THE USE OF THE ELECTRONIC COMPUTER IN KENTUCKY'S HIGHWAY PROGRAM

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Gentlemen; Contrary to several newspaper articles, the Kentucky Department of Highways does not have an "Electronic Brain" in Frankfort. The phrase, "Electronic Brain" is colorful, but grossly misleading. The department did install, in September of last year, an intermediate speed magnetic drum data processing machine, commonly called "Electronic Computer". As yet there is no machine on the market that can "think".

Just a little over two years ago the use of electronic computation in highway engineering began. Since then, great progress has been made. At the present time, 28 State Highway Departments have electronic computer installations. Twelve other states have made application for electronic computers. A number of states are now using computer services available at commercial computer centers and

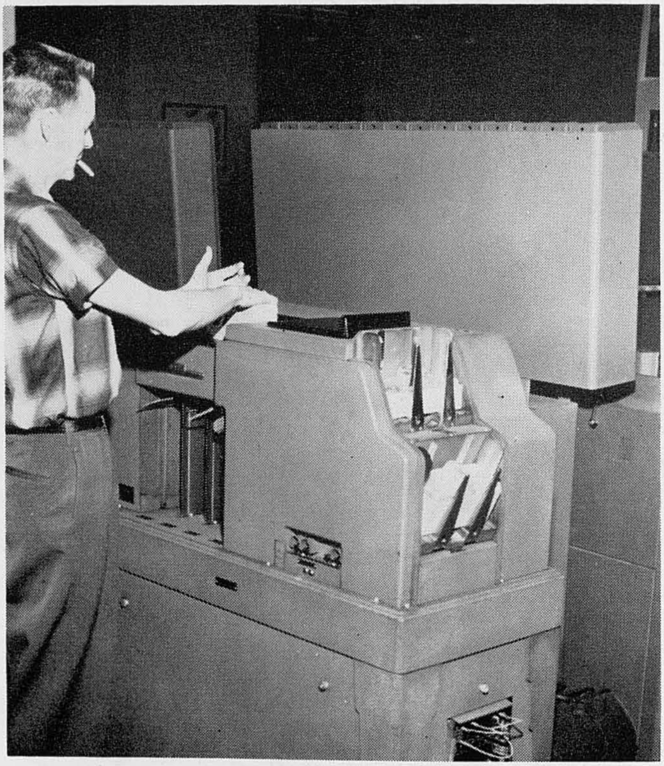

Figure 1.—IBM Type-077 (Collator). The opeartor is merging bid item cards with their respective master cards. This operation is performed one or two days gefore the bids are opened.

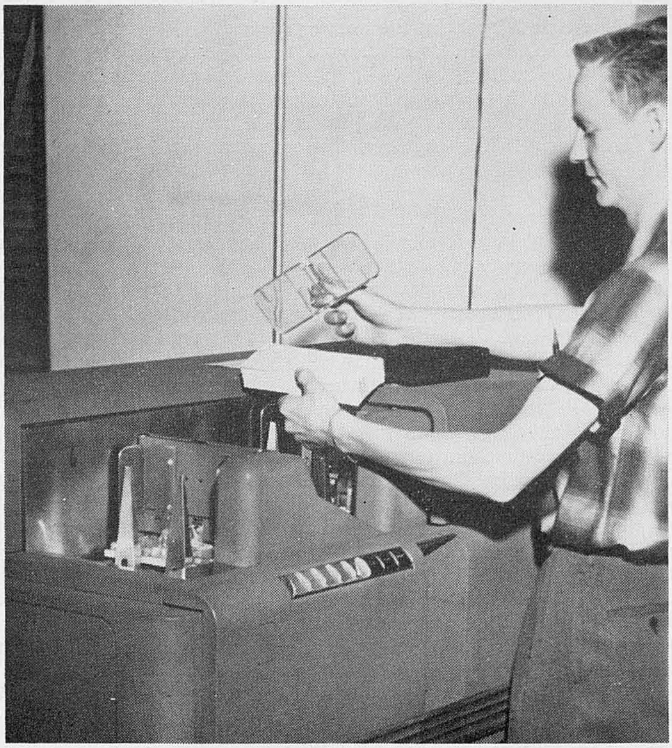

Figure 2.—IBM Type-514 (Reproducer). Using the deck of cards assembled in Figure 1, the operator next uses the reproducer. Here bid item descriptions are automatically reproduced from the master cards into the respective bid item cards. This operation is also completed one or two days before the bids are opened. The bid item cards are filed in a drawer to be used on the date the bids are opened.

universities. At least twenty of the leading highway engineering consultants have installed computers and many more intend to do so in the near future. Our own University here is expecting to install their computer in June or July of this year. Those of us who are active in engineering today, I believe, will witness one of the most outstanding periods of progress ever recorded in engineering history. The electronic computer with its capacity to perform, in a few minutes, engineering computations that were previously all but impossible because of their length and complexity will make this possible.

How many days have you, as an engineer, gone to the office knowing that most of the day would be spent punching a desk calculator, performing routine calculations that you had done many times before? How many times have you wanted to investigate five or six solutions to a problem, but only had time to investigate two or three? Suspecting that you may have missed the most economic solution. How often have you used a "short-cut" solution or "rule of thumb" which gave an approximate rather than an exact answer, because the basic theory involved a long and tedious series of computations? How much time have you spent looking for an error in your calculations, because the checker did not arrive at the same answer? I spent eight years in our Department's Bridge Design Office and feel justified in posing these questions, because from 30 to 40 percent of a design engineers time is spent in the above processes.

If you can visualize an assistant who could perform in a very short time these repetitious calculations and also perform the mathematical computations required by the basic theory, regardless of how long they may be without making an undetected error, you have in part, pictured the role of a properly programmed electronic computer. To the engineer, this computer is a marvelous tool, but its use should follow careful preparation.

You will note above, the phrase "properly programmed electronic computer" was used. The computer itself, is useless without human guidance. As stated before, it cannot think, but is merely a giant calculator capable of performing at very high speeds, those mathematical steps that have been prescribed by the programmer. The role of a programmer is a most important role in the electronic computer field. His job consists of translating mathematical language to machine language, checking and de-bugging program steps, running pilot projects and integrating the program, to a production schedule. It is a very tedious, time consuming chore, but one that is most rewarding when he sees his program running on production. To emphasize the amount of time required to put a project on production with the computer, it has been stated that approximately one programming hour is required per instruction in the final program. Some of the more involved problems require 2 or 3 thousand instructions, so you can readily see that it is quite time consuming. However, after the problems are on production, savings in time become evident. Last year the California Department of Highways processed 70,000 traverses, laid out 14,000 bridges, and processed approximately 400 miles of highway with their electronic computer.

Where does Kentucky stand with its computer organization? The computer was installed in our Machine Records Section, which already contained auxiliary data processing equipment, and today, is called the Data Processing Center. Its function is self explanatory in its name, to process data.

The Data Processing Center Programmers are engaged programming accounting problems. To date they have programmed:

1. Hourly Payroll Program.
2. Distribution of Payroll Costs Program.
3. Position Cost Control Program (break-down of personnel costs by division and section).
4. Gas and Oil Program (monthly inventory of state-owned pump facilities involving usage of gasoline, oil, kerosene, grease, diesel fuel, etc.).

There are many applications of the computer in the accounting field. With the accelerated highway program, many new accounting problems arise. Commissioner Martin stated in his speech to the engineers, "That to properly plan a highway program, we must know continuously the amount of money available and must have well-based estimates of the amounts to become available, for the immediate future by months and for five or six years, by years." Some of the future epplications of computer programs are listed below:

1. Inventory Programs: (a) Equipment, (b) Spare Parts, (c) General, (d) Real Estate.
2. Maintenance Programs: (a) Road Sub-sections (labor charges, etc.), (b) Equipment.
3. Historical Record Programs: (a) Road Identification (type, etc.), (b) Equipment (initial cost, current service cost).
4. Budget Programs: (a) Organizational, (b) Encumbrances, (c) Projects.

Presently there are four engineers working with our computer: Mr. Charlie Brown, Mr. Bruce Irvine, Mr. Byrnes Fairchild and myself. Our job has been to ascertain which problems are adaptable to the computer, program these problems, run pilot projects and submit them for approval or disapproval. The Bureau of

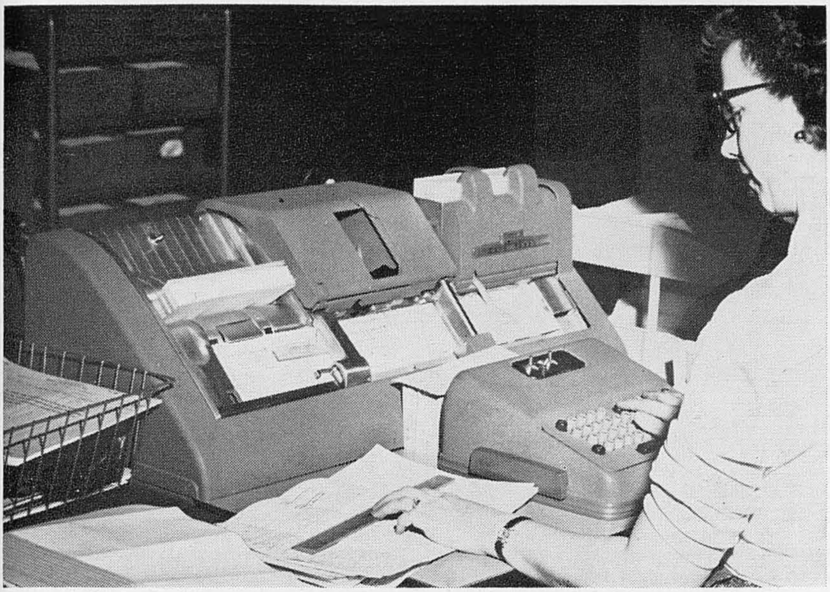

Figure 3.—IBM-024 (Key Punch). After the bids are opened the bid forms are taken to the key punch section. A key punch operator key punches information from the bid forms into cards. This information includes contractor's identification, unit bid, extension, and total bid.

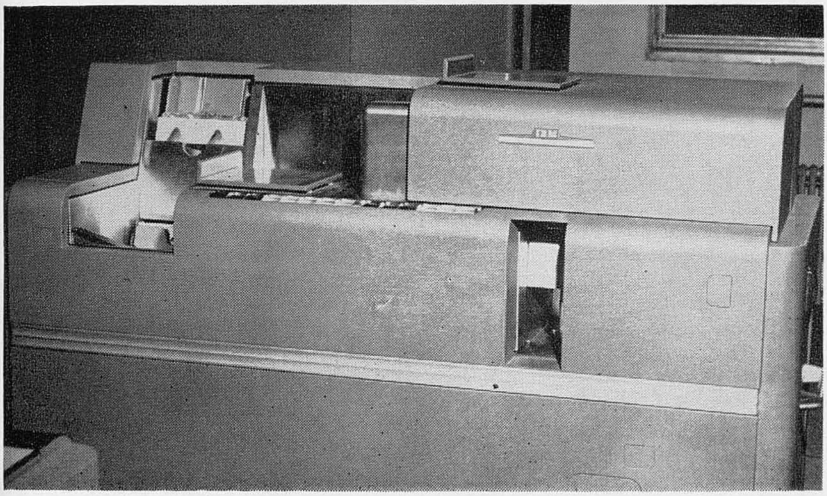

Figure 4.—IBM Type-533 (Read & Punch unit of the electronic computer installation) Cards from the key punch section are placed in the read hopper, shown in upper left corner, to be read and processed. Afer processing in the computer, IBM 650, the answers are punched into cards and are shown middle right of the picture.

Public Roads has established a library of highway engineering electronic computer programs, and the states who have programs running on production, have made their programs available to the late-comers in this electronic field. Kentucky has benefited greatly from these two sources, also the manufacturers of our computer has a share group organization giving us access to programs already in production.

Listed below, are engineering programs for our computer and their status. Mr. Fairchild, of the bridge office, has programmed or adapted the following programs for use by the bridge office.

1. Grade Elevation Program (to compute center-line grade elevations).
2. Tanget or Chord Offset Program.
3. Summation of Bill of Reinforcement.
4. Geometry of Skewed Bridge on Horizontal Curve (adapted from Texas Highway Department).

He is presently programming a Construction Elevation Program which will furnish a complete grid of Construction Elevations, at the top slab and bottom of beam. This problem is approximately 75 percent complete.

The Design Division has the following programs:

1. Bid Tabulation Program.
2. Profile Program.
3. Cut and Fill Program.
4. Traverse Program (adapted from IBM Library Program).

The Bid Tabulation Program is now in production in the Data Processing Center. To acquaint you with some of the data processing equipment, and to show the flow of data through the center I shall show a few slides.

We now are engaged in programming a Road Design Program which will compute our super elevation, widen curves, and super-impose finished template on the original cross-section.

There are 35 engineering problems now being solved by the electronic computer, in the different highway departments. Thirty-two programs under development and 29 computer applications being considered.

These highway problems cover a wide range of types and include:

1. Spiral Coordinates.
2. Three Centered Curves.
3. Right-of-way traverse and area computation.
4. Embankment Stability.
5. Forecasting zonal traffic volumes.
6. Reinforced Concrete Box Culvert Design.
7. Bridge Deflections.
8. Column Analysis.
9. Rigid Frame Pier Analysis.
10. Composite Beam Design.
11. Influence Lines for Continuous Beams.
12. Continuous Steel Beam Bridge Design.
13. Bridge Bearing Elevations.
14. Speed Check Analysis.

After investigating and programming a problem, you have only reached the first plateau. The next task is promotion and integration of your program. This may be the most difficult part. In the past ten months, I have had some important facts revealed, while trying to sell the computer's program. Engineers, by nature, are not easy people to sell. I noticed in one issue of Engineering News Record that one state had ordered its engineers to "Make Full Use" of its elec-

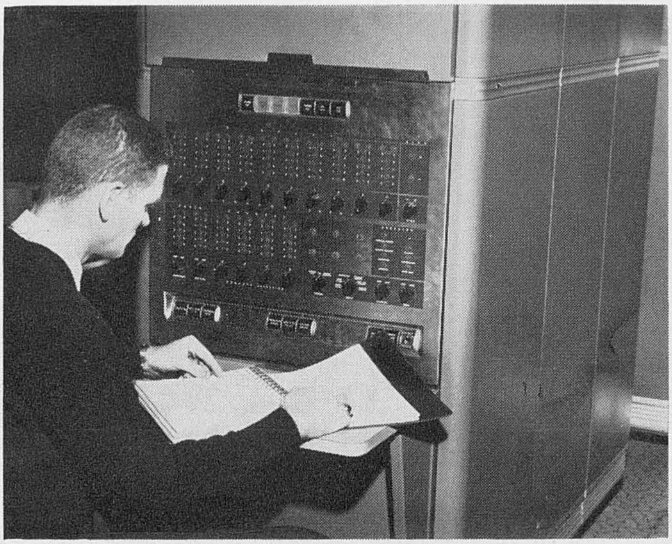

Figure 5.—IBM Type-650 (Magnetic Drum Data Processing Machine, commonly referred to as an "electronic computer"). This unit processes the cards read by the 533 above according to instructions stored on the magnetic drum previously. The 650 operator is shown setting the console switches in preparation for processing the bid cards.

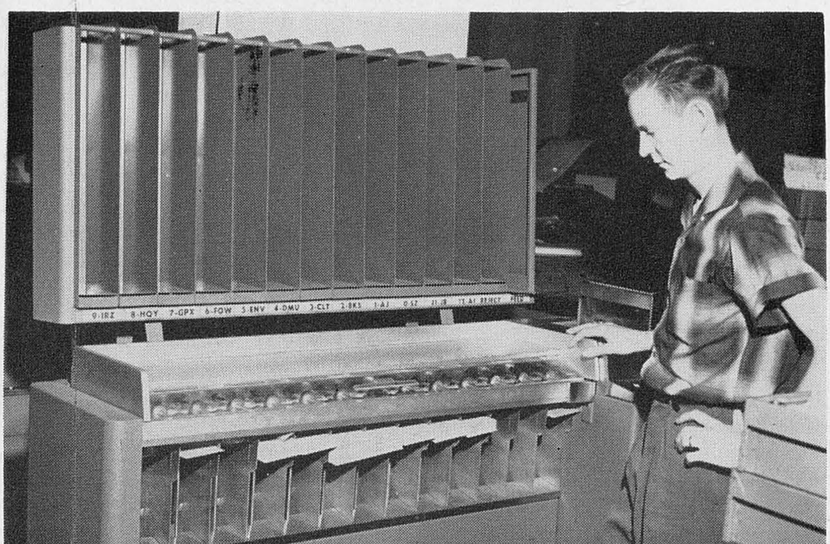

Figure 6.—IBM Type-083 (Sorter). The bid data cards from the 533 are next merged with their respective bid item description cards, which were prepared in Figure 1 and Figure 2. This merging process is accomplished by the sorter, which sorts at the rate of 1,000 cards a minute.

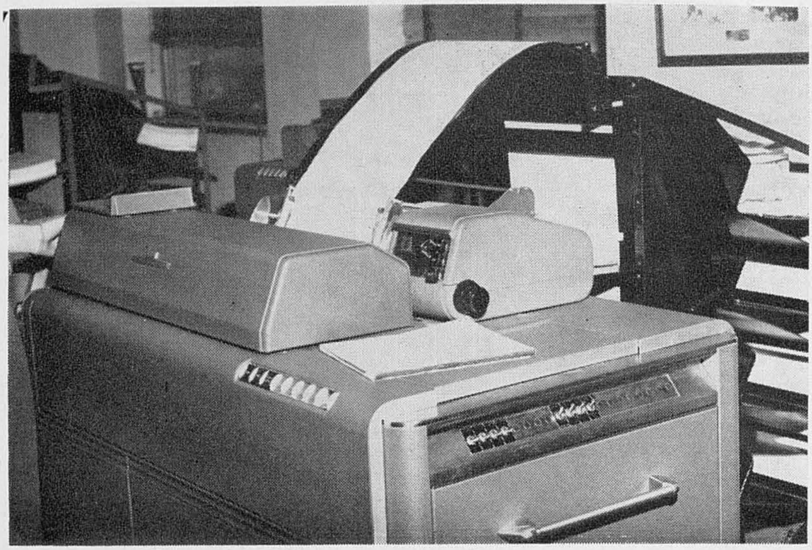

Figure 7.—IbM Type-4U7 (I abulator). The merged deck from Figure 6, with the proper header cards, are ready for the 407 which furnishes the "Tabulation of Road Bids". This form is used to compare the contractor original bid work sheet. The contractor error's are marked in red where they occur on his proposal.

tronic computer. The article stated that initially it was assumed that the engineer would voluntarily supply problems for the computer, but it did not work out that way. Many engineers looked on the computer as a piece of equipment which might disturb their continuity of employment. This distrust on the part of the engineer can cause delay which will prove, very quickly, to be a costly mistake. Engineering personnel affected by this transition to electronic computations should consider it not only an opportunity, but their responsibility to increase the engineer's capacity. After the engineer has learned what the electronic computer can do for him, and what answers he can expect in return, I feel sure he will be willing to adjust his current practices somewhat, so that electronic computation can be carried out in the most economical manner. In doing this, he will have more time to do purely engineering work, to a much greater extent than was possible in the past.

If the engineer will apply this tremendously powerful new tool to his field of activity using the same logical, scientific approach that he uses to solve his design problems, he will increase his engineering productivity, up-grade the engineering profession, and witness one of the most outstanding periods of progress ever recorded in engineering history.

COUNTY : MAGOFFIN
PROJECT NO : RS 77 300
CONTRACTOR : ELAM & WINGO
CONTRACTOR'S CODE : 02

KENTUCKY DEPARTMENT OF HIGHWAYS-

NOTE. 1. MINUS INDICATES UNDERRUN
2. E INDICATES CONTRACTORS EXTENSION WAS IN ERROR

LENGTH OF PROJECT : 02.100 MI
TIME FOR COMPLETION : 225 CAL DAYS
PROJECT CODE : 00014

ITEM NO	ITEM CODE	UNITS	DESCRIPTION	QUANTITY	$ CONTRACTORS UNIT BIDS	$ COMPUTED AMOUNT	$ ENGINEERING UNIT ESTIMATE	$ OVERRUN OR UNDERRUN	% OVER OR UNDER
1.0	0000	ACRE	CLEARING AND GRUBBING	7690	1000000	76900	1000000		
2.0	0000	CU YD	ROADWAY EXCAVATION	27945000	4500	1257525	5500	279450-	18182-
3.0	0000	CU YD	STRUCTURE EXCAVATION UNCL	172000	30000	51600	40000	17200-	25000-
4.0	0000	CU YD	STRUCTURE EXCAVATION COMMON	420000	40000	168000	40000		
5.0	0000	CU YD	STRUCTURE EXC SOLID ROCK	35000	80000	28000	100000	7000-	20000-
6.0	0000	STA	FINAL DRESSING	71600	150000	107400	220000	50120-	31818-
7.0	0000	EACH	PROJECT MONUMENT	2000	350000	7000	400000	1000-	12500-
8.0	0000	M GAL	WATER	140000	10000	14000	10000		
9.0	0000	CU YD	CLASS A CONCRETE	325700	500000	1628500	520000	65140-	3846-
10.0	0000	SQ YD	SLOPE PROTECTION	100000	50000	50000	80000	30000-	37500-
11.0	0000	CU YD	CLASS D CONCRETE	6800	1900000	129200	1800000	6800	5556
12.0	0000	LB	STEEL REINFORCEMENT	52118000	1340	698381E	1400	31271-	4286-
13.0	0000	LIN FT	15 ENTRANCE PIPE R C	224000	25000	56000	42500	39200-	41176-
14.0	0000	LIN FT	18 ENTRANCE PIPE R C	84000	35000	29400	42500	6300-	17647-
15.0	0000	LIN FT	18 CULVERT PIPE R C	504000	40000	201600	42500	12600-	5882-
16.0	0000	LIN FT	24 CULVERT PIPE R C	32000	55000	17600	57500	800-	4348-
17.0	0000	LIN FT	36 CULVERT PIPE R C	124000	105000	130200	110000	6200-	4545-
18.0	0000	LIN FT	42 CULVERT PIPE R C	44000	130000	57200	160000	13200-	18750-
19.0	0000	LIN FT	48 CULVERT PIPE R C	40000	160000	64000	200000	16000-	20000-
19.1	0000		14 REINF CONC PILING ALT 1						
20.1	0000	LIN FT	FURNISH 14 REINF CONC PILING	196000	60000	117600	66600	12936-	9910-
21.1	0000	LIN FT	DRIVING 14 REINF CONC PILING	180000	60000	108000	55500	8100	8108
21.2	0000		10 STEEL PILING @42# ALT 2						
22.2	0000	LIN FT	FURNISH 10 STEEL PILING @42#	180000	50000	90000	50000		
23.2	0000	LIN FT	DRIVING 10 STEEL PILING @42#	180000	50000	90000	45000	9000	11111
23.3	0000		TRAFFIC BOUND LIMESTONE ALT 3						
24.3	0000	TON	CRUSHED LIMESTONE	1610000	30000	483000	37500	120750-	20000-
24.4	0000		TRAFFIC BOUND SLAG ALT 4						
25.4	0000	TON	CRUSHED SLAG						
25.5	0000		BANK OR CREEK GRAVEL ALT 5						
26.5	0000	TON	BANK OR CREEK GRAVEL						
26.6	0000		TRAFFIC BOUND SANDSTONE ALT 6						
27.6	0000	TON	CRUSHED SANDSTONE						

Figure 8.—(Continued on next page)

TABULATION OF ROAD BIDS—(Continued from preceding page)

28.0	0000	ALTERNATE 1 & 3	TOTAL	SECOND	5481106E	694267-	11243-
29.0	0000	ALTERNATE 2 & 3	TOTAL	FIRST	5435506E	680431-	11126-
30.0	0000	ALTERNATE 1 & 4					
31.0	0000	ALTERNATE 2 & 4					
32.0	0000	ALTERNATE 1 & 5					
33.0	0000	ALTERNATE 2 & 5					
34.0	0000	ALTERNATE 1 & 6					
35.0	0000	ALTERNATE 2 & 6					

H. E. 2

COUNTY: JEFFERSON

PROJECT NO.: SP GROUP 5 1958

UNIT TABULATION OF THREE LOW BIDDERS

KENTUCKY DEPARTMENT OF HIGHWAYS

DATE: 03-20-58

LENGTH OF PROJECT: MI

H. E. 2

UNIT TABULATION OF THREE LOW BIDDERS

KENTUCKY DEPARTMENT OF HIGHWAYS

COUNTY: JEFFERSON
PROJECT NO.: SP GROUP 5 1958
ROAD:
TYPE: BIT CONC SURF CL I

DATE: 03-20-58
LENGTH OF PROJECT: MI.
TIME FOR COMPLETION: 060 CAL. DAYS
PROJECT CODE: 022

NUMBER 1 — MIDDLE WEST ROADS CO
NUMBER 2 — H K WILLIAMS CO
NUMBER 3 — GEO M EADY CO

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	NUMBER 1		NUMBER 2		NUMBER 3	
				$ UNIT BID	$ AMOUNT	$ UNIT BID	$ AMOUNT	$ UNIT BID	$ AMOUNT
1.0	EXCAVATION ROADWAY	65000	CU YD	79500	51675	30000	19500	20000	13000
2.0	ADJUST CATCH BASIN FR TO GRADE	75000	EACH	272000	204000	350000	262500	250000	187500
3.0	ADJUST MANHOLE FRAME TO GRADE	43000	EACH	272000	116960	350000	150500	250000	107500
4.0	ADJUSTING PRESSURE DETECTOR	7000	EACH	2000000	140000	500000	35000	4000000	280000
5.0	6 CEMENT CONCRETE BASE	100000	SQ YD	57000	57000	90000	90000	50000	50000
6.0	EDGE KEY	1845000	LIN FT	4800	88560	4000	73800	3500	64575
7.0	EMULSIFIED ASPHALT RS-1	5945000	GAL	2300	136735	1500	89175	1500	89175
7.1	BIT CON SURF CL I LSTONE ALT 1								
8.1	CL I SURF LSTONE AGG	4490000	TON	68500	3075650	70000	3143000	70000	3143000
9.1	CL I SURF-LSTONE-M PATCH	1300000	TON	68500	890500	75000	975000	70000	910000
9.2	BIT CON SUR CL I RIV GR ALT 2								
10.2	CL I SURF CR R GR AGG		TON						
11.2	CL I SURF-CR R GR-M PATCH		TON						
12.0	ALTERNATE 1			TOTAL	4761080		4838475		4844750
13.0	ALTERNATE 2 NO BIDS RECEIVED								
	4 R B TYLER CO 50583.65 5 BRESLIN CONST CO. 53302.60								

Figure 9.—After the awards committee has checked and analyized the bids, the cards are reassembled by the 083 (Sorter). From the sorter they go to the 407 machine for listing and tabulation. Using a pre-printed multilith form we produce a multilith stensil which is used in printing approximately 150 copies of the "Unit Tabulation of Three Low Bidders", for distribution. The cards for each low bidder are retained in the Data Processing Center, to produce at the end of the year, average unit price bids.