A SYSTEMS APPROACH TO A PRODUCTION SCHEDULING PROBLEM INVOLVING ASSEMBLY

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ABSTRACT

A SYSTEMS APPROACH TO A PRODUCTION SCHEDULING PROBLEM INVOLVING ASSEMBLY

by Rodolfo Camanzo Yaptenco

A scheduling problem involving assembly of the type that generally characterizes plywood manufacturing is identified and modelled mathematically in terms of algebraic and difference equations. The facility is viewed as a system made up of a discrete number of components, viz., production centers, that interact with each other only at a discrete number of points, viz., points where inputs are received and outputs removed. The mathematical formulation is shown in considerable detail to illustrate the logic of the approach taken.

Following hypothetical considerations, an actual scheduling problem is subsequently described and modelled. Production centers in the facility are identified and defined, modelled independently of each other and the component models combined (using the inter-connection pattern of the system) to form the system model.

Practical implications of the dynamic case are discussed, with some emphasis given to the economic feasibility of implementing such a model in the real world. The static case (where only one interval is considered

and taken equal to the planning horizon) is also discussed. Results from a computer run of the static model using actual data, e.g., order file, initial inventories, machine capacities available, space limitations, etc., are presented in the appendix.

Certain aspects of the model where improvements can be effected are mentioned.

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By

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure		Page

LIST OF APPENDICES

I. INTRODUCTION

A scheduling problem is said to exist if in the production of goods there are (or there become available) a number of alternatives for sequencing a number of jobs or performing a series of operations on a number of machines and it is desired to choose from these alternatives those that would optimize some chosen objective.

In general, the number of alternatives is very large; consequently, the job of a production scheduler is expected to be complex. It is a wonder, therefore, why schedulers do not seem to find scheduling a problem at all. Pounds (13) provides us with some explanation. He reports that in most cases there are no scheduling problems to start with because ". . . the organization which surrounds the schedulers reacts to protect them from strongly interdependent sequencing problems." Mellor (12) concurs. "In effect," he observes, "industrial schedulers are being asked to get a pint out of a quart pot and are experiencing no difficulty in doing so. The scheduler's protection, of course, comes from extravagant provision of shop capacity or poor commercial performance."

We conclude, therefore, that multiplicity of alternatives *per se* does not make scheduling difficult; rather, it is how restrictive our objective is or how good a schedule is desired and how well the capacity of the facility is utilized. Indeed, if only mediocre schedules are made or if plenty of excess capacity is available, the job of a production scheduler would be trivial. On the other hand, choosing an optimal schedule for a plant operating at or near capacity is a formidable job. Obtaining optimal schedules is of course the object of today's factories, especially with the specter of increasing costs and stiffening competition looming in the future. Thus, the need for efficient methods of selecting optimal or near optimal schedules is very real.

The purpose of the research which forms the basis of this dissertation was to find a method of solution to a certain class of scheduling problems involving assembly, to which plywood manufacturing belongs. The work herein described is an attempt to provide the scheduler assistance by reducing the scale of the problem to a point where it would require only judgment to select a near optimal or optimal schedule. It is expected to free the scheduler from having to contend with normally multifarious alternatives.

II. THE JOB-SHOP SCHEDULING PROBLEM

II-1. Background

Much of the literature about scheduling is concentrated on "job-shop scheduling," a consequence of the fact that it is regarded as the most complex. We define "job-shop scheduling" as the sequencing of a number of jobs that require varied sets of operations and follow diverse routings through a facility of several production centers and compete with each other for productive capacity on common machines. It becomes a problem when sequencing is to be done with some objective in mind, e.g., minimizing total processing time, minimizing total production cost, minimizing lateness of deliveries, minimizing downtime, or some combinations thereof.

The simplest approach to the problem is without any doubt an exhaustive enumeration of all feasible schedules and selecting from the set the schedule that optimizes the objective. The method, however, is not practical since the number of feasible schedules is very large even for small problems. For example, if we have j jobs and m machines and each job needs to be processed by each machine, then the number of feasible schedules is $(j!)^m$.

For five jobs and four machines this number is 207,360,000 --a number which even the modern digital computer cannot search through economically for the optimal schedule. Intuitively, though, one gets the impression that surely the optimal schedule must come only from a much smaller subset of the whole set of feasible schedules. What is obviously needed are some criteria for discarding those schedules that have no possibilities of becoming optimal and searching only those that do, for the optimal schedule.

Giffler and Thompson (8) narrowed the number of feasible schedules to be included in the enumeration by considering only "active" schedules. (They define an "active schedule" as a feasible schedule such that no machine may be idle for a period of time greater than or equal to the processing time required by a job that is available for processing and that processing of a job is started as soon as both machine and job are free.) For moderate-sized problems the method has distinct advantages. However, when considered in terms of the size of real problems it likewise suffers from the combinatorial character of job-shop problems, since the number of active schedules also increases very rapidly with an increase in the number of jobs or the number of operations required on each job.

To get around the immensity of the number of alternatives, a Monte Carlo sampling technique was devised (9) for drawing samples from the set of active schedules, and searching only the samples for the best schedule. Since only samples are considered, the method does not guarantee an optimal schedule, although the probability of obtaining one can be increased by taking more samples. The implication of course is that as more samples are taken to increase the probability of obtaining an optimal schedule, the amount of computation required will correspondingly increase.

A method which has attracted a great deal of attention, and rightfully so, is the heuristics approach (2, 7, 18). In this method simple but effective rules of thumb are used for discriminating between alternative ways of sequencing jobs. These rules may be "borrowed" from rules of thumb used by capable schedulers, or they may be the result of simulated studies of the problem, or from some other appropriate sources. Unfortunately, it cannot show, except perhaps intuitively, that the schedules chosen on the basis of these rules are consistently good. The only justification for their use is that they either represent the sound judgment of skillful schedulers and/or were found effective under simulated conditions. Heuristics, however, provides the opportunity to narrow, rather drastically, the number of alternatives down to manageable proportions, permitting the selection of a schedule which is at least as good (if the rules are chosen properly) as a human scheduler could make. With more experience in the selection of rules, it may be the most practical approach to certain types of scheduling problems.

There are of course other methods (1, 10, 12, 15, 16, 19) that have been proposed for certain idealizations of the scheduling problem. However, there exists a gap between the problems assumed in these formulations and those of the real world. Moreover, the amount of computation seems to limit the size of the problem that can be practically handled. Consequently, applicability is still somewhat limited.

In each of the methods of solution reviewed above, the object was always to find some optimal solution to the problem. Analytical methods tend to require too much computation (at least for now) and empirical methods tend to oversimplify the problem. A combination of analytical and empirical methods might provide the right combination. Indeed, it is a distinct possibility. In other words, instead of trying to obtain a complete solution to the problem, what is suggested here is cutting down the size of the problem by analytical methods to a point where the human scheduler can use his judgment effectively and consistently.

The subject of this dissertation is the formulation of the scheduling problem in a format that is amenable to already available optimizing techniques. It approaches the problem with the systems concept by viewing the production facility as a "system" and describing it in terms of product flows and inprocess inventories in the form of algebraic and difference equations. Its objective is to narrow down the number of alternatives a scheduler must choose from and the number of decisions he has to make. It hopes to present to the human scheduler the problem in a much simplified form and leave to him the details of bringing the problem to complete solution. In effect what is proposed here is some form of sub-optimization.

II-2. Scheduling Problems Involving Assembly

We also note from the literature that attention given to scheduling problems is generally directed at job-shop problems of the type that does not involve intermediate or final assembly. Consequently, the solutions proposed exclude assembly-type problems where jobs (and the parts they require for assembly) compete with each other for productive capacity. In this variation of the job-shop problem, jobs generally require certain parts that are also required by other jobs. Since parts are processed in batches, we can conceive of the problem as made up of jobs which in later stages of manufacture break up and recombine with others to form new jobs. Thus, the problem basically is sequencing the right quantities of material or semi-finished products at each processing center so that assembly of jobs at a later stage in time can proceed with as little interruption as possible without building up in-process inventories.

The development following concerns an assembly-type of scheduling although the method here proposed is not necessarily limited to such types of problems.

III. A SYSTEMS APPROACH TO SCHEDULING

A <u>system</u> is a collection of objects or entities which are related to and interact with one another in some fashion such that each object or entity performs a function that contributes to the objectives of the group. A formalized awareness of the interactions between parts of a system is what is popularly known as <u>systems engineering</u> (6). The key to the whole concept of systems engineering is the simultaneous consideration of the relationships between components of the system and the emphasis given to the effectiveness or the objectives of the whole system rather than that of the parts taken separately.

A production facility, in the context of the definition given above, is a system. It is a collection of processing centers functioning together as a group with a unified objective--the production of goods. It should, therefore, be amenable to the same techniques of systems analysis used in engineering to describe physical systems, <u>provided certain conditions are met</u>. Indeed, if these conditions can in fact be met, then we would have made significant progress because system theory provides a rigorous and consistent analytical framework for describing the behavior of systems.

III-1. System Theory

System theory has its origins in the analysis of electrical networks. It has been extended to include discrete physical systems, and very recently efforts have been made to extend its usefulness to socio-economic systems.

A rigorous treatment of system theory as applied to physical systems may be found in a recent book by Koenig, Tokad, and Kesavan (11). To attempt will be made here to discuss the fundamentals of the theory, except very briefly those that have pertinence to the discussion.

III-1.1 Discreteness

One fundamental requirement of system theory is that a system must be identifiable into a finite number of components that are interconnected and interact only at a discrete number of points. Consequently, each component can be isolated and modelled independently from other components and, through the topology of their interconnections, combined into a system model. System theory, therefore, assumes that the model of a component characterizes that component as an entity without regard to how the component may be interconnected with other components of the system. This assumption is not true of course in cases where the presence of a component has induced effects on other components. In such cases, we may either neglect these induced effects or isolate the components only conceptually.

We note that a production system is identifiable into a discrete number of components, e.g., machines or groups of machines, that constrain or interact with each other only at the points where inputs are received and outputs removed. Hence, the above requirement of discreteness can be satisfied.

III-1.2. Generalized Kirchoff Postulates

Another requirement of system theory is that the performance characteristics of each component should be described in terms of two complementary variables that satisfy the two generalized Kirchoff postulates. This pair of variables, which we shall denote as X and Y, should have analogous connotations, respectively, as voltage and current in electrical systems or pressure and fluid flow in hydraulic systems.

III-1.2.1. Flow Variable, Y_i

Let Y_i be the flow of materials or products in the system. If the flows are expressed in the same units, then the flow variable Y_i satisfies the first Kirchoff postulate. That is, "The algebraic sum of all directed flows at any point in the system must vanish." In symbols, for any cut-set m and any time t, we write,

$$\Sigma Y_{mi}(t) = 0 \qquad \text{(III-1.2.1)}$$

Therefore, it only needs to be established that all flows in the system are expressable in the same units. It will be shown later, in the discussion of an actual problem, that in fact this can be done.

III-1.2.2. Propensity Variable, X_1

The propensity variable, X_1, is most difficult to identify at the present time because little is known about the interrelationships between factors that influence the flow of materials in a production system. We know intuitively and from experience that the flows of materials between any two points is a function of (i) demand for such materials elsewhere in the system, (ii) the levels of in-process inventories, (iii) the costs associated with such flows, (iv) difficulty associated with holding materials in inventory (such as due to space limitations), (v) the capacities of machines in which these materials need to be processed, and (vi) still probably some other factors. Because the relationships between these factors are not known, it is not now possible to identify a propensity variable that could, in addition to the flow variable, be used to describe the performance characteristics of a production system. More research and experience are undoubtedly required before an appropriate propensity variable can be identified.

We can, however, proceed to model a production system in terms of flows and the factors suggested above without necessarily knowing the interrelationships of these factors, for we know in general how these factors independently affect the selection of a schedule. This is best shown by considering a hypothetical example in the next section. There we will model a system in terms of material flows and in-process inventories and use such factors as demnad, costs, space limitations and machine capacities to constrain the selection of a schedule, at the same time making the most use of the resources of the system.

III-2. A Scheduling Problem Involving Assembly

In the classical[1] job-shop problem, the usual assumption is that a succeeding operation on a job cannot be started unless a preceding operation has been completed on the whole job. In other words, no two machines may work on the same job simultaneously. This assumption is obviously suited only for jobs that cannot be split physically (such as jobs consisting only of one unit each) or for jobs that require small processing times on each machine. On the other hand, if the processing times involved are in the order of, say, an hour or more and it is possible and practical to split jobs (such as batch types), the assumption introduces considerable error in the form of excessive and unnecessary

---

[1]Defined as $\underline{n}$ jobs, $\underline{m}$ machines, the processing time of each job on each machine being known and the object is to find the sequence at each machine center that requires the least total processing time.

waiting time. In assembly-type production, the parts that go into assembly are generally processed in batches. At earlier stages of production, i.e., before assembly, these batches are themselves jobs which can be worked on concurrently by two or more machines after allowing sufficient lead time in the preceding operations. In such a case, it is more desirable to use a time interval as a criterion for moving completed portions of jobs to the next operations. For example, if the interval chosen were an hour, then we can for instance make the assumption that the portion of a job completed during a given hour may be moved to and worked on at the next operation during the next hour, but not before then. We also make the restriction that the movement of material between two processing centers occurs in "spurts" and is possible only at the beginning of each period.

Obviously, the choice of an appropriate interval will depend on how discrete the jobs are, i.e., how many units make up a job, and the time it takes to process a unit of a job.

Consider now a facility of several processing centers manufacturing products that require assembly in the last operation, shown schematically in Figure III-2.1. The solid circles represent processing centers and the dotted circles in-process inventories. If we let $Z_i(t)$ represent inventories and $Y_{ij}(t)$ represent material flows during any time $\underline{t}$, then we can write

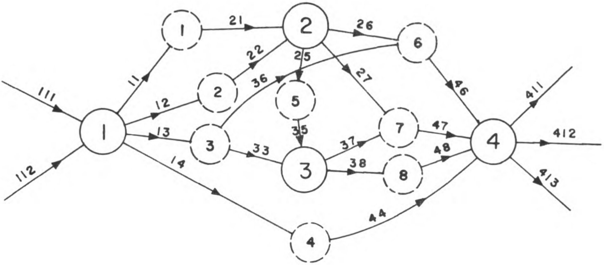

Figure III-2.1--Schematic diagram of a hypothetical production system. Solid circles represent processing centers and dotted circles represent in-process inventories.

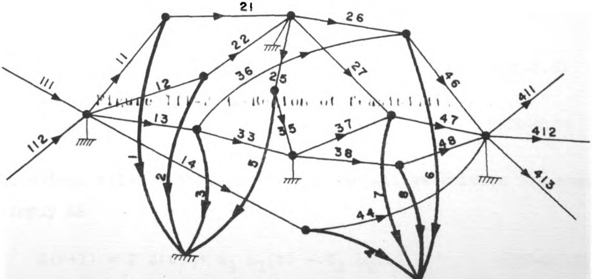

Figure III-2.2--Equivalent system graph of production system shown in Figure III-2.1.

$$z_i(t+1) = p_i\ z_i(t) + \Sigma y_{ji}(t) - \Sigma y_{ki}(t) \qquad \text{(III-2.1)}$$

where $y_{ki}(t)$ represents flow from inventory $\underline{i}$ to machine $\underline{k}$, $y_{ji}(t)$ represents flow from machine $\underline{j}$ to inventory $\underline{i}$ and $\underline{p_i}$ is some constant. In the example shown in Figure III-2.1, $i = 1,2...8$, $j = 1,2,3,4$, and $k = 1,2,3,4$. If we write Equation III-2.1 for all $\underline{i}$, we have

$$z_1(t+1) = p_1\ z_1(t) + y_{11}(t) - y_{21}(t) \qquad \text{(III-2.2)}$$

$$z_2(t+1) = p_2\ z_2(t) + y_{12}(t) - y_{22}(t) \qquad \text{(III-2.3)}$$

$$z_3(t+1) = p_3\ z_3(t) + y_{13}(t) - y_{36}(t) - y_{33}(t) \qquad \text{(III-2.4)}$$

$$z_4(t+1) = p_4\ z_4(t) + y_{14}(t) - y_{44}(t) \qquad \text{(III-2.5)}$$

$$z_5(t+1) = p_5\ z_5(t) + y_{25}(t) - y_{35}(t) \qquad \text{(III-2.6)}$$

$$z_6(t+1) = p_6\ z_6(t) + y_{26}(t) + y_{36}(t) - y_{46}(t) \qquad \text{(III-2.7)}$$

$$z_7(t+1) = p_7\ z_7(t) + y_{27}(t) + y_{37}(t) - y_{47}(t) \qquad \text{(III-2.8)}$$

$$z_8(t+1) = p_8\ z_8(t) + y_{38}(t) - y_{48}(t) \qquad \text{(III-2.9)}$$

Equations III-2.2 through III-2.9 can all be written together simply as

$$Z(t+1) = P\ Z(t) + G_1\ L_1(t) - T_2\ L_2(t) \qquad \text{(III-2.10)}$$

where $Z(t)$ is a vector of in-process inventories, $L_1(t)$ is a vector of outputs $(y_{ji}(t))$, $j = 1,2,3$, and $L_2(t)$ a vector of inputs $(y_{ki}(t))$, $k = 2,3,4$. P, G_1 and G_2 are matrices. Let us assume for the moment that we have valid models of machines 1, 2 and 3 of the form

$$Y_{ji}(t+1) = R\ Y_{ji}(t) + S\ Y_{ki}(t) \qquad \text{(III-2.11a)}$$

or

$$Y_{ji}(t) = D\ Y_{ki}(t) \qquad \text{(III-2.11b)}$$

Then we can combine Equations III-2.10 and III-2.1, eliminating outputs (y_{ji}), $j = 1,2,3$, and write the result in the following matrix form:

$$Z(t+1) = P\ Z(t) + Q\ E(t) \qquad \text{(III-2.12)}$$

where $E(t)$ is a vector of inputs, (Y_{ki}), $k = 1,2,3,4$ and Q is a new matrix resulting from the operations implied above.

Equation III-2.12 can also be obtained by representing Figure III-2.1 by an equivalent system graph shown in Figure III-2.2 and selecting a tree, T (shown in heavy lines). Writing the cutset equations for the tree T, we obtain a mathematical model of the interconnection pattern of the system:

$$
\begin{bmatrix}
1 &&&&&&& \\
& 1 &&&&&& \\
&& 1 &&&&& \\
&&& 1 &&&& \\
&&&& 1 &&& \\
&&&&& 1 && \\
&&&&&& 1 & \\
&&&&&&& 1
\end{bmatrix}
\begin{bmatrix}
y_1(t) \\ y_2(t) \\ y_3(t) \\ y_4(t) \\ y_5(t) \\ y_6(t) \\ y_7(t) \\ y_8(t)
\end{bmatrix}
+
\begin{bmatrix}
-1 &&&&&&&&& \\
& -1 &&&&&&&& \\
&& -1 &&&&& 1 && \\
&&& -1 &&&&&& \\
&&&& -1 &&&&& \\
&&&&& -1 && -1 && \\
&&&&&& -1 && -1 & \\
&&&&&&&&& -1
\end{bmatrix}
\begin{bmatrix}
y_{11}(t) \\ y_{12}(t) \\ y_{13}(t) \\ y_{14}(t) \\ y_{25}(t) \\ y_{26}(t) \\ y_{27}(t) \\ y_{36}(t) \\ y_{37}(t) \\ y_{38}(t)
\end{bmatrix}
+
$$

$$
\begin{bmatrix}
1 &&&&&&& \\
& 1 &&&&&& \\
&& 1 &&&&& \\
&&&& 1 &&& \\
&&& 1 &&&& \\
&&&&& 1 && \\
&&&&&& 1 & \\
&&&&&&& 1
\end{bmatrix}
\begin{bmatrix}
y_{21}(t) \\ y_{22}(t) \\ y_{33}(t) \\ y_{35}(t) \\ y_{44}(t) \\ y_{46}(t) \\ y_{47}(t) \\ y_{48}(t)
\end{bmatrix}
= 0 \qquad \text{(III-2.13)}
$$

The general equation for in-process inventory is given by

$$
Z_i(t+1) = p_i \; Z_i(t) + Y_i(t) \qquad \text{(III-2.14)}
$$

Combining Equation III-2.14 with Equations III-2.11 and III-2.13, Equation III-2.12 can be obtained.

Let the vector $E(t)$ be rearranged such that we can partition it into (i) inputs to machines 1,2, and 3 and (ii) inputs to machine 4. Then we can write

$$
E(t) = \left[\begin{array}{c} E_1(t) \\ \hline E_2(t) \end{array}\right] \qquad \text{(III-2.15)}
$$

where $E_1(t)$ represents inputs to machines 1, 2, and 3 and $E_2(t)$ represents inputs to machine 4 (an assembly process). We can therefore rewrite Equation III-2.12 as

$$Z(t+1) = P\ Z(t) + \begin{bmatrix} Q_1 & Q_2 \end{bmatrix} \begin{bmatrix} E_1(t) \\ \hline E_2(t) \end{bmatrix} \qquad \text{(III-2.16)}$$

or $$Z(t+1) = P\ Z(t) + Q_1\ E_1(t) + Q_2\ E_2(t) \qquad \text{(III-2.17)}$$

Let $J(t) = \begin{bmatrix} J_1(t) \\ J_2(t) \\ J_3(t) \end{bmatrix}$ represent the assembly schedule for machine 4 during time t. The quantities of $E_2(t)$ demanded by the assembly process during the same period is given by

$$E_2(t) = W\ J(t) \qquad \text{(III-2.18)}$$

where W is a matrix whose entries represent the quantities of each part in $E_2(t)$ that is required in the assembly of each unit of product in J(t). Substituting III-2.18 in III-2.17, we obtain

$$Z(t+1) = P\ Z(t) + Q_1\ E_1(t) + Q_2\ W\ J(t) \qquad \text{(III-2.19)}$$

or $$Z(t+1) = P\ Z(t) + Q_1\ E_1(t) + R\ J(t) \qquad \text{(III-2.20)}$$

where $R = Q_2\ W$.

For any given period, Z(t) represents initial inventories and Z(t+1) represent ending inventories. J(t) is the schedule of assembly at machine 4 and $E_1(t)$ represents the schedules at machines 1, 2, and 3 during the same period. In general J(t), $E_1(t)$ and Z(t+1) are unknowns.

However, $Z(t)$ is known so that if we specify $J(t)$ and require that $Z(t+1)$ be non-negative, then we can choose $E_1(t)$. It is clear that $J(t)$ and $E_1(t)$ are both arbitrary; therefore, they can be selected so that some objective is realized.

Equation III-2.20 represents a mathematical model of the system shown in Figure III-2.1. If we assume for simplicity a planning horizon of three periods, then Equation III-2.20 can be solved for t = 0, 1, 2 as follows:

$$Z(1) = P\,Z(0) + Q_1\,E_1(0) + R\,J(0) \tag{III-2.21a}$$

$$Z(2) = P\,Z(1) + Q_1\,E_1(1) + R\,J(1) \tag{III-2.21b}$$

$$Z(3) = P\,Z(2) + Q_1\,E_1(2) + R\,J(2) \tag{III-2.21c}$$

Equations III-2.21a, III-2.21b and III-2.21c can be written in simplified form as

$$\begin{bmatrix} Q_1 & & & R & & & -U & & \\ & Q_1 & & & R & & P & -U & \\ & & Q_1 & & & R & & P & -U \end{bmatrix} \begin{bmatrix} E_1(0) \\ E_1(1) \\ E_1(2) \\ J(0) \\ J(1) \\ J(2) \\ Z(1) \\ Z(2) \\ Z(3) \end{bmatrix} = \begin{bmatrix} -P\,Z(0) \\ 0 \\ 0 \end{bmatrix} \tag{III-2.22}$$

Equation III-2.20 can also be solved recursively for three periods to obtain a much more compact form

$$Z(1) = P\ Z(0) + Q_1\ E_1(0) + R\ J(0)$$

$$Z(2) = P\ Z(1) + Q_1\ E_1(1) + R\ J(1)$$

$$= P^2 Z(0) + P\ Q_1\ E_1(0) + P\ R\ J(0)$$

$$+ Q_1\ E_1(1) + R\ J(1)$$

$$Z(3) = P\ Z(2) + Q_1\ E_1(2) + R\ J(2)$$

$$= P^3 Z(0) + P^2 Q_1\ E_1(0) + P^2 R\ J(0) + P\ Q_1 E_1(1)$$

$$+ P\ R\ J(1) + Q_1\ E_1(2) + R\ J(2) \qquad \text{(III-2.23)}$$

Equation III-2.23 can also be written in matrix form.

$$\begin{bmatrix} P^2Q_1 & PQ_1 & Q_1 & P^2R & PR & R & -U \end{bmatrix} \begin{bmatrix} E_1(0) \\ E_1(1) \\ E_1(2) \\ J(0) \\ J(1) \\ J(2) \\ Z(3) \end{bmatrix} = \begin{bmatrix} -P^3 Z(0) \end{bmatrix} \qquad \text{(III-2.24)}$$

The form given in Equation III-2.22 is preferable, however, since it is important that we be able to impose certain restrictions on the magnitudes that Z(1) and Z(2) can attain. For example, we must require that the value of

Z(t) during any time t should be non-negative and not exceed the maximum that can be tolerated in the system. In Equation III-2.24, there is no way of doing this so that we have no assurance that the quantities of in-process inventories during any period will always be within the range that has meaning in an actual scheduling problem.

It is also necessary to impose restrictions on the magnitudes of $E_1(t)$ since the quantities that can be processed during any period should not exceed the capacities available from the machines during the same period. In addition, there may be other restrictions that are peculiar to the problem. Finally, if we add an objective function, such as a processing cost function, then Equation III-2.22 can be rewritten together with the restrictions and objective function, as follows:

$$\left[\begin{array}{cccccccccc}
Q_1 & & & R & & & -U & & & \\
 & Q_1 & & & R & & P & -U & & \\
 & & Q_1 & & & R & & P & -U & \\
A_1 & & & & & & & & & \\
 & A_2 & & & & & & & & \\
 & & A_3 & & & & & & & \\
 & & & D & D & D & & & & U \\
 & & & & & & B_1 & & & \\
 & & & & & & & B_2 & & \\
 & & & & & & & & B_3 & \\
\hline
C_1 & C_2 & C_3 & C_4 & C_5 & C_6 & C_7 & C_8 & C_9 & C_{10}
\end{array}\right]
\begin{array}{c}
\left[\begin{array}{c}
E_1(0) \\ E_1(1) \\ E_1(2) \\ J(0) \\ J(1) \\ J(2) \\ Z(1) \\ Z(2) \\ Z(3) \\ J'(3)
\end{array}\right] \\ \\
\end{array}
\begin{array}{c}
= \\ = \\ = \\ \leq \\ \leq \\ \leq \\ = \\ \leq \\ \leq \\ \leq \\ =
\end{array}
\left[\begin{array}{c}
-P\ Z(0) \\ 0 \\ 0 \\ K \\ K \\ K \\ OF \\ V \\ V \\ V \\ \hline \text{Min}
\end{array}\right]
\qquad \text{(III-2.25)}$$

The vectors K and V represent, respectively, machine and inventory space capacities and the row vectors C_d, d = 1,2,....,10, are costs associated with each activity. J'(3) represents orders that cannot be satisfied during the planning horizon. Thus, C_{10} is a penalty cost. In Equation III-2.25,

A_1, A_2, A_3 = matrices with entries representing productivity coefficients of each production center for each input

D = unit matrix

U = unit matrix

B_1, B_2, B_3 = row vectors with entries of 1's

K = column vector of machine capacities

OF = order file

V = in-process inventory space capacity

It is now evident from Equation III-2.25 that the scheduling problem has now been formulated in a form that can be solved with linear programming (4). The number of feasible schedules is still very large. However, we do have in the linear programming algorithm an efficient technique for arriving at an optimal solution since the algorithm considers only those combinations that potentially can become optimal. For example, in Figure III-2.3 the range of feasibilities due to the indicated linear constraints is represented by the enclosed area A. If the variables x and y were continuous, the area A represents

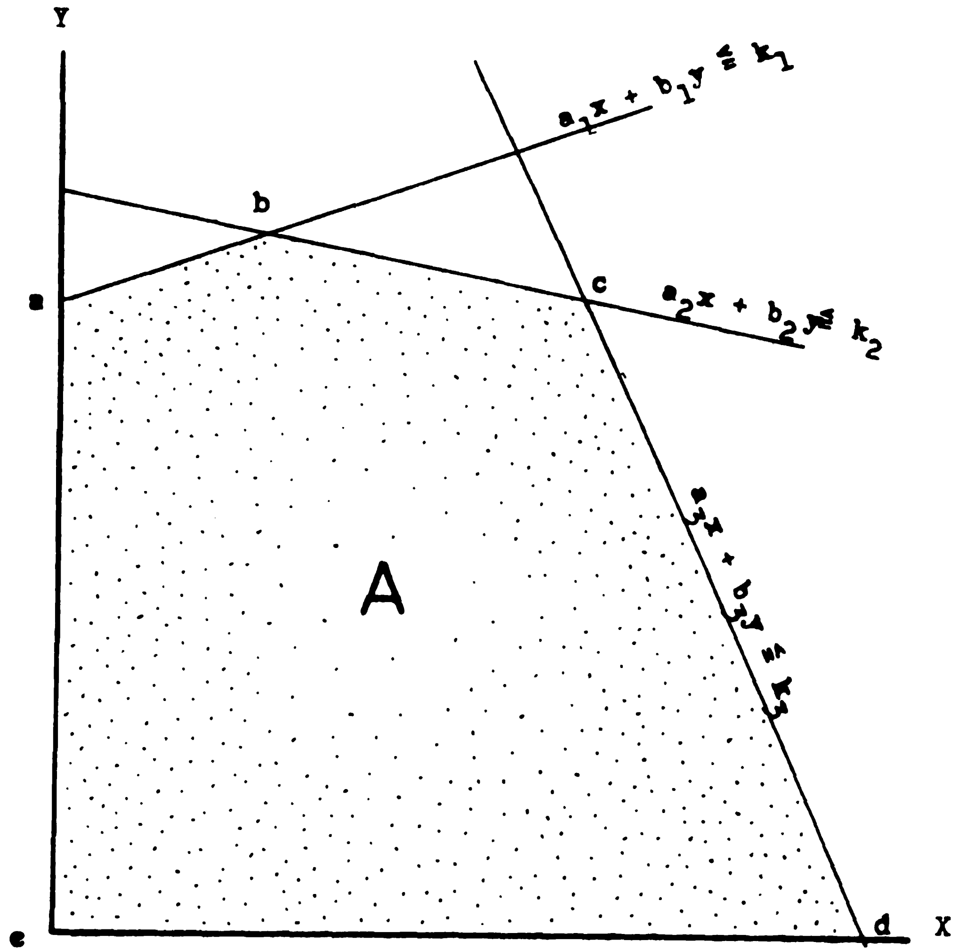

Figure III-2.3--Region of feasibility.

an infinite number of feasible schedules. Linear programming, however, considers only the feasible schedules represented by points a, b, c, d and e; surely a small number compared to the whole set.

We note that originally the problem was dynamic in nature in the sense that the element of time is involved. But through the use of systems concepts we have reduced the problem to an equivalent static problem that is amenable to linear programming. It should be clear, however, that the solution to Equation III-2.20 need not be obtained with linear programming. Possibly other methods, e.g., dynamic programming, would be just as effective. Linear programming was selected, however, because of its simplicity and because of the value of other information obtainable from the solution, e.g., the dual.

The above developments form the basis of the formulation of a mathematical model of an actual scheduling problem.

IV. THE PLYWOOD PRODUCTION SCHEDULING PROBLEM

Assembly-type problems occur very frequently in industry; in fact, it is more the rule than the exception. One such problem occurs in plywood manufacturing, where various veneers that go into the lay-up of plywood panels have to be processed on several machines with sufficient lead time so assembly can later proceed with as little interruption as possible. Since veneers are generally processed on common machines, sequencing the right quantities of material through these machines is of prime importance.[1] The following description of a scheduling problem is that of a mill that utilizes relatively poorer quality logs than generally are used.

IV-1. <u>The Process</u>

Plywood manufacturing (5) includes three major processes: conversion of logs to veneer (also called the

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[1]Sequencing is even more important in many of today's mills, where poorer quality logs are increasingly utilized due to increasing log costs and scarcity of supply, thus requiring more veneer preparation and more competition for machine time. Although this situation is not yet typical of the whole industry at the present time, it is expected to be so in the near future when further increases in log costs, scarcity of supplies and more competition from other materials are to be expected.

green end), preparation of veneers to usable form (the dry end), and assembly of correct mixtures of veneers into plywood panels. Green end equipment includes one barker, two cut-off saws, eight steam vats, one high-speed 8-foot lathe, one 4-foot lathe, and three clippers. Veneer preparation is accomplished with three dryers, one edge gluer, one veneer saw, and four veneer patchers. Lay-up and finishing machinery includes four glue spreaders, two pre-presses, two automatic 30-opening hot presses, one panel saw, one high speed wide belt sander and one panel sorter. In addition, there are other equipment associated with special finishing and packaging of products.

The green end process consists of cutting logs to length, steaming, peeling to veneer, clipping veneer to standard widths, and sorting. As much as possible, veneers are clipped as wide as defects would allow to 54 inches, 27 inches and narrower random widths. The mill utilizes six species of logs for use as faces, backs and centers.[1] Three of these are being peeled to two thicknesses (1/10 and 1/6) and the rest to three thicknesses (1/10, 1/6 and 7/32) or a total of 15 different inputs at the 8-foot lathe distinguished by species and thickness of peel. At the 4-foot lathe (or core lathe), four basic species are used. Three are peeled to 1/6, 7/32, and 5/16 and the fourth to only one thickness of 1/6 or a total of 10 possible inputs

[1]See Figure IV-1.1 for description of a plywood panel.

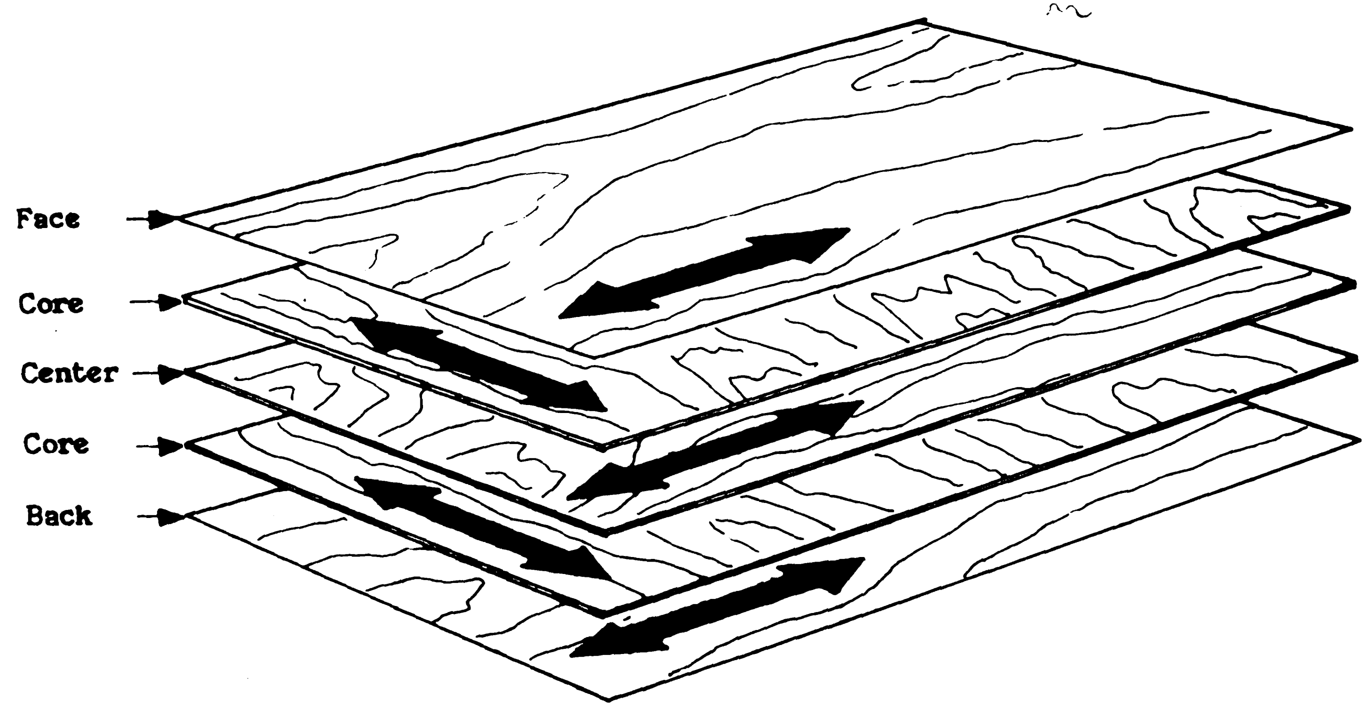

Figure IV-1.1--Typical construction of a plywood panel. Adopted from <u>Basic Plywood Processing</u> by Ted Demas, American Plywood Assoc.

FACE = The better side of a panel in any grade calling for a face and a back; also, either side of a panel where the grading rules draw no distinction between faces.

BACK = The side reverse to the face of the panel.

CORES (Crossbands) = Inner plies running perpendicular to the panel face.

CENTERS = Inner plies running paralle to the panel face.

at the core lathe. Clipping practice at the core lathe is similar to that at the 8-foot lathe. However, because of poorer quality of logs being peeled specifically for core, clipping is generally in random fashion.

The dry end process consists of drying veneers to appropriate moisture contents, sorting dryer output by widths and grades, and further processing on certain types of veneers as the situation requires. Veneers are graded into four grades after drying. Eight-foot stock is sorted to ABCp, C, D and NC grades.[1] Some of the 54-inch stock is directly available after drying for faces and backs (C and D grade) or centers (C, D, and NC grades) while ABCp grade needs further processing at the veneer patchers where they eventually split up to grades A, B, Cp, C, and D. The C, D. and NC grades of 27-inch veneer may be used as centers without further processing or edge glued (except NC grade) for faces and backs. Alternatively, they may be sawn in half for core. The ABCp grade of 27-inch stock is generally edge glued and patched for faces and backs, although some of it is used for patching material.

Core veneer is sorted into four grades: Csolid, C, D and NC and needs no further processing.

Assembly of veneers into plywood starts at the glue spreaders where certain quantities, grades and thicknesses

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[1]ABCp is a veneer grade from which grades A, B and Cp can be recovered. Grade A is the highest, B second highest and NC is the lowest grade.

of veneer are assembled in certain combinations to obtain required panel dimensions and grades. Then assemblies in multiples of 30's or 60's (depending on the thickness) are pre-pressed in preparation for automatic loading and curing in hot presses. Thence, cured panels are trimmed to proper dimensions, sanded and graded for defects. Panels that are defective and cannot be accepted as "on-grade" are reclassified to appropriate lower grades. Thus, only a certain percentage of the original number laid-up at the spreaders can be applied to customer orders so that allowances have to be made to compensate for "falldowns." For sheathing products, the process would have ended after sorting for grades; however, for sanded products and other specialty items additional work on the panels is required, such as repairing minor defects, additional sanding, grooving, coating and other special work the customer may require.

IV-2. The Scheduling Problem

The processes after the spreaders do not pose much of a scheduling problem since the operations follow one another in a fixed sequence and so long as no breakdowns occur in the line, the rest of the operations proceed without requiring too much attention. Indeed, the heart of the scheduling problem lies in the green and dry ends where choices have to be made from among a large number of alternatives. In general, the choice of one alternative over another is influenced by the composition of the order file and of the veneer and product inventories on the floor and by the available machine and storage capacities.

Customer orders for the coming week's production (an order file) are received at the plant superintendent's office on the Friday of the preceding week and may consist of about 15 to 25 customer orders representing approximately 75 percent of plant capacity. Each customer order may consist of any number of items in the some 152 basic products that the mill manufactures. Usually, though, an order ranges from one to ten items, altogether usually forming a carload, sometimes two. Because of limited space in the mill it is not possible to inventory dry veneers or finished products in large quantities. Railroad cars are brought in five at a time and must be loaded and ready within three days at the latest. Because no additional cars can be brought in until previous cars have been cleared away, it is desirable to complete loading whatever cars are on the docks within 24 hours. This means that orders have to be completed and loaded at the rate of approximately four to five orders a day. The problem has been basically that of properly timing veneer preparation so that the right types and quantities of veneer are available at the time they are needed at the spreaders. Moreover, these should be in quantities sufficient to maintain production with a minimum of change-overs but small enough so as not to build prohibitively large in-process inventories.

The availability of the right types and quantities of veneer is important, too, to the proper use of material. Experience has shown that misuse of veneer is extensive when the proper grades are not available in sufficient quantities. In an effort to maintain production, downgrading[1] is sometimes resorted to. Although downgrading is not a policy of the mill, it is common knowledge that it is practiced. At the present time the mill has no measure of how much loss due to improper use of material is being sustained, mainly because it is very difficult (if not impossible) to get factual data about it. However, to those knowledgeable with losses in revenue due to misapplication of material, the feeling is that the practice might be reaching alarming proportions.

In general, if the schedule were to lay-up by customer orders, finished products inventory would be minimized but at the expense of probably too many changes in machine setups and a probable build-up of dry veneer inventory, especially if customer orders lean heavily toward one or two product grades. This is a consequence of the fact that the production of certain grades of veneer is always accompanied by the generation of other grades as well which may not be needed immediately, if at all, or which may be in excess of what is or will be required.

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[1]Using better quality veneer than what is required.

On the other hand, laying-up products that complement each other, i.e., products that use veneers in the proportion they are generated, minimizes veneer inventory. However, these products may belong to various orders making it necessary to hold them in inventory until the other items in the orders are likewise completed.

Efforts are being made by the company to seek orders in the right combinations (through an allocation model) and using the information as a guide for sales efforts. Unfortunately discrepancies between what is desired and what is obtained always exist. Thus, failing to influence the composition of demand for its products, it then becomes necessary for the mill to control production effectively so that whatever discrepancies may exist between the order file and the mixture of veneers obtainable from the raw material could be worked into the plant and still operate within the constraints of machine and storage capacities and delivery dates without incurring unnecessary increases in production costs.

The presence of a number of alternatives for getting required veneers to the spreaders gives the mill flexibility for working around whatever limitations the order file may impose on the mill. It also makes scheduling that much more difficult since compatible decisions have to be made consistently at each production center.

Because of the formidable number of alternatives that a production scheduler has to choose from, it is very unlikely that the choices he makes every day or every week are consistently good because it is simply impossible to consider or to be aware of all interacting factors that should enter into his decisions during the short time available for decision making. Indeed, not even the best and most experienced scheduler can or would be willing to go through even a small number of, say, 200 alternatives every week to determine which combination of alternatives will give him his best (according to some criterion) schedule.

Thus it is desirable to quantify the problem so that, for any given week, order file and initial inventories, a schedule that takes into account all important factors and limitations can be determined.

V. FORMULATION OF A SCHEDULING MODEL

The formulations that will be developed in this chapter concern only the green and dry ends of the plywood mill where the scheduling problem resides. Because of the great number of variables involved, the flows are handled as vectors to simplify the algebra. A listing of the variables included in each vector can be found in Appendix A.

V-1. Choice of Interval

The choice of an appropriate interval of time to be used in the formulation of the problem is an important consideration since it determines the quality of information that can be derived from the solution to the problem and the corresponding cost of computation required to obtain the solution. Ideally the interval would be the smallest lead time being experienced in the system. However, a practical interval, during which it is useful to have information on the level of activities, should probably be something much larger. Indeed, it may be only necessary or helpful to know the state of the system once every two hours, or once a day, or once a month, even though there exists in the system lead times in the order of, say, 10 minutes.

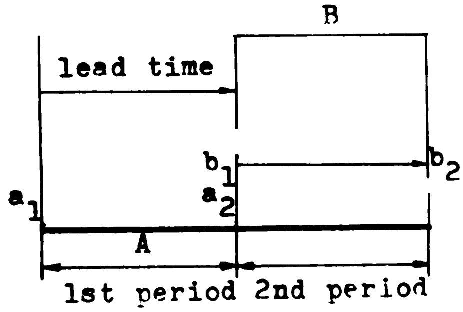
In the problem studied, it is difficult to make a definite statement on what might be the most practical interval of time to use. Practicability has to be measured in terms of the difference between the cost to be incurred and the benefits to be derived. Moreover, the benefits to be derived have to be measured relative to some datum, generally current performance. The cost of computation can be reasonably determined; unfortunately a measure of current performance is not readily available. However, an evaluation of current performance should yield some useful measure of effectiveness. Only then can practicability or economic feasibility be truly determined.

In the following developments, an 8-hour interval is used because it seems the most ideal from the plant superintendent's point of view. Certainly his work would be much simpler if for any given week the schedule of activities of all processing centers has already been determined for all shifts. As a consequence, decision making would be narrowed down and localized to 8-hour periods since there would be no more need to consider the relationship between activities of different shifts, these relationships having been considered already in the solution to the problem.

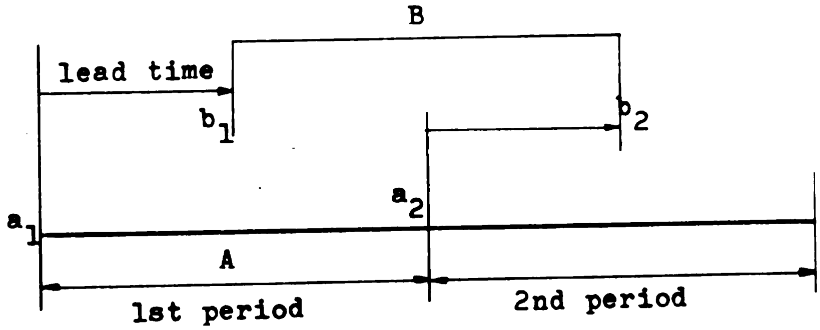
V-2. Model for Processor No. 1

Processor no. 1 basically consists of the 8-foot lathe, belt conveyors, two clippers, a sorting table, sorting carts, and the men associated with each activity. This is shown schematically in Figure V-2.2.

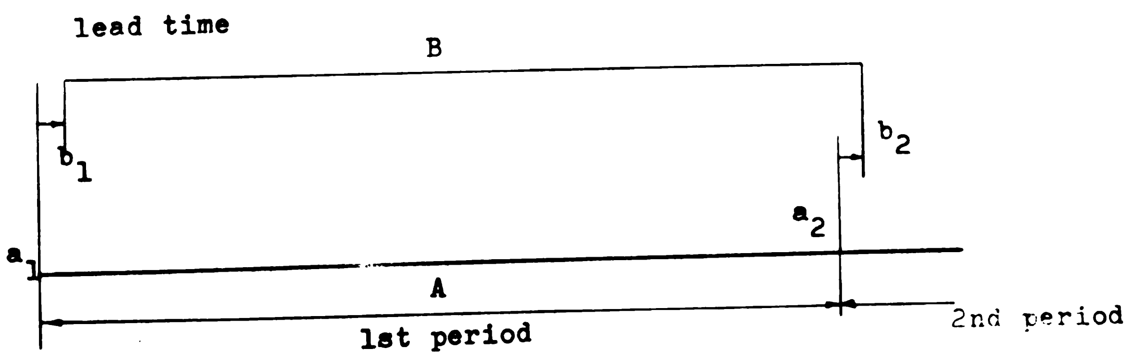
It takes approximately only an average of 10 minutes to process veneer on the lathe and clippers, starting at a point in time when a log is charged to the lathe to a point when it becomes clipped veneer and available for drying. If the interval chosen were 10 minutes, then the lead time required for processing is one period, which means that inputs to the lathe during any 10-minute period will not be available as output from the clippers until the next 10-minute period. If the interval chosen were 20 minutes instead, the lead time will still be 10 minutes; however, inputs to the lathe during any 20-minute period will all be available as clipped veneer after the first half of the next period. The relationship between lead time and period is shown schematically in Figure V-2.1. In the figures, A represents the first period during which input is being taken in and B represents the time (also equivalent to one period) during which output is available. The first input occurs at a_1 and first output becomes available at time b_1. The last input (during the interval under consideration) is taken in at time a_2 which subsequently becomes available as output at time b_2. The lead time, represented by a_1b_1 or a_2b_2, is 10 minutes regardless of the magnitude of the period chosen. However, if lead time is considered in terms of a period, in (a) it is equivalent to one period, in (b) half of a period and in (c) 1/48th of a period. Thus, as the interval is chosen to be larger the lead time becomes relatively smaller. At the chosen interval of



(a) Lead time and period of 10 minutes each.



(b) Lead time of 10 minutes and period of 20 minutes.



(c) Lead time of 10 minutes and period of 8 hours(not drawn to scale).

Figure V-2.1. Relationship between the magnitudes of lead time and period.

8 hours the relative importance of a 10-minute delay becomes very small and insignificant. Moreover, the lathe and clippers have excess capacity relative to the dryers so that the production of the lathe during any period can keep the dryers busy during the same period. We thus assume for practical purposes no delay in processor no. 1, that is, no lead time is necessary for peeling logs to veneer before drying can be initiated, provided that the period in question is large enough. We therefore write for the 8-foot lathe:

$$\begin{bmatrix} Y_{121}(t) \\ Y_{122}(t) \\ Y_{123}(t) \\ Y_{124}(t) \\ Y_{125}(t) \end{bmatrix} = \begin{bmatrix} R'_{11} \\ R'_{21} \\ R'_{31} \\ R'_{41} \\ R'_{51} \end{bmatrix} \quad Y_{110}(t) \tag{V-2.1}$$

We note from Appendix A that Y_{110}, Y_{121}, Y_{122}, Y_{123} and Y_{124} are vector flows. Consequently, R'_{11}, R'_{21}, R'_{31}, R'_{41} and R'_{51} are matrices whose entries represent the quantities of veneer of each type that is obtainable from every unit of input of each variable in Y_{110}. Y_{125} represents the flow of material that is not usable for veneer. Therefore, as far as the scheduling problem is concerned, it is best excluded from further consideration. If we let

$$Y_{120}(t) = \begin{bmatrix} Y_{122}(t) \\ Y_{123}(t) \\ Y_{124}(t) \end{bmatrix} \text{ and } R_{11} = \begin{bmatrix} R'_{21} \\ R'_{31} \\ R'_{41} \end{bmatrix}$$

then we can write V-2.1 as

$$\begin{bmatrix} \dfrac{Y_{121}(t)}{Y_{120}(t)} \end{bmatrix} = \begin{bmatrix} \dfrac{R'_{11}}{R_{11}} \end{bmatrix} Y_{110}(t) \qquad \text{(V-2.2)}$$

Equation V-2.2 is a mathematical model of processor no. 1 shown schematically in Figure V-2.1. To illustrate the structure of Equation V-2.2, we write it in detail as Equation V-2.3 using data from Table V-2.1. In Equation V-2.3, log inputs are expressed in thousand board feet[1] (MBF) and veneer outputs are in thousand surface feet 3/8 basis[2] (M3/8). The first column in the recovery matrix indicates that for every MBF of Douglas fir logs peeled to 1/10th veneer, 1.13 M3/8 of 54-inch veneers, 0.82 M3/8 of 27-inch veneers, 0.46 M3/8 of strips and 0.12 M3/8 of fish tails[3] can be recovered.

We also note from Equation V-2.3 that during a given period any number of inputs can be greater than zero. In other words, two or more inputs can be processed concurrently during any 8-hour period. In practice, of course, inputs are processed sequentially. This is perfectly

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[1]A board foot is the volume of a rectangular piece of wood one-inch thick, 12 inches wide and 12 inches long.

[2]Volume of a panel 3/8-inch thick, 10-feet wide and 100-feet long.

[3]Veneer generated at the 8-foot lathe before the log gets perfectly round so that only one end may be utilized, and only for core. See Figure V-5.1.

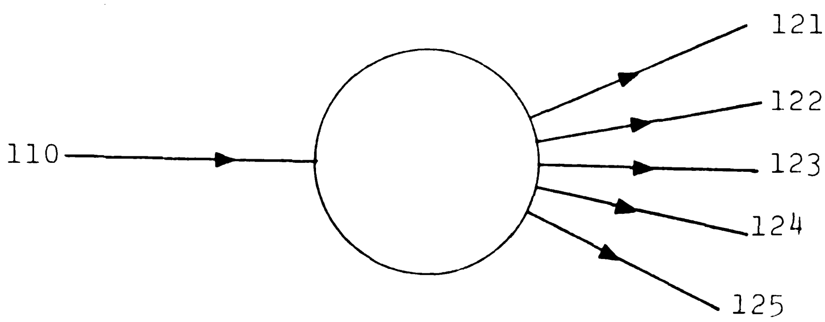

Figure V-2.2--Schematic diagram of processor no. 1 representing the 8-foot lathe, two 8-foot clippers and associated equipment.

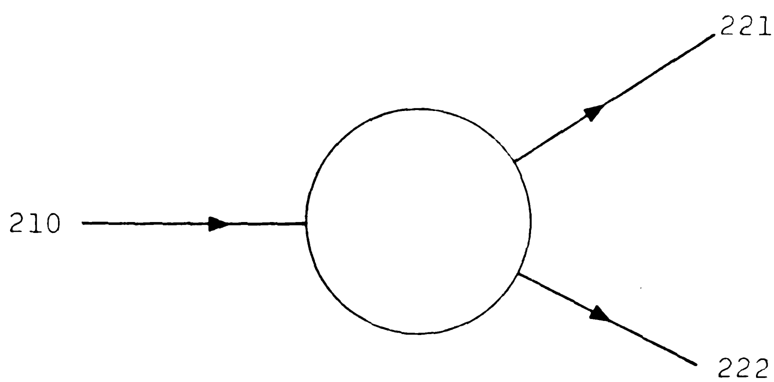

Figure V-3.1--Schematic diagram of processor no. 2 representing the core lathe, clippers and associated equipment.

Veneer Output during time $\underline{t}$ in M3/8 units = [matrix] × Log peels during time $\underline{t}$ in MBF units (V-2.3)

			Doug. Fir to 1/10th	White Fir " "	Spruce " "	Larch " "	P. Pine " "	Hemlock " "	Doug. Fir " 1/6th	White Fir " "	Spruce " "	Larch " "	P. Pine " "	Hemlock " "	Spruce " 7/32nd	P. Pine " "	Hemlock " "
1/10th	Doug. Fir	54s	1.13														
"	White Fir	"		0.59													
"	Spruce	"			1.19												
"	Larch	"				0.95											
"	P. Pine	"					1.07										
"	Hemlock	"						0.77									
1/6th	Doug. Fir	"							1.13								
"	White Fir	"								0.69							
"	Spruce	"									1.32						
"	Larch	"										0.95					
"	P. Pine	"											1.07				
"	Hemlock	"												0.80			
7/32nd	Spruce	"													1.19		
"	P. Pine	"														1.07	
"	Hemlock	"															0.80
1/10th	Doug. Fir	27s	0.82														
"	White Fir	"		1.00													
"	Spruce	"			0.57												
"	Larch	"				0.63											
"	P. Pine	"					0.60										
"	Hemlock	"						0.95									
1/6th	Doug. Fir	"							[illegible]								
"	White Fir	"								1.06							
"	Spruce	"									0.57						
"	Larch	"										0.63					
"	P. Pine	"											0.60				
"	Hemlock	"												0.89			
7/32nd	Spruce	"													0.57		
"	P. Pine	"														1.07	
"	Hemlock	"															0.89
1/10th	Doug. Fir	Strips	0.46														
"	White Fir	"		0.44													
"	Spruce	"			0.46												
"	Larch	"				0.54											
"	P. Pine	"					0.53										
"	Hemlock	"						0.42									
1/6th	Doug. Fir	"							[illegible]								
"	White Fir	"								0.46							
"	Spruce	"									0.46						
"	Larch	"										0.54					
"	P. Pine	"											0.53				
"	Hemlock	"												0.44			
7/32nd	Spruce	"													0.46		
"	P. Pine	"														0.53	
"	Hemlock	"															0.44
1/10th	Fish Tails		0.12	0.11	0.06	0.10	0.12	0.07									
1/6th	Fish Tails								0.12	0.05	0.13	0.10	0.12	0.08			
7/32nd	Fish Tails														0.13	0.12	0.08

TABLE V-2.1.--Green end recoveries in percent.

Width	1/10 DF[1]	1/10 WF	1/10 SP	1/10 LH	1/10 PN	1/10 HL	1/6 WF	1/6 SP	1/6 PN	1/6 HL
54	44.80	27.40	52.00	42.70	46.00	36.30	27.80	58.00	46.00	36.30
27	32.30	47.00	24.80	28.60	26.00	40.10	47.00	24.80	26.00	40.10
Strips	18.20	20.50	20.30	24.50	23.00	19.70	20.50	20.30	23.00	19.70
Fish Tail	4.70	5.10	2.90	4.20	5.00	3.90	4.70	2.90	5.00	3.90
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Recovery	2.53[2]	2.14	2.28	2.22	2.32	2.11	2.26	2.28	2.32	2.21

[1]DF = Douglas Fir, WF = White Fir, SP = Spruce, LH = Larch, PN = Ponderosa Pine, HL = Hemlock.

[2]M3/8 per MBF.

valid since, as will be seen later, the total demand for machine time will always be equal to or less than what is available.

V-3. Model for Processor No. 2

Processor no. 2 is made up of a cut-off saw, a core lathe, a drum clipper, a guillotine clipper and veneer handling accessories. Schematically it is shown in Figure V-3.1 as a single processor receiving logs at one end and producing veneer at the other.

Following the discussion of Section V-2, we likewise write for processor no. 2,

$$\begin{bmatrix} Y_{221}(t) \\ Y_{222}(t) \end{bmatrix} = \begin{bmatrix} R^*_{12} \\ R^*_{22} \end{bmatrix} \quad Y_{210}(t) \qquad \text{(V-3.1)}$$

where $Y_{222}(t)$ represents veneer waste that cannot be used for plywood production. We therefore drop it from further consideration and write simply

$$Y_{221}(t) = R_{20}\ Y_{210}(t) \qquad \text{(V-3.2)}$$

where R_{20} is equivalent to R^*_{12} and represents veneer recovery at the core lathe. Because the logs generally used for core are of poorer quality, core veneer can rarely be clipped into standard widths. Thus veneers from the core lathe are not sorted by widths unlike those from the 8-foot lathe. The entries of R_{20}, therefore, represent total veneer recoveries in M3/8 units from each

MBF of log input in Y_{210}. Equation V-3.2 or V-3.3 represents a mathematical model of processor no. 2.

V-4. Model for Processor No. 3

Three veneer dryers make up processor no. 3. Veneers are brought to the dryers from green in-process inventories and fed manually as fast as is operationally possible. On the other side, veneers are sorted by grades and moved to dry inventory.

It takes approximately 10 to 30 minutes for veneer to dry while traversing the length of the dryers, depending on the thickness and species. The delay due to processing time alone seems small enough to be neglected as argued for processors 1 and 2; however, there are other factors that must be taken into consideration. Firstly, veneers proliferate into several grades after drying so that specific grades do not accumulate fast enough, making it imperative to accumulate them in sufficient quantities before they can be moved to the next operation. For example, ABCp grade veneers which come in small quantities relative to the total output of the dryers cannot operationally be transferred to the patchers as soon as a few sheets are available. Rather, they are accumulated until there is enough to keep a patcher busy for a sufficiently long period.

Secondly, there are technical requirements that must be satisfied. For instance, in the case of C and D grade

$$
\underset{\text{Veneer Output During time } \underline{t} \text{ in M3/8 Units}}{\begin{bmatrix} \text{1/6th White Fir} \\ \text{1/6th Spruce} \\ \text{1/6th P. Pine} \\ \text{1/6th Hemlock} \\ \text{7/32nd Spruce} \\ \text{7/32nd P. Pine} \\ \text{7/32nd Hemlock} \\ \text{5/16th Spruce} \\ \text{5/16th P. Pine} \\ \text{5/16th Hemlock} \end{bmatrix}}
=
\underset{\text{Recovery Matrix}}{\begin{bmatrix} 2.10 & & & & & & & & & \\ & 2.21 & & & & & & & & \\ & & 2.11 & & & & & & & \\ & & & 2.15 & & & & & & \\ & & & & 2.18 & & & & & \\ & & & & & 2.13 & & & & \\ & & & & & & 2.12 & & & \\ & & & & & & & 2.14 & & \\ & & & & & & & & 2.16 & \\ & & & & & & & & & 2.10 \end{bmatrix}}
\underset{\text{Log Peels During time } \underline{t} \text{ in MBF Units}}{\begin{bmatrix} \text{White Fir to 1/6th} \\ \text{Spruce to 1/6th} \\ \text{P. Pine to 1/6th} \\ \text{Hemlock to 1/6th} \\ \text{Spruce to 7/32nd} \\ \text{P. Pine to 7/32nd} \\ \text{Hemlock to 7/32nd} \\ \text{Spruce to 5/16th} \\ \text{P. Pine to 5/16th} \\ \text{Hemlock to 5/16th} \end{bmatrix}}
\qquad \text{(V-3.3)}
$$

veneers that are 54 inches wide, the next operation would be at the spreaders. However, these should be allowed to cool down to room temperature before using due to technical requirements at the spreaders.

It is therefore, necessary that sufficient lead time be allowed for the drying process so that the requirements of succeeding operations are satisfied. A lead time equivalent to one shift was found the most appropriate so that we write as a mathematical model of the drying process,

$$\begin{bmatrix} Y_{330}(t+1) \\ Y_{340}(t+1) \\ Y_{350}(t+1) \\ Y_{360}(t+1) \end{bmatrix} = \begin{bmatrix} & R^{o}_{12} & & R^{o}_{14} \\ R^{o}_{21} & & & \\ R^{o}_{31} & & & \\ R^{o}_{41} & & R^{o}_{43} & \end{bmatrix} \begin{bmatrix} Y_{310}(t) \\ Y_{320}(t) \\ Y_{370}(t) \\ Y_{380}(t) \end{bmatrix} \qquad \text{(V-4.1)}$$

which indicates that inputs to the dryers druing any 8-hour period will not be available for further processing until the next period. Because of the size of the recovery matrix for the dryers, Equation V-4.1 is not shown here in detail. However, it can be constructed from data given in Table V-4.1 and the listing of vectors in Appendix A.

V-5. Model for Processor No. 4

Processor no. 4 consists only of one veneer saw. It provides the opportunity to convert 8-foot veneer to core, hence also the opportunity to peel core material at the 8-foot lathe. Since very little time is required to saw veneer, no lead time is required and we write,

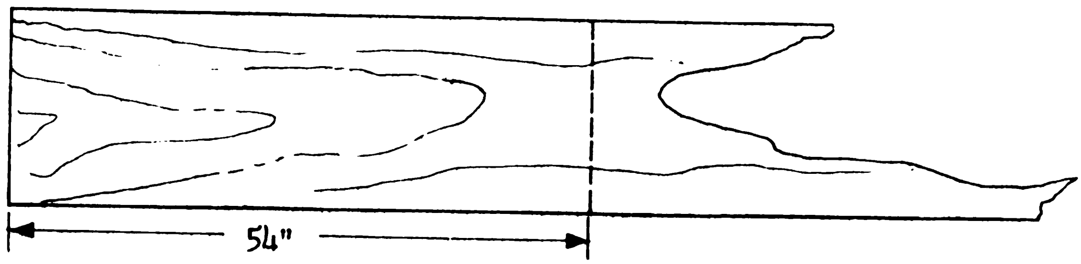

Figure V-3.2--Fish Tail. Core material may be recovered from it by cutting at dotted line. Unusable portion goes to chipper.

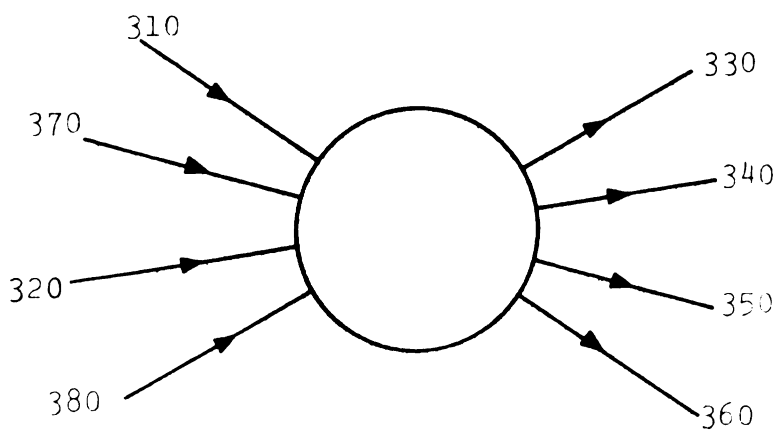

Figure V-4.1--Schematic diagram of processor no 3. representing three veneer dryers.

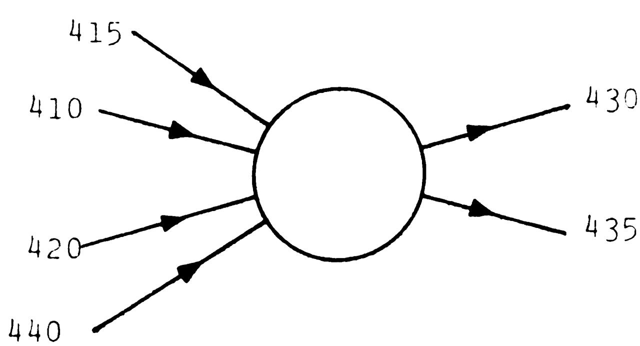

Figure V-5.1--Schematic diagram of processor no. 4 representing a veneer saw.

TABLE V-4.1-a. Dryer grade yields[1] (percent).

Face Stock	Width	ABCp	C[2]	D	NC
1/10	54's	18.89	30.24	49.55	1.32
Doug. Fir	27's	5.40	21.50	60.03	7.07
	Strips	1.40	20.40	68.47	9.63
1/10	54's	4.81	43.58	46.13	5.48
White Fir	27's	0.71	36.30	51.07	11.92
	Strips		6.17	77.59	16.24
1/10	54's	3.08	52.44	41.15	3.33
Spruce	27's	0.06	45.81	47.69	6.44
	Strips		22.28	68.75	8.97
1/10	54's	22.10	34.84	40.11	2.95
Larch	27's	8.69	30.31	54.65	6.35
	Strips	3.46	21.33	64.72	10.49
1/10	54's	4.57	23.18	68.05	4.20
Pond.	27's		13.82	78.05	8.13
Pine	Strips		2.68	77.66	19.66
1/10	54's	11.54	34.45	50.09	3.92
Hemlock	27's	2.21	30.55	58.88	8.36
	Strips		9.76	77.65	12.59
1/6	54's	10.64	42.65	43.58	3.13
White Fir	27's	3.50	45.58	40.00	10.92
	Strips		40.43	49.72	9.85
1/6	54's	12.00	45.00	39.00	4.00
Spruce[3]	27's	2.00	42.00	46.00	10.00
	Strips		26.00	62.00	12.00
1/6	54's	5.50	28.50	62.50	3.50
Pond.	27's	1.50	18.50	73.00	7.00
Pine[3]	Strips		15.00	75.00	10.00
1/6	54's	18.80	38.94	40.63	1.63
Hemlock	27's	4.45	43.34	46.29	5.92
	Strips	1.21	39.92	53.17	12.70

[1]Based on May, June and August dryer production reports.

[2]Includes C Solid. [3]Estimated figures.

TABLE V-4.1-b.--Dryer grade yields.

Core Stock Type		C Solid[1]	C	D	NC
1/6 Pine	Random	9.00	32.98	49.51	8.51
1/6 Hemlock	"	11.00	31.83	46.60	10.57
1/6 Mix	"	10.00	24.61	56.16	9.23
1/6 Redry	"	7.00	12.12	67.63	13.25
7/32 D. Fir	"	12.00	46.92	33.44	7.64
7/32 W. Fir	"	10.00	56.42	27.58	6.00
7/32 Spruce	"	10.00	56.59	26.53	6.87
7/32 Larch	"	15.00	58.69	22.10	4.21
7/32 Pine	"	11.00	50.08	32.80	6.11
7/32 Hemlock	"	13.00	37.00	40.47	9.53
7/32 Mix	"	12.00	46.30	34.07	7.63
5/16 P. Pine	"	12.00	14.90	68.08	5.02
5/16 Mix	"	13.00	25.73	54.41	6.86

[1]Estimated figures. It is difficult to determine precisely the percentage of C solid that can be recovered from core stock because core is only sorted for C solid when there is a need for it. Otherwise, it is sorted as C grade. However, the sum of C solid and C grade is accurate.

$$\begin{bmatrix} Y_{430}(t) \\ \hline Y_{034}(t) \\ Y_{435}(t) \end{bmatrix} = \begin{bmatrix} S_1 & S_2 & S_3 & \\ & & & S_4 \\ & & & S_5 \end{bmatrix} \begin{bmatrix} Y_{410}(t) \\ Y_{420}(t) \\ Y_{440}(t) \\ \hline Y_{415}(t) \end{bmatrix} \qquad \text{(V-5.1)}$$

where $Y_{415}(t)$ represents a vector of fish tails[1] originating from the 8-foot lathe. $Y_{410}(t)$, $Y_{420}(t)$ and $Y_{440}(t)$ represent, respectively, dry strips, 27-inch, and 54-inch veneers that are to be converted to core, the entries in S_1, S_2 and S_3 are all 1's indicating 100 percent recovery. $Y_{034}(t)$ is the quantity of core recovered from fish tails and $Y_{435}(t)$ is the waste material that goes to the chippers.

V-6. Model for Processor No. 5

Processor no. 5 is made up of a jointer and an edge gluer that is used for joining narrower veneer, i.e., 27 inches wide and narrower strips, to obtain full-sized veneer sheets for use as faces, backs or centers. Edge gluing is a slow process and it is necessary that some lead time be allowed for the operation to accumulate enough output sufficient to be considered for input to the next operation. The lead time required may not be quite 8 hours. However, for simplicity we also assume a lead time equivalent to one period. This has the effect of a conservative schedule since it implies that processing of

---

[1]See Figure V-5.1.

needed veneers has to be done one full shift ahead, although in certain cases (such as when only small quantities are required) it might be possible to process veneers during the same shift it is needed. For the edge gluing process we, therefore, write

$$\begin{bmatrix} Y_{531}(t+1) \\ Y_{532}(t+1) \\ Y_{533}(t+1) \\ Y_{534}(t+1) \end{bmatrix} = \begin{bmatrix} G_{11} & G_{12} \\ G_{21} & G_{22} \\ G_{31} & G_{32} \\ G_{41} & G_{42} \end{bmatrix} \begin{bmatrix} Y_{510}(t) \\ Y_{520}(t) \end{bmatrix} \qquad \text{(V-6.1)}$$

where as before, G_{11}, G_{12}, G_{21}, G_{22}, G_{31}, G_{32}, G_{41} and G_{42} are matrices with entries that represent the percentages of each output that can be recovered from each unit of input. Processor no. 5 is shown schematically in Figure V-6.1.

V-7. Model for Processor No. 6

Four veneer patchers make up processor no. 6. It takes in for input full-sized veneer sheets of ABCp grade originating directly from the dryers, from purchased dry veneer, or from the edge gluer. The process involves patching knotholes and similar defects that can be patched and segregating processed veneers into grades A, B, Cp, C and D.

Like edge gluing, patching is also a slow process. Moreover, it takes a while to accumulate the usual

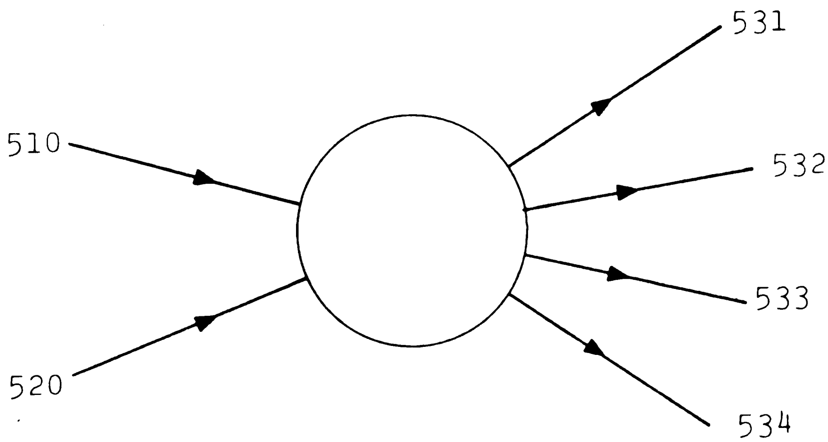

Figure V-6.1--Schematic diagram of processor no. 5 representing veneer jointer and edge gluer.

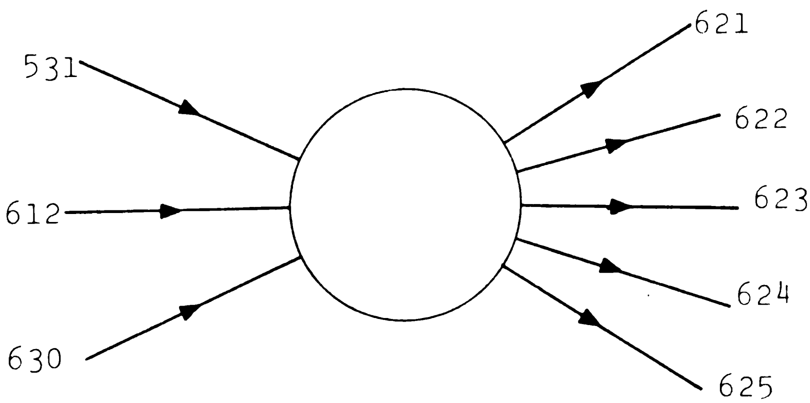

Figure V-7.1--Schematic diagram of processor no. 6 representing four veneer patchers.

quantities required of A, B and Cp grades, due to poorer quality of logs available to the mill. Consequently, it is necessary to allow processor no. 6 a lead time of one period and we write the mathematical model of the process as follows:

$$\begin{bmatrix} Y_{621}(t+1) \\ Y_{622}(t+1) \\ Y_{623}(t+1) \\ Y_{624}(t+1) \\ \hline Y_{625}(t+1) \end{bmatrix} = \begin{bmatrix} T_{11} & T_{12} & T_{13} \\ T_{21} & T_{22} & T_{23} \\ T_{31} & T_{32} & T_{33} \\ T_{41} & T_{42} & T_{43} \\ \hline T_{51} & T_{52} & T_{53} \end{bmatrix} \begin{bmatrix} Y_{611}(t) \\ Y_{612}(t) \\ Y_{630}(t) \end{bmatrix} \qquad \text{(V-7.1)}$$

Y_{625} represents waste generated by the process and may be dropped from further consideration. Schematically the patching process is represented by Figure V-7.1. Data such as that shown in Table V-7.1 for Douglas Fir required by Equation V-7.1 can be obtained from production reports.

V-8. In-Process Inventories

Figure V-8.1 is a schematic diagram of the green and dry end sections of the plywood mill showing the manner component processors previously discussed are interconnected together. The symbols and connotations parallel those in Figure III-2.1 except that the flows indicated are vector flows, that is, each arrow in the diagram represents, in general, more than one flow. The solid circles also represent one or more machines. For example, $Y_{110}(t)$

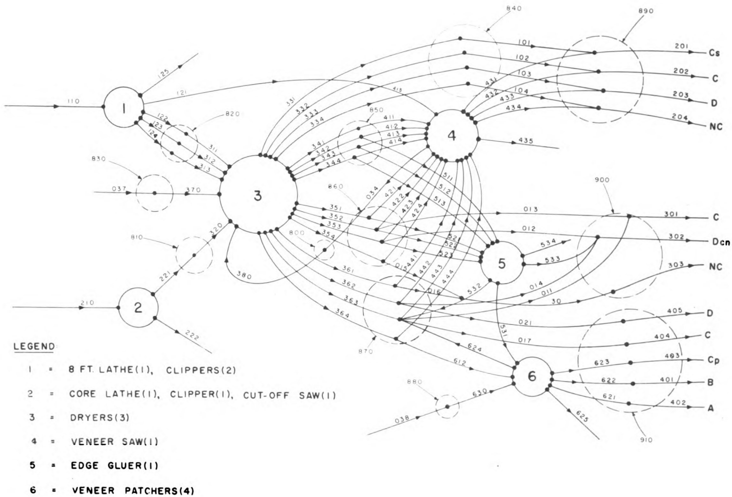

Figure V-8.1--Schematic diagram of green and dry end sections of plywood mill. Solid circles indicate processors and dotted circles in-process inventories. Arrows show direction of material flows in the system.

represents 15 different flows and processor no. 6 represents four veneer patchers.

With reference to Figure V-8.1, we now write the following equations for in-process inventories:

Green Core Originating from Fish Tails

$$Z_{800}(t+1) = U_{01}Z_{800}(t) + U_{02}Y_{034}(t) - U_{03}Y_{380}(t) \quad \text{(V-8.1)}$$

Green Core from 4-foot Lathe

$$Z_{810}(t+1) = U_{11}Z_{810}(t) + U_{12}Y_{221}(t) - U_{13}Y_{320}(t) \quad \text{(V-8.2)}$$

Green Face Stock from 8-foot Lathe

$$Z_{820}(t+1) = U_{21}Z_{820}(t) + U_{22}Y_{120}(t) - U_{23}Y_{310}(t) \quad \text{(V-8.3)}$$

where $Y_{120}(t) = \begin{bmatrix} Y_{122}(t) \\ Y_{123}(t) \\ Y_{124}(t) \end{bmatrix}$ and $Y_{310}(t) = \begin{bmatrix} Y_{311}(t) \\ Y_{312}(t) \\ Y_{313}(t) \end{bmatrix}$

Green Face Stock from Purchased Veneer

$$Z_{830}(t+1) = U_{31}Z_{830}(t) + U_{32}Y_{037}(t) - U_{33}Y_{370}(t) \quad \text{(V-8.4)}$$

Dry Core

$$Z_{840}(t+1) = U_{41}Z_{840}(t) + U_{42}Y_{330}(t) - Y_{43}Y_{100}(t) \qquad \text{(V-8.5)}$$

$$\text{where } Y_{330}(t) = \begin{bmatrix} Y_{331}(t) \\ Y_{332}(t) \\ Y_{333}(t) \\ Y_{334}(t) \end{bmatrix} \text{ and } Y_{100}(t) = \begin{bmatrix} Y_{101}(t) \\ Y_{102}(t) \\ Y_{103}(t) \\ Y_{104}(t) \end{bmatrix}$$

Dry Strips

$$Z_{850}(t+1) = U_{51}Z_{850}(t) + U_{52}Y_{340}(t) - U_{53}Y_{410}(t) - U_{54}Y_{510}(t) \qquad \text{(V-8.6)}$$

Purchased Dry Veneer

$$Z_{880}(t+1) = V_{31}Z_{880}(t) + V_{32}Y_{038}(t) - V_{33}Y_{630}(t) \qquad \text{(V-8.7)}$$

$$\text{where } Y_{340}(t) = \begin{bmatrix} Y_{341}(t) \\ Y_{342}(t) \\ Y_{343}(t) \\ Y_{344}(t) \end{bmatrix}, \qquad Y_{410}(t) = \begin{bmatrix} Y_{411}(t) \\ Y_{412}(t) \\ Y_{413}(t) \\ Y_{414}(t) \end{bmatrix}$$

$$\text{and} \quad Y_{510}(t) = \begin{bmatrix} Y_{511}(t) \\ Y_{512}(t) \\ Y_{513}(t) \end{bmatrix}.$$

Dry 27's

$$Z_{860}(t+1) = U_{61}Z_{860}(t) + U_{62}Y_{350}(t) - U_{63}Y_{420}(t) - U_{64}Y_{520}(t) - U_{65}Y_{012}(t) - U_{66}Y_{013}(t) - U_{67}Y_{015}(t) \qquad \text{(V-8.8)}$$

$$\text{where } Y_{420}(t) = \begin{bmatrix} Y_{421}(t) \\ Y_{422}(t) \\ Y_{423}(t) \\ Y_{424}(t) \end{bmatrix} \quad \text{and } Y_{520}(t) = \begin{bmatrix} Y_{521}(t) \\ Y_{522}(t) \\ Y_{523}(t) \end{bmatrix}$$

Dry 54's

$$Z_{870}(t+1) = U_{71}Z_{870}(t) + U_{72}Y_{360}(t) + U_{73}Y_{624}(t) + U_{74}Y_{532}(t) - U_{75}Y_{440}(t) - U_{76}Y_{612}(t) - U_{77}Y_{011}(t) - U_{78}Y_{014}(t) - U_{79}Y_{016}(t) - T_{71}Y_{017}(t) - T_{72}Y_{021}(t) \qquad \text{(V-8.9)}$$

$$\text{where } Y_{360}(t) = \begin{bmatrix} Y_{361}(t) \\ Y_{362}(t) \\ Y_{363}(t) \\ Y_{364}(t) \end{bmatrix} \quad \text{and } Y_{440}(t) = \begin{bmatrix} Y_{441}(t) \\ Y_{442}(t) \\ Y_{443}(t) \\ Y_{444}(t) \end{bmatrix}$$

Processed Core

$$Z_{890}(t+1) = U_{91}Z_{890}(t) + U_{92}Y_{100}(t) - U_{93}Y_{200}(t) \qquad \text{(V-8.10)}$$

where $Y_{200}(t) = \begin{bmatrix} Y_{201}(t) \\ Y_{202}(t) \\ Y_{203}(t) \\ Y_{204}(t) \end{bmatrix}$ and $Y_{100}(t) = Y_{330}(t)$.

Processed Centers

$$\begin{aligned} Z_{900}(t+1) = {} & V_{11}Z_{900}(t) + V_{12}Y_{013}(t) + V_{13}Y_{012}(t) + \\ & V_{14}Y_{533}(t) + V_{15}Y_{011}(t) + V_{16}Y_{014}(t) + \\ & V_{17}Y_{30}(t) - V_{18}Y_{300}(t) \end{aligned} \qquad \text{(V-8.11)}$$

where $Y_{300}(t) = \begin{bmatrix} Y_{301}(t) \\ Y_{302}(t) \\ Y_{303}(t) \end{bmatrix}$ and $Y_{30}(t) = Y_{015}(t) + Y_{016}(t)$

Faces and Backs

$$\begin{aligned} Z_{910}(t+1) = {} & V_{21}Z_{910}(t) + V_{22}Y_{017}(t) + V_{23}Y_{021}(t) + \\ & V_{24}Y_{620}(t) - V_{25}Y_{400}(t) \end{aligned} \qquad \text{(V-8.12)}$$

where $Y_{400}(t) = \begin{bmatrix} Y_{401}(t) \\ Y_{402}(t) \\ Y_{403}(t) \\ Y_{404}(t) \\ Y_{405}(t) \end{bmatrix}$ and $Y_{620}(t) = \begin{bmatrix} Y_{621}(t) \\ Y_{622}(t) \\ Y_{623}(t) \end{bmatrix}$.

From Equations V-2.1 and V-5.1,

$$Y_{034}(t) = S_4 \; Y_{415}(t)$$

$$Y_{415}(t) = Y_{121}(t) = R'_{11} Y_{110}(t)$$

Substituting in Equation V-8.1, we obtain

$$Z_{800}(t+1) = U_{01} Z_{800}(t) + U_{02} S_4 R'_{11} Y_{110}(t) - U_{03} Y_{380}(t) \tag{V-8.13}$$

We also have from Equation V-3.2,

$$Y_{221}(t) = R_{20} Y_{210}(t)$$

Substituting into V-8.2, we have

$$Z_{810}(t+1) = U_{11} Z_{810}(t) + U_{12} R_{20} Y_{210} - U_{13} Y_{320}(t) \tag{V-8.14}$$

V.9. System Model

Equations V-4.1, V-6.1, V-7.1, V-8.3, V-8.4, V-8.5, V-8.6, V-8.7, V-8.8, V-8.9, V-8.10, V-8.11, V-8.12, V-8.13, and V-8.14 can all be written in matrix form as Equation V-9.1, where

$$A_{11} = U_{02} \; S_4 \; R'_{11} \; , \; A_{12} = U_{12} \; R_{20} \; , \; A_{13} = U_{22} \; R_{11} \; ,$$

$$T'_{11} = \begin{bmatrix} T_{11} \\ T_{21} \\ T_{31} \end{bmatrix} \; , \; T'_{12} = \begin{bmatrix} T_{12} \\ T_{22} \\ T_{32} \end{bmatrix} , \text{ and } T'_{13} = \begin{bmatrix} T_{13} \\ T_{23} \\ T_{33} \end{bmatrix} .$$

If we let,

$$S(t) = \begin{bmatrix} Z_{800}(t) \\ Z_{810}(t) \\ Z_{820}(t) \\ Z_{830}(t) \\ Z_{850}(t) \\ Z_{860}(t) \\ Z_{870}(t) \\ Z_{880}(t) \\ Z_{890}(t) \\ Z_{900}(t) \\ Z_{910}(t) \\ Y_{330}(t) \\ Y_{340}(t) \\ Y_{350}(t) \\ Y_{360}(t) \\ Y_{531}(t) \\ Y_{532}(t) \\ Y_{533}(t) \\ Y_{620}(t) \\ Y_{624}(t) \end{bmatrix}, \quad F(t) = \begin{bmatrix} Y_{011}(t) \\ Y_{012}(t) \\ Y_{013}(t) \\ Y_{014}(t) \\ Y_{015}(t) \\ Y_{016}(t) \\ Y_{017}(t) \\ Y_{021}(t) \\ Y_{037}(t) \\ Y_{038}(t) \\ Y_{110}(t) \\ Y_{210}(t) \\ Y_{310}(t) \\ Y_{320}(t) \\ Y_{370}(t) \\ Y_{380}(t) \\ Y_{410}(t) \\ Y_{420}(t) \\ Y_{440}(t) \\ Y_{510}(t) \\ Y_{520}(t) \\ Y_{612}(t) \\ Y_{630}(t) \end{bmatrix}, \quad E(t) = \begin{bmatrix} Y_{200}(t) \\ Y_{300}(t) \\ Y_{400}(t) \end{bmatrix}$$

$$
\begin{bmatrix} Z_{800}(t+1) \\ Z_{810}(t+1) \\ Z_{820}(t+1) \\ Z_{830}(t+1) \\ Z_{850}(t+1) \\ Z_{860}(t+1) \\ Z_{870}(t+1) \\ Z_{880}(t+1) \\ Z_{890}(t+1) \\ Z_{900}(t+1) \\ Z_{910}(t+1) \\ Y_{330}(t+1) \\ Y_{340}(t+1) \\ Y_{350}(t+1) \\ Y_{360}(t+1) \\ Y_{531}(t+1) \\ Y_{532}(t+1) \\ Y_{533}(t+1) \\ Y_{620}(t+1) \\ Y_{624}(t+1) \end{bmatrix}
=
\begin{bmatrix}
U_{01} & & & & & & & & & & & & & & & & & & & \\
& U_{11} & & & & & & & & & & & & & & & & & & \\
& & U_{21} & & & & & & & & & & & & & & & & & \\
& & & U_{31} & & & & & & & & & & & & & & & & \\
& & & & U_{51} & & & & & & & & U_{52} & & & & & & & \\
& & & & & U_{61} & & & & & & & & U_{62} & & & & & & \\
& & & & & & U_{71} & & & & & & & & U_{72} & & U_{74} & & & U_{73} \\
& & & & & & & V_{31} & & & & & & & & & & & & \\
& & & & & & & & U_{91} & & & U_{92} & & & & & & & & \\
& & & & & & & & & V_{11} & & & & & & & & V_{14} & & \\
& & & & & & & & & & V_{21} & & & & & & & & V_{24} & \\
& & & & & & & & & & & & & & & & & & & \\
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& & & & & & & & & & & & & & & & & & & \\
& & & & & & & & & & & & & & & T'_{11} & & & & \\
& & & & & & & & & & & & & & & T_{41} & & & &
\end{bmatrix}
\begin{bmatrix} Z_{800}(t) \\ Z_{810}(t) \\ Z_{820}(t) \\ Z_{830}(t) \\ Z_{850}(t) \\ Z_{860}(t) \\ Z_{870}(t) \\ Z_{880}(t) \\ Z_{890}(t) \\ Z_{900}(t) \\ Z_{910}(t) \\ Y_{330}(t) \\ Y_{340}(t) \\ Y_{350}(t) \\ Y_{360}(t) \\ Y_{531}(t) \\ Y_{532}(t) \\ Y_{533}(t) \\ Y_{620}(t) \\ Y_{624}(t) \end{bmatrix}
$$

$$
\left[\begin{array}{ccccccccccccccccccccccc}
 & & & & & & & & & & A_{11} & & & & & -U_{03} & & & & & & & \\
 & & & & & & & & & & & A_{12} & & -U_{13} & & & & & & & & & \\
 & & & & & & & & & & A_{13} & & -U_{23} & & & & & & & & & & \\
 & & & & & & & & U_{32} & & & & & & -U_{33} & & & & & & & & \\
 & & & & & & & & & & & & & & & & -U_{53} & & & -U_{54} & & & \\
 & -U_{65}-U_{66} & & & -U_{67} & & & & & & & & & & & & & -U_{63} & & & -U_{64} & & \\
-U_{77} & & & -U_{78} & & -U_{79}-T_{71}-T_{72} & & & & & & & & & & & & & -U_{75} & & & -U_{76} & \\
 & & & & & & & & & V_{32} & & & & & & & & & & & & & -V_{33} \\
 & & & & & & & & & & & & & & & & & & & & & & \\
V_{15} & V_{13} & V_{12} & V_{16} & V_{17} & V_{17} & & & & & & & & & & & & & & & & & \\
 & & & & & & V_{22} & V_{23} & & & & & & & & & & & & & & & \\
 & & & & & & & & & & & & & R^{\circ}_{12} & & R^{\circ}_{14} & & & & & & & \\
 & & & & & & & & & & & & R^{\circ}_{21} & & & & & & & & & & \\
 & & & & & & & & & & & & R^{\circ}_{31} & & & & & & & & & & \\
 & & & & & & & & & & & & R^{\circ}_{41} & & & & & & & & & & \\
 & & & & & & & & & & & & & & & & & & & G_{11} & G_{12} & & \\
 & & & & & & & & & & & & & & & & & & & G_{21} & G_{22} & & \\
 & & & & & & & & & & & & & & & & & & & G_{31} & G_{32} & & \\
 & & & & & & & & & & & & & & & & & & & & & T'_{12} & T'_{13} \\
 & & & & & & & & & & & & & & & & & & & & & T_{42} & T_{43}
\end{array}\right]
\begin{bmatrix} Y_{011}(t) \\ Y_{012}(t) \\ Y_{013}(t) \\ Y_{014}(t) \\ Y_{015}(t) \\ Y_{016}(t) \\ Y_{017}(t) \\ Y_{021}(t) \\ Y_{037}(t) \\ Y_{038}(t) \\ Y_{110}(t) \\ Y_{210}(t) \\ Y_{310}(t) \\ Y_{320}(t) \\ Y_{370}(t) \\ Y_{380}(t) \\ Y_{410}(t) \\ Y_{420}(t) \\ Y_{440}(t) \\ Y_{510}(t) \\ Y_{520}(t) \\ Y_{612}(t) \\ Y_{630}(t) \end{bmatrix}
+
\begin{bmatrix} & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ -U_{93} & & \\ & -V_{18} & \\ & & -V_{25} \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \end{bmatrix}
\begin{bmatrix} Y_{200}(t) \\ Y_{300}(t) \\ Y_{400}(t) \end{bmatrix}
\qquad (V\text{-}9.13)
$$

then we can write Equation V-9.1 simply as

$$S(t+1) = P\ S(t) + Q\ F(t) - G\ E(t) \qquad (V\text{-}9.2)$$

where P, Q and G are matrices. For any given period, E(t) represents veneers demanded by the spreaders due to a lay-up schedule J'(t), that is

$$E(t) = C\ J'(t) \qquad (V\text{-}9.3)$$

where C is a construction matrix with entries representing the quantities of each type of veneer required by each product in J'(t). The matrix C is shown in detail in Equation V-9.3-b for certain selected products.

The lay-up schedule at the spreaders, represented by J'(t), includes allowances for falldown.[1] The relationship between the quantities required by the order file and the quantities to be laid-up is given by

$$J(t) = D\ J'(t) \qquad (V\text{-}9.4)$$

or

$$J'(t) = D^{-1}J(t) \qquad (V\text{-}9.5)$$

where J(t) represents the quantities required by the order file. The falldown matrix D is always square and lower triangular (if product grades are arranged in decreasing order) whose rows are independent of each other. Therefore,

---

[1]Products not acceptable in the grade they were originally laid-up due to defects that developed during manufacture.

D^{-1} exists (17). To illustrate the construction of D, we show it for the products used for an example in Equation V-9.4-b, using data from Table V-9.1. The complete fall-down matrix can be constructed from data given in Tables V-9.1-a and V-9.1-b.

Substituting Equation V-9.4 in V-9.2, we obtain

$$S(t+1) = P\ S(t) + Q\ F(t) - G\ C\ J'(t) \qquad \text{(V-9.6)}$$

or

$$S(t+1) = P\ S(t) + Q\ F(t) - H\ J'(t) \qquad \text{(V-9.7)}$$

where H = G C. Equation V-9.7 is a mathematical model of the production process. For any period <u>t</u> we have the following:

S(t) = Veneer inventories at the beginning of the period.

S(t+1) = Veneer inventories at the end of the period.

F(t) = Schedule of activities at all processing centers preceding the spreaders.

J'(t) = Lay-up schedule at the spreaders.

We are now in a position to solve Equation V-9.7 for t = 0,1, 2.,,,14,15, as follows.

$$S(1) = P\ S(0) + Q\ F(0) - H\ J'(0) \qquad \text{(V-9.8)}$$

$$S(2) = P\ S(1) + Q\ F(1) - H\ J'(1) \qquad \text{(V-9.9)}$$

$$\cdots\cdots\cdots\cdots\cdots\cdots \qquad \cdots\cdots$$

$$S(15) = P\ S(14) + Q\ F(14) - H\ J'(14) \qquad \text{(V-9.22)}$$

$$
\begin{array}{ll}
\text{Faces \& Backs} & \text{1/10th C} \\
 & \text{1/10th D} \\
\text{Centers} & \text{1/10th C} \\
 & \text{1/10th D} \\
 & \text{1/10th NC} \\
\text{Cores} & \text{1/10th C} \\
 & \text{1/10th D} \\
 & \text{1/10th NC} \\
 & \text{1/6th C} \\
 & \text{1/6th D} \\
 & \text{1/6th NC}
\end{array}
=
\begin{bmatrix}
.0171 & .0171 & .0171 & .0085 & .0085 & .0085 & .0085 & .0085 & .0085 \\
 & & & .0085 & .0085 & .0085 & .0085 & .0085 & .0085 \\
 & .0085 & .0085 & & & & & & \\
 & & & & .0085 & .0085 & & & \\
 & & & & & & & .0085 & .0085 \\
.0085 & .0171 & & & & & & & \\
 & & & .0085 & .0171 & & & & \\
 & & & & & & .0085 & .0171 & \\
 & & .0142 & & & & & & \\
 & & & & & .0142 & & & \\
 & & & & & & & & .0142
\end{bmatrix}
\begin{bmatrix}
\text{3/8 CC} \\
\text{1/2 CC} \\
\text{5/8 CC} \\
\text{3/8 CD} \\
\text{1/2 CD} \\
\text{5/8 CD} \\
\text{3/8 CDNC} \\
\text{1/2 CDNC} \\
\text{5/8 CDNC}
\end{bmatrix}
\qquad (V\text{-}9.3\text{-}b)
$$

$$
\begin{bmatrix} 3/8\ \mathrm{CC} \\ 1/2\ \mathrm{CC} \\ 5/8\ \mathrm{CC} \\ 3/8\ \mathrm{CD} \\ 1/2\ \mathrm{CD} \\ 5/8\ \mathrm{CD} \\ 3/8\ \mathrm{CDNC} \\ 1/2\ \mathrm{CDNC} \\ 5/8\ \mathrm{CDNC} \\ 3/8\ \mathrm{SHOP} \\ 1/2\ \mathrm{SHOP} \\ 5/8\ \mathrm{SHOP} \end{bmatrix}
=
\begin{bmatrix}
.8068 & & & & & & & & & & & \\
 & .8417 & & & & & & & & & & \\
 & & .7289 & & & & & & & & & \\
.0851 & & & .8365 & & & & & & & & \\
 & .0428 & & & .8459 & & & & & & & \\
 & & .2467 & & & .7519 & & & & & & \\
.0943 & & & .1429 & & & .9500 & & & & & \\
 & .1049 & & & .1353 & & & .9401 & & & & \\
 & & & & & .1509 & & & .9145 & & & \\
.0138 & & & .0206 & & & .0500 & & & 1.0000 & & \\
 & .0106 & & & .0188 & & & .0599 & & & 1.0000 & \\
 & & .0244 & & & .1972 & & & .0855 & & & 1.000
\end{bmatrix}
\begin{bmatrix} 3/8\ \mathrm{CC} \\ 1/2\ \mathrm{CC} \\ 5/8\ \mathrm{CC} \\ 3/8\ \mathrm{CD} \\ 1/2\ \mathrm{CD} \\ 5/8\ \mathrm{CD} \\ 3/8\ \mathrm{CDNC} \\ 1/2\ \mathrm{CDNC} \\ 5/8\ \mathrm{CDNC} \\ 3/8\ \mathrm{SHOP} \\ 1/2\ \mathrm{SHOP} \\ 5/8\ \mathrm{SHOP} \end{bmatrix}
\qquad \text{(V-9.4-b)}
$$

TABLE V-9.1-a.--Panel falldown summary[1] (exterior sheathing).

Product	On-Grade	Sub-Grade	Non-Cert	Shop	Blows	Sample Size[2]
3/8 CC	80.68	3/8 CD-8.51	9.43	0.63	0.75	1599
1/2 CC	84.17	1/2 CD-4.28	10.49	0.82	0.24	4955
5/8 CC	72.89	5/8 CD-24.67		2.44		450
5/16 CD	85.10		12.37	0.74	1.79	25845
5/16 CD #2	77.89		17.17	1.83	3.11	1417
5/16 CD #3	76.01		18.17	3.49	2.33	2063
3/8 CD	83.65		14.29	1.09	0.97	45828
3/8 CD #2	82.68		13.53	1.91	1.88	3829
3/8 CD #3	83.89		12.42	2.88	0.81	3576
1/2 CD	84.59		13.53	1.18	0.70	150382
1/2 CD #2	82.30		15.28	1.72	0.70	76432
1/2 CD #3	85.11		12.61	1.54	0.74	15579
5/8 CD	75.19		15.09	1.82	7.90	16946
5/8 CD #2	84.07		13.78	1.37	0.78	4969
5/8 CD #3	85.52		11.82	1.57	1.09	--[3]
3/4 CD	85.64		11.37	1.94	1.05	11578
3/4 CD #2	86.08		10.46	2.78	0.68	1185
3/4 CD #3	86.38		11.56	1.64	0.42	7419
5/16 TRU PLY	96.81				3.19	660
1/2 TRU PLY	94.01			2.80	3.19	20187
5/8 TRU PLY	91.45			5.96	2.59	772

[1]Data taken from July, August, September, and up to October 18 (1966) production reports.

[2]Panels.

[3]No data available. Interpolated from 1/2 CD #3 and 3/4 CD #3 figures.

TABLE V-9.1-b.--Panel falldown summary for sanded products in percent.[1]

Original Grade	Grade Breakdown								
	AA	AB	AC	AD	BB	BC	BD	SHOP	TOTAL
AA	55.0	22.0	8.0					15.0	100.0
AB		59.0	18.0	5.0				18.0	100.0
AC			64.0	15.0				21.0	100.0
AD				70.0			8.0	22.0	100.0
BB					73.0	12.0		15.0	100.0
BC						78.0	5.0	17.0	100.0
BD							80.0	20.0	100.0

[1]Falldown figures by product not available.

Transposing terms and rearranging, we can write Equations V-9.8 through V-9.22 as Equation V-9.23. In Equation V-9.23,

A_i = Matrix whose entries are productivity coefficients, that is, processing time for each unit of input at each machine center,

B_i = Matrix with entries of 1's,

D = Falldown matrix,

J_x = Products that cannot be satisfied and must be backlogged,

J_T = Order file,

K_i = Column vector of machine capacities,

I_i = Column vector of inventory space capacities,

C_x = Penalty cost for backlogged orders,

C_i = Cost associated with each activity,

C_i' = Cost of holding veneers on inventory,

$F(j)$ = Production schedule during the (j+1)th period,

$J'(j)$ = Lay-up schedule during the (j+1)th period,

$S(0)$ = Beginning inventories, and

$S(15)$ = Ending inventories.

The submatrices, A_i, are constructed from data such as shown in Tables V-10.1, V-10.2, and V-10.3.

$$
\begin{bmatrix}
Q & & \cdot & & -H & & & & & -U & & \cdot & & \\
& Q & \cdot & & & -H & \cdot & & & P & -U & \cdot & & \\
\cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\
& & \cdot & Q & & & \cdot & -H & & & & \cdot & P & -U \\
A_1 & & \cdot & & & & \cdot & & & & & \cdot & & \\
& A_2 & \cdot & & & & \cdot & & & & & \cdot & & \\
\cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\
& & \cdot & A_{15} & & & \cdot & & & & & \cdot & & \\
& & \cdot & & D & D & \cdot & D & U & & & \cdot & & \\
& & \cdot & & & & \cdot & & & B_1 & & \cdot & & \\
& & \cdot & & & & \cdot & & & & B_2 & \cdot & & \\
\cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\
& & \cdot & & & & \cdot & & & & & \cdot & B_{14} & \\
& & \cdot & & & & \cdot & & & & & \cdot & & B_{15} \\
C_1 & C_2 & \cdot & C_{15} & & & \cdot & & C_x & C'_1 & C'_2 & \cdot & C'_{14} & C'_{15}
\end{bmatrix}
\begin{bmatrix}
F(0) \\ F(1) \\ \cdots \\ F(14) \\ J'(0) \\ J'(1) \\ \cdots \\ J'(14) \\ J_x \\ S(1) \\ S(2) \\ \cdots \\ S(14) \\ S(15) \\
\end{bmatrix}
\begin{array}{c}
= \\ = \\ \cdot \\ = \\ \leqq \\ \leqq \\ \cdot \\ \leqq \\ = \\ \leqq \\ \leqq \\ \cdot \\ \leqq \\ \leqq \\ =
\end{array}
\begin{bmatrix}
-P\ S(0) \\ 0 \\ \cdots \\ 0 \\ K_1 \\ K_2 \\ \cdots \\ K_{15} \\ J_T \\ I_1 \\ I_2 \\ \cdots \\ I_{14} \\ I_{15} \\ \text{Minimum}
\end{bmatrix}
$$

(V-9.23)

TABLE V-10.1.--8-foot lathe production rates.

	Peel Thickness								
	1/10			1/6			7/32		
Species	Output	Reco	Input	Output	Reco	Input	Output	Reco	Input
Douglas Fir	18.717[a] 0.0534[d]	257[b]	7.283[c] 0.1373[e]	25.127* 0.0398*	266*	9.427* 0.1061*	19.761 0.0506	239	8.280 0.1208
White Fir	14.462 0.0691	204	7.105 0.1407	19.151 0.0522	256	7.493 0.1335			
Hemlock	15.161 0.0660	224	6.768 0.1478	17.070 0.0586	228	7.487 0.1336	12.334* 0.0811*	238*	5.192* 0.1926*
Spruce	15.266 0.0655	254	6.010 0.1664	18.252** 0.0548**	230**	7.936** 0.1260**	16.003* 0.0625*	203*	7.876* 0.1270*
Larch	14.244 0.0702	238	5.985 0.1671						
Pine	15.141 0.0605	236	6.416 0.1559	20.544 0.0487	257	9.780 0.1022	15.350** 0.0651**	179**	8.575** 0.1166**

*Less than 50 hours of production.

**Less than 10 hours of production. Otherwise, greater than 100 hours of production.

[a]MSF per hour (3/8). [b]Recovery in surface ft per 100 bd ft of logs (3/8).

[c]Board feet per hour (block scale). [d]Hours per 1000 surface feet of output.

[e]Hours per 1000 bd ft (block scale) of input.

TABLE V-10.2.--Drying productivity.[1]

Veneer Thickness	Species	Hrs/MSF3/8	Hrs/MBF
1/10	Douglas Fir	.0449	.1175
1/10	White Fir	.0815	.1737
1/10	Spruce	.0590	.1345
1/10	Larch	.0648	.1543
1/10	Ponderosa Pine	.0602	.1421
1/10	Hemlock	.0633	.1419
1/6	Douglas Fir	.0783	.1980
1/6	White Fir	.1282	.2731
1/6	Spruce	.1011	.2304
1/6	Larch	.1008	.2400
1/6	Ponderosa Pine	.1005	.2333
1/6	Hemlock	.0924	.2200
7/32	Spruce	.1078	.2384
7/32	Ponderosa Pine	.1144	.2413
7/32	Hemlock	.1019	.2282
5/16	Spruce	.1110	.2453
5/16	Ponderosa Pine	.1177	.2483
5/16	Hemlock	.1130	.2430

[1]Average for all widths.

TABLE V-10.3.--Patching productivity.[1]

Thickness	Species	Veneer Grade	Original Width	Hrs/MSF3/8
1/10	Douglas Fir	AB	54	1.43
1/10	Douglas Fir	ABCp	54	1.47
1/10	White Fir	ABCp	54	1.70
1/10	Larch	"	"	1.33
1/10	Hemlock	"	"	1.77
1/6	Douglas Fir	"	"	0.94
1/6	White Sir	"	"	1.02
1/6	Larch	"	"	0.80
1/6	Hemlock	"	"	1.07
1/10	Douglas Fir	"	27	1.80
1/10	White Fir	"	"	1.97
1/10	Larch	"	"	1.53
1/10	Hemlock	"	"	2.04
1/6	Douglas Fir	"	"	1.08
1/6	White Fir	"	"	1.18
1/6	Larch	"	"	0.99
1/6	Hemlock	"	"	1.24
1/10	Douglas Fir	"	Strips	1.97
1/10	White Fir	"	"	2.13
1/10	Larch	"	"	1.67
1/10	Hemlock	"	"	2.24
1/6	Douglas Fir	"	"	1.17
1/6	White Fir	"	"	1.29
1/6	Larch	"	"	1.01
1/6	Hemlock	"	"	1.35

[1]Estimated figures or based on small sample.

VI. PRACTICAL IMPLICATIONS

The practical usefulness of the preceding formulation (or any other formulation) depends on two important considerations which must be taken into account before any attempt can be made to implement the proposed method. The first consideration is the improvement that can be expected over the present method of scheduling and second, the cost of implementation, in particular, the cost of computing time required to obtain a solution to the problem.

The first consideration is not by any means easy to evaluate because means for measuring scheduling effectiveness are not generally available. Moreover, the proposed method has to be tried and tested for a long enough period before a comparison can be made. Such parameters as (i) unit processing cost, (ii) weekly production "through-put," or (iii) lateness in deliveries, can possible be used to measure scheduling effectiveness. However, it should be borne in mind that the magnitudes of these parameters could change, not as a result of a change in scheduling techniques, but due to some other factors.

There is no question that current methods can be improved upon. This conclusion comes from knowledge that materials are every now and then misapplied, from observing frequent slowdown in production because sufficient lead time was not allowed in preceding operations, from observing the pile-up of in-process inventories because activities at various processing centers were not coordinated properly, and from similar omissions that every now and then hinders the productivity of the mill. But whether or not the improvement can be effected at a relatively smaller cost to make implementation economically feasible is another matter. Indeed, in any industrial innovation, it is the "pay-off" that is the deciding factor. Consequently, it is possible for an improvement to be practical in one application and impractical in another if the dollar savings in one is more than the other, although the size and complexity of the problem in both cases are comparable.

The cost of computation (which for practical purposes represents the cost of implementation) can be easily estimated because the running time for any given size of a problem does not vary very significantly from one run to another. Thus, given the expected cost of computation, the question that remains to be answered is whether it is less than the savings it is anticipated to make.

The scheduling problem of the mill as formulated in Chapter V would result in a linear programming matrix of dimensions in the order of 3000 rows by 5000 columns. The matrix, however, is sparse with a density of approximately

0.53 percent. From past experience on the UNIVAC 1107, it is estimated that the model would entail a computation time of approximately two hours for each weekly schedule and, depending on where it is run, may cost anywhere from $600 to $1000 a run. The question then becomes: Would the expected improvement be worth more than $1000 a week? Initially, of course, this question can be answered only in somewhat vague terms. However, a production manager who has been keeping an eye on inefficiencies or deficiencies in the mill should be able to answer the question emperically with reasonable accuracy.

V-1. The Static Case

The company for some time had been trying to formulate a computer model of a "veneer scheduler" which in effect would determine the quantities of materials (logs and veneers) that would be required by a given order file. In effect, the information to be obtained from the model would be a summary of material requirements for the whole week. Undoubtedly, there would be questions raised as to the usefulness of such information. Admittedly, a lot still remains for the production scheduler to do as far as making specific machine time allocations is concerned. But the information to be derived from such a veneer scheduler will serve a very useful purpose of a guide for quantity requirements of each type of material.

The same type of information can be obtained from the model outlined in Chapter V with very little modification. This is easily done by taking the period equal to the planning horizon, i.e., a week, and making adjustments in the lead times required by each processing center. This is what might be referred to as the static case and was considered an excellent starting point for evaluating the value of the model. The static model as formulated for the mill can be found in Appendix E. It is intended to be run at the beginning of each week with the order file and initial inventories as inputs. Its solution consists of two stages.

VI-1.1. Phase I

The first stage is the determination of the lay-up schedule, i.e., the quantities of each product that are required to satisfy the order file, and of the corresponding quantities of veneers that will be required. The following are the factors considered in the calculation of the lay-up schedule:

1. Products already on inventory at the beginning of the week
2. Allowances to be made for product falldown
3. The order file

Because pressing is done by the press loads, viz., in multiples of 60's for 1/4- and 3/8-inch plywood or 30's for 1/2-inch or thicker plywood, the initial lay-up schedule together with other pertinent data is shown in Appendix B. Corresponding veneer requirements are shown in Appendix C.

VI-1.2. Phase II

Given the veneer requirements shown in Appendix C, the next step is to determine how best these veneers can be made available at the spreaders. This is accomplished with the model shown in Appendix E. The matrix has 491 rows and 927 columns and takes about 11 minutes of computer time on the UNIVAC 1107. The information obtained from the solution includes (i) production schedules for each processing center, (ii) outside veneer required to balance what is available from the raw material against the requirements of the order file, and (iv) veneer requirements that cannot be met during the week and must be backlogged. Valuable information can also be obtained from the dual solution of the problem. The most important of these is the information on machine capacities that are expected to be inadequate (as far as the current order file is concerned), thereby giving the scheduler an opportunity to make necessary arrangements for overtime and other similar adjustments. The production schedule corresponding to veneer requirements indicated in Appendix C is shown in Appnedix D.

VII. CONCLUSIONS

The discussion in Chapters III, IV and V outlines a procedure by which a scheduling problem involving assembly may be modelled mathematically so that a realistic schedule can be derived from its solution. The procedure is built around the premise that alternatives are selected over other alternatives on the basis of cost, within the limitations of machine and storage capacities. To illustrate in part the behavior of the model, we assume a situation in which there is a demand for C centers at the spreaders. Specifications allow the use of Douglas fir, larch, white fir, spruce, ponderosa pine, or hemlock for centers. Normally, the model would choose the most economical source of C centers, since the objective is to minimize total processing cost. Assuming that there are sufficient machine capacities available, it would probably call for a peel of such less expensive material as ponderosa pine or spruce even if there is already available on inventory C grade of Douglas fir. Douglas fir, of course, has more valuable applications. Suppose, however, that there is a shortage in dryer capacity. Then the model would be constrained to use Douglas fir veneer (sustaining a higher material cost because of capacity limitations) or backlog the demand for C centers and suffer a corresponding penalty cost, whichever is the cheaper. On the other hand, if C grade of hemlock were also available from inventory then hemlock would be selected since it is a less valuable material than Douglas fir.

It is clear that the behavior of the model is highly dependent on the relative "costs" associated with each activity or input; therefore, it is important that these "costs" be accurately determined or appropriately chosen. It is highly debatable whether what is referred to here as "cost" is truly cost or a combination of cost and value. In certain cases it can be actual direct processing and material cost, in other instances, a combination of processing cost and value (of material) is more appropriate. For example, in applications where more than one species are equally acceptable (such as the previous example), actual cost or a combination of processing cost and value can be used. However, if the choice were between materials of the same species but of different grades, the picture changes somewhat. Accounting practices in the mill considers actual cost of C and D veneer of the same species to be the same, the processing cost being the same for both grades and there being no accurate method of allocating the cost of material to various grades recoverable from the log.

The model as formulated in the dynamic case (Chapter V) or the static case (Appendix E) is rather formidable in size. Questions might, therefore, be raised regarding the efficiency of the method here proposed for describing scheduling problems. It is difficult at this point to assess the efficiency since there is no basis for comparison. However, it can be pointed out that the problem modelled is not an idealization of reality but an actual problem that involves 152 basic products that are assembled from 43 basic veneer types, 210 dry veneer in-process inventories, 50 green veneer in-process inventories, and 6 processing centers. A typical week might involve 20 customer orders (jobs) each requiring one to ten of the 152 products that the mill manufactures. Surely by any standard, the problem is not trivial.

The model, however, can be simplified by excluding certain activities or inputs that can never or very remotely will ever be chosen over other alternatives; for example, sawing 27-inch C grade of Douglas fir for core (Appendix E, BSI, column 1234) or edge gluing D grade of 7/32 spruce strips (Appendix E, EGI, column 1209). Another possibility is consolidating certain veneer in-process inventories that can be combined; for example, combining all inventories that are 54 inches wide (Appendix E, VI54 and VRFX-X, VRC8-X) and combining all core inventories (VIC4 and VRC4-X). It is estimated that the number of variables can be reduced by about 20 to 30 percent if the above possibilities are undertaken. It will, however, require careful study and time to make sure the removal of these variables does not impair the effectiveness of the model.

Any mathematical model is only as good as the data fed to it. The static case presented in Appendix E was constructed with some estimated figures. While these figures were chosen with care and are believed to be realistic, they still remain estimates of certain production statistics that were not readily available at the time the model was formulated. The following are the data in the model that need upgrading:

1. Recoveries at the edge gluer.
2. Productivity of the edge gluer for each species and each thickness.
3. Productivity of the Riamann veneer patchers.
4. Falldown figures for sanded products.
5. Processing cost at each production center.

The production schedule presented in Appendices B, C and D was obtained from a computer run using actual data. These results were discussed with production people to determine whether or not they are reasonable in the light of what might be expected from usual methods of scheduling. The major difference was in the tendency of the model to bring in outside veneer (through purchase) even before machine capacities are exhausted as contrasted with the usual tendency of peeling all veneers that can be peeled until machine capacities run out. This difference was traced to the fact that it is the policy of the mill to utilize its resources (logs and machines) whenever it can without too much regard to the resulting in-process inventories on the floor. The model, on the other hand sees to it that levels of in-process inventories on the floor do not exceed the prescribed maximum. We point out that bringing in outside veneer is a good way to balance the veneer grades obtainable from the logs against the requirements of the order file, thereby minimizing extraneous veneers not needed for production.

The model also has a greater tendency to up-grade veneers (through edge gluing) than what is normally done. No comments, however, can be made regarding the logic of this tendency until more accurate data from the edge gluing operation is available, viz., productivity of the edge gluer for each species and grade, recoveries for each grade and edge gluing costs.

APPENDICES

APPENDIX A

LIST OF VECTORS AND VARIABLES

Y_{110} Vector--Log inputs to 8-foot lathe

1.	Douglas Fir	peel to 1/10th
2.	White Fir	" " "
3.	Spruce	" " "
4.	Larch	" " "
5.	Ponderosa Pine	" " "
6.	Hemlock	" " "
7.	Douglas Fir	peel to 1/6th
8.	White Fir	" " "
9.	Spruce	" " "
10.	Larch	" " "
11.	Ponderosa Pine	" " "
12.	Hemlock	" " "
13.	Spruce	peel to 7/32nd
14.	Ponderosa Pine	" " "
15.	Hemlock	" " "

Y_{210} Vector--Log inputs to core lathe

1.	White Fir	peel to 1/6th
2.	Spruce	" " "
3.	Ponderosa Pine	" " "
4.	Hemlock	" " "
5.	Spruce	peel to 7/32nd
6.	Ponderosa Pine	" " "
7.	Hemlock	" " "
8.	Spruce	peel to 5/16th
9.	Ponderosa Pine	" " "
10.	Hemlock	" " "

Y_{120}, Y_{310}, and Z_{820} Vector--Green 8-foot veneer

1.	1/10	Douglas Fir	54s
2.	"	"	27s
3.	"	"	strips
4.	"	White Fir	54s
5.	"	"	27s
6.	"	"	strips
7.	"	Spruce	54s
8.	"	"	27s
9.	"	"	strips
10.	"	Larch	54s
11.	"	"	27s
12.	"	"	strips
13.	"	Ponderosa Pine	54s
14.	"	"	27s
15.	"	"	strips
16.	"	Hemlock	54s
17.	"	"	27s
18.	"	"	strips

(Continued)

Y_{120}, Y_{310}, and Z_{820} Vectors (continued)

19.	1/6	Douglas Fir	54s
20.	"	"	27s
21.	"	"	strips
22.	"	White Fir	54s
23.	"	"	27s
24.	"	"	strips
25.	"	Spruce	54s
26.	"	"	27s
27.	"	"	strips
28.	"	Larch	54s
29.	"	"	27s
30.	"	"	strips
31.	"	Ponderosa Pine	54s
32.	"	"	27s
33.	"	"	strips
34.	"	Hemlock	54s
35.	"	"	27s
36.	"	"	strips
37.	7/32	Spruce	54s
38.	"	"	27s
39.	"	"	strips

Y_{121} and Y_{415} Vectors--Fish tails

1.	1/10	Douglas Fir
2.	"	White Fir
3.	"	Spruce
4.	"	Larch
5.	"	Ponderosa Pine
6.	"	Hemlock
7.	1/6	Douglas Fir
8.	"	White Fir
9.	"	Spruce
10.	"	Larch
11.	"	Ponderosa Pine
12.	"	Hemlock
13.	7/32	Spruce
14.	"	Ponderosa Pine
15.	"	Hemlock

Y_{037}, Y_{370}, and Z_{830} Vectors--Purchased green veneer

1.	1/10th	Douglas Fir	AB
2.	"	" "	CD

Y_{221}, Y_{320}, and Z_{810} Vectors--Green core

1.	1/6th	White Fir	random	width
2.	"	Spruce	"	"
3.	"	Pond. Pine	"	"
4.	"	Hemlock	"	"
5.	7/32	Spruce	"	"
6.	"	Pond. Pine	"	"
7.	"	Hemlock	"	"
8.	5/16	Spruce	"	"
9.	"	Pond. Pine	"	"
10.	"	Hemlock	"	"

Y_{034}, Y_{380} and Z_{800} Vectors--Green core from fishtails

1.	1/10th	Douglas Fir	random	width
2.	"	White Fir	"	"
3.	"	Spruce	"	"
4.	"	Larch	"	"
5.	"	Pond. Pine	"	"
6.	"	Hemlock	"	"
7.	1/6th	Douglas Fir	"	"
8.	"	White Fir	"	"
9.	"	Spruce	"	"
10.	"	Larch	"	"
11.	"	Pond. Pine	"	"
12.	"	Hemlock	"	"
13.	7/32nd	Spruce	"	"
14.	"	Pond. Pine	"	"
15.	"	Hemlock	"	"

Y_{330}, Y_{100}, Y_{200}, Z_{840}, Z_{890} and Y_{430}--Dry core

1.	1/10th	C solid	random	width
2.	"	C	"	"
3.	"	D	"	"
4.	"	NC	"	"
5.	1/6th	C solid	"	"
6.	"	C	"	"
7.	"	D	"	"
8.	"	NC	"	"
9.	7/32nd	C solid	"	"
10.	"	C	"	"
11.	"	D	"	"
12.	"	NC	"	"
13.	5/16th	C solid	"	"
14.	"	C	"	"
15.	"	D	"	"
16.	"	NC	"	"

Y_{340}, Y_{410} and Z_{850} Vectors--Dry strips

1.	1/10th	Douglas Fir	ABCp
2.	"	" "	C
3.	"	" "	D
4.	"	" "	NC
5.	"	White Fir	ABCp
6.	"	" "	C
7.	"	" "	D
8.	"	" "	NC
9.	"	Spruce	ABCp
10.	"	"	C
11.	"	"	D
12.	"	"	NC
13.	"	Larch	ABCp
14.	"	"	C
15.	"	"	D
16.	"	"	NC
17.	"	Pond. Pine	ABCp
18.	"	" "	C
19.	"	" "	D
20.	"	" "	NC
21.	"	Hemlock	ABCp
22.	"	"	C
23.	"	"	D
24.	"	"	NC
25.	1/6th	Douglas Fir	ABCp
26.	"	" "	C
27.	"	" "	D
28.	"	" "	NC
29.	"	White Fir	ABCp
30.	"	" "	C
31.	"	" "	D
32.	"	" "	NC
33.	"	Spruce	ABCp
34.	"	"	C
35.	"	"	D
36.	"	"	NC
37.	"	Larch	ABCp
38.	"	"	C
39.	"	"	D
40.	"	"	NC
41.	"	Pond. Pine	ABCp
42.	"	" "	C
43.	"	" "	D
44.	"	" "	NC
45.	"	Hemlock	ABCp
46.	"	"	C
47.	"	"	D
48.	"	"	NC

(continued)

Y_{340}, Y_{410} and Z_{850} Vectors (continued)

49.	7/32nd	Spruce	ABCp
50.	"	"	C
51.	"	"	D
52.	"	"	NC
53.	"	Pond. Pine	ABCp
54.	"	" "	C
55.	"	" "	D
56.	"	" "	NC
57.	"	Hemlock	ABCp
58.	"	"	C
59.	"	"	D
60.	"	"	NC

Y_{510} Vector--Strip input to edge gluer

Same as Y_{340}, escept without NC grades.

Y_{350}, Y_{420}, and Z_{860}--Dry 27-inch veneer

Identical with Y_{340} vector

Y_{520} Vector--27-inch veneer input to edge gluer

Identical with Y_{510} vector

Y_{360}, Y_{440}, and Z_{870} Vector--Dry 54-inch veneer

Identical with Y_{340} vector

Y_{300} and Z_{900} Vectors--Centers

1.	1/10th	C	Any species
2.	"	D	" "
3.	"	NC	" "
4.	1/6th	C	" "
5.	"	D	" "
6.	"	NC	" "
7.	7/32nd	C	" "
8.	"	D	" "
9.	"	NC	" "

Y_{400} and Z_{910} Vector--Faces and Backs

1.	1/10th	Doug. Fir/Larch	A
2.	"	"	B
3.	"	"	Cp
4.	"	"	C
5.	"	"	D

(continued)

Y_{400} and Z_{910} Vector--Faces and Backs (continued)

6.	1/10th	Wh. Fir/Hemlock	Cp
7.	"	"	C
8.	"	"	D
9.	"	P. Pine/Spruce	C
10.	"	"	D
11.	1/6th	Wh. Fir/Hemlock	Cp
12.	"	"	C
13.	"	"	D

Y_{011}--54-inch C center input to spreaders, and
Y_{013}--27-inch C center input to spreaders

1.	1/10th	Doug. Fir
2.	"	White Fir
3.	"	Spruce
4.	"	Larch
5.	"	Ponderosa Pine
6.	"	Hemlock
7.	1/6th	Douglas Fir
8.	"	White Fir
9.	"	Spruce
10.	"	Larch
11.	"	Ponderosa Pine
12.	"	Hemlock
13.	7/32nd	Spruce
14.	"	Ponderosa Pine
15.	"	Hemlock

Y_{012}--27-inch D center input to spreaders, and
Y_{014}--54-inch D center input to spreaders

Identical with Y_{011} and Y_{013}, except it is D grade

Y_{015}--27-inch NC center input to spreaders, and
Y_{016}--54-inch NC center input to spreaders

Identical with Y_{011} and Y_{013}, except it is NC grade

Y_{021}--54-inch D back input to spreaders

Identical with Y_{014}

Y_{017}--54-inch C back/face input to spreaders

Identical with Y_{011}

Y_{612}--54-inch ABCp input to patchers

1.	1/10th	Douglas Fir	ABCp
2.	"	White Fir	"
3.	"	Hemlock	"
4.	"	Larch	"
5.	1/6th	Douglas Fir	"
6.	"	White Fir	"
7.	"	Larch	"
8.	"	Hemlock	"

Y_{624}--edge glued C grade, 54-inch veneer

1.	1/10th	Douglas Fir	C
2.	"	White Fir	"
3.	"	Spruce	"
4.	"	Larch	"
5.	"	Pond. Pine	"
6.	"	Hemlock	"
7.	1/6th	Douglas Fir	"
8.	"	White Fir	"
9.	"	Spruce	"
10.	"	Larch	"
11.	"	Pond. Pine	"
12.	"	Hemlock	"

Y_{038}, Y_{630} and Z_{880}--Purchased dry veneer

1.	1/10th	Douglas Fir	AB
2.	"	" "	CD

Y_{531}--Edge glued 54-inch ABCp

1.	1/10th	Douglas Fir	edge	glued	27's
2.	"	White Fir	"	"	"
3.	"	Larch	"	"	"
4.	"	Hemlock	"	"	"
5.	1/6th	Douglas Fir	"	"	"
6.	"	White Fir	"	"	"
7.	"	Larch	"	"	"
8.	"	Hemlock	"	"	"
9.	1/10th	Douglas Fir	edge	glued	strips
10.	"	White Fir	"	"	"
11.	"	Larch	"	"	"
12.	"	Hemlock	"	"	"
13.	1/6th	Douglas Fir	"	"	"
14.	"	White Fir	"	"	"
15.	"	Larch	"	"	"
16.	"	Hemlock	"	"	"

Y_{125}, Y_{222} and Y_{435}--Green veneer waste, goes to chippers

Y_{534} and Y_{625}--Dry veneer waste, goes to hogs

Y_{533}--D centers originating from edge gluing process

1.	1/10th	D	grade	Mixed species
2.	1/6th	"	"	" "

APPENDIX B

LAY-UP SCHEDULE

Beginning Panel Inventories	Order File for Week	Exact Panel Requirements	Lay-up Schedule	Ending Inventories	Product Description
113				113	3/8 AA Doug. Fir
50				50	1/2 AA Doug. Fir
820	396			424	1/4 AC Doug. Fir
112	264	237	240	3	3/8 AC Doug. Fir
	330	516	540	24	1/2 AC Doug. Fir
518				518	5/8 AC Doug. Fir
231	264	52	60	8	3/4 AD Doug. Fir 5 ply
117	264	210	240	30	1/4 AD Doug. Fir
21	88	45	60	15	3/8 AD Doug. Fir
	176	240	270	30	3/4 AD Doug. Fir 5 ply
1517	3300	2443	2460	17	3/4 BB Doug. Fir 5 ply
69				69	1/4 BC Doug. Fir
342				342	3/8 BC Doug. Fir
1411				1411	1/2 BC Doug. Fir
88				88	5/8 BC Doug. Fir
1447				1823	3/4 BC Doug. Fir 5 ply
72				93	1/4 BD Doug. Fir
88	88			4	3/8 BD Doug. Fir
153				153	1/2 BD Doug. Fir
25				25	5/8 BD Doug. Fir
483				484	3/4 BD Doug. Fir 5 ply
	396	508	540	32	1/4 BC Doug. Fir/Larch
	176	226	240	14	3/8 BC Doug. Fir/Larch
	198	254	270	16	1/2 BC Doug. Fir/Larch
	396	508	510	2	3/4 BC Doug. Fir/Larch
268				268	3/4 BUB/TRUFORM D. Fir/Larch
105				105	5/16 CD Doug. Fir/Larch
176				176	3/8 CD Doug. Fir/Larch
574	3102	2989	3000	11	1/2 CD Doug. Fir/Larch
159				159	5/8 CD Doug. Fir/Larch
372				372	3/4 CD Doug. Fir/Larch 5 ply

29 5/8 CD PTS SUDL D.
Fir/Larch

29				29	5/8 CD PTS SUDL D. Fir/Larch
1367				1367	5/8 CC PTS UDL D. Fir/Larch
1020				1020	3/4 CC PTS UDL " "
117				117	1/2 CD PTS UDL " "
338				338	3/4 CD PTS UDL Doug. Fir/Larch
267				267	5/8 CC White Fir/Hemlock
120	396	335	360	25	1/2 CD White/Fir/Hemlock
	88	106	120	14	3/8 CD White Fir/Hemlock
128				128	3/8 CC PTS UDL W. Fir/Hemlock
142				142	1/2 CC PTS UDL " "
	846	1006	1020	14	5/8 CD White Fir/Hemlock
	220	256	260	14	3/4 CD "
44				44	1/2 CC PTS UDL W. Fir/Hemlock
	318	379	390	11	5/8 CD PTS UDL " "
1675				1675	5/16 CD P. Pine/Spruce
180				180	3/4 CD "
740				740	5/16 CDNC Pine/Spruce
108				123	3/8 CDNC "
2530	792			2223	1/2 CDNC "
697				897	5/8 CDNC "
444				474	3/4 CDND "
75				75	Tilemate REG
232				232	1-1/8 2-4-1 REG
1174				1174	1-1/8 TRUFLOOR REG
432				554	1/4 Shop Sanded
1059				1153	3/8 Sanded Shop
612				723	1/2 "
496				496	5/8 "
2113				2559	3/4 "
226				226	5/16 Rough Shop
75				78	3/8 "
1092				1127	1/2 "
110				129	5/8 "
44	963				3/4 "
743				743	1-1/8 Mixed Shop

APPENDIX C

VENEER REQUIREMENTS

Quantity*	Thickness	Species	Grade	Use/Type
11.8932	1/10	D.Fir/Larch	BCp	Face/Back
37.9894	1/10	D.Fir/Larch	C	"
24.4638	1/10	"	D	"
3.2118	1/10	W.Fir/Hem.	BCp	"
14.4718	"	"	C	"
17.6836	"	"	D	"
10.0750	"	Doug. Fir	A	"
38.3776	"	"	BCp	"
3.6401	"	"	C	"
3.0903	"	"	D	"
39.8792	"	Mixed Species	D	Center
49.4737	1/6	"	C	"
3.6300	"	"	D	"
16.8483	1/10	"	C	Core
56.8064	"	"	D	"
4.3742	1/6	"	C solid	"
35.4826	"	"	D	"
114.8121	7/32	"	C	Core
9.5260	"	"	D	"

*M3/8

APPENDIX D

PRODUCTION SCHEDULE FOR WEEK

Beginning Veneer Inventories

41.470	1/10 Larch 54s D
46.613	1/6 Spruce 54s C
48.560	1/6 Spruce 54s D
194.320	1/10 Pine Strips NC
179.840	1/6 Pine Strips D
37.870	7/32 Pine Strips D
148.900	7/32 Mixed D Core

697.573 M3/8

8-ft Lathe

56.770 MBF	Larch peel to 1/10
37.280 "	Hemlock peel to 1/10
101.630 "	White Fir peel to 1/6
74.560 "	Spruce peel to 7/32

4-ft Lathe

11.160 MBF	White Fir, peel to 1/6

Purchased Veneer

16.450 M3/8	Douglas Fir, green, 1/10 AB
5.59 "	Douglas Fir, green, 1/10 CD

Band Saw

38.010 M3/8	7/32 Spruce 54s C
35.490 "	7/32 Spruce 54s D
1.41 "	1/10 Larch 27s C
21.15 "	1/10 Larch 27s D
5.69 "	1/10 Hemlock 27s C
32.33 "	1/6 White Fir 27s D
30.65 "	7/32 Spruce 27sC
7.06 "	1/10 Larch Strips C
21.43 "	1/10 Larch Strips D
1.61 "	1/10 Hemlock Strips C
12.43 "	1/10 Hemlock Strips D
3.15 "	1/6 White Fir Strips D
9.66 "	7/32 Spruce Strips C
9.53 "	7/32 Spruce Strips D

<u>Edge Gluer</u>

3.26	M3/8	1/10 Larch 27s ABCp
10.30	"	1/10 Larch C
0.74	"	1/10 Hemlock ABCp
4.55	"	1/10 Hemlock 27s C
2.80	"	1/10 Hemlock 27s D
3.80	"	1/6 White Fir 27s ABCp
1.15	"	1/10 Larch strips ABCp
0.63	"	1/10 Hemlock Strips D
0.47	"	1/6 White Fir strips ABCp
20.27	"	1/6 White Fir strips D
179.84	"	1/6 Pine strips D

<u>Raimann Patchers</u>

12.75	M3/8	1/10 Larch 54s ABCp
2.62	"	1/10 Larch 54s ABCp (from edge glued 27s)
5.64	"	1/10 Douglas Fir 54s AB
8.37	"	1/10 Douglas Fir ABCp 54s
28.86	"	1/10 Douglas Fir 54s ABCp (edge glued 27s)
3.50	"	1/10 Hemlock 54s ABCp

APPENDIX E

YAKIMA PLYWOOD MILL

SCHEDULING MODEL

January 1967

CODE FOR READING THE LP1107 OUTPUT
(Next 31 pages)

NOTES:

1. All veneers are given in 1000 SF 3/8 (MSF3/8) and all logs are in 1000 bd. ft. (MBF).

2. Productivity coefficients are in Hrs. per MSF3/8 (dryers, patchers, edge gluer, etc.) and Hrs. per MBF (lathes).

3. Products are in number of panels.

4. To use MATRIX GENERATOR II

   a. Beginning panel inventories and order file (in panels) are punched within the first 10 columns. The product number (row number) is punched in the next 5 columns (11 to 15) right justified. A 1 must be punched in column 20 to indicate that it is an element of a vector.

      Example: (Format is F10.4,2I5)

      264.0   25   1 to indicate that 264 panels of 3/8 BB is on the order file or beginning inventory, as the case may be.

   b. The generator outputs cards in a format compatible with the format required by the LP1107 routine. The first card is a FIRST B card and the last card is an EOF card. Since a FIRST B and EOF cards are already in the LP routine from previous runs, make sure they are not duplicated.

ROWS	VTP8 1001-1027	VTFX 1028-1031	VTC8 1032-1118	VTC4 1119-1134	EGI 1135-1215	EGIX 1216-1221	BSI 1222-1337	RPI 1338-1362	RPIX 1363-1366	PDV 1367-1368	PGV 1369-1370	LI8 1371-1385	LI4 1386-1395	VRP8-B 1396-1408	VRFX-B 1409-1413	VRC8-B 1414-1422	VRC4-B 1423-1438	VI54-E 1439-1522	VI27-E 1523-1582	VIRD-E 1583-1642	VIC4-E 1643-1658	VRP8-X 1659-1671	VRFX-X 1672-1676	VRC8-X 1677-1685	VRC4-X 1687-1701	VI54-I 1702-1785	VI27-I 1786-1845	VIRD-I 1846-1905	VIC4-I 1906-1921	VIC6 1922-1927			
1	V1	V2	V3	V4	V5	V6	V7	V8	V9	C5	C6			H1	H2	H3	H4														=	Minimum	Objective Function
2-14	A3				M1			M5						U1								-I1									=	VRP8'	VRP8
15-19		N3				M3		S6	M6						U2								-I2								=	VRFX'	VRFX } Processed Veneers
20-28			B3		M2	M4		S7								U3								-I3						K1	=	VRC8'	VRC8
29-44				C1			C2										U4								-I4						=	VRC4'	VRC4
45-128	-D3	-D4	-D7		F6		F7	-D5	-D6	D2	M7	S1						-U5				T1	T2	T3		J1				-K2	=	0	VI54
129-188			-F2		-F3	-F4					M8	S2							-U6								J2				=	0	VI27
189-248					-G2	-G3	-G4				M9	S3								-U7								J3			=	0	VIRD } Veneer Inventories
249-264				-P2								S4	S5								-U8				T4				J4		=	0	VIC4
265												L1																			≤	100	Lathe 8
266													L2																		≤	88	Lathe 4
267											L3	L4	L5																		≤	160	DRYERS
268																		W1	W2	W3	W4										≤	900	Veneer Storage
269					L6	L7																									≤	100	Edge Gluer
270							L8																								≤	50	Bandsaw
271								W5	W6																						≤	100	Raimanns
272-355																										K1					=	VI54-I	
356-415																											K2				=	VI27-I	Initial Veneer Inventories
416-475																												K3			=	VIRD-I	
476-491																													K4		=	VIC4-I	

YAKIMA PLYWOOD MILL MODEL

ROW DESCRIPTION

VRF8 (D. Fir/Larch face veneer requirements)

Row No.	Description			
1	Objective function			
2	1/10	Doug.Fir/Larch	54s	BCp
3	"	"	"	C
4	"	"	"	D
5	"	Wh. Fir/Hemlock	"	BCp
6	"	"	"	C
7	"	"	"	D
8	"	P. Pine/Spruce	"	C
9	"	"	"	D
10	1/6	Wh. Fir/Hemlock	"	BCp
11	"	"	"	C
12	"	"	"	D
13	"	P. Pine/Spruce	"	C
14	"	"	"	D

VRFX (Doug. Fir face/back veneer requirements)

15	1/10	Doug. Fir	54s	A
16	"	"	"	BCp
17	"	"	"	C
18	"	"	"	D
19	"	P. Pine	"	C

VRC8 (Center veneer requirements)

20	1/10	Mix	Mix	C
21	"	"	"	D
22	"	"	"	NC
23	1/6	"	"	C
24	"	"	"	D
25	"	"	"	NC
26	7/32	"	"	C
27	"	"	"	D
28	"	"	"	NC

VRC4 (Core veneer requirements)

29	1/10	Mix	Random	C solid
30	"	"	"	C
31	"	"	"	D
32	"	"	"	NC
33	1/6	"	"	C solid
34	"	"	"	C

Row No.	Description			
VRC4 (Core veneer requirements continued)				
35	1/6	Mix	Random	D
36	"	"	"	NC
37	7/32	"	"	C solid
38	"	"	"	C
39	"	"	"	D
40	"	"	"	NC
41	5/16	"	"	C solid
42	"	"	"	C
43	"	"	"	D
44	"	"	"	NC
VI54 (54s Veneer inventory)				
45	1/10	Doug. Fir	54s	ABCp
46	"	"	"	C
47	"	"	"	D
48	"	"	"	NC
49	"	Wh. Fir	"	ABCp
50	"	"	"	C
51	"	"	"	D
52	"	"	"	NC
53	"	Spruce	"	ABCp
54	"	"	"	C
55	"	"	"	D
56	"	"	"	NC
57	"	Larch	"	ABCp
58	"	"	"	C
59	"	"	"	D
60	"	"	"	NC
61	"	Pine	"	ABCp
62	"	"	"	C
63	"	"	"	D
64	"	"	"	NC
65	"	Hemlock	"	ABCp
66	"	"	"	C
67	"	"	"	D
68	"	"	"	NC
69	1/6	Doug. Fir	"	ABCp
70	"	"	"	C
71	"	"	"	D
72	"	"	"	NC
73	"	Wh. Fir	"	ABCp
74	"	"	"	C
75	"	"	"	D
76	"	"	"	NC
77	"	Spruce	"	ABCp
78	"	"	"	C
79	"	"	"	D

Row No.		Description		
VI54 (54s Veneer inventory continued)				
80	1/6	Spruce	54s	NC
81	"	Larch	"	ABCp
82	"	"	"	C
83	"	"	"	D
84	"	"	"	NC
85	"	Pine	"	ABCp
86	"	"	"	C
87	"	"	"	D
88	"	"	"	NC
89	"	Hemlock	"	ABCp
90	"	"	"	C
91	"	"	"	D
92	"	"	"	NC
93	7/32	Spruce	"	ABCp
94	"	"	"	C
95	"	"	"	D
96	"	"	"	NC
97	"	Pine	"	ABCp
98	"	"	"	C
99	"	"	"	D
100	"	"	"	NC
101	"	Hemlock	"	ABCp
102	"	"	"	C
103	"	"	"	D
104	"	"	"	NC
105	1/10	Doug. Fir	"	AB
106	"	"	"	A
107	"	Doug. Fir/Larch	"	BCp
108	"	Wh. Fir/Hemlock	"	BCp
109	1/6	Wh. Fir/Hemlock	"	BCp
110	1/10	Mix	"	D Centers
111	1/6	"	"	"
112	7/32	"	"	"
113	1/10	Doug. Fir/Larch	"	ABCp (edge glued 27s)
114	"	Wh. Fir	"	" "
115	"	Larch	"	" "
116	"	Hemlock	"	" "
117	1/6	Doug. Fir	"	" "
118	"	Wh. Fir	"	" "
119	"	Larch	"	" "
120	"	Hemlock	"	" "
121	1/10	Doug. Fir	"	" (edged glued strips)
122	"	Wh. Fir	"	" "
123	"	Larch	"	" "
124	"	Hemlock	"	" "
125	1/6	Doug. Fir	"	" "
126	"	Wh. Fir	"	" "
127	"	Larch	"	" "
128	"	Hemlock		

Row No.	Description			
VI27 (27s veneer inventory)				
129	1/10	Doug. Fir	27s	ABCp
130	"	"	"	C
131	"	"	"	D
132	"	"	"	NC
133	"	Wh. Fir	"	ABCp
134	"	"	"	C
135	"	"	"	D
136	"	"	"	NC
137	"	Spruce	"	ABCp
138	"	"	"	C
139	"	"	"	D
140	"	"	"	NC
141	"	Larch	"	ABCp
142	"	"	"	C
143	"	"	"	D
144	"	"	"	NC
145	"	Pine	"	ABCp
146	"	"	"	C
147	"	"	"	D
148	"	"	"	NC
149	"	Hemlock	"	ABCp
150	"	"	"	C
151	"	"	"	D
152	"	"	"	NC
153	1/6	Doug. Fir	"	ABCp
154	"	"	"	C
155	"	"	"	D
156	"	"	"	NC
157	"	Wh. Fir	"	ABCp
158	"	"	"	C
159	"	"	"	D
160	"	"	"	NC
161	"	Spruce	"	ABCp
162	"	"	"	C
163	"	"	"	D
164	"	"	"	NC
165	"	Larch	"	ABCp
166	"	"	"	C
167	"	"	"	D
168	"	"	"	NC
169	"	Pine	"	ABCp
170	"	"	"	C
171	"	"	"	D
172	"	"	"	NC
173	"	Hemlock	"	ABCp
174	"	"	"	C
175	"	"	"	D
176	"	"	"	NC

Row No.		Description		

VI27 (27s veneer inventory continued)

177	7/32	Spruce	27s	ABCp
178	"	"	"	C
179	"	"	"	D
180	"	"	"	NC
181	"	Pine	"	ABCp
182	"	"	"	C
183	"	"	"	D
184	"	"	"	NC
185	"	Hemlock	"	ABCp
186	"	"	"	C
187	"	"	"	D
188	"	"	"	NC

VIRD (8 ft random veneer inventory)

189	1/10	Doug. Fir	Strips	ABCp
190	"	"	"	C
191	"	"	"	D
192	"	"	"	NC
193	"	Wh. Fir	"	ABCp
194	"	"	"	C
195	"	"	"	D
196	"	"	"	NC
197	"	Spruce	"	ABCp
198	"	"	"	C
199	"	"	"	D
200	"	"	"	NC
201	"	Larch	"	ABCp
202	"	"	"	C
203	"	"	"	D
204	"	"	"	NC
205	"	Pine	"	ABCp
206	"	"	"	C
207	"	"	"	D
208	"	"	"	NC
209	"	Hemlock	"	ABCp
210	"	"	"	C
211	"	"	"	D
212	"	"	"	NC
213	1/6	Doug. Fir	"	ABCp
214	"	"	"	C
215	"	"	"	D
216	"	"	"	NC
217	"	Wh. Fir	"	ABCp
218	"	"	"	C
219	"	"	"	D
220	"	"	"	NC

Row No.	Description			
VIRD (8 ft random veneer inventory continued)				
221	"	Spruce	Strips	ABCp
222	"	"	"	C
223	"	"	"	D
224	"	"	"	NC
225	"	Larch	"	ABCp
226	"	"	"	C
227	"	"	"	D
228	"	"	"	NC
229	"	Pine	"	ABCp
230	"	"	"	C
231	"	"	"	D
232	"	"	"	NC
233	"	Hemlock	"	ABCp
234	"	"	"	C
235	"	"	"	D
236	"	"	"	NC
237	7/32	Spruce	"	ABCp
238	"	"	"	C
239	"	"	"	D
240	"	"	"	NC
241	"	Pine	"	ABCp
242	"	"	"	C
243	"	"	"	D
244	"	"	"	NC
245	"	Hemlock	"	ABCp
246	"	"	"	C
247	"	"	"	D
248	"	"	"	NC
VIC4 (core veneer inventory)				
249	1/10	Mix	Random	C solid
250	"	"	"	C
251	"	"	"	D
252	"	"	"	NC
253	1/6	"	"	C solid
254	"	"	"	C
255	"	"	"	D
256	"	"	"	NC
257	7/32	"	"	C solid
258	"	"	"	C
259	"	"	"	D
260	"	"	"	NC
261	5/16	"	"	C solid
262	"	"	"	C
263	"	"	"	D
264	"	"	"	NC

Row No.	Description

CAPACITY Constraints

265	Hours available from 8 ft lathe
266	Hours available from core lathe
267	Hours available from dryers
268	Space available for veneer storage
269	Hours available from edge gluer
270	Hours available from band saw
271	Hours available from Raimann patchers

BEGINNING VENEER INVENTORIES

272	1/10	Doug. Fir	54s	ABCp
273	"	"	"	C
274	"	"	"	D
275	"	"	"	NC
276	"	White Fir	"	ABCp
277	"	"	"	C
278	"	"	"	D
279	"	"	"	NC
280	"	Spruce	"	ABCp
281	"	"	"	C
282	"	"	"	D
283	"	"	"	NC
284	"	Larch	"	ABCp
285	"	"	"	C
286	"	"	"	D
287	"	"	"	NC
288	"	Pine	"	ABCp
289	"	"	"	C
290	"	"	"	D
291	"	"	"	NC
292	"	Hemlock	"	ABCp
293	"	"	"	C
294	"	"	"	D
295	"	"	"	NC
296	1/6	Doug. Fir	"	ABCp
297	"	"	"	C
298	"	"	"	D
299	"	"	"	NC
300	"	White Fir	"	ABCp
301	"	"	"	C
302	"	"	"	D
303	"	"	"	NC
304	"	Spruce	"	ABCp
305	"	"	"	X
306	"	"	"	D
307	"	"	"	NC
308	"	Larch	"	ABCp
309	"	"	"	C

Row No.	Description				
310	1/6	Larch	54s	D	
311	"	"	"	NC	
312	"	Pine	"	ABCp	
313	"	"	"	C	
314	"	"	"	D	
315	"	"	"	NC	
316	"	Hemlock	"	ABCp	
317	"	"	"	C	
318	"	"	"	D	
319	"	"	"	NC	
320	7/32	Spruce	"	ABCp	
321	"	"	"	C	
322	"	"	"	D	
323	"	"	"	NC	
324	"	Pine	"	ABCp	
325	"	"	"	C	
326	"	"	"	D	
327	"	"	"	NC	
328	"	Hemlock	"	ABCp	
329	"	"	"	C	
330	"	"	"	D	
331	"	"	"	NC	
332	1/10	Doug. Fir	"	AB	
333	"	"	"	A	
334	"	Doug. Fir/Larch	"	BCp	
335	"	White Fir/Hemlock	"	"	
336	1/6	"	"	"	
337	1/10	Mixed	Mix	D centers	
338	1/6	"	"	"	
339	7/32	"	"	"	
340	1/10	Doug. Fir	54s	ABCp	(edge glued 27s)
341	"	White Fir	"	"	"
342	"	Larch	"	"	"
343	"	Hemlock	"	"	"
344	1/6	Doug. Fir	"	"	"
345	"	White Fir	"	"	"
346	"	Larch	"	"	"
347	"	Hemlock	"	"	"
348	1/10	Doug. Fir	"	ABCp	(edge glued strips)
349	"	White Fir	"	"	"
350	"	Larch	"	"	"
351	"	Hemlock	"	"	"
352	1/6	Doug. Fir	"	"	"
353	"	White Fir	"	"	"
354	"	Larch	"	"	"
355	"	Hemlock	"	"	"

Row No.		Description		
(27s Veneer)				
356	1/10	Douglas Fir	27s	ABCp
357	"	"	"	C
358	"	"	"	D
359	"	"	"	NC
360	"	White Fir	"	ABCp
361	"	"	"	C
362	"	"	"	D
363	"	"	"	NC
364	"	Spruce	"	ABCp
365	"	"	"	C
366	"	"	"	D
367	"	"	"	NC
368	"	Larch	"	ABCp
369	"	"	"	C
370	"	"	"	D
371	"	"	"	NC
372	"	Pine	"	ABCp
373	"	"	"	C
374	"	"	"	D
375	"	"	"	NC
376	"	Hemlock	"	ABCp
377	"	"	"	C
378	"	"	"	D
379	"	"	"	NC
380	1/6	Douglas Fir	"	ABCp
381	"	"	"	C
382	"	"	"	D
383	"	"	"	NC
384	"	White Fir	"	ABCp
385	"	"	"	C
386	"	"	"	D
387	"	"	"	NC
388	"	Spruce	"	ABCp
389	"	"	"	C
390	"	"	"	D
391	"	"	"	NC
392	"	Larch	"	ABCp
393	"	"	"	C
394	"	"	"	D
395	"	"	"	NC
396	"	Pine	"	ABCp
397	"	"	"	C
398	"	"	"	D
399	"	"	"	NC
400	"	Hemlock	"	ABCp
401	"	"	"	C
402	"	"	"	D
403	"	"	"	NC

Row No.		Description		
(27s Veneer continued)				
404	7/32	Spruce	27s	ABCp
405	"	"	"	C
406	"	"	"	D
407	"	"	"	NC
408	"	Pine	"	ABCp
409	"	"	"	C
410	"	"	"	D
411	"	"	"	NC
412	"	Hemlock	"	ABCp
413	"	"	"	C
414	"	"	"	D
415	"	"	"	NC
(Strips)				
416	1/10	Douglas Fir	Strips	ABCp
417	"	"	"	C
418	"	"	"	D
419	"	"	"	NC
420	1/10	White Fir	"	ABCp
421	"	"	"	C
422	"	"	"	D
423	"	"	"	NC
424	"	Spruce	"	ABCp
425	"	"	"	C
426	"	"	"	D
427	"	"	"	NC
428	"	Larch	"	ABCp
429	"	"	"	C
430	"	"	"	D
431	"	"	"	NC
432	"	Pine	"	ABCp
433	"	"	"	C
434	"	"	"	D
435	"	"	"	NC
436	"	Hemlock	"	ABCp
437	"	"	"	C
438	"	"	"	D
439	"	"	"	NC
440	1/6	Douglas Fir	"	ABCp
441	"	"	"	C
442	"	"	"	D
443	"	"	"	NC
444	"	White Fir	"	ABCp
445	"	"	"	C
446	"	"	"	D
447	"	"	"	NC

Row No.			Description	
(Strips continued)				
448	1/6	Spruce	Strips	ABCp
449	"	"	"	C
450	"	"	"	D
451	"	"	"	NC
452	"	Larch	"	ABCp
453	"	"	"	C
454	"	"	"	D
455	"	"	"	NC
456	"	Pine	"	ABCp
457	"	"	"	C
458	"	"	"	D
459	"	"	"	NC
460	"	Hemlock	"	ABCp
461	"	"	"	C
462	"	"	"	D
463	"	"	"	NC
464	7/32	Spruce	"	ABCp
465	"	"	"	C
466	"	"	"	D
467	"	"	"	NC
468	"	Pine	"	ABCp
469	"	"	"	C
470	"	"	"	D
471	"	"	"	NC
472	"	Hemlock	"	ABCp
473	"	"	"	C
474	"	"	"	D
475	"	"	"	NC
(cores)				
476	1/10	Mixed	Random	C solid
477	"	"	"	C
478	"	"	"	D
479	"	"	"	NC
480	1/6	"	"	C solid
481	"	"	"	C
482	"	"	"	D
483	"	"	"	NC
484	7/32	"	"	C solid
485	"	"	"	C
486	"	"	"	D
487	"	"	"	NC
488	5/16	"	"	C solid
489	"	"	"	C
490	"	"	"	D
491	"	"	"	NC

COLUMN DESCRIPTION

VTF8 (veneers transferable directly from veneer to inventory to spreader w/out further processing, 54s) --combination of species

Column No.			Description	
1001	1/10	Doug. Fir	54s	C
1002	"	"		D
1003	"	Wh. Fir	"	C
1004	"	"	"	D
1005	"	Spruce	"	C
1006	"	"	"	D
1007	"	Larch	"	C
1008	"	"	"	D
1009	"	Pine	"	C
1010	"	"	"	D
1011	"	Hemlock	"	C
1012	"	"	"	D
1013	1/6	Doug. Fir	"	C
1014	"	"	"	D
1015	"	Wh. Fir	"	C
1016	"	"	"	D
1017	"	Spruce	"	C
1018	"	"	"	D
1019	"	Larch	"	C
1020	"	"	"	D
1021	"	Pine	"	C
1022	"	"	"	D
1023	"	Hemlock	"	C
1024	"	"	"	D
1025	1/10	Doug. Fir/Larch	"	BCp
1026	"	Wh. Fir/Hemlock	"	BCp
1027	1/6	"	"	"

VTFX (Doug. Fir veneers directly transferable from inventory to spreaders without further processing)--for orders specifying Doug. Fir/pine

1028	1/10	Doug. Fir	54s	A
1029	"	"	"	C
1030	"	"	"	D
1031	"	Pine	"	C nat.

VTC8 (Centers directly transferable from inventory to spreaders w/out processing)

1032	1/10	Doug. Fir	54s	D
1033	"	"	"	NC
1034	"	Wh. Fir	"	D
1035	"	"	"	NC

1036	1/10	Spruce	54s	D
1037	"	"	"	NC
1038	"	Larch	"	D
1039	"	"	"	NC
1040	"	Pine	"	D
1041	"	"	"	NC
1042	"	Hemlock	"	D
1043	"	"	"	NC
1044	1/6	Doug. Fir	"	D
1045	"	"	"	NC
1046	"	Wh. Fir	"	D
1047	"	"	"	NC
1048	"	Spruce	"	D
1049	"	"	"	NC
1050	"	Larch	"	D
1051	"	"	"	NC
1052	"	Pine	"	D
1053	"	"	"	NC
1054	"	Hemlock	"	D
1055	"	"	"	NC
1056	7/32	Spruce	"	ABCp
1057	"	"	"	C
1058	"	"	"	D
1059	"	"	"	NC
1060	"	Pine	"	ABCp
1061	"	"	"	C
1062	"	"	"	D
1063	"	"	"	NC
1064	"	Hemlock	"	ABCp
1065	"	"	"	C
1066	"	"	"	D
1067	"	"	"	NC
1068	1/10	Doug. Fir	27s	C
1069	"	"	"	D
1070	"	"	"	NC
1071	"	Wh. Fir	"	C
1072	"	"	"	D
1073	"	"	"	NC
1074	"	Spruce	"	C
1075	"	"	"	D
1076	"	"	"	NC
1077	"	Larch	"	C
1078	"	"	"	D
1079	"	"	"	NC
1080	"	Pine	"	C
1081	"	"	"	D
1082	"	"	"	NC
1083	"	Hemlock	"	C
1084	"	"	"	D
1085	"	"	"	NC

1086	1/6	Doug. Fir	27s	C
1087	"	"	"	D
1088	"	"	"	NC
1089	"	Wh. Fir	"	C
1090	"	"	"	D
1091	"	"	"	NC
1092	"	Spruce	"	C
1093	"	"	"	D
1094	"	"	"	NC
1095	"	Larch	"	C
1096	"	"	"	D
1097	"	"	"	NC
1098	"	Pine	"	C
1099	"	"	"	D
1100	"	"	"	NC
1101	"	Hemlock	"	C
1102	"	"	"	D
1103	"	"	"	NC
1104	7/32	Spruce	"	ABCp
1105	"	"	"	C
1106	"	"	"	D
1107	"	"	"	NC
1108	"	Pine	"	ABCp
1109	"	"	"	C
1110	"	"	"	D
1111	"	"	"	NC
1112	"	Hemlock	"	ABCp
1113	"	"	"	C
1114	"	"	"	D
1115	"	"	"	NC
1116	1/10	Mix	54s	D Cn
1117	1/6	"	"	"
1118	7/32	"	"	"

VTC4 (Core veneer directly transferable to spreaders from inventory)

1119	1/10	Mix	Random	C solid
1120	"	"	"	C
1121	"	"	"	D
1122	"	"	"	NC
1123	1/6	"	"	C solid
1124	"	"	"	C
1125	"	"	"	D
1126	"	"	"	NC
1127	7/32	"	"	C solid
1128	"	"	"	C
1129	"	"	"	D
1130	"	"	"	NC
1131	5/16	"	"	C solid
1132	"	"	"	C
1133	"	"	"	D
1134	"	"	"	NC

EGI (inputs to edge gluer)

1135	1/10	Doug. Fir	27s	ABCp
1136	"	"	"	C
1137	"	"	"	D
1138	"	Wh. Fir	"	ABCp
1139	"	"	"	C
1140	"	"	"	D
1141	"	Spruce	"	ABCp
1142	"	"	"	C
1143	"	"	"	D
1144	"	Larch	"	ABCp
1145	"	"	"	C
1146	"	"	"	D
1147	"	Pine	"	ABCp
1148	"	"	"	C
1149	"	"	"	D
1150	"	Hemlock	"	ABCp
1151	"	"	"	C
1152	"	"	"	D
1153	1/6	Doug. Fir	"	ABCp
1154	"	"	"	C
1155	"	"	"	D
1156	"	Wh. Fir	"	ABCp
1157	"	"	"	C
1158	"	"	"	D
1159	"	Spruce	"	ABCp
1160	"	"	"	C
1161	"	"	"	D
1162	"	Larch	"	ABCp
1163	"	"	"	C
1164	"	"	"	D
1165	"	Pine	"	ABCp
1166	"	"	"	C
1167	"	"	"	D
1168	"	Hemlock	"	ABCp
1169	"	"	"	C
1170	"	"	"	D
1171	1/10	Doug. Fir	Strips	ABCp
1172	"	"	"	C
1173	"	"	"	D
1174	"	Wh. Fir	"	ABCp
1175	"	"	"	C
1176	"	"	"	D
1177	"	Spruce	"	ABCp
1178	"	"	"	C
1179	"	"	"	D
1180	"	Larch	"	ABCp
1181	"	"	"	C
1182	"	"	"	D
1183	"	Pine	"	ABCp
1184	"	"	"	C
1185	"	"	"	D

1186	1/10	Hemlock	Strips	ABCp
1187	"	"	"	C
1188	"	"	"	D
1189	1/6	Doug. Fir	"	ABCp
1190	"	"	"	C
1191	"	"	"	D
1192	"	Wh. Fir	"	ABCp
1193	"	"	"	C
1194	"	"	"	D
1195	"	Spruce	"	ABCp
1196	"	"	"	C
1197	"	"	"	D
1198	"	Larch	"	ABCp
1199	"	"	"	C
1200	"	"	"	D
1201	"	Pine	"	ABCp
1202	"	"	"	C
1203	"	"	"	D
1204	"	Hemlock	"	ABCp
1205	"	"	"	C
1206	"	"	"	D
1207	7/32	Spruce	"	ABCp
1208	"	"	"	C
1209	"	"	"	D
1210	"	Pine	"	ABCp
1211	"	"	"	C
1212	"	"	"	D
1213	"	Hemlock	"	ABCp
1214	"	"	"	C
1215	"	"	"	D

EGIX (inputs to edge gluer for products requiring all Doug. Fir)

1216	1/10	Doug. Fir	27s	ABCp
1217	"	"	"	C
1218	"	"	"	D
1219	"	"	Strips	ABCp
1220	"	"	"	C
1221	"	"	"	D

BSI (inputs to bandsaw for core)

1222	7/32	Spruce	54s	ABCp
1223	"	"	"	C
1224	"	"	"	D
1225	"	"	"	NC
1226	"	Pine	"	ABCp
1227	"	"	"	C
1228	"	"	"	D
1229	"	"	"	NC

1230	7/32	Hemlock	54s	ABCp
1231	"	"	"	C
1232	"	"	"	D
1233	"	"	"	NC
1234	1/10	Doug. Fir	27s	C
1235	"	"	"	D
1236	"	"	"	NC
1237	"	Wh. Fir	"	C
1238	"	"	"	D
1239	"	"	"	NC
1240	"	Spruce	"	ABCp
1241	"	"	"	C
1242	"	"	"	D
1243	"	"	"	NC
1244	"	Larch	"	C
1245	"	"	"	D
1246	"	"	"	NC
1247	"	Pine	"	ABCp
1248	"	"	"	C
1249	"	"	"	D
1250	"	"	"	NC
1251	"	Hemlock	"	C
1252	"	"	"	D
1253	"	"	"	NC
1254	1/6	Doug. Fir	"	C
1255	"	"	"	D
1256	"	"	"	NC
1257	"	Wh. Fir	"	C
1258	"	"	"	D
1259	"	"	"	NC
1260	"	Spruce	"	ABCp
1261	"	"	"	C
1262	"	"	"	D
1263	"	"	"	NC
1264	"	Larch	"	C
1265	"	"	"	D
1266	"	"	"	NC
1267	"	Pine	"	ABCp
1268	"	"	"	C
1269	"	"	"	D
1270	"	"	"	NC
1271	"	Hemlock	"	C
1272	"	"	"	D
1273	"	"	"	NC
1274	7/32	Spruce	"	ABCp
1275	"	"	"	C
1276	"	"	"	D
1277	"	"	"	NC
1278	"	Pine	"	ABCp
1279	"	"	"	C
1280	"	"	"	D
1281	"	"	"	NC

1282	7/32	Hemlock	27s	ABCp
1283	"	"	"	C
1284	"	"	"	D
1285	"	"	"	NC
1286	1/10	Doug. Fir	Strips	C
1287	"	"	"	D
1288	"	"	"	NC
1289	"	Wh. Fir	"	C
1290	"	"	"	D
1291	"	"	"	NC
1292	"	Spruce	"	ABCp
1293	"	"	"	C
1294	"	"	"	D
1295	"	"	"	NC
1296	"	Larch	"	C
1297	"	"	"	D
1298	"	"	"	NC
1299	"	Pine	"	ABCp
1300	"	"	"	C
1301	"	"	"	D
1302	"	"	"	NC
1303	"	Hemlock	"	C
1304	"	"	"	D
1305	"	"	"	NC
1306	1/6	Doug. Fir	"	C
1307	"	"	"	D
1308	"	"	"	NC
1309	"	Wh. Fir	"	C
1310	"	"	"	D
1311	"	"	"	NC
1312	"	Spruce	"	ABCp
1313	"	"	"	C
1314	"	"	"	D
1315	"	"	"	NC
1316	"	Larch	"	C
1317	"	"	"	D
1318	"	"	"	NC
1319	"	Pine	"	ABCp
1320	"	"	"	C
1321	"	"	"	D
1322		"	"	NC
1323	"	Hemlock	"	C
1324	"	"	"	D
1325	"	"	"	NC
1326	7/32	Spruce	"	ABCp
1327	"	"	"	C
1328	"	"	"	D
1329	"	"	"	NC
1330	"	Pine	"	ABCp
1331	"	"	"	C
1332	"	"	"	D
1333	"	"	"	NC

1334	7/32	Hemlock	Strips	ABCp
1335	"	"	"	C
1336	"	"	"	D
1337	"	"	"	NC

RPI (inputs to Raimann patchers)

1338	1/10	Doug. Fir	54s	AB-54	(originally 54s)
1339	"	"	"	ABCp-54	"
1340	"	Wh. Fir	"	"	"
1341	"	Larch	"	"	"
1342	"	Hemlock	"	"	"
1343	1/6	Doug. Fir	"	"	"
1344	"	Wh. Fir	"	"	"
1345	"	Larch	"	"	"
1346	"	Hemlock	"	"	"
1347	1/10	Doug. Fir	"	ABCp-27	(edged glued 27s)
1348	"	Wh. Fir	"	"	"
1349	"	Larch	"	"	"
1350	"	Hemlock	"	"	"
1351	1/6	Doug. Fir	"	"	"
1352	"	Wh. Fir	"	"	"
1353	"	Larch	"	"	"
1354	"	Hemlock	"	"	"
1355	1/10	Doug. Fir	"	ABCp-R	(edged glued strips)
1356	"	Wh. Fir	"	"	"
1357	"	Larch	"	"	"
1358	"	Hemlock	"	"	"
1359	1/6	Doug. Fir	"	"	"
1360	"	Wh. Fir	"	"	"
1361	"	Larch	"	"	"
1362	"	Hemlock	"	"	"

RPIX (Raimann patcher inputs for products specifying all Doug. Fir)

1363	1/10	Doug. Fir	54s	AB-54 (originally 54s)
1364	"	"	"	ABCp-54 "
1365	"	"	"	ABCp-27(edge glued 27s)
1366	"	"	"	ABCp-R (edge glued strips)

PDV (Purchase <u>Dry</u> Veneer--Doug. Fir)

1367	1/10	Doug. Fir	"	AB
1368	"	"	"	CD

PGV (Purchase <u>Green</u> Veneer--Doug. Fir)

1369	1/10	Doug. Fir	54s	AB
1370	"	"	"	CD

LI8 (8 ft lathe log inputs)

1371	Doug. Fir	Peel to	1/10 veneer
1372	Wh. Fir	" "	" "
1373	Spruce	" "	" "
1374	Larch	" "	" "
1375	Pine	" "	" "
1376	Hemlock	" "	" "
1377	Doug. Fir	Peel to	1/6 veneer
1378	Wh. Fir	" "	" "
1379	Spruce	" "	" "
1380	Larch	" "	" "
1381	Pine	" "	" "
1382	Hemlock	" "	" "
1383	Spruce	Peel to	7/32 veneer
1384	Pine	" "	" "
1385	Hemlock	" "	" "

LI4 (core lathe inputs)

1386	White Fir	Peel to	1/6 core
1387	Spruce	" "	" "
1388	Pine	" "	" "
1389	Hemlock	" "	" "
1390	Spruce	" "	7/32 core
1391	Pine	" "	" "
1392	Hemlock	" "	" "
1393	Spruce	" "	5/16 core
1394	Pine	" "	" "
1395	Hemlock	" "	" "

VRF8-B (Face/back veneer requirements that cannot be met--backlogged)

1396	1/10	Doug. Fir/Larch	54s	B-Cp
1397	"	"	"	C
1398	"	"	"	D
1399	"	Wh. Fir/Hemlock	"	B-Cp
1400	"	"	"	C
1401	"	"	"	D
1402	"	Pine/Spruce	"	C
1403	"	"	"	D
1404	1/6	Wh. Fir/Hemlock	"	B-Cp
1405	"	"	"	C
1406	"	"	"	D
1407	"	Pine/Spruce	"	C
1408	"	"	"	D

VRFX-B (All Pon. Pine Doug. Fir face/back veneer that cannot be met--backlogged)

1409	1/10	Doug. Fir	54s	A
1410	"	"	"	B-Cp
1411	"	"	"	C
1412	"	"	"	D
1413	"	Pine	"	C Nat. (for knotty pine)

VRC8-B (Veneer requirements for centers that cannot be met--backlogged)

1414	1/10	Mix	Mix	C
1415	"	"	"	D
1416	"	"	"	NC
1417	1/6	"	"	C
1418	"	"	"	D
1419	"	"	"	NC
1420	7/32	"	"	C
1421	"	"	"	D
1422	"	"	"	NC

VRC4-B (Veneer requirements for core that cannot be met --backlogged)

1423	1/10	Mix	Random	C solid
1424	"	"	"	C
1425	"	"	"	D
1426	"	"	"	NC
1427	1/6	"	"	C solid
1428	"	"	"	C
1429	"	"	"	D
1430	"	"	"	NC
1431	7/32	"	"	C solid
1432	"	"	"	C
1433	"	"	"	D
1434	"	"	"	NC
1435	5/16	"	"	C solid
1436	"	"	"	C
1437	"	"	"	D
1438	"	"	"	NC

VI54-E (Ending inventory of 54 veneers)

1439	1/10	Doug. Fir	54s	ABCp
1440	"	"	"	C
1441	"	"	"	D
1442	"	"	"	NC
1443	"	Wh. Fir	"	ABCp
1444	"	"	"	C
1445	"	"	"	D
1446	"	"	"	NC

1447	1/10	Spruce	54s	ABCp
1448	"	"	"	C
1449	"	"	"	D
1450	"	"	"	NC
1451	"	Larch	"	ABCp
1452	"	"	"	C
1453	"	"	"	D
1454	"	"	"	NC
1455	"	Pine	"	ABCp
1456	"	"	"	C
1457	"	"	"	D
1458	"	"	"	NC
1459	"	Hemlock	"	ABCp
1460	"	"	"	C
1461	"	"	"	D
1462	"	"	"	NC
1463	1/6	Doug. Fir	"	ABCp
1464	"	"	"	C
1465	"	"	"	D
1466	"	"	"	NC
1467	"	Wh. Fir	"	ABCp
1468	"	"	"	C
1469	"	"	"	D
1470	"	"	"	NC
1471	"	Spruce	"	ABCp
1472	"	"	"	C
1473	"	"	"	D
1474	"	"	"	NC
1475	"	Larch	"	ABCp
1476	"	"	"	C
1477	"	"	"	D
1478	"	"	"	NCth
1479	"	Pine	"	ABCp
1480	"	"	"	C
1481	"	"	"	D
1482	"	"	"	NC
1483	"	Hemlock	"	ABCp
1484	"	"	"	C
1485	"	"	"	D
1486	"	"	"	NC
1487	7/32	Spruce	"	ABCp
1488	"	"	"	C
1489	"	"	"	D
1490	"	"	"	NC
1491	"	Pine	"	ABCp
1492	"	"	"	C
1493	"	"	"	D
1494	"	"	"	NC
1495	"	Hemlock	"	ABCp
1496	"	"	"	C
1497	"	"	"	D
1498	"	"	"	NC

1499	1/10	Doug. Fir	54s	AB
1500	"	"	"	A
1501	"	Doug. Fir/Larch	"	BCp
1502	"	White Fir/Hemlock	"	BCp
1503	1/6	"	"	"
1504	1/10	Mix	"	D centers
1505	1/6	"	"	"
1506	7/32	"	"	"
1507	1/10	Doug. Fir	"	ABCp-27 (edge glued 27s)
1508	"	White Fir	"	" "
1509	"	Larch	"	" "
1510	"	Hemlock	"	" "
1511	1/6	Doug. Fir	"	" "
1512	"	Wh. Fir	"	" "
1513	"	Larch	"	" "
1514	"	Hemlock	"	" "
1515	1/10	Doug. Fir	"	ABCp-R (edge glued strips)
1516	"	Wh. Fir	"	" "
1517	"	Larch	"	" "
1518	"	Hemlock	"	" "
1519	1/6	Doug. Fir	"	" "
1520	"	Wh. Fir	"	" "
1521	"	Larch	"	" "
1522	"	Hemlock	"	" "

VI27-E (Ending inventory of 27 veneers)

1523	1/10	Doug. Fir	27s	ABCp
1524	"	"	"	C
1525	"	"	"	D
1526	"	"	"	NC
1527	"	Wh. Fir	"	ABCp
1528	"	"	"	C
1529	"	"	"	D
1530	"	"	"	NC
1531	"	Spruce	"	ABCp
1532	"	"	"	C
1533	"	"	"	D
1534	"	"	"	NC
1535	"	Larch	"	ABCp
1536	"	"	"	C
1537	"	"	"	D
1538	"	"	"	NC
1539	"	Pine	"	ABCp
1540	"	"	"	C
1541	"	"	"	D
1542	"	"	"	NC
1543	"	Hemlock	"	ABCp
1544	"	"	"	C
1545	"	"	"	D
1546	"	"	"	NC

1547	1/6	Doug. Fir	27s	ABCp
1548	"	"	"	C
1549	"	"	"	D
1550	"	"	"	NC
1551	"	Wh. Fir	"	ABCp
1552	"	"	"	C
1553	"	"	"	D
1554	"	"	"	NC
1555	"	Spruce	"	ABCp
1556	"	"	"	C
1557	"	"	"	D
1558	"	"	"	NC
1559	"	Larch	"	ABCp
1560	"	"	"	C
1561	"	"	"	D
1562	"	"	"	NC
1563	"	Pine	"	ABCp
1564	"	"	"	C
1565	"	"	"	D
1566	"	"	"	NC
1567	"	Hemlock	"	ABCp
1568	"	"	"	C
1569	"	"	"	D
1570	"	"	"	NC
1571	7/32	Spruce	"	ABCp
1572	"	"	"	C
1573	"	"	"	D
1574	"	"	"	NC
1575	"	Pine	"	ABCp
1576	"	"	"	C
1577	"	"	"	D
1578	"	"	"	NC
1579	"	Hemlock	"	ABCp
1580	"	"	"	C
1581	"	"	"	D
1582	"	"	"	NC

VIRD-E (Ending inventory of strips)

1583	1/10	Doug. Fir	Strips	ABCp
1584	"	"	"	C
1585	"	"	"	D
1586	"	"	"	NC
1587	"	Wh. Fir	"	ABCp
1588	"	"	"	C
1589	"	"	"	D
1590	"	"	"	NC
1591	"	Spruce	"	ABCp
1592	"	"	"	C
1593	"	"	"	D
1594	"	"	"	NC

1595	1/10	Larch	Strips	ABCp
1596	"	"	"	C
1597	"	"	"	D
1598	"	"	"	NC
1599	"	Pine	"	ABCp
1600	"	"	"	C
1601	"	"	"	D
1602	"	"	"	NC
1603	"	Hemlock	"	ABCp
1604	"	"	"	C
1605	"	"	"	D
1606	"	"	"	NC
1607	1/6	Doug. Fir	"	ABCp
1608	"	"	"	C
1609	"	"	"	D
1610	"	"	"	NC
1611	"	Wh. Fir	"	ABCp
1612	"	"	"	C
1613	"	"	"	D
1614	"	"	"	NC
1615	"	Spruce	"	ABCp
1616	"	"	"	C
1617	"	"	"	D
1618	"	"	"	NC
1619	"	Larch	"	ABCp
1620	"	"	"	C
1621	"	"	"	D
1622	"	"	"	NC
1623	"	Pine	"	ABCp
1624	"	"	"	C
1625	"	"	"	D
1626	"	"	"	NC
1627	"	Hemlock	"	ABCp
1628	"	"	"	C
1629	"	"	"	D
1630	"	"	"	NC
1631	7/32	Spruce	"	ABCp
1632	"	"	"	C
1633	"	"	"	D
1634	"	"	"	NC
1635	"	Pine	"	ABCp
1636	"	"	"	C
1637	"	"	"	D
1638	"	"	"	NC
1639	"	Hemlock	"	ABCp
1640	"	"	"	C
1641	"	"	"	D
1642	"	"	"	NC

VIC4-E (Ending inventory for core veneers)

1643	1/10	Mix	Random	C solid
1644	"	"	"	C
1645	"	"	"	D
1646	"	"	"	NC
1647	1/6	"	"	C solid
1648	"	"	"	C
1649	"	"	"	D
1650	"	"	"	NC
1651	7/32	"	"	C solid
1652	"	"	"	C
1653	"	"	"	D
1654	"	"	"	NC
1655	5/16	"	"	C solid
1656	"	"	"	C
1657	"	"	"	D
1658	"	"	"	NC

VRF8-X (Excess face/back veneer--returned to inventory)

1659	1/10	Doug. Fir/Larch	54s	BCp
1660	"	"	"	C
1661	"	"	"	D
1662	"	Wh. Fir/Hemlock	"	BCp
1663	"	"	"	C
1664	"	"	"	D
1665	"	Pine/Spruce	"	C
1666	"	"	"	D
1667	1/6	Wh. Fir/Hemlock	"	BCp
1668	"	"	"	C
1669	"	"	"	D
1670	"	Pine/Spruce	"	C
1671	"	"	"	D

VRFX-X (Excess Doug. Fir/Pine face/back veneers--returned to inventory)

1672	1/10	Doug. Fir	54s	A
1673	"	"	"	BCp
1674	"	"	"	C
1675	"	"	"	D
1676	"	Pine	"	C Nat.

VRC8-X (Excess center veneer-returned to inventory)

1677	1/10	Mix	Mix	C
1678	"	"	"	D
1679	"	"	"	NC
1680	1/6	"	"	C
1681	"	"	"	D
1682	"	"	"	NC
1683	7/32	"	"	C
1684	"	"	"	D
1685	"	"	"	NC

VRC4-X (Excess core veneer--returned to inventory)

1686	1/10	Mix	Random	C solid
1687	"	"	"	C
1688	"	"	"	D
1689	"	"	"	NC
1690	1/6	"	"	C solid
1691	"	"	"	C
1692	"	"	"	D
1693	"	"	"	NC
1694	7/32	"	"	C solid
1695	"	"	"	C
1696	"	"	"	D
1697	"	"	"	NC
1698	5/16	"	"	C solid
1699	"	"	"	C
1700	"	"	"	D
1701	"	"	"	NC

BEGINNING VENEER INVENTORIES (54s)

1702	1/10	Douglas Fir	54s	ABCp
1703	"	"	"	C
1704	"	"	"	D
1705	"	"	"	NC
1706	"	White Fir	"	ABCp
1707	"	"	"	C
1708	"	"	"	D
1709	"	"	"	NC
1710	"	Spruce	"	ABCp
1711	"	"	"	C
1712	"	"	"	D
1713	"	"	"	NC
1714	"	Larch	"	ABCp
1715	"	"	"	C
1716	"	"	"	D
1717	"	"	"	NC
1718	"	Pine	"	ABCp
1719	"	"	"	C
1720	"	"	"	D
1721	"	"	"	NC
1722	"	Hemlock	"	ABCp
1723	"	"	"	C
1724	"	"	"	D
1725	"	"	"	NC
1726	1/6	Douglas Fir	"	ABCp
1727	"	"	"	C
1728	"	"	"	D
1729	"	"	"	NC
1730	"	White Fir	"	ABCp
1731	"	"	"	C
1732	"	"	"	D
1733	"	"	"	NC

1734	1/6	Spruce	54s	ABCp	
1735	"	"	"	C	
1736	"	"	"	D	
1737	"	"	"	NC	
1738	"	Larch	"	ABCp	
1739	"	"	"	C	
1740	"	"	"	D	
1741	"	"	"	NC	
1742	"	Pine	"	ABCp	
1743	"	"	"	C	
1744	"	"	"	D	
1745	"	"	"	NC	
1746	"	Hemlock	"	ABCp	
1747	"	"	"	C	
1748	"	"	"	D	
1749	"	"	"	NC	
1750	7/32	Spruce	"	ABCp	
1751	"	"	"	C	
1752	"	"	"	D	
1753	"	"	"	NC	
1754	"	Pine	"	ABCp	
1755	"	"	"	C	
1756	"	"	"	D	
1757	"	"	"	NC	
1758	"	Hemlock	"	ABCp	
1759	"	"	"	C	
1760	"	"	"	D	
1761	"	"	"	NC	
1762	1/10	Douglas Fir	"	AB	
1763	"	"	"	A	
1764	"	Douglas Fir/Larch	"	BCp	
1765	"	White Fir/Hemlock	"	"	
1766	1/6	"	"	"	
1767	1/10	Mixed	Mixed	D centers	
1768	1/6	"	"	"	
1769	7/32	"	"	"	
1770	1/10	Douglas Fir	"	ABCp	(edge glued 27s)
1771	"	White Fir	"	"	"
1772	"	Larch	"	"	"
1773	"	Hemlock	"	"	"
1774	1/6	Douglas Fir	"	"	"
1775	"	White Fir	"	"	"
1776	"	Larch	"	"	"
1777	"	Hemlock	"	"	"
1778	1/10	Douglas Fir	"	ABCp	(edge glued strips)
1779	"	White Fir	"	"	"
1780	"	Larch	"	"	"
1781	"	Hemlock	"	"	"
1782	1/6	Douglas Fir	"	"	"
1783	"	White Fir	"	"	"
1784	"	Larch	"	"	"
1785	"	Hemlock	"	"	"

(27s veneers)

1786	1/10	Douglas Fir	27s	ABCp
1787	"	"	"	C
1788	"	"	"	D
1789	"	"	"	NC
1790	"	White Fir	"	ABCp
1791	"	"	"	C
1792	"	"	"	D
1793	"	"	"	NC
1794	"	Spruce	"	ABCp
1795	"	"	"	C
1796	"	"	"	D
1797	"	"	"	NC
1798	"	Larch	"	ABCp
1799	"	"	"	C
1800	"	"	"	D
1801	"	"	"	NC
1802	"	Pine	"	ABCp
1803	"	"	"	C
1804	"	"	"	D
1805	"	"	"	NC
1806	"	Hemlock	"	ABCp
1807	"	"	"	C
1808	"	"	"	D
1809	"	"	"	NC
1810	1/6	Douglas Fir	"	ABCp
1811	"	"	"	C
1812	"	"	"	D
1813	"	"	"	NC
1814	"	White Fir	"	ABCp
1815	"	"	"	C
1816	"	"	"	D
1817	"	"	"	NC
1818	"	Spruce	"	ABCp
1819	"	"	"	C
1820	"	"	"	D
1821	"	"	"	NC
1822	"	Larch	"	ABCp
1823	"	"	"	C
1824	"	"	"	D
1825	"	"	"	NC
1826	"	Pine	"	ABCp
1827	"	"	"	C
1828	"	"	"	D
1829	"	"	"	NC
1830	"	Hemlock	"	ABCp
1831	"	"	"	C
1832	"	"	"	D
1833	"	"	"	NC
1834	7/32	Spruce	"	ABCp
1835	"	"	"	C
1836	"	"	"	D
1837	"	"	"	NC

1838	7/32	Pine	27s	ABCp
1839	"	"	"	C
1840	"	"	"	D
1841	"	"	"	NC
1842	"	Hemlock	"	ABCp
1843	"	"	"	C
1844	"	"	"	D
1845	"	"	"	NC

(strips)

1846	1/10	Douglas Fir	Strips	ABCp
1847	"	"	"	C
1848	"	"	"	D
1849	"	"	"	NC
1850	"	White Fir	"	ABCp
1851	"	"	"	C
1852	"	"	"	D
1853	"	"	"	NC
1854	"	Spruce	"	ABCp
1855	"	"	"	C
1856	"	"	"	D
1857	"	"	"	NC
1858	"	Larch	"	ABCp
1859	"	"	"	C
1860	"	"	"	D
1861	"	"	"	NC
1862	"	Pine	"	ABCp
1863	"	"	"	C
1864	"	"	"	D
1865	"	"	"	NC
1866	"	Hemlock	"	ABCp
1867	"	"	"	C
1868	"	"	"	D
1869	"	"	"	NC
1870	1/6	Douglas Fir	"	ABCp
1871	"	"	"	C
1872	"	"	"	D
1873	"	"	"	NC
1874	"	White Fir	"	ABCp
1875	"	"	"	C
1876	"	"	"	D
1877	"	"	"	NC
1878	"	Spruce	"	ABCp
1879	"	"	"	C
1880	"	"	"	D
1881	"	"	"	NC
1882	"	Larch	"	ABCp
1883	"	"	"	C
1884	"	"	"	D
1885	"	"	"	NC
1886	"	Pine	"	ABCp
1887	"	"	"	C
1888	"	"	"	D
1889	"	"	"	NC

1890	1/6	Hemlock	Strips	ABCp
1891	"	"	"	C
1892	"	"	"	D
1893	"	"	"	NC
1894	7/32	Spruce	"	ABCp
1895	"	"	"	C
1896	"	"	"	D
1897	"	"	"	NC
1898	"	Pine	"	ABCp
1899	"	"	"	C
1900	"	"	"	D
1901	"	"	"	NC
1902	"	Hemlock	"	ABCp
1903	"	"	"	C
1904	"	"	"	D
1905	"	"	"	NC

(cores)

1906	1/10	Mixed	Random	C solid
1907	"	"	"	C
1908	"	"	"	D
1909	"	"	"	NC
1910	1/6	"	"	C solid
1911	"	"	"	C
1912	"	"	"	D
1913	"	"	"	NC
1914	7/32	"	"	C solid
1915	"	"	"	C
1916	"	"	"	D
1917	"	"	"	NC
1918	5/16	"	"	C solid
1919	"	"	"	C
1920	"	"	"	D
1921	"	"	"	NC

(additional veneer transfers--1/6 54s C veneers for centers)

1922	1/6	Douglar Fir	54s	C
1923	"	White Fir	"	"
1924	"	Spruce	"	"
1925	"	Larch	"	"
1926	"	Pine	"	"
1927	"	Hemlock	"	"

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