A Program for Smoother Roads

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The demands of a traveling public for smooth, all-weather roads have produced a number of plans for the improvement of the riding surfaces of new or reworked highways. This paper is concerned with this problem; it discusses asphaltic laydown equipment with string-line sensoring devices for surface controls and the use of the electronic computer for the mathematical computations required for such controls. The authors have attempted to provide sufficient information relating to program control and reasoning and the mechanics of input and output data so that the reader can use the body of the program involved and produce other programs which may differ in local detail. A sample problem is included to aid in the presentation of the approaches used.

•REALIZING that the traveling public dramatically and quickly reacts to rough roads, highway engineers have, through the years, concerned themselves with old and new road surfaces to palliate abrupt vertical curvature or broken pavements. An economical and practical approach to the revitalization of older surfaces which has been used by many highway departments is the application of asphaltic surfaces of several types. In addition, to provide the smoothest surfaces possible on such construction and on final layers of new construction, a computed grade line has been used to control this surfacing. In the field, such a grade is represented by a surveyed string line. A traveling string line has also been used with much success toward the achievement of good driving surfaces.

For several years the Kansas State Highway Commission has been concerned with the rebuilding of deteriorated wearing surfaces on bituminous and concrete highways which have sufficient width and base for the continuation of their use. By placing a thin layer of asphaltic concrete on these surfaces, it has been possible to continue their use as desirable highways. For many years the material used for this construction was road-mixed asphalt, placed with a blade. As better equipment became available, this method was discarded in favor of central mixing plants and asphalt laydown machines. This technique was in use until the early 1960's when Frank Drake invented a device which made it possible to construct a controlled, rather than a uniform, thickness overlay. By controlling the overlay thickness, a more uniform and smoother riding surface has been obtained.

This intricate control is now required equipment on all laydown machines used on Kansas highways. A sensor is used on a string line which has been preset to the elevation of the surface to be constructed. As the device senses a closure or departure of the string line from the existing surface, the thickness of the material being placed on the road is increased or decreased accordingly. The string line, which is usually placed along the centerline of the roadway, must be set by the ordinates or elevations of a predetermined reference grade.

The establishment of a reference grade by the tangent and vertical curve method is not used because the cost of the amount of surfacing material required would be prohibitive. Instead, the existing nonuniform grade is modified to establish a sufficiently

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improved grade while maintaining the general existing grade trend. This grade can be described by any of several methods, and can be computed either manually or by electronic computer. The Kansas Highway Commission uses a computer to establish the modified grade line, which is described both by elevations and fill ordinates above the original grade line.

PRELIMINARY SURVEY

The complete procedure for the design and construction of an improved wearing surface consists of an original survey, computations for a modified grade, and the actual construction of the project.

The preliminary survey provides the data or information by which an existing grade line can be slightly adjusted so that its characteristics are smooth, and when it is used for spreading asphalt a surface of good riding qualities is attained. The primary purpose of the survey and grade-line adjustment is to place asphaltic mixtures in the varying thicknesses that tend to improve the ridability of the finished surface.

Filling sags, cutting humps, and building ramps on either side of abrupt vertical excurvatures are the tools available to straighten or improve the grade line. To utilize these tools, knowledge of the location, character, and magnitude of each irregularity is required, and this information is obtained in a preliminary survey. This can be illustrated by plotting the existing grade-line elevations to a distorted scale on profile paper. The scale, 1 in. = 25 ft horizontally and 1 in. = 0.5 ft vertically, magnifies the irregularities so that they are easily detected and may be treated or eliminated by manual straightening with a flexible curve or straightedge. The field notes are generally submitted to the design department for grade-line adjustment by the electronic computer.

The vertical measurement is the most important field measurement. The actual locating of the original profile points does not require a great deal of accuracy or detail work. If existing blue top stakes, right-of-way stakes, pavement edge or any other set line is available, a transit is not needed to establish the line to be profiled. When such a line is available, chaining and cross-chaining works very well in establishing the line. Much can be gained by careful work when taking level readings, and little is to be gained by taking excessive time to make exact locations of each profile point.

A series of profile points should be placed along the centerline of the existing roadway surface with one located at each station and each 25-ft interval between stations. Each profile point should be marked with such permanence that it may be readily located at the expected time of construction. A spike and washer has been effectively used for this purpose. Profile points located at stations should be distinguished from those at the 25-ft intervals so that chances for error in placing the thickness values are held to a minimum.

A profile should be run and the data entered in a standard loose-leaf field book. The levels should be based on an assumed elevation and carried through the entire length of the project without making the usual corrections at turn points and bench marks. A correction in the levels at any point in the profile causes a vertical equation which imposes a wave in the adjusted grade line. The height of instrument may be checked at a bench mark for approximate elevation, but should not be corrected. The height of instrument for an instrument setup can be checked by taking a check rod reading on the last profile point of the previous instrument setup.

Existing crown cross-sections at various points along the centerline are needed for the computation of the adjusted grade line and the calculation of the estimate of quantities of material for the leveling course. The distance between locations of cross-sections should not exceed 500 ft. A cross-section should be taken immediately before the beginning of superelevation of each curve and immediately after the end of superelevation. A minimum of three sections should be taken within the fully superelevated portion of each horizontal curve. The sections should be so spaced and of sufficient number to give representative information on each curve.

The cross-section should contain five points of rod readings: centerline, the quarter point (6 ft right and left), and the pavement edges. It is not intended that a lot of time be spent on the cross-section; however, it is important that extreme care be exercised when selecting the place to take the rod reading.

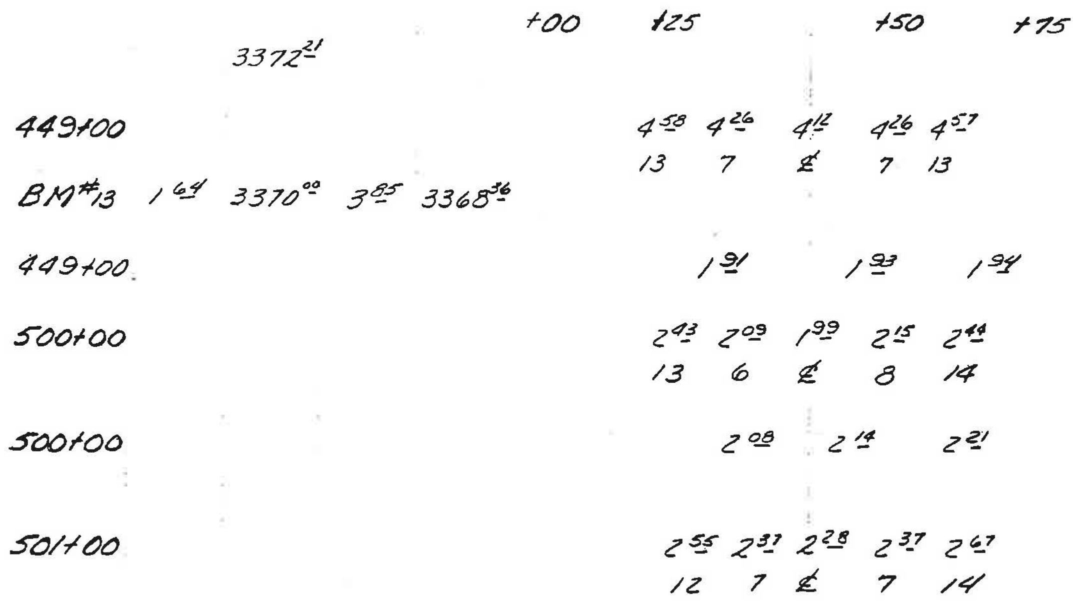


Figure 1. Field notes.

Rod readings for profiling and surface cross-sectioning should be read to the nearest one-hundredth of a foot. Careful reading of the rod should be exercised; however, it is not necessary to wave the rod and use the precautions necessary in making turning point and bench mark readings.

The procedures described follow quite closely the specifications used by the Kansas Highway Commission. They are outlined in detail in the construction manual for overlay operations. Other specifications and procedures may be developed which produce similar results. However, if electronic computation is to be utilized, a uniform surveying procedure is necessary to produce accurate and economical computations. Field notes should also follow a set pattern. Consistency of format in original data provides for easy review of such data, reduces the possibility of error when key punching the data and aids in the writing of, and in the compliance with, operating instructions. A typical set of field notes used by Kansas is shown in Figure 1.

COMPUTATIONS FOR MODIFIED GRADE

On completion of the survey, the field notes are generally transmitted to the design department, and a designing unit is assigned to the project. A preliminary check of the notes is made at this time. The field notes are then delivered to the computer section for processing. Various card formats can be developed for the field information. The Kansas program is designed around the card formats shown in Figure 2. After the data have been placed into proper format, they are ready for computer processing.

The Kansas program was designed for an IBM 1620 60K computer. To allow maximum flexibility, the processing is developed by three separate computer runs. The first pass performs an edit of the data. This pass checks for abrupt changes and irregularities in the centerline profile, for any major deviation in similarity of each cross-section from the previous cross-section processed, and the stationing for incorrect sequence. As these conditions are detected, they are recorded on a typewriter output. The results of this pass are manually checked to determine if noted irregularities are actual errors or existing road surface conditions. Incorrect station sequence is also checked in this pass and noted by typewriter output. Errors of this nature are corrected and the average cross-section run is made. Average cross-sections may be computed over any specified segment of roadway. The averages are retained on output punched cards.

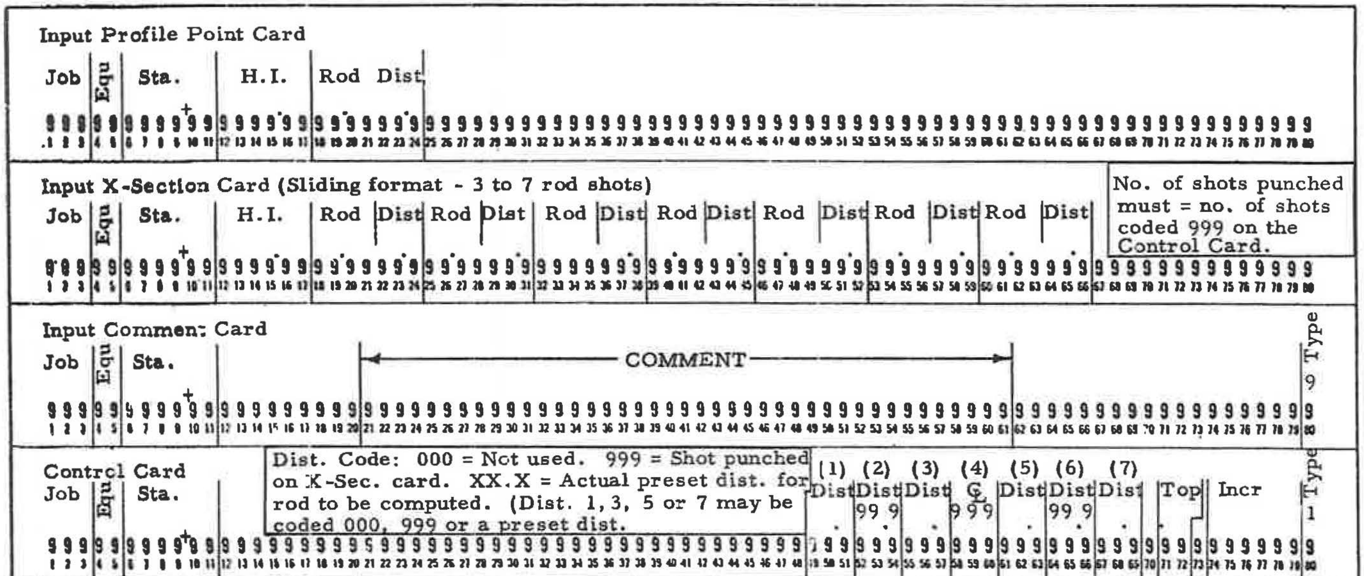
IBM

INTERNATIONAL BUSINESS MACHINES CORPORATION

Form X24-6599-0
Printed in U.S.A.

MULTIPLE-CARD LAYOUT FORM
INPUT CARDS

Company ______ Application GRADE LAYER by ______ Date JUNE, 1965 Job No. ______ Sheet No. ______



Completely punch fields used. Leave all other col's. blank.

Control cards must be used to begin a job, to end a job, at any fill change and at any desired average section point.

Any number of comment cards may be used following any control card or one comment card may be used at any other point. Exception: No comment cards may follow any one of the first four or the last data card. Limit: 1 comment card for each 5 data cards.

The first data card following a control card can not be a X-section card.

Control: Fill = Min. total fill (Includes top lift). Top = Uniform thickness of the top lift. Incr. = Average fill punching increments in stations (Coded 9999 causes increments only at control card breaks).

621110MSP

Figure 2. Kansas program.

The use of an IBM 407 accounting machine provides a listing in the form of plotted cross-sections. The original data for cross-sections have been retained in a format of rod readings, distances from a centerline and controlling heights of instrument. The average cross-sections produced by the second pass are also in the input format. A listing of this output data is produced along with the plotted cross-section. The high point of the average cross-section replaces the height of instrument reading and carries a rod reading of 0 ft. Each average cross-section is computed from the original cross-sections within a segment of the project as controlled by the designer. The output data are returned to the designer for evaluation. Additional runs can be made to improve the project, or if errors persist.

After satisfactory results have been obtained from the first two runs, the grade layer run is made. A fill ordinate is computed and punched out for each profile point and centerline cross-section point. Each fill ordinate is computed to the nearest one-hundredth of a foot and is accompanied by the elevation of the modified grade and the algebraic difference in grade at that point. If the designer specifies that the leveling course be constructed in two layers, the fill ordinates of the bottom layer and the overall fill ordinates are computed. All leveling is accomplished in the bottom layer while the top layer maintains a uniform thickness. At each change of minimum fill as specified by the designer, an average centerline fill ordinate is computed. The final output is listed on a 407 accounting machine and returned to the designer.

The designer uses the average cross-sections in conjunction with the average fill ordinates to compute asphalt and aggregate quantities for the project. Incorporation of these quantities with the grade-layer listing completes the overlay portion of the design plans.

THEORY OF COMPUTATION

Computer programs can be developed using a number of concepts. The basic theory of computation used in the program discussed may be outlined as follows.

The grade-layer program uses a five-point method to compute a modified grade. Five consecutive profile points of the existing grade are analyzed and used to compute a point on the modified grade line. After the computations are made for each point, the grade line is advanced one point within the computer and the process is repeated. Thus each point on the existing grade occupies five consecutive positions for analysis as it is advanced through the computer. The computer uses several different methods for the computation of each point on the modified grade. The configuration of the five points of the existing grade and the average departure of the modified grade from the existing grade up to the point being computed, determine the method to be used. For the purpose of explanation, the five points and all relating data are referred to the notations shown in Figure 3.

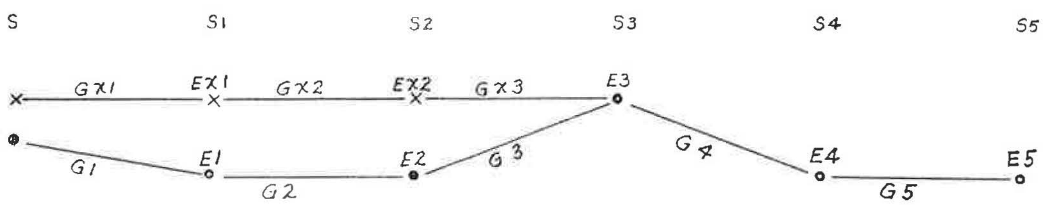


Figure 3.

DEFINITIONS

E1 through E5: original elevations of 5 points being processed;
EX1 through EX2: modified elevations of points 1 and 2;
G1 through G5: grades approaching original elevations of points 1 through 5;
GX1 and GX2: grades approaching modified elevations of points 1 and 2;

GX3: grade between modified elevation of point 2 and original elevation at point 3;
D1 through D4: algebraic grade differences between grades to original elevations at points 1 through 4;
DX1 through DX3: grade differences between grades to modified elevations at points 1 through 3;
S1 through S5: stations of 5 points being processed; and
S: station of point just before S1.

The following figures and the analysis of their configurations show the methods used for the computation of the modified grade line.

CASE I

If the analysis of the original elevations at stations S1 through S5 does not indicate a crest condition, a line is constructed from E3 to E5 and EY4 is established on the line at station S4 (Fig. 4). If EY4 is not lower than E4, a line is then constructed from EX1 to EY4 and EX2 is established on that line at station S2.

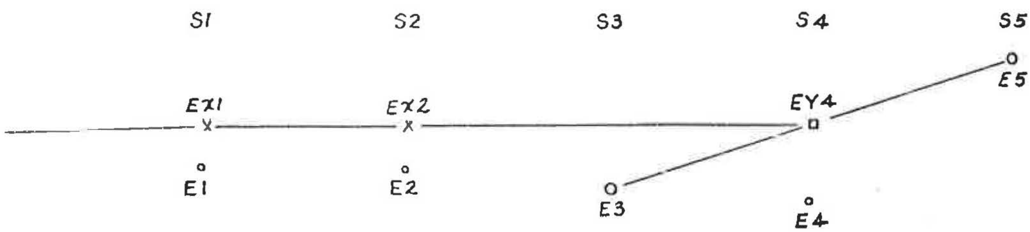


Figure 4.

If EY4 is lower than E4 (Fig. 5), a line is constructed from EX1 to E4, and EX2 is established on that line at station S2.

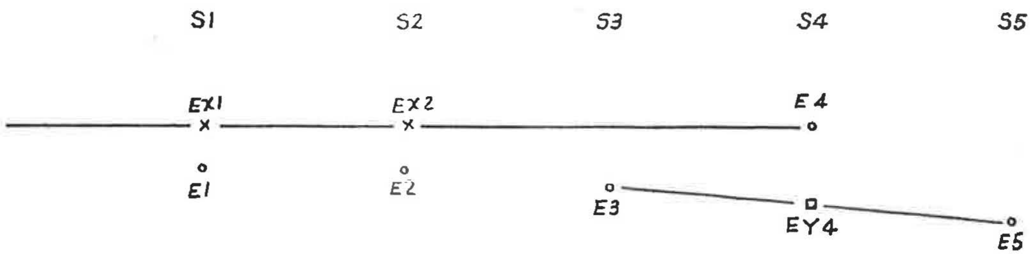


Figure 5.

After the foregoing computation of EY4 has been made, the grade G3 is computed between E2 and E3 (Fig. 6). The grade GY4 is then computed using E3 and the lower of EY4 and E4. The grade difference DY3 is computed at station S3 using G3 and GY4. If DY3 is negative, the previous EX2 is discarded. A line is then constructed from EX1 to E3 and EX2 is established on this line at station S2. If DY3 is positive, EX2 is not recomputed.

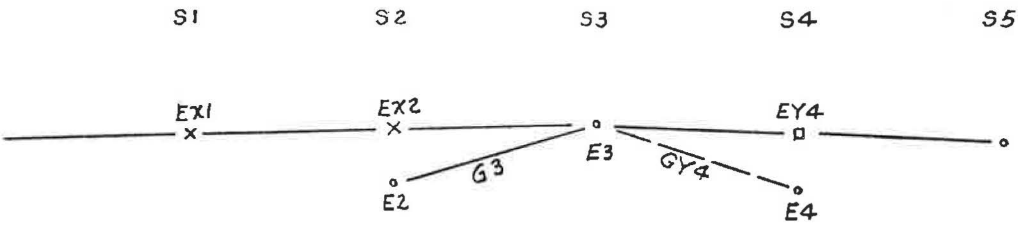


Figure 6.

CASE II

On the completion of case I, the original elevations at stations S1 through S4 are analyzed for a sag condition. If the grades connecting each of these points are increasing in a positive direction, the condition is interpreted as a sag. Therefore, to override the excessive fill that would result from the normal leveling computed in case I, the modified grade is lowered to follow closely the trend of the vertical curve of the existing points. Thus EX2 is modified by the following formula:

$$EX2 = E2 + 0.33333\,(EX2 - E2)$$

If a sag condition exists only at stations S2, S3, and S4 but not at S1, the entrance of a sag condition is indicated and EX2 is modified by a lesser amount than previously shown for a full sag condition:

$$EX2 = E2 + 0.50000\,(EX2 - E2)$$

If a sag condition exists at stations S1, S2, and S3 only, the exit of a sag condition is indicated. EX2 is modified by the following formula:

$$EX2 = E2 + 0.66667\,(EX2 - E2)$$

If the original grade does not meet any of the foregoing sag conditions, EX2 is altered at this juncture.

CASE III

If, on the analysis of the five original points, a crest condition exists, this case is used in place of case I and case II. To determine this condition, the original grade differences D1 through D4 are computed at stations S1 through S4. If all differences are negative, the grade condition is interpreted as a crest and the average grade difference DX of these points is computed by the formula:

$$DX = \frac{D1\,(S2-S) + D2\,(S3-S1) + D3\,(S4-S2) + D4\,(S5-S3)}{2\,(S5-S)}$$

After the foregoing computation has been made, EX2 is computed so that the modified grade difference DX2 at station S2 is equal to DX.

MATERIAL SALVAGING PROCESS

If processing has been executed according to cases I and II, the following analysis and computations should be made. The average vertical difference V between EX2 and E2 for all previous points is computed. EX2 is then modified by the following method:

If $V < 0.020$ ft: $EX2 = EX2 - 0.010$ ft
If $0.020 \text{ ft} < V < 0.030$ ft: $EX2 = EX2 - 0.014$ ft
If $0.030 \text{ ft} < V < 0.040$ ft: $EX2 = EX2 - 0.018$ ft
If $V > 0.040$ ft: $EX2 = EX2 - 0.022$ ft

The reason for this step is to eliminate an excessive difference between the original grade line and the modified grade line. In the case of a relatively uniform original grade where the majority of the grades are under 4 percent and the vertical curves over 400 ft long, a minimum of correction has to be made on the modified grade to keep its grade trend near that of the original grade. If the original grade line follows closely to the ground line in rolling terrain, the modification tendency is toward a flatter grade that is impractical to construct using asphalt surfacing materials. If this condition exists, it is necessary to place further control on the modified grade so that it will closely follow the trend of the original grade. Regardless of the grade under consideration, it is not the intent of this program to produce a radically different grade. The purpose of this program is to correct minor irregularities so that the best riding surface possible may be constructed from the amount of surfacing material allowed.

At the completion of the computation of EX2 in any of the processes executed by this program, EX2 is checked against E2. If the elevation of EX2 becomes less than that of E2, EX2 is replaced by E2. The minimum fill ordinate specified by the designer is then added to EX2 and the fill ordinate to be used for construction is computed by the formula:

$$\text{Fill} = EX2 - E2$$

THEORY OF DESIGN

On the assignment of a project, the design department checks the field notes for mathematical errors. Input comment and cross-section control forms are coded and along with the field notes are submitted to the computer section for key punching and the edit run on the computer.

The edit run listing is checked and the errors are corrected on input profile point and/or input cross-section forms. The project is then broken into non-superelevated segments which connect superelevated curves and the superelevated curve segments. Cross-section control forms are coded for each segment of roadway. The correction forms and the control forms are submitted to the computer section for key punching and the cross-section computer run.

Average cross-sections produced by the cross-section computer run are analyzed for crown condition and the minimum centerline overlay thickness is determined. This is accomplished by applying a predetermined template to the average sections so that no point on the sections is at an elevation any closer than 0.08 ft to template elevation. The centerline ordinate is then scaled and 0.02 ft is added for compaction. This value is coded on the control forms and resubmitted to the computer section for key punching and the leveling course run on the computer.

At this time, quantities are computed. The fill ordinates are incorporated into the plans, completing the design stage of the program.

CONCLUSIONS

The program introduced in this paper is only a part of the total process involved in producing smoother riding surfaces. However, this program, which uses an electronic computer, has been a key element in smoother roads for Kansas. The design time has decreased measurably; a year's resurfacing plans, which in the past required one design unit six months to complete, is now completed in one or two months. The values computed for material quantities have also been improved measurably.

The final judge of the program is the road user. Roughometer tests have proven that resurfacing projects using the string-line method are smoother in most every case. The total roughometer distance measured in a resurfacing year has shown a marked improvement in surface smoothness. There is no question that smoother roads are obtained and with the computer program to reduce design costs, "a program for smoother roads" is here to stay.

MODEL PROBLEM

To aid the user of such a process, a short sample run is included in the Appendix. The sample includes cross-section notes, first input cards, corrections as indicated by the output of the computer typewriter, corrected cards, second output, final cross-sections, and a sample of listed output. In addition to the sample problem, a listing of operator instructions and a program flow chart are also included.

Appendix

Example of Centerline Profile and Cross Section Notes:

CENTERLINE PROFILE

Date ________ Instr. ________
Weather ________ Rod ________

Sta	+Rod	HI	-Rod	Elev.	+00	+25	+50	+75
BM	6.49	106.49		100.00				
200					6.30	6.33	6.10	5.94
201					5.68	5.43	5.16	4.96
202					4.77	4.58		
+50 X-Section					$\frac{4.34}{12L}$ $\frac{4.35}{9}$ $\frac{4.33}{4}$ $\frac{4.31}{CL}$ $\frac{4.28}{2}$ $\frac{4.32}{10}$ $\frac{4.38}{12R}$			
202								3.93
203					3.50	3.08	2.72	2.35
204					2.02*	1.75#		
TP	7.58	112.32	1.75#	104.74				
TPck	7.84		2.02*	104.47				
204							7.26	6.90
206					6.49	6.09	5.72	5.44
207 X-Section					$\frac{5.18}{12L}$ $\frac{5.08}{2}$ $\frac{5.07}{CL}$ $\frac{5.11}{3}$ $\frac{5.18}{12R}$			
207						4.72	4.40	4.18

Note: No rods in this area.

Note: All rods in this area must go with the above HI.

Note: No rods in this area.

Note: All rods in this area must go with the above HI.

An Example Sheet supplied field personnel for the taking of field notes.

Field Notes for Sample Problem — page 1

+00 +25 +50 +75

		3372^{21}								
449+00						4^{58}	4^{26}	4^{12}	4^{26}	4^{57}
						13	7	¢	7	13
BM#13	1^{64}	3370^{00}	3^{85}	3368^{36}	3368^{34}					
449+00							1^{91}		1^{93}	1^{94}
500+00						2^{43}	2^{09}	1^{99}	2^{15}	2^{44}
						13	6	¢	8	14
500+00							2^{08}		2^{14}	2^{21}
									2^{31}	
501+00						2^{55}	2^{37}	2^{28}	~~3^{37}~~	2^{67}
						12	7	¢	~~2~~7	14
501+00							2^{36}		2^{51}	2^{65}
502+00						2^{99}	2^{89}	2^{82}	2^{91}	3^{19}
						12	7	¢	8	14
502+00							2^{98}		3^{12}	3^{30}
503+00						3^{76}	3^{61}	3^{49}	3^{59}	3^{86}
						12	8	¢	7	13
503+00							3^{71}		3^{91}	4^{13}
⊙	2^{60}	3368^{28}	4^{32}	3365^{68}	¢ nail @ 504+00					
								2^{60}		
504+00						2^{80}	2^{65}	~~3^{60}~~	2^{69}	2^{85}
						13	6	¢	6	12
504+00							2^{80}		2^{96}	3^{10}

These corrections were made to the input card after analyzing the Typewriter Error Message output from Pass 1.

page 2

Station					+00		+25		+50		+75
		3368^{28}									
505+00						3^{50}	3^{30}	3^{23}	3^{28}	3^{41}	
						13	5	℄	5	12	
505+00							3^{39}		3^{52}		
+68						3^{90}	3^{74}	3^{66}	3^{74}	3^{94}	
						13	7	℄	5	12	
506+00						4^{07}	3^{95}	3^{88}	3^{96}	4^{13}	
						14	7	℄	5	11	
506+00							4^{09}				
506+50						4^{52}	4^{36}	4^{27}	4^{39}	4^{74}	
						14	8	℄	5	12	
506+00											4^{41}
507+00						4^{80}	4^{63}	4^{54}	4^{67}	5^{00}	
						14	8	℄	5	11	
507+00							4^{66}		4^{82}		4^{93}
BM#14	2^{89}	3365^{80}	5^{37}	3362^{91}	3362^{90}						
508+00						2^{76}	2^{57}	2^{54}	2^{74}	2^{96}	
						14	7	℄	7	12	
508+00							2^{60}		2^{65}		2^{74}
509+00						3^{12}	2^{83}	2^{79}	2^{99}	3^{40}	
						13	7	℄	6	12	
509+00							2^{86}		2^{94}		3^{08}

page 3

Station					+00 +25 +50 +75
		3365^{80}			
510+00					3^{38} 3^{22} 3^{18} 3^{34} 3^{25}
					13 7 ℄ 5 12
510+00					3^{28} 3^{38} 3^{54}
511+00					3^{80} 3^{71} 3^{70} 3^{85} 4^{20}
					13 8 ℄ 7 11
511+00					3^{87} 4^{08} 4^{23}
512+00					4^{53} 4^{37} 4^{34} 4^{45} 4^{74}
					13 7 ℄ 5 11
512+00					4^{45} 4^{59} 4^{74}
⊙	1^{53}	3362^{46}	4^{87}	3360^{93}	℄ nail 513+00
513+00					1^{77} 1^{58} 1^{53} 1^{63} 1^{79}
					13 6 ℄ 6 11
513+00					1^{63} 1^{78} 1^{88}
514+00					2^{19} 2^{02} 1^{99} 2^{10} 2^{35}
					12 6 ℄ 7 12

GRADE LAYER CONTROL CARDS

Route		Project				Type	Work Class	Acc.
No.	Sec.	Class	No.	Sec	Agr. No.			

For Computer Section

Job No. __________

Date Received __________

Estimated Completion Date __________

Request Received By __________

To be coded completely by requesting department

TEMPLATE CONTROL DISTANCES

JOB	EQU	STA	D 1	D 2	D 3	C	D 5	D 6	D 7	Leveling Course Uncomp.	INCR	Total Comp.	
1 2 3	4 5	6 7 8 9 10 11	49 50 51	52 53 54	55 56 57	58 59 60	61 62 63	64 65 66	67 68 69	71 72	74 75 76 77	78 79	80
		X X XX+X X	X X.X		X X.X		X X.X		X X.X	.X X	X X X X	.X X	
000	00	049900	000	999	999	999	999	999	000		9999		1
000	00	050608	000	999	999	999	999	999	000		9999		1
000	00	051400	000	999	999	999	999	999	000		9999		1
				999		999		999					1
				999		999		999					1
				999		999		999					1
				999		999		999					1
				999		999		999					1
				999		999		999					1
				999		999		999					1

KPO: PUNCH ZEROS IN ALL UNFILLED SHOWN COL'S.

Control cards must be used to begin a job, to end a job, at any fill change and any required average section point. Dist. Code: 000 = Not used. . 999 = Shot punched on X-sec. card. Actual dist = dist for rod to be computed.
(D1, D3, D5 & D7 may be coded 000, 999, or a preset dist.)

INCR = Required average fill increments in stations (coded 9999 computes average fill's at control card breaks only).

First & second passes

STA 501+00 ERRATIC SEC.

STA 504+00 ERRATIC SEC.

STA 504+00 FILL 1.14

SAMPLE PROBLEM

TYPEWRITER ERROR

LISTING FROM PASS 1.

GRADE LAYER
CONTROL CARDS

Route		Project				Type	Work Class	Acc.
No.	Sec.	Class	No.	Sec	Agr. No.			

FOR COMPUTER SECTION

JOB NO. ____________

DATE RECEIVED ____________

ESTIMATED COMPLETION DATE ____________

REQUEST RECEIVED BY ____________

TO BE CODED COMPLETELY BY REQUESTING DEPARTMENT

TEMPLATE CONTROL DISTANCES

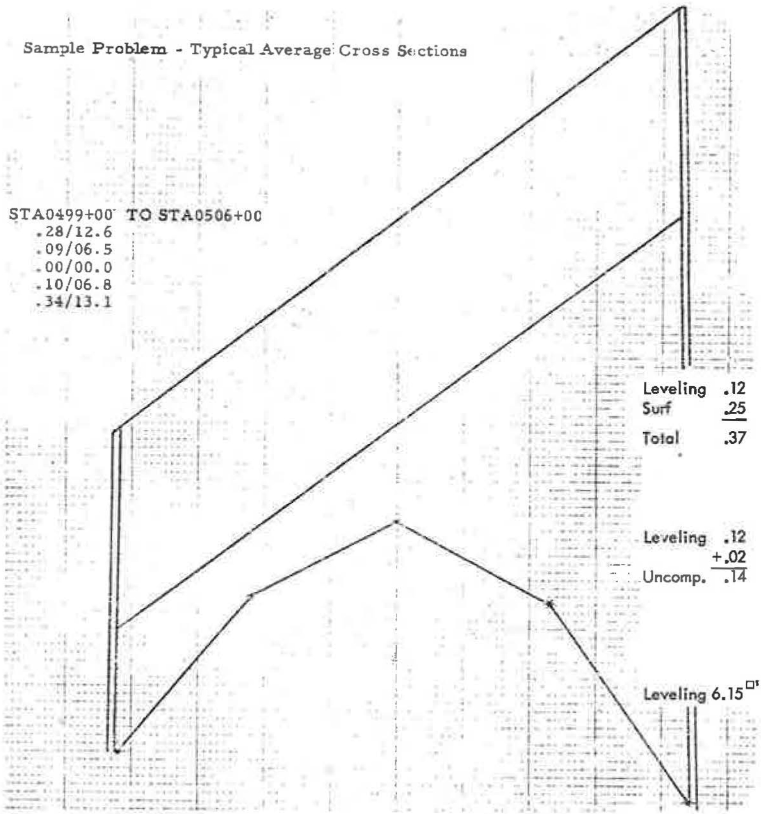
JOB	EQU	STA	D1	D2	D3	C	D5	D6	D7	Leveling Course Uncomp.	INCR	Total Comp.	
1 2 3	4 5	6 7 8 9 10 11	49 50 51	52 53 54	55 56 57	58 59 60	61 62 63	64 65 66	67 68 69	71 72	74 75 76 77	78 79	80
		XX XX+XX	XX.X		XX.X		XX.X		XX.X	.XX	XXXX	XX	
000	00	049900	000	999	999	999	999	999	000	14	9999	37	1
000	00	050608	000	999	999	999	999	999	000	17	9999	25	1
000	00	051400	000	999	999	999	999	999	000		9999		1
				999		999		999					1
				999		999		999					1
				999		999		999					1
				999		999		999					1
				999		999		999					1
				999		999		999					1
				999		999		999					1

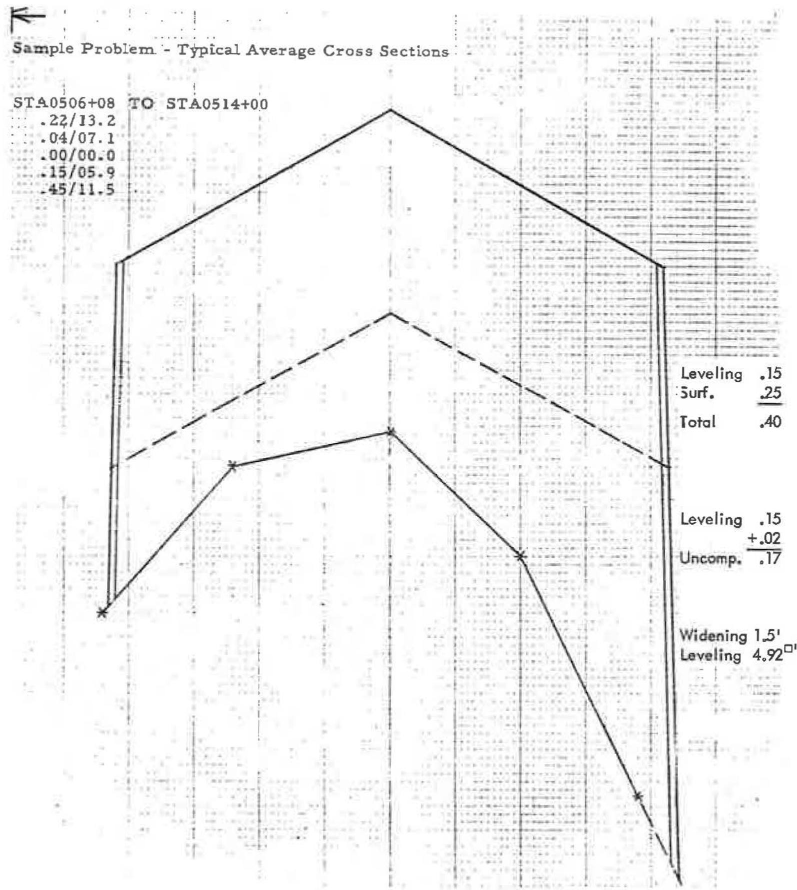
KPO: PUNCH ZEROS IN ALL UNFILLED SHOWN COL'S.

Control cards must be used to begin a job, to end a job, at any fill change and any required average section point.
Dist. Code: 000 = Not used. . 999 = Shot punched on X-sec. card. Actual dist = dist for rod to be computed.
(D1, D3, D5 & D7 may be coded 000, 999, or a preset dist.)

INCR = Required average fill increments in stations (coded 9999 computes average fill's at control card breaks only).

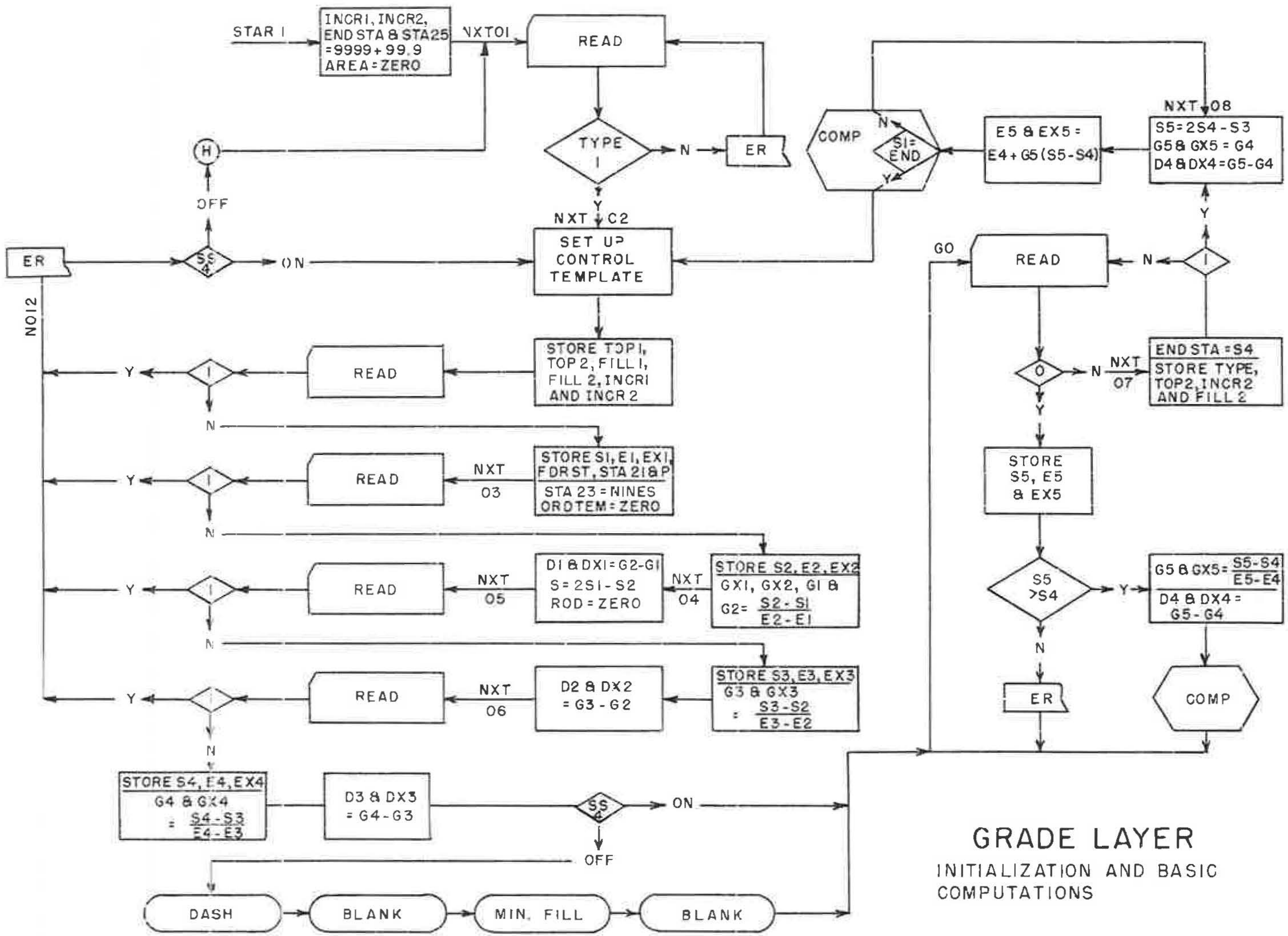
Third pass


Sample Problem - Typical Average Cross Sections
STA0499+00 TO STA0506+00
.28/12.6
.09/06.5
.00/00.0
.10/06.8
.34/13.1
Leveling .12
Surf .25
Total .37
Leveling .12
+.02
Uncomp. .14
Leveling 6.15□'

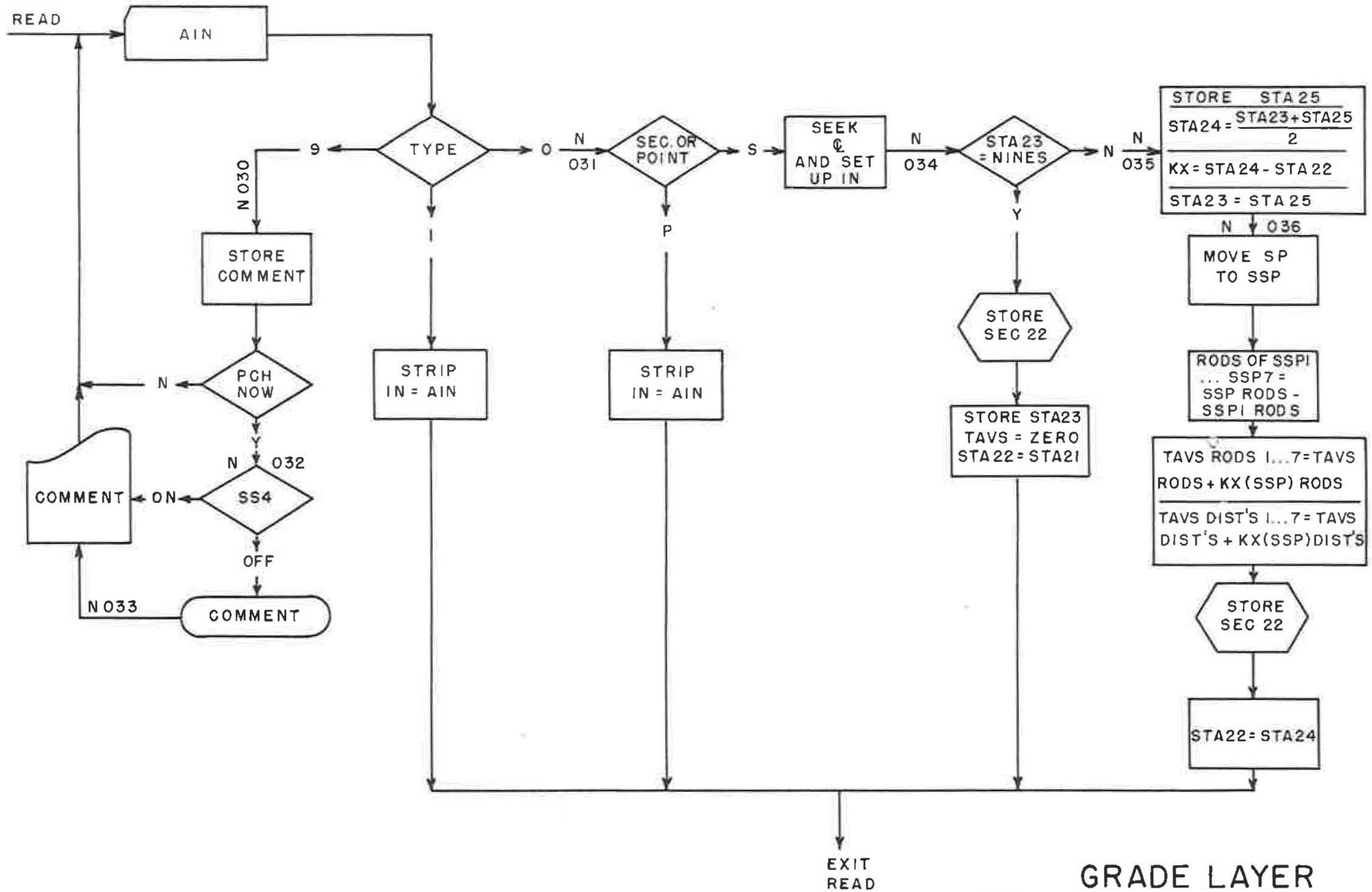

Sample Problem - Typical Average Cross Sections
STA0506+08 TO STA0514+00
.22/13.2
.04/07.1
.00/00.0
.15/05.9
.45/11.5
Leveling .15
Surf. .25
Total .40
Leveling .15
+.02
Uncomp. .17
Widening 1.5'
Leveling 4.92□'

Sample Problem - Typical Listing

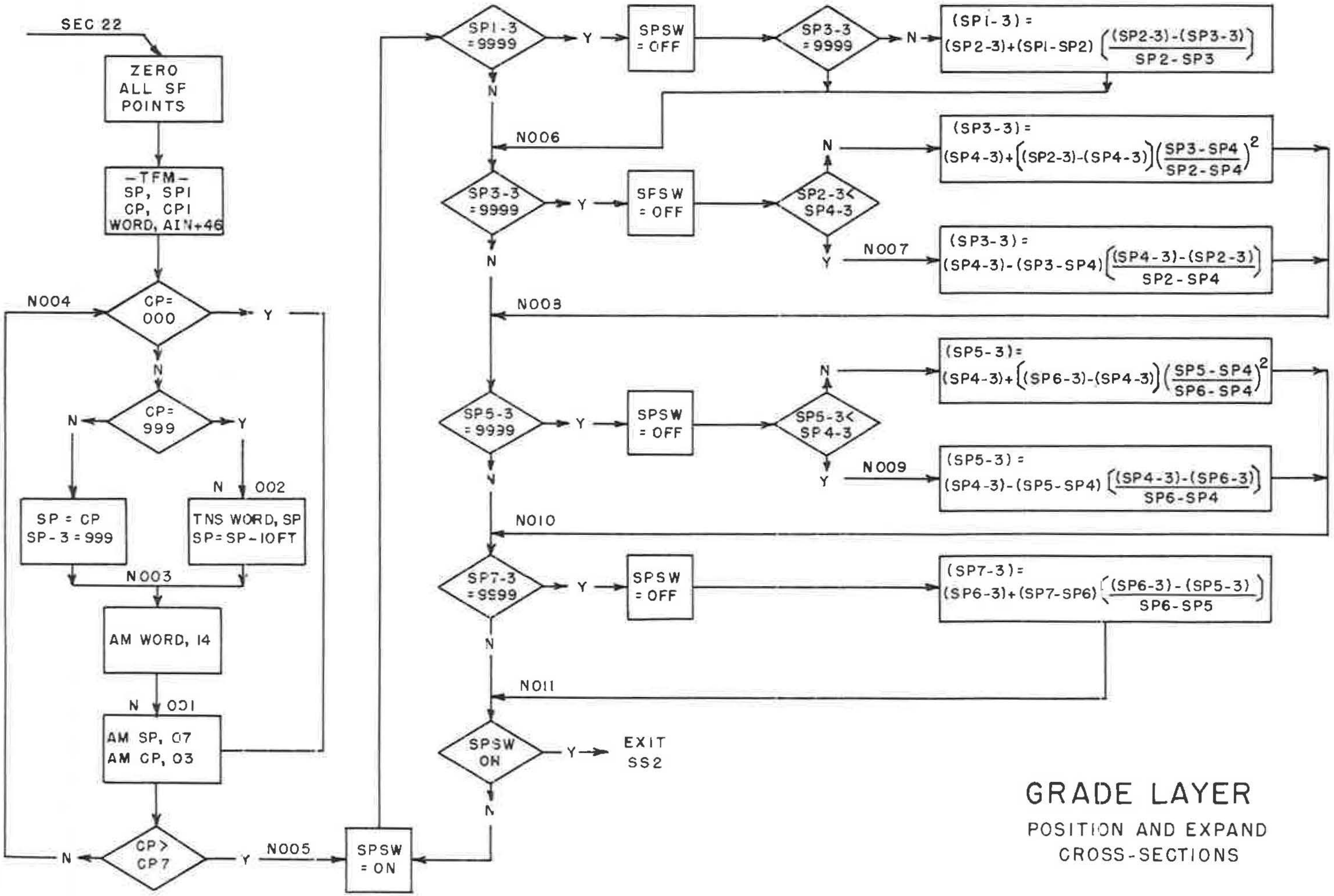
STA.	CR.GR.	ORD.	GR.DIF.
499+00	3368.46	0.14	00.00
499+25	3368.46	0.14	-00.04
499+50	3368.45	0.15	-00.01
499+67	3368.44	0.14	-00.07
499+75	3368.43	0.14	-00.08
500+00	3368.38	0.14	-00.10
500+25	3368.31	0.16	00.01
500+50	3368.23	0.14	00.04
500+75	3368.17	0.15	-00.07
501+00	3368.09	0.14	-00.00
501+25	3368.01	0.14	-00.26
501+50	3367.87	0.15	-00.00
501+75	3367.72	0.14	-00.08
502+00	3367.55	0.14	00.06
502+25	3367.40	0.15	-00.00
502+50	3367.25	0.14	-00.11
502+75	3367.07	0.14	-00.04
503+00	3366.88	0.14	-00.08
503+25	3366.67	0.15	-00.00
503+50	3366.46	0.14	00.01
503+75	3366.25	0.15	00.03
504+00	3366.05	0.14	00.04
504+25	3365.86	0.15	00.11
504+43	3365.74	0.15	-00.07
504+50	3365.69	0.14	00.16
504+75	3365.55	0.14	00.05
504+82	3365.51	0.14	-00.01
505+00	3365.42	0.14	-00.06
505+25	3365.28	0.16	-00.00
505+50	3365.13	0.14	-00.14
505+68	3365.00	0.15	00.01
506+00	3364.78	0.15	00.01
AVERAGE FILL		.145	
506+08	3364.74	0.17	00.06
506+25	3364.60	0.18	00.11
506+50	3364.42	0.18	00.15
506+75	3364.28	0.18	00.04
507+00	3364.15	0.18	-00.00
507+25	3364.02	0.17	-00.02
507+50	3363.88	0.19	00.07
507+75	3363.76	0.18	00.15
508+00	3363.68	0.19	00.06
508+25	3363.62	0.19	-00.00
508+50	3363.55	0.17	-00.12
508+60	3363.51	0.17	00.13
508+75	3363.47	0.18	-00.00
509+00	3363.41	0.17	-00.02
509+25	3363.34	0.17	-00.04
509+50	3363.26	0.17	-00.16
509+75	3363.14	0.19	00.04
510+00	3363.03	0.18	00.04
510+25	3362.93	0.18	-00.05
510+50	3362.82	0.17	-00.15
510+75	3362.67	0.18	-00.08
511+00	3362.50	0.17	-00.00
511+25	3362.33	0.17	-00.05
511+50	3362.15	0.20	00.16
511+75	3362.00	0.20	00.06
512+00	3361.88	0.19	-00.00
512+25	3361.75	0.17	-00.05
512+50	3361.61	0.17	00.02
512+75	3361.47	0.18	00.06
513+00	3361.35	0.19	-00.00
513+25	3361.23	0.17	-00.01
513+50	3361.11	0.20	00.03
513+75	3360.99	0.18	00.02
514+00	3360.88	0.18	00.00
AVERAGE FILL		.181	



GRADE LAYER
INITIALIZATION AND BASIC COMPUTATIONS

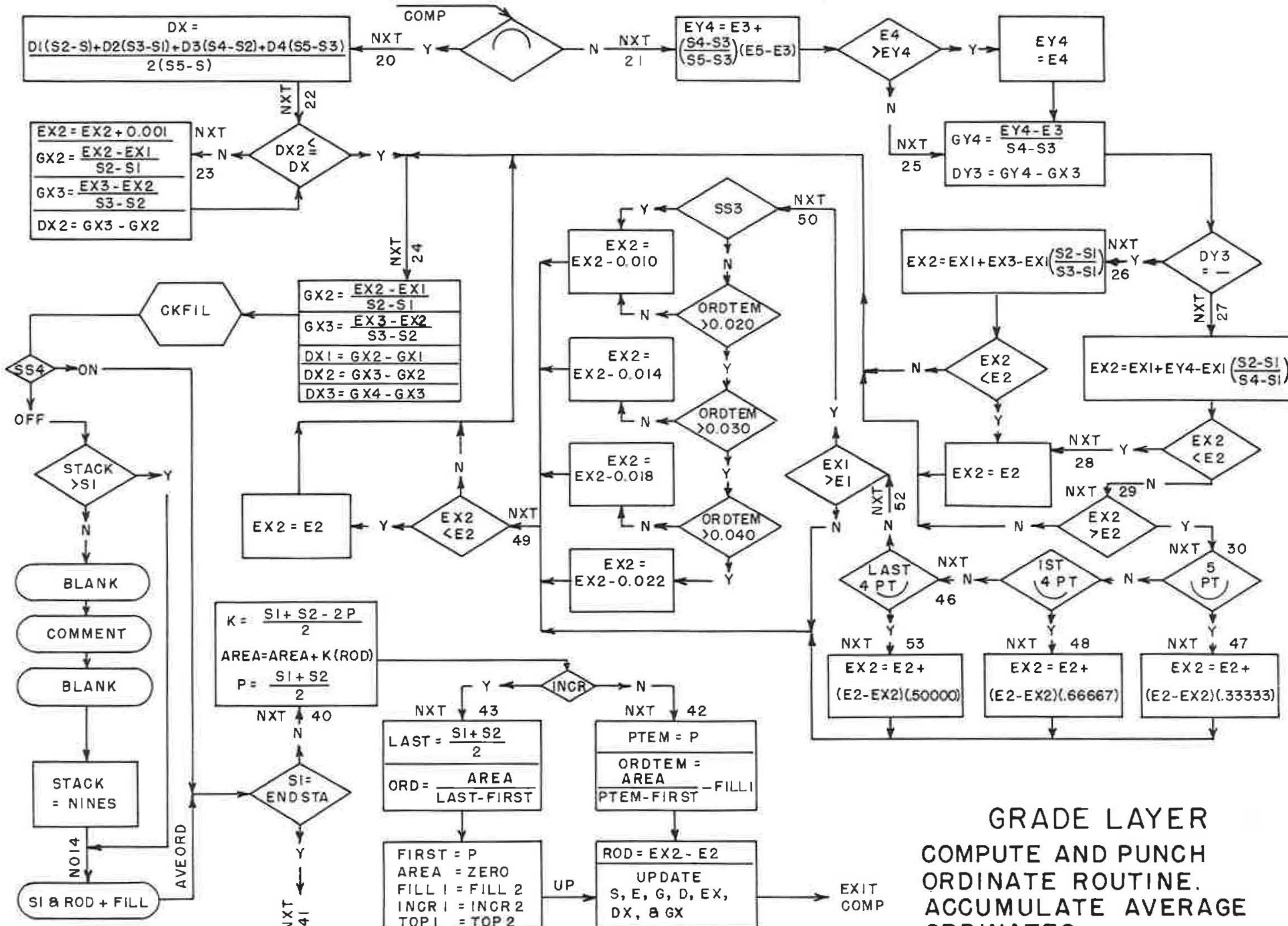


GRADE LAYER
READ-PROCESS COMMENTS,
SET UP PROFILE POINTS,
AND ACCUMULATE AVERAGE
CROSS-SECTIONS.



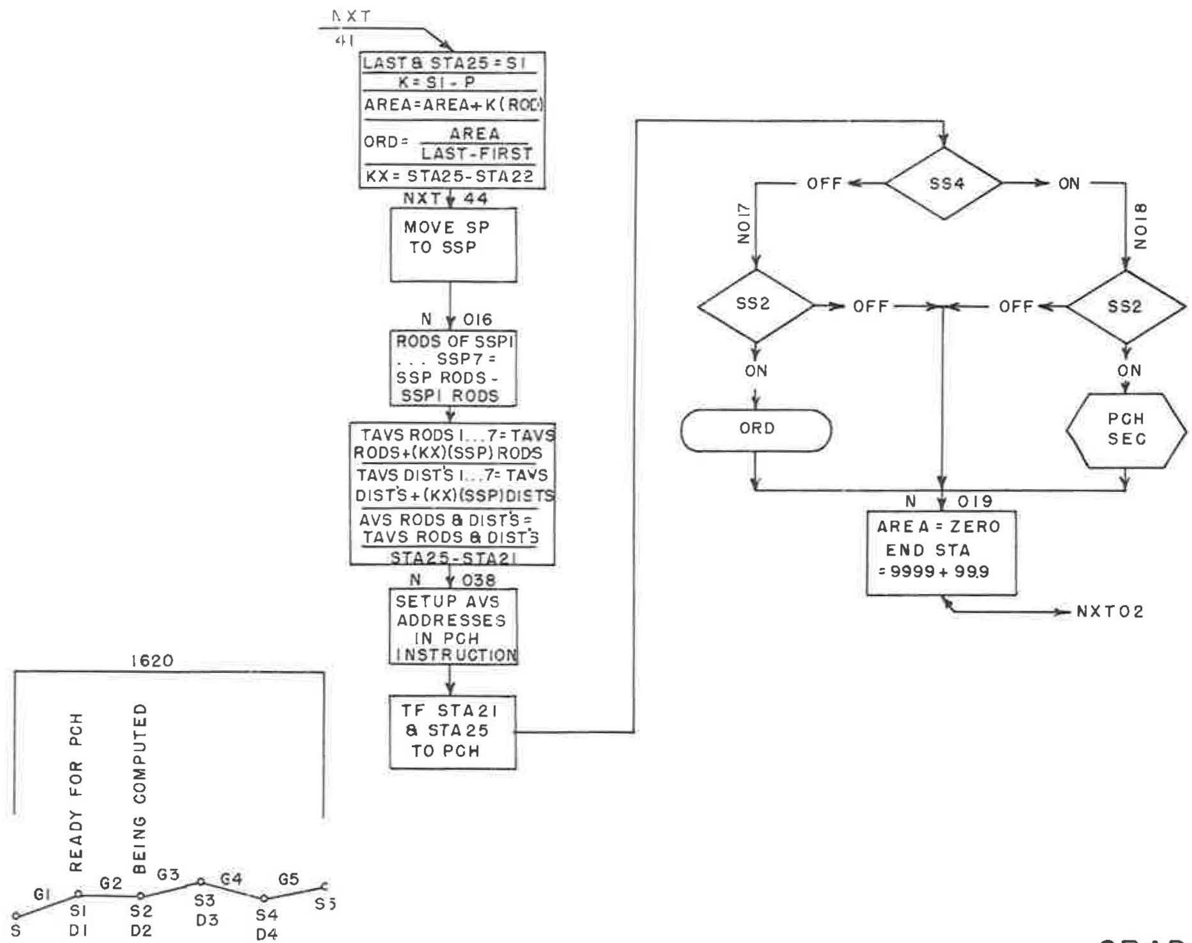
GRADE LAYER

POSITION AND EXPAND CROSS-SECTIONS



GRADE LAYER

COMPUTE AND PUNCH ORDINATE ROUTINE. ACCUMULATE AVERAGE ORDINATES.



GRADE LAYER

ACCUMULATE FINAL AVERAGE CROSS-SECTION AND FINISH COMPUTATIONS

DATA PROCESSING INSTRUCTIONS

I Key punch cross sections and original profile from the field notes.

II Prepare control and comment cards.

III Sort all cards together by equation and station.

IV Make computer edit run.
Normal: Sense Switch 2 and Sense Switch 4 on.
If Sense Switch 2 is off, no X-sections will be punched.
Start program 05000.

ERRORS AND MESSAGES:

1. NO FILL ORDINATE CARD - Control card needed at the beginning of the data deck. Add this card to the front of the deck. Reload the read hopper and depress start.

2. FIVE CONSECUTIVE DATA CARDS REQUIRED - Depress start.

3. XXXX+XX SEQ ER - Depress start.

4. NO CL ON X-SECTION CARD - Invert card and depress start.

5. XXXX+XX FILL = X.XX - No halt involved.

6. XXXX+XX ERRATIC SECTION - No halt involved.

At the completion of the computer run, make a 407 listing using the "Plot X-Section" board. Return the listing and typed output to the programmer.

V Make all card corrections and insert necessary comment cards.

VI Make computer grade layer run.
Sense Switch 2 on.
Start program - 05000.

ERRORS AND MESSAGES:

1. NO FILL ORDINATE CARD - Control card needed at the beginning of the data deck. Add this card to the front of the deck. Reload read hopper and depress start.

2. FIVE CONSECUTIVE DATA CARDS REQUIRED - Call programmer.

3. XXXX+XX SEQ ER - Call programmer.

4. NO CL ON X-SECTION CARD - Call programmer.

5. XXXX+XX FILL = X.XX - Call programmer.

6. XXXX+XX ERRATIC SECTION - No halt.

Make four 80-80 407 listings and return them with the typed listings to the programmer.

VII Make visual inspection of the 407 listings and the typed output.

Send the field notes and the 407 listings to the Designer.