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FPL-38

CROMAX
A Crosscut-First Computer Simulation Program to Determine Cutting Yield

Pamela J. Giese
and
Jeanne D. Danielson

Abstract

CROMAX simulates crosscut-first, then rip operations as commonly practiced in furniture manufacture. This program calculates cutting yields from individual boards based on board size and defect location. Such information can be useful in predicting yield from various grades and grade mixes thereby allowing for better management decisions in the rough mill.

The computer program CROMAX was written in ASCII FORTRAN on the University of Wisconsin's UNIVAC 1100/80 computer. The complete program listing is included as an appendix.

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Jeanne D. Danielson, Forest Products Technologist

Introduction

Knowledge of the cutting yields attainable from a given lumber grade is vital to such basic rough mill decisions as ordering raw material and measuring mill performance. However, traditional methods of acquiring this information may be inadequate in light of present high production costs and low product demand. Mill studies are expensive, and valid only for the study day's conditions. Historical records may be biased by changes in within-grade lumber quality among suppliers, or over time, or by changes in cutting bills.

General cut-up models, such as CROMAX, can predict attainable cutting yields without upsetting mill production and can be run for a variety of cutting bills. Use of information from computer simulation models which determine cutting yields offers great benefits to mill operators. An example is the Rough Mill Improvement Program, developed by Huber and Harsh *(3,4,5),*[2] which offers dimension plants a tool to determine the lowest cost mix of rough lumber grades for a given cutting bill.

Computer-derived cutting yields can also be used as a measure of mill performance, comparing actual mill yield to the highest theoretical yield. This gives the manager a standard which is not influenced by normal variations in production or raw material. To derive this highest theoretical yield, some sort of computer simulation is necessary. The computer program CROMAX was designed to simulate the crosscut-first operation in order to calculate, within the model's constraints, an optimal cutting yield from a given board. CROMAX calculates yield based upon the submitted cutting bill, the value of each size cutting, and the size and location of defects (e.g. knots, splits, checks, etc.) within the board.

Determining Cutting Yield

Determining the cutting yield from a given board requires (1) accurate description of the unique characteristics of the board–board width, board length, and defect location (e.g. knots, splits), (2) awareness of mill requirements as presented by the cutting bill and, the most difficult to attain, (3) ability to make the best crosscut decision followed by an equally good rip decision.

At first glance, obtaining an accurate description of a board would seem a simple task; the board itself is available to the crosscut operator. What better description would one need? However, lighting, viewing position, and speed of the line may hinder the operator's ability to see the whole board and its defects. Technological improvements to automatically measure the board and locate defects and types of defects would be a great asset in making an accurate picture of the board available to an operator or a computer. In lieu of such technology, board descriptions as used in this study have been hand tallied. Without automatic defect detection equipment, current decision models have no immediate real time on-line possibilities. The hand recording of board data (dimension and defect information) has been used as a method of acquiring this information since the early 1960's *(1,7,8).* The method used for recording this board information was described by Lucas *(6)* in 1973. Each board is depicted as a rectangle with an X-Y grid superimposed over it. (The grid origin is at the lower left corner of the board.) Defect locations are read from the grid and tallied (fig. 1).

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[2] Italicized numbers in parentheses refer to literature cited at end of report.

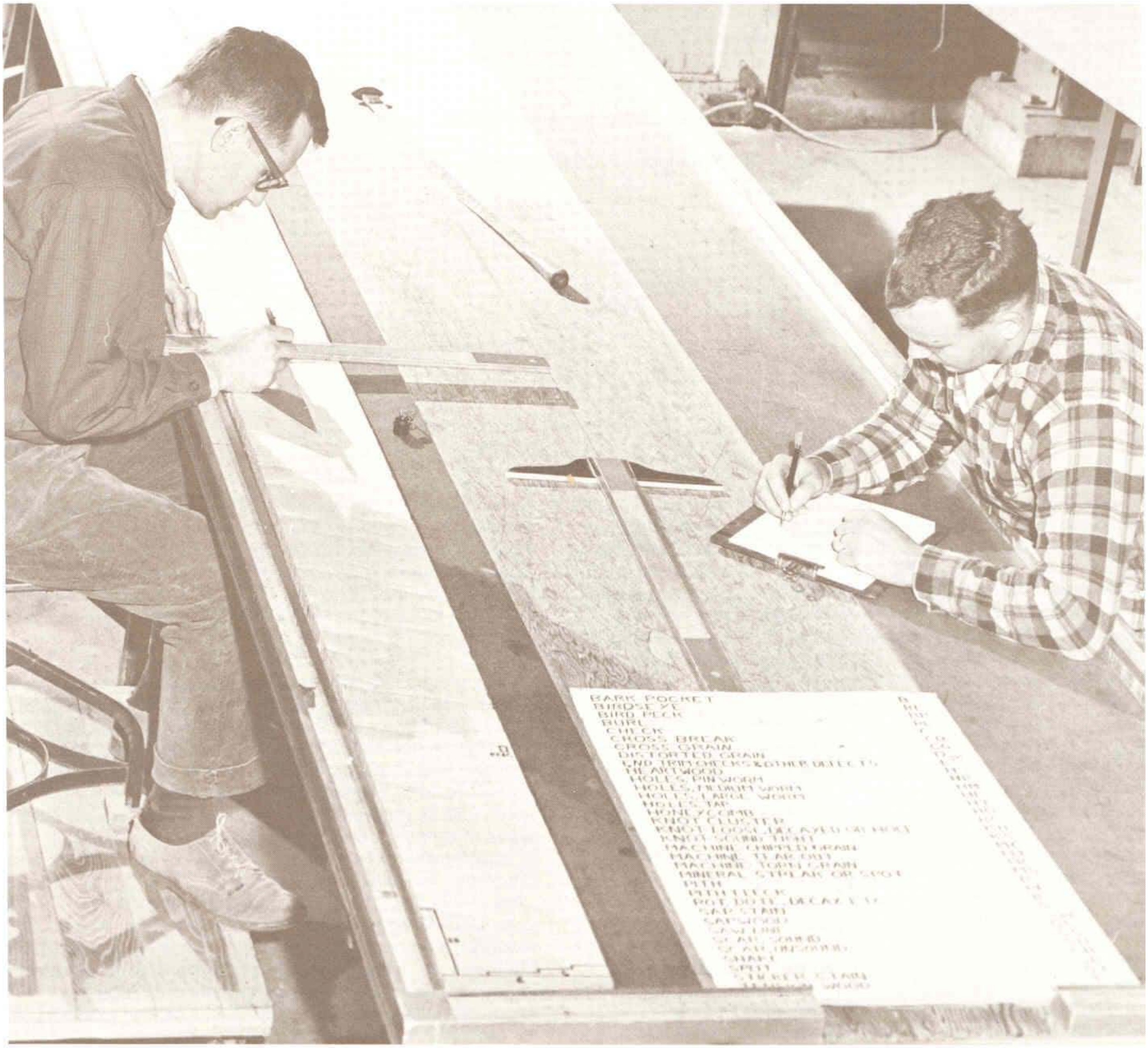

Figure 1.–Boards being tallied for defects.   (122 719)

To obtain the best cutting yield from a given board, the operator or computer must be supplied information on the quantity of each dimension cutting required to meet mill demand. Thus each cutting takes on a relative value–cuttings which are easy to come by, such as narrow, short cuttings, take on a lesser value, while those which are more difficult to recover, such as wide, long cuttings, have a higher value. It is very important that the computer model be able to incorporate information on the relative value of each cutting dimension to determine the best available cutting yield of a given grade. Therefore, models which only look at the surface area of cuttings as a measure of yield neglect the real possibility that higher valued cuttings are being sacrificed to attain greater surface area.

Once the board data and value of the cuttings have been supplied, the board must be crosscut, then ripped, in such a way as to get the highest total value of cuttings from the board. The decision of where to crosscut is the most difficult decision since the crosscuts could be placed anywhere within the board, limited only by the cutting lengths. In contrast, the location of rip lines is dictated by the crosscut boundaries, the cutting widths required, the location of defects, and the width of the board. Once the crosscut decision for cutting one piece has been made, the yield of the rest of the board is affected. A bad decision may sacrifice overall yield from the board to recover one or two good cuttings.

Program Background

The CROMAX program is a further development in the Forest Products Laboratory's ongoing research program for developing computer models to improve yield in secondary wood processing.

The first of these models was the YIELD program developed in 1966 by Wodzinski and Hahm *(9),* which has been used in several cutting yield studies *(1,7,8).* While a great improvement over manual efforts to calculate optimal cutting yields, the program suffered several limitations which prevented it from realistically modeling existing cut-up operations and made it obsolete by today's standards.

The high cost of computer usage at the time necessitated the use of shortcuts which minimized computer time, but which at the same time led to finding less than optimal yields. YIELD searches for the largest clear area between defects and places the longest, widest cutting possible in it. This area is blocked out, and the next largest clear area found and filled, and so on. Given a choice of two cuttings with equal surface areas, the program is biased to the longer cutting. This frequently leads to a situation where the program chooses a long cutting and a very short one over two of medium-length, which in total may be more valuable to the plant.

A mixture of crosscut-first and rip-first operations on different boards results by placing the cuttings in the clear area, then fitting the kerfs around the cuttings. Since most plants are set up for one or the other, either rip-first or crosscut-first, the YIELD program did not accurately model either operation, although it was biased toward the crosscut first.

Efforts to more realistically model the industry led to the development of the OPTYLD program *(2),* which modeled rip-first operations. The CROMAX program was developed from OPTYLD as the need for a crosscut-first model was recognized.

The Model CROMAX

The CROMAX computer program is the first step in the development of computer models of crosscut-first operations which will be suitable for planning and decisionmaking. CROMAX processes an unlimited number of boards, one board at a time. It retains no memory of previous boards or their solutions. The program represents a board as a rectangle superimposed on a Cartesian coordinate system with the lower left corner at the origin. The description of the board is stored in a binary matrix with each cell of the matrix set to either 1 to represent a defect or 0 (zero) no defect. A sample board is shown in figure 2. Before starting the crosscutting process, the ends of the board are trimmed off. The amount trimmed off each board is specified at run-time and is constant for all boards in the run. CROMAX requires specification of all allowable lengths and widths of cuttings. Cutting yields are generated by repeatedly going through all possible combinations of cutting lengths that will fit within the board.

After the ends of the board are trimmed off, the process of generating cutting-yield solutions is begun. The first solution begins at the left end of the board. Crosscuts are placed such that the distance between two crosscuts is equal to the shortest allowable cutting length. Such an area, where the distance between two crosscuts meets or exceeds the shortest allowable cutting length, will be referred to as a section. Each section is ripped to yield the highest value of cuttings. Figure 3 shows this first combination. The value of the cuttings is summed and stored as total cutting value. No defects are allowed within a cutting.

The next series of cutting yields is obtained by maintaining the same section lengths but varying the location of the beginning of the sections. Defects may lie within some of the sections. Defect coordinates of the board are shown in table 1. If a defect ends within the section, an alternative solution is generated by moving the beginning of the section to the end of the defect. Figures 4 through 8 show the first five alternative solutions to the first crosscutting solution. Positions of crosscut lines are moved first at the right end of the board and gradually to the left. Figure 4 shows the first alternative to figure 3. The beginning crosscut of the 11th cutting length section in figure 3 is relocated to the end of the defect which ends at the X coordinate 428 in figure 4. The next alternative (fig. 5) moves the crosscut to the end of the defect ending at the X coordinate 438. For each of these alternatives no other cutting length section to the left is affected. Since crosscuts had been made at X coordinate 416 in the original crosscutting solution, the alternative involving this defect has already been calculated. The next defect ends at X coordinate 353, so a crosscut is placed at this location for alternative 3 (fig. 6). The two sections to the right of 394 must then be moved; this results in the loss of three cuttings from the two previous solutions. Alternative 4 moves the crosscut to 339 (fig. 7). While this alternative picks up another cutting over the previous solution, the cuttings are narrower, plus no cuttings can be made from the area of 380-420. Alternative 5 places a crosscut at 318 (fig. 8). This results in the same number of cuttings as in the previous alternative, but some of the cuttings made here are wider.

Once the location of a section is moved, all section locations to the right must also be moved to accommodate this change. The sections in the new location are then ripped again and the value of cuttings obtained is summed. Their total is compared with the previous high total cutting value. If the new total is higher than the previous high total, the new total replaces the old. All alternative locations of cutting sections are tried and their values compared with the old high value. After the alternatives to the cutting length solution combination have been tried, the next cutting length solution is tried, then its alternates. In this way, all cutting length combinations and alternates are tried.

After all solutions have been tried, the best solution is printed and the next board is read. The best solution for the sample board is shown in figure 9 and table 2.

Program Description

Computer program CROMAX is divided into 11 modules– the main program, 9 subroutines, and 1 function. A flowchart illustrating the basic structure of the program is shown in figure 10. Table 3 lists these modules and their respective entry points. The complete CROMAX program is presented in appendix A.

Main Program

The main program (MAIN) serves as the input/output center of the program as well as coordinating the processing of the board. Figure 11 describes MAIN. When the program is begun, the run-time options are read. These options control the decisionmaking capabilities of CROMAX throughout the run. The trimming options specify the amount to be trimmed off each end of the board. All allowable cutting lengths and cutting widths must be specified. Table 4 lists these decisionmaking run-time options.

Supplying a table of weighted values for cuttings of different dimensions is optional. If a table is not supplied, the total yield of a crosscutting decision is obtained by summing the surface area of the cuttings available. If a table is used, the total yield of a crosscutting decision is obtained by summing the value (surface area times weight factor) of the cuttings available. The use and derivation of the weighted value table (table 5) is discussed in appendix B.

CROMAX builds a table of the best rip width combinations for a given clear area. This table is built upon and used by all boards within the sample. After the run-time, decisionmaking options are read, WINTL (an entry of WFIND) is called to initialize the possible best rip width combinations for a given clear area.

CROMAX then reads the board information and translates the board into a packed binary matrix where each bit corresponds to the 1/4-inch coordinate grid on the board. A value of 1 is assigned to each grid within a defect while a 0 is assigned to each grid within a clear area. The board is rejected if its length or width exceed the allowable board dimensions. The maximum number of cutting length sections within the board is then found. Yield and cutting length section combinations are then initialized and the first cutting length section combination is generated.

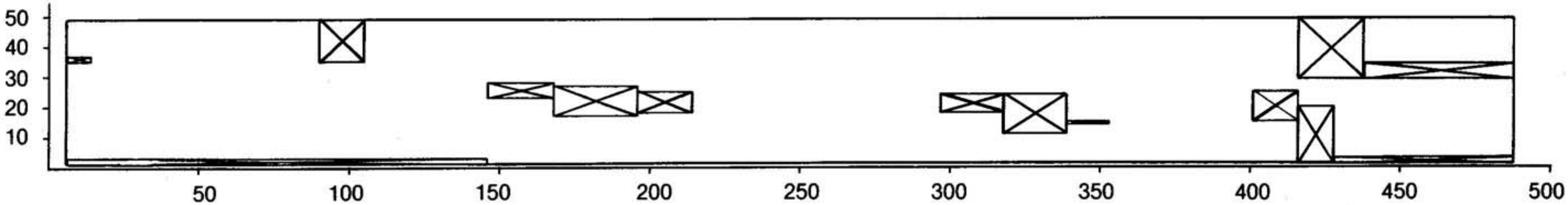

Figure 2.–Sample board. Crossed out boxes represent defects (areas filled with 1's in binary matrix) and remaining areas are clear (filled with O's in matrix). All values are in 1/4-inch units. (ML83 5126)

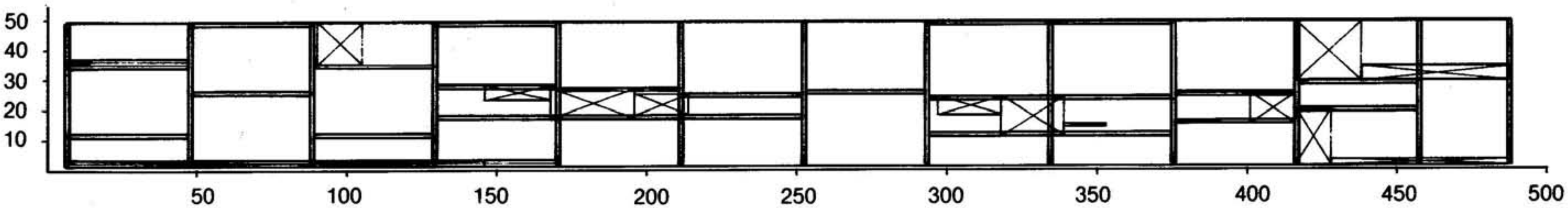

Figure 3.–Board shown in figure 2 after first crosscuts and rips are placed. (ML83 5127)

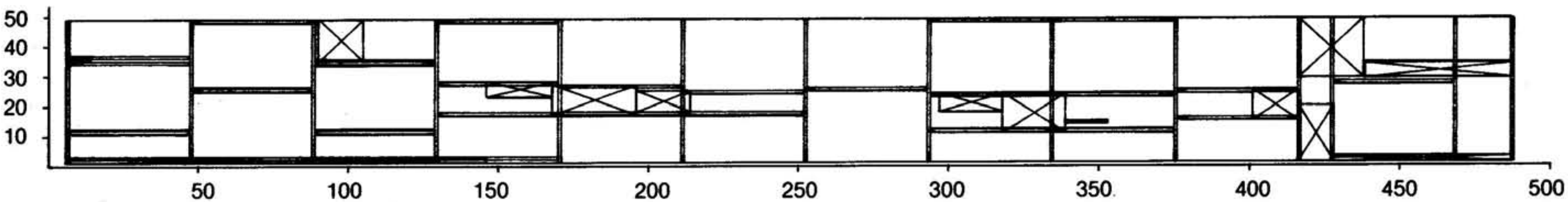

Figure 4.–First alternative to cutting length combination 1 (fig. 3). Note changes in last cutting length section. (ML83 5128)

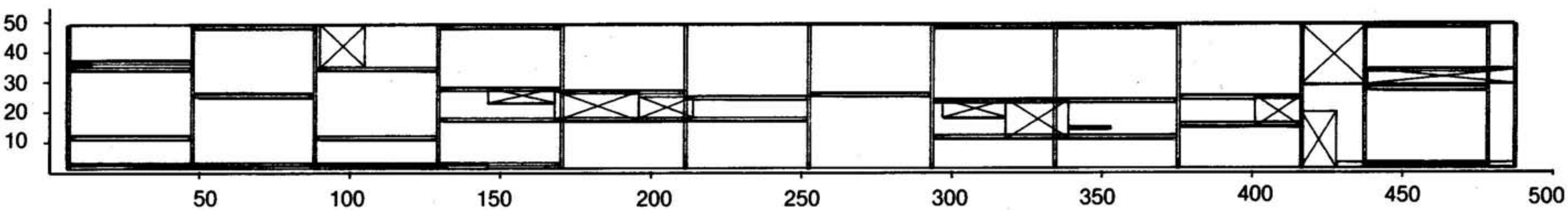

Figure 5.–Second alternative to cutting length combination 1 (fig. 3). (ML83 5129)

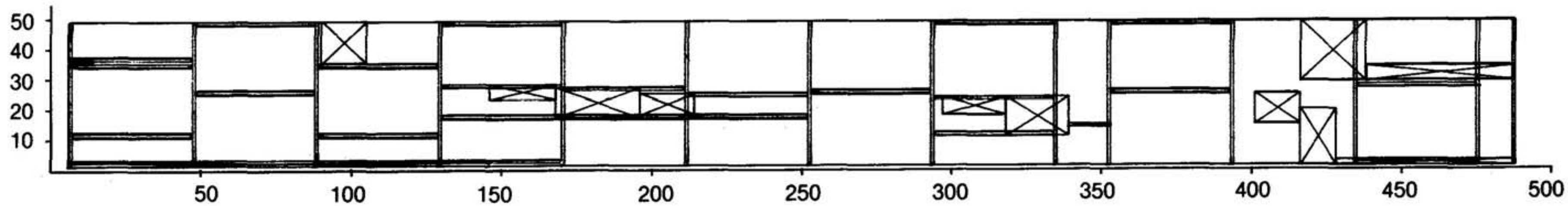

Figure 6.–Third alternative to cuffing length combination 1 (fig. 3). Note changes involving last three sections. (ML83 5130)

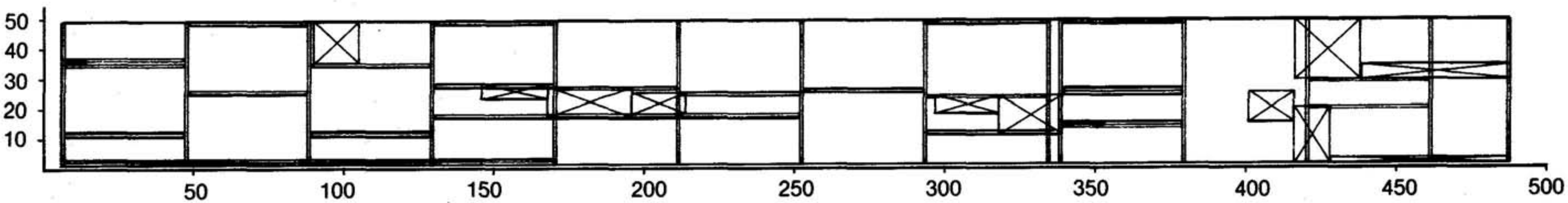

Figure 7.–Fourth alternative to cuffing length combination 1. Note changes involving last three sections. (ML83 5131)

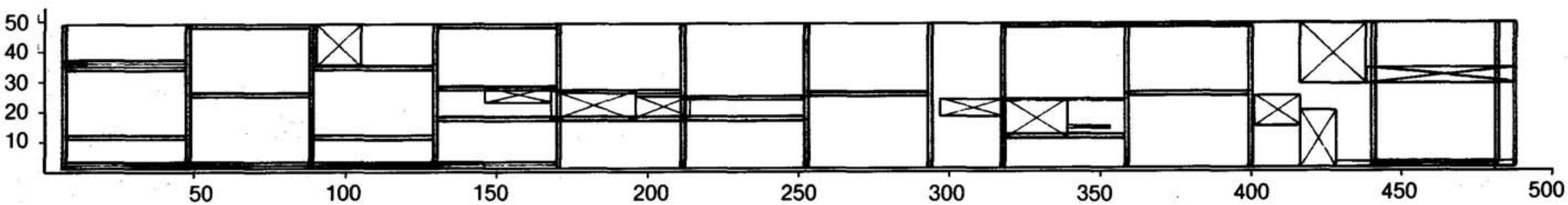

Figure 8.–Fifth alternative to cutting length section combination 1 (fig. 3). Note changes involving last four sections. (ML83 5132)

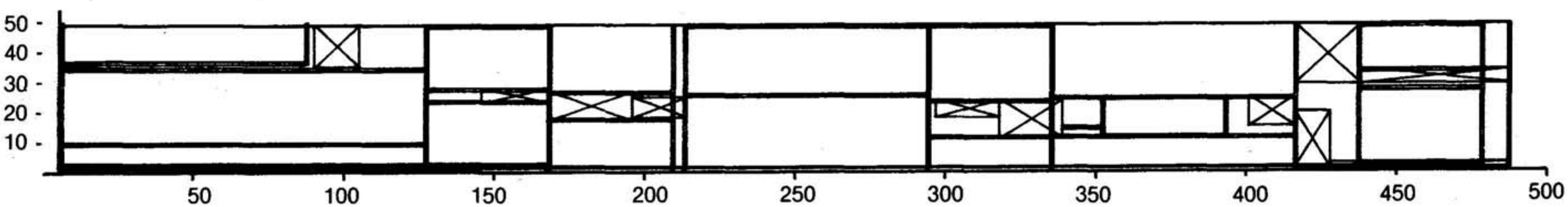

Figure 9.–Best cutting solution for sample board shown in figure 2. (ML83 5133)

Each cutting length section is checked to see if its yield has been calculated before. This is done by calling HOLD. If it has been calculated, its yield is retrieved. The section is also checked by ALTER to see how many defects end within its bounds. These defect coordinates form the alternatives to the cutting length combination which will be attempted; for each defect ending within the section, the beginning of the section is moved to the end of the defect. Subsequent sections are positioned accordingly. CROMAX then calls SAW to cut up all sections that have not yet been calculated. The yields attained from the sections are tallied and totaled, and compared with the previous maximum yield. If the current solution is higher, it and the present combination of cutting lengths are reassigned to be the maximum yield combination. The next alternative position for the cutting length combination is then generated and processed as above. This is repeated for all alternative positions for the cutting length combination. After all alternative positions have been tried, the next cutting length combination is generated and the above cycle is repeated. The coordinates of the cuttings and sawkerfs are not stored, so after all combinations have been calculated, the combination giving the highest yield is rerun and its result printed. The next board is then read. The program stops after all boards have been read and processed.

Subroutine SAW

Subroutine SAW is described by the flowchart in figure 12. Subroutine SAW scans for clear areas within a given cutting length section. When first entered, SAW initializes the yield of the section to zero. If the length of the section exceeds the smallest possible cutting length (this could only occur after the first combination), RANGE is called to set the boundaries of any salvage cuttings. SAW scans the section first by length and then by width in search of defect areas. If a defect is found, the scanning process is stopped and any clear area tested to see if it meets the minimal width. If it does, RIP is called to rip the section. If the whole cutting length section is found to be free of defects, RIP is called to rip the section into cuttings. The whole section is processed in this way; then, if areas remain which have not been utilized, TRIMIT (an entry of RANGE) is called to locate and salvage cuttings. SAW then returns to MAIN.

Subroutine RANGE

Subroutine RANGE contains three routines involved in the salvage cutting process—RANGE, TRIMIT, and STORE. RANGE itself simply initializes to zero the number of actual cuttings found. Entry STORE stores the number of actual cuttings found by RIP and CUTUP. The major routine in RANGE (fig. 13) is TRIMIT, which finds the combination of salvage cuttings giving the highest yield.

Table 1.–Board data for sample board No. 130 (fig. 2)

Grade 2C		**Number of defects = 14**	
Coordinates			
Lower Y	**Lower X**	**Upper Y**	**Upper X**
BOARD			
1	6	49	488
DEFECTS			
1	6	3	146
35	6	37	14
35	90	49	105
23	146	28	168
17	168	27	196
18	196	25	214
11	318	24	339
14	339	15	353
15	401	25	416
1	416	20	428
29	416	49	438
1	428	3	488
29	438	34	488

Note: All values are in 1/4-inch units.

Table 2.–Best cutting solution for sample board (fig. 2)

2C BOARD NUMBER 130

Cuttings

30.00 X 1.50
30.00 X 6.00
20.00 X 3.00
10.00 X 5.00
10.00 X 5.00
10.00 x 4.00
10.00 X 5.50
20.00 X 6.00
20.00 X 5.50
10.00 X 2.50
10.00 X 6.00
20.00 X 2.50
20.00 X 6.00
10.00 X 3.00
10.00 X 6.00
10.00 X 3.50

Total surface area of board	1,446.00 $In.^2$
Total percentage yield	75.38
Total area of cuttings	1,090.00 $In.^2$

Run options used:

Trim	0.25 In.
Cutting widths	1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0 In.
Cutting lengths	10.00, 20.00, 30.00, 40.00 In.

Weighting based on surface area only

Table 3.–Subprograms and entries of CROMAX

Subprogram name	Subprogram type	Additional entries
MAIN	Main program	—
SAW	Subroutine	—
RANGE	Subroutine	TRIMIT, STORE
RIP	Subroutine	—
AMEND	Subroutine	—
ALTER	Subroutine	REVISE
CUTUP	Subroutine	—
HOLD	Subroutine	INTL, REMEM
WFIND	Subroutine	WINTL
TSTORE	Subroutine	TINTL, RETREV
VALUE	Function	—

Table 4.–Run-time options

Option name	Option action	Card format
Trimming*	Any nonnegative integer	5X, I2
Maximization	Any nonnegative integer where if equal to: 0 means maximize on surface area; not 0 means maximize on value	6X, I1
	VALUE TABLE (present only if value maximized)	
Number of lengths and widths	Length—positive integer $\leq$ 8; Width—positive integer $\leq$ 4	2(5X,I2)
Widths**	Nonnegative integers in increasing order	4I5
Lengths**	Nonnegative integers in increasing order	8I5
Weighted values (4 cards)	Real numbers	8F5.2
Number of cutting lengths and cutting widths	Nonnegative integers $\leq$ 10	2(5X, I2)
Cutting lengths*	Integers in increasing order	10I5
Cutting widths*	Integers in increasing order	10I5

* Values are in 1/4-inch units.

** Values are in inches.

On entry to TRIMIT, the areas defining potential salvageable areas are found. A potential salvageable area is defined as the area between cuttings already obtained or between a cutting and the edge of the board. These areas are tested to see if they meet minimum width criteria for a cutting. If the area fails this test, it is ignored. All the potential salvageable pieces are checked to eliminate duplicates. TRIMIT then attempts to cut up the salvageable area. For each salvage area, TRIMIT attempts to cut it up first by cutting the length back and then by ripping the piece narrower. The solution of each of these processes is saved by calling TSTORE. After all possible salvage cuttings have been found, RETREV (an entry of TSTORE) is called to retrieve the yield of each cutting. The best (highest yielding) combination of cuttings is chosen.

Subroutine RIP

Subroutine RIP (fig. 14) rips the clear area found in SAW. Upon entry, RIP calls WFIND to find the best combination of cutting widths in that area. For each width RIP calls CUTUP to saw the cuttings. If the area is salvageable (that is, its length exceeds the minimum cutting length), RIP calls STORE (an entry of RANGE) to store the coordinates of the cutting.

Subroutine AMEND

Because only yield per section, not the coordinates of the cuttings within the section, is stored, it is necessary to rerun the maximum combination to determine cutting and sawkerf coordinates. This is the purpose of AMEND (fig. 15). AMEND is called from MAIN after all combinations have been tried and the maximum yield has been found. AMEND takes each cutting length section, defines its bounds, and calls SAW to cut up the section. The coordinates and dimensions of the cuttings and saw of the cut lines are then available to be included in the program output.

Subroutine ALTER

Subroutine ALTER (fig. 16) has two entry points—ALTER and REVISE. The purpose of ALTER is to find any possible alternatives within the cutting length combination. Alternatives consist of changing the beginning of the cutting length section so that the section begins at the end of a defect lying within the original section.

ALTER looks at the given bounds of the cutting length section and tests each defect to see if its end lies within the section's bounds. If such a defect is found, ALTER checks to see if that alternative has already been found. If it has not, the upper X coordinate of the defect is stored. The next defect is then tried. After all defects have been checked, ALTER next returns to MAIN.

Entry REVISE retrieves the X coordinate for a given alternate combination.

Subroutine CUTUP

Using the coordinates sent to it, subroutine CUTUP (fig. 17) defines the cutting and adds the value of the cutting to the section yield total.

Table 5.–Value weighting table. Both lengths and widths are upper bounds of the ranges

Width	Length							
	18.0	23.0	35.0	42.0	59.0	71.0	83.0	95.0
In.				In.				
1.75	0.790	0.851	0.876	0.897	0.936	1.005	1.085	1.105
2.75	.790	.851	.887	.909	.964	1.038	1.083	1.189
3.75	.790	.851	.887	.921	.988	1.055	1.123	1.235
4.75	.817	.875	.897	.933	1.010	1.079	1.235	1.400

Subroutine HOLD

Subroutine HOLD (fig. 18) has three entry points–HOLD, INTL, and REMEM. The purpose of the subroutine is to store the list of coordinates of the cutting length sections tried, and their corresponding yields. The purpose of entry HOLD is to check whether or not a given section has been calculated before. If it has, the yield for that section is retrieved.

Entry INTL simply initializes the number of sections calculated to zero. Entry REMEM stores the yield of a given cutting length section.

Subroutine WFIND

Subroutine WFIND (fig. 19) has two entry points–WFIND and WINTL. WFIND builds the table of best rip width combinations per clear area. This table is used by all boards within the run. When first entered, WFIND checks to see if the best rip width combination for the given clear area has been calculated yet. If it has, the width combination is retrieved and WFIND returns. If the width combination has not been calculated before, it must be solved. WFIND generates the first width combination by ripping the entire clear area with the smallest width of cutting, taking as many rips as will fit in the area. The value of these cuttings is summed and stored. The next combination of cutting widths is then generated. The total value of the cuttings produced by this combination is then compared with the previous high value. If the current value is higher than the previous high, it becomes the new high value. This process of generating width combinations and testing the sum of the values of these cutting(s) is repeated until all width combinations have been generated. The final high yield and high combination are then stored with the clear area in the table of best width combinations. The rip width combination is then returned as a parameter of WFIND.

Entry WINTL initializes the number of clear areas tested to zero.

Subroutine TSTORE and Function VALUE

Subroutine TSTORE (fig. 20) has three entry points–TSTORE, TINTL, and RETREV. TSTORE is a storage location for possible salvage cuttings produced by TRIMIT. Entry TINTL initializes the number of salvage cuttings to zero. Entry TSTORE checks if the salvage cutting is already stored; if it is, TSTORE returns. If not, TSTORE stores the coordinates of the cutting. The value of the cutting is then added to the total value for the cutting process (additional crosscut or rip) from which the cutting was derived. TSTORE then returns. Entry RETREV decides which salvage process (additional crosscut or rip) produces the highest value of cuttings. RETREV then calls CUTUP to saw each of these cuttings and returns. The value of a cutting is determined by referencing the function VALUE (length, width). VALUE (fig. 21) computes the value of a cutting based upon the surface area of the cutting and the weighting factor derived from the value index table.

Program Input

Input to run CROMAX consists of two types: (1) option cards, and (2) board data cards. The option cards list the decisionmaking options to be used while the board data cards describe the individual boards. Table 6 shows the input used to run CROMAX for the board in figures 2 to 9.

Options

Options available in CROMAX allow the user to alter the decisionmaking capabilities of the program. Table 4 lists the options and their respective formats. Briefly:

1. Trimming–The amount of wood trimmed off each end of the board is defined as trimming. CROMAX reads this value in quarter-inch units and trims each board back this amount; no decisions are made as to whether or not a particular board should be trimmed or if more or less wood should be taken off. The amount off is the same for all boards.

2. Maximization–Value of cutting vs. surface area of cutting. CROMAX has the capability of maximizing the yield decision based upon either the sum of the value of the cuttings, or the sum of the surface area of the cuttings. The latter simply maximizes surface area of cuttings alone. The value maximization determines the best cutting solution based upon the surface area of the cuttings and the weighted value. If the total value of cuttings is to be maximized, a value index table must be supplied, Cards are required for (a) the number of lengths and widths to define the table size, (b) the cutting widths to define the row dimension of the table, (c) the cutting lengths to define the columns of the table, and (d) four value cards, one for each width. Entries on this card represent the value index of the corresponding length position for that width. The value index table allows the user great freedom in selecting key cutting dimensions.

Table 6.–Input used to run sample board (fig. 2). All coordinates are listed: Lower Y-Lower X; Upper Y-Upper X. All values are In 1/4-inch units.

Option Cards		TRIM = 1	
		VALUE = 0	
		NLEN = 4NWID = 10	
		40 80 120 160	
		6 8 10 12 14 16 18 20 22 24	
Board Data Cards		Grade 2C Board Number 130 Total Number of Defects 14	
	Board Coordinates	1- 6	49-488
	Defect Coordinates	1- 6	3-146
		35- 6	37- 14
		35- 90	49-105
		23-146	28-168
		17-168	27-196
		18-196	25-214
		18-297	24-318
		11-318	24-339
		14-339	15-353
		15-401	25-416
		1-416	20-428
		29-416	49-438
		1-428	3-488
		29-438	34-488

3. Number of cutting lengths and widths–The number of cutting lengths and the number of cutting widths must be specified.

4. Cutting lengths–The cutting lengths allowed (up to 10) are specified on this card.

5. Cutting widths–The cutting widths allowed (up to 10) are specified on this card.

Board Data

Boards are described as rectangles superimposed on an X-Y grid, with the X direction along the length of the board and Y across its width. Defects are represented as rectangles within the board. Since a rectangle can be defined by two points, only the lower left coordinate and the upper right coordinate of the board or defect are specified. The order of the coordinates is lower Y - lower X, then upper Y - upper X. The input for the board in figure 2 is given in table 1.

The input for each board consists of three record types: (1) a header card defining the lumber grade, the board number, and the number of defects within the board, (2) a board coordinate card defining the coordinates of the board dimensions (lower left and upper right coordinates), and (3) a defect coordinate card for each defect within the board (up to the number specified on the header card) defining the coordinates of the defect (lower left and upper right coordinates). Data are arranged board after board; the sequence for input goes option cards, board 1, board 2, . . ., board n . . . until the end of file.

Discussion

As automatic defect detection and use of computer controls within furniture and other rough mills increase, computer decisionmaking and modeling of these processes will become more and more important. It is hoped this paper will encourage others to investigate models for crosscut-first lumber processing.

The model and program CROMAX are the first generation of a computer program to simulate crosscut-first operations. The major objective was to develop the basic algorithms to maximize cutting yield; however, to do this CROMAX processes a very large number of different combinations of section lengths. The computing time involved in the process is prohibitive (frequently 5 minutes or more per 8-foot board when run on a UNIVAC 1100/80); consequently yield studies such as performed by Schumann *(7,8)* are not economically feasible. The authors are currently investigating algorithms which will decrease the number of combinations without sacrificing accuracy. Heuristics, which will allow CROMAX “to know” if a cutting decision is “good” or “bad” show the most promise.

Literature Cited

1. **Englerth, George H.; Schumann, David R.** Charts for calculating dimension yields from hard maple lumber. USDA For. Serv. Res. Pap. FPL 118. For. Prod. Lab., Madison, Wis.; 1969.

2. **Giese, Pamela J.; McDonald, Kent A.** OPTYLD—A multiple rip-first computer program to maximize cutting yields. USDA For. Serv. Res. Pap. FPL 412. For. Prod. Lab., Madison, Wis.; 1982.

3. **Huber, Henry A.; Harsh, Stephen B.; Pepke, Edward K.** Improving lumber yields in the rough mill. Wood and Wood Products; April 1978.

4. **Huber, Henry A.; Harsh, Stephen B.** Rough-mill improvement program. Woodworking and Furniture Digest; February 1977.

5. **Huber, Henry A.; Harsh, Stephen B.** In the rough mill, should you rip or crosscut first? Woodworking and Furniture Digest; June 1974.

6. **Lucas, Edwin L.; Catron, Leathern R. R.** A comprehensive defect data bank for No. 2 Common oak lumber. USDA For. Serv. Res. Pap. NE-262. Northeastern For. Exp. Stn., Upper Darby, Pa.; 1973.

7. **Schumann, David R.** Dimension yields from alder lumber. USDA For. Serv. Res. Pap. FPL 170. For. Prod. Lab., Madison, Wis.; 1972.

8. **Schumann, David R.; Englerth, George H.** Yields of random-width dimension from 4/4 hard maple lumber. USDA For. Serv. Res. Pap. FPL 81. For. Prod. Lab., Madison, Wis.; 1967.

9. **Wodzinski, Claudia; Hahm, Eldona.** A computer program to determine yields of lumber. USDA For. Serv. FPL unnumbered publ. For. Prod. Lab., Madison, Wis.; 1966.

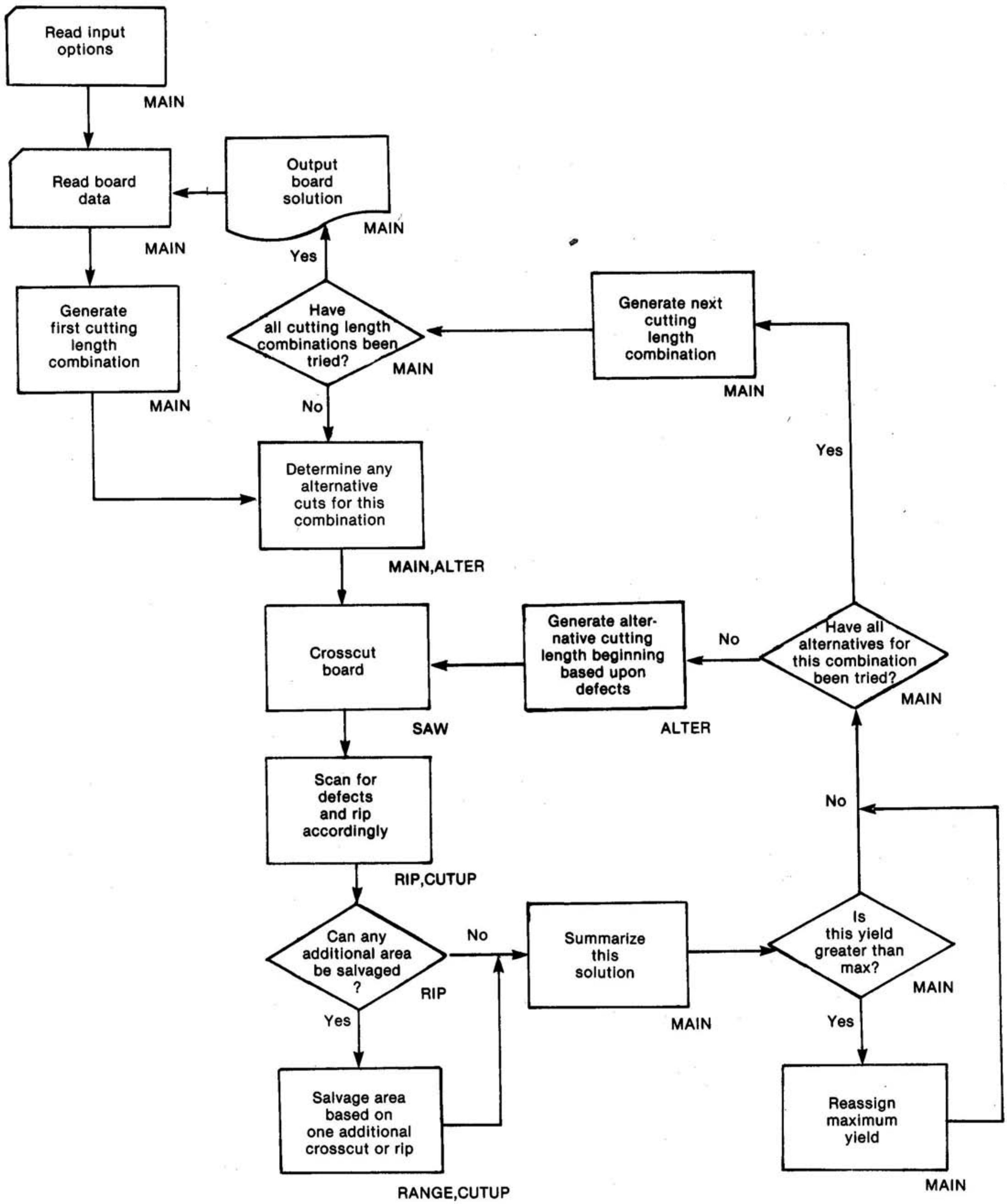

Figure 10.–General flowchart of computer program CROMAX. (ML83 5049)

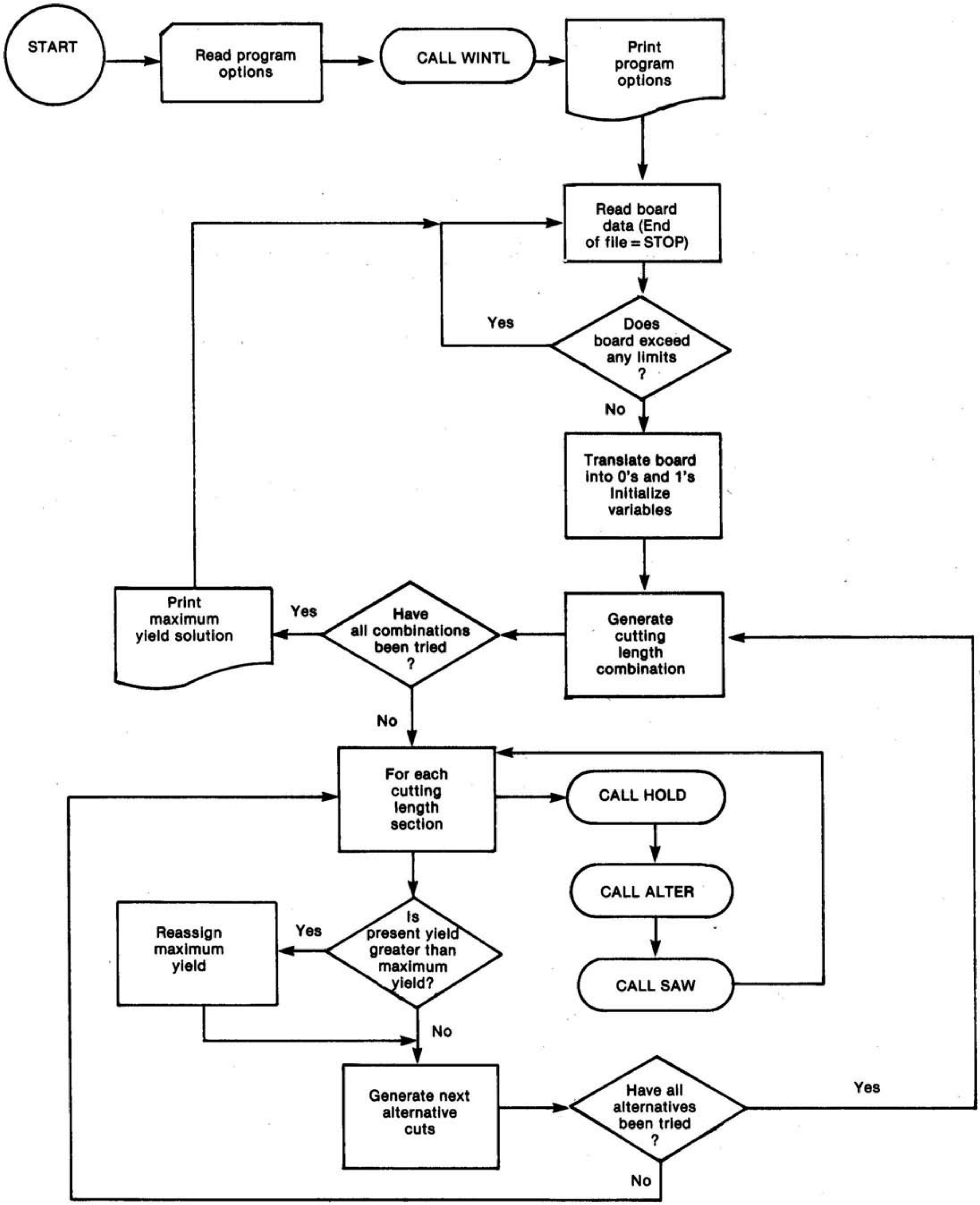

Figure 11.–Flowchart of main program of computer program CROMAX. (ML83 5043)

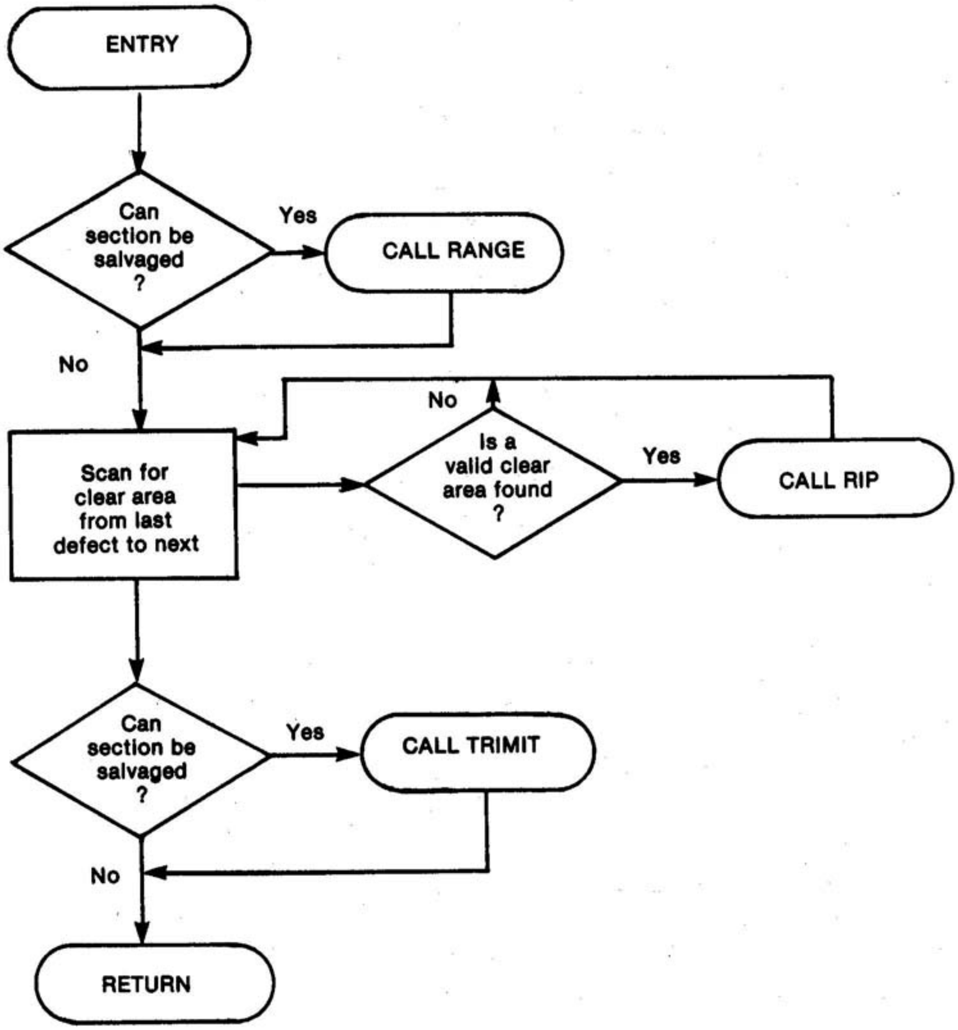

Figure 12.–Flowchart of subroutine SAW. (ML83 5042)

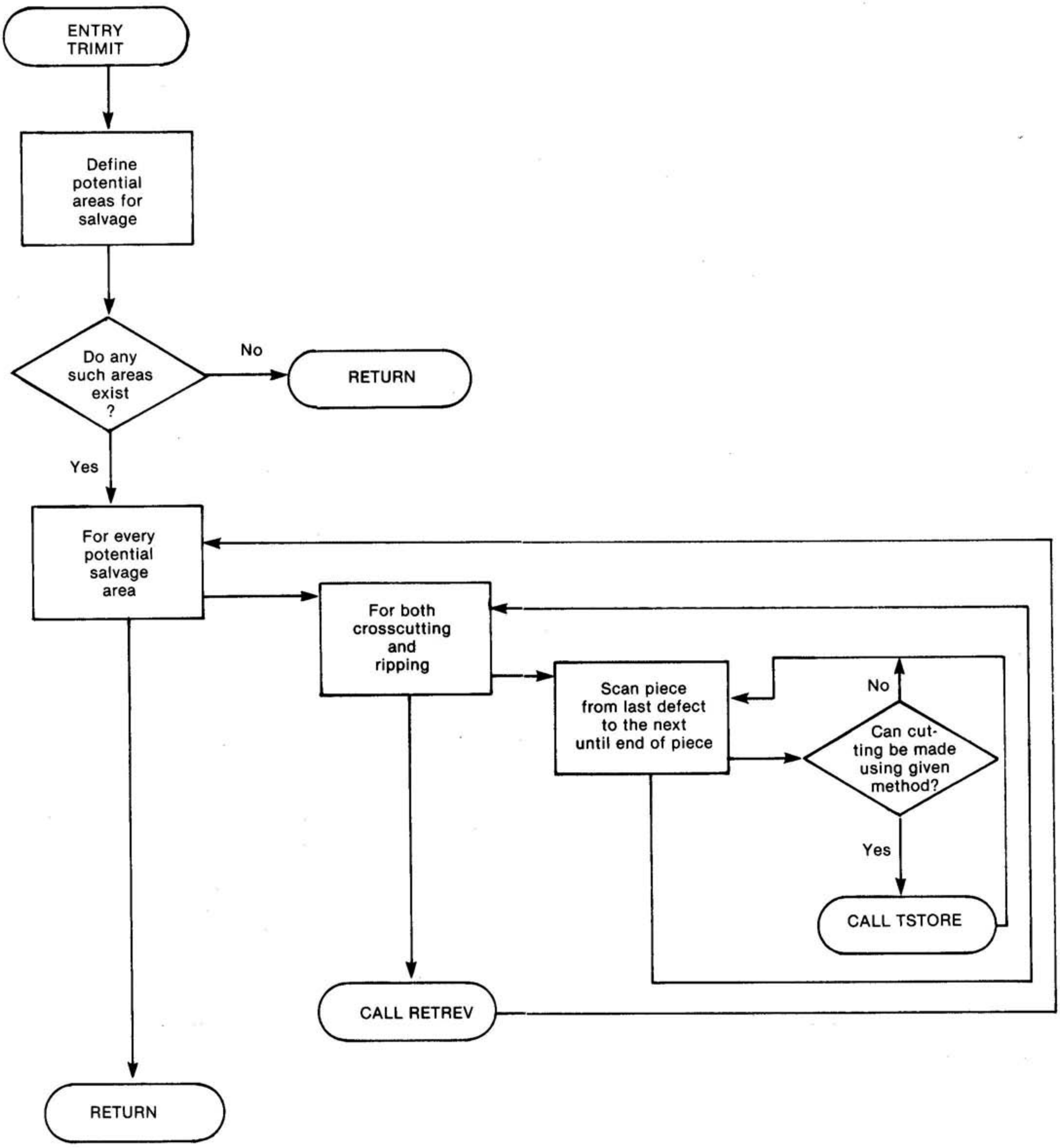

Figure 13.–Flowchart of subroutine RANGE. Entry points are RANGE, TRIMIT, and STORE. (ML83 5044)

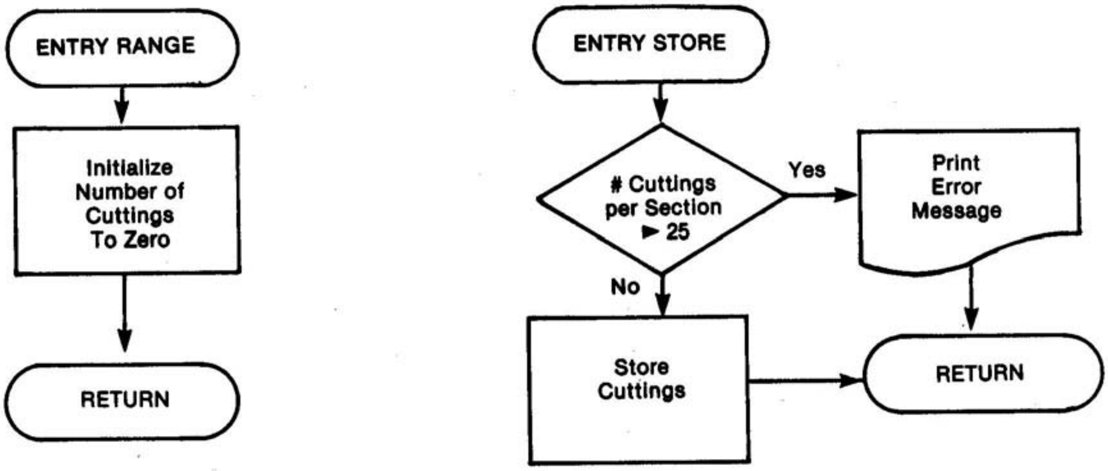

Figure 13.–Flowchart of subroutine RANGE. Entry points are RANGE, TRIMIT and STORE. (Continued)(ML835044)

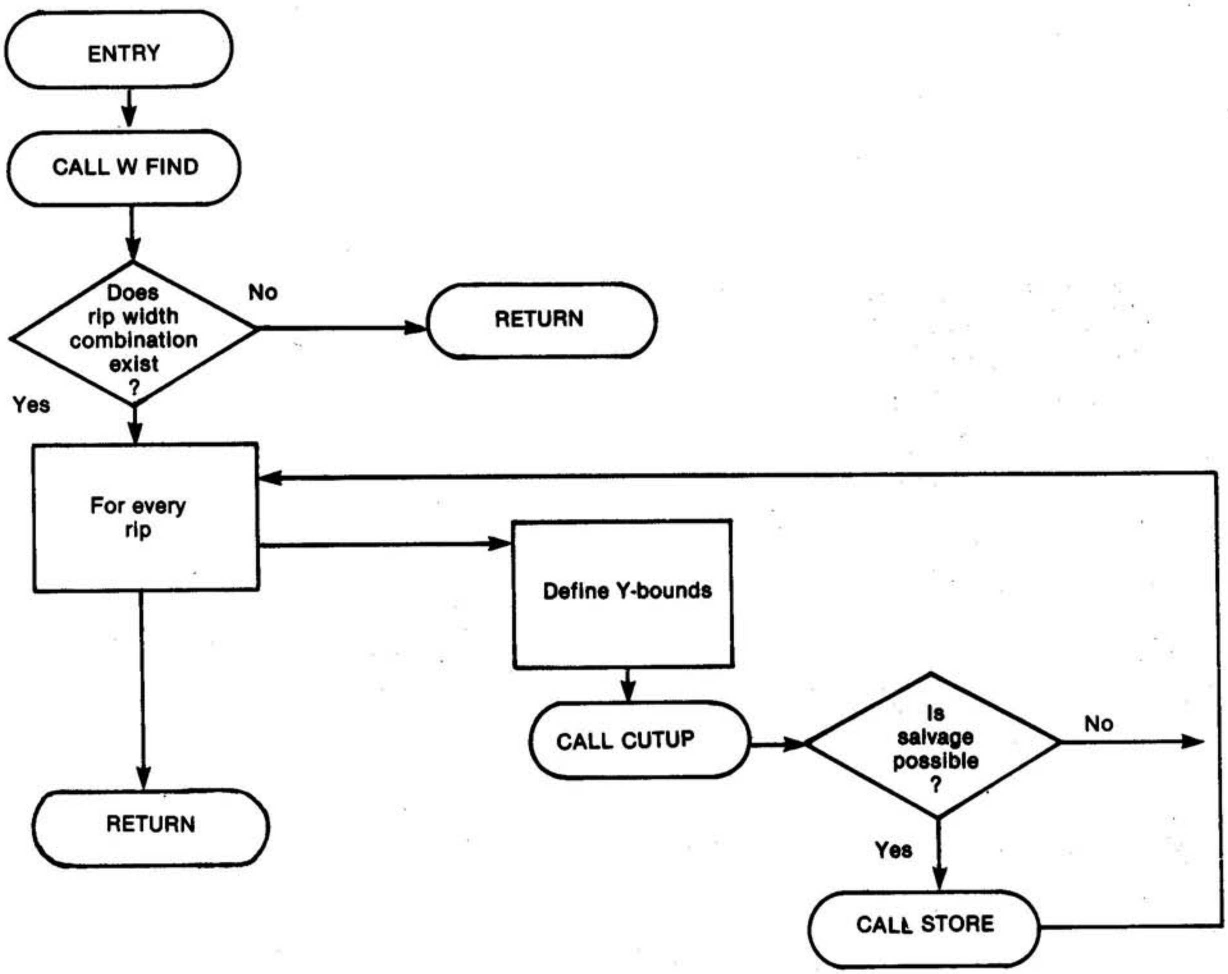

Figure 14.–Flowchart of subroutine RIP. (ML83 5041)

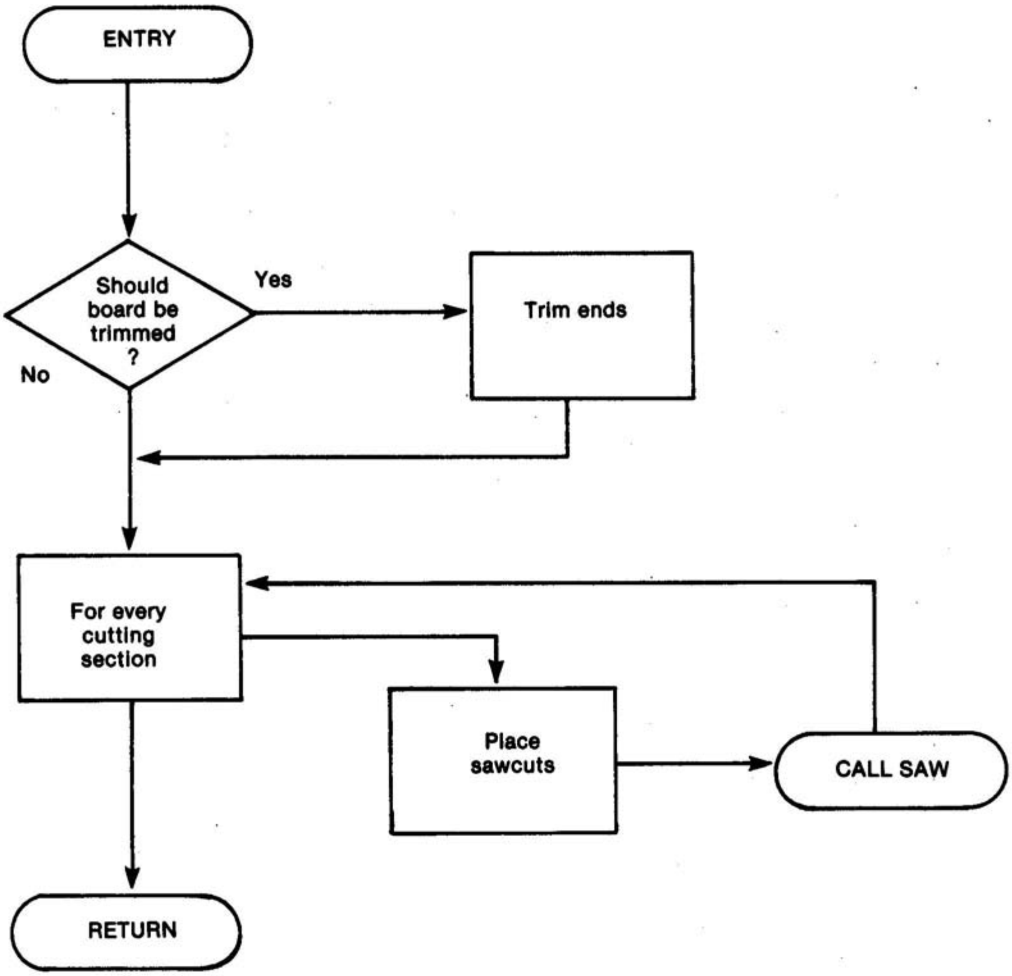

Figure 15.–Flowchart of subroutine AMEND. (ML83 5050)

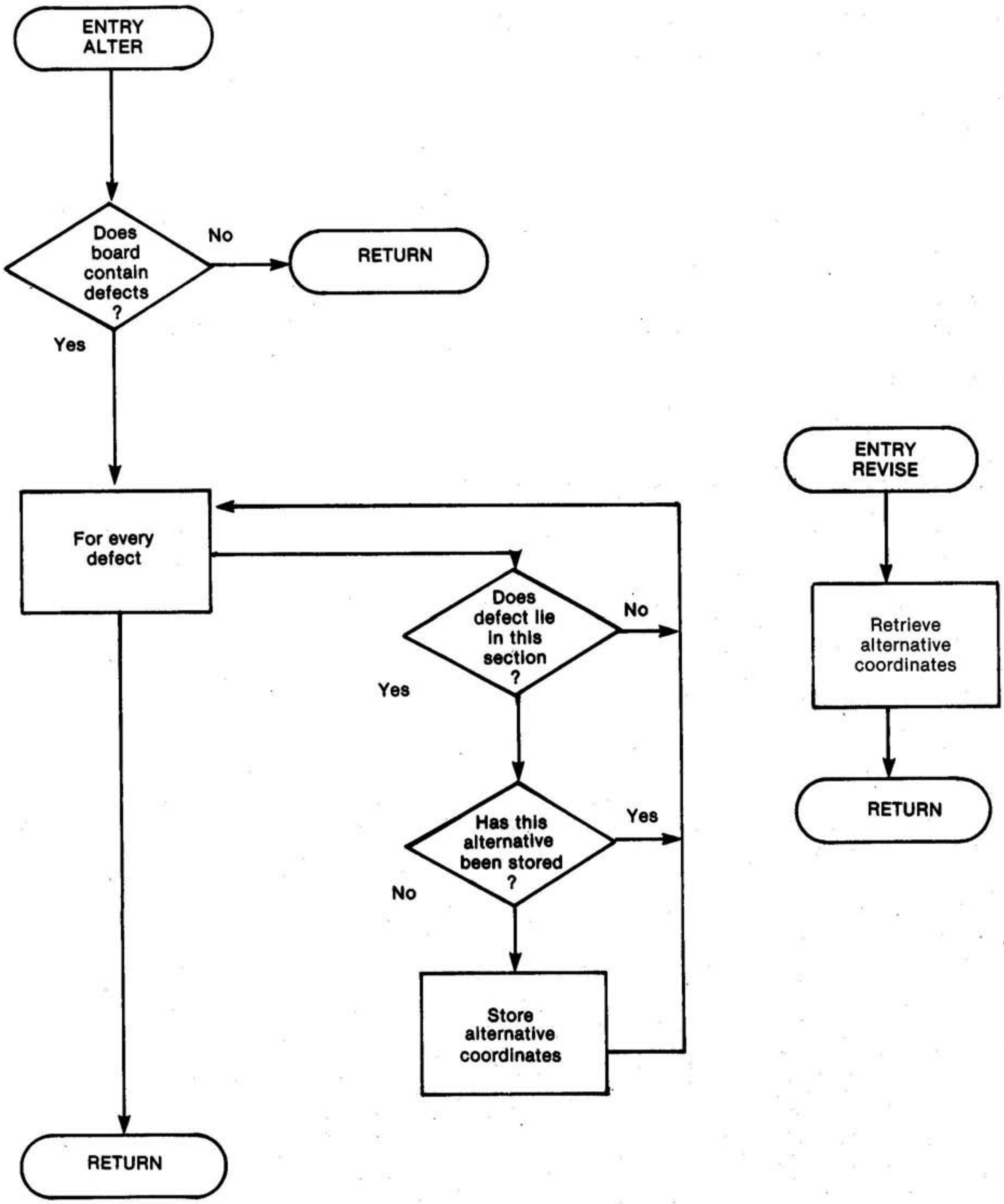

Figure 16.–Flowchart of subroutine ALTER. Entry points are ALTER and REVISE. (ML83 5045)

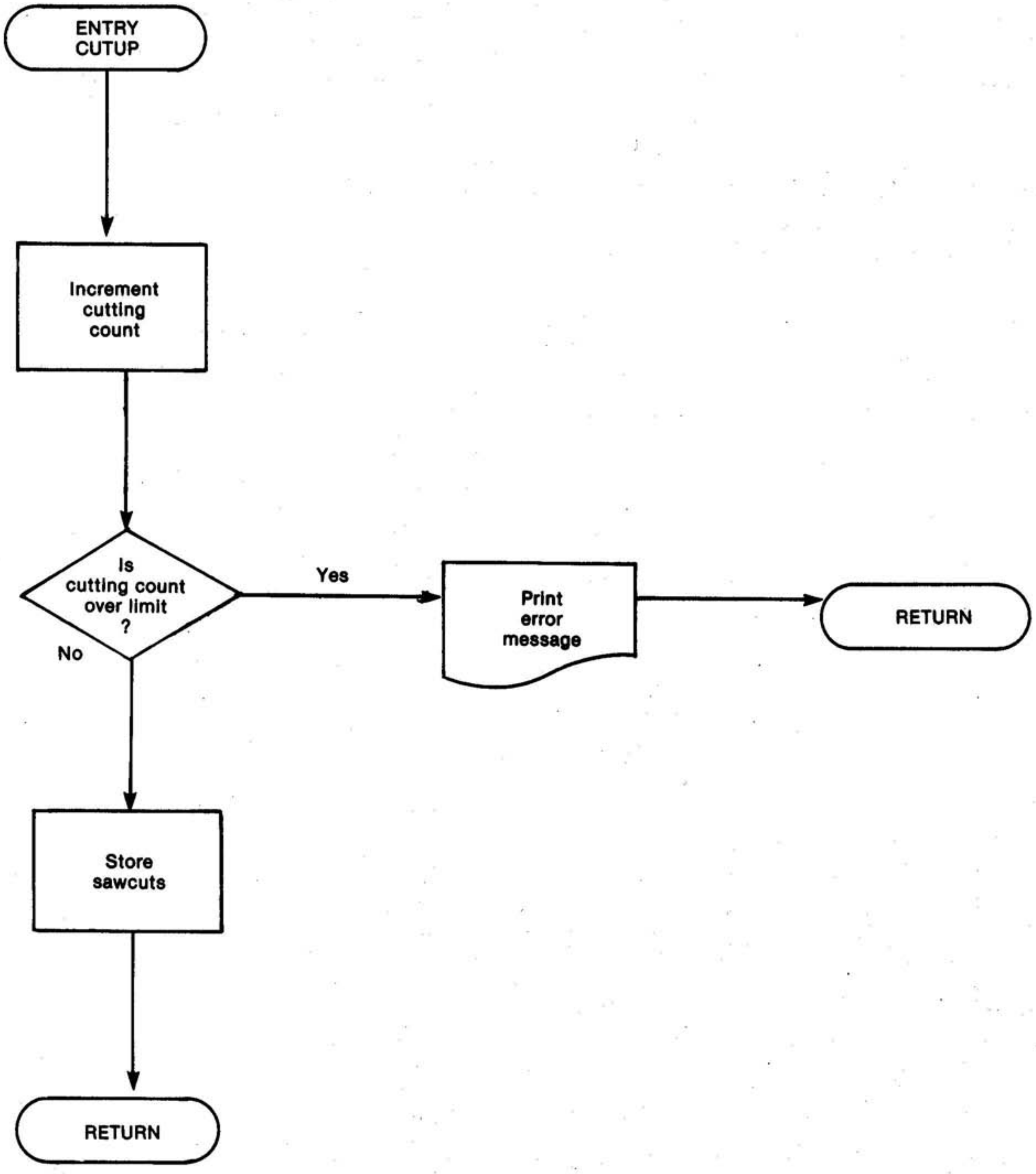

Figure 17.–Flowchart of subroutine CUTUP. (ML83 5046)

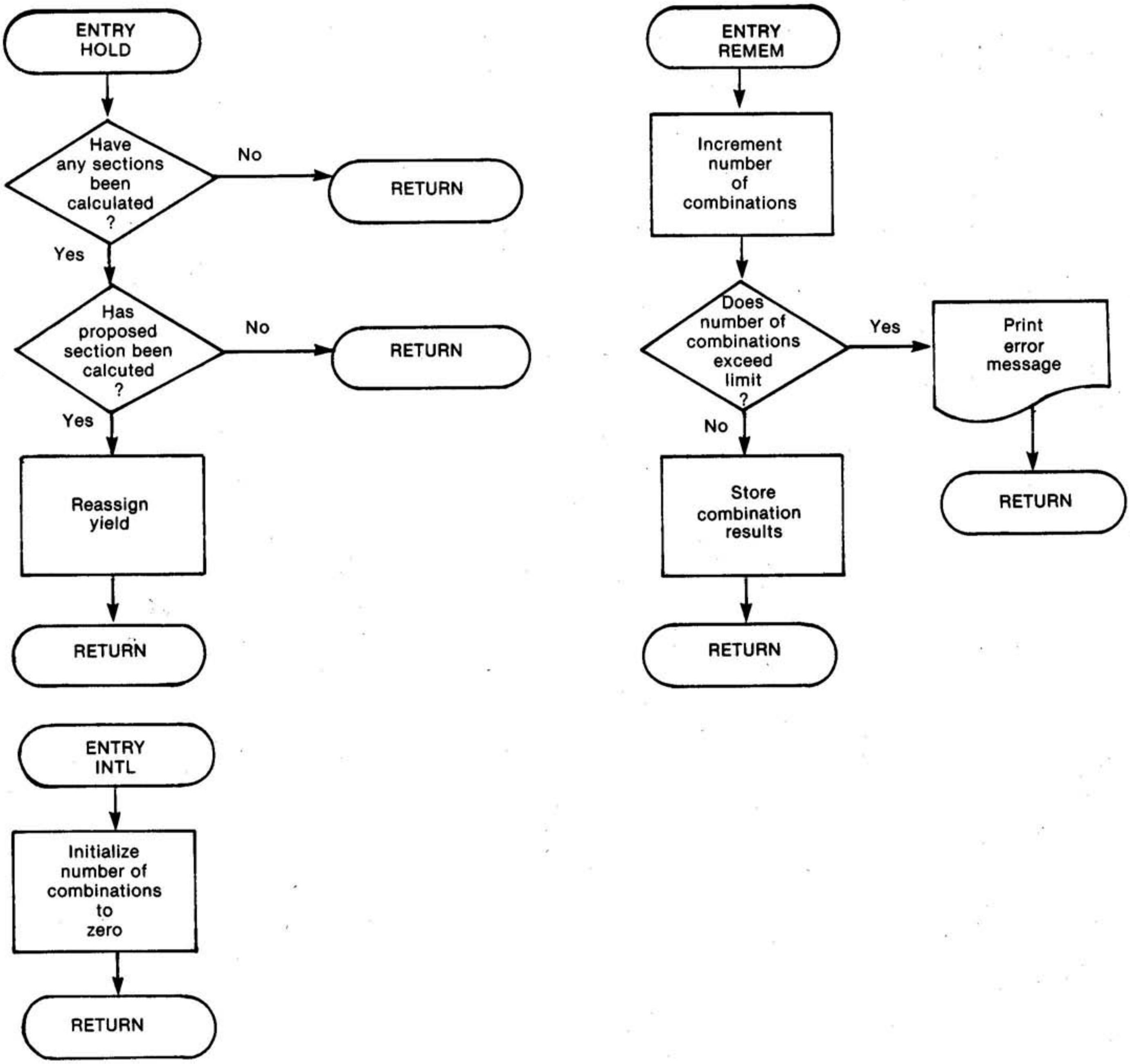

Figure 18.–Flowchart of subroutine HOLD. Entry points are HOLD, INTL, and REMEM. (ML83 5047)

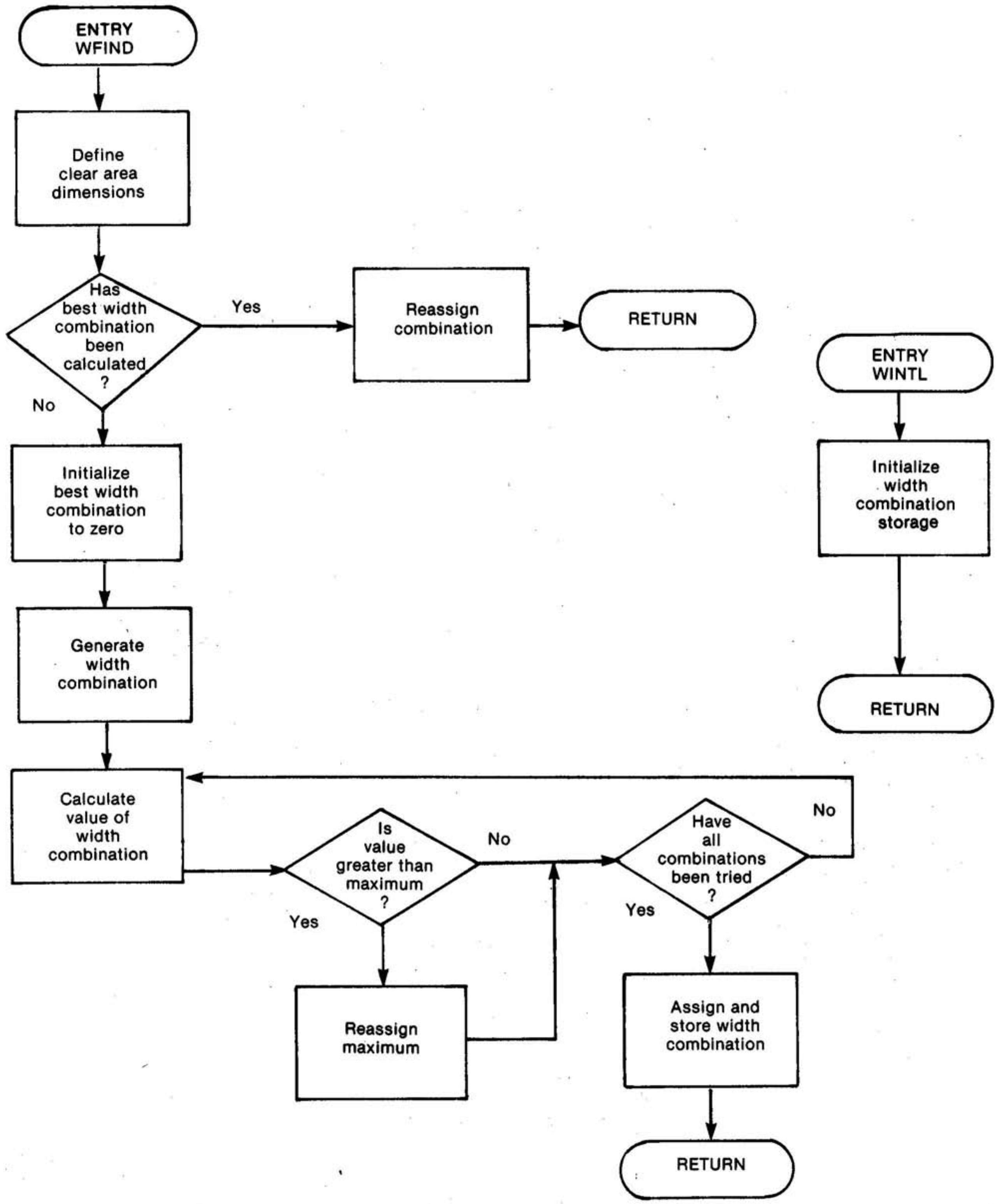

Figure 19.–Flowchart of subroutine WFIND. Entry points are WFIND and WINTL. (ML83 5048)

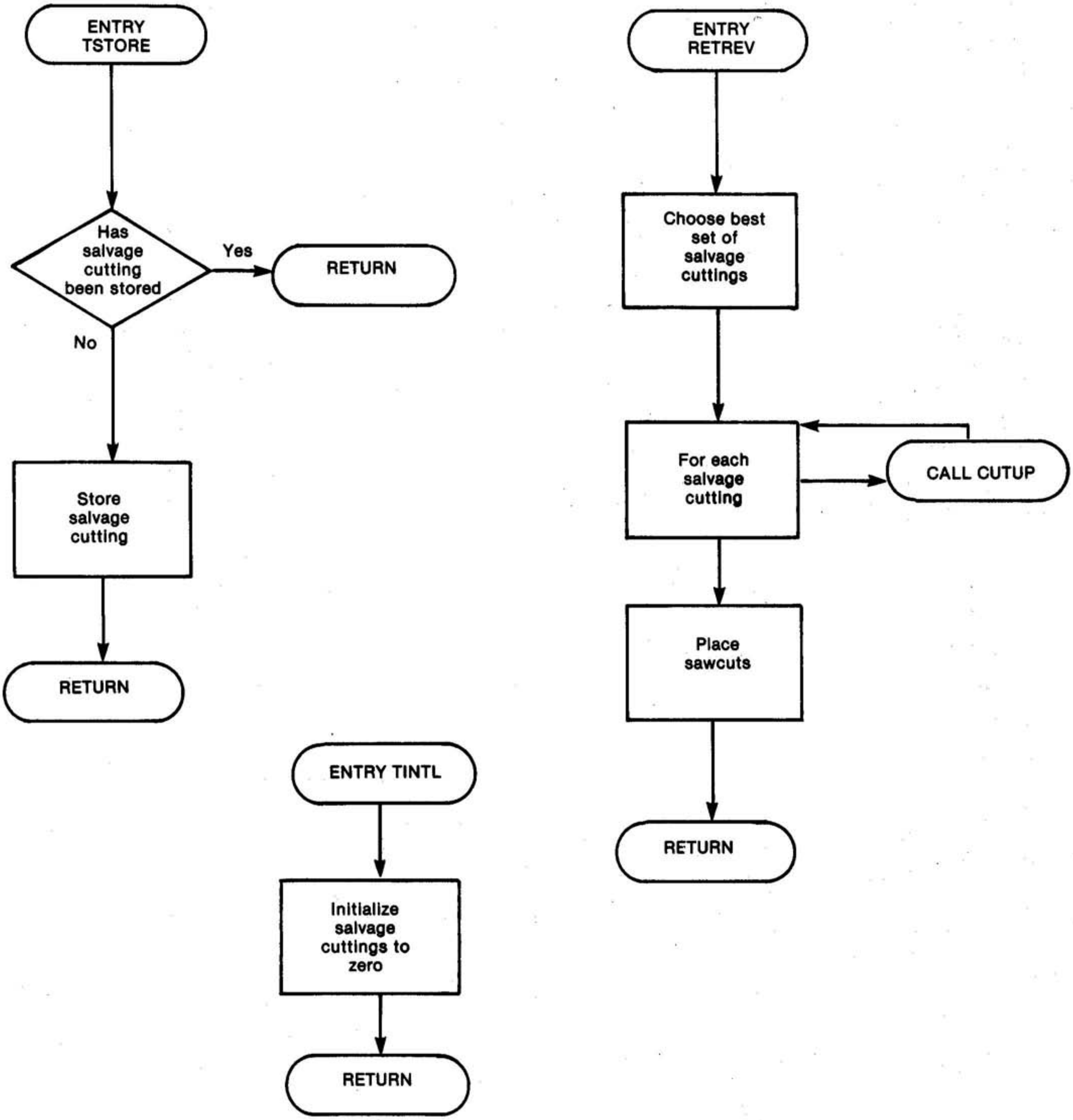

Figure 20.–Flowchart of subroutine TSTORE. Entry points are TSTORE, TINTL, and RETREV. (ML83 5051)

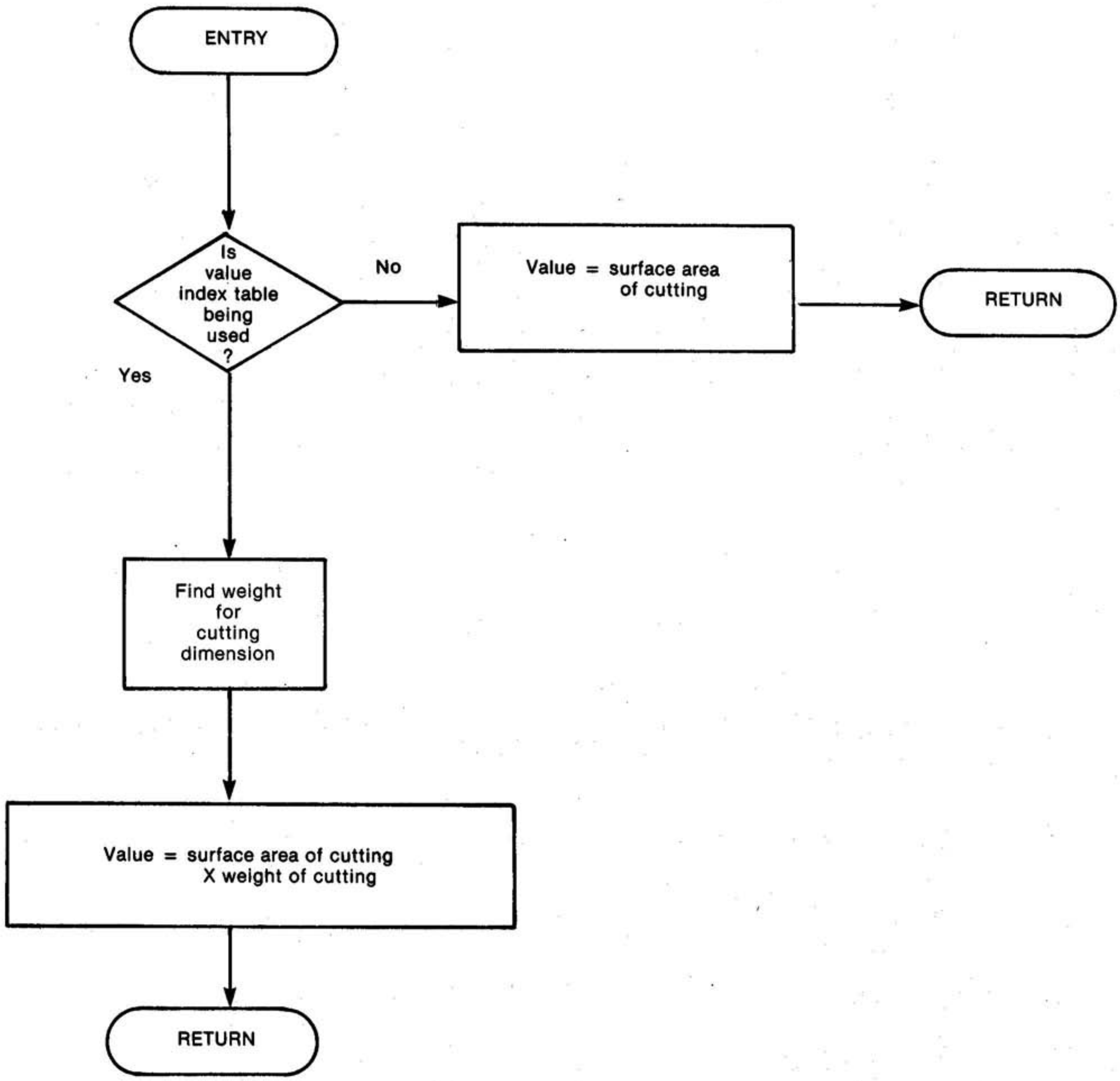

Figure 21.–Flowchart of function VALUE. (ML83 5040)

Appendix A: CROMAX Program Listing

```
C *** CROMAX ***                                                        CROMAX
C *** PROGRAM TO MAXIMIZE CROSSCUTTING                                   CROMAX
C *** U S FOREST PRODUCTS LABORATORY                                    CROMAX
      IMPLICIT INTEGER(A-X)                                             CROMAX
      REAL LTEMP,GRID,AREA,AREAC,WTEMP,INDEX,VTEMP,VALUE                CROMAX
      LOGICAL BAD,DONE,LAST,PURE,TRIM,KNOW(25),OK,REJECT                CROMAX
      CHARACTER*3 GRADE                                                 CROMAX
      CHARACTER*5 NBOARD                                                CROMAX
      DIMENSION Y(2),ALTCOM(25)                                         CROMAX
      COMMON /ALL/NBOARD,BAD,BDLX,BDLY,BDUX,BDUY                        CROMAX
      COMMON/MS/BOARD(100,24)                                           CROMAX
       COMMON/MSR/LENGTH(10),NLEN,WIDTH(10),NWID                        CROMAX
      COMMON/MRA/NCUTS,SAWCUT(200,4),LAST,PIECE(100,2),NPIECE           CROMAX
      COMMON /MRF/YIELD(25)                                             CROMAX
      COMMON /MAFG/RIPCOM(2,25),XLOW(25,2),XHI(25,2)                    CROMAX
      COMMON /MATFG/NSEC                                                CROMAX
      COMMON /MC/ND,DLX(100),DUX(100),NDEF(25),DUY(100)                 CROMAX
      COMMON /MV/INDEX(4,8),VLEN,VWID,LINDEX(8),WINDEX(4),NV            CROMAX
      DATA INDEX/32*1./                                                 CROMAX
      DATA ACTIVE/1/,MAX/2/,UNIT/11/,UNIT2/10/                          CROMAX
      GRID=.25                                                          CROMAX
C *** READ IN OPTIONS                                                   CROMAX
      READ(5,5)EDGE                                                     CROMAX
    5 FORMAT(5X,I2)                                                     CROMAX
      READ(5,6)NV                                                       CROMAX
    6 FORMAT(6X,I1)                                                     CROMAX
      IF(NV.EQ.0)GO TO 9                                                CROMAX
      READ(5,10)VLEN,VWID                                               CROMAX
      READ(5,15)(WINDEX(I),I=1,VWID)                                    CROMAX
      READ(5,15)(LINDEX(I),I=1,VLEN)                                    CROMAX
      DO 8 I=1,4                                                        CROMAX
        READ(5,7)(INDEX(I,J),J=1,8)                                     CROMAX
    7   FORMAT(8F5.2)                                                   CROMAX
    8 CONTINUE                                                          CROMAX
    9 READ(5,10)NLEN,NWID                                               CROMAX
   10 FORMAT(2(5X,I2))                                                  CROMAX
      READ(5,15)(LENGTH(I),I=1,10)                                      CROMAX
   15 FORMAT(10I5)                                                      CROMAX
      READ(5,15)(WIDTH(I),I=1,10)                                       CROMAX
      DO 20 I=1,NLEN                                                    CROMAX
   20   LENGTH(I)=4*LENGTH(I)                                           CROMAX
      WRITE(6,25)(LENGTH(I),I=1,NLEN),(WIDTH(I),I=1,NWID)               CROMAX
   25 FORMAT(1H1///5X,80(1H*)//30X,'CROSS-CUT MAXIMIZATION'//5X,80(1H*)/ CROMAX
     *//15X,'LENGTHS -',4I5/15X,'WIDTH -',3I5)                          CROMAX
      CALL WINTL                                                        CROMAX
C *** READ BOARD                                                        CROMAX
   30 BAD=.FALSE.                                                       CROMAX
      READ(5,35,END=300)GRADE,NBOARD,ND                                 CROMAX
   35 FORMAT(7X,A3,22X,A5,32X,I3)                                       CROMAX
      READ(5,40)BDLY,BDLX,BDUY,BDUX                                     CROMAX
   40 FORMAT(I3,1X,I3,5X,I3,1X,I3)                                      CROMAX
      IF((BDUY.GT.100).OR.(BDUX.GT.864))BAD=.TRUE.                      CROMAX
      IF(BAD)GO TO 55                                                   CROMAX
      DO 45 I=1,100                                                     CROMAX
        DO 43 J=1,24                                                    CROMAX
          BOARD(I,J)=0                                                  CROMAX
   43   CONTINUE                                                        CROMAX
   45 CONTINUE                                                          CROMAX
      WRITE(6,530)BDLX,BDLY,BDUX,BDUY                                   CROMAX
  530 FORMAT(5X,'BDLX,BDLY,BDUX,BDUY=',4I5)                             CROMAX
      LTEMP=(BDUX-BDLX)*GRID                                            CROMAX
      WTEMP=(BDUY-BDLY)*GRID                                            CROMAX
      AREA=(BDUX-BDLX)*(BDUY-BDLY)*GRID*GRID                            CROMAX
      WRITE(6,50)GRADE,NBOARD,LTEMP,WTEMP                               CROMAX
   50 FORMAT(5X,A3,' BOARD NUMBER',A5/10X,F6.2,' X',F6.2)               CROMAX
      BDLY=BDLY+EDGE                                                    CROMAX
   55 IF(ND.EQ.0)GO TO 78                                               CROMAX
      DO 75 I=1,ND                                                      CROMAX
        READ(5,40)DLY,DLX(I),DUY(I),DUX(I)                              CROMAX
      WRITE(6,40)DLY,DLX(I),DUY(I),DUX(I)                               CROMAX
        IF(BAD)GO TO 75                                                 CROMAX
        DLY=DLY+1                                                       CROMAX
        DO 65 KX=DLX(I),DUX(I)                                          CROMAX
          K2=KX/36                                                      CROMAX
          IBIT=IABS(KX-K2*36)+1                                         CROMAX
          K2=K2+1                                                       CROMAX
          DO 60 K1=DLY,DUY(I)                                           CROMAX
            BITS(BOARD(K1,K2),IBIT,1)=1                                 CROMAX
   60     CONTINUE                                                      CROMAX
   65   CONTINUE                                                        CROMAX
   75 CONTINUE                                                          CROMAX
      IF(.NOT.BAD)GO TO 78                                              CROMAX
      WRITE(6,77)NBOARD                                                 CROMAX
   77 FORMAT(5X,'BOARD NUMBER',A5,'EXCEEDS BOUNDS')                     CROMAX
      GO TO 30                                                          CROMAX
C *** ORGANIZE PROCESSING OF BOARD + ASSIGN INITIAL VALUES              CROMAX
   78 NSEC=(BDUX-BDLX)/(LENGTH(1)+1)                                    CROMAX
      IF(NSEC.GT.25)NSEC=25                                             CROMAX
C *** INITIALIZE FIRST COMBINATION                                      CROMAX
      TRYSEC=1                                                          CROMAX
      Y(MAX)=0.                                                         CROMAX
      DONE=.FALSE.                                                      CROMAX
      DO 80 I=1,2                                                       CROMAX
        DO 80 J=1,NSEC                                                  CROMAX
          YIELD(J)=0                                                    CROMAX
          ALTCOM(I)=0.                                                  CROMAX
          KNOW(I)=.FALSE.                                               CROMAX
   80     RIPCOM(1,J)=1                                                 CROMAX
      COMB=1                                                            CROMAX
      CALL INTL                                                         CROMAX
      STARTX=BDLX                                                       CROMAX
      PURE=.TRUE.                                                       CROMAX
      OLDSEC=NSEC                                                       CROMAX
      MAXSEC=NSEC                                                       CROMAX
C *** DEFINE BOUNDS                                                     CROMAX
   85 MAXSEC=NSEC                                                       CROMAX
      NCUTS=0                                                           CROMAX
      DO 90 I=TRYSEC,NSEC                                               CROMAX
          IF(MAXSEC.LT.I)GO TO 90                                       CROMAX
        KNOW(I)=.FALSE.                                                 CROMAX
        YIELD(I)=0.                                                     CROMAX
        XLOW(I,ACTIVE)=STARTX                                           CROMAX
        XHI(I,ACTIVE)=XLOW(I,ACTIVE)+LENGTH(RIPCOM(1,I))                CROMAX
        IF(XHI(I,ACTIVE).GT.BDUX)THEN                                   CROMAX
          MAXSEC=I-1                                                    CROMAX
        ELSE                                                            CROMAX
          STARTX=XHI(I,ACTIVE)+1                                        CROMAX
          IF(COMB.LE.1)GO TO 87                                         CROMAX
          CALL HOLD(XLOW(I,ACTIVE),XHI(I,ACTIVE),YIELD(I),KNOW(I))      CROMAX
   87     CALL ALTER(XLOW(I,ACTIVE),XHI(I,ACTIVE),I,BDLY)               CROMAX
        ENDIF                                                           CROMAX
   90 CONTINUE                                                          CROMAX
                                                                        CROMAX
C *** CALCULATE YIELDS                                                  CROMAX
   93 IF(MAXSEC.LE.0)GO TO 124                                          CROMAX
      IF(MAXSEC.LT.TRYSEC)GO TO 124                                     CROMAX
   95 DO 100 I=TRYSEC,MAXSEC                                            CROMAX
        IF(BAD)GO TO 100                                                CROMAX
        IF(KNOW(I))GO TO 100                                            CROMAX
        NPIECE=0                                                        CROMAX
        CALL SAW(XLOW(I,ACTIVE),XHI(I,ACTIVE),I,TRIM)                   CROMAX
        CALL REMEM(XLOW(I,ACTIVE),XHI(I,ACTIVE),YIELD(I))               CROMAX
  100 CONTINUE                                                          CROMAX
      IF(BAD)GO TO 205                                                  CROMAX
      Y(ACTIVE)=0                                                       CROMAX
      TRYSEC=MAXSEC                                                     CROMAX
      DO 110 I=1,MAXSEC                                                 CROMAX
  110  Y(ACTIVE)=Y(ACTIVE)+YIELD(I)                                     CROMAX
      IF((Y(ACTIVE)-Y(MAX)).LE.-0.01)GO TO 120                          CROMAX
      TY=0                                                              CROMAX
```

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      DO 403 R=1,MAXSEC                                                 CROMAX
        TY=TY+(RIPCOM(1,R)**2)                                          CROMAX
  403 CONTINUE                                                          CROMAX
      IF(COMB.LE.1)GO TO 404                                            CROMAX
      IF((Y(ACTIVE)-Y(MAX)).GE..01)GO TO 404                            CROMAX
      IF(TY.LT.MY)GO TO 120                                             CROMAX
  404 Y(MAX)=Y(ACTIVE)                                                  CROMAX
      MY=TY                                                             CROMAX
      BSEC=MAXSEC                                                       CROMAX
      DO 115 I=1,MAXSEC                                                 CROMAX
        XLOW(I,MAX)=XLOW(I,ACTIVE)                                      CROMAX
        XHI(I,MAX)=XHI(I,ACTIVE)                                        CROMAX
  115 RIPCOM(2,I)=RIPCOM(1,I)                                           CROMAX
C *** ARE OTHER ALTERNATES AVAILIBLE FOR PROCESSING?                    CROMAX
  120 IF(PURE)OLDSEC=TRYSEC                                             CROMAX
      PURE=.FALSE.                                                      CROMAX
      IF(ND.EQ.0)GO TO 124                                              CROMAX
  118 OK=.FALSE.                                                        CROMAX
      DO 113 I=MAXSEC,1,-1                                              CROMAX
        IF(OK)GO TO 113                                                 CROMAX
        IF((I.EQ.1).AND.(NDEF(I).EQ.0))DONE=.TRUE.                      CROMAX
        IF(NDEF(I).EQ.0)GO TO 113                                       CROMAX
        ALTCOM(I)=ALTCOM(I)+1                                           CROMAX
        IF(ALTCOM(I).LE.NDEF(I))THEN                                    CROMAX
          OK=.TRUE.                                                     CROMAX
          TRYSEC=I                                                      CROMAX
        ELSE                                                            CROMAX
          ALTCOM(I)=0                                                   CROMAX
          IF(I.EQ.1)DONE=.TRUE.                                         CROMAX
        ENDIF                                                           CROMAX
  113 CONTINUE                                                          CROMAX
      IF(DONE)GO TO 124                                                 CROMAX
      IF(TRYSEC.EQ.1)STARTX=BDLX                                        CROMAX
      IF(TRYSEC.NE.1)STARTX=XHI(TRYSEC-1,ACTIVE)+1                      CROMAX
      REJECT=.FALSE.                                                    CROMAX
      TSEC=MAXSEC                                                       CROMAX
      IF(MAXSEC.LE.0)GO TO 118                                          CROMAX
        IF(MAXSEC.LT.TRYSEC)GO TO 118                                   CROMAX
      DO 116 I=TRYSEC,TSEC                                              CROMAX
        IF(MAXSEC.LT.I)GO TO 116                                        CROMAX
        IF(REJECT)GO TO 116                                             CROMAX
        KNOW(I)=.FALSE.                                                 CROMAX
        YIELD(I)=0.                                                     CROMAX
        IF(ALTCOM(I).NE.0)CALL REVISE(I,STARTX,ALTCOM(I))               CROMAX
        IF(I.EQ.1)GO TO 117                                             CROMAX
        IF(STARTX.LE.XHI(I-1,ACTIVE))REJECT=.TRUE.                      CROMAX
  117   XLOW(I,ACTIVE)=STARTX                                           CROMAX
        XHI(I,ACTIVE)=XLOW(I,ACTIVE)+LENGTH(RIPCOM(1,I))                CROMAX
        IF(REJECT)GO TO 116                                             CROMAX
        IF(XHI(I,ACTIVE).GT.BDUX)THEN                                   CROMAX
          MAXSEC=I-1                                                    CROMAX
          IF(MAXSEC.EQ.0)REJECT=.TRUE.                                  CROMAX
        ELSE                                                            CROMAX
          STARTX=XHI(I,ACTIVE)+1                                        CROMAX
          CALL HOLD(XLOW(I,ACTIVE),XHI(I,ACTIVE),YIELD(I),KNOW(I))      CROMAX
        ENDIF                                                           CROMAX
  116 CONTINUE                                                          CROMAX
      IF(REJECT)MAXSEC=TSEC                                             CROMAX
      IF(REJECT)GO TO 118                                               CROMAX
      ALTSUM=0                                                          CROMAX
      DO 131 K=1,MAXSEC                                                 CROMAX
  131 ALTSUM=ALTSUM+ALTCOM(K)                                           CROMAX
      IF(ALTSUM.GT.0)GO TO 132                                          CROMAX
      MAXSEC=TSEC                                                       CROMAX
      GO TO 118                                                         CROMAX
  132 NCUTS=0                                                           CROMAX
      GO TO 95                                                          CROMAX
C *** GENERATE NEXT COMBINATION                                         CROMAX
  124 TRYSEC=OLDSEC                                                     CROMAX
      PURE=.TRUE.                                                       CROMAX
  127 RIPCOM(1,TRYSEC)=RIPCOM(1,TRYSEC)+1                               CROMAX
      MAXSEC=NSEC                                                       CROMAX
      DONE=.FALSE.                                                      CROMAX
      IF(RIPCOM(1,TRYSEC).GT.NLEN)GO TO 125                             CROMAX
```

```
      DO 128 I=1,NSEC                                                   CROMAX
  128 ALTCOM(I)=0                                                       CROMAX
      STARTX=BDLX                                                       CROMAX
      IF(TRYSEC.EQ.1)GO TO 126                                          CROMAX
      DO 130 I=1,(TRYSEC-1)                                             CROMAX
        XLOW(I,ACTIVE)=STARTX                                           CROMAX
        XHI(I,ACTIVE)=XLOW(I,ACTIVE)+LENGTH(RIPCOM(1,I))                CROMAX
        CALL ALTER(XLOW(I,ACTIVE),XHI(I,ACTIVE),I,BDLY)                 CROMAX
        CALL HOLD(XLOW(I,ACTIVE),XHI(I,ACTIVE),YIELD(I),KNOW(I))        CROMAX
        STARTX=XHI(I,ACTIVE)+1                                          CROMAX
  130 CONTINUE                                                          CROMAX
  126 COMB=COMB+1                                                       CROMAX
      GO TO 85                                                          CROMAX
  125 RIPCOM(1,TRYSEC)=1                                                CROMAX
      TRYSEC=TRYSEC-1                                                   CROMAX
      IF(TRYSEC.GT.0)GO TO 127                                          CROMAX
C *** ALL COMBINATIONS HAVE BEEN TRIED                                  CROMAX
C *** PRINT OUTPUT                                                      CROMAX
  200 NPIECE=0                                                          CROMAX
      CALL AMEND(BSEC,EDGE)                                             CROMAX
  205 IF(BAD)WRITE(6,77)NBOARD                                          CROMAX
      IF(BAD)NPIECE=-1                                                  CROMAX
      IF(BAD)WRITE(UNIT)NPIECE                                          CROMAX
      IF(BAD)GO TO 30                                                   CROMAX
      WRITE(6,210)                                                      CROMAX
  210 FORMAT(15X,'CUTTINGS')                                            CROMAX
      IF(NPIECE.EQ.0)GO TO 250                                          CROMAX
      YTEMP=0.                                                          CROMAX
      DO 230 I=1,NPIECE                                                 CROMAX
        LTEMP=PIECE(I,1)*GRID                                           CROMAX
        WTEMP=PIECE(I,2)*GRID                                           CROMAX
        VTEMP=VALUE(PIECE(I,1),PIECE(I,2))                              CROMAX
        WRITE(6,225)LTEMP,WTEMP,VTEMP                                   CROMAX
  225   FORMAT(10X,F6.2,' X',F6.2,3X,F11.3)                             CROMAX
      YTEMP=YTEMP+(LTEMP*WTEMP)                                         CROMAX
  230 CONTINUE                                                          CROMAX
      AREAC=(YTEMP/AREA)*100                                            CROMAX
      WRITE(6,240)AREA,AREAC,YTEMP                                      CROMAX
  240 FORMAT(10X,'TOTAL SURFACE AREA OF BOARD - ',F8.2/                 CROMAX
     *       16X,'TOTAL PERCENTAGE YIELD - ',F8.2/                      CROMAX
     *       15X,'TOTAL  AREA OF CUTTINGS - ',F8.2/)                    CROMAX
      IF(NV.NE.0)WRITE(6,245)Y(MAX)                                     CROMAX
  245 FORMAT(14X,'TOTAL VALUE OF CUTTINGS - ',F8.2)                     CROMAX
  250 WRITE(UNIT)AREA,AREAC,NPIECE                                      CROMAX
      WRITE(UNIT)((PIECE(I,J),J=1,2),I=1,NPIECE)                        CROMAX
      IF(NCUTS.LE.0)GO TO 30                                            CROMAX
      WRITE(6,255)                                                      CROMAX
  255 FORMAT(10X,'SAWCUT COORDINATES'/15X,'LX',5X,'LY',5X,'UX',5X,'UY'/) CROMAX
      WRITE(UNIT2,257)NCUTS                                             CROMAX
  257 FORMAT(I5)                                                        CROMAX
      DO 270 I=1,NCUTS                                                  CROMAX
        WRITE(6,260)(SAWCUT(I,J),J=1,4)                                 CROMAX
  260   FORMAT(10X,4I7)                                                 CROMAX
        WRITE(UNIT2,280) (SAWCUT(I,J),J=1,4)                            CROMAX
  280   FORMAT(4I10)                                                    CROMAX
  270 CONTINUE                                                          CROMAX
      GO TO 30                                                          CROMAX
  300 STOP                                                              CROMAX
      END                                                               CROMAX
```

```
*** STATEMENT NUMBERS ***

  5      23  *24
  6      25  *26
  7      32  *33
  8      31  *34
  9      27  *35
 10      28   35  *36
 15      29   30   37  *38   39
 20      40  *41
 25      42  *43
 30     *47   85  238  260  271
 35      48  *49
 40      50  *51   69   70
 43      55  *57
 45      54  *58
 50      64  *65
 55      53  *67
 60      77  *79
 65     *80
 75      68   71  *81
 77      83  *84  235
 78      67   82  *87
 80      93   94  *98
 85    *106  227
 87     118 *120
 90     108  109 *122
 93    *125
 95    *127  207
100     127  128  129 *133
110     137 *138
113     159  160  162 *171
115     150 *153
116     179  180  181  189 *197
117     185 *167
118    *158  177  178  199  205
120     139  146 *155
124     125  126  157  172 *209
125     214 *228
126     218 *226
127    *211  230
128     215 *216
130     219 *225
131     201 *202
132     203 *206
200    *233
205     134 *235
210     239 *240
225     247 *248
230     243 *250
240     252 *253
245     256 *257
250     241 *258
255     261 *262
257     263 *264
260     266 *267
270     265 *270
280     268 *269
300      48 *272
403     141 *143
404     144  145 *147
530      59  *60
```

```
*** VARIABLES ***

ACTIVE    *20  112  113  114  117  119  120  131  132  135  138  139
          145  147  151  152  174  186  187  188  190  194  195  220
          221  222  223  224
ALTCOM      9  *96 *163  164 *168  184  202 *216
ALTER     120  222
ALTSUM   *200 *202  203
AMEND     234
AREA        5  *63  251  252  258
AREAC       5 *251  252  258
BAD         6   10  *47  *52   53   71   82  128  134  235  236  237
          238
BDLX       10  *50   59   61   63   87  101  173  217
BDLY       10  *50   59   62   63  *66  120  222
BDUX       10  *50   52   59   61   63   87  114  190
BDUY       10  *50   52   59   62   63
BITS      *78
BOARD      11  *56   78
BSEC     *149  234
COMB      *99  118  144 *226
DLX        17  *69   70   73
DLY       *69   70  *72   77
DO65KX    *73
DONE        6  *92 *161 *169  172 *213
DUX        17  *69   70   73
DUY        17  *69   70   77
EDGE      *23   66  234
GRADE     *48   64
GRID        5  *21   61   62   63  244  245
HOLD      119  195  223
I         *29  *30  *31  *32  *37  *39  *40   41   42  *54   56  *68
          *69   70   73   77  *93   96   97 *108  109  110  111  112
          113  114  115  117  119  120 *127  129  131  132 *137  138
         *150  151  152  153 *159  161  162  163  164  166  168  169
         *179  180  182  183  184  185  186  187  188  190  191  194
          195 *215  216 *219  220  221  222  223  224 *243  244  245
          246  259 *265  266  268
IABS       75
IBIT      *75   78
INDEX       5   18  *19  *32
INTL      100
J         *32  *55   56  *94   95   98  259  266  268
K        *201  202
K1        *77   78
K2        *74   75  *76   78
KNOW        6  *97 *110  119  129 *182  195  223
KX         74   75
LAST        6   13
LENGTH     12  *37  *41   42   87  113  188  221
LINDEX     18  *30
LTEMP       5  *61   64 *244  247  249
MAX       *20   91  139  145  147  151  152  256
MAXSEC   *104 *106  109 *115  125  126  127  136  137  141  149  150
          159  176  177  178  180 *191  192 *198  201 *204 *212
MY        146 *148
NBOARD     10  *48   64   83  235
NCUTS      13 *107 *206  260  263  265
ND         17  *48   67   68  157
NDEF       17  161  162  164
NLEN       12  *35   40   42  214
NPIECE     13 *130 *233 *236  237  241  243  258  259
NSEC       16  *87  *88   94  103  104  106  108  212  215
NV         18  *25   27  256
NWID       12  *35   42
OK          6 *158  160 *165
OLDSEC   *103 *155  209
PIECE      13  244  245  246  259
PURE        6 *102  155 *156 *210
R        *141  142
REJECT      6 *175  181 *186  189 *192  198  199
REMEM     132
REVISE    184
```

```
RIPCOM     15   *98   113   142  *153   188  *211   214   221  *228
SAW       131
SAWCUT     13   266   268
STARTX   *101   112  *117  *173  *174   184   186   187  *194  *217   220  *224
TRIM        6   131
TRYSEC    *90   108   126   127  *136   155  *166   173   174   178   179  *209
          211   214   218   219   228  *229   230
TSEC     *176   179   198   204
TY       *140  *142   146   148
UNIT      *20   237   258   259
UNIT2     *20   263   268
VALUE       5   246
VLEN       18   *28   *30
VTEMP       5  *246   247
VWID       18   *28   *29
WIDTH      12   *39    42
WINDEX     18   *29
WINTL      45
WTEMP       5   *62    64  *245   247   249
XHI        15  *113   114   117   119   120   131   132  *152   174   186  *188
          190   194   195  *221   222   223   224
XLOW       15  *112   113   119   120   131   132  *151  *187   188   195  *220
          221   222   223
Y           9   *91  *135  *138   139   145  *147   256
YIELD      14   *95  *111   119   132   138  *183   195   223
YTEMP    *242  *249   251   252
```

Subroutine SAW

```
 1          SUBROUTINE SAW(XLOW,XHI,SECT)                                  SAW
 2 C ***    SCAN FOR CUTTINGS                                              SAW
 3          IMPLICIT INTEGER(A-Z)                                          SAW
 4          LOGICAL BAD,TRIM                                               SAW
 5          REAL YIELD                                                     SAW
 6          CHARACTER*5 NBOARD                                             SAW
 7          COMMON /ALL/NBOARD,BAD,BDLX,BDLY,BDUX,BDUY                     SAW
 8          COMMON /MS/BOARD(100,24)                                       SAW
 9          COMMON /MSR/LENGTH(10),NLEN,WIDTH(10),NWID                     SAW
10          COMMON /MRF/YIELD(25)                                          SAW
11          YIELD(SECT)=0                                                  SAW
12          CLRKNT=0                                                       SAW
13          YLOW=BDLY                                                      SAW
14          YHI=BDUY                                                       SAW
15          TRIM=.FALSE.                                                   SAW
16          IF((XHI-XLOW).GT.LENGTH(1))TRIM=.TRUE.                         SAW
17          IF(TRIM)CALL RANGE(XLOW,YLOW,XHI,YHI,SECT)                     SAW
18          DO 100 IY=(BDLY+1),BDUY                                        SAW
19            DO 50 IX=(XLOW+1),(XHI-1)                                    SAW
20              K2=IX/36                                                   SAW
21              IBIT=IABS(IX-K2*36)+1                                      SAW
22              K2=K2+1                                                    SAW
23              IF(BITS(BOARD(IY,K2),IBIT,1).EQ.0)GO TO 50                 SAW
24              GO TO 75                                                   SAW
25     50     CONTINUE                                                     SAW
26            CLRKNT=CLRKNT+1                                              SAW
27            GO TO 100                                                    SAW
28     75     IF(CLRKNT.LT.WIDTH(1))GO TO 80                               SAW
29          YHI=IY-1                                                       SAW
30            CALL RIP(XLOW,YLOW,XHI,YHI,CLRKNT,SECT,TRIM)                 SAW
31            IF(BAD)RETURN                                                SAW
32     80     YLOW=IY                                                      SAW
33            YHI=IY                                                       SAW
34            CLRKNT=0                                                     SAW
35    100 CONTINUE                                                         SAW
36          IF(CLRKNT.GE.WIDTH(1))THEN                                     SAW
37            YHI=BDUY                                                     SAW
38            CALL RIP(XLOW,YLOW,XHI,YHI,CLRKNT,SECT,TRIM)                 SAW
39          ENDIF                                                          SAW
40          IF(TRIM)CALL TRIMIT                                            SAW
41          RETURN                                                         SAW
42          END                                                            SAW
```

```
                    *** STATEMENT NUMBERS ***

  50        23   *25
  75        24   *28
  80        28   *32
 100        27   *35

                    *** VARIABLES ***

BAD          4     7    31
BDLX         7
BDLY         7    13    18
BDUX         7
BDUY         7    14    18    37
BITS        23
BOARD        8    23
```

```
CLRKNT     *12  *26   28   30  *34   36   38
DO100I     *18
DO50IX     *19
IABS        21
IBIT       *21   23
IX          20   21
IY          23   29   32   33
K2         *20   21  *22   23
LENGTH       9   16
NBOARD       7
NLEN         9
NWID         9
RANGE       17
RIP         30   38
SAW          1
SECT         1   11   17   30   38
TRIM         4  *15  *16   17   30   38   40
TRIMIT      40
WIDTH        9   28   36
XHI          1   16   17   19   30   38
XLOW         1   16   17   19   30   38
YHI        *14   17  *29   30  *33  *37   38
YIELD        5   10  *11
YLOW       *13   17   30  *32   38
```

Subroutine RIP

```
 1       SUBROUTINE RIP(LX,LY,UX,UY,CLRKNT,SECT,TRIM)                    RIP
 2 C *** SAW CUTTINGS                                                    RIP
 3       IMPLICIT INTEGER(A-Z)                                           RIP
 4       REAL VALUE                                                      RIP
 5       LOGICAL OK,LAST,DONE,TRIM                                       RIP
 6       DIMENSION WCOM(25)                                              RIP
 7       COMMON /MSR/LENGTH(10),NLEN,WIDTH(10),NWID                      RIP
 8       COMMON /MRA/NCUTS,SAWCUT(200,4),LAST,PIECE(100,2),NPIECE        RIP
 9       DATA ACTIVE/1/,MAX/2/                                           RIP
10 C *** CALCULATE BEST WIDTH COMBINATION TO USE                         RIP
11       NW=0                                                            RIP
12       CALL WFIND(CLRKNT,WCOM,NW,(UX-LX))                              RIP
13       IF(NW.EQ.0)RETURN                                               RIP
14       DO 50 I=1,NW                                                    RIP
15         YHI=LY+WIDTH(WCOM(I))                                         RIP
16         CALL CUTUP(LX,LY,UX,YHI,SECT)                                 RIP
17         IF(TRIM)CALL STORE(LX,LY,UX,YHI)                              RIP
18         LY=YHI+1                                                      RIP
19    50 CONTINUE                                                        RIP
20       RETURN                                                          RIP
21       END                                                             RIP
```

```
                     *** STATEMENT NUMBERS ***

  50         14  *19

                     *** VARIABLES ***

ACTIVE      *9
CLRKNT       1   12
CUTUP       16
DONE         5
I          *14   15
LAST         5    8
LENGTH       7
LX           1   12   16   17
LY           1   15   16   17  *18
MAX         *9
NCUTS        8
NLEN         7
NPIECE       8
NW         *11   12   13   14
NWID         7
OK           5
PIECE        8
RIP          1
SAWCUT       8
SECT         1   16
STORE       17
TRIM         1    5   17
UX           1   12   16   17
UY           1
VALUE        4
WCOM         6   12   15
WFIND       12
WIDTH        7   15
YHI        *15   16   17   18
```

Subroutine RANGE

```
      SUBROUTINE RANGE(PLX,PLY,PUX,PUY,SECT)                          RANGE
      IMPLICIT INTEGER(A-Z)                                           RANGE
      LOGICAL BAD,TRIM,LAST,NOGOOD,WHOLE,TWICE,RIP                    RANGE
      DIMENSION COORD(25,4),TPIECE(25,4),WCOM(25)                     RANGE
      CHARACTER*5 NBOARD                                              RANGE
      COMMON/ALL/NBOARD,BAD,BDLX,BDLY,BDUX,BDUY                       RANGE
      COMMON/MS/BOARD(100,24)                                         RANGE
      COMMON /MRA/NCUTS,SAWCUT(200,4),LAST,PIECE(100,2),NPIECE        RANGE
      COMMON/MAFG/RIPCOM(2,25),XDUM1(25,2),XDUM2(25,2)                RANGE
      COMMON/MSR/LENGTH(10),NLEN,WIDTH(10),NWID                       RANGE
      DATA LX/1/,LY/2/,UX/3/,UY/4/                                    RANGE
      NP=0                                                            RANGE
      LMAX=RIPCOM(1,SECT)                                             RANGE
      IF(LAST)LMAX=RIPCOM(2,SECT)                                     RANGE
      RETURN                                                          RANGE
                                                                      RANGE
                                                                      RANGE
      ENTRY TRIMIT                                                    RANGE
C *** CHECK IF POSSIBLE TRIM PIECES EXIST                               RANGE
C     WRITE(6,200)                                                    RANGE
  200 FORMAT(25X,'TRIMIT ENTERED')                                    RANGE
      WHOLE=.TRUE.                                                    RANGE
      IF(NP.GT.0)WHOLE=.FALSE.                                        RANGE
      LIMIT=NP                                                        RANGE
      IF(WHOLE)LIMIT=1                                                RANGE
      TP=1                                                            RANGE
      DO 20 I=1,LIMIT                                                 RANGE
        IF(BAD)GO TO 20                                               RANGE
        TWICE=.FALSE.                                                 RANGE
        TPIECE(TP,LX)=PLX                                             RANGE
        TPIECE(TP,UX)=PUX                                             RANGE
        IF(.NOT.WHOLE)GO TO 10                                        RANGE
        TPIECE(TP,LY)=BDLY                                            RANGE
        TPIECE(TP,UY)=BDUY                                            RANGE
        TP=TP+1                                                       RANGE
        GO TO 20                                                      RANGE
   10   TPIECE(TP,LY)=COORD(I,UY)+1                                   RANGE
        IF(TPIECE(TP,LY).GT.BDUY)GO TO 19                             RANGE
   15   IF(I.LT.LIMIT)THEN                                            RANGE
        TPIECE(TP,UY)=COORD(I+1,LY)-1                                 RANGE
        ELSE                                                          RANGE
        TPIECE(TP,UY)=BDUY                                            RANGE
        ENDIF                                                         RANGE
   17   IF((TPIECE(TP,UY)-TPIECE(TP,LY)).GE.WIDTH(1))TP=TP+1          RANGE
        IF(TP.LE.25)GO TO 19                                          RANGE
        BAD=.TRUE.                                                    RANGE
        WRITE(6,18)NBOARD                                             RANGE
   18   FORMAT(15X,20(1H*),' OVERFLOW IN TRIMIT',A5,20(1H*))          RANGE
        TP=25                                                         RANGE
        GO TO 20                                                      RANGE
   19   IF(TWICE)GO TO 20                                             RANGE
        TWICE=.TRUE.                                                  RANGE
        TPIECE(TP,UY)=COORD(I,LY)-1                                   RANGE
        IF(TPIECE(TP,UY).LE.BDLY)GO TO 20                             RANGE
        IF(I.EQ.1)THEN                                                RANGE
        TPIECE(TP,LY)=BDLY                                            RANGE
        ELSE                                                          RANGE
        TPIECE(TP,LY)=COORD(I-1,UY)+1                                 RANGE
        ENDIF                                                         RANGE
        TPIECE(TP,LX)=PLX                                             RANGE
        TPIECE(TP,UX)=PUX                                             RANGE
        GO TO 17                                                      RANGE
   20 CONTINUE                                                        RANGE
       IF(BAD)RETURN                                                  RANGE
      TP=TP-1                                                         RANGE
      IF(TP.LE.0)RETURN                                               RANGE
      IF(TP.LT.2)GO TO 24                                             RANGE
C *** MAKE SURE  NO TP'S ARE DUPLICATED                                 RANGE
      TEST=1                                                          RANGE
  170 ICOPY=0                                                         RANGE
      DO 180 I=1,TP                                                   RANGE
        IF(ICOPY.GT.0)GO TO 180                                       RANGE
        IF(I.EQ.TEST)GO TO 180                                        RANGE
        IF(TPIECE(TEST,LX).NE.TPIECE(I,LX))GO TO 180                  RANGE
        IF(TPIECE(TEST,LY).NE.TPIECE(I,LY))GO TO 180                  RANGE
        IF(TPIECE(TEST,UX).NE.TPIECE(I,UX))GO TO 180                  RANGE
        IF(TPIECE(TEST,UY).EQ.TPIECE(I,UY))ICOPY=I                    RANGE
  180 CONTINUE                                                        RANGE
      IF(ICOPY.GT.0)GO TO 185                                         RANGE
  183 TEST=TEST+1                                                     RANGE
      IF(TEST.GT.TP)GO TO 24                                          RANGE
C *** REMOVE TEST                                                       RANGE
  185 IF(TEST.GE.TP)GO TO 24                                          RANGE
      DO 190 K=TEST,TP                                                RANGE
        TPIECE(K,LX)=TPIECE(K+1,LX)                                   RANGE
        TPIECE(K,LY)=TPIECE(K+1,LY)                                   RANGE
        TPIECE(K,UX)=TPIECE(K+1,UX)                                   RANGE
        TPIECE(K,UY)=TPIECE(K+1,UY)                                   RANGE
  190 CONTINUE                                                        RANGE
      GO TO 183                                                       RANGE
C *** CHECK EACH POTENTIAL PIECE FOR GOOD TRIMMEND PIECE                RANGE
C *** INFINITE ADDITIONAL CC ALLOWED                                    RANGE
   24 DO 150 I=1,TP                                                   RANGE
        CALL TINTL                                                    RANGE
        RIP=.FALSE.                                                   RANGE
        DO 140 TRIAL=1,2                                              RANGE
        NOGOOD=.FALSE.                                                RANGE
        IF(TRIAL.EQ.2)RIP=.TRUE.                                      RANGE
        IF(RIP.AND.(TPIECE(I,UY)-TPIECE(I,LY)).LE.WIDTH(1))GO TO 140  RANGE
        CLRKNT=0                                                      RANGE
        XLOW=TPIECE(I,LX)                                             RANGE
        XHI=TPIECE(I,UX)                                              RANGE
        YLOW=TPIECE(I,LY)                                             RANGE
        YHI=TPIECE(I,UY)                                              RANGE
        DO 80 IX=(TPIECE(I,LX)+1),TPIECE(I,UX)                        RANGE
          IF(NOGOOD)GO TO 80                                          RANGE
          K2=IX/36                                                    RANGE
          IBIT=IABS(IX-K2*36)+1                                       RANGE
          K2=K2+1                                                     RANGE
   25     DO 30 IY=(YLOW+1),YHI                                       RANGE
            IF(BITS(BOARD(IY,K2),IBIT,1).EQ.0)GO TO 30                RANGE
             GO TO 35                                                 RANGE
   30     CONTINUE                                                    RANGE
          CLRKNT=CLRKNT+1                                             RANGE
        IF(IX.EQ.TPIECE(I,UX))GO TO 35                                RANGE
          GO TO 80                                                    RANGE
C *** DEFECT DETECTED                                                   RANGE
   35     IF(RIP)GO TO 45                                             RANGE
          IF(CLRKNT.GE.LENGTH(1))GO TO 40                             RANGE
          XLOW=IX                                                     RANGE
          CLRKNT=0                                                    RANGE
          YLOW=TPIECE(I,LY)                                           RANGE
          YHI=TPIECE(I,UY)                                            RANGE
          IF((TPIECE(I,UX)-XLOW).LT.LENGTH(1))NOGOOD=.TRUE.           RANGE
          GO TO 80                                                    RANGE
   40     XHI=IX                                                      RANGE
          ALEN=XHI-XLOW                                               RANGE
          IL=0                                                        RANGE
          DO 55 K=1,LMAX                                              RANGE
            IF(LENGTH(K).LE.ALEN)IL=K                                 RANGE
   55     CONTINUE                                                    RANGE
          IF(IL.EQ.0)GO TO 75                                         RANGE
       XHI=XLOW+LENGTH(IL)                                            RANGE
          CALL WFIND(YHI-YLOW,WCOM,WCNT,LENGTH(IL))                   RANGE
          IF(WCNT.EQ.0)GO TO 75                                       RANGE
          TYLOW=YLOW                                                  RANGE
          DO 60 K=1,WCNT                                              RANGE
            YHI=YLOW+WIDTH(WCOM(K))                                   RANGE
            CALL TSTORE(XLOW,YLOW,XHI,YHI,TRIAL,SECT)                 RANGE
            YLOW=YHI+1                                                RANGE
   60     CONTINUE                                                    RANGE
        XLOW=IX                                                       RANGE
       CLRKNT=0                                                       RANGE
       XHI=TPIECE(I,UX)                                               RANGE
```

```
145          YLOW=TYLOW                                                       RANGE
146        IF((XHI-XLOW).LT.LENGTH(1))NOGOOD=.TRUE.                           RANGE
147            GO TO 80                                                       RANGE
148     75     XLOW=IX                                                        RANGE
149            YLOW=TPIECE(I,LY)                                              RANGE
150            YHI=TPIECE(I,UY)                                               RANGE
151            CLRKNT=0                                                       RANGE
152            IF((XHI-XLOW).LT.LENGTH(1))NOGOOD=.TRUE.                       RANGE
153            GO TO 80                                                       RANGE
154 C ***   CHECK IF RIPPING IS POSSIBLE                                      RANGE
155     45     CLRWID=0                                                       RANGE
156            DO 47 M=(YLOW+1),YHI                                           RANGE
157              CLRWID=CLRWID+BITS(BOARD(M,K2),IBIT,1)                       RANGE
158     47     CONTINUE                                                       RANGE
159            IF(((YHI-YLOW)-CLRWID).LT.WIDTH(1))GO TO 78                    RANGE
160            IF(IY-YLOW.LE.WIDTH(1))GO TO 77                                RANGE
161            YHI=IY-1                                                       RANGE
162            CLRKNT=CLRKNT+1                                                RANGE
163            GO TO 80                                                       RANGE
164     77     IF((YHI-IY).LT.WIDTH(1))GO TO 78                               RANGE
165            YLOW=IY                                                        RANGE
166            CLRKNT=CLRKNT+1                                                RANGE
167            GO TO 80                                                       RANGE
168     78     IF(CLRKNT.GE.LENGTH(1))GO TO 40                                RANGE
169            XLOW=IX                                                        RANGE
170            CLRKNT=0                                                       RANGE
171            YLOW=TPIECE(I,LY)                                              RANGE
172            YHI=TPIECE(I,UY)                                               RANGE
173            IF((XHI-XLOW).LT.LENGTH(1))NOGOOD=.TRUE.                       RANGE
174     80   CONTINUE                                                         RANGE
175    140   CONTINUE                                                         RANGE
176          CALL RETREV                                                      RANGE
177    150 CONTINUE                                                           RANGE
178        RETURN                                                             RANGE
179        ENTRY STORE(TLX,TLY,TUX,TUY)                                       RANGE
180        NP=NP+1                                                            RANGE
181        IF(NP.LE.25)GO TO 160                                              RANGE
182        BAD=.TRUE.                                                         RANGE
183        WRITE(6,155)NBOARD                                                 RANGE
184    155 FORMAT(25X,15(1H*),' OVERFLOW IN STORE',A5,15(1H*))                RANGE
185        RETURN                                                             RANGE
186    160 COORD(NP,LX)=TLX                                                   RANGE
187        COORD(NP,LY)=TLY                                                   RANGE
188        COORD(NP,UX)=TUX                                                   RANGE
189        COORD(NP,UY)=TUY                                                   RANGE
190        RETURN                                                             RANGE
191        END                                                                RANGE
```

```
                    *** STATEMENT NUMBERS ***

10      32   *37
15     *39
17     *44    62
18      47   *48
19      38    45   *51
20      27    28    36    50    51    54   *63
24      67    81    83   *93
25    *110
30     111  *113
35     112   115  *118
40     119  *126   168
45     118  *155
47    *158
55     129  *131
60     137  *141
75     132   135  *148
77     160  *164
78     159   164  *168
80     106   116   125   147   153   163   167  *174
140     96    99  *175
150     93  *177
155    183  *184
160    181  *186
170    *70
180     71    72    73    74    75    76   *78
183    *80    90
185     79   *83
190     84   *89
200    *21
```

```
                    *** VARIABLES ***

ALEN     *127   130
BAD         3     6    28   *46    64  *182
BDLX        6
BDLY        6    33    54    56
BDUX        6
BDUY        6    34    38    42
BITS      111   157
BOARD       7   111   157
CLRKNT   *100  *114   119  *121  *143  *151  *162  *166   168  *170
CLRWID   *155  *157   159
COORD       4    37    40    53    58  *186  *187  *188  *189
DO30IY   *110
DO47M    *156
DO80IX   *105
I         *27    37    39    40    53    55    58   *71    73    74    75    76
           77   *93    99   101   102   103   104   105   115   122   123   124
          144   149   150   171   172
IABS      108
IBIT     *108   111   157
ICOPY     *70    72   *77    79
IL       *128  *130   132   133   134
IX        107   108   115   120   126   142   148   169
IY        111   160   161   164   165
K         *84    85    86    87    88  *129   130  *137   138
K2       *107   108  *109   111   157
LAST        3     8    14
LENGTH     10   119   124   130   133   134   146   152   168   173
LIMIT     *24   *25    27    39
LMAX      *13   *14   129
LX        *11    30    60    74    85   101   105   186
LY        *11    33    37    38    40    44    53    56    58    75    86    99
          103   122   149   171   187
M         157
NBOARD      6    47   183
NCUTS       8
NLEN       10
NOGOOD      3   *97   106  *124  *146  *152  *173
NP        *12    23    24  *180   181   186   187   188   189
NPIECE      8
NWID       10
PIECE       8
PLX         1    30    60
PLY         1
PUX         1    31    61
PUY         1
RANGE       1
RETREV    176
RIP         3   *95   *98    99   118
RIPCOM      9    13    14
SAWCUT      8
SECT        1    13    14   139
STORE     179
TEST      *69    73    74    75    76    77   *80    81    83    84
TINTL      94
TLX       179   186
```

```
TLY        179   187
TP         *26    30    31    33    34   *35    37    38    40    42   *44    45
           *49    53    54    56    58    60    61   *65    66    67    71    81
            83    84    93
TPIECE       4   *30   *31   *33   *34   *37    38   *40   *42    44   *53    54
          *56,   *58   *60   *61    74    75    76    77   *85   *86   *87   *88
            99   101   102   103   104   105   115   122   123   124   144   149
           150   171   172
TRIAL      *96    98   139
TRIM         3
TRIMIT      18
TSTORE     139
TUX        179   188
TUY        179   189
TWICE        3   *29    51   *52
TYLOW     *136   145
UX         *11    31    61    76    87   102   105   115   124   144   188
UY         *11    34    37    40    42    44    53    54    58    77    88    99
           104   123   150   172   189
WCNT       134   135   137
WCOM         4   134   138
WFIND      134
WHOLE        3   *22   *23    25    32
WIDTH       10    44    99   138   159   160   164
XDUM1        9
XDUM2        9
XHI       *102  *126   127  *133   139  *144   146   152   173
XLOW      *101  *120   124   127   133   139  *142   146  *148   152  *169   173
YHI       *104   110  *123   134  *138   139   140  *150   156   159  *161   164
          *172
YLOW      *103   110  *122   134   136   138   139  *140  *145  *149   156   159
           160  *165  *171
```

Subroutine AMEND

```
      SUBROUTINE AMEND(BSEC,EDGE)                                       AMEND
C *** SMOOTH OUT ANSWERS                                                 AMEND
      IMPLICIT INTEGER(A-Z)                                             AMEND
      LOGICAL BAD,LAST,TRIM                                             AMEND
      CHARACTER*5 NBOARD                                                AMEND
      COMMON /ALL/NBOARD,BAD,BDLX,BDLY,BDUX,BDUY                        AMEND
      COMMON /MSR/LENGTH(10),NLEN,WIDTH(10),NWID                        AMEND
      COMMON /MRA/NCUTS,SAWCUT(200,4),LAST,PIECE(100,2),NPIECE          AMEND
      COMMON /MAFG/RIPCOM(2,25),XLOW(25,2),XHI(25,2)                    AMEND
      COMMON /MATFG/NSEC                                                AMEND
      DATA ACTIVE/1/,MAX/2/                                             AMEND
      NCUTS=0                                                           AMEND
      IF(EDGE.LE.0)GO TO 30                                             AMEND
      NCUTS=NCUTS+1                                                     AMEND
      SAWCUT(NCUTS,1)=BDLX                                              AMEND
      SAWCUT(NCUTS,2)=BDLY-EDGE                                         AMEND
      SAWCUT(NCUTS,3)=BDUX                                              AMEND
      SAWCUT(NCUTS,4)=BDLY                                              AMEND
   30 LAST=.TRUE.                                                       AMEND
      DO 100 I=1,BSEC                                                   AMEND
        IF(BAD)GO TO 100                                                AMEND
       IF((XLOW(I,MAX)-1).LT.BDLX)GO TO 65                              AMEND
       NCUTS=NCUTS+1                                                    AMEND
   45  IF(NCUTS.LE.200)GO TO 60                                         AMEND
         WRITE(6,50)NBOARD                                              AMEND
   50    FORMAT(10X,'TOO MANY SAWCUTS',A5)                              AMEND
         BAD=.TRUE.                                                     AMEND
       GO TO 100                                                        AMEND
   60  SAWCUT(NCUTS,1)=XLOW(I,MAX)-1                                    AMEND
       SAWCUT(NCUTS,2)=BDLY                                             AMEND
       SAWCUT(NCUTS,3)=XLOW(I,MAX)                                      AMEND
       SAWCUT(NCUTS,4)=BDUY                                             AMEND
   65 IF((XHI(I,MAX)+1).GT.BDUX)GO TO 75                                AMEND
      NCUTS=NCUTS+1                                                     AMEND
       IF(NCUTS.GT.200)GO TO 45                                         AMEND
       SAWCUT(NCUTS,1)=XHI(I,MAX)                                       AMEND
       SAWCUT(NCUTS,2)=BDLY                                             AMEND
       SAWCUT(NCUTS,3)=XHI(I,MAX)+1                                     AMEND
       SAWCUT(NCUTS,4)=BDUY                                             AMEND
   75  CALL SAW(XLOW(I,MAX),XHI(I,MAX),I,TRIM)                          AMEND
  100 CONTINUE                                                          AMEND
      RETURN                                                            AMEND
      END                                                               AMEND
```

```
                 *** STATEMENT NUMBERS

   30      13   *19
   45     *24    35
   50      25   *26
   60      24   *29
   65      22   *33
   75      33   *40
  100      20    21    28   *41


                 *** VARIABLES ***

ACTIVE    *11
AMEND       1
BAD         4     6    21   *27
```

```
BDLX        6    15    22
BDLY        6    16    18    30    37
BDUX        6    17    33
BDUY        6    32    39
BSEC        1    20
EDGE        1    13    16
I         *20    22    29    31    33    36    38    40
LAST        4     8   *19
LENGTH      7
MAX       *11    22    29    31    33    36    38    40
NBOARD      6    25
NCUTS       8   *12   *14    15    16    17    18   *23    24    29    30    31
           32   *34    35    36    37    38    39
NLEN        7
NPIECE      8
NSEC       10
NWID        7
PIECE       8
RIPCOM      9
SAW        40
SAWCUT      8   *15   *16   *17   *18   *29   *30   *31   *32   *36   *37   *38
          *39
TRIM        4    40
WIDTH       7
XHI         9    33    36    38    40
XLOW        9    22    29    31    40
```

Subroutine ALTER

```
 1        SUBROUTINE ALTER(XLOW,XHI,SECT,BDLY)                         ALTER
 2        IMPLICIT INTEGER(A-Z)                                        ALTER
 3        DIMENSION CHG(25,50)                                         ALTER
 4        LOGICAL HAVEIT                                               ALTER
 5        COMMON /MC/ND,DLX(100),DUX(100),NDEF(25),DUY(100)            ALTER
 6        IF(ND.EQ.0)RETURN                                            ALTER
 7        NDEF(SECT)=0                                                 ALTER
 8        DO 25 I=1,ND                                                 ALTER
 9          IF(DUY(I).LE.BDLY)GO TO 25                                 ALTER
10          IF(DLX(I).GE.XHI)GO TO 25                                  ALTER
11          IF(DUX(I).LE.XLOW)GO TO 25                                 ALTER
12          IF(DUX(I).GE.XHI)GO TO 25                                  ALTER
13          IF(NDEF(SECT).EQ.0)GO TO 15                                ALTER
14          HAVEIT=.FALSE.                                             ALTER
15          DO 10 K=1,NDEF(SECT)                                       ALTER
16            IF(HAVEIT)GO TO 10                                       ALTER
17            IF(DUX(I).EQ.CHG(SECT,K))HAVEIT=.TRUE.                   ALTER
18     10   CONTINUE                                                   ALTER
19          IF(HAVEIT)GO TO 25                                         ALTER
20     15   NDEF(SECT)=NDEF(SECT)+1                                    ALTER
21          CHG(SECT,NDEF(SECT))=DUX(I)                                ALTER
22     25 CONTINUE                                                     ALTER
23        RETURN                                                       ALTER
24        ENTRY REVISE(SECT,NEWLX,ALTCOM)                              ALTER
25        NEWLX=CHG(SECT,ALTCOM)                                       ALTER
26        RETURN                                                       ALTER
27        END                                                          ALTER
```

```
                    *** STATEMENT NUMBERS ***

  10        15    16   *18
  15        13   *20
  25         8     9    10    11    12    19   *22
```

```
                    *** VARIABLES ***

ALTCOM      24    25
ALTER        1
BDLY         1     9
CHG          3    17   *21    25
DLX          5    10
DUX          5    11    12    17    21
DUY          5     9
HAVEIT       4   *14    16   *17    19
I           *8     9    10    11    12    17    21
K          *15    17
ND           5     6     8
NDEF         5    *7    13    15   *20    21
NEWLX       24   *25
REVISE      24
SECT         1     7    13    15    17    20    21    24    25
XHI          1    10    12
XLOW         1    11
```

Subroutine CUTUP

```
 1        SUBROUTINE CUTUP(LX,LY,UX,UY,SECT)
 2        IMPLICIT INTEGER(A-Z)
 3        LOGICAL BAD,LAST
 4        REAL YIELD,VALUE
 5        CHARACTER*5 NBOARD
 6        COMMON /ALL/NBOARD,BAD,BDLX,BDLY,BDUX,BDUY
 7        COMMON /MRA/NCUTS,SAWCUT(200,4),LAST,PIECE(100,2),NPIECE
 8        COMMON/MRF/YIELD(25)
 9        NPIECE=NPIECE+1
10        IF(NPIECE.LE.100)GO TO 50
11          WRITE(6,75)SECT
12    75    FORMAT(10X,'SECTION',I3,'EXCEEDS CUTTING LIMIT')
13          BAD=.TRUE.
14        RETURN
15    50    PIECE(NPIECE,1)=UX-LX
16          PIECE(NPIECE,2)=UY-LY
17          YIELD(SECT)=YIELD(SECT)+VALUE(PIECE(NPIECE,1),PIECE(NPIECE,2))
18        IF(.NOT.LAST)GO TO 90
19          IF((LY.EQ.BDLY))GO TO 85
20          NCUTS=NCUTS+1
21    77    IF(NCUTS.GT.200)THEN
22          WRITE(6,80)NBOARD
23          BAD=.TRUE.
24        ELSE
25    80    FORMAT(10X,'TOO MANY SAWCUTS',A5)
26          IF(NCUTS.GT.100)BAD=.TRUE.
27          SAWCUT(NCUTS,1)=LX
28          SAWCUT(NCUTS,2)=LY-1
29          SAWCUT(NCUTS,3)=UX
30          SAWCUT(NCUTS,4)=LY
31          ENDIF
32    85    IF(BDUY.EQ.UY)GO TO 90
33          NCUTS=NCUTS+1
34          IF(NCUTS.GT.200)THEN
35          WRITE(6,80)NBOARD
36          BAD=.TRUE.
37          ELSE
38          SAWCUT(NCUTS,1)=LX
39          SAWCUT(NCUTS,2)=UY
40          SAWCUT(NCUTS,3)=UX
41          SAWCUT(NCUTS,4)=UY+1
42          ENDIF
43    90  RETURN
44        END
```

```
                  *** STATEMENT NUMBERS ***

   50        10   *15
   75        11   *12
   77       *21
   80        22   *25    35
   85        19   *32
   90        18    32   *43

                  *** VARIABLES ***

BAD          3     6   *13   *23   *26   *36
BDLX         6
BDLY         6    19
BDUX         6
BDUY         6    32
CUTUP        1
LAST         3     7    18
LX           1    15    27    38
LY           1    16    19    28    30
NBOARD       6    22    35
NCUTS        7   *20    21    26    27    28    29    30   *33    34    38    39
            40    41
NPIECE       7    *9    10    15    16    17
PIECE        7   *15   *16    17
SAWCUT       7   *27   *28   *29   *30   *38   *39   *40   *41
SECT         1    11    17
UX           1    15    29    40
UY           1    16    32    39    41
VALUE        4    17
YIELD        4     8   *17
```

Subroutine HOLD

```
 1        SUBROUTINE HOLD(NEWLX,NEWUX,YIELD,HERE)                        HOLD
 2 C ***  STORE RESULTS OF SECTIONS                                      HOLD
 3        IMPLICIT INTEGER(A-X)                                          HOLD
 4        CHARACTER*5 NBOARD                                             HOLD
 5        LOGICAL HERE,BAD                                               HOLD
 6        DIMENSION INDEX(900,2),YSTORE(900)                             HOLD
 7        COMMON/ALL/NBOARD,BAD,BDLX,BDLY,BDUX,BDUY                      HOLD
 8        DATA LX/1/,UX/2/                                               HOLD
 9        HERE=.FALSE.                                                   HOLD
10        IF(NCOMB.LE.0)RETURN                                           HOLD
11        DO 25 I=1,NCOMB                                                HOLD
12          IF(HERE)GO TO 25                                             HOLD
13          IF(INDEX(I,LX).NE.NEWLX)GO TO 25                             HOLD
14          IF(INDEX(I,UX).NE.NEWUX)GO TO 25                             HOLD
15          HERE=.TRUE.                                                  HOLD
16          YIELD=YSTORE(I)                                              HOLD
17     25 CONTINUE                                                       HOLD
18        RETURN                                                         HOLD
19                                                                       HOLD
20        ENTRY INTL                                                     HOLD
21        NCOMB=0                                                        HOLD
22        RETURN                                                         HOLD
23                                                                       HOLD
24        ENTRY REMEM(XLOW,XHI,YLD)                                      HOLD
25        NCOMB=NCOMB+1                                                  HOLD
26        IF(NCOMB.GT.900)THEN                                           HOLD
27          WRITE(6,50)NBOARD                                            HOLD
28     50   FORMAT(15X,25(1H*),'TOO MANY COMBINATION IN',A5,25(1H*))     HOLD
29          BAD=.TRUE.                                                   HOLD
30        ELSE                                                           HOLD
31          INDEX(NCOMB,LX)=XLOW                                         HOLD
32          INDEX(NCOMB,UX)=XHI                                          HOLD
33          YSTORE(NCOMB)=YLD                                            HOLD
34        ENDIF                                                          HOLD
35        RETURN                                                         HOLD
36        END                                                            HOLD
```

```
                 ***  STATEMENT NUMBERS  ***

  25        11    12    13    14   *17
  50        27   *28
```

```
                 ***  VARIABLES  ***

BAD         6     7   *29
BDLX        7
BDLY        7
BDUX        7
BDUY        7
HERE        1     5    *9    12   *15
HOLD        1
I         *11    13    14    16
INDEX       6    13    14   *31   *32
INTL       20
LX         *8    13    31
NBOARD      7    27
NCOMB      10    11   *21   *25    26    31    32    33
NEWLX       1    13
NEWUX       1    14
REMEM      24
UX         *8    14    32
XHI        24    32
XLOW       24    31
YIELD       1   *16
YLD        24    33
YSTORE      6    16   *33
```

Subroutine WFIND

```
 1        SUBROUTINE WFIND(CLRKNT,DCOM,DN,LEN)                              WFIND
 2        IMPLICIT INTEGER(A-Z)                                             WFIND
 3        LOGICAL DONE,OK,BAD                                               WFIND
 4        REAL MAXV,V,VALUE                                                 WFIND
 5        CHARACTER*5 NBOARD                                                WFIND
 6        DIMENSION WCOM(25,2),NW(2),DCOM(25),NDONE(10),CLRWID(10,100),    WFIND
 7       *          CLRCOM(10,100,26)                                       WFIND
 8        COMMON/ALL/NBOARD,BAD,BDLX,BDLY,BDUX,BDUY                         WFIND
 9        COMMON /MSR/LENGTH(10),NLEN,WIDTH(10),NWID                        WFIND
10        DATA ACTIVE/1/,MAX/2/                                             WFIND
11        DONE=.FALSE.                                                      WFIND
12 C *** CHECK IF WCOM HAS BEEN CALCULATEDALREADY                            WFIND
13        ILEN=0                                                            WFIND
14        DO 100 I=1,NLEN                                                   WFIND
15          IF(ILEN.GT.0)GO TO 100                                          WFIND
16          IF(LEN.LE.LENGTH(I))ILEN=I                                      WFIND
17    100 CONTINUE                                                          WFIND
18        IF(ILEN.LE.0)THEN                                                 WFIND
19          BAD=.TRUE.                                                      WFIND
20          WRITE(6,110)NBOARD                                              WFIND
21    110   FORMAT(15X,'SCREW UP IN WFIND, BOARD NUMBER ',A5)               WFIND
22        ENDIF                                                             WFIND
23        IF(BAD)RETURN                                                     WFIND
24        IF(NDONE(ILEN).EQ.0)GO TO 5                                       WFIND
25        N=0                                                               WFIND
26        DO 130 I=1,NDONE(ILEN)                                            WFIND
27          IF(N.GT.0)GO TO 130                                             WFIND
28          IF(CLRKNT.EQ.CLRWID(ILEN,I))N=I                                 WFIND
29    130 CONTINUE                                                          WFIND
30        IF(N.EQ.0)GO TO 5                                                 WFIND
31        DN=CLRCOM(ILEN,N,1)                                               WFIND
32        IF(DN.EQ.0)RETURN                                                 WFIND
33        DO 150 I=1,DN                                                     WFIND
34          DCOM(I)=CLRCOM(ILEN,N,I+1)                                      WFIND
35    150 CONTINUE                                                          WFIND
36        RETURN                                                            WFIND
37      5 MAXV=0                                                            WFIND
38        MAXW=(CLRKNT+1)/(WIDTH(1)+1)                                      WFIND
39        DO 10 I=1,MAXW                                                    WFIND
40     10   WCOM(I,ACTIVE)=1                                                WFIND
41        NW(ACTIVE)=MAXW                                                   WFIND
42     20 V=0                                                               WFIND
43        IF(NW(ACTIVE).LE.0)GO TO 35                                       WFIND
44        DO 25 I=1,NW(ACTIVE)                                              WFIND
45          V=V+VALUE(LENGTH(ILEN),WIDTH(WCOM(I,ACTIVE)))                   WFIND
46     25 CONTINUE                                                          WFIND
47        IF(V.LT.0)GO TO 35                                                WFIND
48        IF(V.LT.MAXV)GO TO 35                                             WFIND
49        NW(MAX)=NW(ACTIVE)                                                WFIND
50        DO 30 I=1,NW(MAX)                                                 WFIND
51     30   WCOM(I,MAX)=WCOM(I,ACTIVE)                                      WFIND
52        MAXV=V                                                            WFIND
53     35 OK=.FALSE.                                                        WFIND
54        DO 40 I=MAXW,1,-1                                                 WFIND
55          IF(OK)GO TO 40                                                  WFIND
56          WCOM(I,ACTIVE)=WCOM(I,ACTIVE)+1                                 WFIND
57          IF(WCOM(I,ACTIVE).GT.NWID)THEN                                  WFIND
58            WCOM(I,ACTIVE)=1                                              WFIND
59            IF(I.EQ.1)DONE=.TRUE.                                         WFIND
60          ELSE                                                            WFIND
61            SUM=0                                                         WFIND
62            OK=.TRUE.                                                     WFIND
63            NW(ACTIVE)=0                                                  WFIND
64            DO 38 K=1,MAXW                                                WFIND
65          SUM=SUM+WIDTH(WCOM(K,ACTIVE))                                   WFIND
66          IF(K.GT.1)SUM=SUM+1                                             WFIND
67              IF(SUM.LE.CLRKNT)NW(ACTIVE)=NW(ACTIVE)+1                    WFIND
68     38   CONTINUE                                                        WFIND
69          ENDIF                                                           WFIND
70     40 CONTINUE                                                          WFIND
71        MAXW=NW(ACTIVE)                                                   WFIND
72        IF(MAXW.EQ.0)DONE=.TRUE.                                          WFIND
73        IF(.NOT.DONE)GO TO 20                                             WFIND
74        DN=NW(MAX)                                                        WFIND
75        NDONE(ILEN)=NDONE(ILEN)+1                                         WFIND
76        IF(NDONE(ILEN).GT.100)THEN                                        WFIND
77          WRITE(6,45)NBOARD                                               WFIND
78     45   FORMAT(25X,'ATTEMPT TO STORE TOO MANY WCOMS IN ',A5)            WFIND
79          BAD=.TRUE.                                                      WFIND
80        ENDIF                                                             WFIND
81        IF(BAD)RETURN                                                     WFIND
82        CLRWID(ILEN,NDONE(ILEN))=CLRKNT                                   WFIND
83        CLRCOM(ILEN,NDONE(ILEN),1)=NW(MAX)                                WFIND
84        IF(DN.EQ.0)RETURN                                                 WFIND
85        DO 50 I=1,DN                                                      WFIND
86          DCOM(I)=WCOM(I,MAX)                                             WFIND
87          CLRCOM(ILEN,NDONE(ILEN),I+1)=WCOM(I,MAX)                        WFIND
88     50 CONTINUE                                                          WFIND
89        RETURN                                                            WFIND
90        ENTRY WINTL                                                       WFIND
91        DO 200 I=1,10                                                     WFIND
92    200 NDONE(I)=0                                                        WFIND
93        RETURN                                                            WFIND
94        END                                                               WFIND
```

```
                 *** STATEMENT NUMBERS ***

     5      24    30   *37
    10      39   *40
    20     *42    73
    25      44   *46
    30      50   *51
    35      43    47    48   *53
    38      64   *68
    40      54    55   *70
    45      77   *78
    50      85   *88
   100      14    15   *17
   110      20   *21
   130      26    27   *29
   150      33   *35
   200      91   *92
```

```
                 *** VARIABLES ***

ACTIVE     *10    40    41    43    44    45    49    51    56    57    58    63
            65    67    71
BAD          3     8   *19    23   *79    81
BDLX         8
BDLY         8
BDUX         8
BDUY         8
CLRCOM       6    31    34   *83   *87
CLRKNT       1    28    38    67    82
CLRWID       6    28   *82
DCOM         1     6   *34   *86
DN           1   *31    32    33   *74    84    85
DONE         3   *11   *59   *72    73
I          *14    16   *26    28   *33    34   *39    40   *44    45   *50    51
           *54    56    57    58    59   *85    86    87   *91    92
ILEN       *13    15   *16    18    24    26    28    31    34    45    75    76
            82    83    87
K          *64    65    66
```

```
LEN        1   16
LENGTH     9   16   45
MAX      *10   49   50   51   74   83   86   87
MAXV       4  *37   48  *52
MAXW     *38   39   41   54   64  *71   72
N        *25   27  *28   30   31   34
NBOARD     8   20   77
NDONE      6   24   26  *75   76   82   83   87  *92
NLEN       9   14
NW         6  *41   43   44  *49   50  *63  *67   71   74   83
NWID       9   57
OK         3  *53   55  *62
SUM      *61  *65  *66   67
V          4  *42  *45   47   48   52
VALUE      4   45
WCOM       6  *40   45  *51  *56   57  *58   65   86   87
WFIND      1
WIDTH      9   38   45   65
WINTL     90
```

Subroutine TSTORE

```
      SUBROUTINE TSTORE(LX,LY,UX,UY,TRIAL,SECT)                        TSTORE
      IMPLICIT INTEGER(A-U)                                            TSTORE
      LOGICAL BAD,LAST,HAVEIT                                          TSTORE
      CHARACTER*5 NBOARD                                               TSTORE
      DIMENSION NP(2),V(2),COORD(50,4,2)                               TSTORE
      COMMON/ALL/NBOARD,BAD,BDLX,BDLY,BDUX,BDUY                        TSTORE
      COMMON/MRA/NCUTS,SAWCUT(200,4),LAST,PIECE(100,2),NPIECE          TSTORE
C *** CHECK IF COORDINATES ARE ALTEADY STORED                           TSTORE
      HAVEIT=.FALSE.                                                   TSTORE
      IF(NP(TRIAL).EQ.0)GO TO 8                                        TSTORE
      DO 5 I=1,NP(TRIAL)                                               TSTORE
        IF(HAVEIT)GO TO 5                                              TSTORE
        IF(COORD(I,1,TRIAL).NE.LX)GO TO 5                              TSTORE
        IF(COORD(I,2,TRIAL).NE.LY)GO TO 5                              TSTORE
        IF(COORD(I,3,TRIAL).NE.UX)GO TO 5                              TSTORE
        IF(COORD(I,4,TRIAL).EQ.UY)HAVEIT=.TRUE.                        TSTORE
    5 CONTINUE                                                         TSTORE
      IF(HAVEIT)RETURN                                                 TSTORE
    8 NP(TRIAL)=NP(TRIAL)+1                                            TSTORE
      IF(NP(TRIAL).LE.50)GO TO 20                                      TSTORE
      BAD=.TRUE.                                                       TSTORE
      WRITE(6,10)NBOARD                                                TSTORE
   10 FORMAT(20X,15(1H-),' OVERFLOW IN TSTORE',A5,15(1H-))             TSTORE
      RETURN                                                           TSTORE
   20 V(TRIAL)=V(TRIAL)+VALUE((UX-LX),(UY-LY))                         TSTORE
      COORD(NP(TRIAL),1,TRIAL)=LX                                      TSTORE
      COORD(NP(TRIAL),2,TRIAL)=LY                                      TSTORE
      COORD(NP(TRIAL),3,TRIAL)=UX                                      TSTORE
      COORD(NP(TRIAL),4,TRIAL)=UY                                      TSTORE
      RETURN                                                           TSTORE
      ENTRY TINTL                                                      TSTORE
      DO 30 I=1,2                                                      TSTORE
        NP(I)=0                                                        TSTORE
        V(I)=0.                                                        TSTORE
   30 CONTINUE                                                         TSTORE
      RETURN                                                           TSTORE
      ENTRY RETREV                                                     TSTORE
      BEST=0                                                           TSTORE
      IF((NP(1)+NP(2)).EQ.0)RETURN                                     TSTORE
      IF((V(1)-V(2)).GT..0001)BEST=1                                   TSTORE
      IF((V(2)-V(1)).GT..0001)BEST=2                                   TSTORE
      IF((BEST.EQ.0).AND.(V(1).LT..0001))RETURN                        TSTORE
      IF(BEST.EQ.0)BEST=1                                              TSTORE
      DO 50 I=1,NP(BEST)                                               TSTORE
        IF(BAD)GO TO 50                                                TSTORE
        CALL CUTUP(COORD(I,1,BEST),COORD(I,2,BEST),COORD(I,3,BEST),    TSTORE
     *             COORD(I,4,BEST),SECT)                               TSTORE
         TIME=1                                                        TSTORE
         IF(COORD(I,1,BEST).EQ.BDLX)GO TO 43                           TSTORE
   35   NCUTS=NCUTS+1                                                  TSTORE
        IF(NCUTS.LE.200)GO TO 42                                       TSTORE
          WRITE(6,40)NBOARD                                            TSTORE
   40     FORMAT(30X,'TOO MANY SAWCUTS IN',A5)                         TSTORE
          BAD=.TRUE.                                                   TSTORE
        GO TO 50                                                       TSTORE
   42       SAWCUT(NCUTS,2)=COORD(I,2,BEST)-1                          TSTORE
            SAWCUT(NCUTS,4)=COORD(I,4,BEST)+1                          TSTORE
            IF(TIME.GE.2)GO TO 44                                      TSTORE
            SAWCUT(NCUTS,1)=COORD(I,1,BEST)-1                          TSTORE
            SAWCUT(NCUTS,3)=COORD(I,1,BEST)                            TSTORE
            TIME=TIME+1                                                TSTORE
           IF(TIME.GT.2)GO TO 50                                       TSTORE
   43       IF(COORD(I,3,BEST).EQ.BDUX)GO TO 50                        TSTORE
             GO TO 35                                                  TSTORE
   44       SAWCUT(NCUTS,1)=COORD(I,3,BEST)                            TSTORE
            SAWCUT(NCUTS,3)=COORD(I,3,BEST)+1                          TSTORE
   50 CONTINUE                                                         TSTORE
      RETURN                                                           TSTORE
      END                                                              TSTORE
```

```
                *** STATEMENT NUMBERS ***

     5      11    12    13    14    15   *17
     8      10   *19
    10      22   *23
    20      20   *25
    30      32   *35
    35     *50    64
    40      52   *53
    42      51   *56
    43      49   *63
    44      58   *65
    50      44    45    55    62    63   *67


                   *** VARIABLES ***

BAD          3     6   *21    45   *54
BDLX         6    49
BDLY         6
BDUX         6    63
BDUY         6
BEST       *38   *40   *41    42   *43    44    46    49    56    57    59    60
            63    65    66
COORD        5    13    14    15    16   *26   *27   *28   *29    46    49    56
            57    59    60    63    65    66
CUTUP       46
HAVEIT       3    *9    12   *16    18
I          *11    13    14    15    16   *32    33    34   *44    46    49    56
            57    59    60    63    65    66
LAST         3     7
LX           1    13    25    26
LY           1    14    25    27
NBOARD       6    22    52
NCUTS        7   *50    51    56    57    59    60    65    66
NP           5    10    11   *19    20    26    27    28    29   *33    39    44
NPIECE       7
PIECE        7
RETREV      37
SAWCUT       7   *56   *57   *59   *60   *65   *66
SECT         1    46
TIME       *48    58   *61    62
TINTL       31
TRIAL        1    10    11    13    14    15    16    19    20    25    26    27
            28    29
TSTORE       1
UX           1    15    25    28
UY           1    16    25    29
V            5   *25   *34    40    41    42
VALUE       25
```

Function VALUE

```
 1        FUNCTION VALUE(X,Y)                                             VALUE
 2        IMPLICIT INTEGER(A-Z)                                           VALUE
 3        REAL INDEX,VALUE                                                VALUE
 4        COMMON /MV/INDEX(4,8),VLEN,VWID,LINDEX(8),WINDEX(4),NV          VALUE
 5        COMMON /MSR/ LENGTH(10),NLEN,WIDTH(10),NWID                     VALUE
 6        IF(NV.NE.0)GO TO 5                                              VALUE
 7        VALUE=FLOAT(X*Y)/(16.*144.)                                     VALUE
 8        RETURN                                                          VALUE
 9      5 IW=0                                                            VALUE
10        DO 10 I=1,VWID                                                  VALUE
11          IF(IW.GT.0)GO TO 10                                           VALUE
12          IF(Y.LE.WINDEX(I))IW=I                                        VALUE
13     10 CONTINUE                                                        VALUE
14        IF(IW.EQ.0)IW=VWID                                              VALUE
15        IL=0                                                            VALUE
16        DO 15 I=1,VLEN                                                  VALUE
17          IF(IL.GT.0)GO TO 15                                           VALUE
18          IF(X.LE.LINDEX(I))IL=I                                        VALUE
19     15 CONTINUE                                                        VALUE
20        IF(IL.EQ.0)IL=VLEN                                              VALUE
21        VALUE=INDEX(IW,IL)*(X*Y)/(16*144)                               VALUE
22        RETURN                                                          VALUE
23        END                                                             VALUE


                *** STATEMENT NUMBERS ***

     5       6    *9
    10      10    11   *13
    15      16    17   *19


                   *** VARIABLES ***

FLOAT        7
I          *10    12   *16    18
IL         *15    17   *18   *20    21
INDEX        3     4    21
IW          *9    11   *12   *14    21
LENGTH       5
LINDEX       4    18
NLEN         5
NV           4     6
NWID         5
VALUE        1     3    *7   *21
VLEN         4    16    20
VWID         4    10    14
WIDTH        5
WINDEX       4    12
X            1     7    18    21
Y            1     7    12    21
```

Appendix B: Use and Derivation of Value Weighting Table

The best decision on crosscutting a board is dependent not only upon what clear areas exist within the board but what types of cuttings are required for the end products. The highest yield of total surface area of cuttings may be attained by sawing the boards into short, narrow cuttings; however, if each of these cuttings require additional processing such as edge gluing or fingerjointing, the value of the decision is diminished by the additional steps required between initial crosscutting and a finished end product. The desirability as well as availability of types of cuttings must be considered in the decision. Cuttings which are easy to get, such as short and narrow cuttings, take on a relatively low value when weighting the value of cutting dimensions. Cuttings which are more difficult to recover such as long, wide cuttings take on a high value. Also, cuttings which have high demand may take on relatively high values. In summary, cuttings of different dimensions are available in different proportions and are required in different proportions. Since these proportions may not be the same, some weighting as to desirability of cuttings should be considered.

The value weighting table used by CROMAX is a matrix dimensioned four rows by eight columns. The rows correspond to upper limits of rip widths while the columns correspond to upper limits of cutting lengths. Each cell specifies the weighting value for a cutting of given dimensions. So if the data in table 5 were used, the weighting value of 0.921 would be assigned to any cutting with a length greater than 35.0 but less than 42.0 inches and a width greater than 2.75 but less than 3.75 inches. Thus, for a cutting of dimension 3.75 X 40 inches, and given value weighting from table 5, CROMAX would calculate the value:

$$\text{Value} = \frac{(\text{weighting factor}) \times (\text{length of cutting}) \times (\text{width of cutting})}{144}$$

so substituting a cutting of dimension 3.75 X 40.0 inches and table 5 factor

$$\text{Value} = \frac{0.921 \times 40.0 \times 3.75}{144}$$

$$\text{Value} = 0.959$$

This value does not represent the dollar value of the cutting but rather the weighting factor to be used in comparisons with the weighting factor of other cuttings. The quantity is divided by 144 in order to make a conversion to square feet for convenience.

Use of Value Weighting Table

The primary use of the value weighting table is to place a weighting factor on the desirability of a cutting. Without such a factor the program would be unable to discriminate between alternative decisions when surface areas were equal. For example, if surface area only of cuttings is considered, four 1.75- by 9.00-inch cuttings would have the same desirability as one 1.75- by 36.00 inches. A greater weighting factor on the 1.75- by 36.00-inch cutting would ensure that it would be chosen over the smaller cuttings. Using table 5, the sum of the values of the four 1.75- by 9.00-inch cuttings is 0.346, while the value of a 1.75- by 36.00-inch cutting is 0.392.

The value weighting table can also be used to insure recovery of certain size cuttings. This could be done by placing a very high value on the highly desirable dimensions while placing a very low or zero value on the other sizes. A weighting value of zero would still yield allowable cuttings since CROMAX never discards allowable cuttings, but these would be salvage cuttings saved intead of wasting clear wood.

Derivation of a Value Weighting Table

Developing a value weighting table can be a major analysis in itself. The weighting factors are a function of the type of processes used in the mill operation (i.e., edge gluing or no edge gluing), the demand for cuttings of various dimensions, and the availability of the cuttings within the grade mix. Since a purpose of running CROMAX is to determine the yield of cuttings within a lumber grade, it may seem recursive to use the same component in developing the weighting table. However, some experimental idea of how hard cuttings are to get should be conveyed within the table; if all cuttings occur at similar frequency, this factor may not be needed.

In developing the value weighting table, let W be the 4 X 8 matrix of weighting factors where W_{ij}, is the weighting factor for a cutting whose width is between width,-, to width, and whose length is between length,-, to length, ($i \leq 4$ and $j \leq 8$). If i or j is 1, the lower bound is zero.

D_{ij} is the demand for cutting $_{ij}$. This may just be the number of pieces of that dimension needed (minus discards) for production. However, if edge gluing or fingerjointing is used, the value of the potential demand for the cutting being used in this process should be included.

H_{ij} is the "difficulty" rating for the cutting–how "hard to get" the piece actually is in comparison to its demand. This could be a proportion rating where 1.0 would equal the most difficult piece or could be a general 1 to 10 scaling of difficulty. About any consistent schema would do.

Putting this information together, a reasonable equation for weighting factor would be:

$$W_{ij} = H_{ij} \times \frac{D_{ij}}{\sum_{k=1}^{4} \sum_{m=1}^{8} D_{km}}$$

Other alternative ways of developing a value weighting table exist. It would be possible also to develop a table based upon the actual dollar value of a finished end product and the cost of the components within the product. Such a method would give at least as good a result as the above method. Another method would be to translate the present cutting bill into a value weighting table and then use CROMAX to give feedback as to where surplus or deficiency exist between CROMAX projections and the cutting bill.

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CROMAX–A Crosscut-First Computer Simulation Program to Determine Cutting Yields, by Pamela J. Giese and Jeanne D. Danielson, Madison, Wis., FPL 1983. 39 p. (USDA For. Serv. Gen. Tech. Rep. FPL-38)

The program CROMAX was designed to simulate crosscut-first, then rip operations as commonly practiced in furniture manufacture. It also calculates cutting yields from individual boards based on board size and defect location.

Keywords: Crosscut, rip, cutting yields, defect location, lumber grades