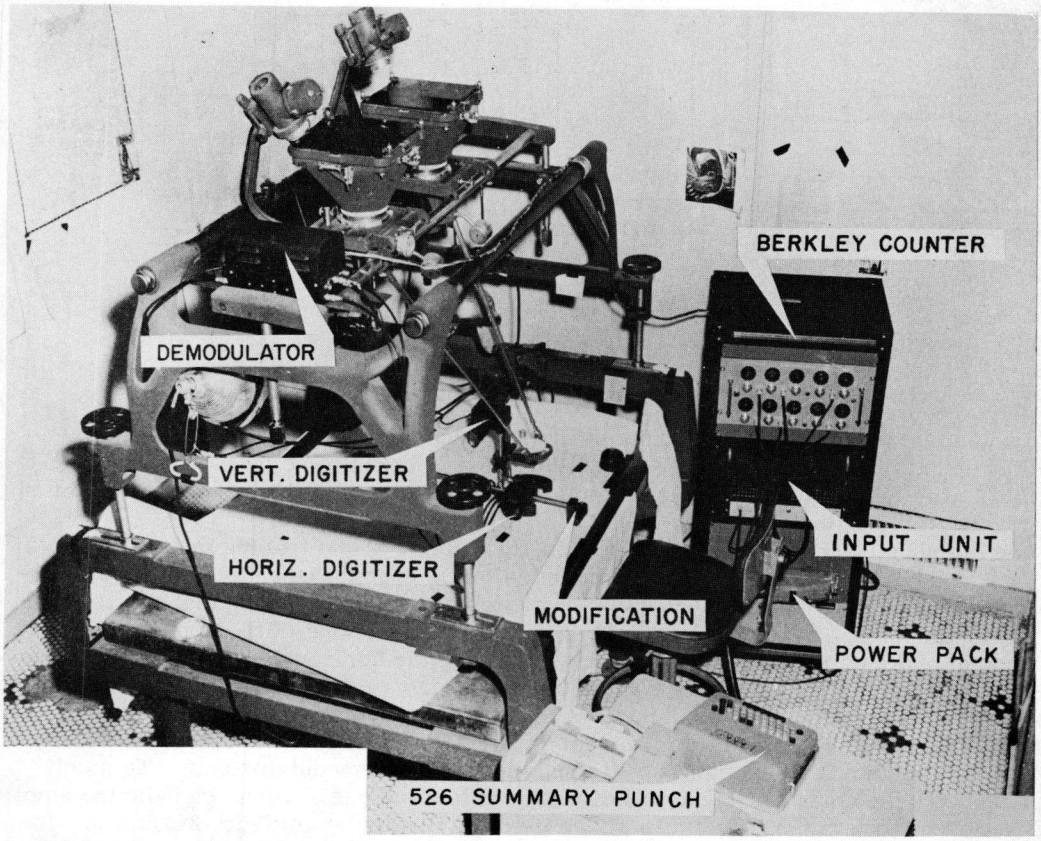


Figure 2. Digital readout.

The Kelsh plotter modification provides the first step in digitizing the stereoplotter (Figure 3). It is an electromechanical means of converting the movement of the tracing table into electrical signals that can be used to indicate the position of the table. These signals are generated by the rotations of quantizers. The quantizers consist of a stationary and a rotating disc on which patterns are etched. These patterns are of such a nature that when a signal is applied to one of the discs and the other rotated 500 pulse counts per revolution of the rotating disc are generated. In addition, an equal number of direction pulses, either leading or lagging the count pulses, are also produced in order to determine the direction of rotation. In this way, each revolution of the quantizer is broken into 500 count pulses plus a direction signal. To monitor the position of the tracing table it is only necessary that a quantizer be so connected to the table that the quantizer rotates for any movement of the table along a desired axis. The count pulses and direction signal can then be used to indicate the deviation of the table from any reference point. If the count and direction signals are appropriately combined

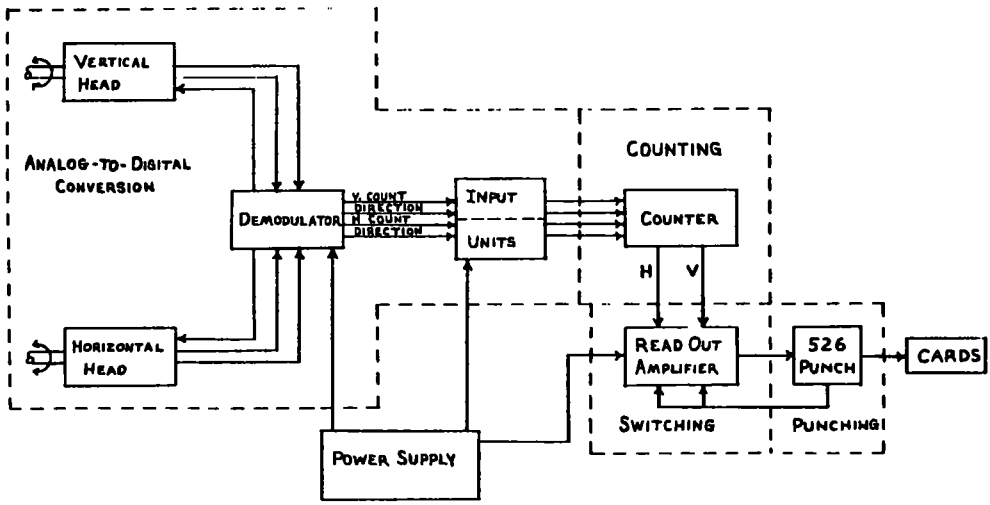


Figure 3. Kelsh plotter recorder system.

with a quantity equal to the coordinate of the reference point along the quantized axis, the movements of the tracing table along the axis will be followed by the accumulated total. At any instant the accumulated total will then be the coordinate of the position of the tracing table at that instant.

The Kelsh plotter modification quantizes the motion of the tracing table along both vertical and horizontal axis. Vertical quantization is accomplished by gearing a quantizer directly to the vertical mechanism of the table in such a manner that the vertical quantizer makes one revolution for each 2 in. of vertical travel of the tracing table. Horizontal quantization is accomplished by attaching the horizontal scale attachment to the tracing table. This attachment restricts the horizontal motion of the tracing table to a straight line and causes the horizontal quantizer to rotate 1 revolution for each 4 in. of horizontal travel of the tracing table.

The input signal for the quantizers is supplied by the demodulator unit. This unit also receives the quantizer count and direction output signals. These signals are amplified and then fed into the input units where they are further amplified. In addition, the vertical count is doubled to produce 1,000 counts per quantizer revolution. The horizontal count is quadrupled to produce 2,000 counts per revolution. This multiplication is necessary in order to produce 1 count pulse at each 0.1-ft scale interval.

The multiplied signals along with the direction signal are fed into the electronic counter unit. This unit serves as an accumulator for the count signals, adding or subtracting counts depending on the direction of travel of the tracing table. The counter unit can be preset to any reference value. The accumulated totals in the counters, therefore, can indicate the actual coordinate position of the tracing table at any instant. The horizontal counter is provided with a left-right switch to reverse the direction of counting when the centerline is crossed so that true distances from the centerline will be accumulated. The contents of the counters are visually displayed at all times.

The output of the counter unit is connected through the readout circuits to the key punch machine. The readout circuits consist of a relay switching matrix and 10 control tubes. The relay matrix is driven as a slave unit by the key punch machine. As the machine prepares to punch a column it causes the relay matrix to connect the appropriate counter tube to the control tubes. The control tubes, representing the digits 0 to 9, then cause the key punch unit to punch the digit displayed in the counter for that position. This is repeated at each column until the contents of the counter unit have been punched into cards. Record cycles are initiated by depressing the record button.

Operation

The development of the system just described was completed in December 1956. Detailed instructions were drawn up and it was put in operation shortly thereafter. The system is controlled by the plotter operator who moves the Kelsh plotter tracing table in the normal manner to the points on the cross-sections at which he desires to take readings (Figure 4).

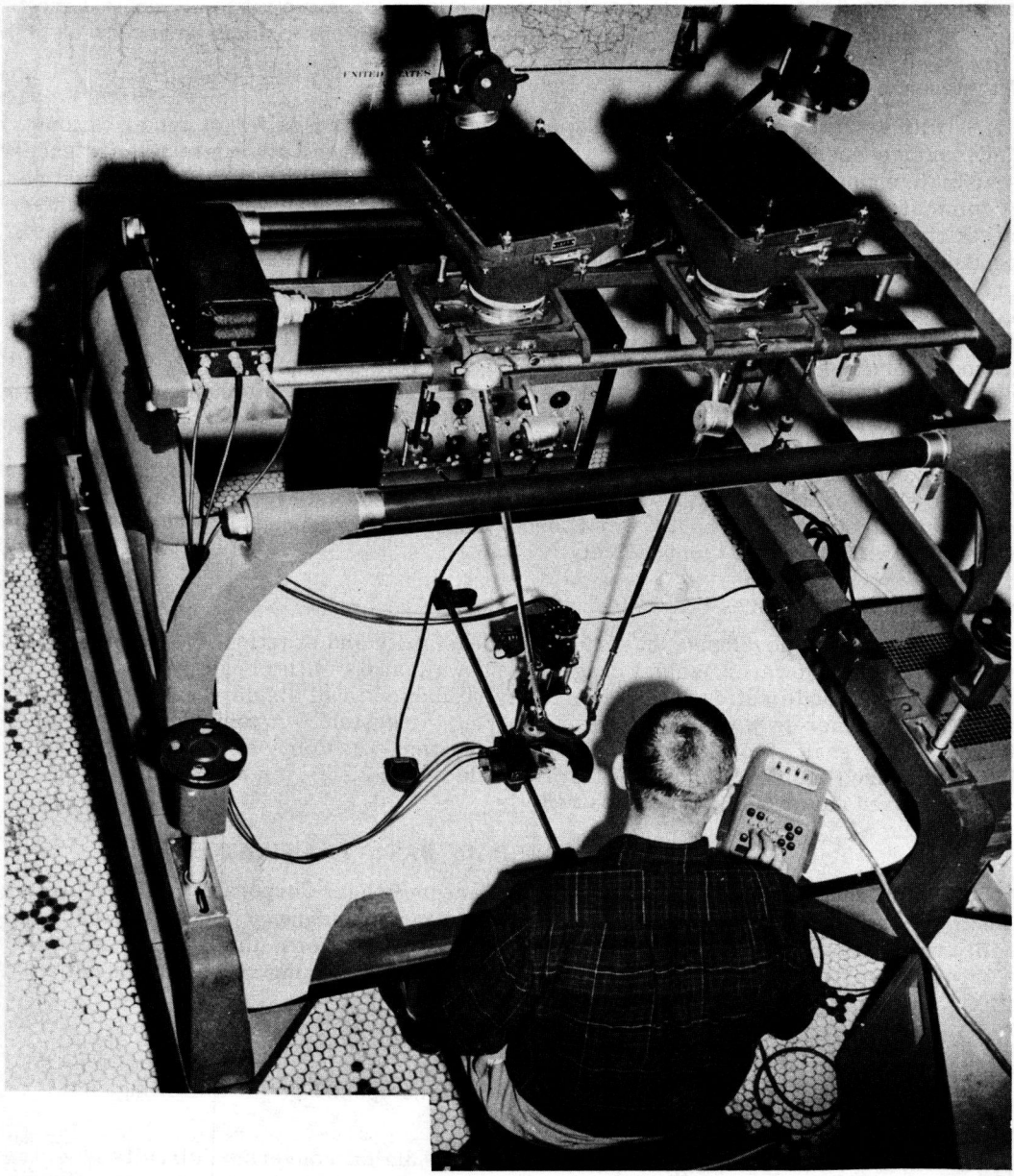


Figure 4. Phototype readout in operational position.

The system is initially set up by aligning the index markers at each end of the modification on the line representing the cross-section. The horizontal counter dial switches (decade switches) are set to indicate zeros, the tracing table is centered over the centerline of the highway and the horizontal reset button is pressed to bring all horizontal counter dials to zero. The centerline elevation is then entered into the vertical counters with their corresponding decade switches and the vertical reset button is pressed. From this point on, for the remainder of the data relating to this cross-section, the counters automatically follow the tracing table's movements. The horizontal and vertical positions of the tracing table at 0.1 ft intervals are visually displayed by the counters at all times and can be recorded by depressing the record button. At each new cross-section the station number must be entered manually into the first card of that cross-section, and the horizontal counters indexed at the centerline. Once the vertical counts have been set they need not be readjusted unless the aerial photographs are changed.

Maintenance

As with any prototype equipment, this system required a number of modifications. Line voltage fluctuations, heat, dirt, and vibration caused the system to require excessive maintenance. On July 1, 1957, the system was subjected to several modifications. A commercial voltage regulator was added to stabilize the input voltage. The counter reset circuit was modified to produce more positive reset operation. Previously the readout circuit would allow recording of data for as long as the record button was depressed, allowing the same point to be recorded over and over again. An interlock relay was added so that one and only one record cycle is initiated per record button depression. The readout circuit also has been modified so that multiple punching in a single column has been eliminated. The original relays frequently failed to make positive contact, thereby not allowing the information in the counter unit to be transferred to the key punch machine. Replacement by modern high-speed, plug-in-wire contact relays has corrected this difficulty. It has been found that the counter unit itself is excessively sensitive to electronic tube variations and aging, causing the counter tubes to skip several digits and at times to rotate continuously from digit to digit without external count signal input. Component changes have reduced these occurrences and eventually will eliminate them entirely.

Other Desirable Features

The system, as developed, has shown the feasibility and practicality of digitizing stereoplotters. However, actual usage has shown that its utility could be increased by several minor modifications. A more easily readable visual display, such as in-line, illuminated numerals would facilitate monitoring the system. A variable scale, rather than the fixed scale, would greatly expand the system's usefulness. The system could be made more flexible if the output format could be variable. An easier method of entering fixed data would also be desired.

THE BENSON-LEHNER TERRAIN DATA TRANSLATOR

A similar system has been developed by the Benson-Lehner Corporation of Los Angeles. Realizing the extensive use of photogrammetry in modern highway design and the feasibility of adopting techniques of digital readout to stereoplotters, the Benson-Lehner Corporation produced the first production machine for digitizing stereoplotter output. Their system is called a "terrain data translator."

Components

The Benson-Lehner terrain data translator is composed of the following units (Figure 5):

1. An electronics unit containing the analog-to-digital conversion circuits, the horizontal position digital display, readout circuits, and format control patchboard,
2. Elevation digital display unit,

3. A horizontal scale, and
4. A control unit.

The functioning of this system is very similar to that of the system developed by the Ohio Department of Highways. Horizontal and vertical axes are digitized by quantizers. Count of the horizontal position of the tracing table is kept in the electronics unit, which also contains a patch board for controlling the output format. Fixed data can be entered into the output by means of the control unit.

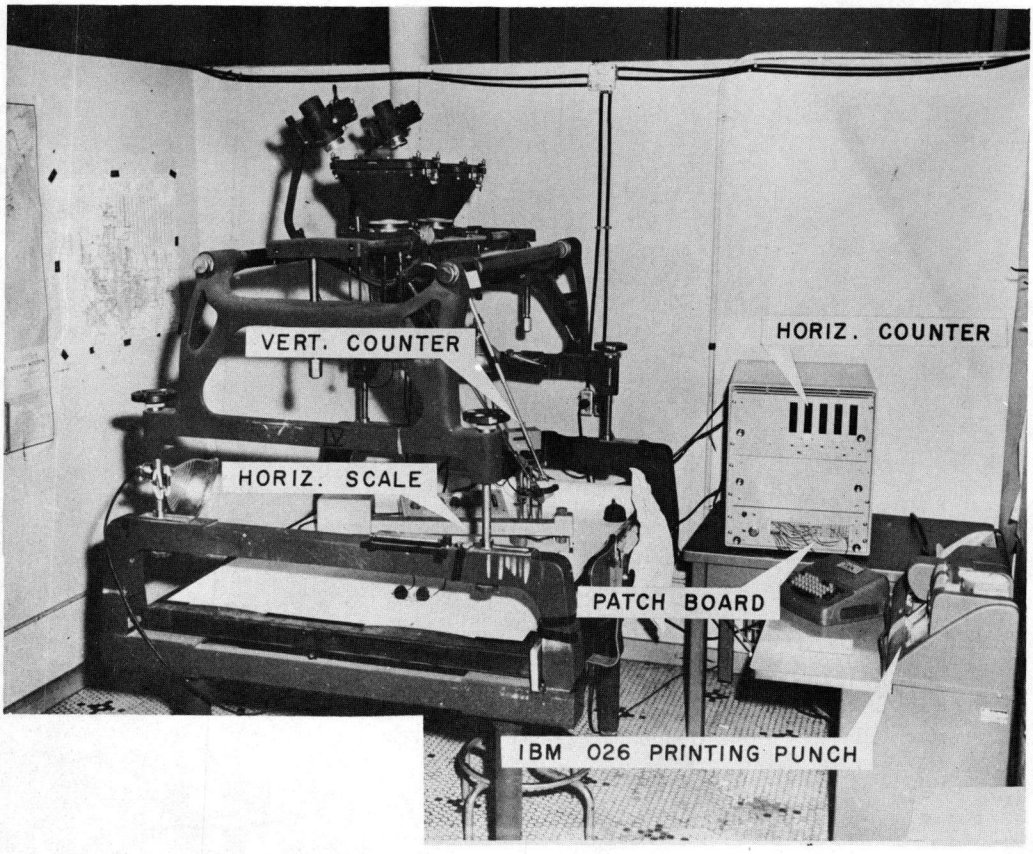


Figure 5. Benson-Lehner terrain data translator.

Because this system is a later development than that by the department, it has several additional desirable features. The position of the illuminated numbers is more advantageous for the operator. Plotting at various scales can be accomplished by changing gears. Output form and format can be varied. Fixed data can easily be entered by the control unit. Actually, both the department system and the Benson-Lehner system could be improved by providing larger, and more easily visible and readable numerals.

In general, the operating procedure for the Benson-Lehner system is very similar to that of the department system (Figure 6).

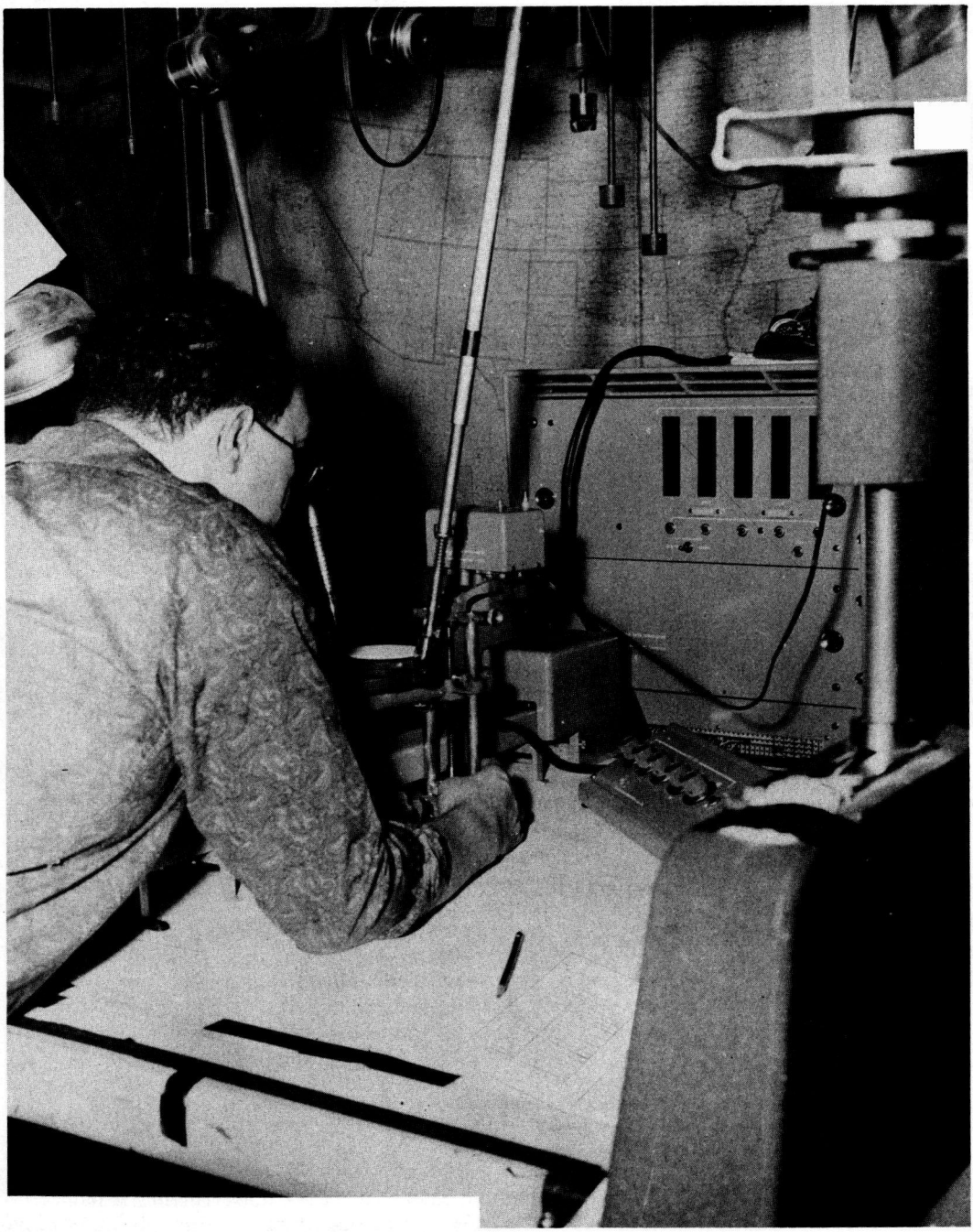


Figure 6. Benson-Lehner terrain data translator in operation.

Maintenance

The Benson-Lehner terrain data translator has been used in production work for only one year, but during this time it was operated on a two- and three-shift basis. Excluding a warranty period during which a number of service calls were required,

this system has demonstrated a high reliability, which is a most important attribute of any electronic device. During a 9-month period in which the machine was operated 1,450 hours, only a routine monthly maintenance check was required.

Use of Automatic Readout for Preliminary Location Studies

Some experience has been obtained in the use of the department readout in obtaining terrain data for use in digital terrain model (DTM) programs. Comparative data are available from an evaluation study of the DTM system presented to the Committee on Electronics of the American Association of State Highway Officials in 1958.

This project involved five models in rough terrain, with two DTM base lines. An abundance of points was read in order to establish criteria for frequency of readings and sections needed. Fourteen thousand points were read at a rate of 200 points per hour for a total of 70 hours stereoplotter time. A 5-ft contour map of the area was then prepared in 50 hours stereoplotter time. The same data were then scaled from the map by two men at the approximate rate of 300 points per hour or 150 points per man-hour. The data were then keypunched at the rate of 500 points per hour and finally verified at 500 points per hour.

Data were stripped from this map with the department readout device the rate of 400 points per hour and with the Benson-Lehner at 500 points per hour.

The data indicate that the most efficient method of procuring DTM data is by production of a suitable map and subsequent stripping by automatic readout. The contour map with its multiplicity of uses is made available at less than 2 extra hours per model. The Benson-Lehner machine appears to be more versatile for this work in terms of selection of scales and flexibility of input. A special increment input control might further speed map stripping.

It is advisable to use a terrain edit program following readout with either machine. This is a computer program for identifying errors and checking the validity of punched data. It is emphasized that a distortion-free copy or the mylar plotting manuscript itself be used to avoid adjustment of data to meet grid positions.

Use of Automatic Readout in the Preparation of Detail Plans

Both readout machines were specifically designed for obtaining cross-section data for the preparation of design plans and to do an adequate job. On timed runs, practically identical results (500 points per hour) were obtained with each machine.

Except for periods when modifications were being made, the Ohio Department of Highways' instrument has been in constant service for four years.

Use of Readout for Obtaining Data for Final Pay Quantities

The Benson-Lehner readout has proved to be better fitted to Ohio's method of reading final sections primarily because of its display. Display of both horizontal and vertical readings on the department instrument is similar to the dial display of a gas meter. The horizontal reading on the Benson-Lehner TDT is somewhat similar but the display is easier to read. The vertical display of the TDT is much superior because it consists of an electric counter on the tracing table within the operator's range of reading vision. Because his eyes are covered with dichromatic filters the quickest recognition of readings outside his near vision range is not permitted.

On test runs the Benson-Lehner TDT records at the rate of 400 points per hour, the department instrument at 300.

THE PHOTRONIX SYSTEM

A third system for digitizing stereoplotter output is that developed in 1957 by Photronix, Inc., of Columbus, Ohio. This system, although not used by the Department, deserves mention in this paper in view of its relevance to the area under consideration.

The Photronix system compares favorably with the department system and includes the following modifications:

1. The Photronix system was built to provide a positive zero registration at centerline without requiring the use of a reset button.
2. The horizontal encoder is driven by a steel band rather than a steel wire.
3. All coding is done directly by means of coded discs that are contained within the Gianni readout heads for both horizontal and vertical measurements. Because the encoder for vertical measurement is larger, it is mounted on a trailer behind the tracing table and is geared directly to the vertical screw of the table.
4. The recording device is a flexo-writer with attached paper tape punch rather than key card punch.
5. Station numbers are entered by means of decade switches rather than by keyboard. Other constant data are programmed into the machine.

There are several distinct advantages to some of the modifications contained in the Photronix system. For example, the advantages of a coded disc readout over a digitizer are that: (a) the unit can be moved more quickly, (b) the risk of dropping bits is eliminated, (c) the operation of the unit is simpler because there are no electronic components, and (d) it is virtually maintenance free.

Another desirable aspect of the Photronix system is the use of a flexo-writer and attached paper tape punch rather than a card punch as the recording device.

This results in considerable space saving in addition to providing an immediate tabulated listing of all readings made by the operator.

CONCLUSIONS

Through the processing of vast amounts of terrain data over a period of four years, it has been demonstrated that digitizing equipment in its present stage of development is accurate, dependable, and practical for many applications in photogrammetry.

Data should be coded as soon as possible in order to take complete advantage of machine processing.

The advent of automated stereoplotters will greatly extend the source of digital terrain information.

Finally, there is a need for simpler, inexpensive coding devices, such as electric counters, that can be used with existing punching equipment for specialized work, such as stripping data from maps and recording comparator measurements, survey data, and readout from stereoplotters.

Discussion

G. P. KATIBAH, Supervising Photogrammetrist, California Division of Highways—The California Division of Highways has purchased an Auto-trol digital scaler, Model 3900, for the purpose of recording photogrammetrically made measurements directly on IBM cards. This instrument was reported by D. E. Winsor at the annual meeting on January 12, 1961. At present the scaler is being used on a State highway improvement project for the conversion of an existing two-lane facility to full freeway standards. Throughout the length of this 9-mi improvement, cross-sections will be measured photogrammetrically for a distance of 200 ft each side of a calculated centerline. The cross-sectioning interval is 50 ft, plus cross-sections at the additional breaks along the centerline.

The terrain is open, rolling, grass lands for the most part. The western portion of the project abruptly changes into cut-up tailings, the remains of past hydraulic and dredge gold-mining operations. This portion is a small percentage of the total project, but is covered with scrub oak growth and is therefore expected to present a photogrammetric problem. For a very short distance, the eastern portion of the project is covered with chaparral growth, which will also present a problem. In general, the area is considered ideal for a "first try" with the new cross-section measuring and digital recording equipment.

Throughout the 9-mi length, a planimetric map will be made on mylar material for the total 400-ft width. Complete topographic maps will be compiled at 6 interchange locations.

The photography has been taken with a 6-in. Zeiss 15/23 camera at a scale of 250 ft to 1 in. Stereomodel scale in the Kelsh stereoplotter is 50 ft to in. A horizontal control baseline was established throughout the entire length of the project, with points targeted every 400 ft on the approximate flight lines. The elevation of each targeted point was measured by surveys on the ground. With the exceptions of the short sections at the very western and eastern ends of the project, wing points were also targeted. Wing points in the very western and eastern ends were images of natural objects selected and identified by a photogrammetrist.

This is California's first experience in attempting an integrated project with the Auto-trol digital scaler. Some initial difficulties with the equipment have been encountered that are being corrected by the manufacturer. The instrument is capable of extremely rapid operation. It is anticipated that, with further experience, a large volume output should be fairly routine.