Leaflet No. 3/ 91-92

Government of the Union of Myanmar
Ministry of Forestry
Forest Department

Design and Construction of Commercial-Sized Solar Lumber Dryers and Study on Its' Application

U Win Kyi (1), B.Sc. (Hons); D.S.; M.S. (Virginia Tech.);
Assistant Director
Forest Research Institute
1992

စက်ရုံအလုပ်ရုံသုံးနေရောင်ခြည်စွမ်းအင်သုံးသစ်ပေါင်းဖို့များ တည်ဆောက်ခြင်းနှင့် ၄င်းတို့၏လက်တွေ့အသုံးချမှုကိုလေ့လာခြင်း

ဦးဝင်းကြည်f(1) (B.Sc. (Hons.) ; D.S.; M.S. (Virginia Tech.))
ဌာနမှူး
သစ်တောသုတေသနဌာန

စာတမ်းအကျဉ်းချုပ်

အရွယ်အစားအမျိုးမျိုးရှိသော စီးပွားရေးအဆင့်သုံး နေရောင်ခြည်စွမ်းအင်သုံး သစ်ပေါင်းဖို့ (၄)လုံးကို ပြည်တွင်းမှရရှိနိုင်သော ပစ္စည်းများဖြင့် စမ်းသပ်တည်ဆောက်ခဲ့ပါသည်။ သစ်ပေါင်းဖို့(၂)လုံးသည် ရေဆင်းတွင်တည်ရှိပြီး ကျန်ပေါင်းဖို့(၂)လုံးမှာ ရန်ကုန်မြို့တွင်တည်ရှိပါသည်။ ၄င်းသစ်ပေါင်းဖို့အသီးသီး၏ အသုံးဝင်မှုကို သိရှိနိုင်ရန် အတွက်လက်တွေ့ စမ်းသပ်မှုများ ပြုလုပ်ခဲ့ပါသည်။ ဤပေါင်းဖို့များဖြင့် ၁လက်မ-ထုရှိသောသစ်ခွဲသားအစိုကို မြန်မာပြည်နွေရာသီနှင့် ဆောင်းရာသီများအတွင်း အစိုဓာတ် (၁၀)ရာခိုင်နှုန်း အောက်သို့ရောက်ရှိအောင် အခြောက်ခံနိုင်ကြောင်း တွေ့ရှိရပါသည်။ အခြောက်ခံရန် ကြာမြင့်သည့်အချိန်မှာ စမ်းသပ်သည့်သစ်မျိုးနှင့် မူလရှိသော အစိုဓာတ်များပေါ်မူတည် (၁၉)ရက်မှ (၅၆)ဂုက်ထိ ကြာကြောင်းတွေ့ရှိရပါသည်။

Design and Construction of Commercial-Sized Solar Lumber Dryers and Study on Its' Application

U Win Kyi (1), B.Sc. (Hons.); D.S.; M.S. (Virginia Tech.)
Divisional Head,
Forest Research Institute

Abstracts

Four commercial-sized solar lumber dryers of different capacities are designed and constructed. Two dryers are located at Yezin and other two at Yangoo. All the dryers are semi-greenhouse type and they all were constructed by using local materials. Some operational tests were conducted on each dryer and the performances of these dryers are given in this paper. Green lumber of 1-inch thickness can be solar-dried at a commercial scale to attain a moisture content below 10 percent during the summer and winter time in Myanmar. The during time ranged from 19 days to 56 days depending on the tested species and their initial moisture contents.

Contents

1. Introduction

Many experimental and prototype solar kilns for drying lumber have been built and tested throughout the world in the past thirty years, with research and testing accelerating during the past ten to fifteen years. As of 1982 there were at least 250 solar lumber kilns throughout the world. The location of these kilns were ranged from equator-Uganda to latitude 52˚ North-United Kingdom (Kyi, 1983)

Four different types of prototype solar dryers were constructed and tested at Forest Research Institute, Yezin since 1982. Two dryers are for drying lumber and two for drying crops and food. The performances of these dryers were given in the paper which was submitted at the Forestry and Forest Products Research Congress in 1986 (Kyi, 1986).

Based on the experiences and results obtained from the semi-greenhouse type solar lumber dryers, the authour predicted that it could be useful in real practic if he could design and construct commercial-sized solar lumber dryers of the same type.

2. Review of Literature

Many commercial-sized solar lumber dryers of different types and of different sizes were constructed and used through out the world. Out of these, several dryers which were located at different latitudes will be reviewed here.

A semi-greenhouse solar kiln was built and operated by, Heartwood Designs at Afton Mountain Region, USA (Whaley, 1981). The kiln was capable of drying 25 to 30 MBF (MBF = 1000 board feet) of lumber per year. About 5 MBF of oaks and poplar are dried for their business and the rest are sold to the private woodworkers. It was noted that the kiln reduced the controlled expense through its functional, reliable design and its use of a free solar energy. It also permitted small firms to dry their own lumber.

Sharma, Nath and Rali (1971) designed and tested a solar lumber dryer at the Forest Research Institute, Dehra Dum (30˚ 9' N, 75˚ 7' E). The capacity of the kiln was 1500 board feet. The roof and walls, except the north wall were covered with a double layer of clear transparent polyethylene sheets. The south-facing roof was tilted at an angle of 27˚ to the horizontal. Two test runs of three tropical hardwood species were conducted from May to June and from October to November. Drying times from green to 13 and 12 percent moisture contents were reported to be 32 days for each test.

The first solar lumber kiln in Australia was designed and tested by Read, Choda and Copper in 1973, at Griffith (34˚ 16' S, 146˚ 10' E). A rock pile was constructed below the drying chamber for thermal storage. The area of the solar collector was 602.5 square feet and it was faced due north, inclined at an angle of 38˚ to the horizontal. The capacity of the chamber was 2750 board feet. It was reported that one inch thick green alpine ash (*Fucalypnuts delegatensis*) dried from 95 to 16 percent moisture content within 20 days.

Several solar kilns which were easy to erect, disassemble and move were operated (Plumptre, 1979: Izler, 1981) at Magdala College of the University of Oxford (51˚ 43' N, 1˚ 16' W), United Kingdom. Each kiln was constructed of two section which were bolted together. The smaller kilns were 21 feet long, 16 feet wide and 11 feet high along the ridge line where the two halves were joined. The whole frame was covered with transparent polyuretheme Myler plastic and black painted corrugated tin was used as the collector.

Another kiln which was much larger these described above was operated at the Eynshan Park Estate sawmill. The capacity of this kiln was 9,000 board feet, and the dimensions were 32.5 feet long, 30 feet wide and 12 feet high. The frame was made of galvanized steel tubing of size 1.5 to 2.25 inches in diameter and was covered with yellow ultraviolet-resistant horticultural plastic. ICI black polycarbonate was used as the collector. All these kilns were designed and tested by Plumptre who started the solar lumber drying in Uganda.

3. Designs and Constructions

Based on the design and experiences obtained from the prototype semi-greenhouse solar lumber dryer and other solar dryers constructed and tested at the Forest Research Institute, Yezin (Kyi, 1986), the author designed and constructed four commercial-sized solar lumber dryers of different sizes and of different capacities during 1986 and 1990. All the dryers are semi-greenhouse type and they all were constructed by using local materials.

3.1 The First Dryer

The first dryer which was constructed at Yezin and displayed at the 1987 Union Day Exhibition in Yangon had a capacity of about 100 cubicfeet (2.9 cubic meter or 1200 board feet) of 1-inch thick lumber.

This dryer is 22 feet long from east to west, 6½ feet wide from south to north, 5 feet high at the south side and 8 ½ feet high at the north side, respectively as shown in Fig. (1). The outside walls were constructed with 1-inch thick lumber whereas the inside walls were seethed with plywood. The gap which is 6 inches wide between the outside and inside walls was filled with dried sawdust for insulation. To reduce the heat loss by conduction through the ground, dried sawdust was firstly put to obtain a level of 6 inches above the ground and then some gravel were placed over the surface of the sawdust. The roof consisted of a window frame of ¼ inch thick glass. As mentioned earlier since this dryer was designed for display at Yangon (16˚ 46' N, 96˚ 09' E), the roof was tilted at about 25˚ to the south, to improve winter performance.

The dryer has an excess door on the west wall for loading and unloading and to permit periodic examination of the lumber and measurement of moisture content. On the north wall, their are eight adjustable air vents of about 108 square inches, four of which are for air inlet near the top and the other four for air outlet near the bottom. Four electric fans of capacity 150 watt each are provided for air-circulation through the lumber pile. All the inside and outside walls were painted flat black to maximize the absorption of solar radiation.

The total cost of this dryer was about 16,000 kyats, at the time of construction.

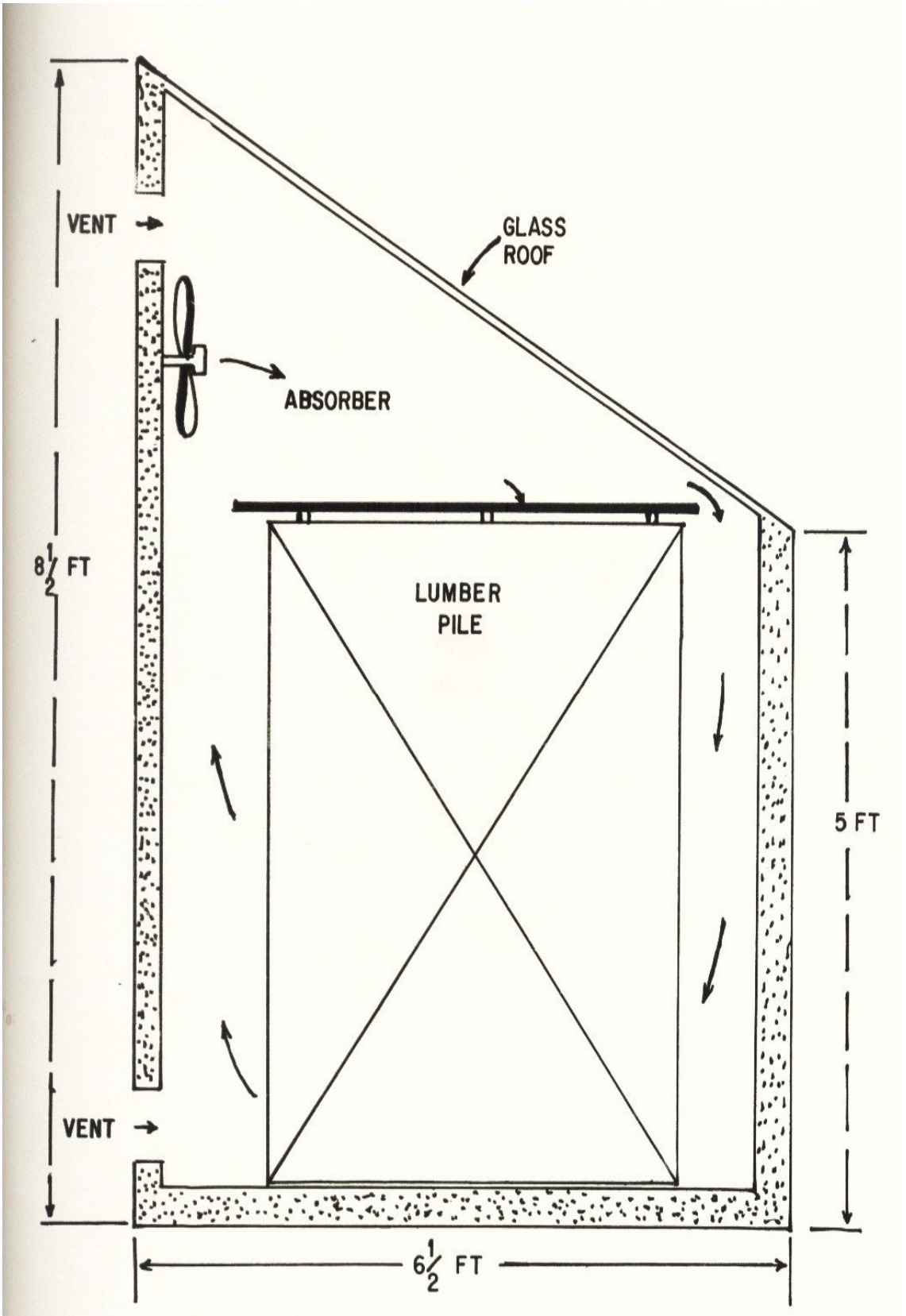

Figure 1: The First Solar Lumber Dryer.

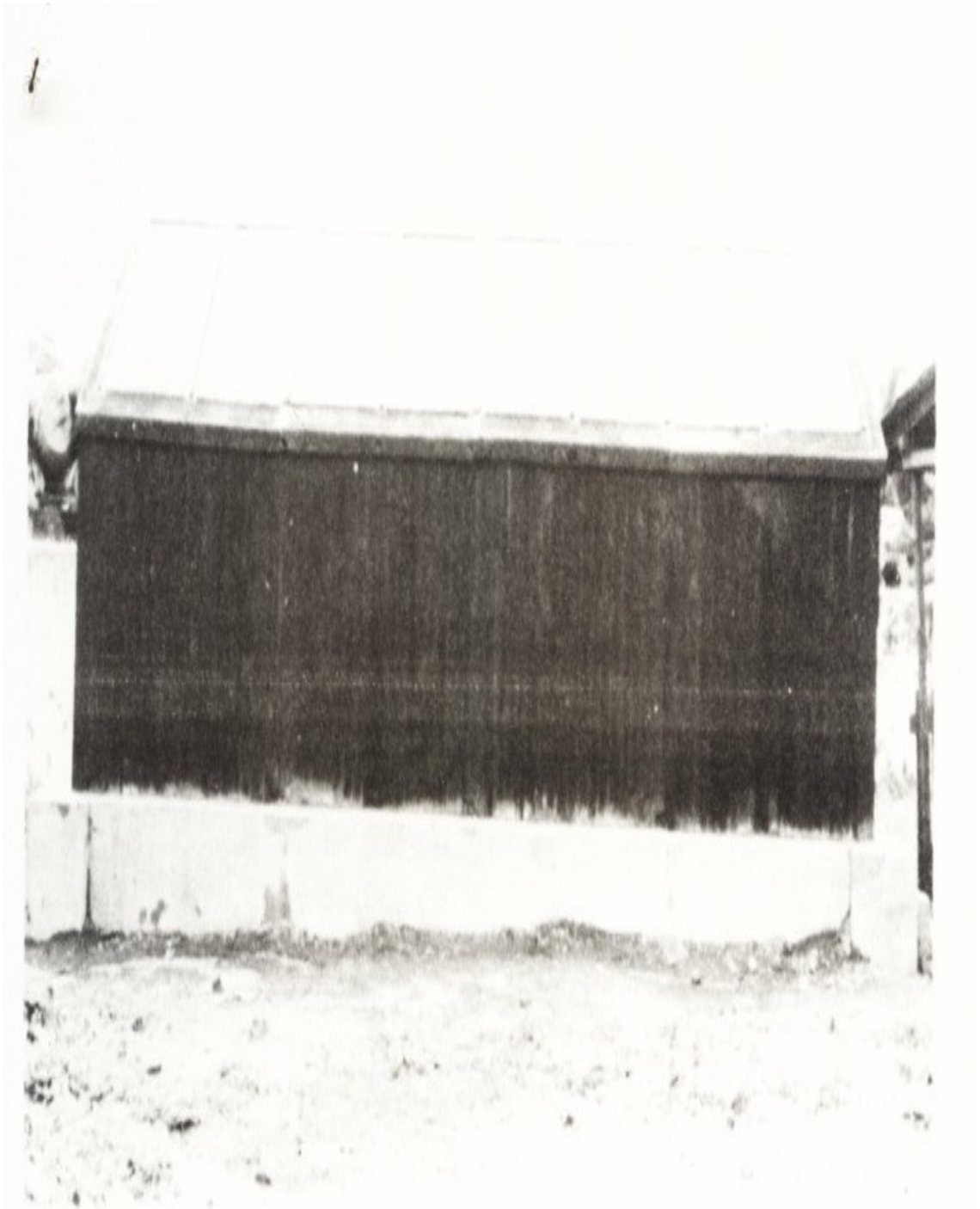

Plate 1. The first solar lumber dryer

3.2 The Second Dryer

The second dryer with a capacity of 125 cubic feet (3.6 m^3 or 1500 board feet) was built at Yezin (19˚ 47' N, 96˚ 15' E), in 1987.

This dryer is 8 feet wide by 24 feet long. It is 6 feet high at the south side and 9 feet high at the north side making the roof tilted at an angle of 20˚ to the south. The inside and outside walls are constructed with bricks and the gap which is 6 inches wide between them was filled with dried sawdust for insulation. The roof was constructed with ¼ inch thick glass.

On the north wall, there are eight adjustable air vents and on the west wall there is an excess door, for the same purposes as the first dryer. The same amount and the same capacity of electric fans as those from the first dryer are also provided for air circulation.

The total cost of this dryer was about 20,000 kyats, at the time of construction.

3.3 The Third Dryer

Based on the experiences of the previous kilns, the author designed and constructed a third solar dryer in 1989. It was also built at the same location as the second kiln but its capacity was increased to 250 cubic feet (7.2 m^3 or 3000 board feet).

The construction materials are the same as those of the second dryer. But the length and the width are increased to 45 feet and 8½ feet, respectively. It is 6½ feet high at the south side and 11¾ feet high at the north side making the roof tilted at an angle of 32˚ to the south.

This dryer has two excess doors, one on the east wall and the other on the west wall, to permit periodic examination of the lumber. Rail lines of about 100 feet in length are also provided inside the dryer along the eastside – westside direction of the dryer. So that lumber can be loaded and unloaded easily by means of the bogy.

There are 16 adjustable air vents of 12" x 9", eight near the top and eight near the bottom of the north wall. Right fans which are driven by four electric motors of capacity 1.0 HP are also provided for air circulation through the lumber piles. In the previous dryers, the electric motors which drive the fans were inside the dryers, so that the coils from these motors were sometimes found to be burnt due to the high temperature inside the dryer. Thus, in the present dryer, the electric motors are placed on the outerside of the north wall.

The total cost of this dryer was about 70,000 kyats at the time of construction.

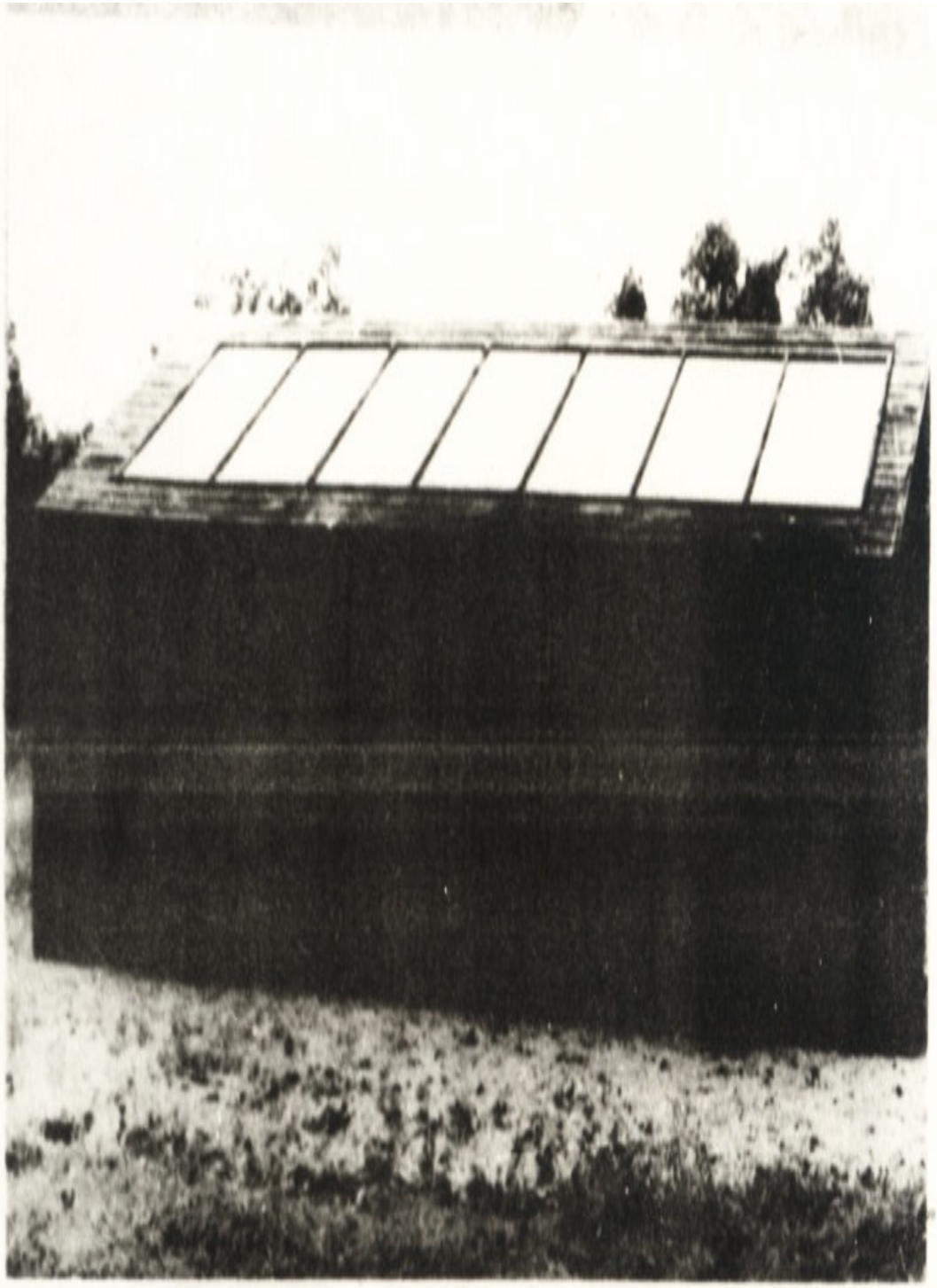

Plate 2. The second solar lumber dryer

3.4 The Fourth Dryer

This solar dryer was designed and constructed in the 1989 at Phawgan, Insein due to the official request of a private sawmill-owner who is exporting teak parquet.

The length and width of this dryer are 25 feet and 7½ feet, respectively. The height of the south wall is 6 feet whereas the height of the north wall is 10 feet. The outside and inside walls were constructed with 1-inch thick lumber. The gap which is 6 inches wide between the outside and inside walls was filled with dried sawdust for insulation. The roof tilted to the south was seathed with plastic sheet.

The dryer has an excess door on the west wall for loading and unloading of lumber. To get the air circulation through the lumber pile, six electric fans which are driven by these electric motors of capacity 1 H. P. are provided on the inside of the north wall. Twelve adjustable air vents are also provide on the north wall for air inlet and air outlet.

The capacity of this dryer is about 150 cubic feet of 1-inch thick lumber and the total cost is estimated at about 50,000 kyats.

4. Operational Tests

To observe the performances of the solar dryers, operational tests were conducted on each dryer.

4.1 Test on the First Dryer

To known the performance of this dryer, one charge of Leza (*Lagerstroemia tomentosa*) lumber was tested at kyaikasan ground, Yangon where the Union Day Exhibition was held.

One-inch thick green Leza lumber was solar dried during January 1987. The board were stacked in the dryer on January 11, 1987. The width and the height of the pile were 3 feet and 4 feet, respectively. A sheet of plywood painted flat black was put on top of the pile to act as an absorber.

The drying test was started on January 12, 1987 and it was terminated on January 31, 1987, 19 days later.

This dryer was handed over to the authorized persons from the Furniture Industry of the Myanmar Timber Enterprise, after the Union Day Exhibition. After the Exhibition, they reconstructed the dryer at the Furniture Industry compound, but it was learned that no other performance had been done with this dryer.

4.2 Tests on the Second Dryer

Six charges of different species and different thickness were tested by this dryer through the summer of 1987 to the winter of 1988.

Firstly, 1-inch thick green Hnaw (*Adina cordifolia*) of specific gravity 0.58 were tested during April, 1987. The width and the height of the pile were $3^2/_3$ feet and 5 feet, respectively. This drying test was started on April 1, 1987 and it was terminated on April 23, 1987, 22 days later.

The second charge conducted was air-dried Hnaw of thickness one inch. The total load of the pile was about 100 cubic feet. This test was started on April 30,1987 and it was completed on May 13, 1987.

The third run was started on June 5, 1987 with air-dried Leza. The thickness of the tested board is one inch and the total load was about 100 cubic feet. This test was terminated on June 28, 1987.

The Fourth run was again tested with 1-inch thick lumber obtained from tops and lops of teak (*Tectona grandis*) trees. It was started on August 17,1987 and terminated on September 10, 1987.

Teak lumber of thickness one inch were tested for the fifth charge and sixth charge. The fifth charge was started on November 24, 1988 and terminated on December 20, 1988 whereas the sixth charge was started on December 23, 1988 and completed on January 12, 1989.

4.3 Tests on the Third Dryer

To observe the performance of this dryer, five charges of different species and of different thickness were tested during 1990 and 1991.

Firstly, a mixture of Padauk (*Pterocarpus macrocarpus)*, Leza, Chinyok (*Garuga pinnata*) and Didu (*Salmalia insignis*) were tested during April, 1990 and May, 1990. The thickness of the tested lumber were ½ inch, 1 inch and 2 inches, respectively. Since the length of this dryer is 45 feet, the tested boards which are 18 feet long were stacked into two different plies. The height and width of each pile were 5 feet and 4 feet, respectively. The total load of the two piles was about 260 cubic feet including 24 sample boards. This test was started on April 1, 1990 and it was terminated on May 22, 1990.

The second charge was conducted during the rainy season of 1990. Leza lumber of different thickness were used for this test. It was started on June 23, 1990 and terminated on July 30, 1990.

The third run was tested with a mixed species of Thinwin (*Milletia pendual*), Thitsi (*Melanorrhoea usitata*), Sit (*Albizzia procera*), Myauklok (*Artocarpus lakoocha*) and Leza. The thickness of the tested boards were 1 inch and 2 inches respectively. This test was started on October 31, 1990.

Semi-airdried Thitsi and Myauklok of one inch thickness were also tested as the fourth charge during the winter of 1991.

The fifth charge was tested with Thitkado (*Cedrela toona*) during April and May of 1991. The thickness of the tested boards were 1 inch and 2 inches, respectively.

4.4 The Fourth Dryer

As mentioned before, this dryer was situated at a private sawmill at Phawgan, Insein. It was learned that, Teak, Padauk and Pyinkado (*Xylia dolabriformis*) lumber of different thickness for making parquet blocks were dried by this dryer during the summer and winter of 1990.

5. Results and Discussions

The result obtained on each of the four solar lumber dryers will be discussed separately followed by the study on the operating cost.

5.1 The First Dryer

The total green volume of lumber used in this test was about 105 cubic feet of Leza. The average initial moisture content of six sample boards was 35.9 percent. The average final moisture content attained after 19 days of during was 1.9 percent. Thus the average daily moisture content loss was about 1,41 percent. The temperature of the dryer ranged from 84˚ – 135˚ F while the ambient temperature ranged from 68˚ – 120˚ F. Thus the temperature of the dryer was 16˚ to 33˚ F higher than of the ambient air, which showed that the walls and the floor of this dryer were well insulated.

Based on this result, it can be seen that, lumber can be solar dried on a commercial-scale during the winter time in Yangon (16˚ 46' N, 96˚ 09' E) to a final moisture content below 10 percent.

Drying defects such as splitting, warping, distortion, honey-combing, case hardening, blue-stain, sticker-stain and discolouration did not occure. But slight surface decking were noticed in some of the boards.

5.2 The Second Dryer

As mentioned in the previous section, six test runs were conducted with this dryer. Results obtained on each test will be discussed separately.

5.2.1 First Run

The total volume of Hnaw lumber tested in this charge was about 115 cubic feet including six sample boards. The average initial and final moisture contents of the sample boards were 40.3 percent and 12.7 percent, respectively. The total drying time was 22 days and thus the average daily moisture content loss was about 1.25 percent. The temperature of the dryer during this test ranged from 95˚ – 143˚ F while the ambient temperature ranged from 75˚ – 104˚ F.

No warping, distortion, honey-combing or case hardening occurred. There were numerous surface checks and slight splitting.

5.2.2 Second Run

The total volume of the lumber used in this test was about 80 cubic feet of air-dried Hnaw. The average initial moisture content was about 14.4 percent. After 13 days of solar drying, the average final moisture content attained was 9.1 percent. The temperature of the dryer ranged from 96˚ – 145˚ F while the ambient temperature ranged from 76˚ – 105˚ F. This test was conducted during April and May of 1987.

Surface checking and splitting occurred. But less surface checking was noticed compared to the previous test, since the boards tested in this charge were initially air-dried.

5.2.3 Third Run

The average initial moisture content of the air-dried Leza lumber which were tested for this charge was about 14.0 percent. After 23 days of solar drying, the average final moisture content reached to 12.1 percent only. Since this charge was tested during the rainy season, it was found that it was impossible to attain a moisture content below 12 percent.

Surface checking, splitting and warping did not occur. No discoloration, insect attack or decay was found.

5.2.4 Fourth Run

The total volume of the lumber which were obtained from teak tops and lops was about 70 cubic feet. These lumber were semi-airdried and the green specific gravity was about 0.78. The average initial moisture content of the sample boards was 24.1 percent. The average final moisture content attained after 24 days of drying was about 12.2 percent. This test was also conducted during the rainy season is during August and September of 1987. Thus it could not attain a final moisture content below 12 percent.

No surface checking, distortion, honey-combing or case-hardening occurred. However, slight warning occurred in some of the boards.

5.2.5 Fifth Run

The thickness of the teak lumber tested in this run was 1 inch and the total volume was about 95 cubic feet. This test was carried out during November and December of 1988. The average initial moisture content and the average final moisture content of the sample boards were 39.1 percent and 12.2 percent, respectively. The total drying time was 26 days.

5.2.6 Sixth Run

The same species and the same thickness as these of the previous charge was again tested during December 1988 and January 1989. The average initial and final moisture contents of the sample boards were 26.0 percent and 9.5 percent, respectively. The total number of during time was 20 days.

Drying defects such as checking, splitting, warping, etc. did not occur in both the fifth run and the sixth run tests.

Parquet blocks (8½ x 3" x 1") were made from the solar-dried lumber obtained from this charge. These teak parquet were used in the guesthouse of this institution since February, 1989. They were found to be free from drying defects up to this date.

To get a comparison, the summary of results obtained from six test runs are also given in Table 1.

5.3 The Third Dryer

Results obtained from each of the five different test runs conducted by this dryer will be discussed separately.

5.3.1 First Run

As mentioned in section 5.3, four different species of different thickness were tested for this run, during April and May of 1990. Results obtained on each species will be given separately.

5.3.2 Padauk

The average initial moisture content of Padauk (Green Specific Gravity 0.76) lumber which have ½ -inch in thickness was 16.6

Table 1. Summary of Results obtained from the second Dryer.

Species	Green Specific Gravity	Thick-ness (inch)	Initial Duration	Initial Moisture Content (%)	Final Moisture Content (%)	Total Drying Time (day)	Drying Defects
Hnaw Air-Dried	0.58	1	1-4-87 to 23-4-87	40.3	12.7	22	Numerous surface checks, slight splitting
Hnaw Air-Dried	0.60	1	30-4-87 to 13-5-87	14.4	9.1	13	Numerous surface checks, slight spliting
Leza	0.50	1	5-6-87 to 28-6-87	14.0	12.1	23	No drying defects
Teak	0.78		17-8-87 to 10-9-87	24.1	12.2	24	Slight warping
Teak	0.60	1	24-11-88 to 20-12-88	39.1	12.2	26	No drying defects
Teak	0.59	1	23-12-88 to 12-1-88	26.0	9.5	20	No drying defects

percent. After 19 days of drying the average final moisture content attained was 9.2 percent.

The average initial moisture content of 1-inch thick Padauk was 32.8 percent and the average final moisture content attained was 10.9 percent. The total drying time was 29 days.

Two-inch thick lumber of the same species were also tested at the same time. The average initial and final moisture contents were 29.0 percent and 14.5 percent, respectively. This test was started on April 1, 1990 and terminated on may 21, 1990. Thus total drying time was 50 days.

Warping was noticed in some of the boards which have ½ inch in thickness whereas few splitting was found in some of the 2-inches thick boards. No other drying defects were occurred.

5.3.3 Leza

Leza lumber of different thickness, ½ inch, 1 inch and 2 inches were also tested at the same time. The average initial moisture content of ½ inch thick lumber was 32.0 percent. After 19 days of drying, the average final moisture content reached to 10.7 percent.

The average initial moisture content of 1-inch thick lumber was 21.7 percent. The average final moisture attained after 19 days of drying was 10.9 percent.

The average initial and final moisture contents of 2-inches thick boards were 35.2 percent and 12.9 percent, respectively. The total drying time was 51 days.

Few surface checking were found in some of the tested boards, especially in 2-inches thick boards. No other drying defects occurred.

5.3.4 Chinyok

The average initial moisture content of Chinyok (Green Specific Gravity 0.63) lumber of thickness ½ inch and 1 inch were 42.6 percent and 54.8 percent, respectively. After 19 days of drying, the average final moisture content attained for the ½ -inch thick lumber was 14.0 percent, whereas the average final moisture content attained for the 1-inch thick lumber was only 35 percent.

The average initial moisture content of 2-inches thick lumber was 79.1 percent. After 50 days of drying, the average final moisture content reached to 52.8 percent only.

No drying defects were occurred. However, according to the final moisture contents attained it can be seen that, the drying rate of this species is very slow compared to the other species.

5.3.5 Didu

Didu (Green Specific Gravity 0.36) lumber of thickness ½ inch and 1 inch were tested at the same time with Padauk, Leza and Chinyok lumber. The average initial and final moisture contents of ½ inch thick lumber were 34.3 percent and 11.3 percent, respectively. Similary, the average initial and final moisture contents of 1-inch thick lumber were 20.0 percent and 9.9 percent, respectively. The total drying time for both thickness was 19 days.

Warping, splitting and surface checking were not marked. No signs of insect attack and no discoloration or decay were found.

During the first run, ie during April and May of 1990, the temperature of this dryer ranged from 90˚ – 130˚ F while the ambient temperature from 76˚ – 120˚ F. compared to the second dryer this dryer was found to be less efficient.

5.3.6 Second Run

Leza lumber of thickness ½ inch, 1 inch and 2 inches were tested during June and July of 1990. The average initial moisture contents of ½ inch, 1 inch and 2 inches thick lumber were 50.0 percent, 27.4 percent, and 52.4 percent, respectively. At the end of the test the average final moisture contents attained for each thickness were 25.9 percent, 19.0 percent and 32.5 percent, respectively.

5.3.7 Third Run

As mentioned earlier, this run was conducted with five different species, of thickness 1 inch and 2 inches.

The average initial moisture content and average final moisture content attained according to the difference species and different thickness together with the drying defects occurred for each species were given in Table 2. This test was started on October 12, 1990 and terminated on January 7, 1991.

5.3.8 Fourth Run

The average initial moisture contents of semi-airdried Thitsi and Myauklok were 24.6 percent and 24.8 percent, respectively. This test was started on January 1, 1991 and completed on January 16, 1991. The average final moisture contents attained at the end of test for Thitsi and Myauklok were 10.1 percent and 8.9 percent, respectively. The thickness of the tested boards was 1 inch.

Warping was noticed in some of the Thitsi boards. No other drying defects occurred in both species.

5.3.9 Fifth Run

The average initial moisture contents of 1-inch thick and 2-inches thick Thitkado lumber were 50.0 percent and 59.7 percent, respectively. This test was started on April 5,1991. After 11 days of drying the average final moisture content attained for the 1-inch thick boards was 11.0 percent. On April 26, 1991 ie after 21 days of drying the average final moisture content of those boards reached to 6.4 percent.

On May 9,1991 ie after 34 days of drying, the average final moisture content attained for the 2-inches thick boards was 12.9 percent.

No drying defects were found to occur. It is found to be a very easy species to dry with a fast frying rate.

Table 2. Test on the Third Dryer-Third Run.

Species	Green Specific Gravity	Thick-ness (inch)	Duration	Initial Moisture Content (%)	Final Moisture Content (%)	Total Drying Time (day)	Drying Defects
Sit	0.57	1	12-10-90				
			to	108.2	14.2	50	Slight splitting & Warping
			1-12-91				
Sit	0.57	2	12-10-90				
			to	106.3	16.9	55	Sight splitting & Warping
			6-1-91				
Leza	0.51	1	23-10-90				
			to	83.2	9.8	64	Few surface-checking
			26-12-90				
Leza	0.51	2	23-10-90				
			to	88.4	20.4	64	Few surface-checking
			26-12-90				
Thitsi	0.78	1	31-10-90				
			to	77.4	15.2	56	Warping occurred in some
			26-12-90				of boards, especially in the
							boards which have sapwood
Thitsi	0.78	2	31-10-90				
			to	81.2	22.4	56	? ?
			26-12-90				
Thitsi	0.78	1	27-11-90				
			to	49.0	15.0	41	? ?
			7-1-91				
Myaukl ok	0.52	1	31-10-90				
			to	166.8	13.3	56	No drying defacts occurred
			26-12-90				
Myaukl ok	0.52	2	31-10-90				
			to	113.6	21.1	56	But care must be taken to avoid
			26-12-90				the likelihool of the fungus
							because of the high initial
							moisture content

Species	Green Specific Gravity	Thick-ness (inch)	Duration	Initial Moisture Content (%)	Final Moisture Content (%)	Total Drying Time (day)	Drying Defects
Thinwin	0.85	1	31-10-90				
			to	22.7	11.9	34	Slight warping, few surface
			4-12-90				checking: slow drying rate.

5.4. The Fourth Dryer

Teak lumber of thickness 10 mm (about 0.4 inch) and 15 mm (0.6 inch) were solar dried at Insein during the summer time and winter time of 1990. It was found that, 10 mm thick lumber reached to an average moisture content of about 10 percent within 7 days, whereas 15 mm-thick lumber reached to an average moisture content of about 10 percent within 12 days. The average initial moisture content of the teak lumber were about 20 to 25 percent.

Padauk and Pyinkado lumber for marking parquet flooring were also dried by this dryer and it was learned that it can attain 10 percent moisture content in not more than two weeks time.

5.4.1 Study on the Operating Cost

Based on the experiences obtained from these tested solar lumber dryers, operating cost for drying one ton (50 cubic feet or 1.4 cubic meter) of 1-inch thick lumber can be estimated as follow.

A solar lumber dryer of capacity 5 ton (250 cubic feet or 7 cubic meter) can be built at a cost of 120,000 kyats. According to the results obtained, one charge of 1-inch thick green lumber of average initial moisture content of about 40 to 50 percent can be dried per month for at least eight months per year. Therefore, there will be total of eight charges or 40 tons per year.

It is believed that, an operator at a salary of k 1000/- per month can control four dryers which have the same capacity as this dryer. Thus with charges or 20 tons of lumber per month, cost for operator will be k 50/- per ton.

Electric power consumption for the dryer can be calculated as follow.

The dryer was usually operator during 8 am to 5pm daily. Thus total running hour of the electric motors for one month is 9 hr x 30 = 270 hours. The capacity of each of the four motors which are dribing the eight circulation fans is 1 H.P (0.746 K. watt). Taking the electric power cost as k 1.00 per K whr, the total cost for one month will be about (0.746 x 4 x 270) x k 1.00 = k 805.68. Thus the electric power cost for drying one ton of green lumber, will be 805.68/5 = k 161.14.

For loading, piling and unloading the lumber, labour cost is 65/- per ton.

Assuming the maintainance cost for the dryer as 6000 kyats per year, it will be 150 kyats per ton for maintainance.

Finally, the total cost to solar-dry one ton of green lumber is:

1.	Wages for operator…….	K 50.00
2.	Electric power cost……..	K 161.14
3.	Labour cost ……	K 65.00
4.	Maintainance cost ……	K 150.00
	Total cost ……..	K 426.14

6. Conclusions

Conclusions drawn from the four different sizes of solar lumber dryers are as follows:-

(1) Green lumber of 1-inch thickness can be solar-dried at a commercial scale to attain a moisture content below 10 percent during the summer and winter time in Myanmar.
The drying time ranged from 19 days to 36 days depending on the tested species and their initial moisture contents.

(2) It is not possible to attain a moisture content below 12 percent for solar drying of lumber during the rainy season in Yezin.

(3) One ton of green lumber of moisture content 40 to 50 percent can be solar-dried commercially at a cost of about 450 kyats.

(4) A commercial-sized solar lumber dryer requires a minimum of capital investment, no energy except for the fans, low-level operating skills and high quality dried lumber can be obtained.

References

1. Izlar, B. 1981. Solar-heated dry kilns. Technical release 81-R-36, July, 1981.American Pulpwood Association. 1696 Massachusetts Ave., N.W., Washington, D.C. 20036.
2. Kyi, W. 1983. Predicting drying times of some Burmese woods for two types of solar kilns. Unpublished M.S. Thesis. VPI & SU, Blacksburg, Virginia. 149 pp.
3. -------- 1986. Evalution of solar dryers tested at the Forest Research Institute, FRI Leaflet No.13/85-86. 21 pp.
4. Plumptre, R.A. 1979. Simple solar heated timber dryers: Design, performance and commercial viability. Commons. For. Rev. 58 (4) : 243-250.
5. Read, W.R., A. Choda, and P.I. Cooper. 1974. A solar lumber kiln. Sol. Energy, 15(4) : 309-316.
6. Sharma, S.N., P. Nath, and B.I. Bali. 1972. A solar timber seasoning kiln. J. Timber Devel. Assoc. India. 18(2): 28-31.
7. Whaley, S.R. 1981. Solar kiln drying. pp 28-29.