# WORK SAMPLING AND VIDEO TAPE ANALYSIS OF PALLET MANUFACTURING OPERATIONS

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY

Winton A. Ross

1968

THESIS

# ABSTRACT

## WORK SAMPLING AND VIDEO TAPE ANALYSIS OF PALLET MANUFACTURING OPERATIONS

by Winton A. Ross

Selected pallet manufacturing operations are examined with respect to work methods, work station layout and efficient use of machinery and manpower. They are six cut-off saws, two nailing machines, three block pallet nailing tables and two U. J. wire stapling machines. Another objective is to use a portable video tape recorder in time study analysis and comment on its performance.

Work sampling is the primary tool used to measure and describe the present situation on the four operations. Time data are obtained through video tape analysis and conventional stop watch time study techniques. Specific time studies are reported on to describe the work methods in use and the working relationships between crew members.

A considerable number of opportunities for improvement were discovered. Recommended changes to realize improvement and their effects are given and discussed. Method changes are justified by decreases in delay time since no or very minimal capital expenditures are needed.

By using a video tape recorder (VTR), valuable insight as to its use as a work study tool was also gained. The model of VTR used worked out very well in time study applications.

Shortcomings in the work methods used on the four operations are typical of many small- to medium-sized pallet plants. An objective analysis of the particular operations provides useful information to these other mills as well as showing the mill studied the way to make definite cost-saving improvements.

# WORK SAMPLING AND VIDEO TAPE ANALYSIS OF PALLET MANUFACTURING OPERATIONS

By

Winton A. Ross

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Forest Products Department

1968

# ACKNOWLEDGMENTS

The author expresses his sincere gratitude to Dr. Aubrey Wylie for his guidance and suggestions throughout this study. I also thank Mr. W. R. Parks for giving me the opportunity to conduct a study at Spring Arbor Industries, Inc. and Mr. Bud Gray and Mr. Leon Smith for all of their assistance at the plant.

Last, but by no means least, I thank Dr. Otto Suchsland and Dr. Donald Bowersox (Marketing, Transportation and Administration) for their effort in reading and commenting on the paper.

TABLE OF CONTENTS

LIST OF TABLES

| Table | | Page |
| --- | --- | --- |

## LIST OF FIGURES

LIST OF APPENDICES

# PART I

# INTRODUCTION

## The Wooden Pallet Industry

The importance of the wooden pallet industry is exemplified by the fact that over 7 per cent of all lumber or 20 per cent of all hardwood lumber produced in the United States in 1967 was used in the manufacture of pallets and containers. Pallet lumber consumption was estimated at 2,586,550,000 board feet (1). In Michigan, the pallet industry includes over one-hundred firms with combined annual sales of $25 million.

There are two economic factors of importance in the development of a large and growing pallet industry in Michigan. For one, there is an abundant supply of low to good quality hardwood timber in the state. Two, the food and automotive industries, two of the heaviest users of pallets, have many plants located in the southern half of the state.

Wooden pallets are simple in design, can be produced with a minimum investment in machinery and can be constructed using inexpensive, otherwise hard to market, low grade material. Many pallet plants have been started by a father and his sons nailing up pallets in their backyard during their spare time. As a result, there are many people in the pallet industry who are unfamiliar with the wood industry and/or with efficient methods of manufacturing.

Marginal profit situations are characteristic of most pallet plants, Michigan plants included. Low production rates, high labor costs, inefficient use of machinery and excessive waste are a few of the reasons for this situation. Quite often opportunities for improvement are overlooked because plant managers:

1) have a limited amount of money to spend on technical assistance,
2) have very little knowledge of Industrial Engineering techniques,
3) do not know that a limited number of research publications on efficient pallet manufacturing methods are available through government agencies, and
4) quite often do not realize that their plants have inefficient production methods.

The general objective of this study is to investigate selected operations in a Michigan pallet plant in order to identify areas for greatest improvement and make suggestions to that effect. Many pallet plants have similar operations to the ones studied in this report. Therefore, the techniques used and results obtained here will apply to a substantial number of other plants.

## Subject of Study

The subject of this study is Spring Arbor Industries, Inc., a pallet, skid and box mill located in Spring Arbor, Michigan. Their manufacturing facilities are located in two separate buildings--Assembly (Figure 1) and box line. The majority of their products are sold within a thirty-mile radius of the plant. Approximately forty full-time and one-hundred-forty part-time employees make up the total labor force. The plant operates fourteen hours per day, five days a week and usually five hours on Saturday.

Spring Arbor purchases crating grade lumber, cant stock and a small amount of pre-cut pallet stock from surrounding sawmills. The lumber and cant stock are processed into various components. All of this material is then assembled into pallets, boxes, bases and skids.

The writer's specific area of interest at Spring Arbor concerns four operations (thirteen work stations) located in the assembly building. They are six cut-off saws, three nailing tables, two nailing machines and two U. J. wire stapling machines (Table 1). Thirty-six men are required to completely staff these operations. Using a fourteen-hour working day--five days a week, this represents 126,000 man-hours of direct labor per year (assuming 250 working days per year). Because of the high labor content any increase in productivity on these operations could amount to a considerable cost savings.

TABLE 1.--Summary of four operations in study.[1] (Source: In plant observations)

| Operation | Machinery and Equipment | Crew Size | Material Used | Part or Assembly Produced |
|---|---|---|---|---|
| Cut-Off Saw | 6-Porter 43-J automatic hydra-cut saws (2 saws are used only for cutting blocks) | 3 men per saw on four saws 1 man for each of the 2 block saws (14 men) | Majority is carting grade hardwood lumber. Some softwood is also used. | Boards used for pallet decking, stringers, box siding, and bases. |
| Nailing Machine | 1-Morgan model #26-48" automatic nailer 1-Morgan model #30-72" automatic nailer | 2 men per machine (4 men) | Stringers, deck boards and nails. | Finished stringer type pallet. |
| Block Pallet Assembly | 3-Nailing Tables with adjustable metal jigs and 2-paslode nailing guns per table | 4 men per table (12 men) | Blocks, deck boards (slots) and nails. | Finished block type pallet. |
| Wire Stapling Machine | 1-52" capacity Saranac cleater 1-70" capacity Saranac cleater | 3 men per machine (6 men) | Deckboards, runners and wire. | Finished base, box panel siding and block pallet decks |
| Summary | Total of 13 machines or jobs | Total of 36 men | Hardwood and softwood lumber, nails and wire. | Pallet, box, skid and base components. Finished pallets, skids and bases. |

[1]Material handling equipment consists of roll-about carts, pallets, and hand lift trucks (electric power).

## Objectives of Study

The purpose of this study is to systematically investigate important factors affecting the efficiency and economy of four selected pallet plant operations in order to effect improvement and reduce manufacturing costs. The main objectives are to:

1. Improve the work methods at each operation.
2. Obtain more efficient manpower and equipment usage.
3. Use a portable video tape recorder for time and motion study analysis and comment on its performance and applications (Appendix IV).

## Literature Review

### Work Study

Organized work study procedures have been in existence since the turn of the century. Gilbreth, Taylor, Emerson and Tippet were most prominent in laying the early groundwork (4, 6, 10). These men developed specific work study techniques that were applied to solve many manufacturing problems of the period.

Currie (6) states that "work study may be regarded principally as a procedure for determining the truth about the activities of existing people and existing plant and equipment as a means to the improvement of those activities." The techniques of work study provide a means of recording in convenient form the pertinent facts about how an organization is using its resources. These records then can be analyzed to ascertain where waste and unnecessary effort occur so that steps can be taken to eliminate them (6).

There are in existence many research publications on work study and operations improvement in all industries. In the following paragraphs specific research publications in the forest products industries, pallet plants in particular, are discussed in brief.

In an article by Keppler, Huxster and Dyson (8) work sampling methods and time study techniques are discussed. Its purpose is to give the forest products specialists an appreciation and working knowledge of the subject. Specific applications of industrial engineering in the wood industry are shown.

In a 1958, U. S. Forest Service study by Heebink and Forbes (7), a typical pallet plant is described. All of the factors relevant to hardwood pallet manufacturing are discussed and an "ideal" plant layout is developed.

A report by Koch (9) describes a proposed integrated pallet plant for the utilization of Michigan low grade hardwood. He discusses market potential, the manufacturing process, cost data and the expected annual profit of such a plant. But, this research along with the work of Heebink and Forbes, involved the establishment of a new mill, rather than the improvement of an existing one.

Probably the most important work involving improvement of an existing pallet plant operation was done by Bowyer (5). His thesis includes discussion of applications and results of work sampling and time study in a Michigan pallet plant and two layout change proposals.

A report by Wheeler, Harold and Wylie (15) includes the economic factors of converting wood residues into animal and poultry bedding. Work study techniques are applied to obtain cost and production data for the particular pallet plant studied.

## Tools of the Work Study Analyst

To study any industrial process there must be a system of measuring performance and a universal criterion for expressing those measurements. Since the most widely accepted basis of payment for services is time it is most logical to measure work with time (8). Therefore the basic tool of the work study analyst is a timing device.

There are many types of stop watches, micro-timers, etc. that an analyst may employ. Time can also be measured through the use of motion picture analysis either by counting frames while viewing the film or inserting a timing device in the picture during the filming.

One of the newest work study tools is the video tape recorder (VTR). VTR was developed in 1956 for television broadcasting station use (13). By 1962, with the rapid advancement in technology, it was simplified and its cost reduced. This prompted many individuals to consider its applications in fields other than TV broadcasting.

In the April, 1966, issue of the Journal of Industrial Engineering, Sakuma (12) reports that there are many applications for the video tape recorder in the industrial engineering field. He lists such things as work study, time study, work sampling, motion study and employee training.

The use of the video tape recorder closely parallels the motion picture camera in work study analysis. But, according to Sakuma, VTR has definite advantages over motion pictures. Listed below are six advantages discussed by Sakuma.

1. No film developing is required--immediate reproduction is possible by simply rewinding and playing back the video tape.
2. Video tape can be used repeatedly at least 1000 times--this is a decided cost advantage for the VTR.
3. VTR has a longer maximum continuous recording time--ranges from sixty to ninety-three minutes.
4. Recording can be monitored--eliminates the chances for a recording mistake.
5. Larger number of fields (frames) per second (higher accuracy).

6. Same recording can be used for micromotion and memomotion studies.

A search reveals that there are no research publications on the direct application of this new tool in work study in wood products industries. A major objective in this study is to apply the VTR in time study work at a pallet plant and comment on its performance.

## Limitations and Assumptions

A study of this type is only a small segment of what would be needed to evaluate the total pallet manufacturing process. This research is limited to the examination of only four operations within the total process. With that in mind, following is a list of specific limitations and assumptions.

1. Any improvements suggested deal primarily with work methods and the machinery currently in use at the four operations. The objective is to increase productivity on the machines presently in use--not to increase production by buying more or better equipment.
2. Assume any increase in production can be marketed without lowering price.
3. Assume additional raw material procurement will be no problem.
4. Assume product designs adequately satisfy end-use requirements and can be produced with minimum wastage.

# PART II

# METHODOLOGY

At the outset of the study the objectives and procedures were explained to the management of Spring Arbor Industries. During an employee meeting, Bud Gray, accountant for the firm, explained to the day work employees what I would be doing and asked for their cooperation. Also, before making a video tape recording of an operation, the plant superintendent and I explained to the men involved the reasons for the study and what we wanted them to do.

Before making any detailed analysis of the four operations, measurements were taken of the entire assembly building layout; all room dimensions, doorway and machinery locations were recorded. Detailed work place layout measurements and machinery specifications of the cut-off saws, block nailing tables, nailing machines and U. J. stapling machines were also recorded. These data were brought to the laboratory and a scale drawing of the entire assembly building made (Figure 1).

An operation analysis, using the Methods Engineering Council's Analysis Sheet, Form No. 101, was performed next (Figure 2). Its only purposes were to give a complete view of the manufacturing processes and to serve as a study guide; so the important factors affecting production would not be overlooked.

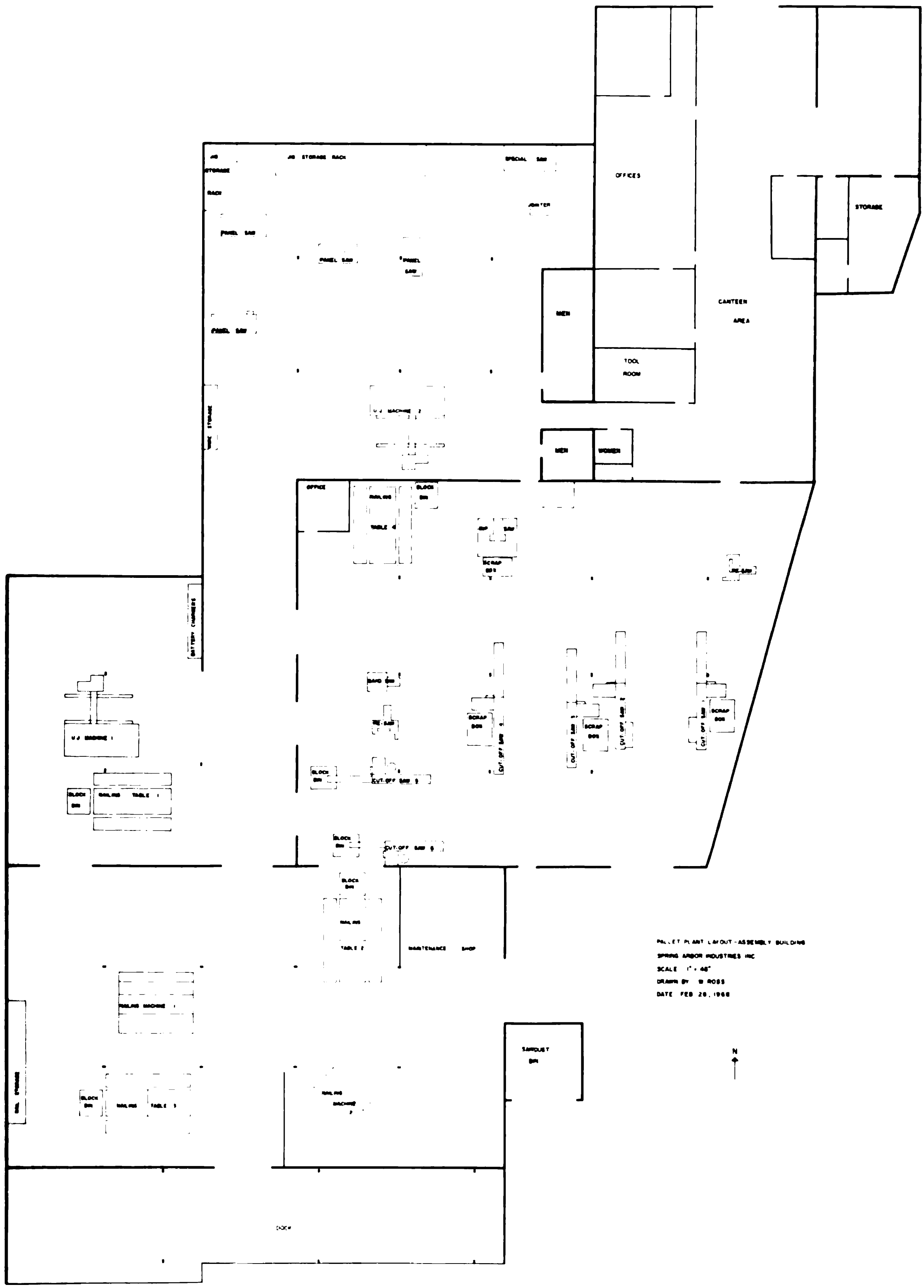



Figure 1.--Assembly building layout.

Date ____________ Dept. ____________ Dwg. ____________ Sub. ____________

Mould ____________ Die ____________ Style ____________ Item ____________

Pattern ____________ Ins. Spec. ____________ L. Spec. ____________ Sub. ____________

Part Description ______________________________________________

______________________________________________

Operation ______________________________ Operator ______________________________

| DETERMINE AND DESCRIBE | DETAILS OF ANALYSIS |
|---|---|
| **1. PURPOSE OF OPERATION** | Can purpose be accomplished better otherwise? |
| **2. COMPLETE LIST OF ALL OPERATIONS PERFORMED ON PART**<br>No. Description Work Sta Dept.<br>1. ____<br>2. ____<br>3. ____<br>4. ____<br>5. ____<br>6. ____<br>7. ____<br>8. ____<br>9. ____<br>10. ____ | Can oprn. being analyzed<br>be eliminated?<br>be combined with another?<br>be performed during idle period of another?<br>Is sequence of oprns. best possible?<br>Should oprn. be done in another dept. to save cost or handling? |
| **3. INSPECTION REQUIREMENTS**<br>a—Of previous oprn.<br>b—Of this oprn.<br>c—Of next oprn. | Are tolerance, allowance, finish and other requirements<br>necessary?<br>too costly?<br>suitable to purpose? |
| **4. MATERIAL**<br>Cutting compounds and other supply materials | Consider size, suitability, straightness, and condition<br>Can cheaper material be substituted? |
| **5. MATERIAL HANDLING**<br>a—Brought by<br>b—Removed by<br>c—Handled at work station by | Should crane, gravity conveyors, totepans, or special trucks be used?<br>Consider layout with respect to distance moved |
| **6. SET-UP** (Accompany description with sketches if necessary)<br>a—Tool Equipment<br>Present<br>Suggestions | How are dwgs. and tools secured?<br>Can set-up be improved?<br>Trial pieces<br>Machine Adjustments<br>TOOLS<br>Suitable?<br>Provided?<br>Ratchet Tools<br>Power Tools<br>Spl. Purpose Tools<br>Jigs, Vises<br>Special Clamps<br>Fixtures<br>Multiple<br>Duplicate |

Methods Engineering Council
Form No. 101

**ANALYSIS SHEET**

Figure 2.

**7. CONSIDER THE FOLLOWING POSSIBILITIES.**

1. Install gravity delivery chutes.
2. Use drop delivery.
3. Compare methods if more than one operator is working on same job.
4. Provide correct chair for operator.
5. Improve jigs or fixtures by providing ejectors, quick-acting clamps, etc.
6. Use foot-operated mechanisms.
7. Arrange for two-handed operation.
8. Arrange tools and parts within normal working area.
9. Change layout to eliminate back tracking and to permit coupling of machines
10. Utilize all improvements developed for other jobs

**RECOMMENDED ACTION**

**8. WORKING CONDITIONS.**

a—Other Conditions

Light
Heat
Ventilation, Fumes
Drinking Fountains
Wash Rooms
Safety Aspects
Design of Part
Clerical Work Required (to fill out time cards, etc.)
Probability of Delays
Probable Mfg. Quantities

**9. METHOD** (Accompany with sketches or Process Charts if necessary.)

a. Before Analysis and Motion Study

b—After Analysis and Motion Study

Arrangement of Work Area
Placement of
Tools
Materials
Supplies
Working Posture
Does method follow Laws of Motion Economy?
Are lowest classes of movements used?

See Supplementary Report Entitled

Date

OBSERVER ____________________ APPROVED BY ____________________

The next task was to conduct a work sampling study of the four operations. It should be noted at this time that work sampling has two main uses. It may be used to measure activities and delays and/or to establish a time standard for an operation. In this study it is used to measure activities and delays.

Probable activities and delays at each of the four operations were classified into elements and defined (Appendix I). A work sampling study form was also prepared for each work station. Refer to Figure 3 for an example.

An observation (one sample) consisted of looking at a particular work station at a given point in time and recording what was happening under the appropriate element. Individual observations were made at one-half minute intervals; the time interval between observations on the same work station ranged from approximately six to fifteen minutes. After collection these data were converted to percentage figures showing the portion of time spent performing each element (activity) at each work station (Tables 8 through 23, Appendix I).

Every attempt was made to keep the observations random and unbiased. For example:

1. Each day the sampling forms were arranged in random order. This determined the daily observational sequence.

Study Subject Cut-Off Saw # ____ Operator

Description ______________________

Date ______________________

Observer Winton Ross

| Item | Repetitions |
| --- | --- |
| Normal Cycle | |
| Setting Up | |
| Idle-avoidable | |
| Wait on Handler | |
| Wait on off-bearer | |
| Receive Instructions | |
| Delay-Move in Lumber | |
| Delay-Move out boards | |
| Personal | |
| | |
| | |
| Not Operate | |
| | |
| | |
| | |

Figure 3.--Example of Work Sampling Form.

2. The observer tried to be inconspicuous as possible in order to keep the workers from determining the exact instant that they were being observed.
3. Since all operation cycle times were considerably less than the six-minute minimum interval discussed above, individual observations were independent.

The next phase of the study was to record the operations on video tape for the purposes of: (1) time and motion study analysis, and (2) evaluation of the video tape system as a work study tool. These tapes were brought back to the laboratory and played back through the monitor to answer these questions:

1. What is the present work method at each operation?
2. What are the element and cycle times of a given job?
3. What is the production efficiency of a given crew or operator and why?
4. What types of data can be obtained with the video tape recording system and how does it compare with conventional stop watch time study and motion picture analysis?

Time study data were obtained from the video tape by using a micro-timer while watching the playback on the TV monitor (Figure 4). Some time study data were also obtained with conventional stop watch study techniques.

Figure 4.--Analyzing video tape with micro-timer.

On the basis of all this information (layout drawings, operation analysis forms, work sampling results and time study data) problem areas are assessed and suggestions for improvement made for the four operations. Comparisons of current to proposed production methods are based on percentage increases in production.

A subjective evaluation of the video tape recorder's performance as a work study tool is also made.

# PART III

# RESULTS

## Work Sampling

As stated earlier, work sampling data were kept separately for each work station within each operation. Also noted earlier was the fact that all work stations within an operation were, for all practical purposes, identical with respect to kind of machinery, crew size and work methods (Appendix II).

There was no attempt made in the work sampling study to keep track of individual employees and what operation they were working on for several reasons. For one, Spring Arbor Industries has a unique labor situation. They hire a substantial number of part-time workers and as a result have a high labor turnover rate. One man may operate a U. J. machine one day, off-bear for a cut-off saw the next day, work in a nail crew the third day and not be there at all the fourth day. One can imagine the difficulties this would cause in attempting to classify data by employees.

Two, it is assumed, since work methods employed at similar work stations are basically the same, that individual worker's effort rate and skill differences would have little effect on work sampling results. While it is possible that the length of a given work cycle might be different for different operators or crews, the chances are good that the length of time used to perform each element of the cycle will be changed a proportional amount. Thus, when elemental times are expressed as a percentage of the total cycle time, the results should be the same regardless of the individual cycle times.

Another reason has to do with the objective of the work sampling study. The objective was not to determine the effect of different employees on production efficiency, but to describe the present situation and discover areas where improvements are needed. It is realized that the labor turnover situation may be a large factor in causing specific production problems, but this is extremely difficult to measure objectively.

For convenience of discussion and ease of calculation the sampling data for the work stations within each operation have been combined (Tables 2 through 7). By doing this one can refer to an average cut-off saw, block cut-off saw, nailing machine, block pallet nailing table or U. J. machine for discussion purposes.

### Cut-Off Saw Operation

Referring to Table 2, a number of interesting facts become immediately apparent. Note the large percentage of time used in getting material to and from an average saw (10.4%). Also note the large amount of lost time due to the operator waiting on the off-bearer (9.3%).

TABLE 2.--Work sampling summary--(cut-off saws 1, 2, 3, 4-operator).

| Element | Number of Observations | Percent of Operating Time |
|---|---|---|
| Normal cycle | 595 | 72.8 |
| Setting up | 25 | 3.1 |
| Move in lumber | 52 | 6.4 |
| Move out boards | 33 | 4.0 |
| Wait on handler | 6 | 0.7 |
| Wait on off-bearer | 76 | 9.3 |
| Receive instructions | 6 | 0.7 |
| Personal | 8 | 1.0 |
| Idle-avoidable | 12 | 1.5 |
| Miscellaneous | 4 | 0.5 |
| Operate Total | 817 (64.2%) | 100.0% |
| Total Observations | 1273 | |

The average saw operates only 64.2 per cent of a day. If 64.2 is multiplied by four we get an estimate of the utilization of the four saws (2.57 of a possible 4.00). In essence this means, that at Spring Arbor's current production rate, three saws would more than do the job.

A description of all elements is found in Appendix I.

Data in Table 3 clearly indicate that the block saws are very inefficient--only 59.5 per cent productive (normal cycle). Actually the basic production method and machinery used are efficient; other factors cause the low productivity.

TABLE 3.--Work sampling summary--(block cut-off saws 5 and 6-operator).

| Element | Number of Observations | Per Cent of Operating Time |
|---|---|---|
| Normal cycle | 143 | 59.5 |
| Setting up | 6 | 2.5 |
| Move in cants | 20 | 8.3 |
| Move out blocks | 21 | 8.8 |
| Level blocks | 22 | 9.2 |
| Receive instructions | 1 | 0.4 |
| Clean up station | 11 | 4.6 |
| Idle-avoidable | 5 | 2.1 |
| Personal | 7 | 2.9 |
| Miscellaneous | 4 | 1.7 |
| Operate Total | 240 (37.7%) | 100.0% |
| Total Observations | 636 | |

Too much time is spent by the operator leveling blocks in the bins (9.2%). However, because of the way blocks dump into the bins, some time is undoubtedly needed for this task. The reason for such a high figure is that the operator is overly concerned about getting as many blocks into the bin as possible. As can be seen, this is a costly task just to get an extra seventy-five or so blocks in a block bin.

Note the low machine capacity utilization (37.7%). This means that a great many more blocks than needed can be produced. As a result there is little attention given to this operation concerning scheduling or efficiency. If, for example, more cant material is needed at a saw and other problems are pressing within the plant, nobody gets too concerned about it. This is also true about moving out full block bins.

Nailing Machine Operation

Material handling activities on the average nailing machine involve only a small portion of the total time (2.4% and 1.4%). This is not a critical problem area but it still deserves some discussion. A majority of the 3.8 per cent delay is the fault of the crew, not of the material handling system. It was mentioned in Appendix II that finished pallets were stacked to a specified height before being moved to storage. When this height is reached, production on the nailing machine comes to a complete halt until they have been completely moved out of the way. This is not necessary because there is plenty of room to start another stack and continue production.

TABLE 4.--Work sampling summary--(nailing machines 1 and 2--2 man crew).

| Element | Number of Observations | Per Cent of Operating Time |
|---|---|---|
| Normal cycle | 422 | 73.3 |
| Setting up | 21 | 3.7 |
| Move material in | 14 | 2.4 |
| Move pallets out | 8 | 1.4 |
| Repair pallets | 40 | 6.9 |
| Adjust machine | 11 | 1.9 |
| Nail jam | 15 | 2.6 |
| Fill nail hopper | 7 | 1.2 |
| Receive instructions | 2 | 0.3 |
| Idle-avoidable | 25 | 4.4 |
| Personal | 7 | 1.2 |
| Miscellaneous | 4 | 0.7 |
| Operate Total | 574 (90.4%) | 100.0% |
| Total Observations | 635 | |

Other problem areas are: (1) a lot of time spent repairing pallets, (2) nail jamming, and (3) just plain loafing (idle-avoidable). The major causes of these delays are respectively slat thickness variations, use of poor quality nails and lack of a real incentive to work harder than necessary to get by. They account for 13.9 per cent of the total working time.

The machine utilization is fairly high (90.4%), but there is still time available if production requirements increase.

Block Pallet Assembly Operation

Since the nail and lay up crews perform two separate functions (Appendix II) they were kept separate for work sampling (Tables 5 and 6). Both crews on a given table

TABLE 5.--Work sampling summary--(block nailing tables 1, 2 and 3-nail crew).

| Element | Number of Observations | Per Cent of Operating Time |
|---|---|---|
| Normal cycle | 406 | 53.5 |
| Setting up | 12 | 1.6 |
| Move out pallets | 4 | 0.5 |
| Wait on lay up crew | 205 | 27.1 |
| Lay up blocks | 86 | 11.3 |
| Repair pallets | 32 | 4.2 |
| Receive instructions | 4 | 0.5 |
| Idle-avoidable | 5 | 0.7 |
| Personal | 4 | 0.5 |
| Miscellaneous | 1 | 0.1 |
| Operate Total | 759 (87.7%) | 100.0% |
| Total Observations | 865 | |

TABLE 6.--Work sampling summary--(block nailing tables 1, 2 and 3-lay up crew).

| Element | Number of Observations | Per Cent of Operating Time |
|---|---|---|
| Normal cycle | 587 | 77.4 |
| Setting up | 11 | 1.4 |
| Move out pallets | 6 | 0.8 |
| Wait on nail crew | 15 | 2.0 |
| Lay up blocks | 91 | 12.0 |
| Repair pallet | 16 | 2.1 |
| Receive instructions | 4 | 0.5 |
| Idle-avoidable | 13 | 1.7 |
| Personal | 7 | 0.9 |
| Miscellaneous | 9 | 1.2 |
| Operate Total | 759 (87.7%) | 100.0% |
| Total Observations | 865 | |

were not observed at the same time. During the study each nail crew and then each lay up crew were observed. Therefore, observations on each crew at each table are independent. So, these data should represent what each crew is doing independently of the other on an average table.

It is very interesting to note that an average nail crew is waiting a large portion of the time on the lay up crew (27.1%). That indicates a considerable work imbalance and may be the reason for the difference in idle-avoidable times between crews. This will be discussed later in more detail in the time study section.

A considerable portion of the operating time is used by both crews to lay up blocks (11.3% and 12.0%). One might expect that the time should be equal for both crews but, after close examination it was discovered that the lay up crew actually does spend more time on this element. When the blocks in the jig are used up they start tossing more into the jig. The nail crew finish nailing on the last pallet before they assist them.

The only other delay of interest on this operation is repair pallets. It is caused by "sloppy" nailing procedures and less frequently by blocks splitting when nailed. As expected the nail crew spends the most time on this delay (4.2%). Sometimes they are assisted by the lay up crew (2.1%).

A considerable portion of time is available for increased production requirements (12.3%).

Wire Stapling Operation

Table 7 indicates that the largest delay occurrence is wait on lay up man (12.7%). As with the block nailing tables, this illustrates an unbalanced assignment of work activities. Ideally the operator should be feeding jigs through the machine one after the other. He also has to wait on the off-bearer 3.2 per cent of the time.

TABLE 7.--Work sampling summary--(U. J. machines 1 and 2--operator).

| Element | Number of Observations | Per Cent of Operating Time |
|---|---|---|
| Normal cycle | 268 | 62.1 |
| Setting up | 37 | 8.6 |
| Move material in | 17 | 3.9 |
| Move material out | 6 | 1.4 |
| Wait on lay up man | 55 | 12.7 |
| Wait on off-bearer | 14 | 3.2 |
| Receive instructions | 1 | 0.2 |
| Out of wire | 13 | 3.0 |
| Idle-avoidable | 5 | 1.2 |
| Personal | 4 | 0.9 |
| Miscellaneous | 12 | 2.8 |
| Operate Total | 432 (75.9%) | 100.0% |
| Total Observations | 569 | |

The same type of material handling problems occur here as on the nailing machines. Production does not necessarily have to stop when material is moved in or out but it often does (3.9% and 1.4%). It is simply used as an excuse for an unauthorized rest period.

Three per cent lost time is due to changing wire spools. This is not an important delay, but it could be reduced by a slight change in method.

A considerable portion of time is available for increased production requirements (24.1%).

## Time Study

Work sampling data in the preceding section and Appendix I give an overall picture of how crew operating time is used at the four operations. The time study data (video tape and stop watch) discussed below provide an insight into the coordinated working and waiting time of the crews. It illustrates the work methods in use at each operation more clearly than the work sampling data. This is necessary before any recommendations for method change can be made.

It is also intended that these data represent the kinds of information that can be obtained through video tape analysis. When this is known specific statements concerning the possible applications of this "new tool" can be made (Part V).

A great number of different sizes, styles and types of products are manufactured at Spring Arbor. An attempt was made to pick the highest volume or most typical products to time study. This was determined from discussions with the plant superintendent. Specific time study reports are in Appendix III.

### Cut-off Saw Operation

Due to the large number of variables in cut-off saw operations, no attempt is made to estimate overall production rates on saws #1, 2, 3 and 4. The primary objective in their analysis is to demonstrate the kinds of information that can be obtained from video tape analysis. A specific production run is reported on (Figure 13, Appendix III).

Figure 14 is a report of a typical production run on block saw #5. It is used to substantiate the statement made earlier about the block producing capacity of this operation. For example, the production rate given is 16,660 blocks per eight-hour day (includes 20% allowance). At this rate enough blocks for 1,851 pallets could be produced (nine blocks per pallet--an average of 462 pallets for each of the four tables). Even if all tables were used 100 per cent of the time, which they are not (work sampling data), enough blocks could be produced on just one saw.

## Nailing Machine Operation

The number of steps or work elements performed by a nailing crew depends on the style of pallet. Double face pallets require six more steps than single face (Figures 15 and 16, Appendix III).

The repair pallet element previously discussed as a problem area (page 26) is further substantiated by time study (Figure 15, Appendix III). On the JDF #2 base it represents 5.5 per cent of the average cycle time. When slat material is not of uniform thickness the nailing machine can not drive all nails flush with the wood surface. The nails "sticking up" must be driven down with hammers (repair pallet).

Figure 5 gives a graphic representation of the crew's working relationship. Note how each man works together very well and the lack of any apparent work method problems.

## Block Pallet Assembly Operation

From work sampling it was determined that a considerable work imbalance existed between the nail and lay up crews. Time study data bears this out. The average cycle time (15 cycles) for block pallet-H is 0.82 minutes (Figure 17, Appendix III). During this time the lay up crew is constantly busy while the nail crew is idle 0.32 minutes per pallet (39.0% of the average cycle time).

A new method was devised that re-arranged the work duties. It was explained to the four men on Table #3. After allowing them to become familiar with the new work method, another time study was taken. Results show a decrease in cycle time to 0.69 minutes (production increase of 18.8%). Figure 6 is a graphic comparison of the two methods.

| Operator | | Time (Min) | | Helper |
|---|---|---|---|---|
| Set Backstop | 0.03 | .00 | 0.10 | Handle Up Stringers (3) |
| Handle Up Top Slats (4) | 0.08 | | | |
| Wait On Helper | 0.08 | .10 | 0.09 | Position Stringers |
| Lay Up Top Slats | 0.10 | .20 | 0.10 | Lay Up Top Slats |
| Nail Top (3 strokes) | 0.15 | .30 | 0.15 | Nail Top (3 strokes) |
| | | .40 | | |
| Turn Pallet | 0.03 | | 0.03 | Turn Pallet |
| Set Backstop | 0.03 | | 0.03 | Lower Table |
| Handle Up Bottom Slats (2) | 0.05 | .50 | 0.05 | Wait on Operator |
| Lay Up Bottom Slats | 0.05 | | 0.05 | Lay Up Bottom Slats |
| Nail Bottom (3 strokes) | 0.08 | .60 | 0.08 | Nail Bottom (3 strokes) |
| Stack Pallet | 0.08 | .70 | 0.08 | Stack Pallet |
| | | .80 | | |
| | | .90 | | |
| | | 1.0 | | |
| | | 1.1 | | |

Avg. Net Time/Pallet - 0.76 Min.

Figure 5.--Multiple Activity Chart. Nailing Machine #2 34" x 34"; 2-Way Pallet (Net Times) Source: Figure 16, Appendix III.

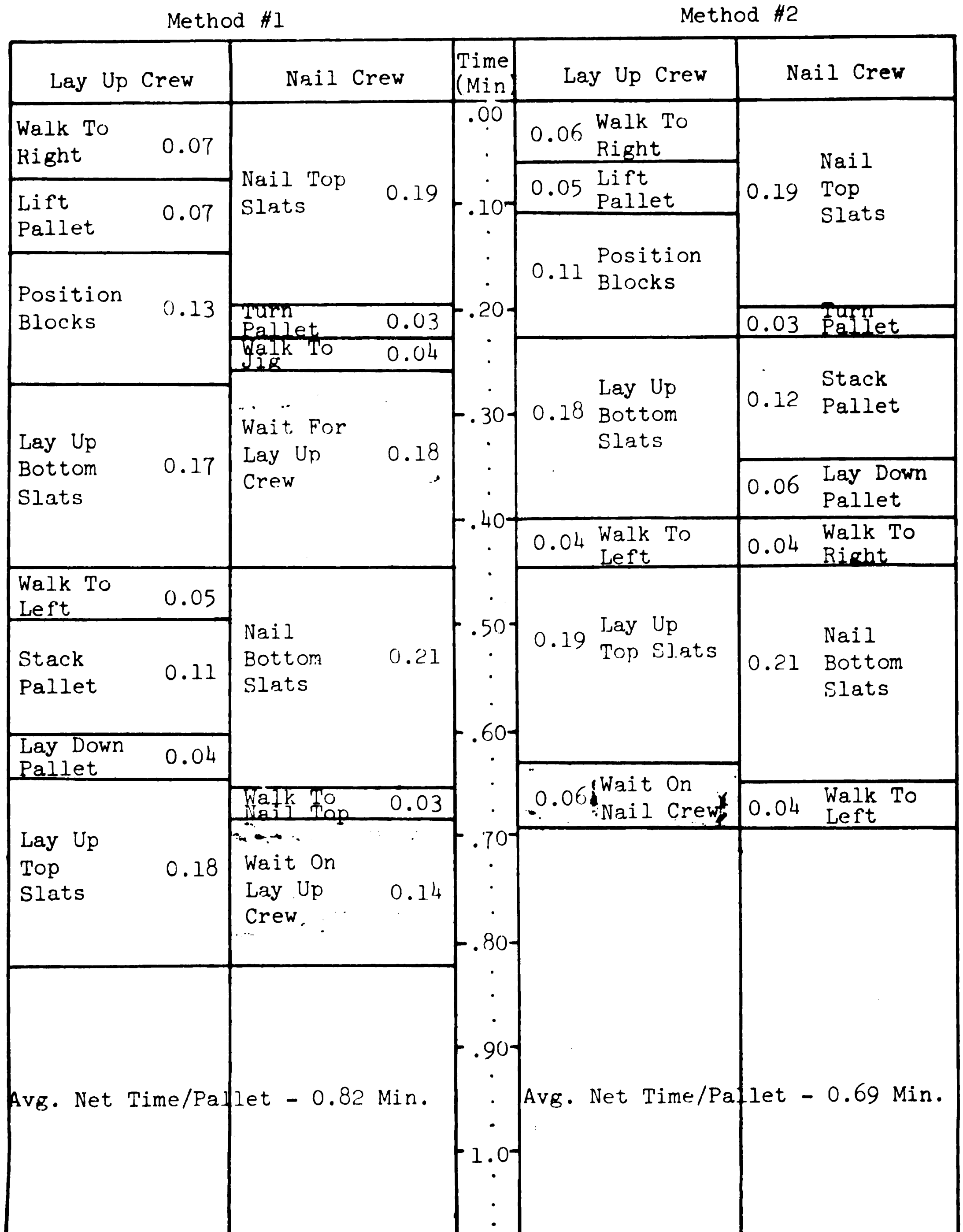



**Figure 6.**--Multiple Activity Chart. Block Pallet Table #3 - Block Pallet-H (Net Times) Source: Figure 17, Appendix III.

Two general types of block pallets are made. On one type individual slats are placed and nailed to the blocks at the table. The other involves the use of a pre-assembled slat top--the top is stapled together on a U. J. machine. One would expect the cycle time to be shorter on the pallet with the pre-assembled top. This was found to be untrue (0.85 min. as compared to 0.82 min. per cycle, Figures 17 and 18) for several reasons.

When making the first type of pallet the blocks are positioned in the jig to the exact dimensions of the pallet. The jig is not used to help position blocks on the pre-assembled top type--but rather, they are positioned by estimate. They then have to be re-positioned when the top is placed on them. This is time consuming, especially when there are a lot of blocks on the table. This accounts for the large difference in average times for element #4 (Figures 17 and 18, Appendix III) which increase the cycle time for the 36" x 36" red code pallet.

An interesting sidelight is the fact that the red code pallet is priced ten cents lower than the H pallet. Not only does it take longer on the block nailing table to make; it also has the extra cost of stapling the top assembly on the U. J. machine. This is just one example of the inaccuracy of pricing pallets primarily according to their lumber content (pallet red code has 8.1 bd. ft.--pallet H has 8.4 bd. ft.).

## Wire Stapling Operation

Work sampling data (page 30) showed a 12.7 per cent delay due to the lay up man. This delay does not occur on every product manufactured because it is strongly related to the number of boards that the lay up man must handle and to how fast each crew member works. On one panel (Figure 19, Appendix III) the operator has no waiting time because of trouble he is having keeping the boards in the jig. Normally he would on this panel. The panel reported on in Figure 20 is more normal and shows an operator waiting time of 0.11 minutes. To eliminate this idle time a change in the work method is necessary.

These two time studies illustrate some of the problems associated with this operation. On certain box panels the boards must be placed edge to edge in the jig. If the combination of boards for each panel have been cut oversize they will not easily fit into the jig. This problem directly accounted for an increase in cycle time of 0.23 minutes on the panel in Figure 19. Also note how this increased the waiting time of the lay up man and off-bearer.

The working relationships of the crew are more clearly illustrated in Figure 7.

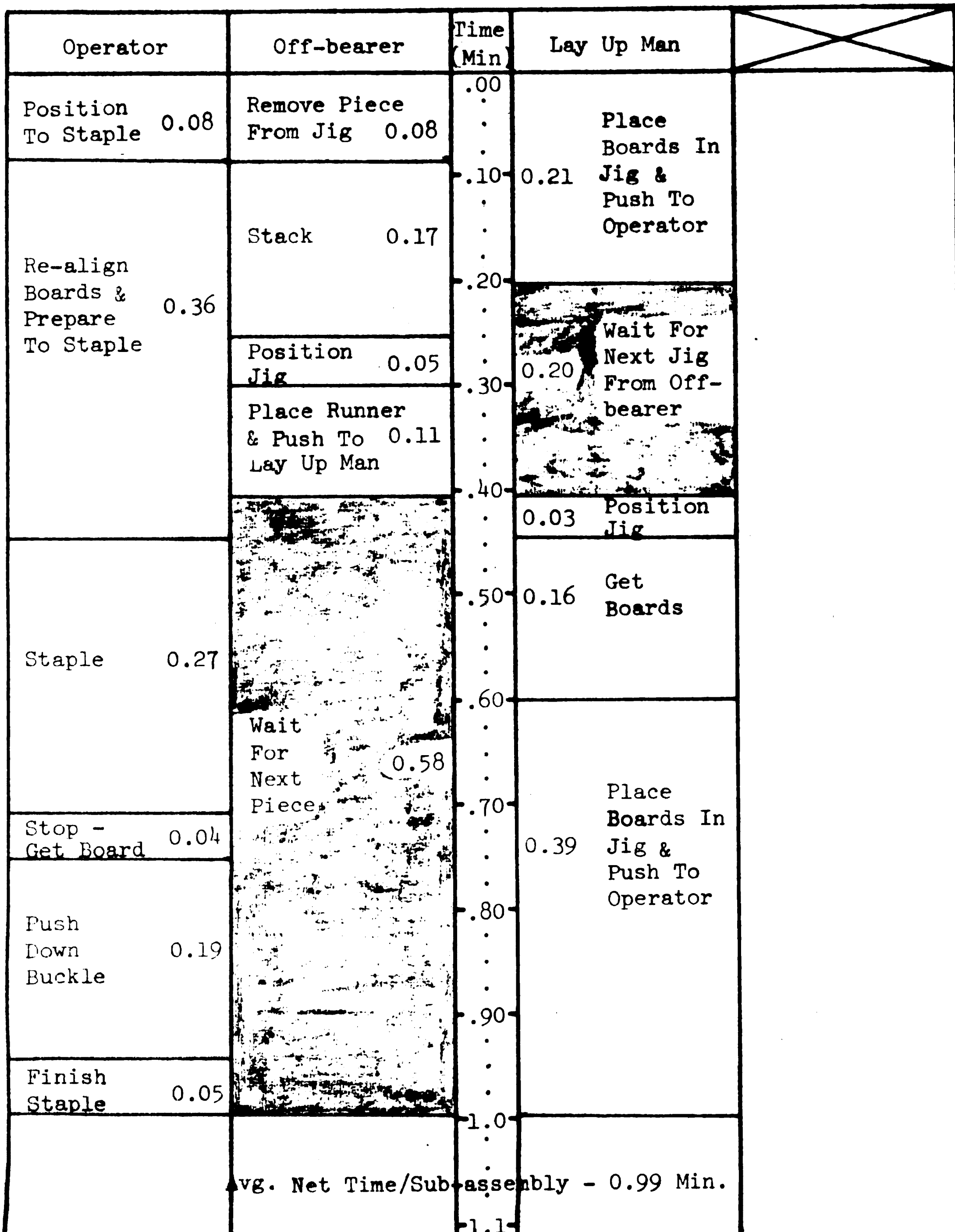



Figure 7.--Multiple Activity Chart. U.J. Machine - 15 3/8" x 44 3/8" Box Siding Sub-assembly (3 Jigs) (Net Times) Source: Figure 19, Appendix III.

## Other

During the data collection period a number of plant-wide problem areas were discovered. This information was obtained from personal observation and through discussions with employees and management.

The general attitude of the employees is satisfactory, but there is a definite lack of motivation to work harder than necessary to get by. This was pointed out in the work sampling results as a cause for some of the material handling and idle-avoidable delays. During a conversation with one employee he said, "I get paid the same whether we make 100 pallets or 500 pallets a day. So, why should I work very hard?"

Scheduling production runs is difficult because of the large number of part-time employees that are hired. These men come and go, working to their own schedule. The plant superintendent seems to have little advance notice as to how many men will be available at given times of the day. The wire stapling machines act as a "catch-all" for men that can not be assigned to other operations. This is one of the reasons for using four man crews on the U. J. machines at times.

Training of operators and crew members is also difficult with part-time help. As mentioned before, one man may work on four or five operations for one month and then quit. As a result an individual employee may never become proficient at any one job.

Employee restroom, drinking fountain and canteen facilities are adequate. But, men that smoke must step outside the north entrance to the assembly building during breaks. This is extremely uncomfortable during foul weather.

Further discussion on these items is in Part IV.

# PART IV

# SUGGESTIONS FOR IMPROVEMENT

There are an unlimited number of suggestions for improvement that can be made after any plant study. In this report, attention is primarily given to the major problem areas that can be improved upon without investing any money.

### Cut-Off Saw Operation (Saws #1, 2, 3 and 4)

1. Sell one of the saws or operate all four saws eight to nine hours per day instead of fourteen hours.

Idle machinery is an expense in depreciation and opportunity cost. In Spring Arbor's case it also takes up much needed floor space. Work sampling data indicated an average saw operating time of only 64.2 per cent. With better scheduling of production it may be possible to eliminate the night shift on these saws.

2. Instruct operators to move out of the way cut-to-length pieces and continue production when an off-bearer gets behind in his work. (Reduce delay time by 9.0%.)

As discussed in the work sampling section the operator stops work when this happens. He could easily push the piece on down the conveyor and continue working.

One other point needs attention. The off-bearer has to do a lot of walking in stacking pieces on the carts and pallets. A special effort should be made by the sawroom foreman to see that the most numerous length pieces are stacked on the pallets and carts closest to the off-bearer. This would help considerably in keeping the off-bearer from getting behind in his work.

3. Use one lumber handler for two saws.

This would eliminate two jobs when all four saws are operating. In fact, at any one time the maximum number of handlers would be two. Production would not increase but labor cost would go down.

4. Install a more readily readable backguage.

A common metal measuring tape is currently in use. This is hard to read, thereby causing an undue amount of decision time for the operators. One approach is to use a piece of angle iron set behind and parallel to the infeed gauge fence. Magnets may be color-coded red, green, blue or other colors to correspond to a sequence of cuts. When the operator sets the stops, which are also color-coded, on the outfeed gauge fence he sets the magnets up on the angle iron. This simple backgauge reduces the mental gymnastics required of the operator in choosing the combinations of cuttings to utilize the entire board.

## Block Saws #5 and 6

1. Tell the operators to stop filling the block bins so full. (Reduce delay time by 7.0%.)

This was discussed in the work sampling section (p. 24) as a major cause of lost time. There is no need to spend that much time (9.2%) in leveling blocks just to fill a bin to capacity. Time could be better spent in cutting more blocks.

2. Sell one of the block saws.

Since the average utilization of both saws is only 37.7 per cent it should be quite apparent that one saw could do the job, even if production requirements increased by 25 per cent. This would also make available much needed room around the block saw work station.

3. Install a buzzer system to give warning that more cant material is needed or a full block bin needs to be removed. (Reduce delay time by 10.0%.)

When the operator is running low on material or has a full block bin, he could simply press the buzzer. A similar system is working very well at the nailing and U. J. machines.

Currently 17.1 per cent of the operating time, of which a good part is actual waiting time, is spent in moving in cants and moving out blocks. A buzzer system should reduce this to a more reasonable 5 to 10 per cent.

3. Management should give more attention to this operation.

Just because it is not a production bottleneck, it should not be considered unimportant. This was discussed in the work sampling section (page 25). Block cost could be substantially reduced just by looking at this operation in a different light and making a few minor improvements.

## Nailing Machine Operation

1. Discontinue use of Brand X nails--start using Brand Y nails--less expensive nail. (Reduce delay time by 4.0%.)

Most of the nail jamming (2.6%) is the result of poorly machined nails becoming stuck in the feed mechanism. If it is not fixed immediately, the machine does not drive the required number of nails in a pallet. These nails must then be driven in with a hammer. This activity causes a part of the 6.9 per cent repair pallet delay.

2. Establish and maintain thickness control on slat material for nailing machines--at least ± 1/16". (Reduce delay time 5%.)

Material that does not meet this specification should be scheduled for the U. J. machines or other operations where thickness variation is not so critical. If this is not possible Spring Arbor's management should investigate the possibility of planing some of the lumber or working with their suppliers more closely.

3. Add a third man to the crew when making two-sided pallets with less than four bottom slats. (Would reduce man minutes from 1.52 down to 1.32 minutes on the 34" x 34" pallet time studied [Figure 16, Appendix III].)

The extra man would be placed at the back of the machine. The original two-man crew would push a pallet through the machine after nailing the top slats. They would start another pallet while the third man turned the last one over, nailed the bottom slats on with a nailing gun and stacked it.

Caution should be used in determining when to assign a third man. If the two-man crew can complete the first half of the pallet in less time than the extra man can finish the last half, the extra man will turn out to be a production "bottleneck." This may cause an undesirable increase in total man minutes. The possibility of this occurring is a function of the number of bottom slats and the size (weight) of the pallet.

4. Instruct crews that they are not to stop production when a stack reaches its specified height. (Reduce delay time by 1.4%.)

There is ample room to start another stack until the lift truck removes the full one. Actually, there is enough room to have two stacks at the same time.

## Block Pallet Assembly Operation

1. Change the work method of the two crews. (Decrease cycle time by 15.8%--increase productivity of nail crew 27.1%.)

The effect of this on pallet-H has already been discussed. Since the majority of the block pallets are similar in design their cycle times will be reduced proportionally.

2. Alter the procedure of tossing blocks from the bin onto the table. (Reduce delay time by 5%.)

Instead of using four men for this task use only two. Throw up only fifty or so blocks at a time instead of tossing up as many blocks as possible (presently 200 plus). It is impossible to exactly balance the work load of the two crews, therefore, one of the crews will have some idle time during which they can toss blocks up. With fewer blocks on the table at any one time there will be less trouble with positioning them in the jig.

Another possibility is to have one man throw up blocks for all four tables. He would travel from table to table tossing fifty plus blocks up on each table. This may work out very well using only part-time employees. With this procedure the nail and lay up crews could spend the majority of their time making pallets.

3. Instruct the men in the importance of good nailing procedures. (Reduce delay time by 2.0%.)

Most of the 4.2 per cent repair pallet delay is a result of "sloppy" use of the air nailing guns. As a result nails are not driven completely into the wood and must be driven down with hammers. This problem could be lessened if the nail crew would take more care in using the air guns. Some of the block splitting would also be reduced.

## Wire Stapling Operation

1. When making panels with more than six boards (slats) a four-man crew may reduce panel cost. Use three men on all other panels.

The operator "waiting" on the lay up man varies from almost zero to considerably more than 12.7 per cent depending on the panel. It was noted during the work sampling study that this delay was small when panels with less than six boards or block pallet tops were being made.

Although no specific data were taken on four-man crews, it was observed that each man spent a lot of time waiting for a jig. Four jigs instead of three should be used to reduce this delay.

When three-man crews are used, it may be better to position the lay up man and slat material in the general area of the off-bearer. They both could assist each other in placing slats and runners in the jig. Jigs would then be pushed to the other end of the table within reach of the operator.

One basic time relationship must be satisfied before assigning four men to this operation. The cycle time per panel must be reduced by more than 25 per cent before a four-man crew would reduce the cost of a panel. The total man minutes per panel for both crew sizes must be known then before making a final decision. Just because the operator is waiting does not mean that a fourth man would always be better.

2. Train the operators in a new method of handling the "out of wire" situation. (Reduce delay time by 2.0%.)

At the present time all of the wire on a spool is used before a new one is installed. The new spool must then be partly rolled out and fed into the staple forming heads. The operators should stop production before a roll is completely used up. Then, by installing a new spool and splicing the ends together it would feed itself through the heads. The splicing would have to be done in such a way as to allow the splice to go through the heads without binding up. Some type of thin metal collar that could be crimped at both ends would do the job.

Larger wire spools should be purchased. This would also reduce the "out of wire" delay because each spool would last longer.

General to the Firm

1. Establish some type of wage incentive program.

General effort rates or employee motivation are below average based on experience from observing other plants. It is felt that a wage incentive program that would directly award an employee for harder than normal work would greatly reduce their direct labor to sales cost ratio.

2. Set up a formal training program for cut-off saw operators.

Such a program, for example, could cover end trimming procedures, how to use a backgauge, and how much defect of what types should be removed from boards. All of the lumber that Spring Arbor purchases is processed on this operation. Therefore, the saw operators can have a great effect upon the total cost picture, they can "make or break" a pallet plant. For this reason it is felt that a formal training program would reap many benefits.

3. Establish "safe" indoor smoking facilities.

This suggestion really needs no further discussion.

4. Effort should be made in using full-time employees as machine operators. A real serious look should be taken at the advantages and disadvantages of using part-time help.

# PART V

# CONCLUSIONS

Four operations (thirteen work stations) have been described and analyzed according to limited objectives. Specific problem areas have been pointed out and suggestions for improvement made. The majority of the suggestions deal only with method changes which involve no capital expenditures. Therefore, percentage decreases in delay time sufficiently justify making the suggested changes. These are given where applicable in Part IV.

One objective of this report was to use a portable video tape recorder (VTR) for time study work and comment on its performance. By using a VTR some insight has been acquired into its value as "a new industrial engineering tool."

The majority of time study information reported on was obtained from video tape analysis. It is basically the same as could have been extracted from standard movie film analysis. But, one real advantage of using VTR instead of a movie camera was direct cost. A total of eight hours of video tape was used. Cost of the tape was $320 ($40/one hour reel of tape). It would have taken 120-100 foot rools of 16 MM film to make eight hours of motion pictures. This would have cost $1050 for film and developing ($8.75/roll-black and white, filmed at sixteen frames per second). The video tape is reusable and the film is not which gives an even better cost advantage for VTR.

The initial cost of a VTR system is higher than a 16 MM motion picture system. But, as illustrated above, savings in film cost alone would pay for the VTR in a short time.

Ease of operation and convenience are two other "plus" factors for the VTR. It can be set up and operating in less than ten minutes. With the use of a monitor there is very little chance of ever making a mistake in exposure settings or failing to get on tape exactly what is wanted. If one is not satisfied he can simply erase the tape and record the activity over again. With movie film one has to wait until it is developed before determining if a mistake has been made. If one has been made, the equipment must be set up again and the activity re-filmed.

With VTR less attention has to be given to lighting problems in a plant. The subjects can be in a poorly lighted area and still be video taped without the aid of floodlights.

Elemental times of 0.01 minutes were easy to obtain with the VTR used in this study. Shorter elements could be timed with film analysis but this is unnecessary unless a very detailed (micromotion) time study is desired.

The method used to obtain time data from the tapes was crude when one considers all of the sophisticated equipment that has been designed specifically for time analysis of motion picture film. Video recorders were not designed specifically for work study. Just recently they have been applied in that regard, therefore, little attention has been given to designing time measuring equipment for VTR time study work.

Compared with conventional stop watch time study VTR also has definite advantages. More attention can be given to accuracy and the breakdown of elements when an operation is analyzed in the laboratory. If mistakes are made or elements are missed the tape can be re-run. If an element is missed in the plant with the stop watch one must wait until it re-occurs.

When more than one man is working at an operation each person must be time studied separately. On an operation like the block nailing tables, this would mean that each crew's cycle times would be computed for different pallets. By putting the operation on video tape each crew's cycle times are computed for the same pallets. Therefore, work interrelationships between crews or workers can be more accurately determined with fewer cycles. Also, less time is needed in the plant gathering the time study data. There is always the possibility of using a time study engineer for each worker, but this increases the cost considerably.

There are numerous applications for VTR in the field of industrial engineering besides time study. Its use in employee training probably represents the most attractive one at this time. VTR training tapes can be produced in less time than films primarily due to the shortening of the planning phase. Tape cost is lower than film by a 3.29 factor (one minute of film cost 3.29 times as much as one minute of tape).

VTR training can be used for a wide range of purposes such as guidance in standard work methods, training new employees, explanation of principles and handling of production machines, and training in correct safety procedures.

No specific statement can be made as to who should buy or use a VTR system. It depends completely upon the individual situation and the needs of the people considering its purchase. One thing is certain. With further research and development of VTR's, they will eventually replace the motion picture camera as a work study tool.

A secondary objective of this report, beyond satisfying the requirements for a Master of Science Degree, has been to demonstrate to Spring Arbor Industries and other pallet firms the value of work study analysis. The intent is to provide this company with "facts and figures" about specific opportunities for improvement.

Many small firms in the forest products industry simply have no basis other than personal opinion to guide them in making management decisions. This is usually due to their lack of knowledge of work study principles and of the savings that can be realized with better work methods. Related to this is their belief that, due to low profit margins, they cannot afford to pay for professional help. The tragedy of this reasoning is that they actually cannot afford not to get help.

For example, Spring Arbor Industries annual sales is around $1,000,000. Direct labor cost for the whole plant is 32 per cent of sales or $320,000. If delay time on all operations in the plant was reduced an average of 5 per cent, the direct labor cost would be reduced by $16,000. This is assuming that the number of units sold remains constant, therefore, the total hours needed to produce the units would be reduced. If the market would absorb increased production, the $16,000 would increase by the amount of profit that would be made on the extra production. Therefore, the $16,000 increased profit is a fairly conservative estimate, especially when one considers that the average delay time reduction on the four operations is well over 5 per cent. It should be quite apparent from this example that Spring Arbor, and many other pallet plants in Michigan for that matter, could easily pay for the services of at least one Industrial Engineer.

In conclusion, it is the opinion of the writer that if plant managers would apply work study techniques in their plants (work sampling in particular) the characteristically low profit margins in pallet plants would be a thing of the past.

# BIBLIOGRAPHY

# BIBLIOGRAPHY


1. Baldwin, W. C. 1968. "Pallets from Low Grade Hardwoods," Forest Products Journal, XVIII (March, 1968), 11-13.

2. Barnes, Ralph M. 1931. Industrial Engineering and Management. New York and London: McGraw-Hill Book Co. 366 pp.

3. ________. 1957. Work Sampling. New York: John Wiley & Sons, Inc. 283 pp.

4. ________. 1958. Motion and Time Study. New York: John Wiley & Sons, Inc. 655 pp.

5. Bowyer, James. 1966. "An Analysis of a Pallet Manufacturing Process." Unpublished Master's thesis, Michigan State University.

6. Currie, R. M. 1959. Work Study. London: Sir Isaac Pitman & Sons, Ltd. 232 pp.

7. Heebink, Thomas B. and Fobes, Eugene W. 1958. "Hardwood Pallet Manufacturing," U. S. Forest Service, Forest Products Laboratory Report No. 2132. 32 pp.

8. Keppler, William E., Huxster, William T. and Dyson, Peter J. 1962. "Work Measurements," North Carolina State University Agr. Ext. Service Report. 35 pp.

9. Koch, Peter. 1964. "Using Low-Grade Hardwood--A Proposed Integrated Plant Design," Michigan State University Cooperative Extension Service Bulletin No. 460. 28 pp.

10. Maynard, H. B. (Ed.). 1963. Industrial Engineering Handbook. New York, Toronto and London: McGraw-Hill Book Co. 1699 pp.

11. Niebel, Benjamin W. 1955. Motion and Time Study. Homewood, Illinois: Richard D. Irwin, Inc. 433 pp.

12. Sakuma, Akiyuki. 1966. "A New Industrial Engineering Tool: The Use of the Video Tape Recorder," The Journal of Industrial Engineering, XVII (June, 1966), 209-216.

13. Weiler, H. D. 1966. "Art of Video Recording and Its Pioneers," Audio, L (February, 1966), 39-41.

14. ________. 1966. "Application for Video Recording and Closed Circuit TV," Audio, L (December, 1966), 60-61.

15. Wheeler, Edwin Y., Harold, Monte R. and Wylie, Aubrey E. 1967. "Animal and Poultry Bedding from Residues of Primary Wood Conversion," Michigan State University Agr. Experiment Station Report 60. 12 pp.

APPENDICES

## APPENDIX I

## WORK SAMPLING REPORTS

## Work Sampling

### Presentation of Data

As described in Part II, periodic observations were made at thirteen work stations in an attempt to determine the use of time in an average work day. On the cut-off saws and U. J. machines only the operators were observed--they were considered the "key" as to what activity was occurring. The two-man crews on each nailing machine were observed as one unit. The nail crew and lay up crew on each block nailing table were also observed as one unit.

Sampling was done for eight days spaced over the period from February 12, 1968, to April 17, 1968. Raw data were converted to percentage figures for the first day and accumulated daily into running average charts (Tables 8 through 23). Under the eighth day column are estimates of the amount of time each work station was attended by an operator or crew and the proportion of the attended time given to various tasks. The per cent of time sums may not come out to exactly 100 per cent because of rounding errors.

Accuracy of Data

In any work sampling study there is always the question of how many observations to take. The purpose of a study will suggest the degree of accuracy desired and therefore the number of observations needed. There should be a balance between the accuracy desired and the economics (time) involved in taking a large sample.

The purpose of work sampling in this report is to define areas for improvement. No attempt is made to statistically justify any of these data.

It was decided in advance of the study that an accumulated (running) average chart would be employed to serve as a guide for determining the sample size. When the accumulated average per cent occurrence of a given activity (element) varied less than ± 2 per cent it was assumed that enough samples had been taken. For example, the normal cycle element in Table 8 ranges from 72 per cent to 74 per cent over the last four days of study and appears to level off at 74 per cent. Realistically speaking the eighth day of observations added very little value to the study.

## Description of Work Sampling Elements

### Elements Common to All Operations

Normal Cycle.--This includes all normal (productive) work that is carried on at a particular work station. At the cut-off saws and U. J. machines the operator is observed; he is the "key" as to what is happening at the work station. At the nailing machines and block nailing tables each two-man crew is considered as one person or unit.

Both men in a crew must be non-productive before the crew is considered non-productive. For example, if one man is working and the other waiting, the crew is observed as working. This holds for all elements.

Setting Up.--This includes all work that is necessary to change over what is being produced at a given operation. Such tasks as moving in new material, changing jigs, resetting machines, etc., fall into this element.

Receive Instructions.--This element occurs when an operation or crew is non-productive because someone with authority is giving them oral or written instructions.

Personal.--When an operation is non-productive or delayed because one or more men is (are) getting a drink,

going to the restroom, etc. If the personal time does not disrupt the productivity of a given operation, it is not recorded as personal time.

Idle-Avoidable.--This basically involves loafing by an operator or crew member when it causes an operation to be non-productive.

Miscellaneous.--This includes various unimportant elements that occur sporatically and infrequently such as talking, walking, etc.

Not Operate.--When a particular operation is idle because of no crew or no work to be done.

## Elements Specific to An Operation

Cut-off Saws #1, 2, 3 and 4

Wait on Handler.--When the operator can not complete his next task because of the handler being behind in his work.

Wait on Off-Bearer.--When the operator can not complete his next task because of the off-bearer being behind in his work. This usually occurs when the off-bearer gets behind in stacking and sorting the boards. Before the operator cuts another board, he waits for the off-bearer to return to his station.

Move in Lumber.--Includes all the time that a cut-off saw is out of material (lumber). At least the three-man crew at a saw and sometimes up to six or seven men are involved in pushing the empty cart out and pushing in another load. Production is assumed to begin when the operator starts up his saw again.

Move Out Boards.--This is similar to the Move in Lumber element except here a full pallet or cart of processed boards is removed from the work station and a new one placed in.

Cut-off Saws #5 and 6

Move In Cants.--The period of time from when the operation is out of cant material to when a new cart of cants is rolled in and the operation is back to a normal cycle. This includes waiting for the cants to be delivered from storage when applicable.

Clean Up Station.--Time spent by the operator sweeping and doing general clean up work around the cut-off saw. This is normally done when block production is caught up.

Move Out Blocks.--Includes the time from when the operator stops cutting blocks because of a full storage bin (box) until it is replaced with an empty one and production is back to normal.

Level Blocks.--When the block storage bin is almost full the blocks pile up and start falling onto the floor. The operator stops production and levels out the pile so more blocks can be added.

U. J. Machines #1 and 2

Move Material In.--Includes all the time from when the operation is out of material until new material is moved in and production back to normal.

Move Material Out.--The finished products (pallet tops, box sides, etc.) are stacked to a specified height or number. If the stack is not removed immediately the crew stops work until it is.

Wait on Lay Up Man.--When the operator is idle because the lay up man is behind in his work.

Wait on Off-Bearer.--When the operator is idle because the off-bearer has not removed the finished assembly from the machine.

Out of Wire.--This includes all lost time due to changing an empty wire spool.

Nailing Machines #1 and 2

Move Material In.--Same as U. J. Machines #1 and 2.

Move Pallets Out.--The finished pallets are stacked to a specified height or number. If the stack is not removed immediately the crew stops work until it is.

Repair Pallets.--One or both crew members use a hammer to drive in nails not driven all the way in or missed by the nailing machine. Normal production stops during this time.

Adjust Machine.--This is lost time due to the operator making minor adjustments on the nailing machine such as table height. It has nothing to do with the setting up element.

Nail Jam.--Lost production due to nails jamming in nail tracks or nail feed heads. The operator must climb up on machine and unjam it. If it is not unjammed nails will be missing causing the Repair Pallet element to occur.

Fill Nail Hopper.--Lost time due to dumping more nails into the hopper.

Block Nailing Tables
#1, 2 and 3 (Lay up
Crew)

Move Out Pallets.--When the finished block pallet stack is at a certain height (given number of pallets) production stops until this stack is removed. All lay up crew lost time because of this occurrence is included under this element.

Wait on Nail Crew.--This occurs when the lay up crew is waiting on the nail crew to complete its task.

Lay Up Blocks.--Production stops when there are no more blocks on the nailing table (inside the jig). All four men at a table toss up and place blocks in the jig from the block storage bin located at the end of the table. This element consists of the time necessary to complete this task.

Repair Pallet.--This consists of re-nailing slats to blocks or driving down nails that are not flush with the wood. Hammers located on the table are usually used. All four men stop production but usually only two men are actively involved in making the repair.

Block Nailing Tables
#1, 2 and 3 (Nail
Crew)

Move Out Pallets.--Same as the lay up crew Move Out Pallets element. Again, all four men (both crews) are idle during this time.

Wait on Lay Up Crew.--The nail crew must wait until the lay up crew lays out the slats before they can nail. This idle time is included under this element.

Lay Up Blocks.--Same as lay up crew Lay up Blocks.

Repair Pallets.--Same as lay up crew Repair Pallets. Most often the nail crew is actively involved making the repair.

TABLE 8.--Running average chart--cut-off saw #1 (operator).

| Elements | Day | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First | | Second | | Third | | Fourth | | Fifth | | Sixth | | Seventh | | Eighth | |
| | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time |
| Normal Cycle | 16 | 84 | 44 | 77 | 81 | 70 | 97 | 71 | 111 | 72 | 127 | 73 | 140 | 74 | 179 | 74 |
| Setting Up | -- | -- | 1 | 2 | 5 | 4 | 5 | 4 | 6 | 4 | 6 | 3 | 6 | 3 | 9 | 4 |
| Move in Lumber | -- | -- | 2 | 3 | 9 | 8 | 11 | 8 | 12 | 8 | 13 | 7 | 13 | 7 | 15 | 6 |
| Move out Boards | 1 | 5 | 3 | 5 | 7 | 6 | 8 | 6 | 10 | 6 | 11 | 6 | 11 | 6 | 14 | 6 |
| Wait on Handler | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 1 | 1 | <1 |
| Wait on Off-Bearer | -- | -- | 2 | 3 | 5 | 4 | 7 | 5 | 7 | 5 | 8 | 5 | 9 | 5 | 11 | 5 |
| Receive Instructions | -- | -- | -- | -- | 2 | 2 | 3 | 2 | 3 | 2 | 4 | 2 | 4 | 2 | 4 | 2 |
| Personal | -- | -- | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 |
| Idle-Avoidable | 2 | 11 | 4 | 7 | 4 | 3 | 4 | 3 | 4 | 3 | 4 | 2 | 4 | 2 | 4 | 2 |
| Miscellaneous | -- | -- | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | <1 |
| Operate Total | 19 | 76 | 61 | 91 | 115 | 95 | 137 | 96 | 155 | 79 | 175 | 81 | 190 | 71 | 240 | 75 |
| Not Operate | 6 | | 6 | | 6 | | 6 | | 42 | | 42 | | 79 | | 79 | |
| Total | 25 | | 67 | | 121 | | 143 | | 197 | | 217 | | 269 | | 319 | |

TABLE 9.--Running average chart--cut-off saw #2 (operator).

| Elements | Day | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First | | Second | | Third | | Fourth | | Fifth | | Sixth | | Seventh | | Eighth | |
| | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time |
| Normal Cycle | -- | -- | -- | -- | 28 | 76 | 46 | 79 | 83 | 74 | 83 | 74 | 113 | 72 | 128 | 73 |
| Setting Up | -- | -- | -- | -- | 2 | 5 | 2 | 3 | 4 | 4 | 4 | 4 | 4 | 3 | 5 | 3 |
| Move in Lumber | -- | -- | -- | -- | 3 | 8 | 3 | 5 | 7 | 6 | 7 | 6 | 12 | 8 | 13 | 7 |
| Move out Boards | -- | -- | -- | -- | -- | -- | 2 | 3 | 5 | 4 | 5 | 4 | 5 | 3 | 7 | 4 |
| Wait on Handler | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 1 | 1 | <1 |
| Wait on Off-Bearer | -- | -- | -- | -- | 3 | 8 | 4 | 7 | 7 | 6 | 7 | 6 | 11 | 7 | 12 | 7 |
| Receive Instructions | -- | -- | -- | -- | -- | -- | -- | -- | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 1 |
| Personal | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 1 | 1 | 1 | 3 | 2 | 3 | 2 |
| Idle-Avoidable | -- | -- | -- | -- | 1 | 3 | 1 | 2 | 2 | 2 | 2 | 2 | 3 | 2 | 3 | 2 |
| Miscellaneous | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 |
| Operate Total | -- | 0 | -- | 0 | 37 | 31 | 58 | 41 | 112 | 57 | 112 | 52 | 156 | 58 | 176 | 55 |
| Not Operate | 25 | | 67 | | 84 | | 84 | | 84 | | 104 | | 112 | | 142 | |
| Total | 25 | | 67 | | 121 | | 142 | | 196 | | 216 | | 268 | | 318 | |

TABLE 10.--Running average chart--cut-off saw #3 (operator).

| Elements | Day | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First | | Second | | Third | | Fourth | | Fifth | | Sixth | | Seventh | | Eighth | |
| | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time |
| Normal Cycle | 13 | 68 | 27 | 69 | 39 | 70 | 39 | 70 | 41 | 68 | 51 | 64 | 55 | 63 | 55 | 63 |
| Setting Up | -- | -- | 1 | 3 | 1 | 2 | 1 | 2 | 2 | 3 | 2 | 2 | 4 | 5 | 4 | 5 |
| Move in Lumber | 1 | 5 | 1 | 3 | 2 | 4 | 2 | 4 | 3 | 5 | 5 | 6 | 5 | 6 | 5 | 6 |
| Move out Boards | 2 | 11 | 2 | 5 | 2 | 4 | 2 | 4 | 2 | 3 | 4 | 5 | 4 | 5 | 4 | 5 |
| Wait on Handler | 1 | 5 | 1 | 3 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| Wait on Off-Bearer | 2 | 11 | 7 | 18 | 10 | 18 | 10 | 18 | 10 | 17 | 13 | 16 | 14 | 16 | 14 | 16 |
| Receive Instructions | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Personal | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 1 | 1 | 1 | 1 | 1 |
| Idle-Avoidable | -- | -- | -- | -- | 1 | 2 | 1 | 2 | 1 | 2 | 3 | 4 | 3 | 3 | 3 | 3 |
| Miscellaneous | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Operate Total | 19 | 76 | 39 | 58 | 56 | 46 | 56 | 39 | 60 | 31 | 80 | 37 | 87 | 32 | 87 | 27 |
| Not Operate | 6 | | 28 | | 65 | | 86 | | 136 | | 136 | | 181 | | 231 | |
| Total | 25 | | 67 | | 121 | | 142 | | 196 | | 216 | | 268 | | 318 | |

TABLE 11.--Running average chart.--cut-off saw #4 (operator).

| Elements | Day | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First | | Second | | Third | | Fourth | | Fifth | | Sixth | | Seventh | | Eighth | |
| | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time |
| Normal Cycle | 17 | 81 | 49 | 78 | 85 | 73 | 98 | 71 | 140 | 73 | 153 | 72 | 192 | 73 | 233 | 74 |
| Setting Up | -- | -- | 1 | 2 | 4 | 3 | 4 | 3 | 4 | 2 | 6 | 3 | 6 | 2 | 7 | 2 |
| Move in Lumber | 1 | 5 | 3 | 4 | 6 | 5 | 8 | 6 | 11 | 6 | 13 | 6 | 18 | 7 | 19 | 6 |
| Move out Boards | 1 | 5 | 1 | 2 | 5 | 4 | 6 | 4 | 8 | 4 | 8 | 4 | 8 | 3 | 8 | 3 |
| Wait on Handler | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 1 | 3 | 1 | 3 | 1 | 3 | 1 |
| Wait on Off-Bearer | 2 | 9 | 8 | 13 | 14 | 12 | 19 | 14 | 24 | 13 | 25 | 12 | 32 | 12 | 39 | 12 |
| Receive Instructions | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Personal | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 1 | 1 | <1 | 2 | 1 | 2 | 1 |
| Idle-Avoidable | -- | -- | -- | -- | 2 | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 |
| Miscellaneous | -- | -- | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | <1 | 1 | <1 | 1 | <1 |
| Operate Total | 21 | 84 | 63 | 94 | 117 | 97 | 138 | 97 | 192 | 98 | 212 | 98 | 264 | 99 | 314 | 99 |
| Not Operate | 4 | | 4 | | 4 | | 4 | | 4 | | 4 | | 4 | | 4 | |
| Total | 25 | | 67 | | 121 | | 142 | | 196 | | 216 | | 268 | | 318 | |

TABLE 12.--Running average chart--block cut-off saw #5 (operator).

| Elements | Day | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First | | Second | | Third | | Fourth | | Fifth | | Sixth | | Seventh | | Eighth | |
| | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time |
| Normal Cycle | 14 | 64 | 28 | 60 | 38 | 58 | 50 | 59 | 71 | 58 | 86 | 60 | 108 | 60 | 124 | 60 |
| Setting Up | 1 | 5 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 2 | 4 | 2 |
| Move in Cants | 2 | 9 | 5 | 11 | 5 | 8 | 7 | 8 | 9 | 7 | 12 | 8 | 17 | 9 | 20 | 10 |
| Move out Blocks | 2 | 9 | 3 | 7 | 6 | 9 | 10 | 11 | 16 | 13 | 17 | 12 | 17 | 9 | 18 | 9 |
| Level Blocks | -- | -- | 5 | 11 | 6 | 9 | 6 | 7 | 12 | 10 | 12 | 8 | 16 | 9 | 20 | 10 |
| Receive Instructions | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Clean up Station | 2 | 9 | 3 | 7 | 5 | 8 | 5 | 6 | 7 | 6 | 7 | 5 | 8 | 4 | 8 | 4 |
| Idle-Avoidable | -- | -- | -- | -- | 2 | 3 | 3 | 4 | 3 | 2 | 4 | 3 | 5 | 3 | 5 | 2 |
| Personal | 1 | 5 | 2 | 4 | 2 | 3 | 3 | 4 | 4 | 3 | 4 | 3 | 5 | 3 | 7 | 3 |
| Miscellaneous | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 1 | 2 | 1 |
| Operate Total | 22 | 88 | 47 | 70 | 65 | 54 | 85 | 60 | 123 | 63 | 143 | 66 | 180 | 67 | 208 | 65 |
| Not Operate | 3 | | 20 | | 56 | | 57 | | 73 | | 73 | | 88 | | 110 | |
| Total | 25 | | 67 | | 121 | | 142 | | 196 | | 216 | | 268 | | 318 | |

TABLE 13.--Running average chart--block cut-off saw #6 (operator).

| Elements | Day | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First | | Second | | Third | | Fourth | | Fifth | | Sixth | | Seventh | | Eighth | |
| | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time |
| Normal Cycle | 2 | 25 | 7 | 50 | 7 | 41 | 7 | 41 | 12 | 52 | 12 | 52 | 19 | 59 | 19 | 59 |
| Setting Up | 2 | 25 | 2 | 14 | 2 | 12 | 2 | 12 | 2 | 9 | 2 | 9 | 2 | 6 | 2 | 6 |
| Move in Cants | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Move out Blocks | 1 | 12 | 2 | 14 | 3 | 17 | 3 | 17 | 3 | 13 | 3 | 13 | 3 | 9 | 3 | 9 |
| Level Blocks | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2 | 6 | 2 | 6 |
| Receive Instructions | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 4 | 1 | 4 | 1 | 3 | 1 | 3 |
| Clean up Station | 1 | 13 | 1 | 8 | 3 | 17 | 3 | 17 | 3 | 13 | 3 | 13 | 3 | 9 | 3 | 9 |
| Idle-Avoidable | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Personal | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Miscellaneous | 2 | 25 | 2 | 14 | 2 | 13 | 2 | 13 | 2 | 9 | 2 | 9 | 2 | 6 | 2 | 6 |
| Operate Total | 8 | 32 | 14 | 21 | 17 | 14 | 17 | 12 | 23 | 12 | 23 | 11 | 32 | 12 | 32 | 10 |
| Not Operate | 17 | | 53 | | 104 | | 125 | | 173 | | 193 | | 236 | | 286 | |
| Total | 25 | | 67 | | 121 | | 142 | | 196 | | 216 | | 268 | | 318 | |

TABLE 14.--Running average chart--nailing machine #1 (2-man crew).

| Elements | Day | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First | | Second | | Third | | Fourth | | Fifth | | Sixth | | Seventh | | Eighth | |
| | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time |
| Normal Cycle | 14 | 64 | 45 | 70 | 91 | 76 | 106 | 76 | 137 | 75 | 150 | 74 | 194 | 77 | 233 | 77 |
| Setting Up | -- | -- | 3 | 5 | 4 | 3 | 8 | 6 | 8 | 4 | 8 | 4 | 8 | 3 | 8 | 3 |
| Move Material In | 1 | 4 | 1 | 2 | 3 | 3 | 3 | 2 | 3 | 2 | 4 | 2 | 6 | 2 | 7 | 2 |
| Move Pallets Out | 1 | 5 | 2 | 3 | 3 | 3 | 3 | 2 | 3 | 2 | 3 | 1 | 3 | 1 | 3 | 1 |
| Repair Pallets | 1 | 4 | 4 | 6 | 6 | 5 | 7 | 5 | 11 | 6 | 13 | 6 | 16 | 6 | 20 | 7 |
| Adjust Machine | -- | -- | 1 | 2 | 1 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 3 | 1 | 3 | 1 |
| Nail Jam | -- | -- | 1 | 2 | 2 | 2 | 2 | 1 | 5 | 3 | 6 | 3 | 6 | 2 | 6 | 2 |
| Fill Nail Hopper | -- | -- | -- | -- | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 3 | 1 |
| Receive Instructions | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 |
| Idle-Avoidable | 4 | 18 | 6 | 9 | 6 | 5 | 6 | 4 | 7 | 4 | 9 | 4 | 10 | 4 | 12 | 4 |
| Personal | -- | -- | -- | -- | -- | -- | -- | -- | 2 | 1 | 2 | 2 | 2 | 1 | 4 | 1 |
| Miscellaneous | 1 | 5 | 1 | 2 | 1 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 |
| Operate Total | 22 | 88 | 64 | 96 | 118 | 98 | 140 | 98 | 182 | 92 | 202 | 93 | 253 | 94 | 303 | 95 |
| Not Operate | 3 | | 3 | | 3 | | 3 | | 15 | | 15 | | 16 | | 16 | |
| Total | 25 | | 67 | | 121 | | 143 | | 197 | | 217 | | 269 | | 319 | |

TABLE 15.--Running average chart--nailing machine #2 (2-man crew).

| Elements | Day | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First | | Second | | Third | | Fourth | | Fifth | | Sixth | | Seventh | | Eighth | |
| | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time |
| Normal Cycle | 15 | 65 | 30 | 68 | 58 | 67 | 73 | 68 | 106 | 69 | 119 | 69 | 154 | 69 | 189 | 69 |
| Setting Up | 2 | 9 | 2 | 5 | 7 | 8 | 10 | 9 | 13 | 8 | 13 | 8 | 13 | 6 | 13 | 5 |
| Move Material In | -- | -- | -- | -- | 2 | 2 | 3 | 3 | 3 | 2 | 3 | 2 | 6 | 3 | 7 | 3 |
| Move Pallets Out | -- | -- | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 4 | 2 | 4 | 2 | 5 | 2 |
| Repair Pallets | 1 | 4 | 3 | 7 | 5 | 6 | 5 | 5 | 8 | 5 | 10 | 6 | 15 | 7 | 20 | 7 |
| Adjust Machine | 3 | 13 | 5 | 11 | 7 | 8 | 7 | 6 | 8 | 5 | 8 | 5 | 8 | 4 | 8 | 3 |
| Nail Jam | -- | -- | -- | -- | -- | -- | 2 | 2 | 3 | 2 | 3 | 2 | 7 | 3 | 9 | 3 |
| Fill Nail Hopper | -- | -- | -- | -- | 1 | 2 | 1 | 1 | 3 | 2 | 3 | 2 | 4 | 2 | 4 | 1 |
| Receive Instructions | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Idle Avoidable | 1 | 4 | 2 | 4 | 2 | 2 | 3 | 3 | 5 | 3 | 5 | 3 | 8 | 4 | 13 | 5 |
| Personal | 1 | 5 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 3 | 1 |
| Miscellaneous | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 |
| Operate Total | 23 | 92 | 44 | 66 | 86 | 71 | 108 | 76 | 154 | 78 | 171 | 79 | 223 | 83 | 273 | 86 |
| Not Operate | 2 | | 23 | | 35 | | 35 | | 43 | | 45 | | 45 | | 45 | |
| Total | 25 | | 67 | | 121 | | 143 | | 197 | | 216 | | 268 | | 318 | |

TABLE 16.--Running average chart--block nailing table #1 (nail crew).

| Elements | Day | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First | | Second | | Third | | Fourth | | Fifth | | Sixth | | Seventh | | Eighth | |
| | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time |
| Normal Cycle | 10 | 40 | 30 | 45 | 45 | 49 | 54 | 47 | 54 | 46 | 64 | 46 | 94 | 50 | 121 | 51 |
| Setting Up | 1 | 8 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 4 | 2 |
| Move out Pallets | 1 | 8 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | <1 |
| Wait on Lay Up Crew | 10 | 40 | 23 | 34 | 28 | 30 | 34 | 30 | 37 | 31 | 45 | 33 | 56 | 30 | 68 | 29 |
| Lay Up Blocks | 1 | 8 | 7 | 10 | 10 | 11 | 14 | 12 | 14 | 12 | 16 | 12 | 21 | 11 | 27 | 11 |
| Repair Pallet | 1 | 8 | 3 | 4 | 3 | 3 | 6 | 5 | 6 | 5 | 6 | 4 | 8 | 4 | 10 | 4 |
| Receive Instructions | 1 | 8 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 |
| Idle-Avoidable | -- | -- | -- | -- | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 2 | 1 |
| Personal | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | <1 |
| Miscellaneous | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 1 | 1 | 1 | 1 | 1 | 1 | <1 |
| Operate Total | 25 | 100 | 67 | 100 | 92 | 84 | 114 | 86 | 118 | 63 | 138 | 67 | 187 | 72 | 237 | 77 |
| Not Operate | -- | | -- | | 18 | | 18 | | 68 | | 68 | | 71 | | 71 | |
| Total | 25 | | 67 | | 110 | | 132 | | 186 | | 206 | | 258 | | 308 | |

TABLE 17.--Running average chart--block nailing table lay up crew #1.

| Elements | Day | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First | | Second | | Third | | Fourth | | Fifth | | Sixth | | Seventh | | Eighth | |
| | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time |
| Normal Cycle | 18 | 72 | 45 | 67 | 64 | 70 | 81 | 72 | 84 | 71 | 100 | 72 | 141 | 75 | 181 | 76 |
| Setting Up | -- | -- | 2 | 3 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 2 | 1 | 5 | 2 |
| Move Out Pallets | -- | -- | 2 | 3 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 3 | 2 | 3 | 1 |
| Wait on Nail Crew | 1 | 4 | 4 | 6 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 3 | 4 | 2 | 4 | 2 |
| Lay up Blocks | 1 | 4 | 6 | 9 | 9 | 10 | 13 | 12 | 13 | 11 | 15 | 11 | 21 | 11 | 24 | 10 |
| Repair Pallet | 1 | 4 | 2 | 3 | 2 | 2 | 3 | 3 | 4 | 3 | 4 | 3 | 5 | 3 | 7 | 3 |
| Receive Instructions | 1 | 4 | 1 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 2 | 1 | 3 | 1 |
| Idle-Avoidable | 1 | 4 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 3 | 4 | 2 | 5 | 2 |
| Personal | -- | -- | -- | -- | 1 | 2 | 1 | 1 | 1 | 1 | 1 | <1 | 1 | 1 | 1 | <1 |
| Miscellaneous | 2 | 8 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 3 | 4 | 2 | 4 | 2 |
| Operate Total | 25 | 100 | 67 | 100 | 92 | 84 | 114 | 86 | 118 | 63 | 138 | 67 | 187 | 72 | 237 | 77 |
| Not Operate | -- | | -- | | 18 | | 18 | | 68 | | 68 | | 71 | | 71 | |
| Total | 25 | | 67 | | 110 | | 132 | | 186 | | 206 | | 258 | | 308 | |

TABLE 18.--Running average chart--block nailing table nail crew #2.

| Elements | Day | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First | | Second | | Third | | Fourth | | Fifth | | Sixth | | Seventh | | Eighth | |
| | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time |
| Normal Cycle | 16 | 64 | 41 | 61 | 58 | 59 | Not Making Block Pallets | | 93 | 61 | 97 | 60 | 128 | 60 | 149 | 59 |
| Setting Up | -- | -- | -- | -- | 2 | 2 | | | 2 | 1 | 3 | 2 | 3 | 1 | 3 | 1 |
| Move Out Pallets | 1 | 4 | 2 | 3 | 2 | 2 | | | 2 | 1 | 2 | 1 | 3 | 1 | 3 | 1 |
| Wait on Lay Up Crew | 5 | 20 | 16 | 24 | 24 | 24 | | | 35 | 23 | 37 | 23 | 50 | 23 | 59 | 23 |
| Lay Up Blocks | 3 | 12 | 6 | 9 | 8 | 8 | | | 14 | 9 | 15 | 9 | 19 | 9 | 26 | 10 |
| Repair Pallet | -- | -- | 2 | 3 | 4 | 4 | | | 6 | 4 | 6 | 4 | 8 | 4 | 10 | 4 |
| Receive Instructions | -- | -- | -- | -- | -- | -- | | | -- | -- | -- | -- | -- | -- | -- | -- |
| Idle-Avoidable | -- | -- | -- | -- | -- | -- | | | -- | -- | -- | -- | 1 | <1 | 2 | 1 |
| Personal | -- | -- | -- | -- | 1 | 1 | | | 1 | 1 | 1 | 1 | 1 | <1 | 2 | 1 |
| Miscellaneous | -- | -- | -- | -- | -- | -- | | | -- | -- | -- | -- | -- | -- | -- | -- |
| Operate Total | 25 | 100 | 67 | 100 | 99 | 100 | 99 | 100 | 153 | 100 | 161 | 100 | 213 | 100 | 254 | 99 |
| Not Operate | -- | | -- | | -- | | -- | | -- | | -- | | -- | | 3 | |
| Total | 25 | | 67 | | 99 | | 99 | | 153 | | 161 | | 213 | | 257 | |

TABLE 19.--Running average chart--block nailing table lay up crew #2.

| Elements | Day | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First | | Second | | Third | | Fourth | | Fifth | | Sixth | | Seventh | | Eighth | |
| | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time |
| Normal Cycle | 22 | 88 | 54 | 81 | 78 | 79 | Not Making Block Pallets | | 123 | 80 | 129 | 80 | 172 | 81 | 204 | 80 |
| Setting Up | -- | -- | -- | -- | -- | -- | | | -- | -- | 1 | 1 | 1 | <1 | 1 | <1 |
| Move Out Pallets | 1 | 4 | 2 | 3 | 2 | 2 | | | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 |
| Wait on Nail Crew | -- | -- | -- | -- | -- | -- | | | 2 | 1 | 2 | 1 | 3 | 1 | 5 | 2 |
| Lay Up Blocks | 2 | 8 | 6 | 9 | 12 | 12 | | | 19 | 12 | 19 | 12 | 24 | 11 | 30 | 12 |
| Repair Pallet | -- | -- | 2 | 3 | 2 | 2 | | | 2 | 1 | 2 | 1 | 3 | 1 | 3 | 1 |
| Receive Instructions | -- | -- | -- | -- | -- | -- | | | -- | -- | -- | -- | -- | -- | 1 | <1 |
| Idle-Avoidable | -- | -- | 2 | 3 | 2 | 2 | | | 2 | 1 | 2 | 1 | 3 | 1 | 3 | 1 |
| Personal | -- | -- | -- | -- | 2 | 2 | | | 2 | 1 | 3 | 2 | 3 | 1 | 3 | 1 |
| Miscellaneous | -- | -- | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 |
| Operate Total | 25 | 100 | 67 | 100 | 99 | 100 | 99 | 100 | 153 | 100 | 161 | 100 | 213 | 100 | 254 | 99 |
| Not Operate | -- | | -- | | -- | | -- | | -- | | -- | | -- | | 3 | |
| Total | 25 | | 67 | | 99 | | 99 | | 153 | | 161 | | 213 | | 257 | |

TABLE 20.--Running average chart--block nailing table nail crew #3.

| Elements | Day | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First | | Second | | Third | | Fourth | | Fifth | | Sixth | | Seventh | | Eighth | |
| | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time |
| Normal Cycle | 10 | 40 | 15 | 40 | 41 | 45 | 53 | 47 | 85 | 53 | 95 | 52 | 111 | 51 | 136 | 51 |
| Setting Up | 1 | 4 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 3 | 2 | 3 | 1 | 5 | 2 |
| Move Out Pallets | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Wait on Lay Up Crew | 9 | 36 | 14 | 37 | 31 | 33 | 36 | 32 | 46 | 29 | 53 | 29 | 64 | 29 | 78 | 29 |
| Lay Up Blocks | 4 | 16 | 4 | 11 | 10 | 11 | 11 | 10 | 16 | 10 | 18 | 10 | 26 | 12 | 33 | 12 |
| Repair Pallet | -- | -- | 2 | 5 | 6 | 7 | 9 | 8 | 9 | 6 | 9 | 5 | 11 | 5 | 12 | 5 |
| Receive Instructions | 1 | 4 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 |
| Idle-Avoidable | -- | -- | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | <1 |
| Personal | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 1 | 1 | 1 | 1 | 1 | 1 | <1 |
| Miscellaneous | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Operate Total | 25 | 100 | 38 | 63 | 92 | 81 | 113 | 84 | 161 | 85 | 181 | 87 | 218 | 87 | 268 | 89 |
| Not Operate | -- | | 22 | | 22 | | 22 | | 28 | | 28 | | 32 | | 32 | |
| Total | 25 | | 60 | | 114 | | 135 | | 189 | | 209 | | 250 | | 300 | |

TABLE 21.--Running average chart--block nailing table lay up crew #3.

| Elements | Day | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First | | Second | | Third | | Fourth | | Fifth | | Sixth | | Seventh | | Eighth | |
| | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time |
| Normal Cycle | 17 | 68 | 28 | 74 | 69 | 75 | 81 | 72 | 121 | 75 | 137 | 27 | 164 | 75 | 202 | 75 |
| Setting Up | 1 | 4 | 1 | 3 | 2 | 2 | 3 | 3 | 3 | 2 | 5 | 3 | 5 | 2 | 5 | 2 |
| Move Out Pallets | -- | -- | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | <1 | 1 | <1 |
| Wait on Nail Crew | 2 | 8 | 2 | 5 | 3 | 3 | 5 | 4 | 5 | 3 | 5 | 3 | 6 | 3 | 6 | 2 |
| Lay Up Blocks | 4 | 16 | 5 | 13 | 13 | 14 | 16 | 14 | 21 | 13 | 22 | 12 | 28 | 13 | 37 | 14 |
| Repair Pallet | -- | -- | -- | -- | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 4 | 2 | 6 | 2 |
| Receive Instructions | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Idle-Avoidable | -- | -- | -- | -- | 1 | 1 | 3 | 3 | 3 | 2 | 4 | 2 | 5 | 2 | 5 | 2 |
| Personal | -- | -- | -- | -- | 1 | 1 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 1 | 3 | 1 |
| Miscellaneous | 1 | 4 | 1 | 3 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 3 | 1 |
| Operate Total | 25 | 100 | 38 | 63 | 92 | 81 | 113 | 84 | 161 | 85 | 181 | 87 | 218 | 87 | 268 | 89 |
| Not Operate | -- | | 22 | | 22 | | 22 | | 28 | | 28 | | 32 | | 32 | |
| Total | 25 | | 60 | | 114 | | 135 | | 189 | | 209 | | 250 | | 300 | |

TABLE 22.--Running average chart--U. J. machine #1 (operator, 3-man crew).

| Elements | Day | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First | | Second | | Third | | Fourth | | Fifth | | Sixth | | Seventh | | Eighth | |
| | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time |
| Normal Cycle | 16 | 67 | 40 | 62 | 61 | 54 | 75 | 56 | No Observations Taken (Two- and Four-Man Crews Working) | | 87 | 56 | 96 | 57 | 125 | 62 |
| Setting Up | -- | -- | 2 | 3 | 7 | 6 | 11 | 8 | | | 16 | 10 | 16 | 10 | 16 | 8 |
| Move Material In | 1 | 3 | 1 | 1 | 7 | 6 | 8 | 6 | | | 9 | 6 | 9 | 5 | 10 | 5 |
| Move Material Out | -- | -- | -- | -- | 2 | 2 | 3 | 2 | | | 3 | 2 | 3 | 2 | 3 | 1 |
| Wait on Lay Up Man | 3 | 13 | 11 | 17 | 14 | 12 | 15 | 11 | | | 15 | 10 | 15 | 9 | 16 | 8 |
| Wait on Off-Bearer | 1 | 4 | 6 | 9 | 9 | 8 | 10 | 7 | | | 11 | 7 | 11 | 7 | 12 | 6 |
| Receive Instructions | -- | -- | -- | -- | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | <1 | 1 | <1 |
| Out of Wire | 3 | 13 | 4 | 5 | 6 | 5 | 6 | 4 | | | 7 | 5 | 7 | 4 | 7 | 3 |
| Idle-Avoidable | -- | -- | 1 | 3 | 3 | 3 | 3 | 2 | | | 3 | 2 | 3 | 2 | 3 | 1 |
| Personal | -- | -- | -- | -- | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | <1 | 2 | 1 |
| Miscellaneous | -- | -- | -- | -- | 2 | 2 | 2 | 2 | | | 2 | 1 | 6 | 4 | 7 | 3 |
| Operate Total | 24 | 96 | 65 | 98 | 113 | 94 | 135 | 95 | | | 155 | 96 | 168 | 79 | 202 | 77 |
| Not Operate | 1 | | 1 | | 7 | | 7 | | | | 7 | | 46 | | 62 | |
| Total | 25 | | 66 | | 120 | | 142 | | | | 162 | | 214 | | 264 | |

TABLE 23.--Running average chart--U. J. machine #2 (operator, 3-man crew).

| Elements | Day | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First | | Second | | Third | | Fourth | | Fifth | | Sixth | | Seventh | | Eighth | |
| | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time | No. of Obs. | % of Time |
| Normal Cycle | 7 | 50 | 27 | 63 | 46 | 58 | 60 | 60 | 91 | 61 | 96 | 61 | 118 | 61 | 143 | 62 |
| Setting Up | -- | -- | 3 | 7 | 13 | 16 | 13 | 13 | 13 | 9 | 13 | 8 | 21 | 11 | 21 | 9 |
| Move Material In | -- | -- | -- | -- | 2 | 3 | 2 | 2 | 6 | 4 | 6 | 4 | 6 | 3 | 7 | 3 |
| Move Material Out | -- | -- | -- | -- | -- | -- | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 1 |
| Wait on Lay Up Man | 7 | 50 | 11 | 26 | 13 | 16 | 17 | 17 | 27 | 18 | 29 | 18 | 32 | 16 | 39 | 17 |
| Wait on Off-Bearer | -- | -- | -- | -- | -- | -- | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 |
| Receive Instructions | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Out of Wire | -- | -- | -- | -- | 1 | 1 | 1 | 1 | 4 | 3 | 4 | 3 | 6 | 3 | 6 | 3 |
| Idle-Avoidable | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 |
| Personal | -- | -- | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 |
| Miscellaneous | -- | -- | 1 | 2 | 3 | 4 | 3 | 3 | 3 | 2 | 3 | 2 | 5 | 2 | 5 | 2 |
| Operate Total | 14 | 56 | 43 | 80 | 79 | 73 | 100 | 78 | 150 | 82 | 157 | 77 | 195 | 76 | 230 | 75 |
| Not Operate | 11 | | 11 | | 29 | | 29 | | 33 | | 46 | | 60 | | 75 | |
| Total | 25 | | 54 | | 108 | | 129 | | 183 | | 203 | | 255 | | 305 | |

# APPENDIX II

# DESCRIPTION OF FOUR OPERATIONS

## Present Methods

### Cut-off Saw Operation

There are six Porter automatic hydracut saws in use at Spring Arbor (Table 24). Four saws (Nos. 1, 2, 3, 4) are located in parallel production lines (Figure 1) and are primarily used for cutting into specified lengths, 2/4", 4/4", 5/4" and 6/4" x W" x L' lumber. Of this, approximately 95 per cent is green crating grade mixed hardwood and 5 per cent No. 3 common spruce. Saws No. 5 and 6 are also located together but separated from the battery of four saws. They are only used for cutting blocks for the block pallet assembly operation. All cant (timber) stock is aspen.

TABLE 24.--Machinery specifications--cut-off saws (Source: in plant observation and manufacturers' specs.)

| | Saws #1,2,3,4 | Block Saws #5,6 |
|---|---|---|
| Porter Model | 43J1-20" stroke length | Same |
| Motor | 7 1/2 H.P. | 10 H. P. |
| Saw Arbor Speed | 3600 RPM | 3480 RPM |
| Saw Blade | 18" Dia.--carbide teeth | Same |
| Height | 55" | Same |
| Miscellaneous | Hand pedal control<br>Metal tape backgauge | Foot pedal control |

Sawlines #1, 2, 3 and 4 are operated by a three-man crew (Figure 8). Basic work methods of the crews are identical. Each crew consists of a lumber handler, operator and off-bearer. The lumber handler unstacks the lumber from a cart, turns the poor side up and places it on the dead roll conveyor within reach of the operator. The operator positions each board for the trim cut and after squaring the end, proceeds to cut it up into specified lengths. Defect and end trim cuttings over four inches in length are tossed into the scrap box. All other trimmings fall into a small box under the dead roll conveyor. As the lumber is being processed the off-bearer stacks the cut-to-length pieces on two-wheel factory carts and/or pallets located near the saw.

Lumber to be cut on these saws is placed on four-wheel carts located just outside the large door south of the saws. When needed, the carts are pushed by at least three men and most generally up to six men, through the doorway and into position between saws #1 and 2 or #3 and 4. One lumber cart will serve two saws. When a cart or pallet is loaded with cut-to-length pieces it is removed by an electric hand fork lift or pushed away by manpower.

Block saws #5 and 6 are each operated by one man (Figure 9). He unstacks cants from a cart, positions two to four cants on the dead roll conveyor, trims the ends and then proceeds to cut them into blocks.

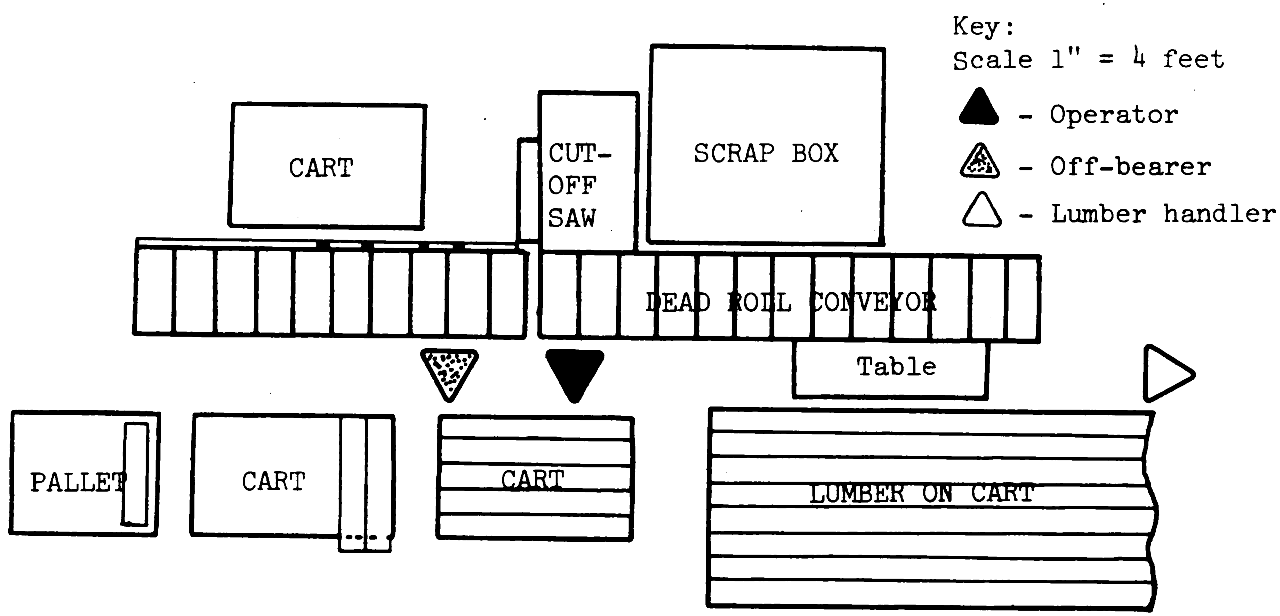



Figure 8.--Typical cut-off saw layout (Cut-off saw operation).

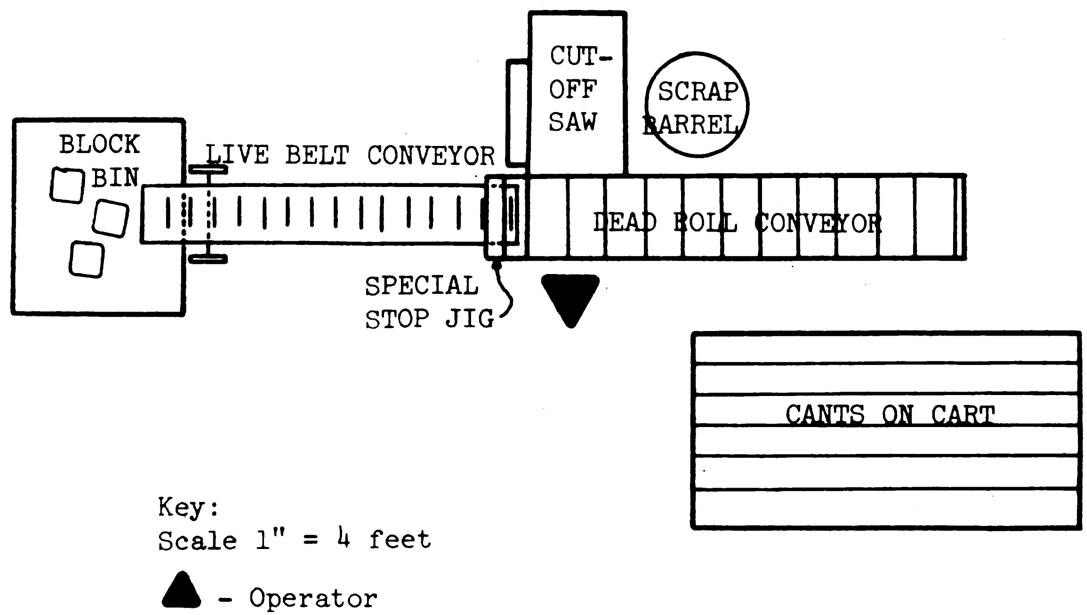



Figure 9.--Typical block cut-off saw layout (Cut-off saw operation).

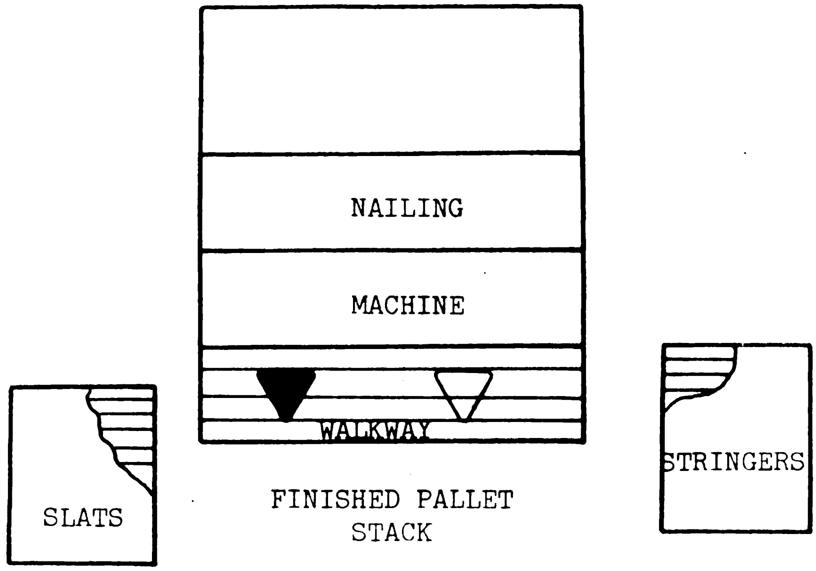
Special steel jigs for cutting different length blocks are used. They enable the operator to simply push the cants up flush with the backstop, activate the foot pedal to make one saw pass and repeat that process until the cants (two-four @ a time) are cut up. Blocks fall onto a moving belt conveyor which dumps into a block bin. End trimmings are tossed into the scrap barrel.

Cant material on carts is positioned between these saws in a manner similar to the way lumber is moved into the battery of four cut-off saws. It usually takes only one man (block saw operator) to do this job. When a block bin is full it is replaced with an empty one and then removed to storage by an electric hand fork lift.

## Nailing Machine Operation

Spring Arbor operates two Morgan nailing machines (Table 25). They are used only for assembling and nailing stringer type pallets. Work methods used and general work station layouts are for all practical purposes identical (Figure 10). The material used consists of various sizes of mixed hardwood stringers and slats (deckboards) depending upon the pallet being manufactured.

The crew at each machine consists of an operator and helper. Such tasks as laying up slats, feeding pallets into the machine, turning over pallets if they are two-sided and stacking the finished pallets are performed simultaneously by both men. The operator is




Key:
Scale 1" = 4 feet
▲ - Operator
△ - Helper

Figure 10.--Typical nailing machine layout (Nailing machine operation).

TABLE 25.--Machinery specifications--nailing machines. (Source: in plant observation and manufacturers' specs.)

| | Nailing Machine #1 | Nailing Machine #2 |
|---|---|---|
| Morgan Model | 30 nail tracks--72" opening | 26 nail tracks--48" opening |
| Motor-main drive | 10 H. P. | 7 1/2 H. P. |
| Motor-table raising | 3 H. P. | 2 H. P. |
| Nail driving force | 60,000 lbs. | 40,000 lbs. |
| Working table height | 44" | 43" |
| Overall height | 9'5" | 9'3" |
| Miscellaneous | Foot pedal control for activating nail stroke | Same |

responsible for handling up slats to the table and operating all machine controls except the table height and nail bin oscilation. His helper is responsible for handling up and positioning stringers on the table and operating the two controls mentioned above.

Stringer and slat stock are brought to the machines by an electric hand fork lift. Finished pallets are stacked to a specified height and then moved to temporary dock storage by the same kind of fork lift. No special jigs for pallet assembly are required--machines can be set for a wide range of pallet sizes.

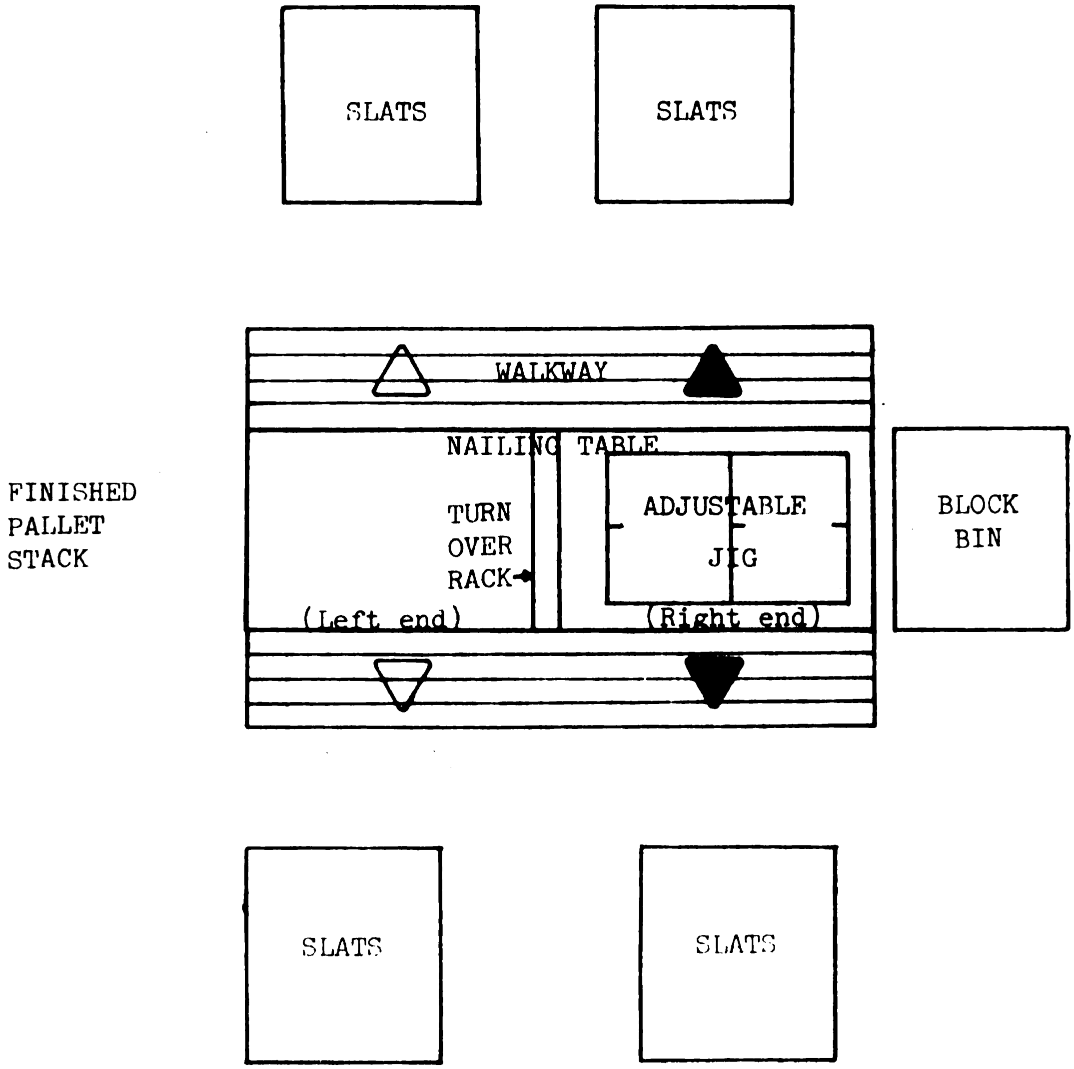
## Block Pallet Assembly Operation

Presently there are four block pallet nailing tables in use at the plant. Only three of the four were in use during most of the data collection period. For that reason only three tables are reported on (Table 26). The work methods, crew sizes and general layouts are the same on Tables #1, 2 and 3 (Figure 11).

The purpose of this operation is to assemble blocks and slats into finished block pallets. All of the block material is aspen; slats are of mixed hardwood. The two most common block sizes are 3 1/2" x 3 1/2" x 2 5/8" and 3" x 3" x 3 1/2". Slats are 1/2" thick but come in a variety of widths and lengths. An adjustable metal jig clamped to each table is used to assist in block and slat placement and control the outside dimensions and squareness of the pallets.

Each table has a four-man crew--two nail gun operators and two lay up men. For discussion purposes they are referred to as nail crew and lay up crew. These two crews switch off jobs periodically.

Positioning blocks in the jig, handling up and laying out slats, turning the pallet over and stacking finished pallet are the major tasks of the lay up crew. The nail crew's only job is to nail the top and bottom slats to the blocks.




Key:
Scale 1" = 4 feet
▲ - Nailing crew member
△ - Lay up crew member

* - 2 air nailing guns hang from the ceiling

Figure 11.--Typical block nailing table layout*
(Block pallet assembly operation).

TABLE 26.--Nailing table information--block pallet tables. (Source: in plant observations).

| Item | Tables #1,2,3 |
| --- | --- |
| Size | 4' x 13'--33" tall (steel) |
| Jigs | One metal rod--adjustable jig/ table--one steel turn over rack/table |
| Tools | Two Paslode air nailing guns/ table with a clip capacity of 106 $6^d$ nails |

All four men at a table toss up blocks from the block bin and place them in the jig. The purpose is to get as many blocks in the jig (one layer) as possible. When the blocks are used up in the making of pallets, production stops again and the jig is re-filled. The blocks are usually tossed out of the bin by the lay up crew and placed in the jig by the nail crew. A more detailed discussion of the work relationships between these two crews is given in Part III.

Material handling of the slats, blocks and finished pallets is accomplished in a manner similar to the nailing machines. Finished pallets are stacked to a specified height before being moved to storage.

## Wire Stapling Machine Operation

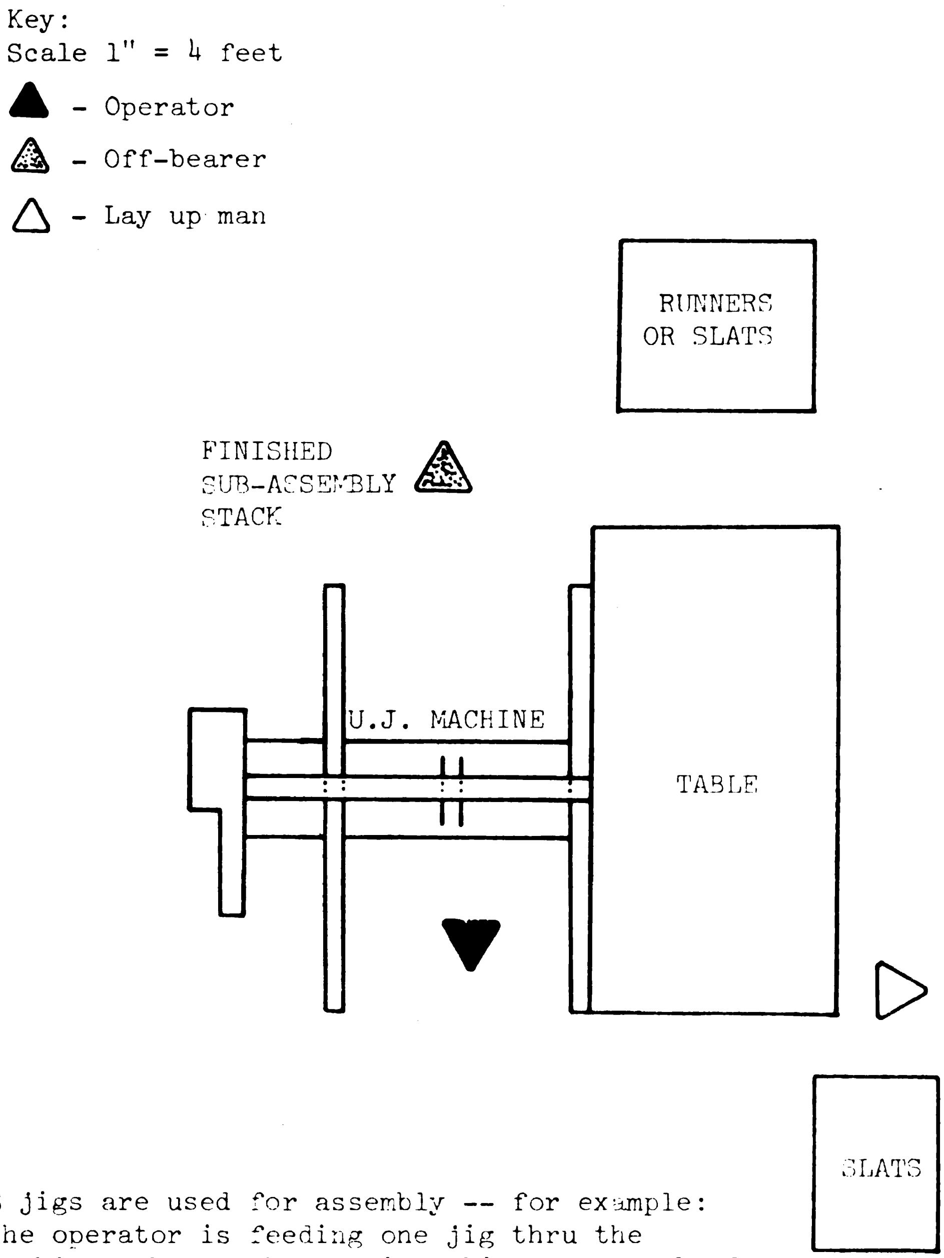
This operation consists of two Saranac wire stapling machines (U. J. machines) (Table 27). They are used to

TABLE 27.--Machinery specifications--wire stapling machines. (Source: in plant observation and manufacturers specs.)

| | U. J. Machine #1 | U. J. Machine #2 |
|---|---|---|
| Saranac Model | 52" capacity | 70" capacity |
| Motor | 3 H. P. | Same |
| Working Table Height | 40" | Same |
| No. of Stapling Heads | 3 | 4 |
| Miscellaneous | Foot pedal control<br>Hand feed | Same |

produce panel box sides and ends, pre-assembled block pallet tops, bases and other similar parts. Raw materials used are various sizes of slats and runners depending on the product to be produced. Saranac machines make their own staples from inexpensive coils of wire as they operate.

Basically, the only difference in the two machines is the size of the work that can be fed through. Each machine is usually operated by a three-man crew: (1) operator, (2) off-bearer, and (3) lay up man (Figure 12). It should be noted that another lay up man is added to this crew on certain jobs. Since this happened only occasionally during the study no work sampling data was taken on four-man crews.




* - 3 jigs are used for assembly -- for example: the operator is feeding one jig thru the machine, the off-bearer is taking an assembled piece from a jig and the lay up man is placing slats in the third jig.

Figure 12.--Typical U.J. machine layout* (Wire stapling operation).

Three jigs are employed on each job at a machine. They are stored in the jig storage racks when not in use. On a typical set up they are passed in "merry-go-round" fashion through the machine.

The slats or cross pieces are placed in the jig by the lay up man. He slides the jig to the operator who feeds it through the machine to drive the staples. At the machine's out-feed end, the off-bearer removes the finished piece from the jig, stacks it and places the required runners in the empty jig. He then slides it to the lay up man and the process is repeated.

Material handling of the slats, runners, and finished panels is similar to the nailing machine and block pallet operations. Finished panels, bases, etc. are stacked to a specified height before being moved to storage.

# APPENDIX III

# TIME STUDY REPORTS

| Material | Cut-To-Length Pieces | |
|---|---|---|
| | Code | Length |
| 1" x 4" x 16'11" Lumber--Oak | 1 | 84" |
| | 2 | 41 1/2" |
| | 3 | 27" |
| | 4 | 35 1/4" |
| | 5 | 31" |
| | 6 | 24" |
| | D | Defect Cut |
| | T | Trim Cut |

Time study summary--(net times--delays removed).

| Board Number | Cutting Sequence | Waste (inches) | Time/Board (minutes) |
|---|---|---|---|
| 1 | T1DD2D6 | 53.5 | 0.56 |
| 2 | T115 | 4.0 | 0.38 |
| 3 | T1D1 | 35.0 | 0.41 |
| 4 | T11D6 | 11.0 | 0.46 |
| 5 | T113 | 8.0 | 0.37 |
| 6 | T115 | 4.0 | 0.39 |
| 7 | T1233 | 23.5 | 0.67 |
| 8 | T1D1 | 35.0 | 0.37 |
| 9 | T1DDD43 | 56.7 | 0.52 |
| 10 | T115 | 4.0 | 0.39 |
| 11 | T115 | 4.0 | 0.38 |
| 12 | T115 | 4.0 | 0.37 |
| 13 | T1D1 | 35.0 | 0.39 |
| 14 | T113 | 8.0 | 0.45 |
| 15 | T116 | 11.0 | 0.45 |
| 16 | T115 | 4.0 | 0.36 |
| 17 | T115 | 4.0 | 0.41 |
| 18 | T115 | 4.0 | 0.42 |
| 19 | T115 | 4.0 | 0.36 |
| 20 | T115 | 4.0 | 0.38 |
| 21 | T1D4DD6 | 59.7 | 0.73 |
| 22 | T22225 | 6.0 | 0.35 |
| 23 | T22225 | 6.0 | 0.41 |
| 24 | T22223 | 10.0 | 0.46 |
| 25 | T2DDD2D2 | 78.5 | 0.50 |
| 25 | | 476.9 inches | 10.94 min. |

Material Used: 141 Bd. Ft.
Material Yield: 128 Bd. Ft.
Waste Factor: 10%

Avg. Time/bd: 0.44 min.

Avg. Production Rate: 702 Bd. Ft./hr

Figure 13.--Time study report--cut-off saw #1 (3-man crew)*

*Data obtained from video tape analysis. Refer to Figure 8 for work station layout.

Material

Aspen Cants (Timbers)--
3 1/2" x 3 1/2" x 8'4"
2 cants are loaded @
a time

Blocks

3 1/2" x 3 1/2" x 2 5/8"
2 blocks are cut per saw
pass

Element times (net).

| Element | No. Obs. | Range (min.) | Avg. Time Per Two Cants |
|---|---|---|---|
| (Operator--100% Effort) | | | |
| 1. Load 2 cants | 16 | 0.16-0.37 | 0.24 |
| 2. Saw (36 passes) | 16 | 1.23-1.40 | 1.33 |
| 3. Toss end trim (intermittent) | 13 | 0.06-0.22 | ÷ 16 - 0.09 |
| | | | 1.66 min. |

1.66 min/72 blocks
26.56 min/32 cants
26.56 min/1152 blocks or
23.05 min/1000 blocks

Production for 8-hour day (20% delay allowance) is 16,660 blocks.

Element Breakdown

1. Move toward cants on cart--activate foot pedal.

2. Activate foot pedal--release foot pedal.

3. Release foot pedal--move toward cants.

Figure 14.--Time study report--block cut-off saw #5 (operator)*

*Data obtained from stop watch time study. Refer to Figure 9 for work station layout.

**Material**

Stringers:

3--5/4" x 3 3/4" x 38 1/2"

Top Slats: Variable No.--
1/2" x random width" x 31"

Nails: 18--12 x 1 5/8"
per stringer

**Pallet**

31" x 38 1/2"--2 way, single face (solid)
Non-reversible-JDF #2 base

Element times (net).

| Element | No. Obs. | Range (min) | Avg. Time Per Pallet (min) |
|---|---|---|---|
| (Operator--90% Effort) | | | |
| 1. Set backstop | 17 | 0.03-0.07 | 0.05 |
| 2. Handle up slats | 17 | 0.12-0.21 | 0.16 |
| 3. Lay up slats | 17 | 0.22-0.54 | 0.35 |
| 4. Nail pallet-3 strokes | 17 | 0.21-0.36 | 0.26 |
| 5. Stack pallet | 17 | 0.07-0.11 | 0.09 |
| 6. Repair pallet (intermittent) | 6 | 0.02-0.35 | ÷ 17 - 0.05 |
| | | | 0.91 min. |
| (Helper--90% Effort) | | | |
| 1-A. Handle up stringers | 17 | 0.05-0.11 | 0.08 |
| 1-B. Position stringers | 17 | 0.05-0.13 | 0.08 |
| 1-C. Wait on operator | 17 | 0.03-0.09 | 0.05 |
| 3. Lay up slats | | (Same as operator) | 0.35 |
| 4. Nail pallet-3 strokes | | (Same as operator) | 0.26 |
| 5. Stack pallet | | (Same as operator) | 0.09 |
| 6. Repair pallet (intermittent) | | (Same as operator) | 0.05 |
| | | | 0.91 min. |

**Element Breakdown**

1. Operator release pallet--remove hand from backstop control handle.
2. Operator remove hand--set slots on stringers.
1-A. Helper release pallet--set stringers on machine table.
1-B. Helper set stringers on table--release last stringer.
1-C. Helper release last stringer--start slat lay up.
3. Operator and helper start slat lay up--activate foot pedal.
4. Activate foot pedal--pull pallet from machine.
5. Pull pallet from machine--both men release pallet.
6. This element occurs intermittently after the pallet is pulled from the machine and before it is stacked.

Figure 15.--Time study report--nailing machine #1 (2-man crew)*

*Data obtained from video tape analysis. Refer to Figure 10 for work station layout.

**Material**

Stringers:
3--6/4" x 3 3/4" x 34"

Top Slats:
4--1/2" x 4" x 34"

Bottom Slats:
2--1/2" x 4" x 34"

Nails: Top--
8/stringer, Bottom--
4/stringer 12 x 1 5/8"

**Pallet**

34" x 34"--2 way, double face
Non-reversible

Element times (net)

| Element | No. Obs. | Range (min) | Ave. Time Per Pallet (min) |
|---|---|---|---|
| (Operator--110% Effort) | | | |
| 1. Set backstop | 24 | 0.02-0.04 | 0.03 |
| 2. Handle up top slats | 24 | 0.06-0.13 | 0.08 |
| 3. Wait on helper | 24 | 0.03-0.18 | 0.08 |
| 4. Lay up top slats | 24 | 0.08-0.19 | 0.10 |
| 5. Nail top (3 strokes) | 24 | 0.13-0.20 | 0.15 |
| 6. Turn pallet over | 24 | 0.03-0.04 | 0.03 |
| 7. Set backstop | 24 | 0.02-0.05 | 0.03 |
| 8. Handle up bottom slats | 24 | 0.03-0.09 | 0.05 |
| 9. Lay up bottom slats | 24 | 0.04-0.07 | 0.05 |
| 10. Nail bottom (3 strokes) | 24 | 0.07-0.11 | 0.08 |
| 11. Stack pallet | 24 | 0.06-0.10 | 0.08 |
| | | | 0.76 |
| (Helper--110% Effort) | | | |
| 1-A. Handle up stringers | 24 | 0.07-0.18 | 0.10 |
| 1-B. Position stringers | 24 | 0.06-0.13 | 0.09 |
| 4. Lay up slats | | (Same as operator) | 0.10 |
| 5. Nail top | | (Same as operator) | 0.15 |
| 6. Turn pallet over | | (Same as operator) | 0.03 |
| 7-A. Lower table | 24 | 0.02-0.05 | 0.03 |
| 7-B. Wait on operator | 24 | 0.03-0.09 | 0.05 |
| 9. Lay up bottom slats | | (Same as operator) | 0.05 |
| 10. Nail bottom | | (Same as operator) | 0.08 |
| 11. Stack pallet | | (Same as operator) | 0.08 |
| | | | 0.76 |

**Element Breakdown**

Elements 1, 2, 4, 5, and 11 are the same as 1, 2, 3, 4, and 5 in Figure 15 for the operator. Elements 1-A, 1-B, 4, 5, and 11 are the same as 1-A, 1-B, 3, 4, and 5 in Figure 15 for the helper.

3. Operator set slats on table--start slat lay up.
6. Operator and helper pull pallet from machine--release pallet.
7. Operator release pallet--remove hand from backstop control.
7-A. Helper release pallet--release table height control.
8. Operator remove hand--set slats on pallet.
7-B. Helper remove hand--operator set slats on pallet.
9. Operator set slats on pallet--activate foot pedal.
10. Activate foot pedal--pull pallet from machine.

Figure 16--Time study report--nailing machine #2 (2-man crew)*

*Data obtained from video tape analysis.

**Material**

Blocks:
9--3 1/2" x 3 1/2" x 2 5/8"

Top Slats:
3--1/2" x 3" x 38"
3--1/2" x 3 3/4" x 51"

Bottom Slats: Same as top slats

Nails: 36 $6^d$

**Pallet**

38" x 51"--2 sided-reversible block pallet-Code H

Element times (net)--present method.

| Element | No. Obs. | Range (min) | Avg. Time Per Pallet (min) |
|---|---|---|---|
| (Lay Up Crew--100% Effort) | | | |
| 1. Walk to right (jig) | 15 | 0.05-0.08 | 0.07 |
| 2. Lift pallet (set in rack) | 15 | 0.05-0.09 | 0.07 |
| 3. Position blocks | 15 | 0.10-0.18 | 0.13 |
| 4. Lay up bottom slats | 15 | 0.13-0.22 | 0.17 |
| 5. Walk to left | 15 | 0.04-0.06 | 0.05 |
| 6. Stack pallet | 15 | 0.08-0.13 | 0.11 |
| 7. Lay down pallet from rack | 15 | 0.03-0.04 | 0.04 |
| 8. Lay up top slats | 15 | 0.15-0.23 | 0.18 |
| | | | 0.82 min. |
| (Nail Crew--100% Effort) | | | |
| A. Nail top slats | 15 | 0.15-0.23 | 0.19 |
| B. Turn pallet 90° | 15 | 0.02-0.04 | 0.03 |
| C. Walk to jig (right) | 15 | 0.03-0.06 | 0.04 |
| D. Wait on lay up crew | 15 | 0.14-0.21 | 0.18 |
| E. Nail bottom slats | 15 | 0.15-0.28 | 0.21 |
| F. Walk to nail top (left) | 15 | 0.03-0.04 | 0.03 |
| G. Wait on lay up crew | 15 | 0.10-0.20 | 0.14 |
| | | | 0.82 min. |

Element times (net)--new method.

| Element | No. Obs. | Range (min) | Avg. Time Per Pallet (min) |
|---|---|---|---|
| (Lay Up Crew--100% Effort) | | | |
| 1. Walk to right (jig) | 15 | 0.04-0.07 | 0.06 |
| 2. Lift pallet (set in rack) | 15 | 0.04-0.06 | 0.05 |
| 3. Position blocks | 15 | 0.09-0.13 | 0.11 |
| 4. Lay up bottom slats | 15 | 0.12-0.23 | 0.18 |
| 5. Walk to left | 15 | 0.03-0.05 | 0.04 |
| 8. Lay up top slats | 15 | 0.14-0.23 | 0.19 |
| 9. Wait on nail crew | 15 | 0.04-0.07 | 0.06 |
| | | | 0.69 min. |
| (Nail Crew--100% Effort) | | | |
| A. Nail top slats | 15 | 0.15-0.26 | 0.19 |
| B. Turn pallet 90° | 15 | 0.02-0.04 | 0.03 |
| 6. Stack pallet | 15 | 0.09-0.15 | 0.12 |
| 7. Lay down pallet from rack | 15 | 0.03-0.09 | 0.06 |
| C. Walk to jig (right) | 15 | 0.02-0.05 | 0.04 |
| E. Nail bottom slats | 15 | 0.18-0.25 | 0.21 |
| F. Walk to nail top (left) | 15 | 0.02-0.05 | 0.04 |
| | | | 0.69 min. |

**Element Breakdown**

(Lay Up Crew)

1. Move toward right--touch pallet in jig.
2. Touch pallet in jig--touch blocks.
3. Touch blocks--release blocks.
4. Release blocks--move toward left.
5. Move toward left--touch finished pallet.
6. Touch pallet--touch half finished pallet in rack.
7. Touch pallet in rack--release pallet.
8. Release pallet--move toward right.
9. Finish lay up top slats--move toward right.

(Nail Crew)

A. Start nail--finish nail.
B. Finish nail--release pallet.
C. Release pallet--arrive at jig (right).
D, Arrive at jig--start nail.
E. Start nail--finish nail.
F. Finish nail--arrive at left end of table.
G. Arrive at left--start nail.

Figure 17.--Time study report--block nailing table #3 (4-man crew)*

*Data obtained from video tape analysis. Refer to Figure 11 for work station layout.

Material

Blocks:
9--3" x 3" x 3 1/2"

Top Slats:
(Pre-assembled top)-stapled
4--1/2" x 3 3/4" x 36"
3--1/2" x 3 3/4" x 36"

Bottom Slats:
3--1/2" x 3 3/4" x 36"
3--1/2" x 3 3/4" x 36"

Nails: 36 $6^d$

Pallet

36" x 36"--2 sided, non-reversible block pallet-code-Red

Element Times (net)--Present Method

| Element | No. Obs. | Range (min) | Avg. Time Per Pallet (min) |
|---|---|---|---|
| (Lay Up Crew--100% Effort) | | | |
| 1. Walk to right (jig) | 27 | 0.04-0.07 | 0.06 |
| 2. Lift pallet (set in rack) | 26 | 0.04-0.07 | 0.05 |
| 3. Position blocks | 24 | 0.04-0.15 | 0.08 |
| 4. Place top assembly | 25 | 0.18-0.45 | 0.24 |
| 5. Walk to left | 24 | 0.04-0.07 | 0.05 |
| 6. Turn over and stack pallet | 24 | 0.10-0.17 | 0.14 |
| 7. Lay down pallet from rack | 16 | 0.04-0.06 | 0.04 |
| 8. Lay up bottom slats | 20 | 0.16-0.23 | 0.19 |
| | | | 0.85 min. |
| (Nail Crew--100% Effort) | | | |
| A. Nail bottom slats | 25 | 0.19-0.32 | 0.24 |
| B. Walk to jig (right) | 25 | 0.03-0.05 | 0.04 |
| C. Wait on lay up crew | 24 | 0.09-0.20 | 0.12 |
| D. Nail top assembly | 26 | 0.03-0.29 | 0.17 |
| E. Walk to left | 25 | 0.02-0.05 | 0.04 |
| F. Wait on lay up crew | 24 | 0.20-0.30 | 0.24 |
| | | | 0.85 min. |

Element Breakdown

(Lay Up Crew)

1. Move toward right--touch pallet in jig.
2. Touch pallet in jig--touch blocks.
3. Touch blocks--release blocks.
4. Release blocks--move toward left.
5. Move toward left--touch finished pallet.
6. Touch pallet--touch half finished pallet in rack.
7. Touch pallet in rack--release pallet.
8. Release pallet--move toward right.

(Nail Crew)

A. Start nail--finish nail.
B. Finish nail--arrive at jig (right).
C. Arrive at jig--start nail.
D. Start nail--finish nail.
E. Finish nail--arrive at left.
F. Arrive at left--start nail.

Figure 18--Time study report--block nailing table #3 (4-man crew)*

*Data obtained from video tape analysis. Refer to Figure 11 for work station layout.

Material

Runners:
1--1" x 2 3/4" x 44 3/8"

Boards:
12 avg.--1/2" x W" x 15 3/8"
(slats)

Staples: 2 per slat--formed by machine

Box Side Panel

15 3/8" x 44 3/8"--boards are placed edge to edge.

Element times (net)--present method.

| | Element | No. Obs. | Range (min) | Avg. Time Per Panel (min) |
|---|---|---|---|---|
| | (Operator--80% Effort) | | | |
| 1. | Operate machine (staple) | 16 | 0.12-0.33 | 0.27 |
| 2. | Get board (intermittent) | 3 | 0.10-0.37 | ÷ 16 - 0.04 |
| 3. | Push down buckle (intermittent) | 10 | 0.11-0.72 | ÷ 16 - 0.19 |
| 4. | Operate machine (finish) | 10 | 0.05-0.23 | ÷ 16 - 0.05 |
| 5. | Position to staple | 16 | 0.07-0.12 | 0.08 |
| 6. | Re-align boards | 16 | 0.10-0.74 | 0.36 |
| | | | | 0.99 min. |
| | (Off-bearer--80% Effort) | | | |
| A. | Remove piece from jig | 17 | 0.05-0.12 | 0.08 |
| B. | Stack | 17 | 0.12-0.29 | 0.17 |
| C. | Position jig | 17 | 0.03-0.07 | 0.05 |
| D. | Place runner and push | 17 | 0.08-0.16 | 0.11 |
| E. | Wait for next piece | 17 | 0.10-1.26 | 0.58 |
| | | | | 0.99 min. |
| | (Lay Up Man--80% Effort) | | | |
| I. | Position jig (intermittent) | 11 | 0.02-0.12 | ÷ 19 - 0.03 |
| II. | Get boards | 19 | 0.06-0.32 | 0.16 |
| III. | Place boards in jig | 19 | 0.38-0.88 | 0.60 |
| IV. | Wait for next jig (intermittent) | 9 | 0.04-0.86 | ÷ 19 - 0.20 |
| | | | | 0.99 min. |

Element Breakdown

1. Activate foot pedal--release foot pedal.
2. Release foot pedal--touch jig.
3. Touch jig--activate foot pedal.
4. Activate foot pedal--release foot pedal.
5. Release foot pedal--touch boards.
6. Touch boards--activate foot pedal.

A. Operator release foot pedal--move toward stock.
B. Move toward stack--release panel.
C. Release panel--release jig.
D. Release jig--push to lay up man.
E. Push to lay up man--operator release foot pedal.

I. Touch jig from off-bearer--release jig.
II. Release jig--set boards on table.
III. Set boards on table--push jig from off-bearer.
IV. Push jig to operator--touch jig from off-bearer.

Figure 19.--Time study report--U. J. machine #1
(3-man crew)*

*Data obtained from video tape analysis. Refer to Figure 12 for work station layout.

**Material**

**Runners:**
2--1" x 3" x 39"
1--1/2" x 3" x 39"--middle

Boards:
5--1/2" x 6 1/2" x 30"
1--1/2" x 3 3/4" x 30"

Staples: 18 strokes/panel

Element times (net).

Box End Panel

30" x 39"-R.H. code-1/2" gap between boards

| Element | No. Obs. | Range (min) | Avg. Time Per Panel (min) |
|---|---|---|---|
| (Operator--100% Effort) | | | |
| 1. Position to staple | 17 | 0.19-0.45 | 0.31 |
| 2. Operate machine (staple) | 17 | 0.17-0.25 | 0.20 |
| 3. Wait for next jig | 17 | 0.03-0.26 | 0.11 |
| | | | 0.62 min. |
| (Off-bearer--100% Effort) | | | |
| A. Remove piece from jig | 16 | 0.05-0.17 | 0.12 |
| B. Stack | 16 | 0.12-0.25 | 0.18 |
| C. Place runners & push | 16 | 0.22-0.50 | 0.28 |
| D. Wait for next piece (intermittent) | 3 | 0.10-0.15 | ÷ 16 - 0.02 |
| | | | 0.60 min. |
| (Lay Up Man--100% Effort) | | | |
| I. Position jig (intermittent) | 12 | 0.03-0.16 | ÷ 17 - 0.05 |
| II. Get boards | 17 | 0.06-0.20 | 0.12 |
| III. Place boards in jig | 17 | 0.29-0.67 | 0.44 |
| | | | 0.61 min. |

Element Breakdown

1. Touch jig--activate foot pedal.
2. Activate foot pedal--release foot pedal.
3. Release foot pedal--touch jig.

A. Operator release foot pedal--move toward stack.
B. Move toward stack--release panel.
C. Release panel--push jig to lay up man.
D. Push jig--operator release foot pedal.

I. Touch jig from off-bearer--release jig.
II. Release jig--set boards on table.
III. Set boards on table--push to operator and touch jig from off-bearer.

Figure 20.--Time study report--U. J. machine #1 (3-man crew)*

*Data obtained from stop watch time study--crew member cycle times are not the same because each man was time studied individually. Refer to Figure 12 for work station layout.

APPENDIX IV

DESCRIPTION OF VIDEO TAPE RECORDER

## Sony Home Videocorder Specifications

(Videocorder CV 2000)

| | |
|---|---|
| Video recording system: | Rotary two-head slant-track scanning |
| Recording time: | 60 minutes, continuously, using V-32 tape (2370 ft.) |
| Tape speed: | 7 1/2" I. P. S. |
| Tape width: | 1/2" |
| Resolution: | Greater than 200 lines |
| Power requirements: | 115-120 volts, 60-cycle, ± 0.4 cps AC |
| Power consumption: | 80 watts |
| Dimensions: | 18" x 10 7/8" x 15 5/8" |
| Weight: | 46 lbs. |

(Video Camera Kit VCK-2000)

| | |
|---|---|
| Video tube: | Sony high sensitivity vidicon type, M-3016 |
| Lens: | f.1.9, 25 mm, telephoto f.1.9 75 mm |
| Horizontal resolution: | 400 lines |
| Automatic sensitivity control range: | 100 lux to near infinity (with f.1.9 lens) |
| Power requirements: | AC 115-120v, 60 cls |
| Power consumptions: | 10w |
| Dimensions: | 3 1/8" (w) x 5 1/2" (h) x 9 7/8" (l) |
| Weight: | 5 lbs. 15 ozs. |

(CVM-51UWP Monitor)

| | |
|---|---|
| System: | American TV standards |
| Channel coverage: | VHF channels 2-13 |
| | UHF channels 14-83 |
| Picture tube: | 8-inch picture measured diagonally |
| Power requirements: | AC 115-120 V, 60 cls.<br>23 W (Maximum)<br>DC 12V, 15 W (Maximum) |
| Dimensions: | 9" (w) x 10" (h) x 8 5/8" (d) |
| Weight: | 10 lbs. |