UNIVERSITI PUTRA MALAYSIA

TECHNO-ECONOMIC ASSESSMENT OF THE FURNACE-TYPE LUMBER DRYER TECHNOLOGY IN THE PHILIPPINES

LOLINDA M. MAGSANOC

TECHNO-ECONOMIC ASSESSMENT OF THE FURNACE-TYPE LUMBER DRYER TECHNOLOGY IN THE PHILIPPINES

BY

LOLINDA M. MAGSANOC

This report is submitted to the
Faculty of Forestry Universiti Pertanian Malaysia
in partial fulfillment of the requirements for the degree of
Master of Science (Wood Industries Technology)

November 1991

FACULTY OF FORESTRY

APPROVAL SHEET

Name of Candidate : LOLINDA M. MAGSANOC

Name of Project : TECHNO-ECONOMIC ASSESSMENT OF THE FURNACE-TYPE LUMBER DRYER TECHNOLOGY IN THE PHILIPPINES

Approved By :

DR. RAZALI ABDUL KADER
Associate Professor
(Supervisor/Examiner)

MR. DORAISINGAM MANIKAM
Lecturer
(Supervisor/Examiner)

DR. RAZALI ABDUL KADER
Associate Professor
(Coordinator)
M.S. Wood Industries Technology Programme

DR. YUSUF HADI
Associate Professor
(Dean. Faculty of Forestry)

ABSTRACT

The Project covers the assessment of the technical and economic aspects of the furnace-type lumber dryer technology in Regions II and III, Philippines. These regions are located in the northern part of the Philippines where the furniture and woodcraft industry are concentrated. Seven dryers were subjected for assessment for possible damages through time. These include a 1,500 bd. ft. (3.54 cu.m), five (5) 10,000 bd.ft. (23.58 cu.m) and a 12,000 bd.ft.(28.30 cu.m) capacity dryers. Of the five 10,000 bd. ft. (23.58 cu.m) capacity dryers, one was constructed in 1982, two in 1989 and the other two in 1990. The 1,500 bd. ft. (3.54 cu.m) and 12,000 bd. ft.·(28.30 cu.m) capacity dryers were constructed in 1982 and 1990, respectively. A major damage was observed on the flue pipe of the 1982 - 10,000 bd.ft. (23.58 cu.m) dryer. However, a temporary measure was adopted hence it is still in operation. The newly constructed dryers on the other hand have slight damages on the furnace and flue pipe which was attributed to improper firing and carelessness in operation.

The economic feasibility study shows that the payback period is within three or four years of operation for all kiln capacities. Managers however revealed that within a year of operation or at about 10 loadings of a 10,000 bd. ft.(23.58 cu.m) dryer, they have recovered the cost of establishment.

ACKNOWLEDGMENT

The author wishes to express her utmost gratitude to the following people who provided support and guidance in the conduct of this Study Project :

Her project supervisors/examiners Dr. Razali Abdul Kader, Mr. Doraisingam Manikam for their guidance. Acknowledgement is also due to Messers Adolf David Kemp Hardie and Ismail bin Hashim for their guidance during the initial phase of the study;

The ASEAN Timber Technology Centre (ATTC) for the financial assistance, the Forest Products Research and Development Institute (FPRDI) for the opportunity given to her to pursue with the course, and the staff of the Technology Utilization Division for all the technical and morale support;

Engr. Felix C. Moredo for his morale support and technical assistance. Engr. Ricardo F. Casin, Ms. Carolyn Marie C. Garcia, Mr. Arturo D. Capati, and Mr. Eduardo C. Olifernes for their assistance during the data gathering and visits to companies. The JB Woodcraft, Department of Trade and Industry Region II, PGB Woodcraft, Ilagan Industries, La Flor de la Isabela, and the Quirino Association of Wood Furniture Producers for their cooperation during data gathering;

Misses. Rachaneewan Charoenwanying, Teow Sheau Horng, Ong Ee Siew and Ivy Khoo who are always there to cheer her up;

Her friends Zeny, Precy, Susan, Rose & Edgar, Tito Paul & family, Nel, Ycel, Jhey, K.G. and Karyn for the laughters and tears;

Mr. Romeo E. Udanga and Mrs. Fritzi Ann L. Udanga for their unselfish assistance, morale support, friendship and sleepless nights;

Her mother Necesitas and "Nanay" Monica for their love and prayers.

Special acknowledgement to her inspirations in life, her husband Sancho and daughter Samantha Lian for their great patience, love and prayers;

And for Him for all the challenges and blessings.

"Maraming Salamat Po!"

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF TABLES

CHAPTER I

INTRODUCTION

Lumber drying is a vital process in furniture production. Freshly cut lumber is saturated with moisture and exhibits low mechanical and strength properties which are detrimental to wood processing. Wood dried below the fibre saturation point (about 25% moisture content) exhibits high strength to weight ratio which makes the material very competitive with steel and concrete as a structural material. Properly dried lumber has superb machinability and is a good substrate for adhesives and any finishing materials. These are the critical factors in any wood-based industries because these are the selling points of the product. In the Philippines, the two most extensively adopted methods of lumber drying are air drying and kiln drying. There are advantages and disadvantages of using either method but the ultimate factor for consideration is the end-use of the product. Export-oriented industries adopt kiln drying because of the quality and volume it produces at a given period of time. Small-scale woodcraft and furniture industries on the other hand are deprived of the big capital investment necessary for a more sophisticated equipment hence are forced to adopt the cheaper technologies available i.e. air drying or furnace-type drying. As a consequence, a substantial volume of the products suffer in quality because of the occurrence of molds, checkings, splittings, warping and other drying defects during the manufacturing process and in service. This eventually leads to loss in product competitiveness in the market and undermines the viability of the business.

Cognizant of the situation, the Forest Products Research and Development Institute (FPRDI), one of the leading research institutions in the Philippines, developed a technology which caters for the small and medium-scale industries -- the furnace-type lumber dryer. The furnace-type lumber dryer is simple and cheap compared with the conventional steam-heated kiln drying but produces a competitive product in the world market (Casin and Salita, 1984). It makes use of alternative sources of energy (off-cuts, sawdust and wood residue) to generate heat to dry lumber at a minimal cost and thus lessen the dependence on imported fuel oil.

The Philippines is composed of 14 regions. Appendix 1 shows the regionalised map of the Philippines. Regions II and III are the subject of this Study Project since some of the oldest dryers are located in these regions. The most popular furniture material in these regions is Narra (*Pterocarpus indicus*) because of its aesthetic value, good machining properties and market value.

With the redirection of the Philippines' national policies towards the development of small- and medium-scale industries, the Department of Science and Technology (DOST) launched a Comprehensive Technology Transfer and Commercialization Program. The Program is composed of representatives from the different government research organisations and consolidates technologies that have been developed by research and development institutes. Massive promotion of consolidated technologies from different research and development institutes including the furnace-type lumber dryer technology is being conducted in the regions where entrepreneurs of small-and medium-scale industries exist. Some of the strategies being implemented through the program are the conduct of Technology Forum and Regional Trade Fairs from the north to the south of the Philippines. Other activities include the use of print and broadcast media and dialogues with private organisations.

The process of technology transfer however does not end with the mere delivery of the technology. Proper monitoring and continuous assessment are vital for a successful undertaking to materialise. Generally, a post evaluation of the technology is being conducted ten years after its launching. Since the furnace-type lumber dryer technology has been in existence for about ten years, this study is deemed timely.

Objective: This study was conceived to evaluate the technology and development of the furnace-type lumber dryer. It may also serve as a guide for future technical evaluation of any technology developed.

CHAPTER II

LITERATURE REVIEW

Wood drying has become a necessity in the wood working industry in order to produce quality products and wise utilisation of forest resources. Drying can be classified into four major groups: air drying, vacuum drying, radio frequency drying and chemical drying. However, although many methods of wood drying have been tried, only a few entails low investment and minimal damage to the material (Pratt, 1986).

The most commonly used method of lumber drying is air drying. Some of the key factors affecting the process of air drying are temperature, air movement, relative humidity, movement of moisture in wood and source of heat.

The use of solar energy for lumber seasoning involves the same variables as in any other air drying methods. The technology makes use of a simple wooden frame with a transparent or translucent cover, a heat collector, fan vents and a concrete floor. Transparent or translucent walls are used to transmit the largest practical percentage of the incident solar energy into the dryer. The inside surfaces of the dryer are painted black in order to absorb maximum energy. The energy is transferred from the heated surfaces to the air through convection. The heated air circulated by fans pass through the load of lumber where it evaporates and removes the water from the wood. The process is very simple and relatively cheap compared with other technologies but is still unattractive to most tropical countries like the Philippines.

Simpson and Tchernitz (1984) related that in 1975 a feasibility study was conducted to investigate the use of solar energy to improve the drying practices of the small-and medium-scale industries in the developing countries. The initial target was the then Republic of the Philippines but though the project looked feasible the solar dryer was never built in the country.

In 1979 a new drying system was developed by the FPRDI and because of strong government support, the technology became a success -- this is the Furnace-type lumber dryer technology.

The FPRDI furnace-type lumber dryer has three designed capacities to suit different production scale of the industry. These are the 2,500 bd.ft. (5.9 cu.m), the 5,000 bd.ft. (11.79 cu.m) and the 10,000 bd.ft. (23.58 cu.m) capacity dryers of 25 mm thick lumber. Appendices 2.1, 2.2 and 2.3 illustrate the structural features of the designed capacities, respectively. A different design can be made according to the specification of the adoptor/client. The kiln structure is made of concrete hollow blocks with vents on one side. The floor has rails for easy loading and unloading of lumber piles. The 10,000 bd.ft. (23.58 cu.m) capacity has a back door for easy unloading of the kiln. As the kiln dried lumber is being taken out, another batch of load can be taken in while the chamber is still hot thus maximising the use of energy generated from the furnace. The roof consists of layers of marine plywood with the inner layer made of plain asbestos cement boards topped by roof trusses and galvanised iron corrugated sheets. Alternatively, a roof made of reinforced pre-mixed cement may be used.

The main heating system of the dryer is the furnace which is fired with wood residues. It is lined with refractory bricks on the innermost lining and cement hollow blocks for outer lining. The grates, ash pits, clean-out door and the main fuel door are made of cast iron. At the rear of the furnace adjacent to the wall of the drying chamber is a circular opening for the flue pipe. Its diameter varies according to the capacity of the chamber. The flue pipe runs along the length of the chamber with a return U-bend connection vertically positioned leading to a chimney outside the chamber. The number of runs of horizontal flue pipe varies accordingly to the capacity. Temperature is manually controlled by the door openings in the furnace, rate of firing and a butterfly damper located at the base of the chimney. The control of temperature is based on the dry bulb thermometer reading. Appendix 3 shows the different features of the system.

For the humidification system, a single run of galvanised iron water pipe with a number of adjustable spray nozzles is located in-between the horizontal flue pipe. The dryer is also equipped with a dry and wet bulb thermometer which indicates the temperature inside the dryer. The temperature difference of the two thermometer indicates the humidity inside the chamber. Whenever necessary, a fine mist of water is released from the nozzles and strikes the hot surface of the flue pipe. The water then turns into vapour and creates a humid environment inside the kiln. The chamber is equipped with a number of inlet and exhaust vents which are manually controlled. These inlets are made of cast iron or wood. The vents opening controls the volume of incoming fresh air and exhaust moisture laden air from the chamber. Appendix 4 features the different components of the system.

The air circulation system on the other hand is composed of a number of propeller fans on short shafts aligned above the load along one side of the dryer. Fans can either be V-belt driven or directly connected to an electric motor. Appendices 5 shows the different parts of the air circulation system.

Construction of the various kiln design takes about three months depending on the resources of the adoptor. Appendices 6.1, 6.2 and 6.3 details the Bill of Materials for the three designed capacities.

The success of the furnace-type lumber dryer made another challenge to local researchers to reevaluate the solar dryer technology. In 1984, Casin and Salita modified the conventional solar dryer system to include an auxiliary heater. The new design is an external-type dryer with water resistant plywood for its walls and corrugated galvanised iron for roofing. Continuous operation of the dryer showed that partially air-dried lumber (36-46% moisture content) can be dried to 10% moisture content in 5 to 6.5 days. Comparative analysis using the Present Worth of Cost (PWC) method showed that solar-furnace dryer with auxiliary heater is more economical compared with custom drying and furnace-type lumber drying.

Though the study indicated competitive advantages over the other systems of drying, it still failed to attract the wood-based industries in the Philippines. It was learned that the solar-furnace type dryer with an auxiliary heater did not get full government support in promoting its use and in introducing the technology to the public (Casin, 1991). Its failure is also due to the natural calamities occurring in the region, like typhoons and earth quakes.

The adoption of any drying method is influenced by factors such as the availability of equipment/facilities, the cost involved, the size of target or potential adoptors and their attitude towards development, government policies and environmental factors.

CHAPTER III

METHOD

Preliminary discussions on the manner in which the study project will be conducted includes the setting of the target area and the number of samples for assessment. The first proposal was to take Region IV as the area of the study because of its accessibility and lesser cost involved. However upon discussion with the Technology Utilization Division (TUD) of the Forest Products Research and Development Institute, it was recommended that the area be changed to Region II and III because some of the oldest dryers are located in the area. It was further agreed that at least one dryer per capacity per year will be a good sample size. This however is subject to the availability of the dryers for assessment. An existing checklist which was used in evaluating a different type of lumber dryer was modified to suit the current needs (Ismail, 1991). The checklist was revised upon discussion with the authors' supervisors. The revised checklist appears in Appendix 7. It was used as a guide in the assessment of the different components of the lumber dryer. The checklist is divided into seven parts to wit: the air circulation system; the heating system; humidifying system; recording-controlling instruments; general plant and operating conditions, and the economic aspect of the technology. The study however concentrated on the technical aspect of the technology.

The first visit was to Region III. There were only two dryers available for assessment during the period and both dryers are owned by the JB Woodcraft company in Betis, Pampanga, about 135 km north of Manila. The company started its operation as a handicraft manufacturer but in 1980 it was expanded into furniture manufacturing. In 1989, the company was a recipient of the Golden Shell Award in the furniture manufacturing category. In conjunction with their expansion program, the company established another site for a more systematic operation. Its product lines include chairs, tables, handcarved furniture components and wooden accessories. Its market includes U.S.A., Japan, Australia, U.K., Canada, France and Hongkong. Their two dryers are of 1,500 bd.ft. (3.54 cu.m) and 12,000 bd.ft. (28.30 cu.m) capacity constructed in 1982 and 1990, respectively. The former was located in the old factory site while the later was constructed at the new site. During the visit, the smaller dryer was loaded hence only the external features were assessed. The bigger dryer on the other hand was not in operation since early 1991 because the site was under renovation. Nevertheless, assessment was done in accordance with the guide checklist. Another visit was made three weeks later in order to check the features of the small dryer.

The succeeding dryers subjected for assessment are located in the provinces of Quirino, Isabela and Cagayan, Region II and are of 10,000 bd.ft. (23.58 cu.m) capacity. One of the dryers was formerly under the Ilagan Cooperative Industries in Ilagan, Isabela but due to some management problems, it was later sold to one of its members. It is an export-orientated venture with doors and furniture components as their major product. This third dryer was constructed in 1982 and is one of the oldest running furnace-type dryer in the country.

The fourth dryer was constructed in 1989 in Tuguegarao, Cagayan under the PGB Woodcraft company. The company is a single proprietorship furniture manufacturer which caters both for local and international markets. Solid doors and furniture components are also their main products. Another dryer located in the same province was established in 1990 under the La Flor de la Isabela. The company ventures into cigar production and uses special packaging to cater to their export market. Cigar boxes used to be contracted from another company but with the establishment of the furnace dryer, La Flor has been producing their own specialty boxes. The sixth dryer was constructed in 1989 under the Department of Trade and Industry in Region II. It was envisioned to serve as a demonstration facility and to service the drying requirements of small entrepreneurs who cannot afford to construct any dryer. It was however idle for more than a year and was only used during the initial firing.

The last dryer inspected was in Cabaruguis, Quirino. It was constructed in 1990 under the Quirino Association of Wood Furniture Producers to service the drying requirements of the association. Unfortunately, the dryer has not been in use since its initial firing in mid 1990.

During the assessment, the components of the different systems were inspected for some possible deformations, crackings and malfunctioning of the components using the checklist as the guide. The operators and the supervisor were also interviewed while the assessment is being conducted. Some information on the economic aspects of the technology were also gathered during the survey.

The companies surveyed in this study is summarized below:

Company Name	Capacity (cu.m)	Year Established
A - Ilagan Industries	23.58	1982
B - PGB Woodcraft	23.58	1989
C - La Flor de la Isabela	23.58	1990
D - DTI Training Center	23.58	1989
E - Quirino Asso. of Wood Furniture Producers	23.58	1990
F - JB Woodcraft	3.54	1982
	28.30	1990

CHAPTER IV

RESULTS AND DISCUSSION

The study covered five dryers in Region II, all of 10,000 bd. ft. (23.58 cu.m) capacity and two dryers in Region III, one of 1,500 bd.ft. (3.54 cu.m) capacity and the other 12,000 bd.ft. (28.30 cu.m). The five dryer operators in Region II include the Ilagan Industries, PGB Woodcraft, La Flor de la Isabela, DTI Regional Training Center and the Quirino Association of Wood Furniture Producers. In Region III, both dryers are being operated by the JB Woodcraft. The assessment was carried out using a modified checklist of all the features of the lumber dryer. An interview with the operators and supervisors were conducted simultaneously with the inspection.

A. The technical features of the dryer

a. The 1,500 bd.ft. (3.54 cu.m) capacity

Company F was among the first adoptor of the technology. However, since their operation in 1982 was small, they requested a smaller capacity dryer to suit to their needs. The dryer was constructed in cooperation with another government agency, the Industrial Technology Development Institute (ITDI). The kiln was constructed inside the factory. It has a back loading and the heating system has six heating coils where the heat from the furnace passes through. These coils were attached to a hood which was connected to a chimney. To effect even distribution of heat, a metal plate was positioned about 12" away from the heating coils. The dryer was equipped with one propeller fan attached to an electric motor through a V-belt connection. Vents were located on both sides. The wet and dry bulbs were installed at one side with a dripping tap directly over the wick of the wet bulb.

The dryer was still functional even after almost ten years in operation. However, some damages were observed on the kiln structure and heating system. The doors and floor were said to have cracked two years ago. The floor was plastered with cement but the doors were left unattended. No cracking on the walls was observed. The outside lining of the furnace had cracked and the spark breaker was destroyed due to improper feeding of solid wood residues. The door fittings were in good condition and were free of debris. One of the heating coils was said to have severe damage due to excessive heat hence was cut off two years ago. The heating coils are not detachable, thus once it is damaged, it cannot be replaced. The metal plate bordering the heating coils and the load was damaged during the initial firing because the fan was positioned too close to the plate. When the chimney was damaged two years ago, a hollow log was used in its place. However, the connecting point between the hood and the log was not properly done hence black smoke leaked into the chamber during operation. The motor has not been changed since its installation in 1982 while the V-belt was changed twice. Electrical wirings were left hanging beside the dryer without metal conduits. Appendix 8 shows the damaged features of the 1,500 bd.ft. (3.54 cu.m) capacity dryer.

b. The 10,000 bd.ft. (23.58 cu.m) capacity

i. The kiln structure

The kiln walls and floor were inspected and it was noticed that some crackings occurred in the wall connecting the furnace and the chamber of Company A's dryer. This was attributed to excessive exposure to heat and steam spray for almost 10 years of continuous operation. As expected, the dryers' life span is about 10 years. Interviews revealed that after eight years of continuous operation the efficiency of the dryer started to decline although the output is still profitable. During the early years of usage, the dryer was able to dry 25 mm thick Lauan species in 8 to 10 days to a final moisture of 10%. However, now it takes 14 days to dry the same type of load. The other four dryers (Companies B,C,D,and E) were relatively new compared to Company A's dryer hence, there was no cracking on the floor nor on the walls. Besides, Company D and E's dryers were idle and have had only one loading since their establishment. Company C's dryer had cracks on the wall near the flue pipe because of excessive firing during the initial loading. The false ceiling was properly maintained with coating materials except for Company A where only the outer lining of the ceiling was coated with asbestos.

Doors were found to be intact except for Company A where crackings were observed on the inner side of the door. The door jamb had also been attacked by decaying organisms because of the moisture that condenses in this area during drying operation.

Rails and carriages which were designed to ease the loading and unloading system were not being used by Company A and B. Management revealed that there is no need to rush in the loading and unloading since there is not much supply of lumber to be loaded. Company C on the other hand had no problem with lumber supply hence the use of rails was very convenient in the operation. Appendices 9.1 shows the damaged areas of the kiln structure.

ii. The heating system

Most defects were noted on the heating system obviously because of its direct exposure to heat and flame. Company A's dryer, being the oldest in the group was the most damaged. The outer wall had cracked and some bricks had been displaced. Also, the main furnace door has no lock and the ash pit was not properly closed because of some debris around the area. Clean-out door on the other hand was in good condition. Company B's grate bars and Company C's spark breaker were also damaged due to improper feeding of wood residues.

The flue pipe of Company A has worn out in early 1991 and the company employed temporary measures in order not to disrupt the operation. The defect was caused by material failure as the pipe has been in service for almost 10 years. For Company B, the pipe have expanded as a result of excessive firing during the initial load. Insulation was still in good condition. However the gaskets should be replaced once the flue pipe is changed. The supports of the flue pipe were painted but Company A's structure started to corrode together with the nuts and bolts.

The chimneys were observed to be properly maintained. However, the butterfly damper of Company A ceased to function early in 1991. The company thus regulated the temperature inside the chamber by the rate of firing and vents opening. Company B and C have had no problem with their butterfly damper since their structure is new and although it has been in continuous operation since its construction. Company D and E's chimneys however had corroded because of non maintenance of the dryer. Appendix 9.2 features the damaged areas of the heating system.

iii. The humidification system

Early design of vents as exhibited by Company A's dryer was made of wooden materials. Prolonged direct exposure to rain and other atmospheric factors however resulted in shrinkage and swelling of the material. To date, new designs were equipped with cast iron vents to ensure proper fitting. Nevertheless, vents were still manually operated.

Spray nozzles of the three dryers (Company A, B and C) were found to be in good condition because the structure was being cleaned after every load. It was not possible to check the internal features of Company D and E's dryers because there were remnants of the initial loading. The firings were done about a year ago and since then these dryers were not cleaned. In every design, nozzles were positioned in between the middle and the bottom runs of the horizontal flue pipe. The position of the nozzles also ensures that the load of lumber and the control bulbs will not be directly hit by the spray of water released.

Control bulbs can either be along the side of the flue pipe or at the other side of the chamber. In the former case, a piece of metal covers the control bulbs to ensure total protection from the mist. In the latter, a cover is not necessary because of its distance from the spray nozzles. Wet bulb temperature is maintained through the installation of a dripping tap thus maintaining a wet wick throughout the drying operation. The above mentioned damaged areas are featured in Appendix 9.3.

iv. The air circulation system

For the 10,000 bd.ft. (23.58 cu.m) capacity dryers four (4) propeller fans on short shafts were installed. The dryers of Companies A, C, D and E were designed with fans having 42" diameter and 430 RPM each connected to a single motor of 2HP capacity. Company B on the hand had fans directly driven by electric motors. It was observed that fans were properly lubricated while the belts and pulleys are being tightened after every load. Belts were replaced after every 10 loads or after one year of usage. The motors had been functioning properly. However, one of the motors of Company A was replaced because of damage through time. In the old design (Company A), electrical wirings were not properly installed. New designs however (as exhibited by Companies B, C, and D) were provided with metal conduits and control switches were enclosed in a box. Company E's dryer on the other hand was left unattended for almost a year hence all the electrical wirings were lost. Appendix 9.4 shows the different features mentioned above.

c. The 12,000 bd.ft. (28.30 cu.m) capacity

The design of the 12,000 bd.ft. (28.30 cu.m) capacity dryer of Company F has modified features compared with the other designed capacities. The dryer was inside the factory thus operation was very convenient even during rainy season. It has a side loading and vents were located at the roof instead of having them along the sides. The dryer had only one loading since its construction in 1990 because the area was under renovation since early 1991. The company will increase their production line to include solid doors. No damages were observed on the dryer because it was still new. Appendix 9.5 shows some of the special features of the dryer.

In general, 29% (two out of seven) of the dryers have damaged kiln structures and heating and humidification systems because of their prolonged exposure to heat. These dryers have been in service for almost ten years (the expected life span of the dryer) hence material failure developed. Another 29% of the dryers have minor damages on the furnace due to improper feeding. However, these dryers were constructed about two to three years ago hence the structure are still new. The other 42% (three out of seven) were idle. One of these dryers was constructed in 1990 but due to the renovations being done on the site, the dryer has not been used. On the other hand, the other two dryers were left unattended due to some management problems.

B. General plant and operating conditions

Company A's kiln dryer is located 100 meters away from the working area. The stacking area was just in front of the kiln hence loading was very convenient. The area however was not very clean and less organised. Stickers were scattered around the area and inside the dryer which were left uncovered. Corroded carriages which have not been in use for about three years were stacked outside the kiln together with the other stickers. Cross bearers were not evenly spread out and some bearers were being placed on the passageways to accommodate more lumber. This practice affects the air circulation and drying rate of the load. It was observed that the ends of the lumbers for drying were not properly sealed hence the dried lumbers have a lot of end checkings and splitting. These reduces the recovery of quality wood from the material and increases wastage. After drying, kiln dried lumbers were being cooled inside the stacking area before it is transferred into the working area. On the other hand, the company uses uniform-sized stickers which makes piling of lumber easier and more systematic. Appendices 10.1 shows some of the practices of the company.

The company employs one supervisor, four kiln operators and one alternate as an understudy. These operators worked on an eight-hour shift. However, they have no formal trainings on the operation of the kiln because they were new in the company. The first operator who had the training on kiln operation has moved into another job and there was no understudy during that time. These new personnel were doing what has been the practice of the company without the real knowledge of the reasons behind such practices.

The company does not keep a drying schedule record for every kiln charge. They used to adopt the prescribed drying schedule from FPRDI for about five years. However, as expected, the efficiency of the dryer declined thus the drying schedule was modified. The original drying time of 8 to 10 days became 14 days in order to achieve 10% moisture content. Each load has its sample boards which were used to determine the moisture content. *Pterocarpus indicus* was the only species being used by the company because of its great demand and market value. *Shorea* spp. were tried once with the assistance of the FPRDI personnel. Though the result was good, the company prefers *P. indicus* because the region is well known for furniture made of this species.

Company B on the other hand has fewer problems with the kiln since the dryer has been in operation for less than two years. So far, they have had 14 full loads and it was revealed that the cost of establishing the dryer has been paid-off in such a short time. One full load of lumber will dry in 10 to 14 days depending on the highest moisture content of the lumber in the load. The dryer should operate for 11 months in a year to allow for general maintenance.

The dryer is located 20m away from the working area and 10m away from the stacking area. The company is employing one full time supervisor and three operators who