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A GUIDE FOR ESTIMATING WOOD RESIDUES PRODUCED AT PALLET PLANTS IN THE TENNESSEE VALLEY

The wood pallet and container industry used 4.0 billion board feet, 13 percent of the Nation's lumber production, in 1975. The manufacture of wooden pallets and containers produces 10 to 15 percent residue if measured on a nominal board-foot basis and 30 to 40 percent residue by lumber weight. Residues and part yield on a dry-weight basis are computed for each of the eight machine types commonly used in the pallet industry. The dry weight per thousand board feet of pallet lumber is given separately for 15 wood species encountered. The data are presented to provide methods for estimating residues on a nominal board-foot or weight basis in the following ways: (1) by the pallet, (2) per thousand board feet of lumber input, or (3) for a given period of time.

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A GUIDE FOR ESTIMATING WOOD RESIDUES PRODUCED AT PALLET PLANTS IN THE TENNESSEE VALLEY

INTRODUCTION

The use and acceptance of pallets by American industry have increased phenomenally since World War II. The savings accruing from pallet use are enormous. Yearly growth has been 8 to 10 percent since the 1950's. In 1975, 4.0 billion board feet, 13 percent of the Nation's lumber, went into wooden pallets and containers.

The manufacture of wooden pallets and containers produces 30 to 40 percent residue by weight of the lumber input contingent upon the machinery, the size of parts, and the initial size of the lumber or cant. These large amounts of residue have attracted the attention of particleboard, fiberboard, the energy industry, and other users of industrial wood residues. Big questions facing the pallet manufacturer are "how much residue am I producing?" And "what type of residue is it?" As far as is known, no formal study of pallet residues has been made. Individual pallet and container producers have conducted in-house residue studies; however, these data are generally not transferrable to other plants.

Because of the difficulty in obtaining residue estimates for the pallet industry and to answer requests for residue information, TVA's Division of Forestry, Fisheries, and Wildlife Development conducted this study. Preliminary work and discussions with plant managers showed that data could not be developed by studying plants. Rather an estimate had to be obtained for each machine type. To provide these answers machines were sampled separately at each plant with adequate replications to give a good working average of residue yields by each machine. See Table 10, Appendix, for regression equations and R^2 values of each machine.

The data were collected at nine pallet plants located in Ohio, Kentucky, Tennessee, and Alabama. Eight machine types commonly used in the manufacture of pallets were sampled. No effort was made to differentiate between the same types of machines made by different manufacturers, although occasionally there are inherent differences between machines and residue produced. This, in part, accounts for the low R^2 values in Table 10.

HOW THE STUDY WAS CONDUCTED

Weighing lumber and cants appeared to be the most accurate and easiest way of collecting the data. Weighing also eliminated the variation in moisture content and wood density as well as sawing and volume measurement inaccuracies. But the nominal board-foot measurements were made because these are used at pallet plants when purchasing lumber and selling pallets.

The moisture content of each piece was determined with a portable electronic moisture meter. The data were then checked by comparing meter readings with oven-dry samples taken in the laboratory.

Table 1 shows the machine, number of observations, type, and number of residue samples. Dimension and weight measurements, called observations, were taken on 1,044 pieces of lumber, cants, and parts. From these, 1,601 residue samples were obtained. These samples and observations provided the basis for developing the residue and yield data.

Fifteen species of wood were identified. Table 2 lists these along with their computed oven-dry weight per MBF, nominal measure, number of times each species was tallied, and the average moisture content (MC) of the observations. All moisture calculations are on the dry-weight basis. The formula is:

$$MC = \frac{\text{Green Weight - Dry Weight}}{\text{Dry Weight}} X\ 100$$

These average moisture percentages given in Table 2 are suitable for general use. An average of 60 percent is used in the examples unless stated. Additional data are contained in Table 8 in the Appendix.

Table 2 weights should not be used in lieu of lumber weights published by the National Hardwood Lumber Association because of lumber thickness variation, different MC, and degree of remanufacturing which has taken place.

Table 1. Number of Observations and Residue Samples by Machine and Type of Residue

Machine	Type of Residue						Residue Samples	Observations
	Cull	Edgings	End Trim	Sawdust	Shavings	Shims		
Band Resaw	-	-	-	21	-	-	21	21
Chamfer	-	-	-	-	64	-	64	64
Cut Off	4	-	176	189	-	-	369	189
Gang Rip	24	-	-	326	-	181	531	326
Multiple Trim Saw	-	-	59	59	-	-	118	59
Notcher	-	-	-	-	70	-	70	70
Straight Line Rip	1	113	-	171	-	-	285	172
Surfacer	-	-	-	-	143	-	143	143
Total	29	113	235	766	277	181	1,601	1,044

Table 2. Oven-Dry Weight, Observations, and Moisture Content of Pallet Lumber and Parts by Species

Species	Oven-Dry Weight Nominal Basis Pounds/MBF	Number of Observations	Average MC of Species Percent Dry Basis
Group I			
Persimmon	3,146	1	71
Oaks	3,079	557	62
Gum	2,950	12	77
Elm	2,918	5	48
Hickory	2,915	125	73
Average	3,044		
Group II			
Beech	2,676	22	63
Ash	2,499	19	66
Yellow-Poplar	2,468	112	65
Sycamore	2,418	5	74
Maple	2,412	64	70
Average	2,469		
Group III			
Cottonwood	2,273	3	78
Buckeye	2,207	1	57
Basswood	2,037	6	75
Pine	1,974	111	28
Butternut	1,646	1	100
Average	2,007		

Average moisture content for 1,044 observations = 61 percent

THE RESULTS

Residues by Nominal Board-Foot Measurement

Generally, pallet lumber and cants, and pallet parts and pallets are purchased and sold on a nominal basis. The volume difference between lumber purchased and pallets sold is the residue. It is the number of board feet paid for, but not sold. Thus, residues are a measurable cost.

On the other hand, residues are purchased and sold by weight, usually tons, or some equivalent measurement. Residue weights are also explained in this report.

Nominal measurement groups specific board dimensions. Thus, a board 1.13 inches thick would be tallied as a 1-inch board. If it were 5.97 inches wide it would be called 6 inches. And if it were 8 feet, 4 inches long it would be tallied as an 8-foot piece. The nominal board-foot volume of this board is: $\frac{1 \times 6 \times 8}{12} = 4$ board feet, while the actual volume is

$$\frac{1.13 \times 5.97 \times 8.333}{12} = 4.68 \text{ board feet.}$$

Table 3 shows the general conversions for changing actual measurements to nominal. Some pallet manufacturers may use different guidelines. Normal measuring and scaling practices are used when purchasing lumber and cants.

Table 3. Criteria for Determining Nominal Board-Foot Measurements for Pallet Parts for this Study

Actual Measurements Inches	Nominal Measurements Inches
Less than 0.51 thick	1/2
0.51 - 0.75	3/4
0.76 - 1.00	1.0
1.01 - 1.25	1-1/4
1.26 - 2.00	2
1.50 - 2.50 wide	2
2.51 - 3.50	3
3.51 - 4.50	4
etc.	

Length is measured to the last full foot when purchasing and to the nearest inch when selling.

Using Nominal Board-Foot Data for Pricing

Lumber is an important cost in pallet manufacturing, amounting to about 40 percent of the total cost. Thus knowledge of nominal board-foot yields and residues is important to cost control efforts.

Table 4 gives the normal flow of parts through the average plant, the machines used, and their yield factors. There is a large variation in the range of yield factors as shown in Table 9, Appendix. These factors are expressed as percents in decimal form for ease of use. The residue volume can be obtained by subtracting the board-foot yield from the input volume.

An example of how to use the yield and residue data in Table 4 follows:

Step 1. For each load of lumber, trace its flow through the plant and note the yield factors for each machine used in making pallet parts.

2. Multiply the yield factors sequentially for each machine used to obtain a plant yield.

3. Multiply the plant yield by the volume of input lumber. The answer is board feet of usable parts.

4. Residue is the yield substracted from the input volume.

5. Each load of lumber that has a different flow through the plant must be computed as in Steps 1 through 4.

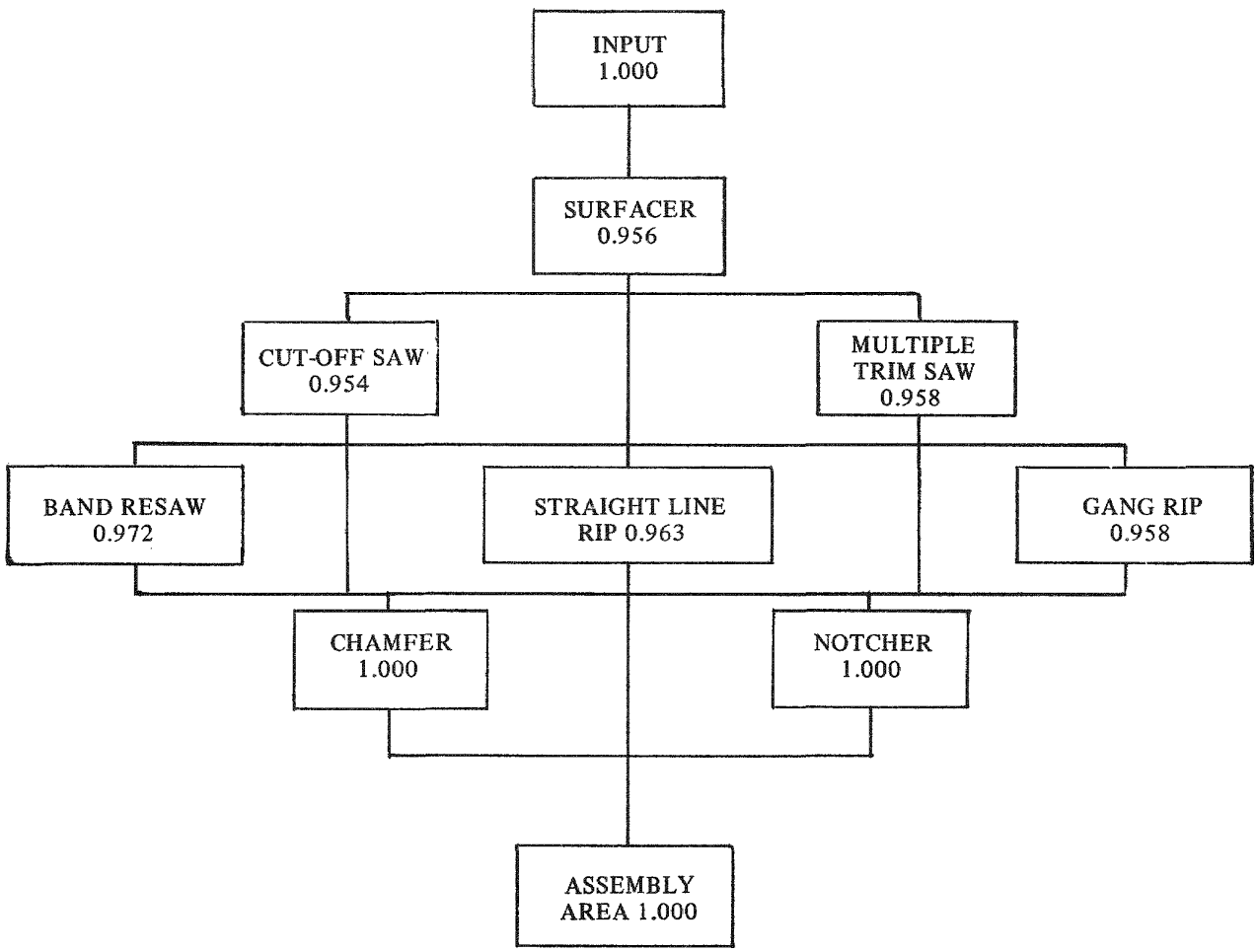
An example of the above is the case where 4 MBF of one-inch lumber for deck boards and 3 MBF of four-inch thick cants are used for stringers.

Step 1. Deck board flow is: surfacer 0.956, cut-off saw 0.954, straight line rip 0.963, chamfer 1.000, assembly area 1.000

2. 0.956 x 0.954 x 0.963 x 1.000 x 1.000 = .8782

3. 0.8782 x 4,000 = 3,513 board feet of parts

Table 4. Flow Diagram of Typical Pallet Plant Showing Machines and Average Yields of Parts, Nominal Board-Foot Basis



Yield factors are percents in decimal form, e.g., 0.956 is 95.6%.

4. Residue = 4,000 - 3,513 = 487 board feet

5. The flow of cants is: surfacer 0.956, multiple trim saw 0.958, gang rip 0.958, notcher 1.000, assembly area 1.000. The yield factor is 0.8773. 3,000 board feet x 0.8773 = 2,632 board feet of usable parts and 368 board feet of residue.

The yield for both loads of lumber is 6,145 board feet or 87.8 percent. If delivered lumber costs $110/MBF, parts exclusive of labor cost $125.31/MBF.

Occasionally breakage occurs or grading is done at the chamfering and notching machines and in the assembly area. If this occurs, the yield factor for these machines should be appropriately reduced.

Estimating residues and parts yield by the method explained in Table 4 allows the manufacturer to estimate the number of pallets that can be made from a specified amount of lumber. In the preceding example, 7 MBF produce 6,145 board feet of parts. If the pallet being considered required 25 board feet, then 245 pallets can be made.

If the manufacturer received an order for 2,000 of these pallets, how much rough lumber must be purchased? Two thousand pallets require 50 MBF. Since the yield is 0.878, 56,948 board feet of lumber and cants must be purchased.

Residues by Weight

The first part of this study has dealt with residue losses that are an expense to the manufacturer. This section explains how a manufacturer can estimate residue weights for the purpose of selling residues or estimating amounts that will have to be burned or otherwise disposed. The weights of the various types of residues will also be determined.

The difference in residue output estimates between the nominal board-foot measurement and weight can be easily explained. Nominal board-foot measurement is an inaccurate measurement for volume while weight is a very accurate measurement. The manufacturer may purchase one MBF of one-inch boards and all boards be 1-1/8 inches thick. Yet under nominal measurement the payment is for one MBF instead of 1,125 board feet.

Much of the hardwood lumber purchased by the pallet producer is sawed for the furniture and flooring market. It is usually in thicknesses of one to two inches. National Hardwood Lumber Association standards allow rough boards to be sawed from 3/8-inch to 3/4-inch thick in 1/8-inch increments and 3/4-inch to 2-inches thick in 1/4-inch increments. However, the pallet manufacturer is usually unable to obtain boards of the thickness needed so nearly all the board input is remanufactured. Cants are rarely the correct thickness and width.

Hardwood pallet lumber is usually purchased on a random width basis, while deck boards are nominally four and six inches wide and stringers four inches high. With these variations residues from the surfacer and straight line rip can sometimes be large. The surfacer has weight yield factors for each major lumber and cant size. The nominal board-foot basis of measurement required only one factor.

The notching and chamfering machines produce residues that were not included in the nominal measurement. The average yield from the notcher is 82.5 percent and the residue 17.5 percent. The chamfer has a residue of 4.7 percent.

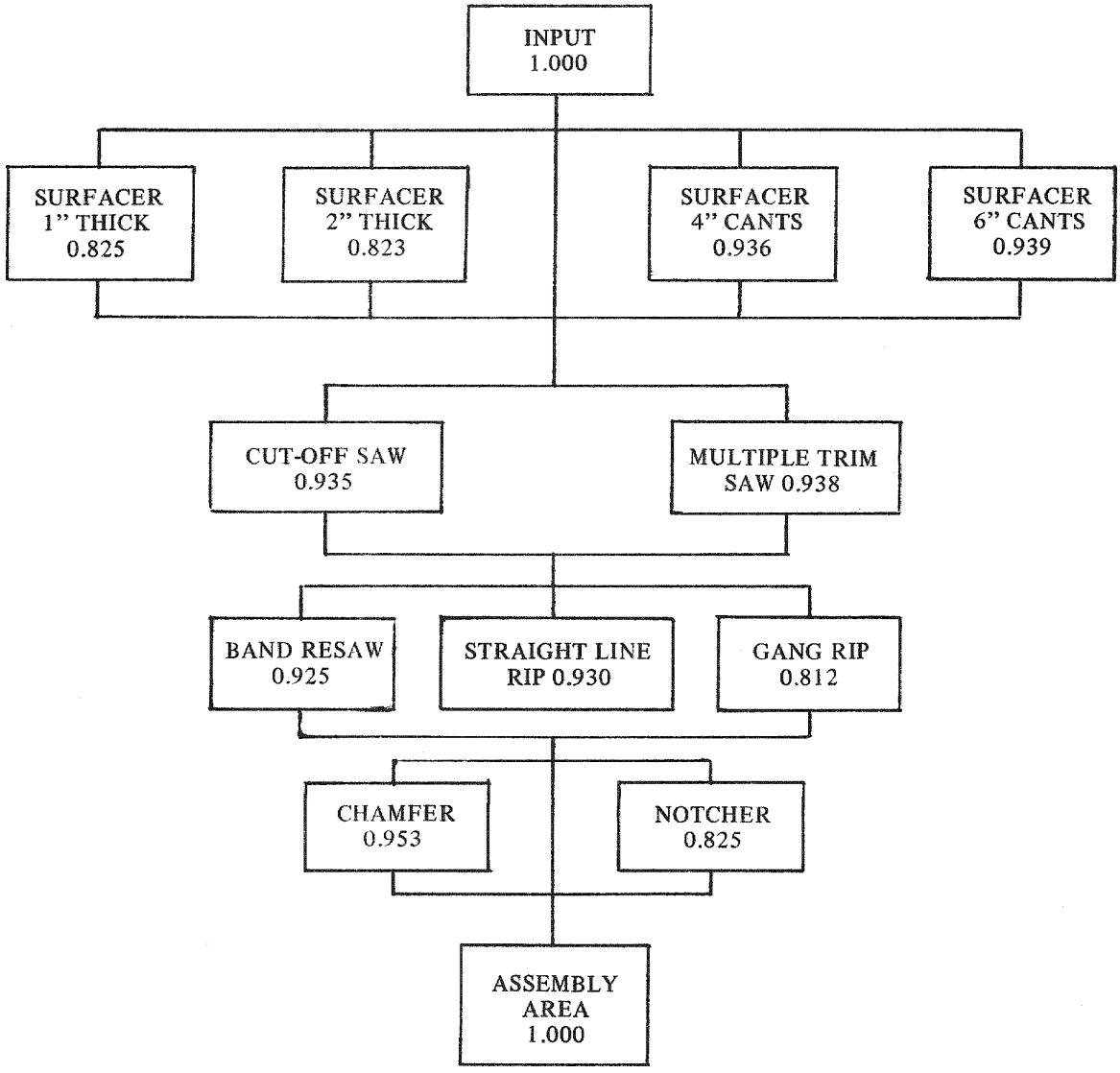
Since measuring residues on a weight basis rather than the nominal board-foot basis accounts for all the residue, as well as moisture in the wood, residue weights per MBF of lumber used can be quite large. However, as pointed out, much of this weight was not paid for so it is not a direct cost to the manufacturer. But the mass of residue can be a liability if it presents a disposal cost to the manufacturer.

Table 5 is a flow chart similar to Table 4. The exception is that the surfacer has four different yield factors instead of one as with the nominal board-foot measurement. Otherwise, use is the same as Table 4.

The yield of 1 MBF of one-inch lumber through the surfacer, cut-off saw, straight line rip, and chamfer is 68.4 percent and residue is 31.6 percent. If Group I species at 60 percent MC were used, residues would be 1,539 pounds.

Another example of using Table 5 is the use of four-inch cants to make stringers. The cants move from input (1.000) to the four-inch surfacer (0.936) to the multiple trim saw (0.938) to the gang rip (0.812) to the notcher (0.825) and then to the assembly area.

Table 5. Flow Diagram of Typical Pallet Plant Showing Machines and Average Yield of Parts, Weight Basis



Yield factors are percents in decimal form, e.g., 0.825 is 82.5%.

The yield is 58.8 percent and residue is 41.2 percent. If the operator were using oak at 62 percent MC, then residue would weigh 2,055 pounds per MBF.

In summary the steps are:

1. Determine the flow of lumber through the plant.

2. Determine the species or species group of the lumber.

3. Determine the MC.

4. Obtain green weight of lumber by multiplying dry weight times the quantity (1 plus MC).

5. Multiply yield factors of each machine that processed wood. The final answer is the overall yield factor.

6. Multiply lumber weight by yield factor to get yield, or by residue factor to get residue. Residue can be determined by subtracting yield from initial input weight.

Estimating Weights of Residue by Types

The machines used to produce pallet parts make residues of different configurations and shapes. Six different types of residues were identified. These were grouped into three distinct categories, i.e., sawdust, shaving, and chippable. Each has a potentially different use and. consequently, market.

Usually purchasers would like to have the residues separated by type. The pallet manufacturer needs to know how much of each residue type he has so he can decide whether the cost of separation and marketing is worthwhile. Table 6, Percentage of Residue by Machine and Type, gives the data necessary to make these estimates.

Table 7 is an example of residue weight by type of residue and machine that made the residue. It is based on one MBF of one-inch lumber being manufactured into chamfered deck boards. A more complete example is given in Tables 11 and 12, Appendix.

The residue data are computed using the weight basis yield factors taken from Table 5. This gives the yield by machine. The residues are computed by subtracting the yield from input. The percentage data from Table 6 are used to separate the total residue into its component parts. The residue types are then summed to obtain the total residue from the complete operation.

The importance of knowing the type and amounts of residue cannot be over-emphasized. A pulp company, for example, not only would like to know the total tons of residue, but the type of residue as well. Trim, cull, shims, and edgings are chippable and can be made into pulp chips. Some pulp companies will purchase sawdust for boiler fuel. If chip prices are $10.30 per ton and fuel prices are $1.50 per ton, the residue from Table 7 is worth $1.94 for chips and $0.11 for fuel. The shavings are worth $1.52 if animal bedding is $3.00 per ton. Residue value from one MBF is $3.57.

Good marketing partly depends upon knowing how much and when a product is available. When residue markets are developed and a history of sales accumulated, residue sales and estimates of volume may show variation. This is to be expected in some cases since the data are the average for nine plants. Also, residues may originate at work areas not included in this study. Two such places would be in the storage yard and in the assembly area where parts may be broken during assembly or rejected during inspection. Further adjustments to compensate between estimated production and sales can be made by adjusting individual machine yields and the average MC.

Table 6. Percentage of Residue by Machine and Type, Weight Basis

Machine	Type of Residue					
	Sawdust	Shavings	Trim	Cull	Shims	Edgings
Surfacer	-	100.0	-	-	-	-
Cut-Off Saw	12.0	-	87.5	0.5	-	-
Multiple Trim	10.7	-	89.3	-	-	-
Band Resaw	100.0	-	-	-	-	-
Straight Line Rip	44.0	-	-	1.7	-	54.3
Gang Rip	78.7	-	-	8.3	13.0	-
Chamfer	-	100.0	-	-	-	-
Notcher	-	100.0	-	-	-	-

Table 7. Weight of Residue from One MBF by Type and Machine*

Type of Residue	Machine				Total Residue
	Surfacer	Cut-Off	Straight Line Rip	Chamfer	
	----------	----------	Pounds	----------	----------
Sawdust		31	116		147
Shavings	852			164	1,016
Trim		228			228
Cull		2	4		6
Edgings			143		143
Total Residue	852	261	263	164	1,540

*Based on Group I average weight of 4,870 pounds per MBF at 60% MC. Residue is 31.6% in this example. The residue is estimated from the yield factors in Table 5.

CONCLUSIONS

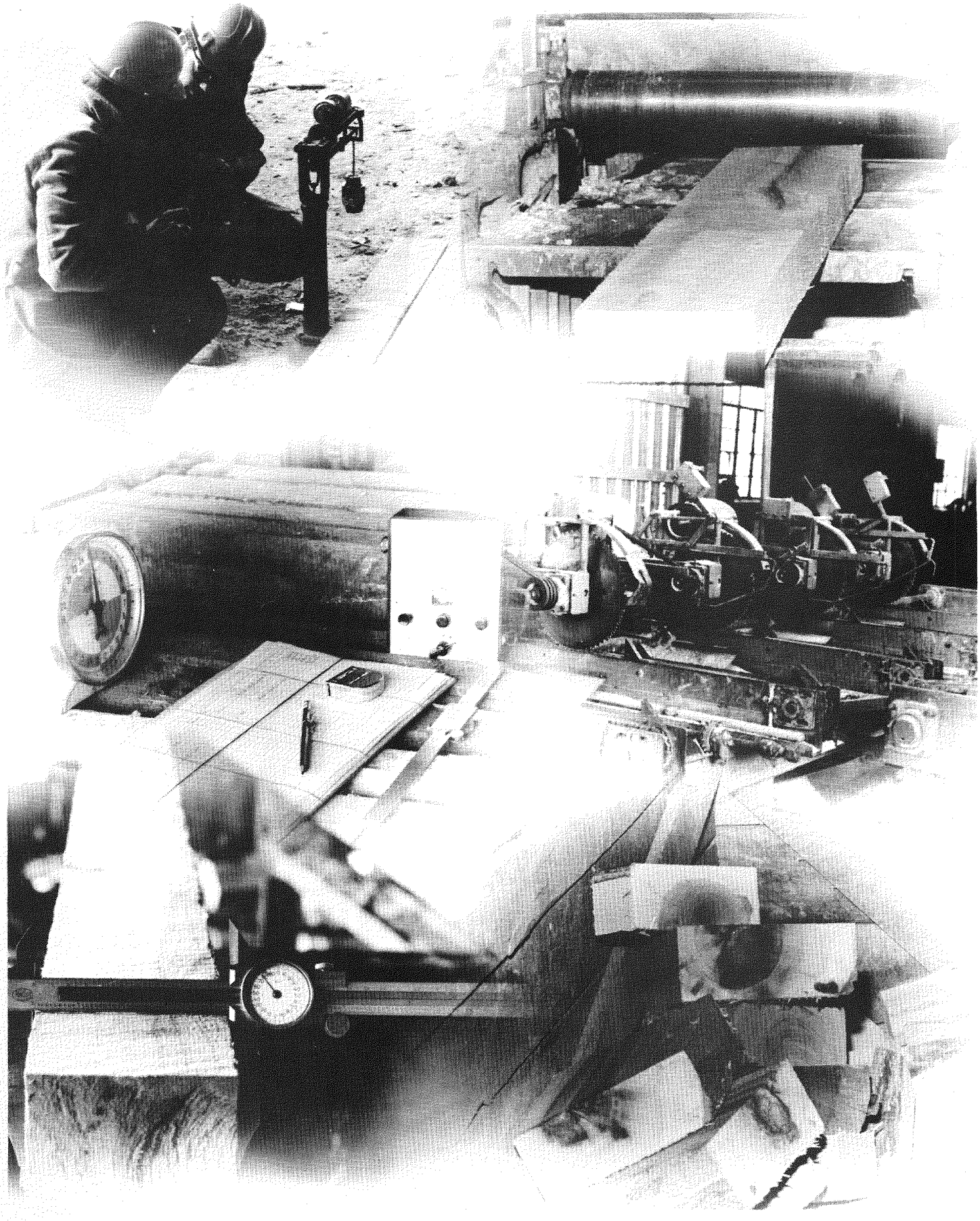
This study shows there are wide variations in residue estimates, depending on lumber specifications, plant equipment, kind of orders, and how the residue measurements are made. Communication between the lumber supplier, usually a sawmill operator, and the pallet manufacturer can reduce residues. Close sawing practices plus good mill maintenance keep residues minimal. Some pallet plant equipment makes less residues than other. One case in point is the thin kerf saws. Another is a notching machine making a smaller than specified notch.

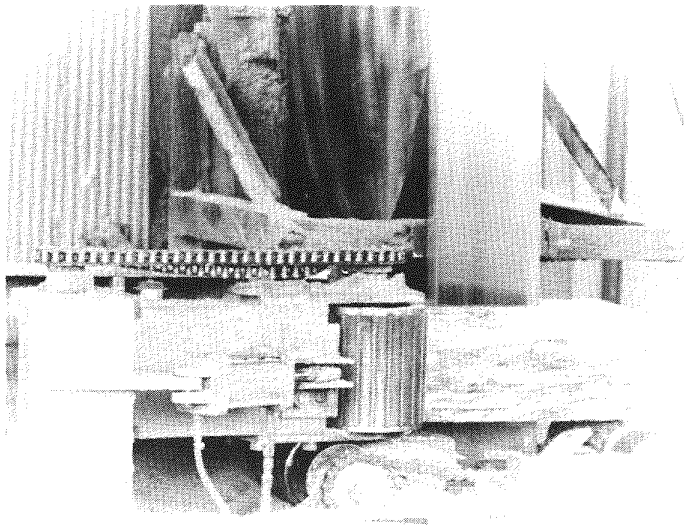
Nominal board-foot measurement gives residues of 10 to 15 percent, while on the weight basis, the same residues amount to 30 to 40 percent. Both measurement systems are important and useful to the pallet manufacturer. Since lumber and pallet transactions are generally on a nominal basis, any board-foot volume differences can be considered as a direct raw material cost. A monetary value can be placed on the residues; thus the data become part of the pallet pricing system, the same as labor and nails. However, nominal measurements do not provide answers to a number of other equally important questions that the weight basis gives.

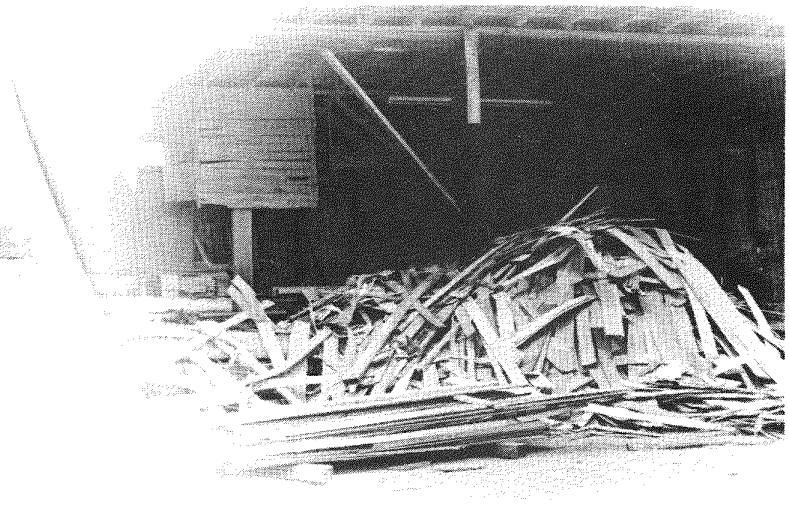
Weight measuring is a precise method that accounts for all residues—including wood which is not a cost to the manufacturer, e.g., oversize boards and cants. Weighing also accounts for variations in MC and density of the wood. These factors both affect the weight of residue produced; the wetter and denser the wood, the heavier the residue. Knowledge of the exact amounts of residues and where they originate in the plant is useful to the manufacturer in analyzing, planning, designing, and purchasing equipment and facilities. This is valuable information for discussing residues with potential buyers.

A good grasp of residues and their origin is an important part of an overall management program.

APPENDIX







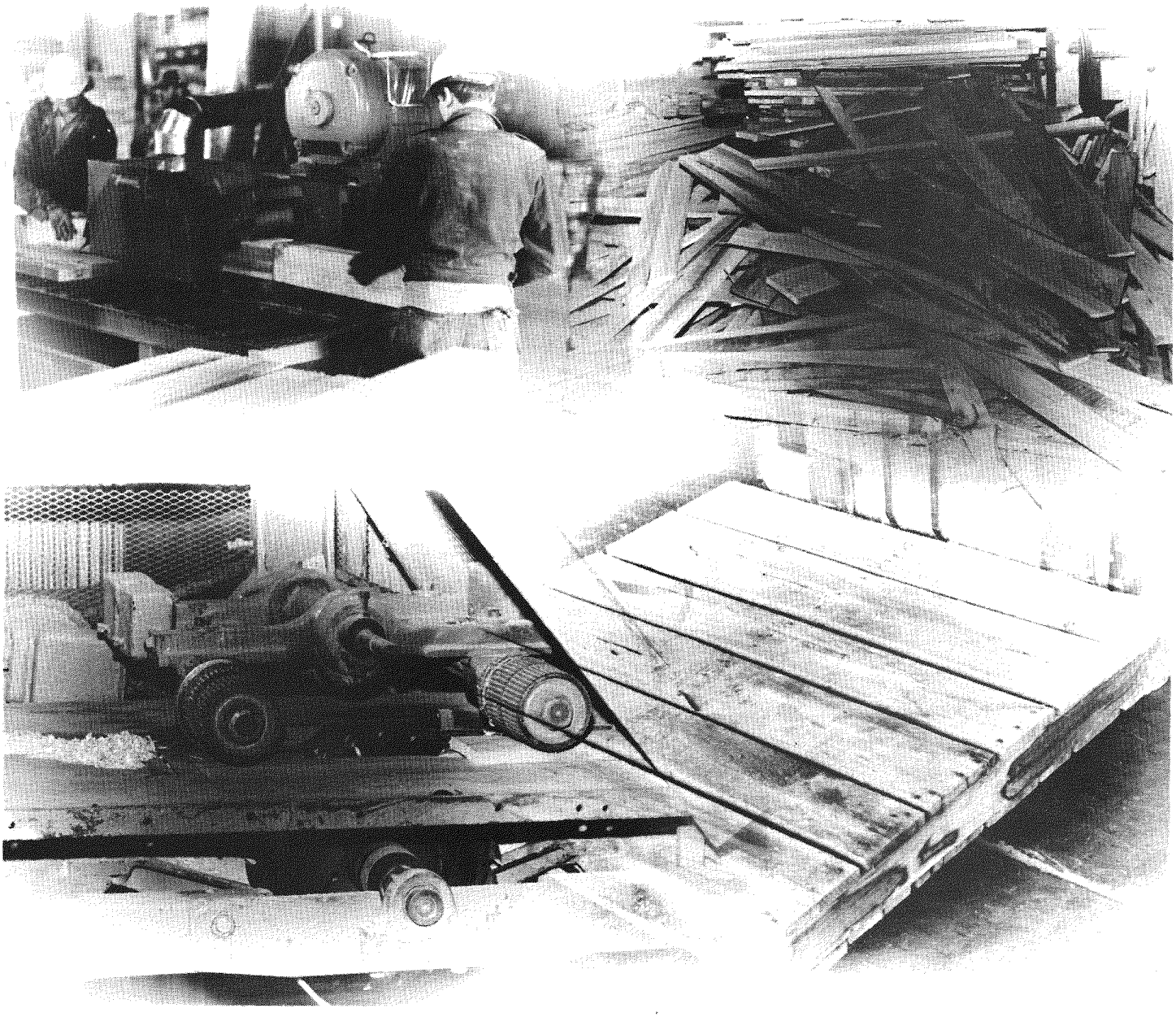


Table 8. Average Moisture Content by Species and Machine

Species	Machine											All Av. MC
	Band Resaw	Chamfer	Cut-off	Gang Rip	Multiple Trim Saw	Notcher	Straight Line Rip	Surfacer (Output) 1"	2"	4"	6"	
	-Percent-											
Pine	20	75	35	-	27	18	24	-	38	100	-	30
Oak	57	63	60	62	56	66	59	58	75	76	61	62
Hickory	94	73	64	73	72	69	81	62	80	78	69	72
Maple	35	65	71	64	53	90	75	54	60	77	67	73
Yellow-poplar	23	59	76	66	80	68	60	78	-	64	60	64
Beech	72	-	59	87	-	65	57	64	-	54	65	67
Butternut	100	-	-	-	-	-	-	-	-	-	-	100
Sycamore	-	98	75	65	-	-	53	75	-	-	-	73
Basswood	-	-	71	-	-	-	-	-	-	80	-	74
Gum	-	-	74	62	95	75	-	-	-	57	-	74
Elm	-	-	49	57	-	-	-	45	-	-	-	49
Ash	-	-	77	54	-	100	57	77	63	78	-	69
Persimmon	-	-	-	71	-	-	-	-	-	-	-	71
Cottonwood	-	-	-	-	78	-	-	-	-	-	-	78
Buckeye	-	-	-	-	-	57	-	-	-	-	-	57
Average moisture content	40	66	57	64	58	66	55	61	42	73	64	61

Table 9. Range of Yields and Residues by Machine

	Surfacer	Multiple Trim Saw	Cut-off	Gang Rip	Band Resaw	Straight Line Rip	Notcher	Chamfer
Nominal Board-foot Basis								
Yield								
High	.996	.985	.985	1.000	1.000	1.048	1.000	1.000
Low	.805	.916	.902	.926	.934	.712	1.000	1.000
Residue								
High	.195	.084	.098	.074	.066	.288	0	0
Low	.004	.015	.015	0	0	−.048	0	0
Weight Basis								
Yield								
High	0.947	0.955	0.950	0.845	0.942	0.959	0.871	0.975
Low	0.802	0.905	0.911	0.779	0.895	0.742	0.700	0.919
Residue								
High	0.198	0.095	0.089	0.221	0.105	0.258	0.300	0.081
Low	0.053	0.045	0.050	0.155	0.058	0.041	0.129	0.025

Table 10. Equations for Estimating Pounds of Residue Based on Pounds of Lumber Input, Oven-Dry Weight

		R^2	Number of Observations
Band Resaw	$\hat{Y} = -0.1840673 + 0.0995872\ X$	.835	21
Chamfer	$\hat{Y} = -0.1685799 + 0.0987571\ X$	.689	64
Cut Off	$\hat{Y} = 0.5140784 + 0.0433822\ X$	.299	189
Gang Rip	$\hat{Y} = 0.0402350 + 0.1944915\ X$	.413	326
Multiple Trim	$\hat{Y} = 0.7456812 + 0.0544014\ X$	.360	59
Notcher	$\hat{Y} = 0.7373760 + 0.0343112\ X$	.062	70
Straight Line Rip	$\hat{Y} = 0.3748757 + 0.0368546\ X$	.076	172
Surfacer			
1" Output	$\hat{Y} = -1.0082639 + 0.2266230\ X$	.487	63
2" Output	$\hat{Y} = -3.8379586 + 0.2776192\ X$	.792	19
4" Output	$\hat{Y} = 0.6675570 + 0.0763016\ X$	.188	54
6" Output	$\hat{Y} = -7.6324462 + 0.1442628\ X$	.396	7
Total Observations			1,044

Table 11. Estimate of Residues by Part and Machine for Three-Month Operation

Parts[1]	Lumber and Cants		Machine											Remainder to Assembly Area
			Surfacer				Cut-Off Saw	Multiple Trim Saw	Band Saw	Straight Line Rip	Gang Rip	Chamfer	Notcher	
	Amount	Weight	1-Inch 0.825[6]	2-Inch 0.823	4-Inch 0.936	6-Inch 0.939	0.935	0.938	0.925	0.930	0.812	0.953	0.825	
	MBF[2]		Tons at 60 Percent MC											
4" Deck Board														
1" Board	90	219[4]	181[7]	-	-	-	169	-	-	157	-	-	-	157
4" Cant	100	244	-	-	228	-	-	214	-	-	174	-	-	174
4" Chamfered Deck Board														
1" Board	10	24	20	-	-	-	19[11]	-	-	18	-	17	-	17
4" Cant	100	244	-	-	228	-	-	214	-	-	174	166	-	166
6" Deck Board														
1" Board	50	122	100	-	-	-	94	-	-	87	-	-	-	87
6" Cant	100	244	-	-	-	229	-	215	-	-	175	-	-	175[13]
6" Chamfered Deck Board														
2" Board	10	24	-	20	-	-	19	-	18	17	-	16	-	16
6" Cant	100	244	-	-	-	229	-	215	-	-	175	167	-	167
2 x 4 Stringers														
2" Board	190	462	-	380	-	-	-	356	-	331	-	-	273	273
Amt to System	750[3]	1,827[5]	365[8]	486	488	488	321[12]	1,294	19	656	858	384	331	1,827[14]
Yield of Parts			301[9]	400	457	458	301	1,214	18	610	698	365	273	1,232[15]
Residue, Green Tons			64[10]	86	31	30	20	80	1	46	160	19	58	595[16]

Table 11 is a complete example of one plant's yield of parts and residue for one calendar quarter. Due to rounding, some entries may not check. The numbers in parentheses are keyed to explanation below.

(1) The major parts are listed. Under each major part the size of board or cant used to make that part is listed.

(2) MBF is estimate of volume used to make these parts.

(3) This is the amount purchase tickets indicate was bought during the quarter. It is adjusted for changes in inventory. It should agree with the sum of lumber and cant volume for each part.

(4) This is the weight of the lumber or cants. In this example, Group I Species at 60% MC is used. One MBF weighs 3,044 pounds dry and 4,870 pounds green. 90 MBF weigh 210 tons.

(5) 1,827 tons is the sum of the lumber weights of the different parts. It is also 750 MBF x 2.435 tons/MBF.

(6) Yield data are taken from Table 5.

(7) 181 tons is the product of the weight of input lumber and the yield factor, i.e., 219 tons x 0.825.

(8) 365 tons is the sum of the lumber weights before surfacing. It is the sum of 219 + 24 + 122.

(9) 301 tons is the sum of the lumber weights after surfacing. It is the sum of 181 + 20 + 100. It is also the product of the input weight x the yield factor, i.e., 365 tons x 0.825.

(10) 64 is the tons of green residue. It is the amount to the surfacer less the yield of parts. It is also the product of the amount to the surfacer and the residue factor. The residue factor is 1.000–0.825 = 0.175. 365 x 0.175 = 64.

(11) 19 tons is the product of 20 x 0.935. 20 tons of wood came from the surfacer. After it went through the cut-off saw operation, 19 tons were left. One ton of residue was produced.

(12) 321 tons is the sum of the weights that went to the cut-off saw. It is the sum of 181 + 20 + 100 + 20.

(13) 175 tons is the weight of the parts made from 244 tons of 6" cants. The 244 tons of cants went to the surfacer and 229 tons were left, then to the multiple trim saw where 215 tons (229 x 0.938) were left, then to the gang rip where 40 tons (215 x 0.188) of wood were removed as residue leaving 175 tons.

(14) 1,827 is the amount of wood started through the plant. It is also the sum of 365 + 486 + 488 + 488 which is the weight of the one-inch, two-inch, four-inch, and six-inch thick lumber and cants before they were surfaced.

(15) 1,232 is the sum of the weights of the different pallet parts that are available to the assembly area.

(16) 595 is the total tons of residue produced. It is the difference between amount to the system and yield of parts. It is also the sum of the residues produced by the different machines. The three months' average yield is 0.674 (1,232 ÷ 1,827). The three months' average residue is 0.326 (595 ÷ 1,827).

Table 12. Estimate of Tons of Residue by Machine and Type for Three-Month Operation*

Machine	Residue at 60 Percent MC						
	Sawdust	Shavings	Trim	Cull	Shims	Edgings	Total
	----------Tons----------						
Surfacer	-	211.0	-	-	-	-	211
Cut Off Saw	2.4	-	17.5	0.1	-	-	20
Multiple Trim Saw	8.6	-	71.4	-	-	-	80
Band Resaw	1.0	-	-	-	-	-	1
Straight Line Rip	20.2	-	-	0.8	-	25.0	46
Gang Rip	125.9	-	-	13.3	20.8	-	160
Chamfer	-	19.0	-	-	-	-	19
Notcher	-	58.0	-	-	-	-	58
Total	158.1	288.0	88.9	14.2	20.8	25.0	595
Percent of Total	27	48	15	2	4	4	100

*These data developed from residue estimates in Table 6 and Table 11.

Table 12 data provide the foundation for a marketing strategy. For example, a pallet manufacturer wants to know if marketing his residues will be profitable. Table 12 shows 148.9 tons of chippable material, 158.1 tons of sawdust, and 288 tons of shavings are available each quarter.

The boiler fuel market for sawdust nets the manufacturer $1.50 per ton. The shavings are sold for animal bedding to stable owners or poultry farmers for $3.00 per ton. The chips are sold to the pulp industry for $10.30 net. The projected quarterly income from sales is $2,634.82. Additional equipment to chip, screen, separate, and load residues is estimated to be $40,000. The cost of disposing of the residue would offset the cost of operating the equipment. Thus, the pallet manufacturer could expect to recoup his capital cost in 16 quarters or four years.