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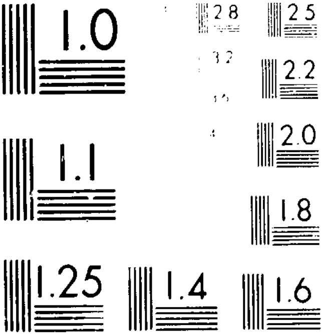
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Seminar on Wood Based Panels and Furniture Industries

Beijing, China, 20 March - 4 April 1981

MECHANIZATION AND AUTOMATION POSSIBILITIES IN THE WOOD-BASED PANELS INDUSTRY*

by

Horatio P. Brion**

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Corrigendum

Page 10, line 4

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Page 64, figure 25, detail "G"

For 8-Ft. STOPPER "F" read 8-Ft. STOPPER "G"

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I. INTRODUCTION

Ever since man learned to lighten his work load by inventing the wheel, the world has attained industrial progress thru varying stages of mechanization, and in the last few decades, automation. However, the world at present is composed of nations with economies in disparate stages of development, such that mechanization and automation are little known in some under-developed nations; while some developing nations, in their effort to attain a desired degree of industrialization are already beginning to profit from the benefits that mechanization and automation offer. The gap in the state of development of mechanization and automation between developed and developing countries is so huge that, in many cases, this gap is measured in terms of technological development attained over several human generations and thru sizable financial outlays.

This paper is written as an effort to share with the peoples of less developed economies some aspects of the wood processing experiences of other developing nations in their effort to industrialize, in spite of their financial and technological handicaps.

Learning from the experiences of highly - developed economies, the Organization for European Economic Cooperation (now the Organization for Economic Cooperation and Development - OECD) sponsored the development of a programme by which small and medium - sized industries could partake of the benefits enjoyed by large industries through the low-cost, standardized, simple and flexible equipment that would be within their financial capabilities to procure and which would require a simpler degree of technology to install. "LOW COST AUTOMATION" (LCA), as we know now, is based on its requisite degree of "MECHANIZATION" and was initiated in the late 1950's. The Netherlands, in 1960, led in the formalisation of a national program for the dissemination of LCA as part of its programme of industrialisation, with very encouraging results. The need for concentrated efforts to propagate the application of LCA to wood processing, particularly in the furniture and joinery industry, materialised in the early 1970's during one of the furniture manufacturing courses in Lehti, Finland, jointly sponsored by UNIDO and the government of FINLAND.

II. CONCEPTS OF LCA APPLICATION

Our experience during recent UNIDO - sponsored courses on the selection of machinery and equipment indicated that many entrepreneurs of developing countries tend to view mechanisation and automation in terms of the sophisticated machines displayed in fairs or presented in brochures. Demonstration runs of these pieces of equipment provide a very admirable spectacle to the entrepreneurs, who then down - grade their simple and old machines as obsolete. They would not spend on the old machines to get more production out of it. Quite a number of these entrepreneurs are often swayed to convert their simple type of operations to some sophisticated, highly-automated operations, only to find out later that they do not understand enough of these complex machinery to benefit fully from their use. Other entrepreneurs, though convinced of the production capabilities of the sophisticated machines, are discouraged from taking futher steps toward higher productivity because their meager financial resources prevent them from acquiring these high - priced machinery.

A closer look into the basic concepts of and potential benefits from Low Cost Automation and Mechanisation is thus indicated. Recognizing that automation can occur only if some degree of mechanisation already exists, the term LCA as used in this paper will include the following stages of mechanisation and automation :

a. The use of simple machines ;

b. The complementation of jigs and fixtures to these basic machines thus obtaining more products of better quality ; and

c. The connection of devices to these tools and machines to make them more self - acting as required by the operations, and so on, until the point just before Full Automation is acheived.

This is graphically illustrated in Figure 1 below.

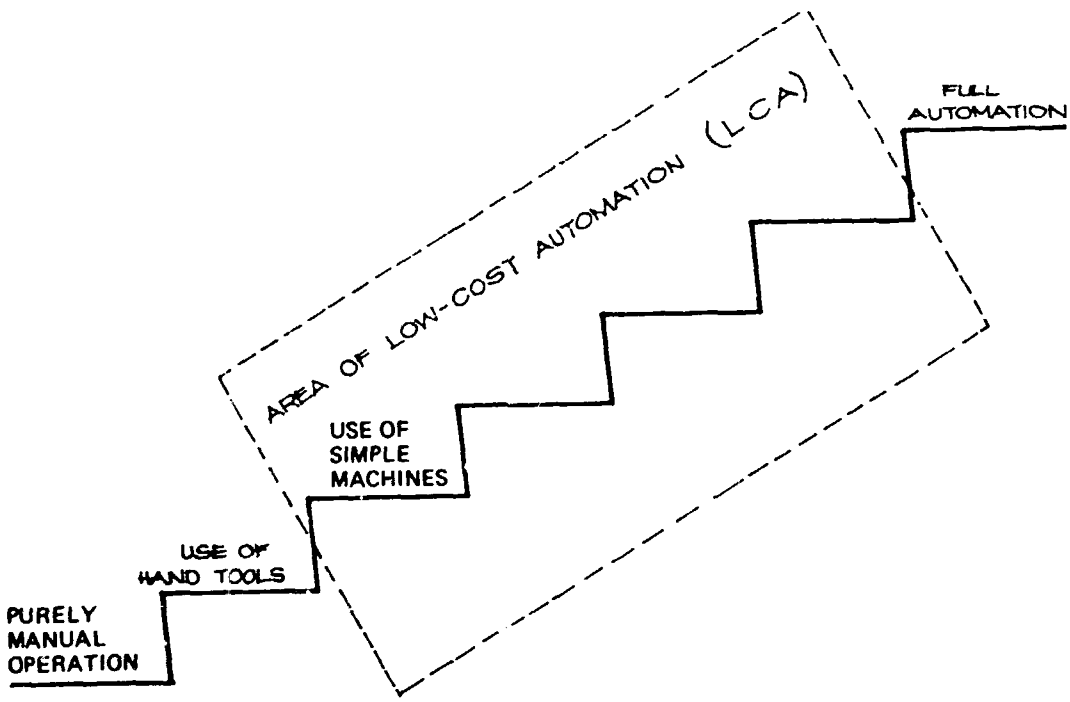


Figure 1. The location of LCA in the progression from purely manual to fully automatic operation

Furthermore, this paper distinguishes LCA from the mechanization and automation built into machines by machinery manufacturers in the following manner :

a. LCA set-ups are designed, fabricated and installed in the user's factory;

b. LCA makes use of standard and readily available component parts ;

c. LCA makes use of existing basic machines ;

d. Whenever possible, LCA also makes use of non-conventional parts such as old wheels, steel sheets and bars, coil springs, etc., which are often found in the junk and scrap piles in factories ; and

e. LCA is designed to be very flexible, allowing one set-up to be dis-assembled and the same component parts used in another set-up whenever the situation will require and/or permit doing so.

LCA is described as "LOW-COST" (as distinguished from CHEAP) because its use takes into account the financial and technological capabilities of the user, not necessarily to scheive PERFECTION but to attain certain desired partial advantages in manufacturing operations.

Thus, the concepts of LCA cells for the mechanization of those human tasks (in an industrial plant) which have been determined to be necessary and advantageous at the time mechanization is installed. The relative nature of the concepts of LCA permits industrial firms to mechanise and automate only those features of their operations which are economically justifiable. The following graphical illustration gives a general idea of the relative costs to automate based on Full Automation as 100% cost (see Figure 2).

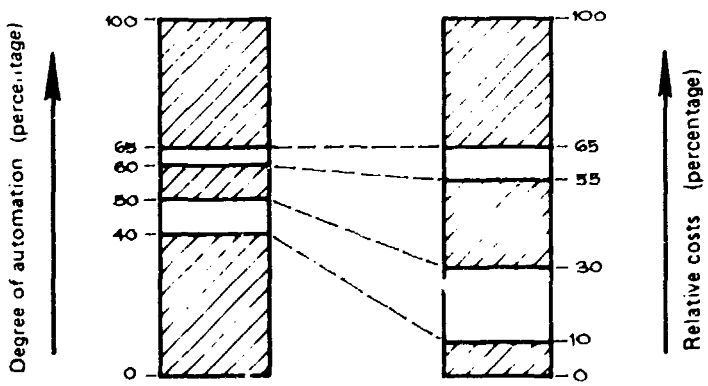


Figure 2. Relative cost of partial automation

Since every manufacturing establishment has its own set of criteria for the economic justification of proposed additions or changes in its operations, it is not easy to lay down definite rules for the adoption of automation which will cover all situations of need that may arise in manufacturing operations. At the moment, it is only possible to set guidelines which will help entrepreneurs (or their managerial and technical personnel) to recognise situations in their factories which can be improved by the use of mechanization and/or LCA. The guidelines will further help the LCA proponents to evaluate properly the feasibility and economic justifiability of the proposed LCA systems.

III. MANUFACTURING SITUATIONS NEEDING LCA APPLICATION

The human factor in manufacturing operations, particularly those which are highly repetitive, often leads to problems which give rise to high rate of product rejects, low and variable outputs, high rate of material wastage, low rate of machine utilisation, and/or high incidence of industrial accidents. These undesirable situations arise as the worker, skilled though he may be, tend to develop work fatigue. The workers become careless or are easily distracted by emotional or environmental forces. The problem is aggravated by the poor working conditions usually found in factories where the workers' welfare is given lower ranking in the order of priorities set by management.

The following examples of end results occur as the labourers' working attitude deteriorate under the above-mentioned adverse conditions of work :

a. The log bolts are not squarely cut at the ends, giving rise to unnecessary material loss ;

b. The log bolt is not properly centered on the rotary lathe (veneer peeling machine) resulting to lower recovery rates of veneer ;

c. Green veneer sheets are carelessly handled causing end splits and damage to veneer surfaces ;

d. High incidence of drift in veneer thickness ("thick-and-thin") as the lathe operator's judgment is impaired by work fatigue ;

e. Low recovery from clipping green veneer of the 1st and 2nd roundings as the clipper operators become tired and tend to care less about the quality and volume of their output;

f. Inefficient use of the roller driers because the veneer sheets are not properly fed into the driers ;

g. Faulty clipping of dried veneer sheets resulting in excessive allowances, or at times, no allowance at all, for trimming at the panel sizing section ;

h. Poorly jointed edges of core veneer sheet for splicing ;

i. Weak spliced joints because of faulty glue mixture or poor jointed edges of the veneer sheets ;

j. Poor core veneer lay-up causing core gaps or core laps in the assembled plywood panel ;

and many other errors of ommission or commission which ultimately result to increased production costs.

Application of ICA to the above-listed problems can help bring down production costs, for in general, the use of ICA helps improve the following aspects of production operations :

a. Product Quality
b. Labour Utilisation
c. Material Utilisation
d. Machine Time Utilisation ; and
e. Industrial Safety

IV. WHAT IS ICA

A. ICA SYSTEMS AND COMPONENTS

ICA systems make use of the following devices in order to achieve linear and/or rotary motion in work-performing applications and for control of these motions according to a desired sequence of activities :

1. Mechanical Devices
2. Pneumatic Components
3. Hydraulic Devices
4. Electrical Components ; and
5. Electronics

The 1st four types of devices are used principally for work - performing motions and their control, while electronic devices are exclusively used for control purposes.

B. MECHANICAL DEVICES

Mechanical devices, as used in ICA systems have the following advantages :

a. High degree of reliability can be attained ;

b. Excellent synchronization is possible ;

c. Simple maintenance needs, which can usually be done by the factory maintenance crew.

However, mechanical devices have these disadvantages :

a. High degree of engineering skill is required in the design of the "custom-built" parts ;

b. Low degree of flexibility, because the program is fixed and difficult to change ;

c. Since parts are "custom-built", replacement of worn-out parts will be very costly ;

d. Not economical for interconnecting devices which are located some distance apart ;

e. It is difficult to build into a mechanical system any feature to check if the steps in a program is properly done (as when a cutting tool becomes dull or breaks).

Mechanical cams (see Figure 3) are often used in ICA for purposes of "Control Timing".

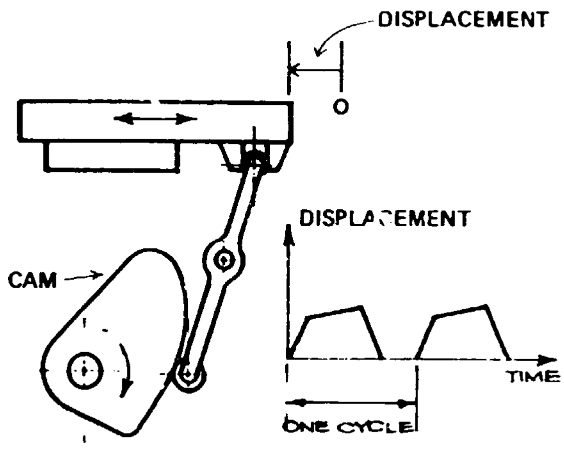


Figure 3 Mechanical cam steering

Another mechanical device frequently used in ICA systems is the "screw - and - nut" device which translates rotary to linear motion. (see Figure 4)

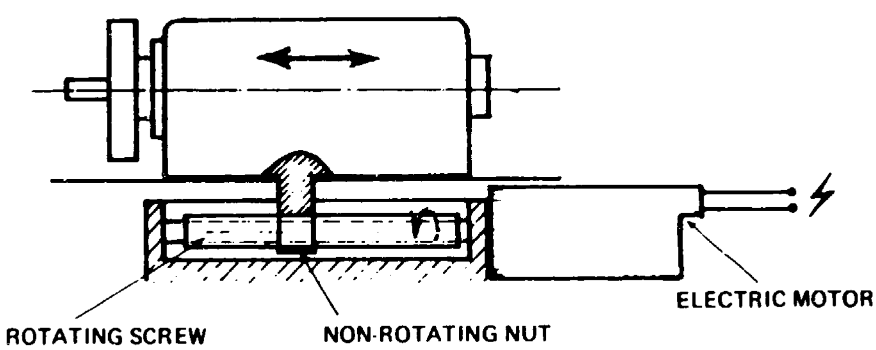


Figure 4 Conversion of rotary to linear movement

C. PNEUMATIC COMPONENTS

Typical of pneumatic components in ICA systems is the pneumatic Cylinder which makes possible "back - and - forth" motion. (see Figure 5). Since the pneumatic cylinder is powered by air, which is compressible, low piston speeds are difficult to control.

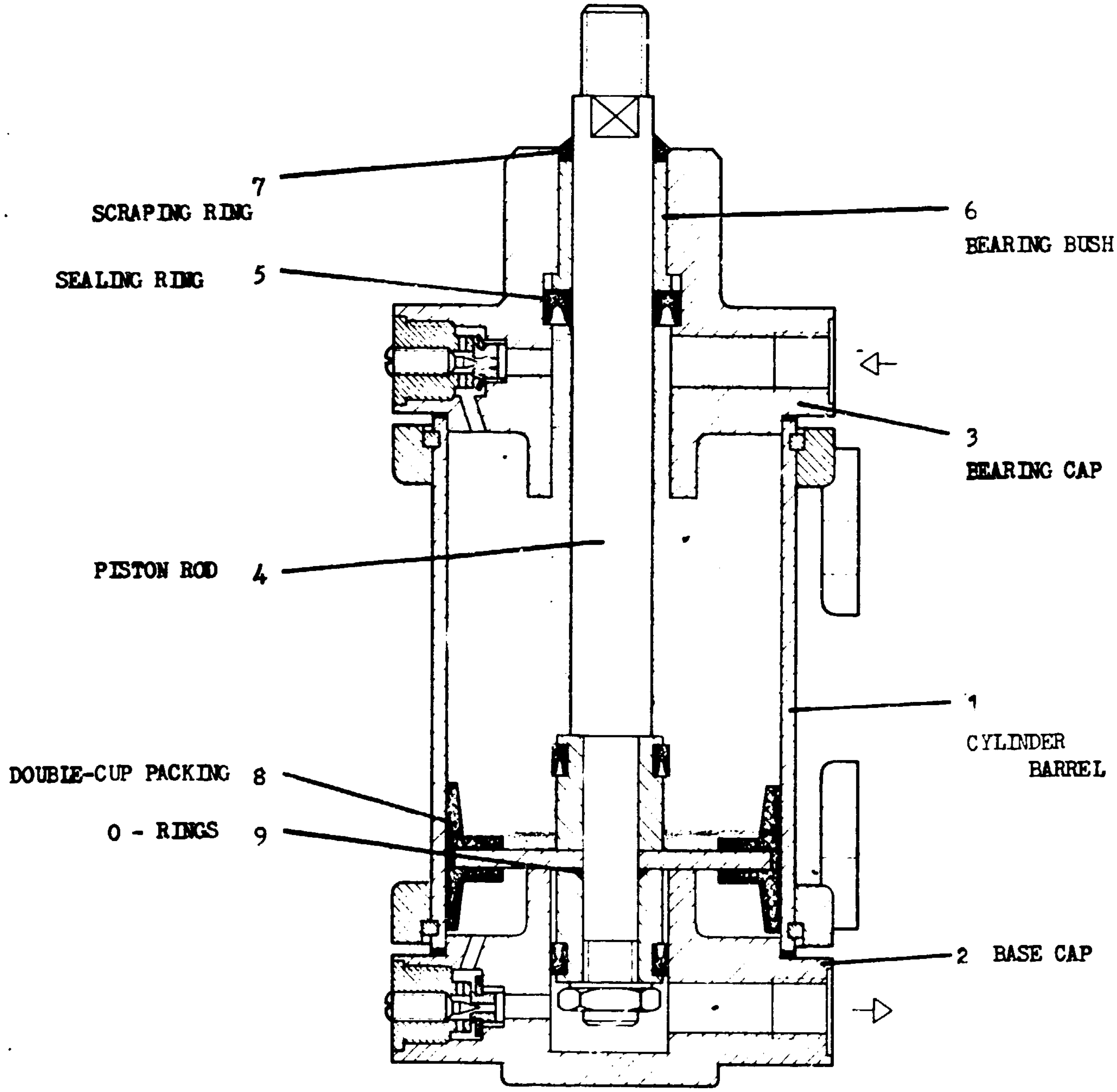


FIGURE 5

PNEUMATIC CYLINDER

This situation arises at piston speeds below 75 mm/min. (3 in./min.) where the piston moves unevenly due to the pulsating effect of air which is being compressed. However, a more even piston movement can be achieved at speeds as low as 40 mm/min. (1.6 mm/min.) by connecting a hydraulic damping unit to the pneumatic cylinder, as shown in Figure 6.

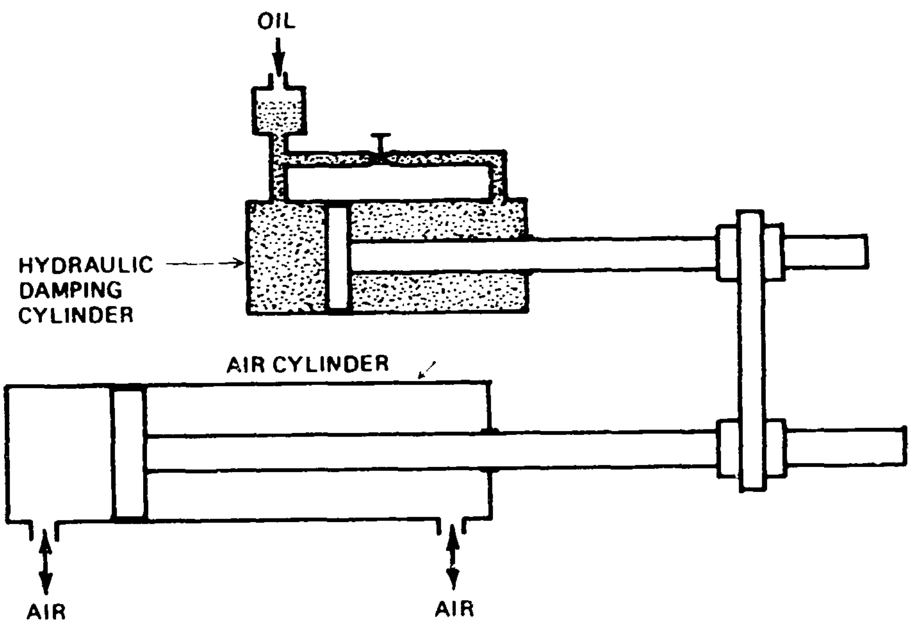


Figure 6 Double-acting air cylinder with parallel hydraulic damping cylinder

The control of the piston movement (forward and backward) is achieved thru the use of another basic component of pneumatic systems, the directional control valve. The valve illustrated in Figure 7 has either two or three distinct positions. The valve positions are attained by manual, mechanical, electrical or pneumatic actuation whichever is most suitable for a given situation.

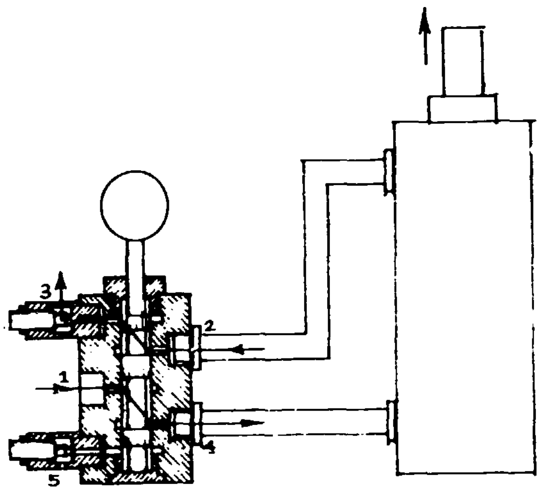


Figure 1 Three-way valve

The pneumatic cylinder and the directional control valve are basic pneumatic systems components for linear motion. Rotary motion in pneumatic systems is achieved by the use of air motors which may be of the vane or piston type. Rotary motion in vane-type air-motors is attained by blowing air under pressure on the vanes mounted on a common shaft, thus producing a turbine effect to move the shaft in a rotary manner. This feature is usually found in air-operated hand tools such as pneumatic drills, wrenches, screw-drivers, grinders, etc.

Pneumatic automation systems have the following advantages :

a. High-degree of flexibility ;

b. Capable of good regulation of force or power ;

c. Requires simple piping system, for there is no need for a return line ;

d. Power source is relatively safe for the system normally requires air at only 7 to 10 atm. pressure ;

e. Compressed air devices normally can be stalled without damaging them ; and

f. Since the power medium is air, inter - connection of distant devices in a factory is easily acheived through an adequate piping system.

However, purely pneumatic LCA system have the following disadvantages :

a. The compressibility of air becomes a dis - advantage where the work load is variable and the speed is desired to be fairly constant ;

b. Compared to hydraulic or electric sources of energy, compressed- air is relatively more expensive per unit energy delivery.

Because of its numerous advantages, pneumatic devices are found to be more favorable and are commonly used in LCA systems.

D. HYDRAULIC DEVICES

Compressed-air is the medium of power transmission in pneumatic systems ; OIL is the energy source for hydraulic devices. Oil is practically incompressible, which makes possible accurate control of piston movement in hydraulic cylinders even at low speeds. The incompressible characteristic of oil also enables transmission of high forces over small areas so that hydraulic cylinders are comparatively smaller than pneumatic cylinders of the same power rating.

From the view-point of economy, a hydraulic system is more expensive than a pneumatic system because of the following reasons :

a. Hydraulic devices require special individual pumps to supply oil at the required quantity and pressure ; whereas a single air-compressor can provide air to several pneumatic devices ;

b. Hydraulic devices operate at greater pressures than pneumatic components, hence hydraulic systems require precise and tight fitting of pipings and couplings. These cost more than air-pipings and pneumatic devices.

In general, hydraulic devices in ICA systems have the following advantages :

a. They are compact, yet they can deliver large forces ;

b. Transmission of energy over long distances is possible thru the proper installation of piping networks ;

c. It is self-lubricating, oil being the medium of power transmission ;

d. A high degree of flexibility is also possible ;

e. Shock loads can be absorbed without loss of longevity ;

f. Over-load prevention devices can easily be incorporated into a hydraulic system ;

g. Adequate variable speed control is possible ;

h. High precision can be achieved in controlling speed and positioning of loads ;

i. As in pneumatic systems, hydraulic systems can be easily linked to electrical and electronic control systems ;

j. Its operating cost is lower than that in pneumatic system.

On the other hand, hydraulic devices in an ICA system have the following disadvantages :

a. More expensive to set up than a pneumatic system ; and

b. Maintenance and installation is more complicated than in pneumatic systems.

E. ELECTRICAL DEVICES

Electrical devices become the cheapest choice in situations where the energy required by work - performing devices has to be transmitted over considerable distances. The most familiar work-performing electrical device is the electric motor, which can be conveniently located wherever main power lines exist. Only rotary motion can be directly obtained from an electric motor. Thus, some device, such as the screw-and-nut mechanism illustrated in Figure 4, has to be used to obtain linear motion from a system powered by an electric motor. For short linear movements, a magnetic coil that moves a sliding iron member as shown in Figure 8, can be used. There are several types of electric motors designed with distinct operating characteristics to fit particular work requirements such as : high starting torque, constant speed, highly variable speeds, etc. Electric motors, however, can not be stalled for a prolonged period without damaging the motor itself.

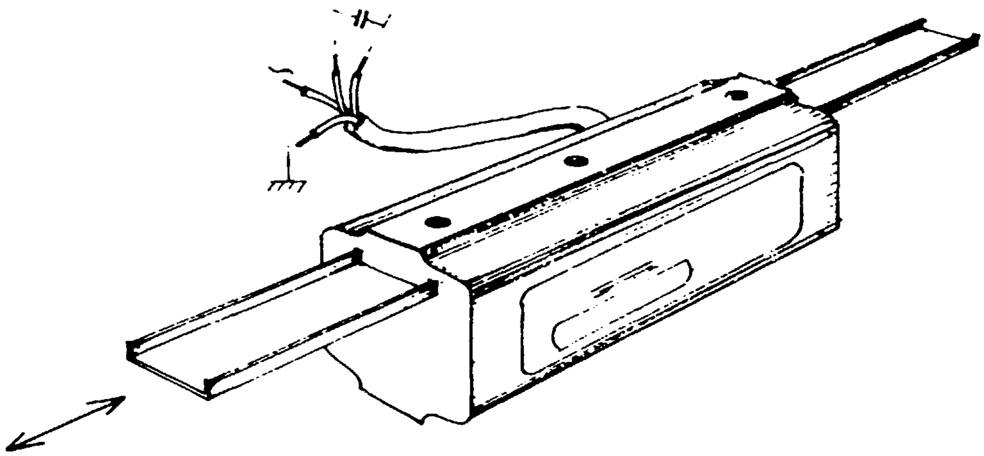


Figure 8 Magnetic coil for short linear movements

Current is usually delivered to electrical devices thru the use of electro - mechanical devices called relays, where electrical contacts are closed, or opened, according to a pre-designed manner by energising or de-activation, respectively, of an electromagnet. Special purpose devices such as time relays, pulse relays and step relays belong to this type of switch devices.

Furthermore, electrical components such as resistors and capacitors can be used to do the same functions as pneumatic restrictors and reservoirs, respectively, in pneumatic systems.

LCA systems make more use of electrical devices for timing control and less as work-performing units.

F. ELECTRONIC DEVICES

The use of electronic devices in ICA systems is limited mainly to controlling the work-performing components of the system, which may be pneumatic, hydraulic or electric units. Recent developments in transistor technology makes it possible to build compact control devices. Transistorised modular devices with specific functions can also be built with the combination of transistors and other electronic components.

G. ICA LANGUAGE

Like other technological systems, ICA makes use of its own language in order to be readily understood. ICA component units and devices are represented by symbols, a few representative samples of which are shown in Figure 9.

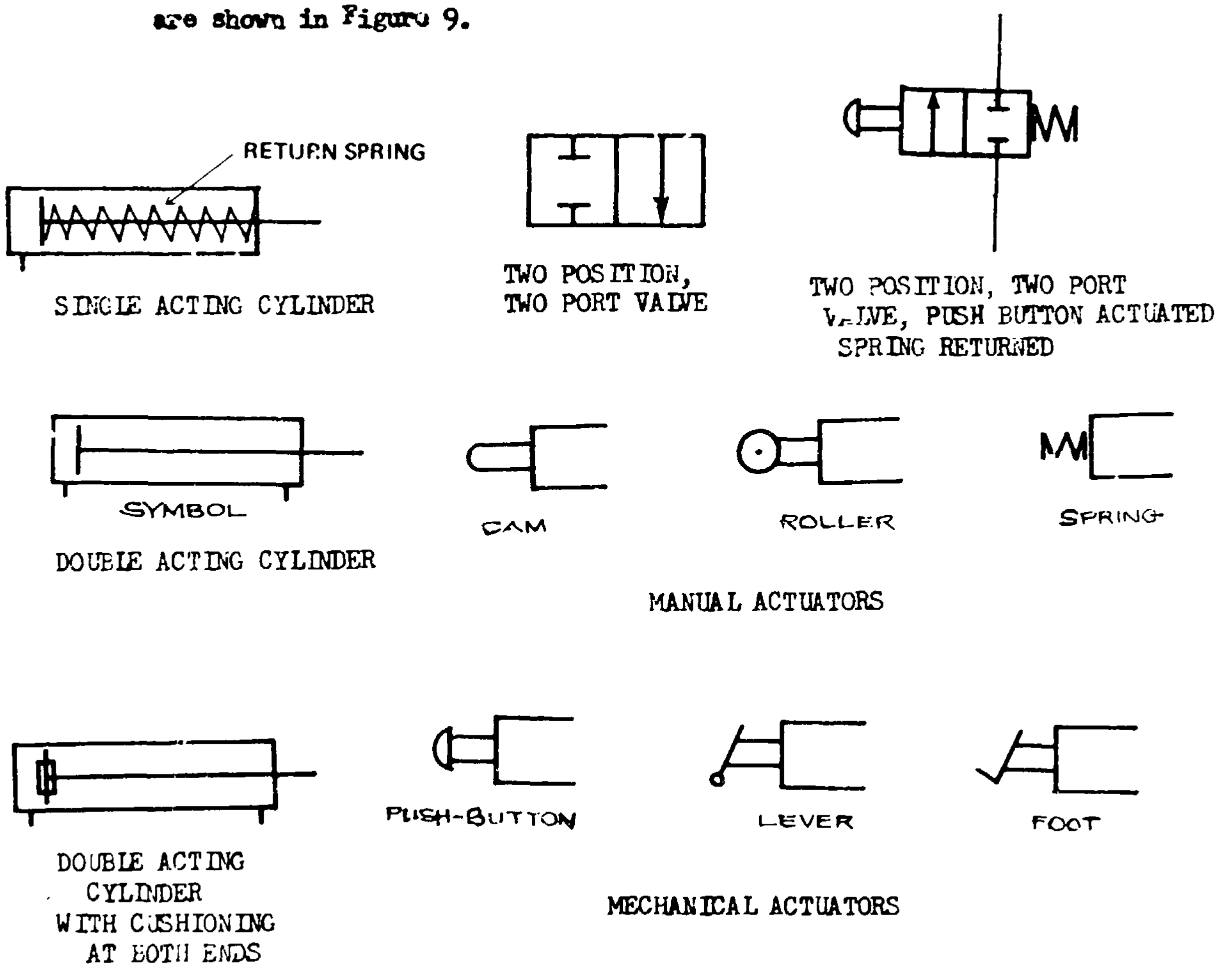


FIGURE 9

REPRESENTATIVE SAMPLES OF SYMBOLS FOR ICA DEVICES AND COMPONENTS

The use of these symbols is illustrated in the schematic diagram of a cylinder controlled by an electrically operated pneumatic valve, Figure 10. The interconnections of these units are illustrated in Circuit Diagrams such as that shown in Figure 11, while the corresponding sequence and duration of each motion is laid - out in Time-Motion Diagrams, an example of which is shown in the lower portion of Figure 10.

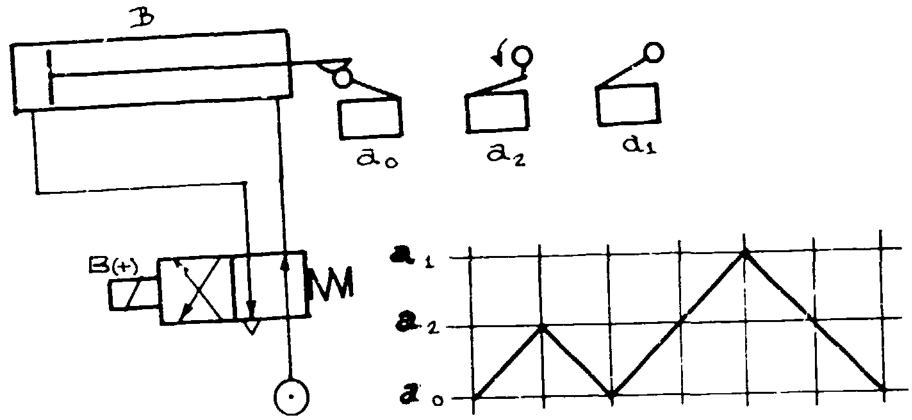


FIGURE 10

PNEUMATIC CIRCUIT OF CYLINDER WITH TWO SUCCESSIVE STROKES OF DIFFERENT LENGTHS

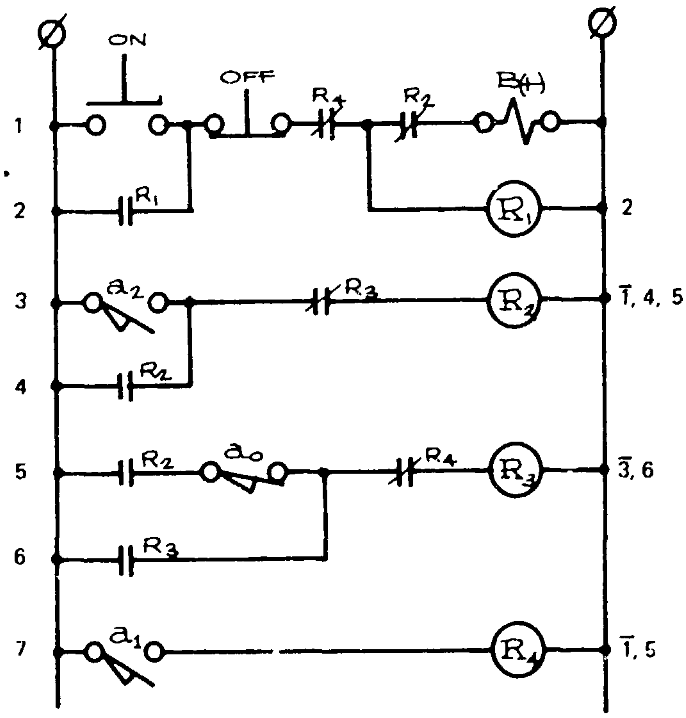


FIGURE 11

ICL CIRCUIT DIAGRAM

The reader is referred to more exhaustive and comprehensive papers written on ICA for a deeper understanding of the technical aspects (nomenclature, design procedures, choice of ICA components, etc.) on the subject (see Bibliography).

V. ANALYSIS AND DECISION -MAKING ON THE ADOPTION OF ICA SYSTEMS

Adoption of ICA systems in manufacturing operations requires intensive and realistic studies involving the following considerations :

1. Exact definition of the problem to be solved and its attendant negative effects to the manufacturing operations as regards to volume of production, product quality, other elements of production costs and industrial safety ;
2. Exploration of all options open to management to solve the problem ;
3. Confirmation thru value analysis (or such other similar techniques) that ICA offers the best solution among the options evaluated ;
4. Review and finalization of the design of the ICA system to be used, and final costing of the Project ;
5. Managerial decision to adopt and install the recommended ICA system ;

The responsibility for the proper appreciation of these considerations rest on both managerial and technical (engineer's) personnel.

A. THE TECHNICAL VIEWPOINT

Knowing the exact nature of the problem to be solved, the technical department of a manufacturing plant must first ascertain the definite need for automation by examining all possible options to solve the problem, including those solutions which do not involve automation (such as process simplification, change in product design, etc.)

Once the need for automation is confirmed then the engineer chooses the ICA system which offers the best advantage to the operations (pneumatic, hydraulic, electrical, electronic, or any combination of these devices), considering the availability and cost of the required components and the capabilities of his staff to install and maintain the system.

The ICA design is then finalized, its cost determined, and the potential advantages for the use of the design are listed and valuated.

The project proposal is then submitted for approval or disapproval by management.

B. THE MANAGERIAL VIEWPOINT

Oftentimes, a change in manufacturing process affects aspects of the entire manufacturing operations which are beyond the jurisdiction of the firm's technical department. Managers expected to make a decision on the recommended adoption of an ICA system should thus consider the following factors :

Economic Aspects ;
Technical Pre-requisites ;
Personnel Requirements ; and
Capabilities of Management

1. Economic Aspects

The universally accepted principle in industrial ventures that the benefits to be derived from any change in production process should outweigh the cost to be incurred for such a change, also applies to ICA systems.

Of course, there are instances where some of the benefits are not readily quantifiable, e.g., quality improvement and strengthening of industrial safety. Nevertheless, whatever is the primary reason for adoption of automation, knowing the relative costs of the project proposals will still guide management to arriving at a wise decision.

Assuming that the decision to automate will be based purely on the economic viability of the project, the guiding rule for determining the maximum investment on a proposed project is as follows :

Maximum Allowable Investment = The net change in total production costs from the current to the projected volume levels, adjusted for the cost of money factor, during the estimated life period of the proposed ICA installation.

This relationship is expressed in more detail mathematically by the following formula :

$$I_{max} = \left[\frac{nN}{1 + \frac{i}{200}(n + 1)}\right]\left[\left(\frac{Q_2}{Q_1} - 1\right)\left(m + w\left(1 + \frac{p}{100}\right) + V_1\right) + \left(V_1 - V_2\right)\right]$$

where :

I_{max}	=	maximum allowable investment
i	=	current interest rate on money (percent per annum)
n	=	depreciation period (years)
N	=	number of operating hours per year
Q_1	=	current hourly output
Q_2	=	projected hourly output to be produced thru the installation of ICA
m	=	fixed hourly machine cost including overhead
w	=	direct hourly wages
p	=	proportion of indirect labour cost (percentage of w)
V_1	=	variable hourly machine cost at output Q_1

V_2 = variable hourly machine cost at output Q_2

2. Technical Pre-requisites

The benefits expected from the installation of an automated system may not be fully realised if the machine operators and maintenance crew are not yet ready for such venture into automated process. Thus, the Manager who is expected to make the final decision whether to automate or not should be aware of the following comparative changes in the qualitative and quantitative requirements for technical personnel when he decides to go into automation :

Function	Number of Employees	Skill Required
Direct Production	Fewer	Lower
Maintenance	More	Higher
Transport	Fewer	Higher
Engineering	More	Higher

3. Capabilities of Management

The introduction of automation in a factory increases productivity, which brings with it greater demands for raw materials, more complicated scheduling, more precise technical requirements, and such other requirements needed to sustain the level of productivity.

In general, automation makes more complicated the inter-relationships among the elements of production (men, materials, machinery, time and money). If management is not fully prepared to handle the increased demands on its managerial capabilities it will be preferrable to delay going into any higher degree of automation. It is recommended that a company start with the simplest type of automation and gradually advance to more complex types as its management capabilities improve.

C. SAMPLE ANALYTICAL APPROACH TO ICA

1. The Case of the Bottom Sander

Situation :

A plywood factory producing 3.6 mm x 4 ft. x 8ft. plywood panels accepted an order for 90,000 panels of 3.3 mm x 4 ft. x 8 ft. panels, 3-ply, both face and bottom surfaces sanded, to fill in their production capacity during the slack season for pre- finished panels. The existing sanding line consisted of a bottom scraper and a double wide-belt top sander. The plan was to use the wide-belt sander to sand both top and bottom surfaces. This was to be done by sanding the bottom first, bring the panels back to the sander and sand the top surface. In this manner, it was expected to produce 9,000 panels per day of 3 work-shifts and complete the order for 90,000 panels in 10 working days.

Problem :

Production for the first day was 8,000 panels. On the second day only 7,000 panels were produced. Indications were that the output would still decrease in the following days as the frequency of changing the sanding belts was 30% above normal, and still increasing the incidence of machine "down - time".

Analysis from the Production Department

The sanding belts were clogging-up too fast because the oscillating device of the sanding machine was not functioning properly, and should be immediately replaced by a more sensitive unit, possibly one using a photo-cell.

Analysis from the Engineering Department

The pneumatic oscillating device on the wide-belt sander was functioning properly. The dust exhaustion system was also working adequately. The wide-belt sanding machine was working properly, in general, and should be able to sand at least 8 panels per minute. The problem is not in the machine!

Management's Action

A task force composed of representatives from the Production, Equipment Maintenance, Quality Control and Industrial Engineering Departments was immediately set up with instructions to find a solution to the problem within 24 hours, or else - - - - - - - !

Task Force's Findings

Tests conducted on the materials that clogged the sanding belts showed a mixture of sanding dust and dried glue. Incidence of sanding belt clogging was high when sanding bottom surfaces. However, clogging was almost NIL when sanding panel top surfaces only. Since the bottom veneer was peeled off a wood specie more porous than that of the top veneer, glue "bleed - thru" was more prevalent on the bottom surfaces than on the top surfaces of the panels. This situation was the cause of excessive clogging of the sanding belts.

Solution Adopted and Results

The viscosity of the glue mix was adjusted by cutting down on the water content but without impairing the spreading and adhesive properties of the glue mix. Incidence of adhesive "bleed - thru" became minimal and production went up to 14,000 panels per working day (10 panels per minute). The order for 3.3 M panels was completed in time!

Lesson From the Problem

People are oftentimes so highly impressed by the production capacity potentials of advanced automation so that they forget to look deeper into the cause(s) of their production problems, explore other available options; and recommend, without hesitation, the use of highly automated devices.

2. The Case of the Roller Drier Feeder Device

Situation :

A plywood plant was planning to increase its output of 3.6 mm x 4' x 8' plywood panels from 15,000 panels/day (160 cu. m./day) to 20,000 panels/day (214 cu. m./day). Among the problems to be solved was the required increase in the capacity of its veneer drying facilities, composed of 3 batteries of roller track drier, to meet the present projected increase and allow another 10% to 20% available capacity for further future expansion. Management has agreed to purchase a 3-deck continous drier to dry top and bottom veneer sheets, together with the corresponding veneer reeling system provided that the output of the roller driers for core and bottom veneer components (clipped from 2nd and 3rd roundings) is increased to match the drying capacity of the continous drier. Engineering studies indicated that the outputs of the roller type driers can be improved by installing adequate veneer feeding devices to the driers. At present, only one battery of roller-drier, double deck, is equipped with an adequate mechanical veneer feeding device. The other two batteries of driers are manually fed. Inquiries from machine suppliers revealed the fact that such veneer feeding devices are not being produced anymore. Instead, a more sophisticated pneumatic type of veneer feeding device was offered by one of the suppliers.

__Available Options__ :

1) Buy and install the more sophisticated pneumatic type of veneer feeding device, and attain a drier capacity 150% of the projected total future requirements, at a total cost of $15,700.00.

2) Fabricate and install a mechanical type of veneer feeding device, similar to the existing veneer feeder on the twin deck roller-drier, and attain 95% of the current proposed increase in capacity, and 85% of the total programmed future capacity.

This option may be accomplished by :

a. Fabricating the veneer feeder in the plant's own engineering shop and installation work being done by company mechanics and electricians, at a total cost of $8,900.00.

b. Contracting the services of a local machine and foundry shop to fabricate and install the device at a total cost of $10,000.00.

3) Design and fabricate an improvement on the existing veneer feeding device by installing a simple LCA system, using electro-pneumatic gadgets in the mechanical feeder, thus attaining a 125% output over present feeding capacity. This option was estimated to cost $11,500.00.

Management's Viewpoint

From a purely economic point of view, it appeared that Option 2-a, supported by the plant's Engineering Department's assurance that their shop can do the fabrication and installation work satisfactorily, would be the most advantageous among the options explored. However, Management entertained serious doubts over the Engineering Department's claim that the estimated 5% deficit for the current proposed capacity increase and the 15% deficit for the programmed total future capacity can be overcome by :

a. Operating the driers for 20 work shifts/week (compared to the present 18 work shifts/week) ; or

b. Revising the temperature zones of each drier battery to allow a 10% to 15% speed-up of the rollers.

Management then examined the option to purchase the sophisticated pneumatic veneer feeding device. Although highly progressive in thinking, Management found out that the technological level of its Engineering Department was not yet developed up to a point where adequate operation and maintenance of complicated electronic-pneumatic devices could be assured.

The option to fabricate an improved version of the existing veneer feeder was found to be more attractive for the following reasons :

a. The proposed improvement assures capacities which will meet the projected immediate and near future increases in veneer drying capacities ; and

b. The adaption of ICA to the design (see Figure 12) of the improved veneer feeder would provide ample, yet relatively inexpensive, opportunity for the plant's engineering and production personnel to develop their knowledge of simple automation. Management viewed this opportunity as an important step towards modernizing their plywood plant, considering that more recent developments in plywood machinery designs involve more and more of the automation features that are required in high volume plywood production.

Management's Decision

A check with local suppliers of ICA components showed that they are sufficiently knowledgeable of the capabilities of their products and they have a competent technical staff to guide their customers in the design and fabrication of devices using their ICA systems components.

Management approved Option No. 3 for immediate implementation!

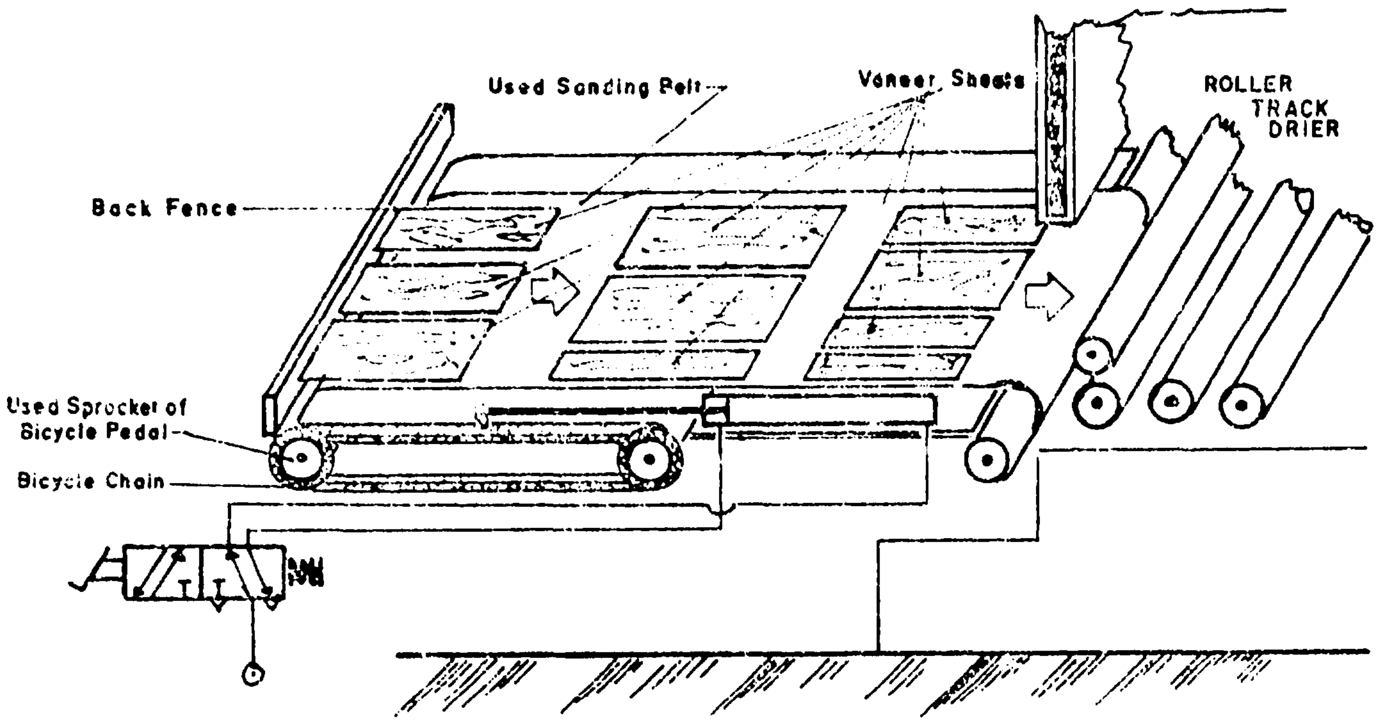


FIGURE 12

LCA SOLUTION TO THE VENEER DRIER FEEDING PROBLEM

VI. APPLICATION OF ICA TO PLYWOOD MANUFACTURING

The plywood market has tripled in size during the last two decades, with increased acceptance of laminated panels in housing and construction activities. This increase in market was matched by a corresponding increase in the size of plywood manufacturing plants. It is now a common thing to hear about plywood plants producing 50,000 panels/day (178 cu.m./8-hrs.). In fact, some plywood plants in South Korea and Japan are rated at the astounding capacities of 100,000 panels/day (356 cu.m./8-hrs.) and higher.

The giant stride in plywood manufacturing technology was made possible by the use of automation built into the machines and extensive mechanisation of material transport equipment by their manufacturers. Thus, opportunities for the application of ICA in such big plywood plants, under the guidelines enumerated in Sections II and V of this paper, are very limited.

This paper, therefore, is concerned more with the opportunities of ICA application in plywood plants with capacities of 25,000 panels per 24-hours (approximately 90 cu.m./8-hrs.) or less. These small plants usually have basic and simple veneer production, drying, glue spreading, hot presses, trim saws and sanding machines, and are relatively more labour intensive than the giant plywood plants. Thus, these small factories provide ample opportunities for the installation of ICA systems to improve product quality, reduce material wastage, increase product output and improve industrial safety conditions.

A. FLOW PROCESS AND OPPORTUNITIES FOR ICA APPLICATION

An examination of the flow process in small plywood factories (90 cu.m./8-hrs. or lower capacity) (see Figure 13) and the analysis of activities and practices observed in each phase of the production operations for possible additional mechanisation and ICA application reveal the following :

(Note : The operations described in the following paragraphs is a composite picture of the most common practices in a number of small plywood factories visited by the writer in the Philippines and abroad.)

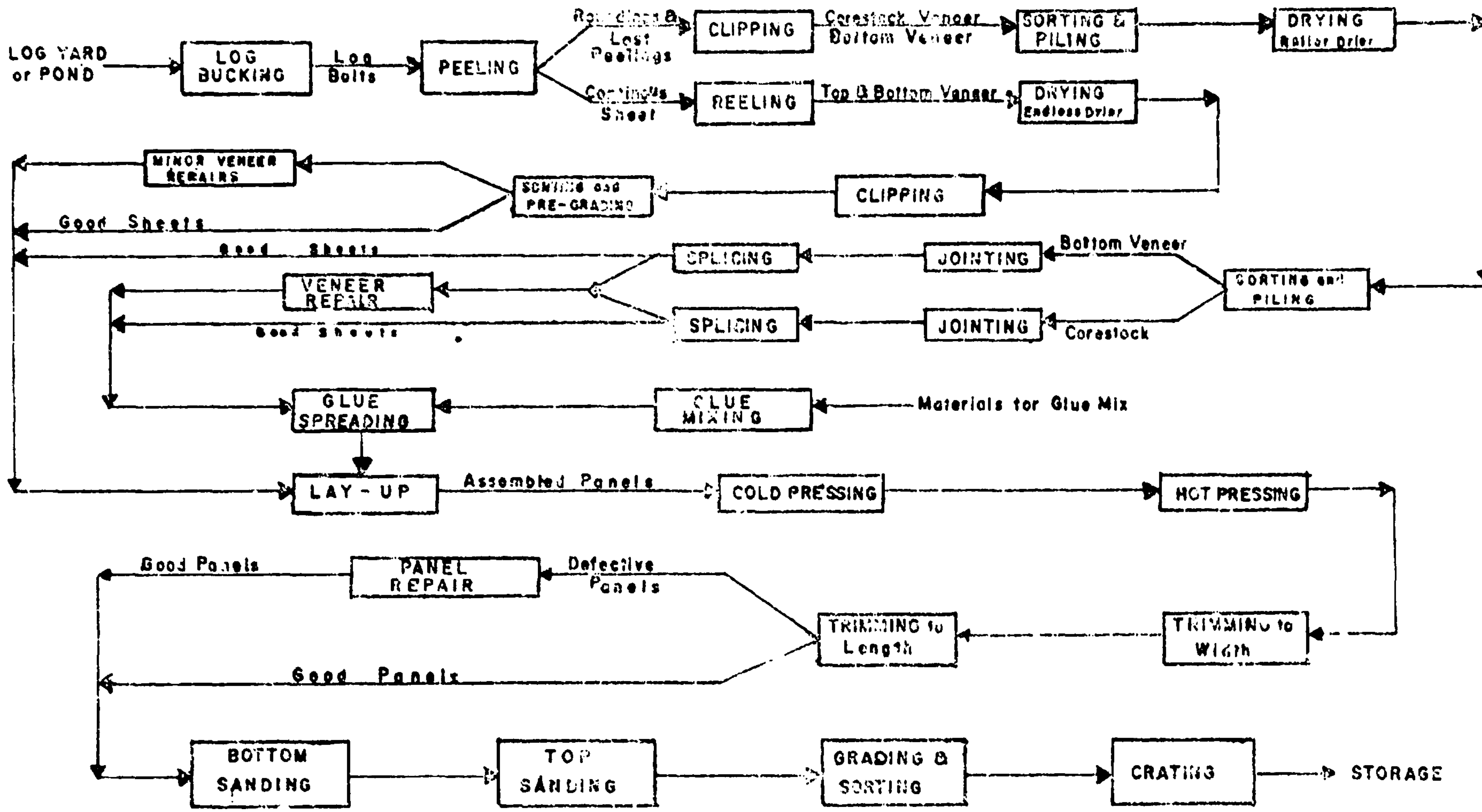


FIGURE 13

FLOW PROCESS, PLYWOOD MANUFACTURING

1. Log Handling

It is a common practice to dump the logs off a truck or trailer by running the rear wheels or one side of the hauler over a wedge ramp to tip the logs over the other side of the truck chassis. In the case where the logs fall to the water in a log pond, damage occurs to the logs as they fall one on top of the other. Worse damage is possibly suffered by logs dropped onto the hard ground of a log yard where there is no water to absorb part of the shock stresses as the logs fall on top of one another. Internal stresses sustained by the log pieces during dragging and/or yarding operations in the forest are thus considerably magnified. These damages become evident in the peeled veneer sheets as splits, cracks, stress marks etc.

A simple type of A-Frame hoist, operated by the drum-mechanism of a discarded double-drum yarder (from the logging operations) and powered by a second-hand diesel-engine (see Figure 14) offered a solution which cost less than half the cost of a 40-ton crane.

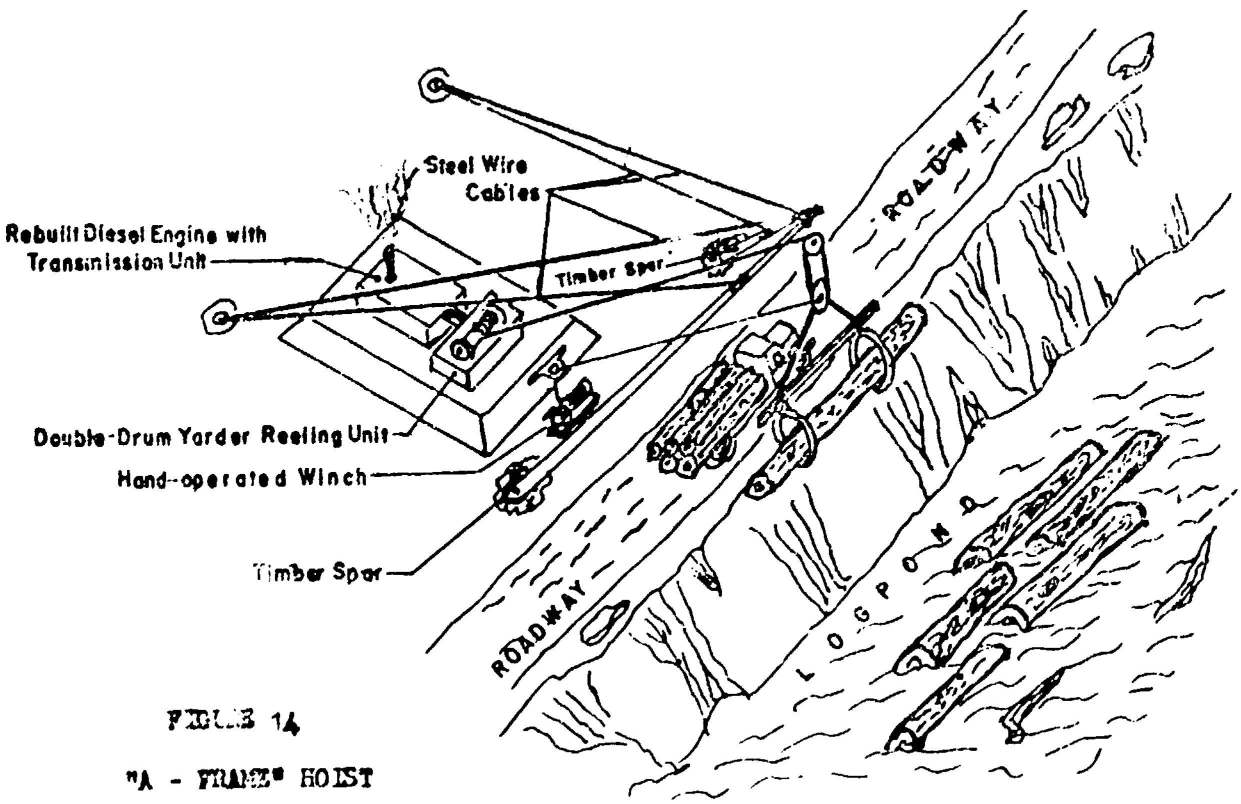


FIGURE 14

"A - FRAME" HOIST

2. Log Debarking

In countries where labour is still very cheap, it is almost impossible to justify the use of a log debarking machine. Current practice in the southern Philippines is to farm out this job on contract basis at less than US$0.10 per cubic meter. This was also found to be the practice in plywood plants in other developing countries where labour is cheap.

3. Log Bucking

Material loss in this operation due to UNSQUARE-end cuts at both ends of the log bolt is oftentimes unnoticed. A drift of 1 inch (25.4 mm.) when bucking each end of a piece of log results to a material loss of 0.01 cu.m. for every log bolt cut from a log piece with at least 60 cm. diameter. This means a daily log loss of approximately 10 cu.m. based on 978 pieces of 4 ft. and 8 ft. log bolts, the required input to produce 90 cu.m. of plywood every 8 hours. At current price of export grade logs ($130.00/cu.m.) this means an estimated annual material loss of $403,000.00. This loss does not even include the losses due to lower veneer recovery from log bolts with UNSQUARE ENDS.

The magnitude of potential material savings in log bucking can easily justify some degree of mechanization and automation in this operation.

4. Log Steaming

This operation may not be necessary when the plywood plant has a log pond for log storage. However, in plants, where logs are stacked in log yards, steaming may become necessary, particularly if the logs become too dry for peeling purposes because of long storage periods.

Normally, plants which steam the logs, have adequate log handling facilities (hoists on mono-rail tracks, or the like) and temperature control system installed even at the start of plant operations. Nothing much can be contributed by the installation of ICA in this operation.

5. Peeling Operations

a. Log Centering and Lathe Charging

A well centered axis of rotation on both ends of a log bolt leads to high veneer recovery rates in peeling operations. Optical centering is usually done in small plywood plants, while log bolt charging on the peeling lathe is facilitated by the use of an overhead traveling hoist with gripping hooks, which transports the log bolt to the peeling machine and holds the log in place until the lathe spindles (chucks) are located on the centers chosen at both ends of the log bolt. This is normally done by two men, who also clean the log's lateral surface of foreign materials such as stones, sand particles, pieces of metals, etc.

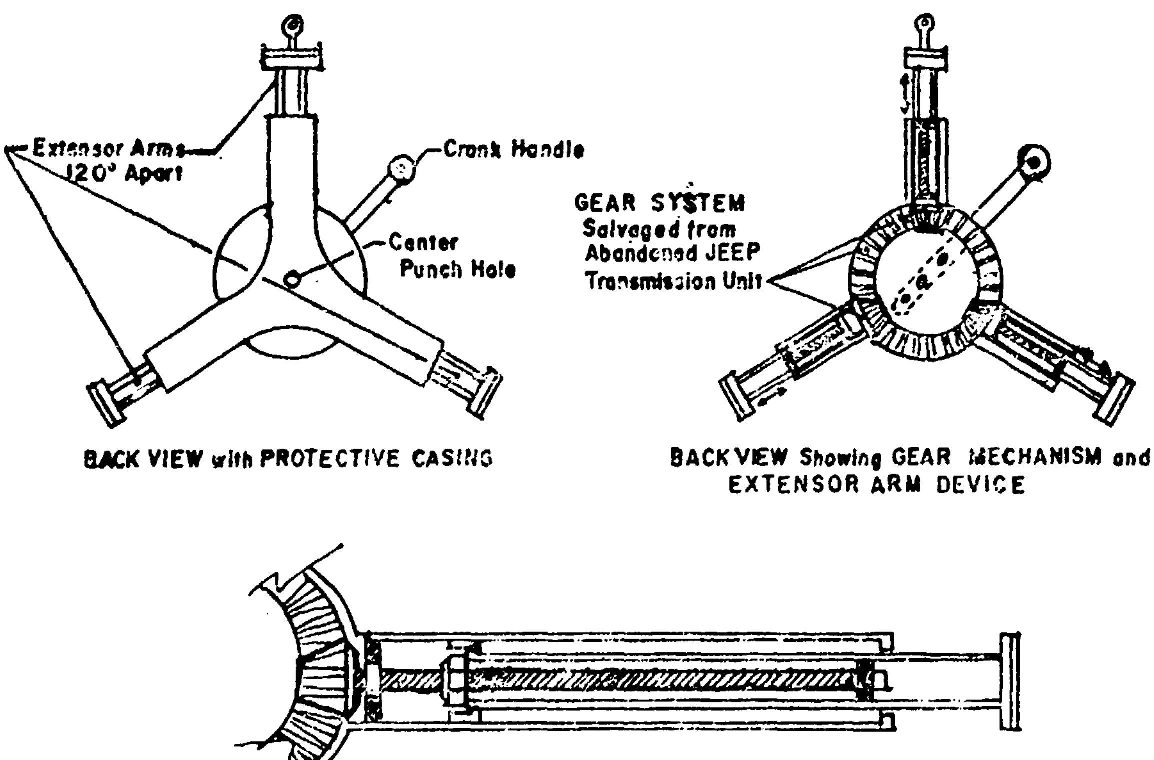
In developing countries, cost of labour is generally low. Hence, it is usually impossible to reach an economic justification for the acquisition of the more modern combined log centering and lathe charging machine. In the case of those factories where the high volume of work and cost of labour may justify the use of an automatic log centering and lathe charging machine, it is wise to be reminded that such an acquisition requires more efficient and immediate equipment maintenance activities, for then the lathe will be laid idle whenever the log centering and lathe charging machine breaks down.

Nevertheless, even a non-circular log end can be well centered with the use of a little mechanisation and simple LCA device, as shown in Figure 15.

b. Log Peeling

Conventional lathes usually require two men to operate. One man operates the lathe itself, while the other man operates the veneer transport systems linked to the lathe. Modern peeling systems incorporate the controls for log centering, lathe charging and material transport devices with the controls for operating the lathe itself, thus requiring only one operator, where four men were formerly required. Veneer peeling is a precision operation. Correspondingly, the controls which allow such precision in the veneer lathe operation should not be tampered with. In the event that more advanced automation is desired to be added to the conventional lathe, it is best that the lathe manufacturers be consulted on the matter.

Nevertheless, knowledge of the basic principles of ICA will greatly help in the more efficient maintenance of the lathe's automatic control systems, as these controls are designed under the same principles of pneumatics, hydraulics and electrics used in ICA.



BACK VIEW with PROTECTIVE CASING

BACK VIEW Showing GEAR MECHANISM and EXTENSOR ARM DEVICE

DETAIL of EXTENSOR ARM DEVICE

FIGURE 15

PORTABLE LOG CENTERING DEVICE

6. Green Veneer Handling Facilities

a. Continuous Veneer Sheets

Peeled continuous veneer is best handled by a reeling system whereby the continuous veneer sheet is wound on a veneer reel (or bobbin). The speed of reeling is usually matched to the peripheral speed of the logs being peeled, in order to prevent breaking of the continuous sheet of peeled veneer. A plywood plant with adequate machining and metal fabrication equipment can fabricate a veneer reeling system similar to that shown in Figures 16 & 17, which involves limited mechanization and automation.

b. Veneer Round-Ups

A good portion of the corestock requirements of a small plywood plant is normally obtained from the 1st and 2nd round-ups produced in peeling operations. This is augmented by the material peeled from log areas about 1 inch away from the periphery of the log core. These corestock materials come in numerous trapezoidal and parallelogramic pieces with widely varying widths. Thus, handling and storage of the material can become a problem which may adversely effect plywood production output.

The round-ups and last peelings from a log piece have to be clipped to obtain roughly rectangular pieces in order to allow efficient drying and facilitate splicing later on in the manufacturing operations. The clipping rate should match the peeling rate to prevent a pile-up of green veneer before the clipper and veneer storage fixture will be required. Otherwise, green veneer storage before the clipper machine will be necessary.

Since the efficiency and speed of clipping is primarily dependent on the clipper operator's judgment, it is imperative that the clipper be provided with devices which allows maximum clipping speed, and at the same time protecting the clipper operator from accidentally cutting his

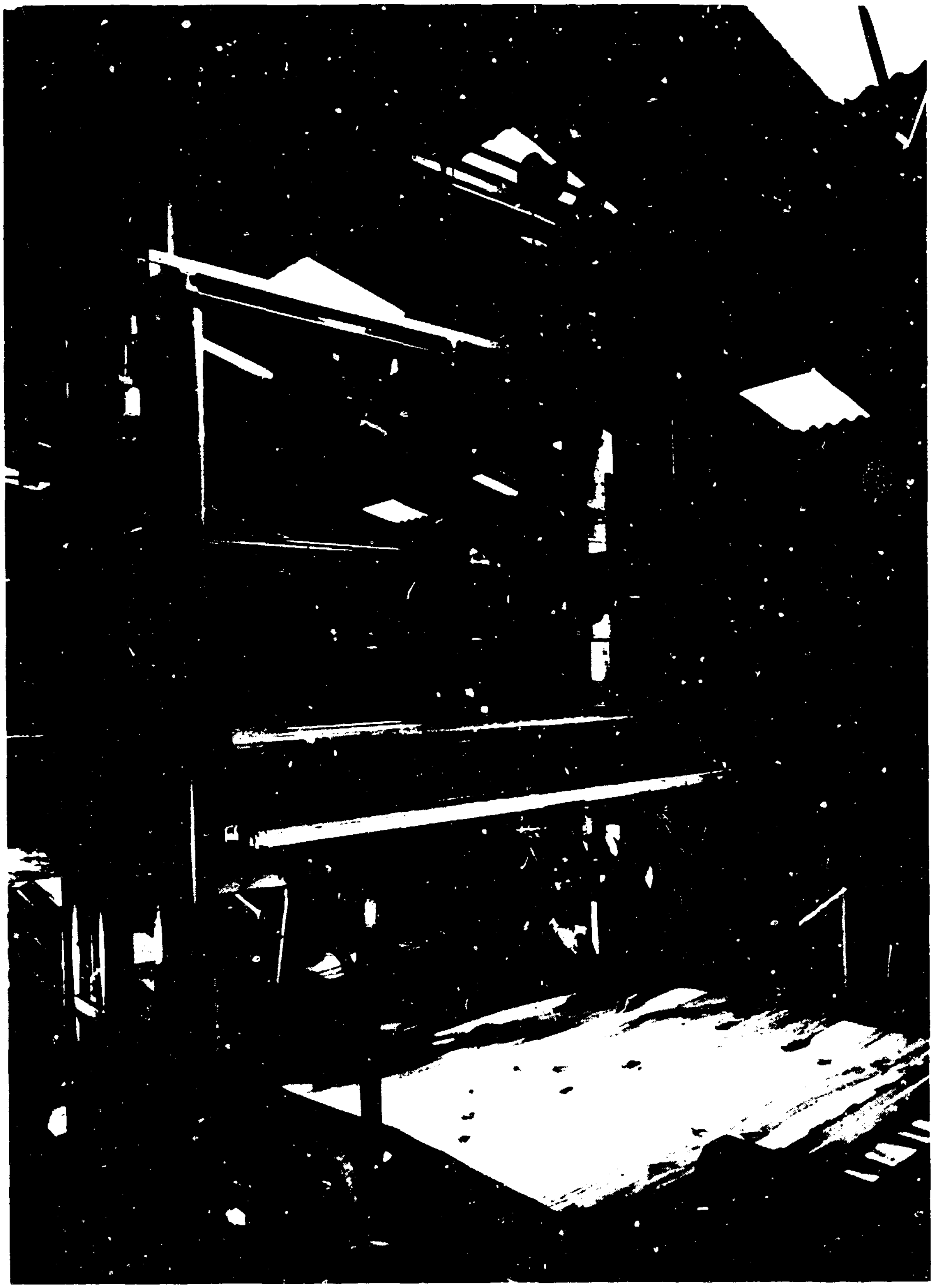


Figure 16: Veneei reeling system.

Figure 17:

Reeled bobbins storage

fingers or hand during the clipping operation.

Veneer clipper knives are normally actuated by compressed air with cutting cycles as short as 1/20 second. This fast clipping rate requires more responsive safety features on the machine, particularly clippers where the veneer is fed manually. The current ultimate improvement of the machine is by feeding it thru a veneer conveyor system and hooking-up an "OPTIMIZER" which scans the veneer surface for unpassable defects and signals the clipper knives when to cut off these defects. In this manner, there is no contact possible between the operator's hands and the clipper knife.

A simple safety device for a manually-fed, foot operated, compressed-air powered veneer clipper is shown in Figure 18.

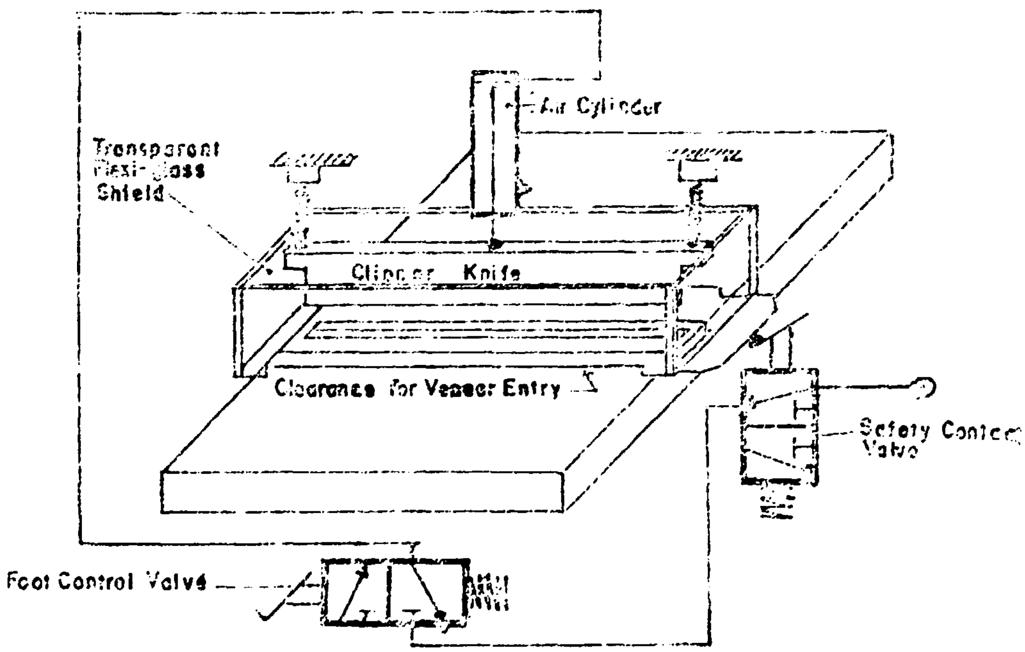


FIGURE 18

VENEER CLIPPER SAFETY DEVICE

Normally, small plywood plants use veneer pallets, flat trucks or dollies mounted on swivel wheels to store clipped green veneer. To cope with the larger outputs of conveyor-fed veneer clipping, a "ZIG-ZAG" veneer storage conveyor system (Figure 19) may be installed. In factories where a large percentage of the log input is of less than 50 cm. diameter, the "DECK" system of storing veneer pieces is recommended. Both the "ZIG-ZAG" and "DECK" systems save on factory floor space.

Figure 19: "Zig-zag" veneer storage conveyor

7. Veneer Drying

Continuous veneer sheets are dried in continuous (endless) veneer driers which are equipped with automatic feeding systems hooked-up (and synchronized) with the veneer reeling system. Hence, except for possible improvement of the temperature and air draft control devices, continuous driers offer very limited opportunity for further application of ICA. Even if such improvement is thought of to be necessary and possible, the drier manufacturers should be consulted on the proposed improvement as this may affect the other characteristics originally designed into the drier.

Roller track driers are usually manually fed, as in the case where full sheets (4' x 8') are fed into the drier. The need for a feeding device arises when "off-size" veneer pieces (i.e. pieces clipped from roundings, narrower or shorter than a full sheet) are to be dried on roller track driers. Faulty positioning and highly variable rate of feeding the veneer pieces lead to inefficient loading of the roller track drier. To attain the ideal utilisation of the drying area on roller track driers, the veneer pieces should be laid end-to-end and edge-to-edge occupying the full width of the drier opening thus leaving no void in the available drying surface of the roller tracks. A drier feeding device as shown in Figure 12 will help attain maximum use of the drying space in a roller drier when drying "off-size" veneer sheets.

8. Dry Veneer Section

a. Continuous Veneer Line

The output of the continuous veneer drier is normally clipped to the desired width (or length) on an automatic clipper, activated by a limit switch located at a predetermined distance from the clipper knife. A switching device is also connected to the clipper controls to allow manually controlled clipping. Veneer sections with unacceptable defects are clipped off by activating the clipper manually. The clipped full sheets are then transported by belt conveyors to a grading-and-sorting deck, where sheets good for plywood tops (faces) are segregated from those which are good only for plywood bottoms (backs). Top (face) veneer sheets are further segregated according to color, as the case may be, and piled on pallets or dollies. Bottom (back) veneer sheets with minor defects are piled separately from the good sheets, and are sent to the veneer repair section. The good sheets are sent to the Plywood Assembling Section.

Again, proper maintenance of the automatic clipping device requires knowledge of the basic principles of automation, particularly pneumatics.

b. <u>Clipped Corestock and Bottom (Back) Veneer Pieces</u>

Small plywood plants are usually equipped with separate machines for jointing and splicing veneer. A "GUILLOTINE", powered by a hydraulic cylinder, is commonly used for jointing several pieces of veneer (piled one on top of another) at a time. Splicing glue is brushed manually on one jointed edge, while the veneer pile is still compactly pressed by the jointer clamping device. A problem usually encountered in this procedure is that of maintaining the squareness of one jointed face of the veneer pile, while setting the jointer to cut the other edge. Faulty jointing produces veneer sheets with parallelogram or trapezoidal shapes and results in snaky-edged sheets when spliced. These sheets further slow down lay-up activities as it becomes more difficult to align the veneer sheets having irregular edges.

A number of types of veneer splicing machines are available. One model has a rotating heated calender which presses on and cures the glued joints of veneer pieces fed into the calender by a feed conveyor. The output is a continuous sheet which is clipped by a clipper installed in tandem to the splicer. This clipper is automatically operated in a manner similar to the clipper located after the continuous (endless) drier, discussed in Section 8-a above. There are splicer models which lay a length of glue string in a "ZIG-ZAG" manner across the joint. Other splicers apply a thermoplastic type of adhesive in regularly spaced pre-determined spots over the joint. A more advanced model, known as the Automatic Veneer Composer (AVEC) combines the jointing, splicing, gluing (or taping) and clipping operations, producing full sheets of pre-determined widths and lengths.

The installed basic jointer, splicer and clipper of a small plywood plant would probably be from different manufacturers and have different infeed and outfeed characteristics. Any plan to automate this section will therefore have to synchronise the output speed of the jointer to the infeed speed of the splicer; and the output speed of the splicer to the infeed speed of the clipper. In plants where the "GUILLOTINE" (knife type of jointer) is used, automated hook-up of the jointer to the splicer is hardly possible. Automation of the two operations is more feasible when a cutter-block type of jointer is available. In fact there are automatic jointing-splicing machines available in the equipment market where the jointing operations is done by a cutter block. Thus, once a way is found to hook-up the jointer to the splicer, further automation can be attained by connecting the splicer to the clipper in the manner described in the preceding paragraph.

9. Veneer Sheets Lay-Up and Plywood Assembling Operations

The material input of this section is supplied from various sections of the plywood plant, namely : Top and Bottom veneers from the grading and sorting deck after the continuous dryer clipper; bottom veneers and corestock sheets from the veneer repair and patching section; and bottom veneer and corestock sheets coming from the veneer splicing line. Plywood components are usually piled on pallets, each pallet containing only one type of component (top veneer sheet only, or corestock only or, bottom veneer sheets only).

In conventional 3-ply construction, only the corestock is passed thru a double-roll glue spreader. The corestock, glued on both surfaces, is then laid by hand over a sheet of bottom veneer. Then, a sheet of top veneer is laid, also by hand, on top of the corestock veneer. To hasten veneer lay-up operations, a composite pile of top, bottom, top, bottom, etc., sheets is made up from a pallet of top sheets and a pallet of bottom sheets. Thus, after the 1st corestock sheet is glued and laid-up on the 1st bottom sheet, a pair of Top and Bottom sheets is pulled off the composite pile and laid on the open surface of the glued corestock sheet. The process is repeated until the pile of laid-up panels is built to a height matching two loads of the hot press. In some plants, where cold pre-pressing is done, the laid-up panels are piled on top of a 3/4" (19 mm) thick wooden caul laid on a wheeled pallet to permit easy transport of the pile from the glue spreader area to the cold press, thence to the hot press.

Large modern plywood plants use automatic lay-up and gluing systems, similar to the model shown in Figure 20. Use of the automatic lay-up system is made a necessity by high volume production, or when producing large size panels, whose component plies are hard to handle manually.

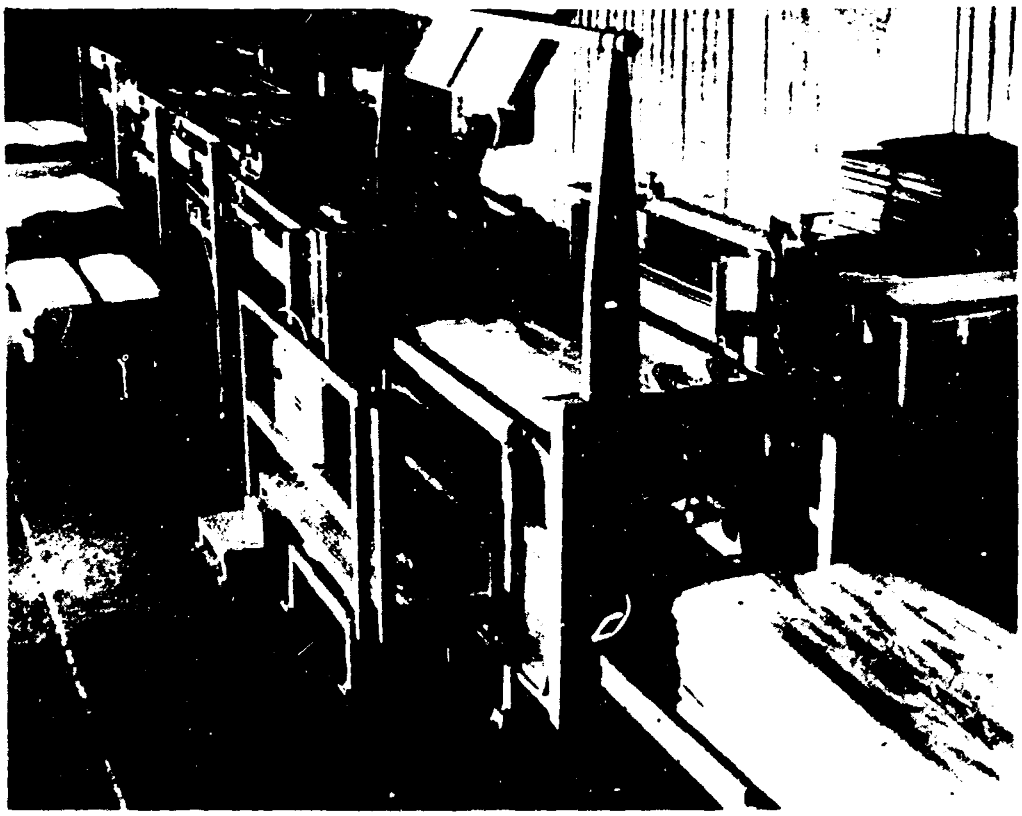


Figure 20: Automatic lay-up and gluing system

The two production systems discussed in the preceding paragrahs represent the extremes in lay-up and gluing technology. The first system is purely manual and is thus highly labor intensive. It also requires a large area of factory floor space. There is only one piece of simple machine to maintain : The double roll glue spreader. However, its output is low. The veneer plies and the glued-up panels are more exposed to possible damage as a result of the extensive handling by human hands.

On the other hand, the automatic system is almost fully automated. It requires only one man to operate. The production output is very high. The veneer plies and the glued-up panels are less exposed to material handling damage. The system can produce large size panels (5' x 10'). But the level of technology required to keep the machines and material transport accessories in good operating condition is also high.

Definitely, the equipment complement of the manual system costs much less to acquire, install and maintain than that of the automated system. Thus, justification for automation of this section of the small plant is hardly possible.

10. Cold And Hot Pressing

Cold pre-pressing is done on a hydraulic press. In small and medium plywood plants, loading and unloading is done manually.

Application of automation to the operation finds limited opportunity for the hydraulic presses are installed complete with the desired controls.

However, simple mechanization by way of roller conveyors (dead or live) may be installed to facilitate loading and unloading the press and reduce the chances of accidents occurring during the transport of glued-up panels.

Multi-opening hot presses in small plywood plants are usually manually loaded and unloaded. Automatic loading and unloading of the panels into the press platens become necessary when the pressing capacity requirement reaches 20,000 panels/day

(70 cu.m./8-hrs.) or more. Automation allows maximum utilization of the hot press and saves on factory floor space.

Since hot presses are specifically designed and built for either manual or automatic loading and unloading operations, it is hardly possible to convert a manually operated hot press to an automatic loading and unloading one.

However, knowledge of ICA systems will help k ep the automatic controls of the hot press in good operating condition.

11. Panel Trimming and Sanding Operations

a. Panel Trimming Line

The basic machine for trimming the edges of plywood panels is the trimsaw with two circular sawblades mounted on the same shaft and set apart at the desired width or length of the panel to be cut. There are usually two of these machines, one for trimming the plywood panels to the desired width and the other, for trimming to the desired length. These machines are usually equipped with feeding devices which keep the panel adequately pressed on the machine bed as it is pushed against the sawblades. Without conveyorization between the two trimsaw machines, feeding and unloading each trimsaw is done manually by two workers at each end of the saw. Thus the two saws require a minimum of 8 workers. Panels are transported to and from the machines by means of wheeled dollies or pallets moved by a mobile hand-lift.

b. Sanding Operations

The basic machinery for sanding the trimmed plywood panels are usually a double belt top sander and a double drum bottom sander. In some plants, the bottom surfaces of the panels are scraped on a scraping machine, rather than sanded. Feeding and unloading the machines are done manually by two men at each end of the machine, thus at least 8 men are required to operate the whole sanding line, in either case.

The foregoing set-up of the panel trimming and sanding lines provide ample opportunity for the application of mechanization and automation, particularly in the labour intensive feeding and unloading aspects of the operations. In fact, with automation and conveyorization, the trim saw line can be hooked-up to the sanding line, and arrive at a system which will require at most 3 men. This step in modernization of the two lines, without replacing the machines with new equipment is discussed in more detail in a latter section of this paper.

12. Panel Grading, Sorting and Crating

Grading sanded panels is done by sight; while sorting and crating are all manually accomplished. Again, this section of a small plywood plant, being highly labour intensive, provides possibilities for the application of LCA.

With the conveyorization of the sanding line, a powered conveyor extension can be connected to the output end of the last sanding machine (Top Sander) and grading activities can be conducted visually while the panels move along the conveyor. A highly advanced improvement would be to use a scanning device, similar to the "OPTIMIZER", discussed in paragraph VI-A-6b and rig up a combination sorter-piling machine. Crating can be done by a machine especially designed for the purpose with built-in steel strapping device. Transport of the piled panels from the sorter-piler to the crating machine can be facilitated by conveyorization.

Once more, the economic consideration for automating this phase of plywood manufacturing, would greatly outweigh any other factor, to justify the move to modernize.

VII. APPLICATION OF LCA TO SMALL FIBREBOARD PLANTS

About ten years ago, it was of general acceptance in industrialized countries that the minimum economic size of a fibreboard plant is 100-tons per day (30,000 tons/year). With the recent increase in the costs of equipment, labour and raw materials, it can be presumed that the minimum economic size has increased beyond the 100 tons/day level. This size of plant, with all its advanced mechanisation and automation built into the production machinery and transport equipment could not be economically justified in developing countries which wanted to manufacture fibreboard to complement the need for panelling materials in their housing programme, in spite of the readily available low cost raw materials and cheap labor. However, it was proven in the middle 1970's that, for purposes of domestic cosumption in developing countries, fibreboard plants with capacities below 50 tons per day (6,000 tons/year) are viable. Fibreboard plants with capacities of 12 tons/day (3,600 tons/year) and 24 tons/day (7,200 tons/year) were successfully installed and operated in African countries by native labour, under the supervision of expatriates from developed countries. The main features of these small-size fibreboard plants are :

a. Batch system of production ;
b. Wet process of fibreboard manufacture, which does not require the use of bonding agents hardly available in developing countries ;
c. Use of basic machines wherever allowed by production constraints ;
d. Manual transport systems for materials-in-process and finished goods.

These small fibreboard plants offer opportunities for the application of ICA in order to :

a. Reduce Labour Cost ;
b. Provide Better Industrial Safety Features and ;
c. Save on materials waste or damage during transport in between operation.

This paper therefore discusses the possibilities of adopting ICA in such small fibreboard plants.

A. FLOW PROCESS AND SITUATIONS FOR POSSIBLE ICA APPLICATION

Figure 21 shows the flow-process involved in a 24 tons/day, batch-type, wet process fibreboard plant in Kenya. The operations en - closed by the broken line are performed with the use of machinery and transport equipment specifically designed and constructed for the type of process and rated production capacity of the plant. Hence, their controls are built into the machinery and equipment. It is best that the machinery supplier be consulted on any proposed alterations on these machines. The operations outside of the enclosing broken line are those which use simple basic machines and equipment, do not need special design and, thus, may be supplied by other manufacturers. These are the operations where ICA finds better chances of application and shall be the focus of the discussions in the following paragraphs. A better appreciation of the operations involved in this type of fibreboard plant is given in the pictorial flow process shown in Figure 22. (The raw material preparation operations, i.e., log debarking, log bucking and splitting are not shown in the pictorial diagram.)

1. Log Handling

Log handling for purposes of fibreboard panels is not saddled with the constraints found in plywood manufacturing. Furthermore, the log input of fibreboard plants are commonly smaller than those in plywood plants. Hence, log handling in fibreboard plants lend itself better to more manual operations. It has been observed that mechanization of log handling in fibreboard plants becomes more of a necessity when the log volume to be handled is big enough to justify the acquisition of mechanized log handling equipment.

2. Log Debarking

Small volumes of log inputs, as in the 24-tons/day fibreboard plant which requires 1.65 tons of logs for production raw material and 1.25 tons of fuel wood for every ton of end-product, could hardly justify the use of debarking machines particularly where labour is very cheap. Hence, manual debarking is recommendable at present.

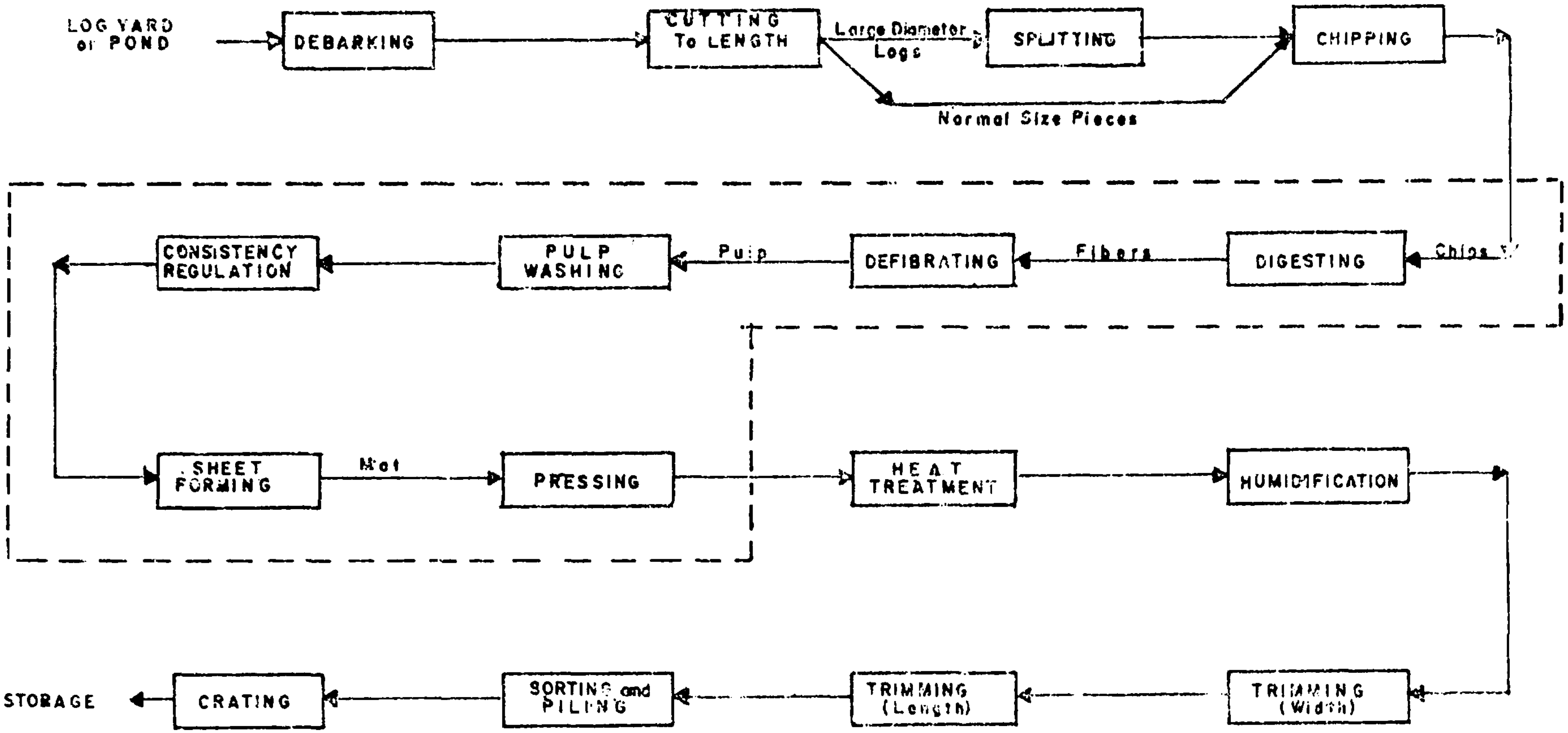


FIGURE 21

FLOW PROCESS, PANEL - TYPE FIBERBOARD PRODUCTION

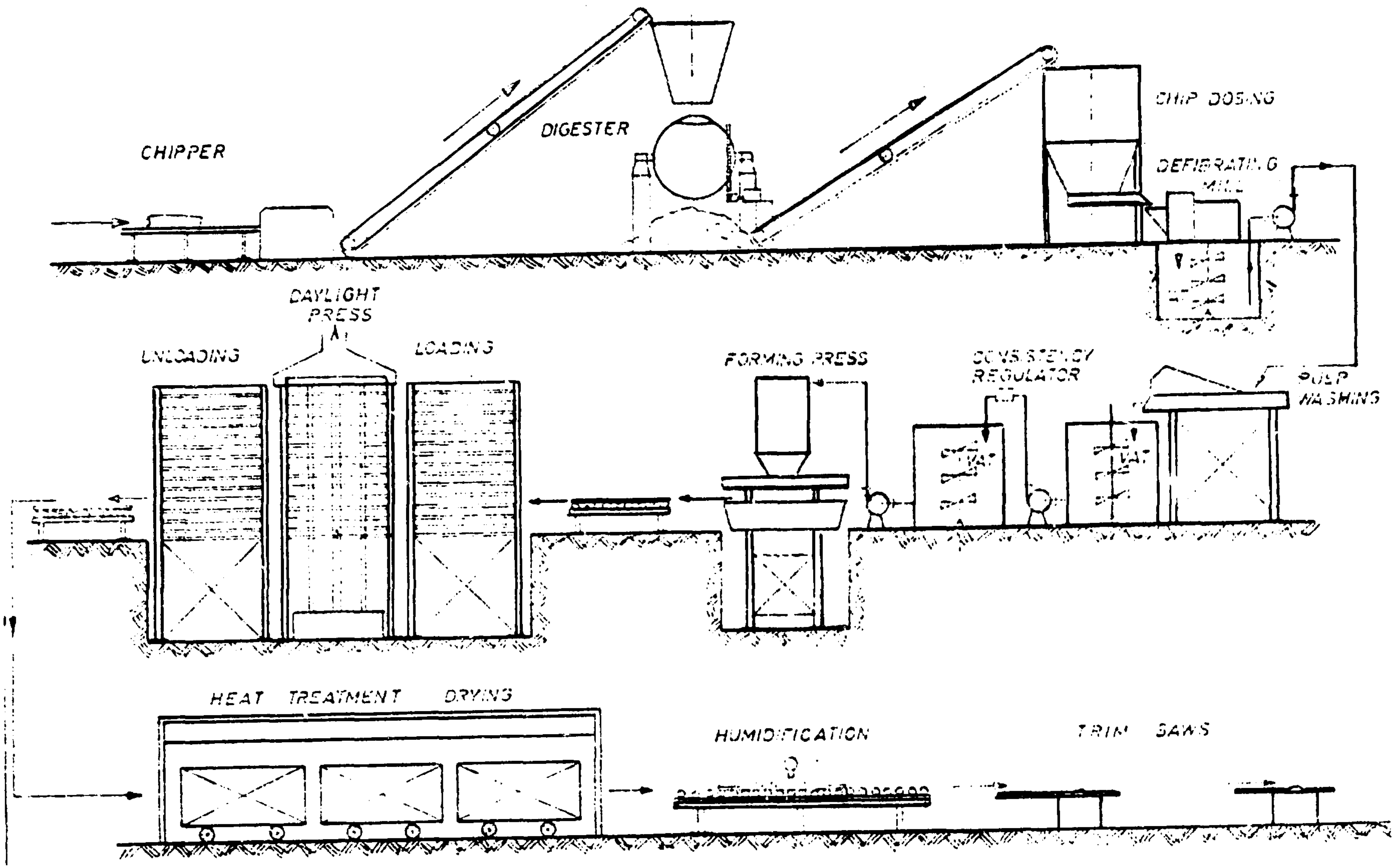


FIGURE 22

PICTORIAL FLOW PROCESS, BATCH – TYPE FIBREBOARD PRODUCTION

3. Log Bucking and Splitting

Where the log supply comes with lengths too long and/or diameters too large to be handled by the clipping machine and its feed conveyor system, preparatory bucking and splitting have to be done on the logs. Furthermore, the logs are washed before they are fed into the clipping machine to remove dirt and other foreign materials which adversely affect clipping operations.

The log input of the fibreboard will come mainly from wood waste by-products of other wood processing activities. Hence only a small portion of the mill's input have to be bucked or split. This small volume to be bucked can not justify the use of an automated device. Hand-operated chain saws are more adaptable to this operation.

Where the log diameters are too large to allow safe splitting by hand, a hydraulic operated log splitter is used. Again, the volume of logs to be split is so small to justify further mechanization or automation of the operation. However, safety considerations require the installation of a protective device which prevents the worker from splitting his hand (or fingers) together with the logs.

4. Chipping Operations

A drum type chipper reduces the logs into chips. (Disc-type chippers may be used if the input does not include small residues from saw mills or plywood factories.) Log pieces are laid by hand on a belt conveyor which feeds the log pieces into the feed rollers of the chipping machine. The chips produced are exhausted onto specially designed belt conveyor which empties its load into chip bins. Loading of wood pieces on the in-feed belt conveyor is controlled by the workers assigned to do the job.

The problems that may possibly arise in this operation are :

a. Unnoticed inclusion of metallic objects with the wood input of the machine will damage the chipping knives;

b. Clogging of the chip well at the foot of the chip conveyor when the latter malfunctions or stops, while the chipping machine continues to run.

A magnetic metal detector installed on the infeed belt conveyor which stops the conveyor when metallic objects are detected on the conveyor will help solve the first problem cited above.

Clogging of the machine input opening may be prevented by installing a warning device which automatically stops the chipper when over-size wood pieces are pushed against the sensing component of the warning system.

Clogging of the chip well can be prevented by installing a mechano-electric device which will simultaneously stop the chipper motor and infeed conveyor.

5. Digesting, Defibrating, Pulp Washing, Consistency Regulation, Sheet Forming and Pressing Operations

As mentioned in Sec. VII-A of this paper, the component machines, equipment and transport facilities in these operations of the small fibreboard plant were designed to the particular capacity and type of process for the plant. Correspondingly, the controls have been built into the machines and equipment to assure facility in attaining a desired balance in this series of operations. Any plan to revise some operating features of one machine may adversely affect the performance of the other machines in the series. Hence, it is wise to consult the equipment suppliers before any such alteration is introduced into the system.

Nevertheless, proper maintenance of the controls of these machines will be facilitated by a good knowledge of ICA for these control systems are designed under the same principles used in ICA.

6. Heat Treatment

Heat treatment of the pressed boards is done in a steam-heated chamber for 4-hours. The boards are loaded in multi-opening tray trucks, which are then pushed into the heat treatment chamber. Each truck daylight can carry two thin boards or one thick board. The trucks, mounted on wheels, are manually pushed in and out of the treatment chamber.

Except for the improvement and maintenance of the temperature controls of the chamber, it appears that application of ICA to this operation is hardly possible without radically changing the installed equipment and the concept of the heat treating operation as used in this plant.

7. Humidification

The heat treated boards are then humidified by spraying water on the rough-back-side of the boards. This operation is deemed necessary to prevent warping of the boards when in use. The moistened boards are then stacked in a pile for sometime to allow normalization of moisture content over the whole thickness of the boards.

The machine used in this operation is of very simple design (see Figure 23).

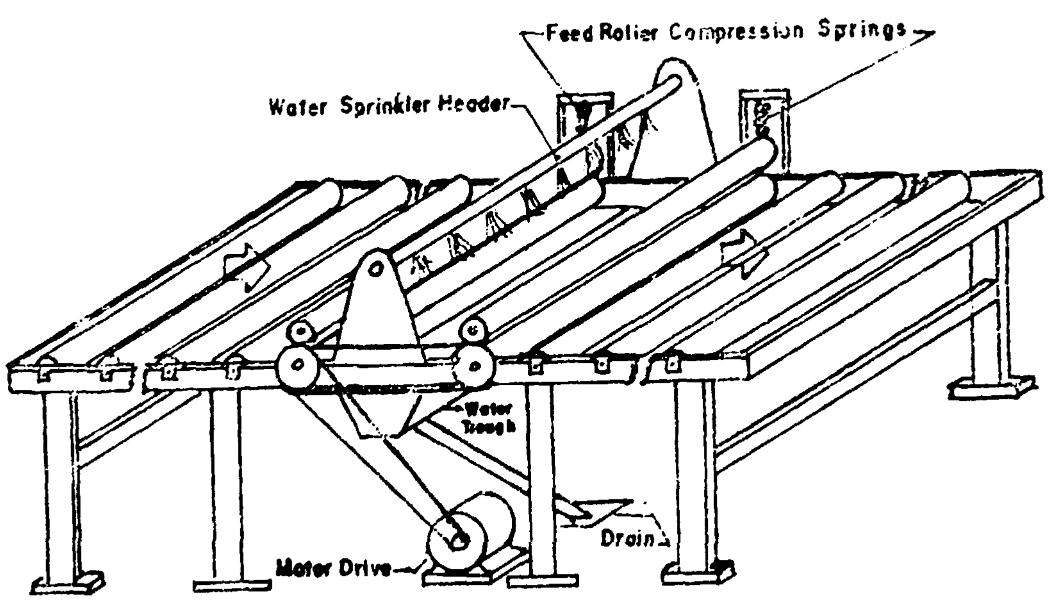


FIGURE 23

HUMIDIFYING MACHINE, SMALL FIBREBOARD PLANT

To provide better handling of the boards (and prevent damage to the boards) at both the infeed and outfeed ends of the machine, it is possible to install hydraulic operated "SCISSORS-LIFT" at each end so that the board-in-process can always be made to rise (or fall) to the same level as the machine bed. This makes it possible for the infeed worker to just slide a board into the rollers of the machine. The same ease is achieved at the outfeed end of the machine, where the board is made to slide from the roller bed onto the pile supported by the scissors-lift. Both scissors-lifts can be raised or lowered by a foot-controlled hydraulic valve.

8. <u>Panel Trimming Operations</u>

Trimming the boards to final size is done on a gantry saw equipped with three sawblades mounted on the travelling gantry. Two sawblades mounted on the same shaft cut the board edges as the gantry travels from one end to the other end of the machine. The third saw is suspended from a movable base which is made to travel in a line perpendicular to the cuts made by the twin saws. The third saw is activated at the beginning of the cycle to cut one end of the board, stops automatically as the cut is completed, and then re-activated to cut the other end of the board (to a pre-programmed length), after the twin saws have completed cutting the board to the desired width. The boards are fed into and unloaded from the machine by hand.

Obviously, this saw is purposely designed for batch type operations. At least two men are required at each end of the machine. Nevertheless, it is possible to adapt ICA to automate the operations, together with a properly designed conveyor system for the machine.

This can be done in the following manner :

1) Install a "Scissors-Lift" at the infeed end ;
2) Install a pneumatic feeding device for the pile of boards on the scissors-lift ;

3) Install a wide-belt conveyor on the machine bed, such that the conveyor will be activated after a signal from the feeding device ;

4) Install a limit switch at the discharge end of the machine bed so that the wide-belt conveyor is stopped and the cutting cycle is started when the leading end of the board hits the limit switch ;

5) Install a switching device which will activate the wide-belt conveyor again after completion of the cutting cycle, so that the trimmed board is discharged into another "scissors-lift". The wide belt conveyor is automatically stopped after the board is completely discharged off the machine bed.

6) The gantry is then automatically moved to the feed end of the machine, and the whole cycle is repeated.

If sorting, piling and crating operations are desired to be hooked-up automatically to the trimming operations, the scissors-lift at the discharge end can be eliminated, and a live conveyor system installed in its place, similar to that discussed in Sections VI.A.11 and 12 of this paper (Plywood manufacturing operations). A sorting, piling and crating system, similar to that discussed in similar operations in plywood manufacturing can be installed for this purpose, provided the factory situation justifies the improvement.

VIII. APPLICATIONS OF ICA TO PARTICLE BOARD PLANTS

The development of equipment for the manufacture of particleboard during the last two decades has been directed to the reduction of manpower requirements, as a response to the high wage levels in industrialized countries. Thus, we find the out-dated particleboard plants being sold to and installed in developing countries where the cost of labour is low. Nevertheless, we may find situations in these old plants for the application of ICA to achieve the following :

a. Improvement of Product Quality ;
b. Increase in Board Production ;
c. Reduction of Rejects ; and
d. In general, reduction of unit cost of Production.

A. FLOW PROCESS AND OPPORTUNITIES FOR ICA APPLICATION

The basic steps in the production of particleboard for a system whose input is composed of logs, slabs, branches and faggots is illustrated in Figure 24. The opportunities for the application of ICA and mechanization, like that in the manufacture of fibreboard, is confined to machines and transport systems which are basic in design and universally used for the particular operation. It was further discovered that application of ICA to especially designed and engineered machines and corresponding material transport systems is hardly possible without affecting performance of the machine itself in relation to the balance of flow for which these machines and transport systems were originally designed. In cases such as these, the objectives of modernization may be achieved by the replacement of the present machine with more advanced models. As explained in the beginning of this paper, this method of modernization is outside the scope of ICA application as conceived in this paper.

1. Material Preparation Activities

In particleboard plants where the raw material input is in the form of logs, the preliminary operations performed are similar to that in the manufacture of fibreboard. Logs and branches are cut to appropriate lengths. Over-size logs are split to smaller sizes which can be fed to the chipping machine.

2. Flaking to Mat Pressing and Cooling Operations

The succeeding operations, from FLAKING to MAT PRESSING, are done in machines especially designed for the particular process and capacity, together with the corresponding materials transport system which maintains the balance of flow. In out-dated particleboard plants, increase in production capacity in these particular sections of the process can be

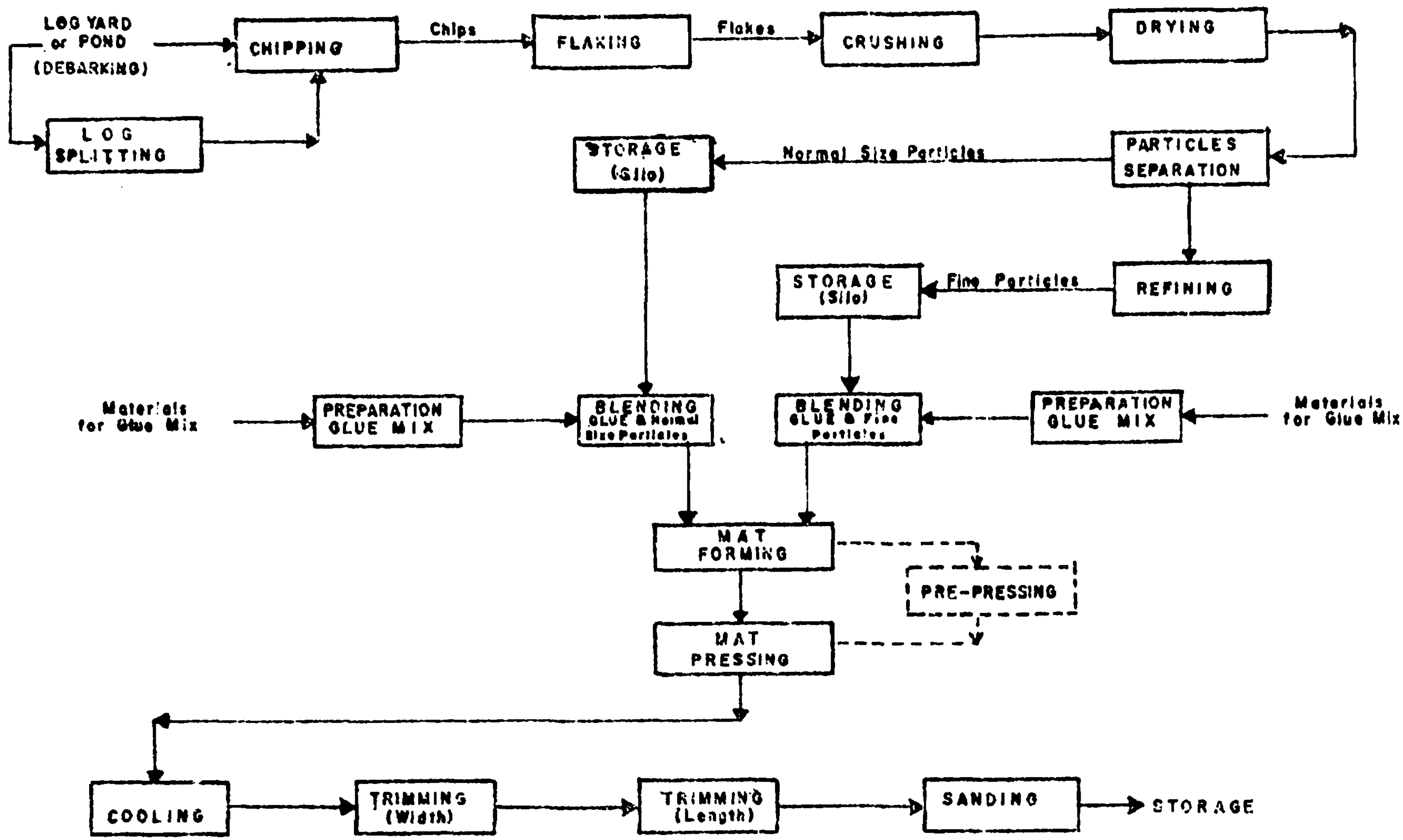


FIGURE 24

FLOW PROCESS, PARTICLEBOARD MANUFACTURING achieved by addition of similar units or their replacement by more units with larger capacities.

The opportunity to install ICA in these operations is thus very limited.

3. Glue Mixing and Particles Blending

This is considered the heart of a particleboard plant. Product quality is controlled by these operations. H. Dressler has compiled the progress in the development of glue-chip-mixing machines and it is indicated that efficiency in blending glue and chips can hardly be achieved by automation of the existing machine, but by its replacement with a more advanced model.

4. Trimming and Sanding Operations

These operations in a particleboard plant are basically the same as those operations in a plywood plant. Hence, application of ICA to these operations, as discussed in Section VI - A - 11 of this paper also applies to the manufacture of particleboard.

IX. ILLUSTRATIVE EXAMPLES OF ICA APPLICATION

Time and space constraints do not allow the illustration of ICA application to all the situations discussed in the preceding paragraphs. Thus, the ICA solution to a only few representative problems are discussed below. The presentation of the solutions follow the guidelines enumerated in Section V of this paper.

A. LOG BUCKING FOR SQUARE ENDS - (PLYWOOD MANUFACTURING)

1. Situation

Log bolts for peeling are cut at a floating log house (about 20 meters from the shore) by a gasoline fueled chainsaw mounted on a metal be. anchored to the floor of the log - house. A lever mechanism allows the chainsaw to be raised and lowered vertically in an arc. The log to be cut is gripped tightly to the edge of the log-house floor by means of grappling hooks held by workers while the log is being cut. The product of this operation are log bolts 8 ft.-6 in. (2.590 meters) and 4 ft.-6 in. (1.370 meters) long. 65% of the log bolts do not have square end cuts.

Production engineers calculated that a material savings of 2 in. (0.051 meters) per log bolt can be had by reducing the peeling length allowance from 6 in. (0.1524 meters) to 4 in. (0.1016 meters), provided the log bolts are cut squarely at each end. This means an annual potential materials savings of 4,340 cu. m. or approximately US$564,200.00 at log prices current at that time, for the 25,000 panel/day plywood plant. This can be attained by arrangements with the logging operations people to bring down logs already cut in multiples of 8 ft. - 4 in. or 4 ft.-4 in. or a combination of the two lengths. In this manner, a better balance in the production of TOP, CORE-STOCK and BOTTOM veneer sheets can be attained. Furthermore, the log ends arising from the log bucking operations at the plywood plant will be minimized.

Problem

What device or system to construct and install which will assure square-end cuts on the log bolts?

Options Available

1) To help keep the sea-water more or less smooth and prevent undesirable relative movement between the log and the log-cutting-house, it was proposed to build a 1.1 km. breakwater (causeway) around the log-house area at an approximate cost of US$110,000.00. There will be no change in the log bucking operations.

2) Another proposal was to build a concrete log-cutting-house about 15 meters from the shore (as allowed by tide considerations); and mechanise log loading on the cutting platform. All other phases of the cutting operations will be the same as before. This proposal will require two men/shift less than the original log-bucking work crew. Furthermore, it will mean an

annual savings of US$8,000.00, in terms of maintenance and repair of the log-house. It was estimated that the proposed system will be at least 80% effective. The proposal was estimated to cost US$175,000.00.

3) A third proposal was to build the concrete log-house 5 meters from the shore; install a cable-winch to tow the logs from the logpond to the log cutting house; mechanize and automate the log loading, length measuring and log cutting activities. The proposal also includes the installation of a conveyor system to transport the log bolts from the log-cutting-house to the log-well located just before the peeling section of the plywood plant. This proposal will reduce the log-bucking and transport crew by 10 men/shift; save US$8,000.00 per year on maintenance cost of the log-cutting house; assure better the squareness of log-ends; maintain the desired length allowance of 4 inches (0.1016 meters) on each log bolt; provide better safety to the workers and require log-bucking operations for only 2 shifts/day, even during rainy weather. The proposed system was expected to be 95% effective. The proposal was estimated to cost US$275,000.00. Other costs resulting directly from the automation and mechanization aspects of the proposal are as follows :

a) Training of engineer in ICA systems ---- US$2,500.00

b) Training of one technician to operate ICA system as installed in the log-cutting-house ------------ US$1,500.00

c) Increase in maintenance cost of equipment ------------------------------ US$ 450.00/mo

d) Increase in salaries of 5 key personnel due to added skills --------- US$ 500.00/mo

4) <u>Value Analysis of the Available Options</u>

Option No. 1, to build a break-water around the log-cutting-house area was rejected at the outset since there was no tangible assurance that smooth seas around the log-cutting-house will result to squareness in cutting log bolts.

On the basis of an average 1,000 log bolts to cut every day, 310 days per year, 5 years equipment depreciation period, Options 2 and 3 were compared.

The results were as follows :

a) Total Volume of Logs to Cut in 5 Year Period, at 50% Recovery :

5 Yrs. x 310 days/yr. x 2,675 cu. m./day =

4,146,250 cu. m.

b) Operating Costs :

Cost Item	Option No. 2		Option No. 3	
(1) Labour Costs (5 Yrs.)	No. of Men	Basic Pay (5 Yrs)	No. of Men	Basic Pay (5 Yrs)
Engineer (Additional)	None	------	1 man	$12,000.00
Supervisory Level	3 men	$ 18,000.00	2 men	16,000.00
Skilled Workers	3 men	12,400.00	2 men	10,333.00
Unskilled Workers	42 men	121,520.00	12 men	24,720.00
Totals ----	48 men	$151,920.00	17 men	$73,053.00
(2) Maintenance Costs (5 yrs.)				
Building and Structure		$100,000.00		$127,000.00
Machinery and Equipment		125,000.00		152,000.00
Totals ----		$225,000.00		$279,000.00
(3) Fringe Benefits for Labour (By Law and Company Policy)				
38% of the Basic Pay		US$ 57,730.00		US$ 27,760.00

(4) Power and Fuel	US$ 12,000.00	US$ 18,000.00
(5) Depreciation of Buildings and Equipment	US$175,000.00	US$275,000.00
(6) Administrative Costs	US$ 50,000.00	US$ 54,000.00
Total Costs for 5 Year Period	US$671,650.00	US$726,813.00

c) Material Savings Aspect

	Option No. 2	Option No. 3
Efficiency	80 %	95 %
Value of Material Savings	US$451,360.00	US$535,990.00

d) Summary

Total Operating Cost for 5 Year Period	US$671,650.00	US$726,813.00
Average Annual Operating Cost	134,330.00	145,362.00
Expected Annual Material Savings	451,360.00	535,990.00
Net Savings Per Year	US$317,030.00	US$390,628.00

The foregoing analysis indicates that Option No. 3 offers the best solution among the options evaluated.

5) Maximum Allowable Investment

At the then current cost of money of 14% per annum, the maximum allowable investment for the mechanization and automation project of the log-bucking operations under Option No. 3, was determined with the condition that it will be acceptable only if the pay-back period does not exceed 2 years, according to company policies.

a) Maximum Allowable Investment in Option No. 3 :

The current (before mechanization and automation) cost picture is as follows :

(1)	Labour Costs	For 5 Years
	Supervisory, 3 men @ $2,000.00/yr. ———	$ 18,000.00
	Skilled Workers, 3 men @ $2.67/day ———	12,400.00
	Unskilled Workers, 48 men @ $1.87/day ———	138,880.00
	T o t a l s —— 54 men ———	$169,280.00
(2)	Maintenance Cost	
	Building and Structure ———	$ 87,000.00
	Machinery and Equipment ———	10,000.00
	T o t a l ———	$ 97,000.00
(3)	Fringe Benefit, 38 % of Basic Pay ———	$ 64,326.00
(4)	Power and Fuel ———	$ 5,000.00
(5)	Depreciation, Buildings, Structure and Equipment ———	$ 40,000.00
(6)	Administrative Costs ———	$ 35,000.00

then :

$$I_{max} = \left[\frac{1}{1 + \frac{14}{200}(5 + 1)}\right]\left[5\ (535,990) - (\$726,813 - \$410,606)\right]$$

$$= \underline{\$2,363,743.00}$$

Thus, the estimated Project Cost for Option No. 3 of $275,000.00 is still below the Maximum Allowable investment for the Project.

(Note : Another equivalent form of the I_{max} formula is used in this case in view of the absence of data in the form required by the original formula given in Section V - B - 1 of this paper.)

b) "Pay-back" Period :

No. of Years to Pay	=	$275,000.00 / $390,628.00	=	0.704 years or 8-1/2 months

6) Management Decision

Option No. 3 was approved for implementation. The automated and mechanized solution is presented in Figures 25 and 25 (a).

B. MECHANIZATION AND AUTOMATION OF PANEL TRIMMING AND SANDING OPERATIONS, (PLYWOOD PLANT)

1. Current Situation

Management of a plywood plant rated at 20,000 panels/day, wishes to increase its capacity to 25,000 panels per day. Among the production areas to be improved are the Panel Trimming and Sanding Sections. Although the machines are rated to produce 20 panels per minute, current production is only 12,000 panels/day (8.33 panels/minute).

This low output was analysed to have been caused by manual feeding and off-loading of the trimming and sanding machines. Furthermore, transport of panels between machines is by wheeled flat trucks (trolleys) pushed by two men.

The current manpower complement of the two lines are as follows :

Panel Trimming Line

Technician ————————— 1 Man/Shift

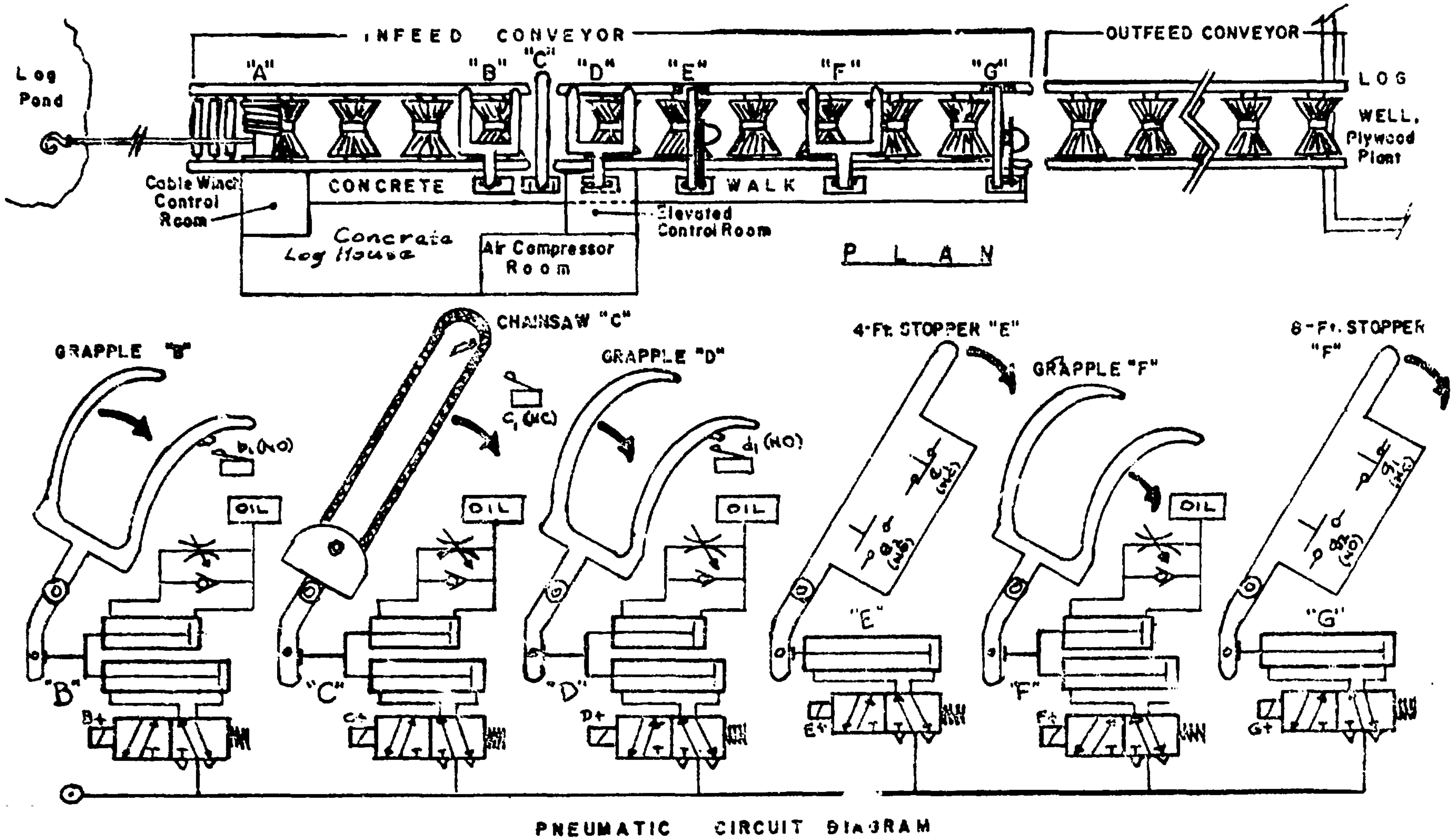
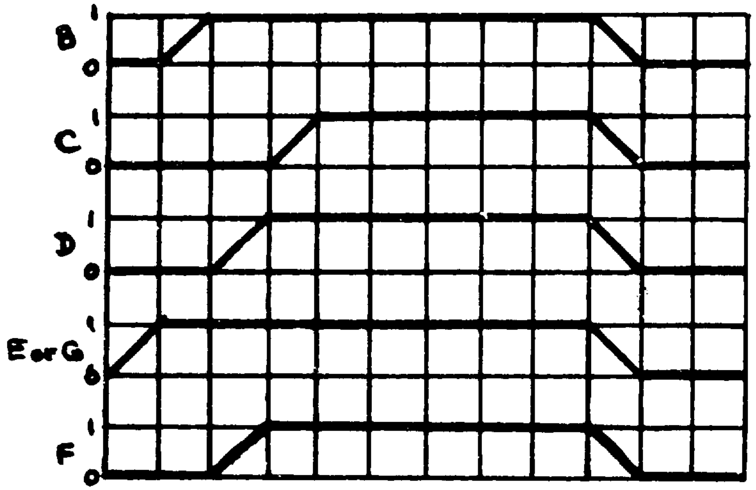
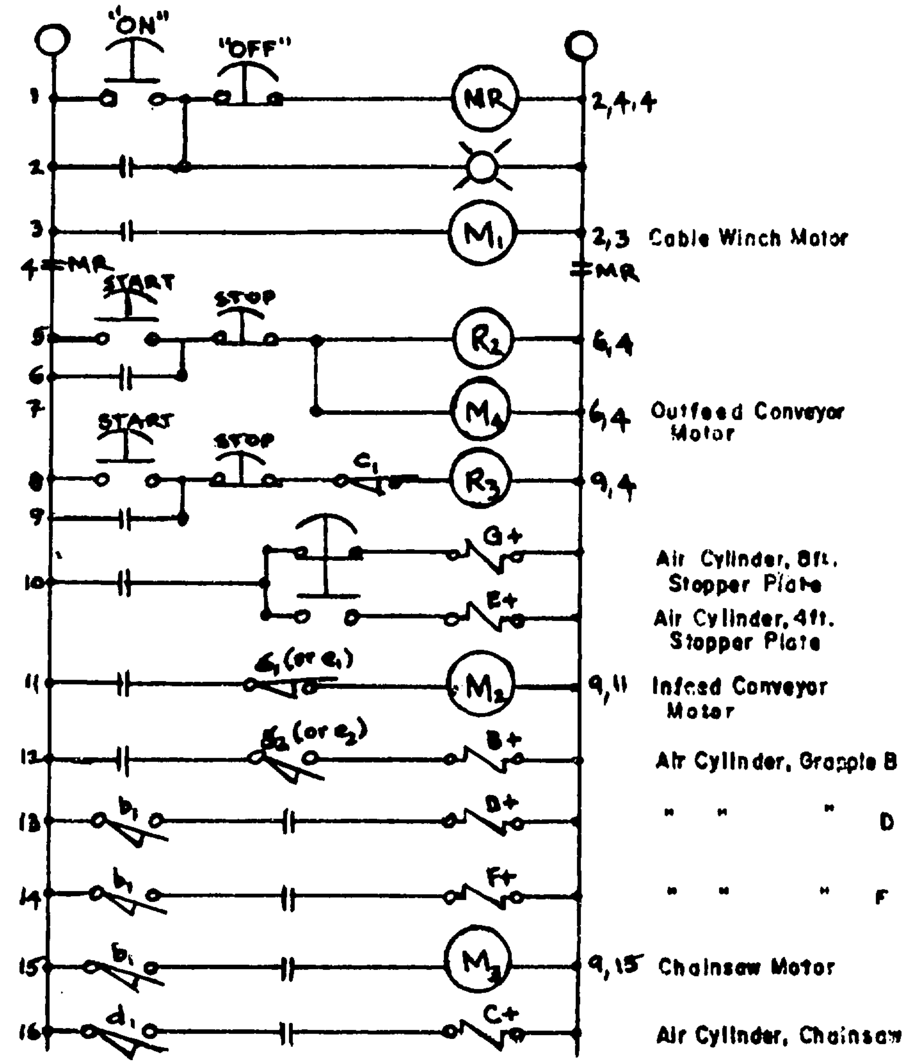


FIGURE 25

AUTOMATED LOG BUCKING AND TRANSPORT PLYWOOD PLANT
(SOLUTION TO SAMPLE PROBLEM NO. 1)



TIME - MOTION DIAGRAM



ELECTRICAL CIRCUIT DIAGRAM

FIGURE 25 (e)

AUTOMATED LOG BUCKING AND TRANSPORT PLYWOOD PLANT

First Trim Saw	4 Men/Shift
Second Trim Saw	4 Men/Shift
Material Handlers between Trimming Line and Sanding Line	2 Men/Shift
Total	11 Men/Shift
Production Output	500 Panels/Hour

Sanding Line

Technician	1 Man/Shift
Bottom Sander	4 Men/Shift
Top Sander	4 Men/Shift
Material Handler between Sanding Line and Panel Inspection Section	2 Men/Shift
Total	11 Men/Shift
Production Output	500 Panels/Shift

2. Problem

Solution is sought to obtain the maximum possible output from the trimming and sanding line.

3. Options Available

a. Conveyorise the transport of panels between the two trimming machines ; conveyorise transport of panels between the two sanding machines ; and install "Scissors-Lift" at both ends of each of the conveyorized lines, This move will reduce total manpower requirements of the two lines to 14 man/shift. The proposed conveyorization will cost US$8,500.00 and increase the output to 900 panels/hour. However, this proposal uses only 80% of the available trim saw capacity and 70% of the available sanding line capacity. To attain the production target of an average 150,000 panels per week it was proposed to operate the line for 359 days per year, instead of the normal 310 working days/year.

b. Conveyorise fully the transport of panels from the first trim saw machine to the Top Sanding machine; and install "Scissors-Lift" at both ends of the conveyorised line. This proposal will require re-location of the second trim saw and the two sanders and will cost US$44,500.00. On the other hand, the completed line will have an output capacity of 18 panels/minute or about 26,000 panels/day ; and further reduce the manpower requirements to 6 men/shift. This solution also facilitates :

a) Conveyorization and automation of the transport of panels from a Hot Press with automatic loading and unloading devices which is planned to be installed within the next 2 years ; and

b) Conveyorisation of the Panel Inspection Line after the last wide-belt sander.

4. Value Analysis

From the maintenance and work fatigue viewpoints, it appears that Option (a) will be hard to implement. Although higher in project costs, Option (b) adequately assures satisfaction of the production targets without unduly straining the work capacity of the workers.

5. Final Design of the Conveyorised Line

The conveyor system design as finalised is shown in Figures 26 and 27.

6. Maximum Allowable Investment For the Project

The Project is principally directed to an increase in production capacity. In so doing, Option (b) indicated also a significant reduction in personnel requirements.

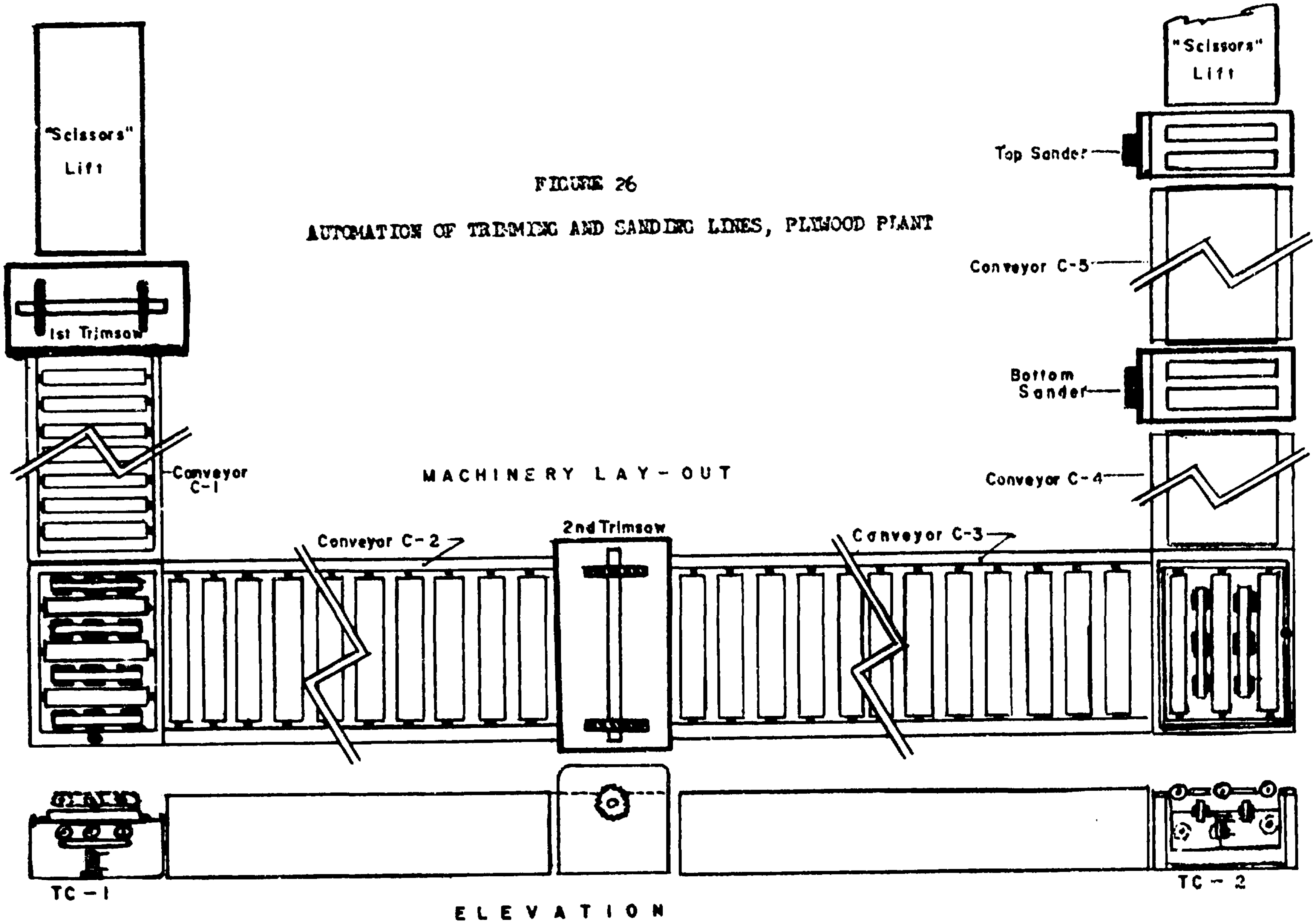
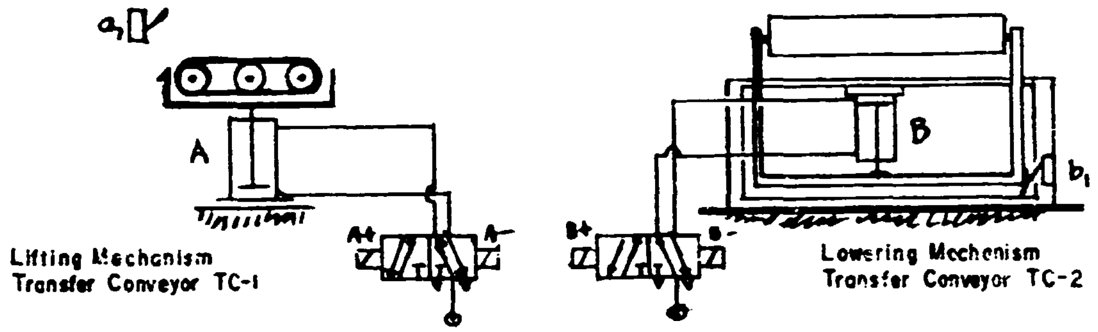
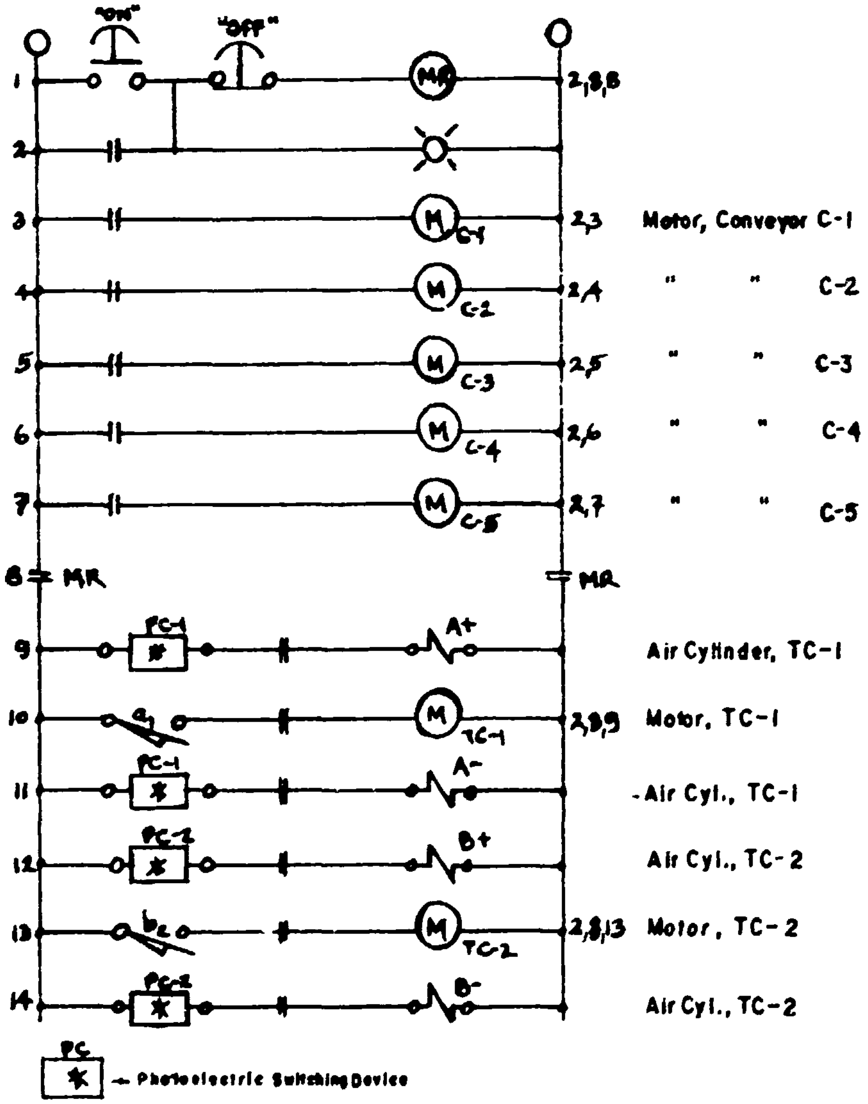


FIGURE 26

AUTOMATION OF TRIMMING AND SANDING LINES, PLYWOOD PLANT



PNEUMATIC CIRCUIT DIAGRAM



ELECTRICAL CIRCUIT DIAGRAM

FIGURE 27

AUTOMATED TRIMMING AND SANDING LINE

The maximum allowable investment for the project is computed as follows :

Pertinent General Data :

i	=	Current Cost Of Money ----------	14 % per annum
n	=	Machine Depreciation Period ----	5 Years
N	=	Number of Operating Hours/Year ----------------	7,440 hours/year
Q_1	=	Output before mechanization and ICA ----------------	500 panels/hour
Q_2	=	Output after mechanization and ICA ----------------	1,080 panels/hour
m	=	Fixed Hourly Machine Cost ------	US$1.75/hour
w	=	Direct Hourly Wages, Average ---	US$0.28/hour/man
p	=	Proportion of indirect labour Cost Average ------------	38 % of "w"
V_1	=	Variable Hourly Machine Cost at Q_1 --------------	US$0.08/hour
V_2	=	Variable Hourly Machine Cost at Q_2 --------------	US$0.12/hour

$$I_{max} = \left[\frac{5 \times 7{,}440}{1 + \frac{14}{200}(5 + 1)}\right]\left[\left(\frac{1080}{500} - 1\right)\left(1.75 + 0.28\left(1 + \frac{38}{100} + 0.08\right)\right) + (0.08 - 0.12)\right]$$

$$= \underline{\text{US\$64,592.00}}$$

7. Pay-back Period

Management's policy calls for a maximum pay-back period of 2 years for projects of this size. The net savings (loss) per year for the Project is computed as follows :

Cost Item	Present System	Option (b)
1) Direct Labour Cost	6 Men - US$43,650.00/yr.	18 Men - US$11,900.00/yr.
2) Labour Fringe Benefits, 38 % of Direct Labour Costs	16,587.00/yr.	4,522.00/yr.
3) Power Costs	2,500.00/yr.	3,200.00/yr.
4) Machine and Equipment Depreciation Cost	13,500.00/yr.	22,400.00/yr.
5) Maintenance and Production Supplies Costs	4,500.00/yr.	6,200.00/yr.
6) Training of Technicians	---------	1,250.00/yr.
7) Administrative Cost	2,800.00/yr.	2,450.00/yr.
Total Costs --------	US$81,237.00/yr.	US$51,922.00/yr.

Net Savings = US$81,237.00 - $51,922.00 = US$29,315.00/yr.

Payback Period = $\frac{\text{US\$44,500.00}}{\text{US\$29,315.00/yr}}$ = 1.52 years or approximately 18 months

8. Management's Decision

Implement Option (b).

C. LOG SPLITTING OPERATIONS, (SMALL CAPACITY FIBREBOARD PLANT)

The volume of work in this operation is too small to justify any sophisticated form of conveyorisation and automation. However, the risks to human safety is too great to ignore the need for a safety device for the machine.

1. Current Situation

Two men pick-up a piece of over-size log (already cut to the desired length) from the log pile near the hydraulic splitter machine. The two men position the log piece upright under the blade and hold the log in position while a third man pushes the control button to ram the blade along the axis of the log piece.

2. <u>Options Available</u>

a. Design and install a log grappling device which will hold the log in an upright position while the splitter blade is rammed against it. The device is loaded on the grappling device by two men, one of whom operates the splitter as soon as the log is set in place. After the first split, the grappling device (with the log) is pushed by hand nearer to the splitter blade and another split on the log is made. The process is repeated until the log piece is reduced to smaller pieces good for the chipping machine. The grappling device is estimated to cost US$570.00, installed. It can split logs at 80% of the time it takes to do so by the current practice.

b. Design and install a device which will pick up the log pieces from a log conveyor and position the log piece upright under the blade. The grappling device is also worked in the same manner as in Option 2-a, but the movement of the log and the grappling device is pneumatically automated. This device will require only one man to operate the log conveyor, the log grappling and positioning device and the hydraulic splitting machine. It is estimated to cost US$2,700.00, installed. It can split logs at 70% of the time it takes to do it at present.

2. <u>Analysis</u>

The cost of production in Options 2 (a) and 2 (b) will be affected by the following cost items only (all other cost factors being the same) :

Cost Item	Present	Option 2(a)	Option 2 (b)
Direct Labour Cost	$1,500.00	$1,200.00	$1,150.00
Depreciation of Added Device	None	$0.0153	$0.0457
Additional Power Cost	None	None	$0.012
Total Costs	$1,500.00	$1,200.00	$1,150.06
Net Savings per Ton of Product	------	$ 298.98	$ 349.94

On purely economic basis, it appears that the device in Option 2 (b) is more advantageous to install.

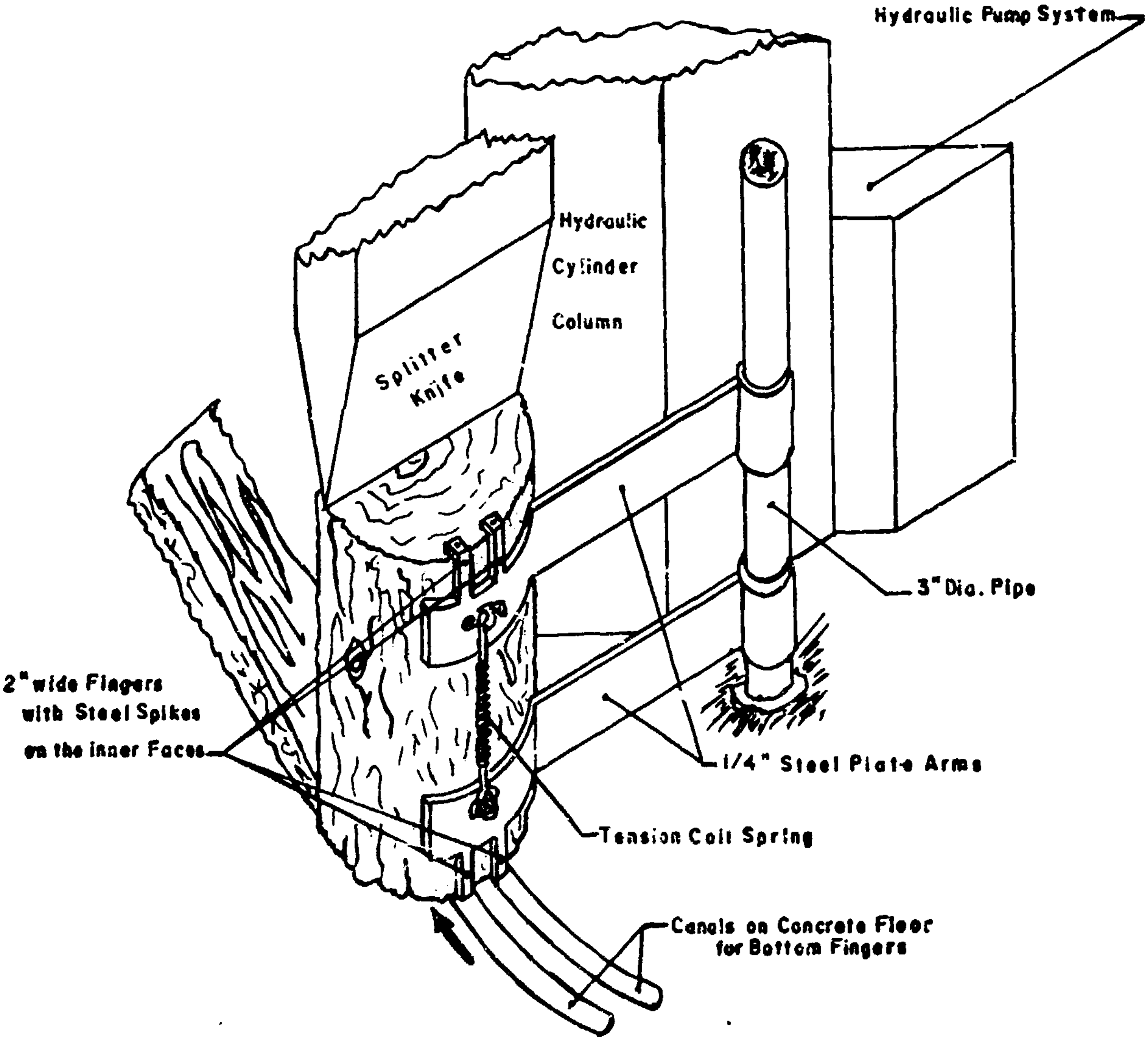
4. Maximum Allowable Investment and Other Considerations

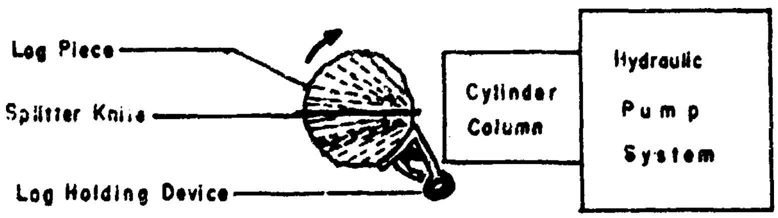
Inasmuch as it is hardly possible to valuate the increase in safety of the two devices proposed to solve the problem, other considerations will have to be used as the basis for the selection of the system to be adopted ; considering further that the level of safety offered by both devices is the same.

A survey of the three workers assigned to the log splitter showed that none of them has the aptitude to be trained in the more complex procedures of operating the device proposed in Option 2. Furthermore, government regulations require that the present operators of the machine should be given priority in training for the new job.

5. Management's Decision

In spite of the larger savings offered by Option 2 (b), management decided to install the device proposed in Option 2 (a) Figure 28 shows a schematic drawing of the device.





LOG SPLITTING PATTERN

FIGURE 28

SAFETY DEVICE FOR LOG SPLITTING MACHINE
(SOLUTION TO SAMPLE PROBLEM NO. 3)

X. OTHER FACTORS AFFECTING THE DECISION TO AUTOMATE

The preceding illustrative examples bring out the fact that the decision to mechanise and automate may not be solely based on purely economic considerations. Some situations tend to lay more emphasis on the technological aspect of the problem, while others are highly influenced by government laws and company policies. The assignment of values to these factors also raises another factor to consider, i.e., the capability of management to properly weigh these factors and come up with a wise decision.

Adaptation of LCA into a production system does not end with the installation of the LCA device. Proper operations of the LCA - equipped machine and its adequate and regular maintenance are required to obtain maximum and effective utilisation of the machine and also prolong its life. The following pointers will help to make a good decision to automate.

A. THE LABOUR FORCE

The installation of LCA on a machine requires proper training of the machine operator on its use. Hence, a training program should be set-up for the purpose.

B. THE MAINTENANCE CREW

LCA adds more precision to machine operations. Thus, it requires a higher degree of maintenance technology. It is wise to have at least one man among the maintenance crew trained in LCA systems. In plants where employment of competent engineers is hardly possible, a well-experienced mechanic or electrician can be trained in LCA systems.

C. KNIFE - GRINDING AND SAW - FILING ACTIVITIES

With increased production output brought about by the installation of LCA systems in a manufacturing plant, the demand for better maintained cutting tools (knives, bits, saws, etc.) is also increased. Before LCA installation, small errors in cutting-tools maintenance may not significantly affect production operations. LCA systems demand a higher quality in cutting tools maintenance in order to :

1. Avoid frequent down-time to change cutting tools ;
2. Lengthen the life of the cutting tool ; and
3. Attain good quality cuts and surfacing on the product.

D. SOURCES OF LCA TECHNOLOGY

Lack of technology to design, fabricate, install, maintain or operate automated and more mechanized systems as presented in the preceding sections of this paper, should not deter management from making a decision to automate or increase the mechanization in its factory. LCA technology may be acquired through the following sources :

1. Machinery suppliers ;
2. Training centers in industrialized countries ;
3. Manufacturing plants which are already using automated systems ;
4. LCA components manufacturers and suppliers ; and, if all the above fail, you can always contact
5. UNIDO

E. INVENTORY CONTROL

Increased production through the use of LCA systems will not be possible if the operations is not supported with adequate raw materials, machine spare parts, production supplies, etc. Thus, it is required that the material and supplies control system of a manufacturing concern be also included in the considerations to automate or mechanize plant operations further.

IX. SUMMARY

This paper has outlined the steps to be taken in a factory's programme of improvement thru further mechanization and automation of its operations. The nature and concepts of LOW COST AUTOMATION were also discussed. Guidelines were provided to help management decide on WHAT, WHEN and HOW to automate. Time and space constraints allowed only a number of the numerous aspects involved in mechanization and automation to be discussed in this paper. Surely, there are others which become important to consider in certain factory situations other than those discussed in this paper. Management is advised to be on the look-out for these factors, as they may outweigh the other factors at hand.

Nevertheless, the management of an out-dated wood-processing plant should not despair, for this paper has shown that aside from financial benefits there are other things to be gained by the use of more mechanization and automation in its factory.

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