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Computerized Technique for Recording Board Defect Data

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Abstract

A computerized technique for recording board defect data has been developed that is faster and more accurate than manual techniques. The lumber database generated by this technique is necessary input to computer simulation models that estimate potential cutting yields from various lumber breakdown sequences. The technique provides detailed information on the location and type of defects.

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Introduction

Computer simulation of furniture rough-mill operations requires a lumber database as input for estimating potential cutting yields from lumber. The database must contain detailed information regarding the location and type of defects in relation to the clear or defect-free areas of each board.

The major advantage of a lumber database is that all manufacturing sequences can be tested with the same raw material. Variation that is present when working with actual board samples is eliminated because the same sample is used for multiple tests. So, the user is sure that any changes in the test results are due to the process and not the raw material.

The major disadvantages associated with lumber databases are the time and expense required to develop them. A computerized technique for recording board defect data has been developed and refined so that the recording of board defect data is both faster and more accurate than manual techniques (Lucas and Catron 1973). This paper outlines the features inherent in this technique for recording defect data, illustrates the resulting board plots and digitized information, and presents an application of the technique for a specific type of digitizing equipment.

Board Information Needed

If all boards are rectangular in shape, a board's dimensions can be described by rectangular coordinates: lower left corner of the board represented on an x,y grid by the coordinates (0,0), and the upper right corner of the board represented by coordinates corresponding to the width and length of the board. Then the position of all defects occurring in a board can be described in relation to the (0,0) reference point at the lower left corner of the board. To maintain consistency with other published works on lumber defect databases (Gatchell et al. 1992), the y-axis is measured vertically and the x-axis is measured horizontally; so, the y-axis measures width and the x-axis measures length. When the data are stored on computer disks, the width dimension is always given as the first number in the pair. For example, a rectangle with lower left and upper right corner coordinates of (0,0) and (23,287), respectively, has a width of 23 units and a length of 287 units.

Rectangular representation of boards is required by lumber grading programs: HaLT2 (Klinkhachorn et al. 1992a) and ReGS (Gatchell 1992), and processing programs: CORY (Brunner et al. 1989) and GR-1ST (Hoff et al. 1991). These programs work only with rectangular cuttings taken from rectangular boards.

In practice, boards are rarely perfect rectangles. Crook, sidebend, or taper, singly or in combination, often occur in otherwise flat boards, particularly those that have been dried. The problem with defective boards is representation of the parameters of board and defect dimensions.

Polygonal representation of defects can be done (Klinkhachorn et al. 1992b) but requires extensive computer time to grade and process boards. Automated Lumber Processing System (ALPS), with laser cuttings, may be the beneficiary of this approach.

Because we want to use a rectangular representation for all data in each board, the dimensions of the smallest rectangle enclosing the board do not always coincide with the dimensions of the board. In fact, this requires recording three widths: the width of the smallest rectangle that will enclose the board, the narrowest width of the board, and the measured width of the board. For the perfectly rectangular board, these three widths are the same. However, as noted earlier, actual boards can deviate significantly from the ideal and, as a result, variations can occur in these three widths. It is important to differentiate between these widths and their use in subsequent analyses.

The width of the smallest rectangle completely enclosing a board is called the board rectangle width. In our application illustrated in Appendix 1, Figure 1, this width is recorded automatically as coordinates of the upper right corner of the board rectangle are entered. Boards with crook will have a larger board rectangle width than the measured width of the board.

The measured board width follows the National Hardwood Lumber Association (NHLA) grading rules specification where width of tapering lumber is measured at a point one-third the length of the piece from the narrow end (NHLA 1990). In our application, this width is recorded manually for all boards, regardless of the presence or absence of taper. This width is used to calculate board surface measure when grading the board.

Finally, the narrow-end board width, often referred to as market width, is the width of a tapered board at its smallest end. In our application, this width is not used. However, it may be determined easily by inspecting the width coordinate for the taper recorded as void (code 002) at the board's narrow end. The width coordinate corresponds to the narrow-end board width. This width is also used to calculate board surface measure; however, this board surface measure is used only to calculate the volume of lumber when it is sold, hence the term, market width.

Defect Information Needed

The input of defect information to the lumber database consists of pairs of x,y coordinates on a grid corresponding to the lower left (LY,LX) and upper right (UY,UX) corners of the smallest rectangle completely enclosing each defect. The grid system and a unique origin at (0,0), which is the same physical corner of the board regardless of the face being mapped, are used to map all natural defects on each face of each board.

Each defect is described by a defect-type code, defect-size code for worm holes, coordinates of defect location on the board rectangle, and face on which the defect occurs. The defect type and size codes used by Gatchell et al. (1992) in developing a red oak database are shown in Table 1. Other wood characteristics could be included.

Table 1.—Defect codes and descriptions

Code	Description
002	Void
003	Pith
004	Decay
005	Shake
006	Pith related split
008	Wane
010	Bark pocket
011	Grub hole — Diameter 1/4 inch and over
111	Shot worm hole — Diameter between 1/16 and 1/4 inch
211	Pin worm hole — Diameter 1/16 inch or less
012	Unsound knot
013	Burl with bark or check
015	Sound knot
018	Incipient decay
020	Bud trace with bark or check
024	Split

A defect unique to the lumber database is void (code 002). It is the space between the edge of the board and the smallest rectangle enclosing the board. Void reflects the amount of any crook or taper present on a board and is assumed to be the same throughout the thickness of the board.

Inclusion of void in the defect data is necessary for the correct calculation of surface measure and, therefore, the correct grading of lumber with computer grading programs. As it lies outside of the wood, it is usually recorded on only one face and is accounted for in grading and processing programs. If the processing program cannot account for this one-face recording, then void should be recorded on both faces.

Defect definition is not always straightforward. Huber et al. (1990) identifies one group of defects, including holes and knots, as easy to recognize. Others, including stain and incipient decay, are less readily identified. The subjectivity involved in defect definition and recognition has serious implications when establishing value (grading) and converting a board to parts.

One of the most difficult defects to judge is stain. Light stain is considered a sound defect. That is, it is allowed on the sound face of a cutting. If it is defined as decay or rot, then it is not allowed. National Hardwood Lumber Association (NHLA 1990) defines incipient decay as "The early stage of decay that has not proceeded far enough to soften or otherwise perceptibly impair the hardness of wood. It is usually accompanied by a slight discoloration or bleaching of wood." Stain is defined: "In hardwoods, the word 'stain' is used to describe the initial evidences of decay" (NHLA 1990).

Another common problem in encoding defects is that some defects will fit more than one defect description because different defect characteristics are grouped together too tightly to separate with multiple rectangles. Very often an unsound knot (code 012) is surrounded by ingrown bark (code 010). In this situation, the defect is encoded based on the most dominant defect characteristic in the group.

The database developer must clearly define procedures so that the user may make any necessary adjustments. For example, users evaluating sound cuttings rather than clear-face cuttings may want to redefine a defect allowed in sound cuttings but not in clear-face cuttings. An example of this type of defect is incipient decay. Gatchell et al. (1992), for instance, defines any incipient decay (code 018) adjacent to rot (code 004) as rot. Any heavy stain that is independent of decay is defined as incipient decay and not allowed on the back face for a grading cutting. Any stain that would sand out or not be objectionable under a clear finish is ignored. The user is directed to convert any incipient decay defect (code 018) to an allowable stain if so desired.

Code identification of defects allows maximum manipulation of the database. The user may wish to allow all defects of a certain size or type, or both, on one face of a cutting. By temporarily eliminating these defects from consideration, yields of pieces other than those that are clear on both faces can be determined.

Defects must be identified separately for each side of the board. The side of the board with the largest area containing defects or conversely, the smallest area containing clear cuttings, is referred to in this paper and in the recorded defect data for each board as the front side or Side 1. Depending on the grading rules used to classify defects, this may or may not be the side of the board that establishes the grade of the board. For example, for FAS and the clear-face Common grades, the grading face is that face with the lower grade or, when both faces grade the same, that face with the smaller total area in the grading cuttings (NHLA 1990). For Selects and the Face grades, the better face is used. The identification of defects on separate sides of the board allows the database user to decide after the collection of the data which side of the board will be considered as the side used for grading purposes.

Although the database does not have to conform to NHLA standards for defect identification, some standard is necessary to establish what a defect is. In recording defect data as illustrated in the Appendices, we have chosen to follow the NHLA rules regarding specification of defects. In fact, the procedure is flexible enough to accommodate any existing grading rules because the user can include any desired defect specifications in the recorded data.

How to Record Data

Equipment Needed

There is a variety of digitizing equipment available on the market today. All do essentially the same thing: establish a basic reference point and locate and record subsequent points on an x,y grid relative to this reference. At the Forestry Sciences Laboratory, Princeton, West Virginia, a transverse arm or wand is used to locate the points and convert that information into digitized coordinates in an x,y grid system. Other equipment using sonic location to identify points is also available. However, the end result, that is, digital coordinates in an x,y grid system, is the same.

Second, some means of recording the digital coordinates is needed. As noted earlier, this requires the use of a computer to maximize the efficiency of recording the digital coordinates and to minimize the possibility of errors in transcribing the data. Use of micro-computers also enables the direct recording of the data in a format that is suitable for subsequent analysis by grading or yield simulation programs.

Accuracy in Recording

For an ideal situation, all distances from the origin of the x,y grid would be in decimals of inches that meet high degrees of analytical accuracy. However, if carried to an extreme, this would require computers of exceptional speed. Computer programs must, within their design limitations, compare a series of areas to determine a solution in deciding on grades or best cutup procedures. These areas are normally rectangular. The finer the scale of measurement, the greater the number of solutions. While greatly increasing the time to generate a solution, it can be shown that small changes in dimension have no important effect on results in general.

Most digitizing equipment counts the number of basic units. The Princeton equipment works on a quarter-inch basis, for example. Our data recorder always rounds down. Thus, 0.49 is recorded as 0.25 and is translated to one quarter-inch unit. A defect that is 2.79 inches in length by 1.9 inches in width is recorded as 11 by 7 quarter-inch units.

At first glance, always rounding down may seem to introduce a bias. However, it is the intent of encoding to present a series of defects in the proper spatial relationship to each other and the board outline. All defects must have an X and Y dimension that exceeds zero. If the capacity to round up or down were present, a quarter-inch wide defect could have a zero Y dimension. In a crooked or tapered board, a defect could be placed in the void outside the board outline. Until vision systems are developed that allow the precise location of defects, it will be necessary for the human operator to manually ensure that the defect size is properly reflected in the data by positioning the point attached to the wand appropriately. One such method is described in Appendix 1 and illustrated in Appendix 1, Figure 4.

Two computational reasons suggest that precision of measurement to the nearest quarter-inch is adequate. First, most of the software currently developed for grading lumber by computer or for evaluating yields of a lumber breakdown process uses the quarter-inch unit of measurement for analyses. Second, because boards are typically long and narrow, the width (Y direction) of a defect is much more critical than its length (X direction) in determining the location of a cutting unit. It can be shown that measuring the width of the rectangle enclosing the defect to the nearest quarter-inch will adequately capture this critical dimension relative to all other defects.

For large and irregular shaped defects such as wane, splits, and voids, the specific procedure for marking rectangles around a defect is to include all areas of the defect while minimizing the inclusion of clear wood within the rectangle. This process, called stair-stepping, is accomplished by dividing the defect into more than one rectangle in quarter-inch increments. The only accuracy lost is the potential for further minimizing the inclusion of clear wood by reducing the size of the increments to less than a quarter-inch. Here again, the potential for error is small when compared with the major increase in computational time required for analysis and the negligible possibility of significant changes in grade or yield estimation.

If polygonal coordinates rather than rectangular coordinates are used to record defect location, a cutting unit may be found that stepped-up defects in quarter-inch increments do not permit. But in most situations this will be a moot point. Generally, what is gained is a slightly shorter or slightly wider cutting, or both. This has the effect, if any, of making another cutting slightly narrower or longer.

It should be noted that physically marking the corners of each defect or increment of a stair-stepped defect allows for easy rechecking and helps prevent the omission of a defect as the data are being recorded.

Even though the minimum size of a recorded defect is a quarter-inch by a quarter-inch, the defect code allows identification of the relative size of the defect within the quarter-inch rectangle. For example, the worm hole defect codes (codes 011, 111, and 211) shown in Table 1 allow for three size classes ranging from less than 1/16 inch to greater than 1/4 inch in diameter. Other small unsound defects could also be identified by a specific defect code based on size. In the application illustrated in Appendix 1, only worm holes are broken down by size class.

Care must be taken when encoding back side defects to maintain the relationship of all recorded coordinates to the origin (0,0). Before digitizing defects on the back side of the board, the board must be flipped over. The digitizer coordinates are again set to zero so that the upper left corner of the board becomes the new origin with coordinates (0,0). This is, in fact, the lower left corner of the unflipped board and is the same (0,0) reference point used to record board rectangle length, width, and defect coordinates for the front side of the board. In mathematical terms, the digitizer is now working in the +x,-y quadrant of the x,y grid. In practical terms, the digitizer converts the -y dimensions to +y dimensions. This procedure ensures that all defects occurring on the back side of the board are correctly described in relation to the front side defects.

Data Format

Defect data format for a sample board is illustrated in Table 2. These data are stored on a computer file for each board and are broken down into three areas: header information, board rectangle coordinates, and defect information.

The sample header includes the following information:

Grade of Board	OC	Board Number	3067
Total Number of Defects	15	Measured Board Width	22

As noted earlier, the measured board width is in quarter-inch units. So, the sample board is 5-1/2 inches wide, as measured at one-third of the length of the board from its narrow end. The sample board rectangle coordinates are given as follows: 0- 0 and 23-287. Again, these coordinates are recorded in quarter-inch units of measure. The first pair of coordinates for the board rectangle always identifies the origin or reference point from which all defects are measured. The second pair of coordinates indicates that the board is completely enclosed in a rectangle 5-3/4 inches wide by 71-3/4 inches long.

Each line of defect information provides the coordinates of the defects [(LY, LX) (UY, UX)], the side of the board containing the defect, and the defect code. Using the first defect as an example, we note that it is an unsound knot (defect code 012) on Side 1 of the board, with a width of 3/4 inch (12 minus 9) and a length of 1 inch (32 minus 28).

The preceding information may be used to plot the board with its accompanying defects. A plot of sample board number 3067 is shown in Appendix 3. In this example, defects located on the back side of the board are indicated by dashed lines and defects located on the front side are indicated by solid lines.

Summary

A computerized technique for recording board defect data has been presented that is faster and more accurate than manual techniques. The lumber database generated by this technique is a necessary input to computer simulation models that estimate potential cutting yields for a variety of lumber breakdown processes, that is, rip-first or crosscut-first processes. The technique allows collection of detailed information regarding the location of defects and type of defects in relation to the clear or defect-free areas of each board.

This technique is described in detail in Appendices 1 to 4 for equipment available at the Princeton Laboratory. Appendix 1 describes the equipment and software used and gives a step-by-step description of operating instructions that are necessary to identify and record board defect data. Appendix 2 illustrates the computer screens that appear as users follow the operating instructions. Appendix 3

Table 2.—Defect data for sample board

Column 1

GRADE OC BOARD NUMBER 3067 TOTAL NUMBER OF DEFECTS 15
MEASURED BOARD WIDTH 22

0- 0	23-287		
9- 28	12- 32	1	12
8- 73	10- 90	1	24
14-168	18-173	1	12
8-178	11-181	1	12
9-181	11-189	1	10
15-187	16-188	1	10
8-222	12-234	1	11
10- 22	12- 30	2	12
10- 0	11- 12	2	24
0- 28	5- 38	2	10
9-101	18-111	2	5
10-169	13-172	2	12
15-162	23-172	2	12
11-237	13-244	2	11
10-297	12-298	2	15

illustrates a plot of a sample board. And Appendix 4 contains an explanation of possible system and defect collection error messages that users may encounter in running the computer software.

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Appendix 1.
Application of Digitizing Technique Using Numonics Digitizer — User's Manual

Hardware Requirements

The equipment used to map defects includes a Numonics Corporation 1224 Graphics Calculator. The Numonics Model 1224 electronic digitizer can function by itself for measurement and display of directly scaled coordinates and output these measurements to a computer. The four major components of Model 1224 are:

- Display Console: Digital readout display and electronic circuits for translating and calculating data.
- Reading Head: Carriage and optical pick-up system for detecting carriage translation along the X-axis (abscissa).
- Transverse Arm: Arm moves in Y-axis (ordinate) and motion is detected in carriage in reading head.
- Keyboard: Sixteen character keys and four shift keys used to control operation of Model 1224.

This device uses a transverse arm mounted on rails to allow a pointer to move along the entire face of a board. Optically scanned lines communicate the pointer's precise position to the graphics calculator.

The following is necessary to operate the Numonics electronic digitizer and capture the digitized board information to the computer:

- An IBM/IBM-compatible computer with a minimum of 512k bytes of system memory.
- An 80-column monochrome or color display monitor.
- Two 5-1/4-inch, double-sided, double-density floppy disk drives, or one floppy disk drive (for above disk type) and one hard disk drive (hard disk is preferred).
- A printer.
- PC DOS version 3.0 or higher or compatible MS-DOS.
- A diskette containing DIGITIZER-PC programs.

Note: The PC version of DIGITIZER-PC was developed using MicroSoft-C programming language, linked with assembly language routines for capturing the signals from the serial port of the PC (connected to the Numonics electronic digitizer). This program was chosen because of its flexibility in handling the data transmission between digitizer and PC.

Description of Programs

The DIGITIZE for PC's package consists of two programs. These are executable compiled C-language programs (Filename.EXE):

DIGITIZE.EXE — Creates the defect database file from input received from the digitizer and from the computer keyboard. Data input includes:
- board number
- board width
- grade of board
- surface measure
- defect-type code
- defect location on board rectangle
- face of defect location (front or back of board)

VERIFDAT.EXE — Allows user to verify defect data entries in the database file independently of the digitizing program. This program is included as a subroutine within the digitizing program to allow verification of data entries without exiting from the digitizing program to the DOS prompt. Note: This program searches only for the first occurrence of a board number. Hence, if board numbers are repeated in the database file, this program will only display the information recorded for the first occurrence of that number.

Operating Instructions

(Screens Are Shown in Appendix 2)

In the following instructions, references will be made to the upper and lower side of the table or upper and lower corner of a defect. As shown in Figure 1, the upper side of the table or corner of defect is away from the operator and the lower side or corner is nearest the operator. Instructions that require operator input are highlighted by the symbol ● and digitizer keypad entries are shown as **boldface** characters.

- Turn on PC and Numonics digitizer.
  The data collection software contains a batch file to self-load when the PC boots up. Screen 1 will appear.

- Zero digitizer.
  For digitizing on Side 1 of the board, the stylus of the digitizing wand is placed in the lower left-hand corner of the digitizing table (again refer to Fig. 1). This point is defined as (0,0) for Side 1 of the board. Travel out the length of the board is in the x-positive direction and travel towards the digitizing unit is in the y-positive direction. With the stylus being steadily maintained at (0,0), the following sequence of buttons is pressed on the digitizer keypad.

- Press keys
  Acc/OFST and **DDP** simultaneously
  O/res
  En

Both numbers of the digitizer must read zero, if not, repeat process.

For digitizing on Side 2 of the board, the stylus is placed in the upper left-hand corner of the digitizing table (Fig. 2). This point is defined as (0,0) for Side 2 of the board. Travel out the length of the board is in the x-positive direction and travel toward the operator is in the y-negative direction. The digitizer is zeroed with the stylus in this (0,0) position by pressing the same buttons on the digitizer keypad as

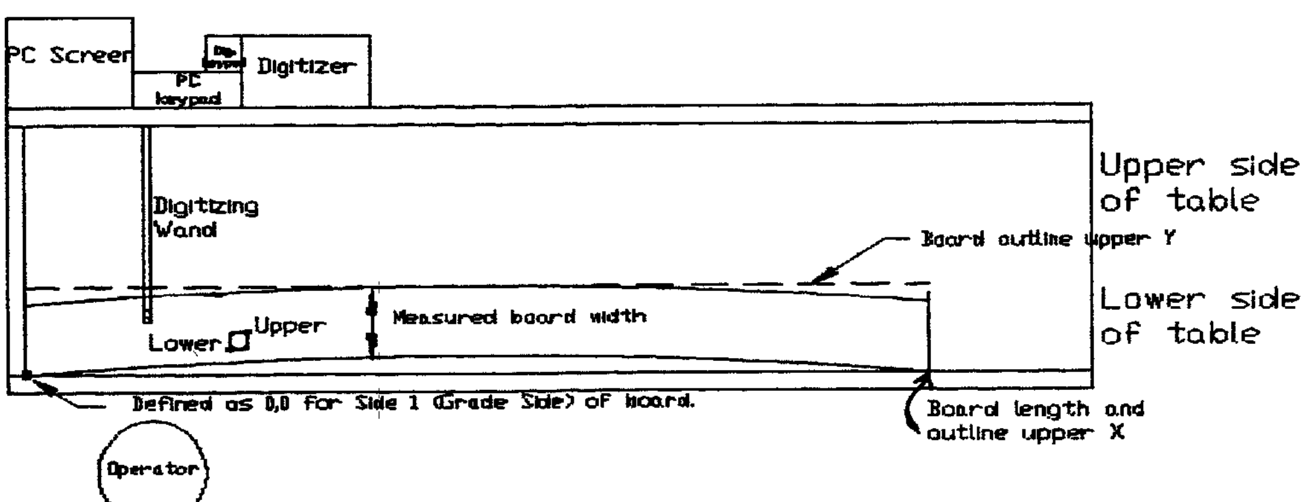


Figure 1.—Top view of digitizing table—front side of board.

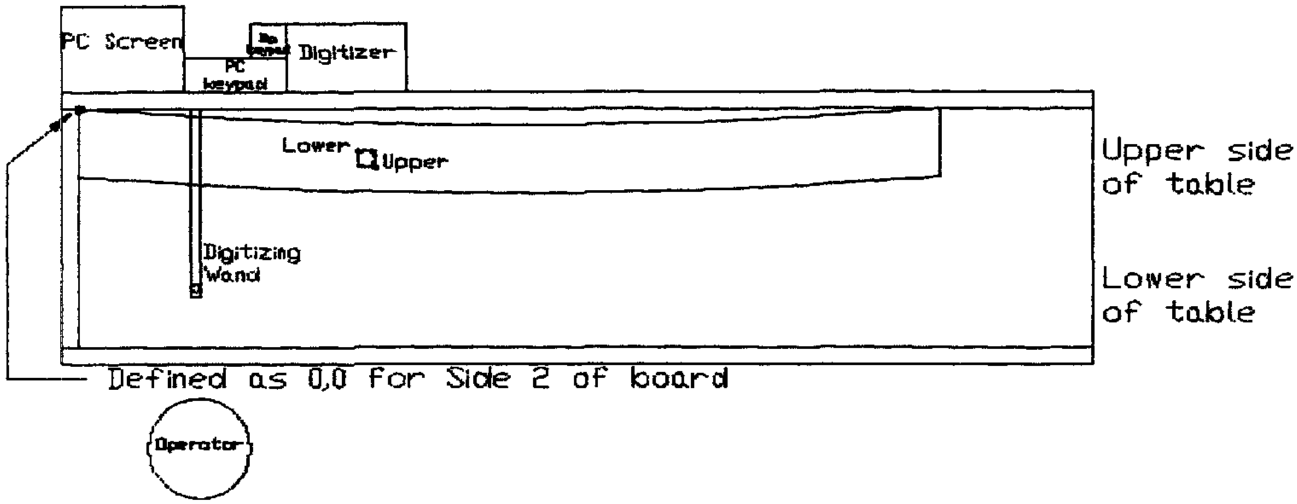


Figure 2.—Top view of digitizing table—back side of board.

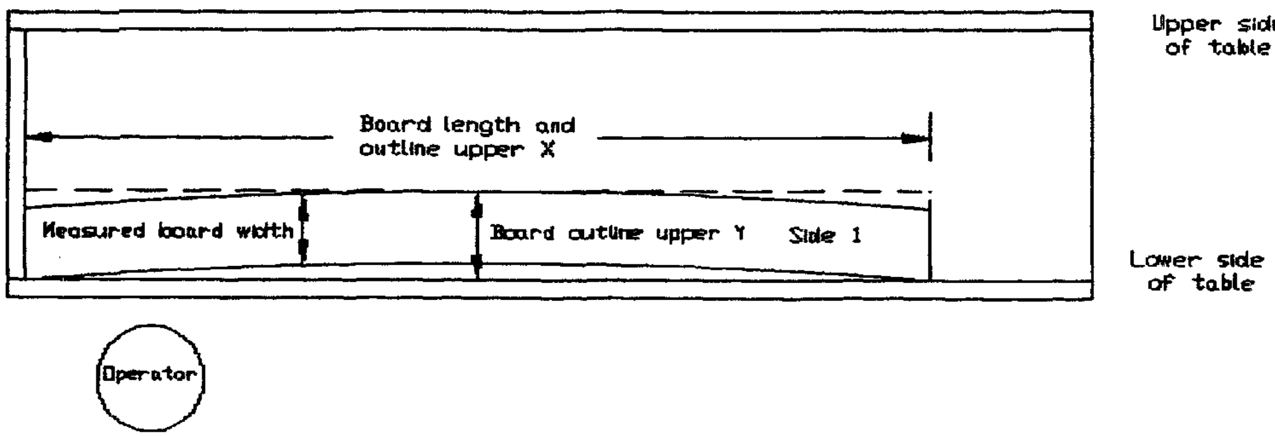


Figure 3.—Orientation of board on table.

described above for Side 1 of the board. As noted earlier, the digitizer records travel in the y-negative direction as a positive value. Thus, in recording defect locations on Side 2 of the board, the upper left corner of the defect corresponds to the (LY,LX) coordinate and the lower right corner of the defect corresponds to the (UY,UX) coordinate.

The digitizer reading head in which the wand travels has a range of 48 inches in the x-axis. When defects have been entered out to 48 inches on the board, the digitizing unit must be moved before continuing with defect entry. To prevent adversely affecting the set (0,0) point, the wand must be locked down before moving the unit. The wand is locked by moving the toggle switch located on the left end of the reading head down to the HOLD position. Maintaining the wand, while locked down in any y-axis position at the right end of the reading head, move the digitizing unit the desired distance and return the toggle switch to the up position before releasing the wand.

Each board is evaluated to determine the face with the most defects. This face is Side 1 (Grade side) of the board and is always digitized first. Place the board on the diagramming table as shown in Figure 3 with Side 1 face up and any sweep curving away from the operator. The sweep is oriented this way to stabilize the position of the board and allow positioning to be repeatable for digitizing and coordinate checks. Note: Before entering Side 2 defects, the board must be flipped over and moved to the upper side of the table as shown in Figure 2 and the stylus set to zero at the proper position.

- From Screen 1
  Select **1** to continue with data entry process — Screen 2 will appear.
  Select **0** to exit to DOS

- From Screen 2
  Enter **filename** for board defect datafile.

Filenames are limited to eight characters plus an extension. If new unused filename is chosen, Screen 3 will appear. If a filename is chosen that has been previously used, Screen 4 will appear.

Measure the width of the board one-third the length from the narrowest end of the board in quarter-inch increments. For example, a 6-inch-wide board would be measured as 24 quarter inches.

Measure the board outline upper y limit. This is the greatest point the upper edge of board lies from the lower edge of the table (again refer to Fig. 3). The distance measured is from the upper edge of the board to the lower edge of the table in quarter-inch increments. If the board is actually rectangular, the upper y measurement will be equal to the measured board width. If the board contains sweep or is tapered, the upper y measurement will be greater than the measured board width.

Measure the length of the board in quarter-inch increments. A board 12 feet long will be measured as 576 quarter inches.

Record the measured values at any convenient location on the board. They will be entered in the digitizing program at Screen 3.

- From Screen 3
  Enter **board number**: 4 digits are allowed.
  Enter **measured board width**: in quarter-inch increments measured at one-third of the length from narrowest end of board (Fig. 3).
  Enter **measured board length**: in quarter-inch increments.
  Enter **board outline upper y:** the highest point of board on upper y axis in quarter-inch increments.
  Enter **board outline upper x**: in quarter-inch increments.
  Is the information for this board correct? Y or N:
  Select **Y** and Screen 5 will appear.
  Select **N** and you will be able to correct values entered on Screen 3.
- From Screen 4
  Selections self explanatory.
- From Screen 5
  Start board defect entry with Side 1? Y, N, or 0 for no defects.
  Select **Y** to start digitizing Side 1 of board. Screen 6 will appear.
  Select **N** to start digitizing Side 2 of board. Screen 6 will appear.
  Select **0** if board has no defects. Screen 9 will appear.

Before entering board defects, it is desirable to diagram or outline the defects on the board. This is done to ensure that all defects are encoded and to facilitate locating the lower and upper x,y coordinates of each defect. Diagramming consists of penciling in rectangles around each defect. The vertical lines are scribed along the right-hand edge of a T-square (Fig. 4). The left-hand edge of the T-square has been notched in quarter-inch increments to facilitate drawing the horizontal lines. The pencil is placed in the appropriate notch and the T-square and pencil are moved along the diagramming table the desired length of the line. The specific procedure for penciling rectangles around a defect is to include all areas of the defect while minimizing the inclusion of clear wood within the rectangle. For irregular shaped defects, wane, splits, and voids, this is accomplished by dividing the defect into more than one rectangle. This process is called stair-stepping and is usually done in quarter-inch increments.

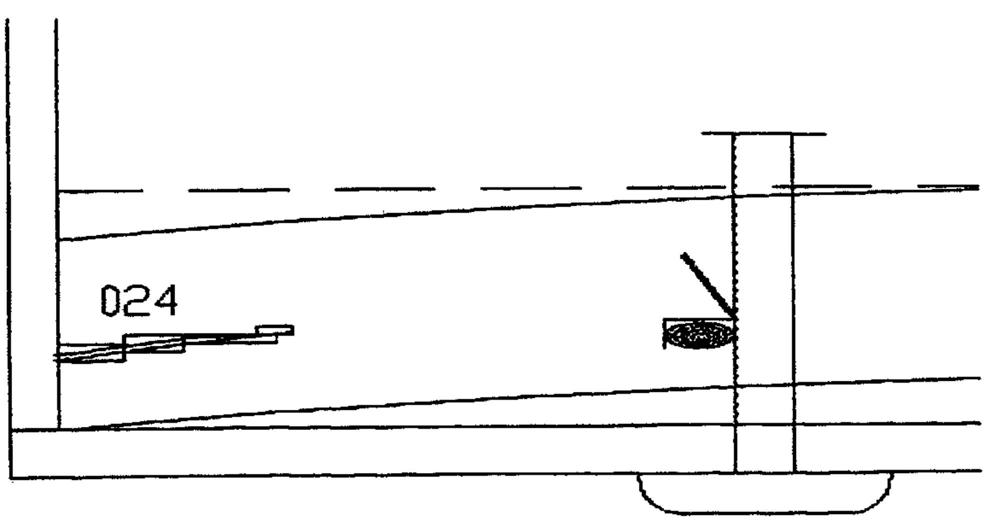


Figure 4.—Pencil outlining of defects on board.

- From Screen 6
  Screen 6 shows the starting data entry on defect 1, Side 1, of the board and asks for the defect type code (Table 1) of the first defect.

  Enter **defect** code. Screen 7 will appear.

Note: A help screen (Screen 14) listing defect descriptions and applicable codes is available by pressing **RETURN** before entering the defect code.

- From Screen 7
  Screen 7 displays the defect code entered on Screen 6 and asks for the input of four values. Pressing the **En** button on the digitizer keypad one time will enter the lower x and lower y value. After the pointer is moved, pressing **En** again will enter the upper x and upper y values.

To enter a defect location on Side 1 of the board, place the stylus at the lower left-hand corner of the defect and press the **En** button on the digtizer keypad. Move the stylus to the upper right-hand corner of the defect and press the **En** button again to record that location. The DIGITIZE program uses these two points to locate the x,y coordinates of the rectangle that is penciled around the defect. After all four values are entered, Screen 8 will appear.

To enter a defect location on Side 2 of the board, place the stylus at the upper left-hand corner of the defect and press the **En** button on the digitizer keypad. Move the stylus to the lower right-hand corner of the defect and press the **En** button again to record that location.

- From Screen 8
  Select **1** to enter another defect on Side 1 of board.
  Select **2** when all defects on Side 1 have been entered and you wish to start on Side 2 defects.
  Select **R** if you have made a mistake in entering the defect code number or coordinates. You will be allowed to re-enter the data.
  Select **E** if you wish to alter coordinate values with keyboard entries.
  Select **0** if you have entered all defects on both sides of board. Screen 9 will appear only if all defects are located within the boundary of the board outline. If a defect is recorded with coordinates outside the board's defined boundary, Screen 12 will appear.

- From Screen 9
  Screen 9 allows corrections to be made to the header card information or the defect data, or both, after data entry has been completed. You do not have the capability to add or delete defects from the data, so it is important to record all defects while working from Screen 8.

  Select **Y** to make corrections to data.
  Screen 11 will appear.

  After desired corrections are completed, Screen 10 will appear.

  Select **N** to go to next board. Screen 10 will appear.

  Screen 9 also allows verification that the board defect data were written to the computer's disk storage.

  Select **Y** to verify board was written to data file.
  Screen 13 will appear.
  Select **N** to go to next board.
  Screen 10 will appear.

- From Screen 10
  Select **Y** to enter another board. Screen 3 will appear.
  Select **N** to exit to DOS.

- From Screen 11
  Enter **defect number** that is to be corrected.
  Select **E** to edit data for defect.
  Select **X** to EXIT. Screen 9 will appear.

- From Screen 12
  Press any key to make corrections to information on board outline. Screen 3 will appear.
  After corrections are made to board outline information, Screen 9 will appear.

- From Screen 13
  Screen 13 displays data file.
  Press any key to return to Screen 9.

- From Screen 14
  Screen 14 displays defect descriptions.
  Press any key to continue.
  Press any key to return to defect entry.

Special Procedures for Digitizing Voids and Pith

Voids are areas where no wood exists between the board outline and the actual edges of the board due to crook, side bend, or taper in a board. Voids cannot be penciled in, therefore, an alternate procedure must be used to delineate them.

Diagramming Voids on the Lower Edge of Boards. (This procedure is described for boards with a crook of 1/2 inch.) The notched edge of the T-square is placed at the beginning of the sweep area on the lower edge of the board. The T-square is advanced slowly toward the opposite end of the board until the amount of sweep exceeds 1/4 inch (the edge of the board will be in the first notch on the T-square). This point is marked and labeled 1 as shown in Figure 5. The T-square is advanced until the amount of sweep exceeds 1/2 inch (the edge of the board will be in the second notch on the T-square). This point is marked and labeled 2. The T-square is advanced until the amount of sweep is less than 1/2 inch (the edge of the board will start to fall below the second notch on the T-square). This point is marked and labeled 2. The T-square is advanced until the amount of sweep is less than 1/4 inch (the edge of the board will start to fall below the first notch on the T-square). This point is marked and labeled 1.

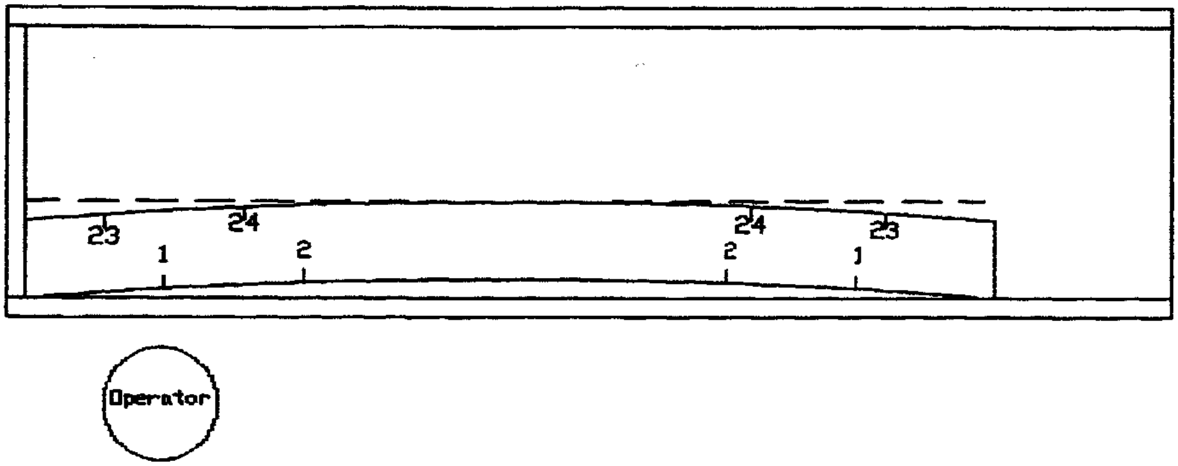


Figure 5.— Diagramming voids on edge of board.

Voids are entered on Screen 6 with a defect code of 002. The marks labeled in the diagramming step above must be used. When the prompt on Screen 7 asks for the input of the coordinate values, the stylus is placed at the first mark on the left end of the board. This mark will be labeled 1. The stylus must be held against the edge of the table at this location thus forcing the lower Y value to be 0. Press **En** on the digitizer keypad to enter the first two values. Move the stylus toward the right end of the board to the next mark labeled 2. The stylus must be moved away from the edge of the table to force the upper Y value to be 1. Press **En** to enter the second two values. The next void is entered with the stylus in the same X coordinate position (the end of the first void is the beginning of the second void), but it is again held against the table to force the lower Y value to be 0. Press **En** to enter the first two values. Move the stylus to the next mark which is also labeled 2. Force the upper Y value to be 2. Press **En** to enter the second two values. To enter the final void, hold the stylus in the same X coordinate position and force the lower Y value to be 0. Press **En** to enter the first two values. Move the stylus to the last mark which is labeled 1. Force the upper Y value to be 1. Press **En** to enter the second two values.

For a board with only a quarter-inch sweep, only one void on the bottom edge of the board would need to be digitized.

Diagramming Voids on the Upper Edge of Board. The notched edge of the T-square is placed at one end of the board and advanced slowly toward the opposite end. When the upper edge of the board passes across a notch on the T-square, that location is marked with the value that corresponds to that notch. This process is continued for the length of the board. The maximum recorded value must be equal to the recorded upper y value. Figure 5 illustrates a board with the voids properly marked.

Start with the stylus at the left end of the board positioned at X equal to 0 and Y equal to the value labeled on the first mark. From Screen 7, press **En** to enter the first two values. Move the stylus to the first mark. Force the upper Y value to be equal to the board outline upper Y. Press **En** to enter the second two values. Enter the next void by holding the stylus in the same X position and force the lower Y value to be equal to the value labeled on the second mark. Press **En** to enter the first two coordinates. Move the stylus to the next mark with the upper Y equal to the board outline upper Y. Press **En** again to enter the second two values. Continue this procedure across the length of the board remembering that there will be a section that will have no void. Note that the lower Y value of each void is always equal to the value labeled on the mark to the right of the stylus location and the upper Y value is always equal to the board outline upper Y.

Voids are only entered for Side 1 of the board. It would be repetitive to enter them for Side 2 of the board.

Diagramming Pith Located Within a Board. When inside the board, pith is the one defect that must be shown as if on the surface of Side 1. Pith usually is diagrammed on one side of a board or the other depending on the surface from which it is visible. The method for diagramming pith within the board is to start a pith defect where the visible pith disappears on Side 1 of the board and end it at the location where the visible pith reappears on Side 2 of the board. This is simplified by determining the coordinates of the defect on Side 2 of the board and reproducing them on Side 1 of the board. On many boards this defect will be at an angle to the X axis and will require stair-stepping. The widths of the internal pith defects are made to be the same as the visible pith defects.

Appendix 2. — DIGITIZE Screens.

Note: The **boldface** entries shown at the various steps are for illustration only. The output of these illustrations, defect data for sample board No. 3067, is shown in Table 2.

The following screens appear on the computer as the defect data are collected:

Screen #1:

Board Databank Digitizer Utility
USDA Forest Service
Princeton West Virginia
Forestry Sciences Laboratory

Main Function Menu for Board Data Bank Encoding

1: Enter Board Data from Digitizer
0: EXIT to DOS

Please enter your selection, 0 or 1:..

Screen #2:

Board Databank Digitizer Utility
USDA Forest Service
Princeton West Virginia
Forestry Sciences Laboratory

Enter filename for board defect datafile:..

Screen #3:

Board Databank Digitizer Utility
USDA Forest Service
Princeton West Virginia
Forestry Sciences Laboratory

- - - Board Defect Data Entry - - -

Enter board number:......
Enter measured board width:..
Enter measured board length:..
Enter board outline upper Y:..
Enter board outline upper X:..

Is the information for this board correct? Y or N:..

Screen #4:

Board Databank Digitizer Utility
USDA Forest Service
Princeton West Virginia
Forestry Sciences Laboratory

Datafile, ***** already exists. Would you like to:

1: Append new data to end of datafile
2: Recreate datafile (destroys all data currently in file)
3: Retry with new filename
0: Quit and exit to main menu

Please enter your selection, 0-3:..

Screen #5:

Board Databank Digitizer Utility
USDA Forest Service
Princeton West Virginia
Forestry Sciences Laboratory

Start board defect entry with Side 1? Y, N, or 0 for no defects: ..

Screen #6:

Board Databank Digitizer Utility
USDA Forest Service
Princeton West Virginia
Forestry Sciences Laboratory

Defect 1 Coordinates, Side 1

Enter code for defect type:..

Press RETURN for list of defects and codes

Screen #7:

Board Databank Digitizer Utility
USDA Forest Service
Princeton West Virginia
Forestry Sciences Laboratory

Defect 1 Coordinates, Side 1
Enter code for defect type: **12**
Board defect lower x value: ..
Board defect lower y value: ..
Board defect upper x value: ..
Board defect upper y value: ..

Screen #8:

Board Databank Digitizer Utility
USDA Forest Service
Princeton West Virginia
Forestry Sciences Laboratory

Defect 1 Coordinates, Side 1
Enter code for defect type: **12**
Board defect lower x value: **35**
Board defect lower y value: **8**
Board defect upper x value: **38**
Board defect upper y value: **11**

1: Enter another defect for this side   2: Change board sides
R: Redigitize board defect   E: Edit defect with keyboard
0: Finish this board's defect data entry

Please select one of the above options:..

Screen #9:

Board Databank Digitizer Utility
USDA Forest Service
Princeton West Virginia
Forestry Sciences Laboratory

Would you like to check this data and correct any mistakes? Y or N: ..
Verify that board was written to data file? Y or N: ..

Screen #10:

Board Databank Digitizer Utility
USDA Forest Service
Princeton West Virginia
Forestry Sciences Laboratory

Enter another board? Y or N: ..

Screen #11:

Board Defect Digitizer Utility
Board Defect Checking and Correction

Board Number: **3067**   Total Number of Defects: **1**
Board upper x coordinate: **387**   Board upper y coordinate: **23**

1: 8-35 11-38 1 12

Please enter your selection: ..

U = Up Screen   D = Down Screen   X = EXIT   E = Edit

Screen #12:

Board Databank Digitizer Utility
USDA Forest Service
Princeton West Virginia
Forestry Sciences Laboratory

A defect was entered for the last board which is outside the board's defined boundary. This must be corrected at this time.

Upper coordinates for the defect are:
Upper X ****
Upper Y ****

Press any key to make corrections to the board header.

Screen #13:

Board Databank Digitizer Utility
USDA Forest Service
Princeton West Virginia
Forestry Sciences Laboratory

GRADE OC BOARD NUMBER 3067 TOTAL NUMBER OF DEFECTS 15
MEASURED BOARD WIDTH 22

1:	0- 0	23-287		
2:	9- 28	12- 32	1	12
3:	8- 73	10- 90	1	24
4:	14-168	18-173	1	12
5:	8-178	11-181	1	12
6:	9-181	11-189	1	10
7:	15-187	16-188	1	10
8:	8-222	12-234	1	11
9:	10- 22	12- 30	2	12
10:	10- 0	11- 12	2	24
11:	0- 28	5- 38	2	10
12:	9-101	18-111	2	5
13:	10-169	13-172	2	12
14:	15-162	23-172	2	12
15:	11-237	13-244	2	11
16:	10-297	12-298	2	15

More board defects. Press any key to contiue.

End defect list. Press any key to continue.

Screen #14:

Board Databank Digitizer Utility
USDA Forest Service
Princeton West Virginia
Forestry Sciences Laboratory

Defect Descriptions

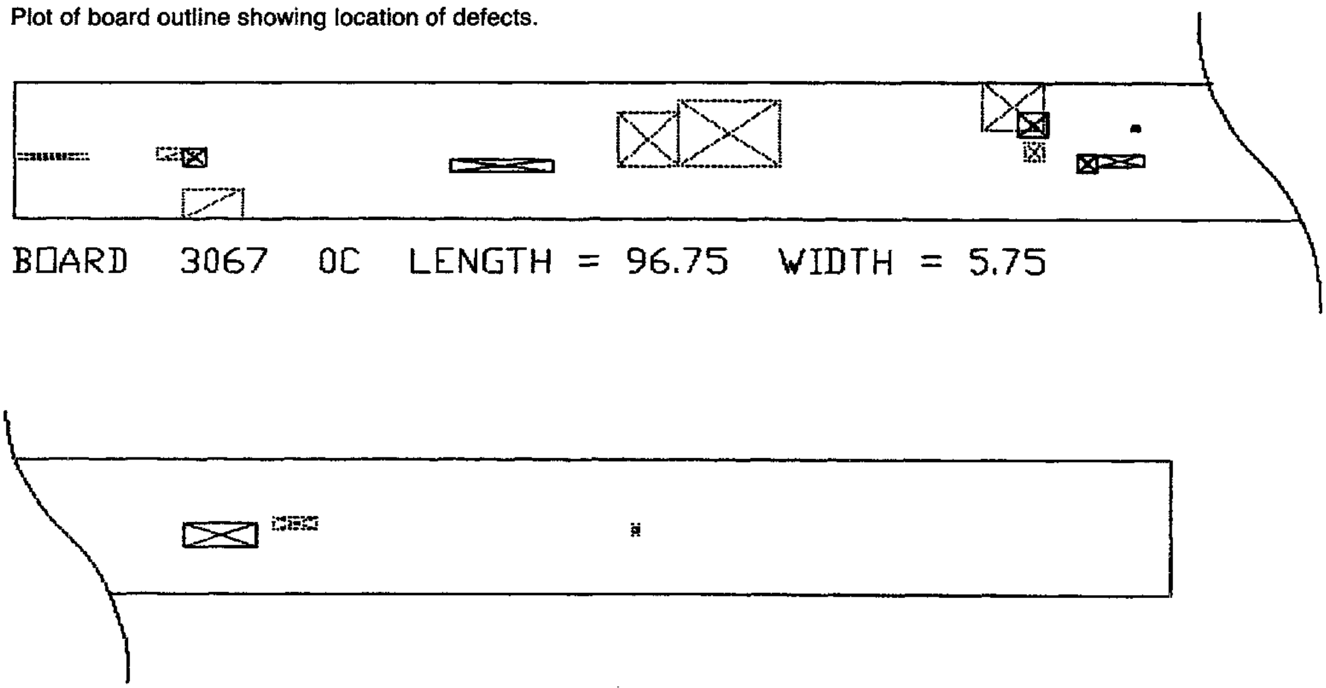
Defect		Code Number
Void —	the space between the edge of the board and the smallest rectangle enclosing the board. Caused by crook, taper, or differential shrinkage.	2
Pith		3
Decay		4
Shake		5
Pith related tear or split		6
Wane and/or scant wood thickness owing to bark		8
Bark pocket		10
Unsound knot		12
Sound knot		15
Incipient decay and objectionable stain		18
Bud trace with bark		20
Split		24
Worm holes:		
Grub and other holes 1/4" and over		11
Shot worm hole; greater than 1/16" less than 1/4"		111
Pin worm hole; 1/16" or less		211

More: Press any key to continue:

Press any key to return to defect entry.

Appendix 3.

Plot of board outline showing location of defects.



Appendix 4. System and defect collection error messages.

The digitizer program reports on two classes of errors, system and defect collection. System errors occur when there is a problem opening a data file, writing defect data, or collecting defect coordinates from the digitizer. Defect collection errors are reported when the coordinates read do not conform to a standard or make no sense; for example, a zero area defect. For both classes of errors, possible causes and solutions are listed in the order of their likelihood. Throughout this list "XXX" is used to represent the name of your datafile and "II" to represent the board number you are verifying. This is not a list of all the causes or solutions, only the most common ones.

SYSTEM ERRORS:

1. ERROR: Unable to delete old data file XXX
   Occurs when replacing an old data file.
   Causes:
   1. The read-only attribute of the old data file may be set.
   2. The write protect tab on your data diskette may be on.

   Solutions:
   1. Try resetting the read-only attribute with the MS-DOS command

      ATTRIB -R filename

      Where filename is the name of your data file. Be sure that you want to replace the old data file. Once a file is overwritten it is impossible to retrieve the old data file.
   2. Remove/reset the write protect tab on your data diskette.

2. ERROR: Unable to open data file XXX
   Occurs when opening a new or existing data file in preparation to write board defects.
   Causes:
   1. Your data disk may be full.
   2. The read-only attribute of your data file may be set.
   3. The write protect tab on your data diskette may be covered or on.

   Solutions:
   1. Check the space remaining on your data diskette using the DIR command. If there is very little or no space remaining on the diskette, switch to another diskette.
   2. and 3. See solutions 1 and 2 for Error 1.

3. ERROR: Unable to open file—Program exiting to main function menu.
   Occurs when opening a new data file.
   Cause:
   The data file does not exist in the system and the program is unable to create the new filename.

   Solutions:
   1 and 2. See solutions 1 and 2 for Error 1.

4. ERROR: Unable to access file(s) in file system for writing defects.
   Occurs when program is writing defect data to data file.
   Causes:
   1. The data diskette has run out of space.
   2. The data diskette was accidentally swapped with another.
   3. The write protect tab or switch is on preventing write access.
   4. The data diskette has failed.

   Solutions:
   1. Check the space remaining on the data diskette. You may be able to delete some old files and continue with the same diskette.
   2. Check that you are using the same disk you started with.
   3. Remove or reset the write protect tab or switch.
   4. Use the MS-DOS utility CHKDSK to check the diskette for failure. CHKDSK will report any faults and can actually repair some simple disk faults. It is recommended that you begin using another data diskette.

DEFECT COLLECTION ERRORS:

Errors 1 through 3 occur after both coordinates of a defect have been entered.

1. ERROR: Board defect has reversed coordinates.
   Cause:
   You have entered a defect coordinate which has a lower x or y coordinate greater than the upper x or y coordinate, respectively.
   Solution:
   Re-enter or edit the defect.

2. ERROR: Board defect coordinates describe a zero area defect.
   Cause:
   You have entered a defect coordinate which has a lower x or y equal to the upper x or y coordinate, respectively.
   Solution:
   Re-enter or edit the defect.

3. ERROR: Board defect coordinates describe a defect outside of the board.
   Cause:
   One of the coordinates of the defect lies outside of the board dimensions.
   Solution:
   1. Re-enter the board defect.
   2. If the coordinates for the defect are correct and the board dimensions are incorrect, then accept the error. When you are through entering defect data, you will be automatically placed in the board dimension editing screen.

4. ERROR: DEFECTS.TXT was not found.
   Occurs when user requests to see list of defect descriptions.
   Cause:
   The program is unable to find DEFECTS.TXT in the current directory or by using the APPEND path.
   Solution:
   1. Place DEFECTS.TXT in the same directory as the other digitizer programs.
   2. Put the path to DEFECTS.TXT in the APPEND path.
   3. If DEFECTS.TXT was edited or copied, make sure that the filename is correct.

5. ERROR: Integer overflow on keyboard input.
   Cause:
   User entered a board number, defect code, or coordinate that had more than 5 digits.
   Solution:
   Enter a number with 5 or fewer digits.

6. ERROR: Invalid defect number.
   Occurs when editing board defect data.
   Cause:
   A number of a defect was entered that does not exist or is not included in the defects currently displayed on the screen.
   Solution:
   Enter a new, valid defect number.

Errors 7 through 11 occur when verifying that the board data just entered was written to the data file. These errors are also reported by the VERIFDAT utility. If any of these error conditions arise, the program, DIGITIZE or VERIFDAT, will stop immediately.

7. ERROR: Unable to close datafile XXX for verification.
   Causes:
   1. The data diskette was accidentally swapped with another.
   2. The data diskette has failed.
   Solutions:
   1. Check that you are using the same disk you started with.
   2. Use the MS-DOS utility CHKDSK to check the diskette for failure. CHKDSK will report any faults and can actually repair some simple disk faults. It is recommended that you begin using another data diskette.

8. ERROR: Unable to re-open datafile XXX for verification.
   See the causes and solutions for Error 7.

9. ERROR: Unexpected end of file encountered during defect data search for board number II.
   Causes:
   1. The board data file has been edited which has left it in an inconsistent state. An example of this is where a defect has been deleted from a file and the defect count field in the board header was not changed to reflect this. This causes the verify procedure to read the next board's header as a defect record.
   2. Some editors such as KEDIT place special end of file characters at the end of files. If the data file has been edited with one of these editors, the program may have a problem in detecting the end of file. It is also possible that any data written to a file with these end of file characters will be LOST!
   3. The data file or data disk, or both, has failed or been corrupted.
   Solutions:
   1. Check that the number of defects for each board agrees with the defect count field in the header.
   2. Locate a suitable editor who can edit the data file strictly in a text mode. Most editors supplied with programming languages are suitable. Use the editor to remove any blank or suspicious lines at the end of the data file.
   3. See solution 2 to Error 7.

10. ERROR: Unable to find board number II in datafile.
    See the causes and solutions for Error 9.

11. ERROR: Unable to re-open datafile for appending.
    See the causes and solutions for Error 7.

Anderson, R. Bruce; Thomas, R. Edward; Gatchell, Charles J.; Bennett, Neal D. 1993. **Computerized technique for recording board defect data.** Res. Pap. NE-671. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 17 p.

A computerized technique for recording board defect data has been developed that is faster and more accurate than manual techniques. The lumber database generated by this technique is a necessary input to computer simulation models that estimate potential cutting yields from various lumber breakdown sequences. The technique allows collection of detailed information regarding the location and type of defects.

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