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Evaluation of Solar Dryers Tested at the Forest Research Institute

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သစ်တောသုတေသနဌာန၌ နေရောင်ခြည် စွမ်းအင်သုံး ပေါင်းဖိုများ တည်ထောင်ခြင်းနှင့် လက်တွေ့စမ်းသပ်ခြင်း

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Evaluation of Solar Dryers Testedat the Forest Research Institute

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Abstracts

Four different types of solar dryers were constructed and tested at the Forest Research Institute, tow for drying lumber and two for drying crops and food. Solar dryers provide a method of utilizing solar energy more efficiently than conventional methods both for lumber and crops. One inch thick green lumber was reduced to 8 percent moisture content in three to four weeks. Air-dried lumber of 1-inch thickness can be solar dried to a moisture content below 10 percent in less than two weeks, at a very little cost. In drying coffee seed and bananas the drying time reduced by 25-50 percent.

Contents

1. Introduction

A considerable amount of work has been carried out in the past decade on the harnessing of solar energy in various ways ranging from high temperature furnaces to domestic water heaters.

Tropical areas between latitude 35^o North and South receiving 2000 hours of bright sunshine in the year are ideal for collecting and utilizing solar heat. Most parts of Burma (located between latitude 10^o and 28^o North) are favorable for this purpose during eight to ten months of the year. (Kyi, 1983)

Many developing countries with significant forest resources increasingly prefer to process logs into finished wood products instead of exporting raw logs.

Higher yield and better quality lumber, veneer and other finished products depend on application of the best technology in processing, especially in drying. In the United States of America 60 to 70 percent of the energy used in lumber processing was consumed in lumber drying (Skaar, 1977). Wengert, (1974) calculated that the energy required for kiln drying lumber in the United States was about 22 billion KWhr in 1972, approximately equivalent to 0.1 percent of the total energy consumed annually in the United States.

According to the present conditions of Burma, only three methods of drying, namely: air drying, kiln drying and solar drying are feasible. Because of the low operating cost (without suing any energy) air drying is useful but has some limitations: long period of drying time; high inventory carrying cost; mainly dependence on weather conditions; high final moisture content.

Kiln drying can eliminate long air drying times and reduce final moisture content lower than that of air drying. However, it is not only high in initial investment but also expensive in operating cost. The problem, therefore, is to investigate a low-cost (both investment and operating cost) procedure which will dry lumber faster and to a lower moisture content then does air drying, and with a minimum of drying defects. Solar drying may be the solution to that problem.

In preserving crops and food, the traditional method is drying of the material in the sum. By making better use of the available solar radiation, the drying time and the harmful effects caused by dusts, dirt, and insect infestation could be reduced.

2. Objectives

The principal objectives of this study are:

(1) To evaluate two different types of lumber dryers and describe the principles and practices of lumber drying using solar energy.

(2) To examine different types of solar crop and food dryers which apply solar drying principles to other commodities.

3. Review of Literature

Many experimental and prototype solar kilns have been built and tested throughout the world in the past 25 years, with research and testing accelerating during the past 5 to 10 years (Kyi, 1983).

A Regional Workshop on Solar Drying held in Manila, 1978, discussion various aspects in which solar drying could be effectively used, namely: drying of grain marine products, lumber and cash crops (A.R.N.S.E. , 1978).

Interest in solar drying of lumber has increased in recent years. As tests indicated that shorter drying time, lower final moisture content and less lumber degrade occurs in solar drying than in air drying. There is lower energy cost in solar drying than in kiln drying.

As of 1982 there were at least 250 solar lumber kilns throughout the world. Of these about 40 are experimental kilns built at universities or government research laboratories, and the others are commercial kilns. One of the commercial kilns, operated at the Deco Materials Service of Somerset, Ohio, U.S.A., has a capacity of about 317 tons (190 MBF) was the largest. The locations of the solar lumber kilns were ranged from equator-Uganda to latitude 52^o North - United Kingdom (Kyi, 1983).

4. Designs and Constructions

A solar dryer is basically a greenhouse that traps the solar energy and circulates the heated air through the material being dried. Most solar dryers consist of a slanted side facing the sun for maximum solar exposure. To get the maximum solar radiation, the optimum roof angle, above the horizontal, is equal to the latitude of the location, but can be increased by 10^o to improve winter performance (Wengert, 1980). Within the dryer, or mounted on the side, is a collector of metal or some other material painted flat black to absorb solar radiation. The collector must be covered with some transparent or translucent material which allows solar energy (short wave radiation) to be transmitted but inhibit the escape of heat (long wave radiation).

Four different types of solar dryers were constructed and tested at the Forest Research Institute (FRI), two for drying lumber and two for drying crop and food. The first solar lumber dryer was designed by J.L.Tschernitz and W.T. Simpson, of the U.S. Forest Products Laboratory, Madison, Wisconsin, and the rest were designed by the author.

4.1. Solar Lumber Dryers

Two different types of solar lumber dryers, external collector type and semi-greenhouse type, were studied.

4.1.1 External Collector Type Solar Lumber Dryer

This dryer was constructed by C. de Zeeuw [1]/ and U Soe Tint, of the FRI , Yezin in September, 1982.

It mainly consists of two parts, the solar collector and the drying chamber, as shown in Figure 1. The capacity of this solar dryer was about 80 cubic feet (about 1½| ton) of 1-inch thick, lumber. The detailed description is given in an FRI leaflet (Tint et al, 1985). The cost of this experimental dryer was about 61.000 Kyats including 51,000 Kyats of foreign exchange.

4.1.2 Semi-Greenhouse Type Solar Lumber Dryer

A semi-greenhouse type solar lumber dryer was constructed by the FRI for display at the 38th Anniversary Union Day Exhibition Rangoon, in February 1985.

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[1]/ C. de Zeeuw, Consultant in Wood Technology, FRI, Eosin, Burma.

The dryer as shown in Figure 2 is feet long from east to west, and 5 feet wide from north to south. It is 8 feet high at the north side and feet high at the south side.

It has a capacity of 30 cubic feet of 1-inch thick lumber. The inside and outside walls are seathed with in-kanyin (Dipterocarpus spp.) plywood with 6-inches of dried sawdust between for insulation. The floor is of similar construction. The roof tilted at a 30^{o} angle to the south, consists of a window frame of … inch thick locally-made glass.

The dryer has an excess door on the west wall for loading and to permit periodic examination of the lumber and measurement of moisture content. There are four adjustable air vents of about 66 square inches, two near the top and two near the bottom of the north wall. Two Burma made electric fans are provided for air-circulation, each using 70 watts.

All the outside and inside walls were painted flat black to maximize the absorption of solar radiation.

The total cost of this dryer was about 6,000 Kyats.

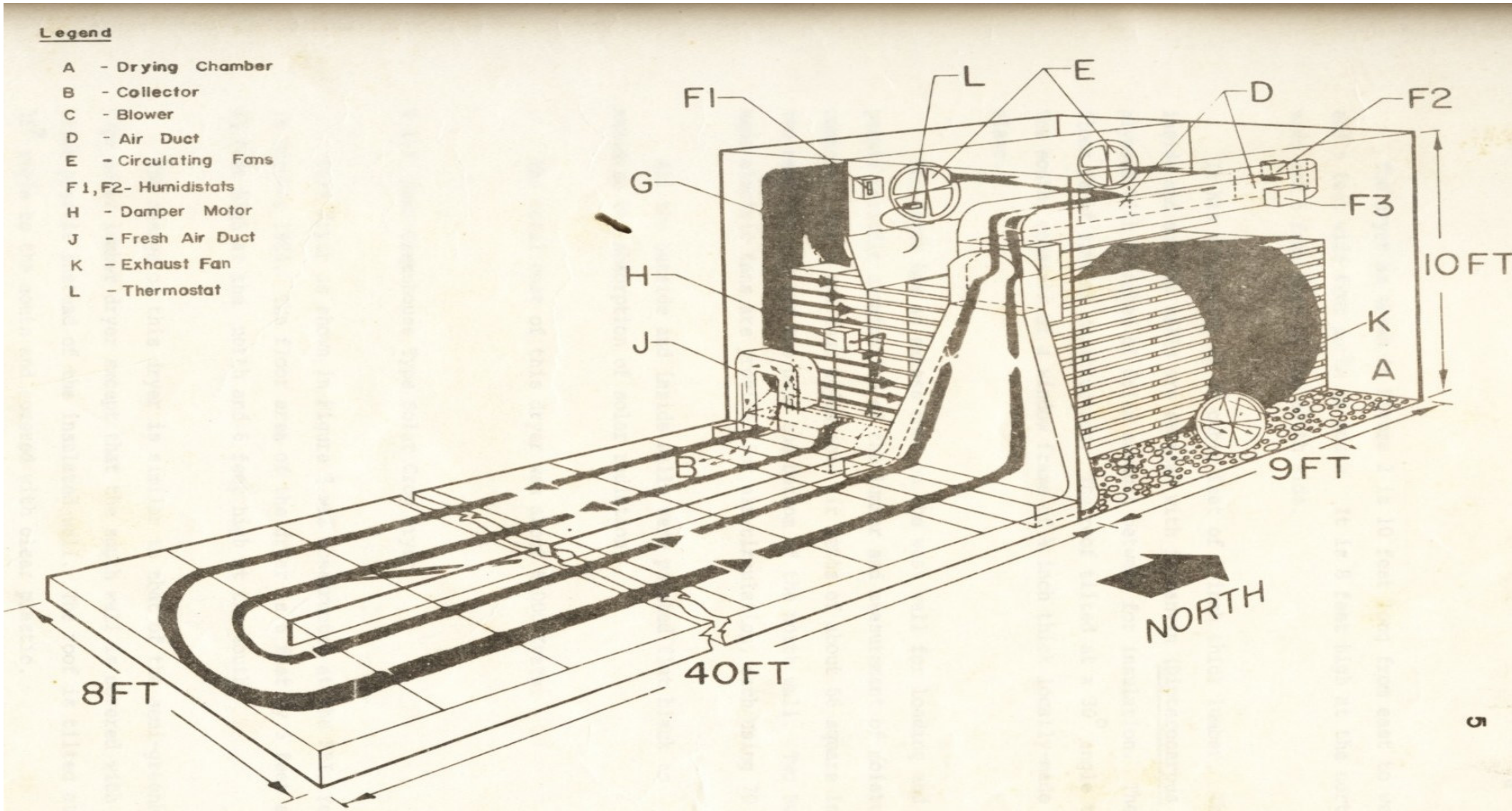

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Figure 1: External-Collector Type Solar Lumber Dryer (Courtesy U S D A Forest Products Laboratory)

4.1.3 Semi-Greenhouse Type Solar Crop Dryer

This dryer as shown in Figure 3 was constructed at the FRI, Yezin in October 1984. The floor area of the dryer is 5 feet by 5 feet and 8 ½ feet high at the north and 6 feet high at the south.

The design of this dryer is similar to that of the semi-greenhouse type solar lumber dryer except that the south wall is covered with clear plastic instead of the insulated wall. The roof is tilted at 35^{o} angle to the south and covered with clear plastic.

There is an access door on the north wall for loading and unloading and four adjustable vents on the north wall for inlet and outlet of air by convection. The total cost of the dryer was about 1,700 Kyats.

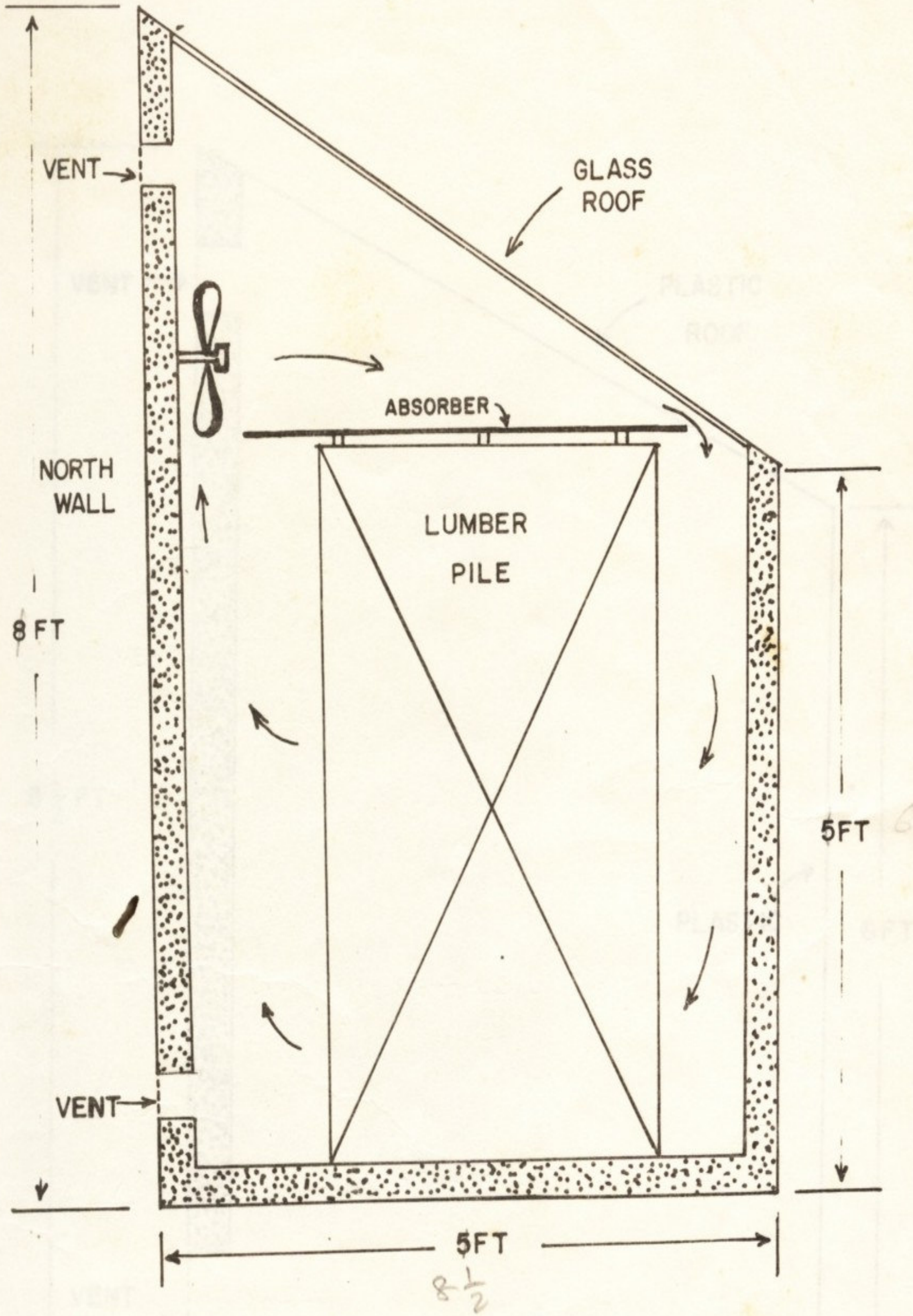

Figure 2: Semi-Greenhouse Type Solar Lumber Dryer.

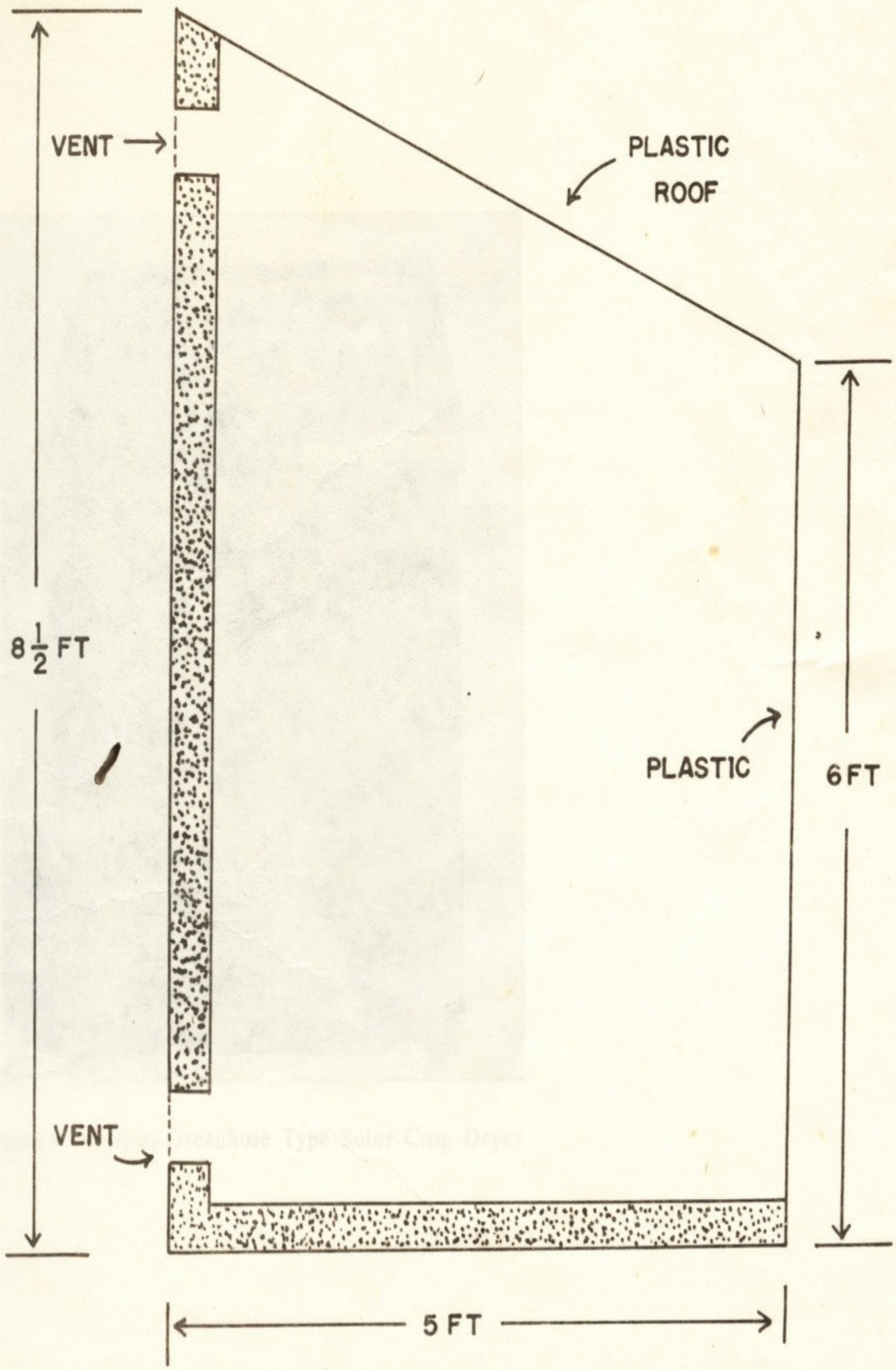

Figure 3: Semi-Greenhose Type Solar Crop Dryer.

Figure 3 : Semi-Greenhose Type Solor Crop Dryer

4.1.4 Box Type Portable Solar Dryer

This simple solar dryer as shown in Figure 4 was constructed for household use. The size is 28" x 19" x 10". The walls are constructed of 1-inch lumber and the floor consists of two layer of plywood insulated with 4 inches of dried sawdust. The lid is 1/8-inch glass easily opened for loading and unloading. There are 8 vents 1- inch in diameter, 4 low in the front side and 4 high in the rear side for air movement by convection. All wood surfaces are painted black inside and out. The position of the dryer can be moved and tilted easily to get the maximum solar radiation. The total cost of this dryer is only 120 Kyats.

5. Operational Tests

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

5.1 External-collector Type Solar Lumber Dryer

To observe the performances of this dryer, one charge of green rubberwood *(Hevea brasiliensis* Muell. Arg.) and one charge of girdled thinbaw-kokko *(Samanea saman* Merr.*)* were tested.

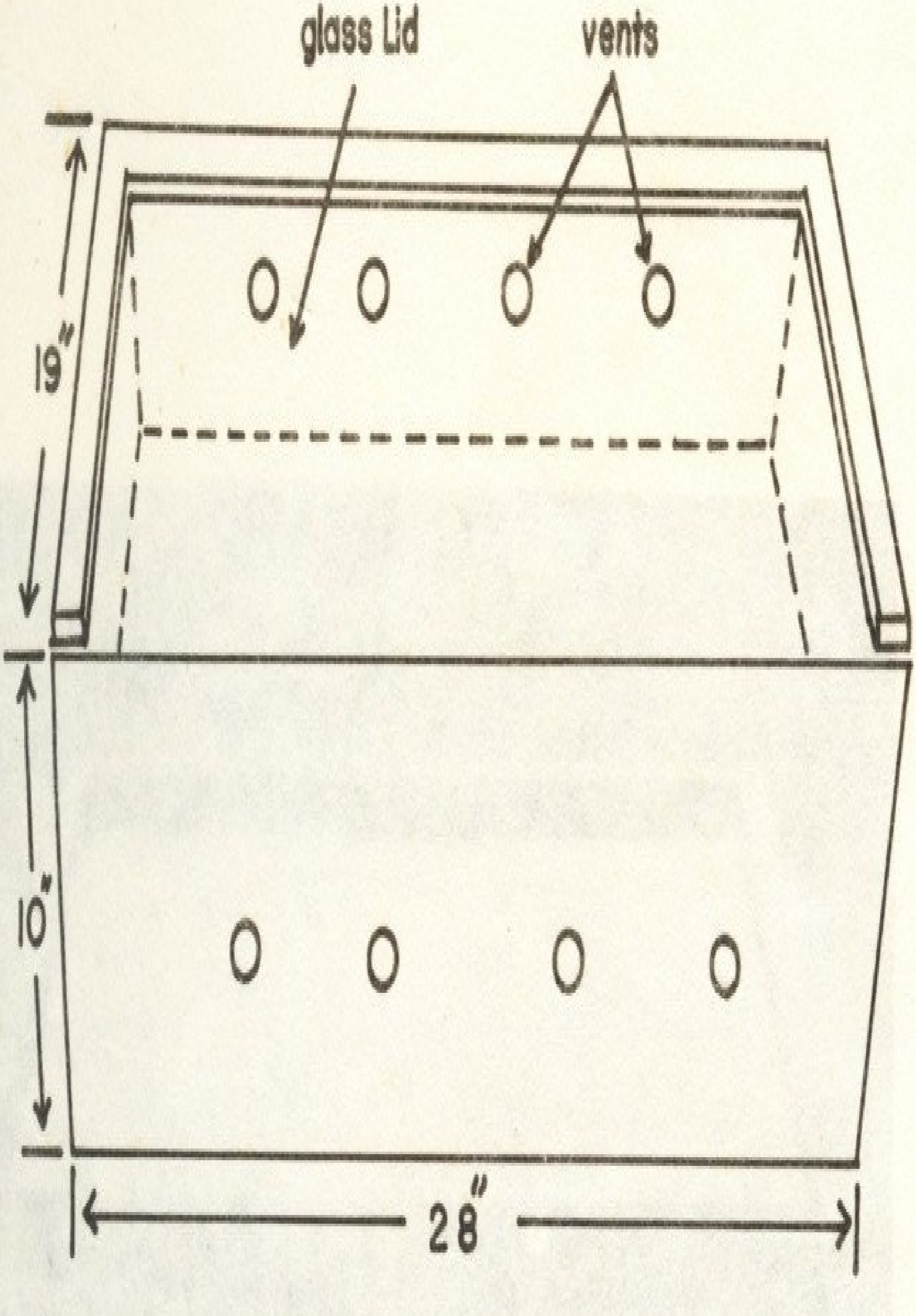

Figure 4: Box Type Portable Solar Dryer.

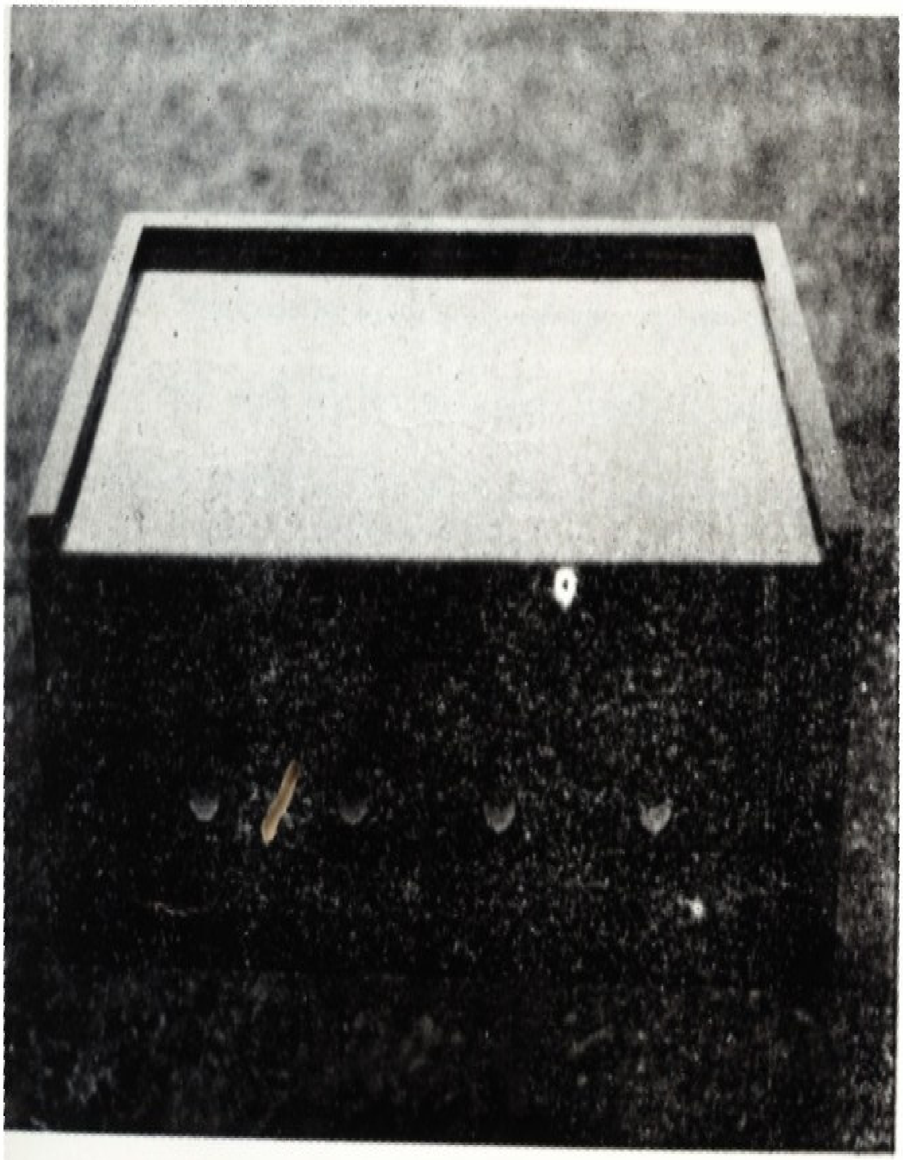

Figure 4 : Box Type Portable Solor Dryer

5.1.1 First Run

One-inch thick green rubberwood (0.56 green specific gravity) was solar dried during December, 1983 and January 1984. The detailed description of the tested material and the experimental procedure were given in the FRI Leaflet (Tint et al, 1985).

5.1.2 Second Run

Girdled thinbaw-kokko of 1-inch and 2-inches thick lumber was also tested during May, 1985. Three logs sawed at the FRI sawmill produced 58 boards 2-19 inches wide.

The boards were stacked in the drying chamber on May 6, 1985. The total load of the pile was about 70 cubic feet (1.4 ton) including 6 sample boards. The pile was 4 feet wide and 3½| feet high.

Solar drying was started on May 7,1985. All sample boards were weighed every morning before 8 am. The moisture content of each sample board as calculated immediately after weighing to verify rate of drying. The test was terminated after 18 days of days of drying, because of continuous rain.

5.2 Semi-Greenhouse Type Solar Lumber Dryer.

Two test runs were conducted, one with 25 cubic feet of green kuthan (*Hymenodictyon excellsum* Wall.) and the other with 23 cubic feet of air-dried thinbaw-kokko.

5.2.1 First Run

The first test was carried out during December 1984 and January 1985 at Kyaikasan ground, Rangoon.

Lumber used in this test was cut from 3 9-foot logs. There were 35 boards which ranged from 5 inches to 18 inches width. The boards were cut 8 feet long and averaged 1.2 inches, thick.

The boards were stacked in the dryer on December 27, 1984. The width and the high of the pile were 2½| feet and 4½| feet, respectively. A sheet of plywood painted flat black was on top of the pile to act as an absorber.

The drying test was started on December 28, 1984 and it was completed on January 21, 1985, 25 days later.

5.2.2 Second Run

The second drying test was conducted at the FRI during October 1985.

Lumber used in this test was from 2 logs of girdled thinbaw-kokko. Before solar drying these lumber were air-dried under an open seed for about two months.

This test was started on October 20, 1985 and it was completed on October 30, 1985 after 11 days of drying.

5.3 Semi-Greenhouse Type Solar Crop Dryer

As a preliminary test some Rakkine bananas *(Musa sapientum* var. *arakensis* Ripley) were dried in this dryer during November, 1984. At the same time some bananas of the same variety and quality were dried in the sun.

Coffee seeds from Thantaung also were tested in this dryer during May, 1985. The seeds were put on two shelves of black-painted plywood. To compare the difference in drying times with traditional sun drying, some coffee seeds were also dried in the sun.

5.4 Box Type Portable Solar Dryer

This dryer was also tested with bananas and coffee seeds at the same time as the tests mentioned in section (5.3). During the drying process, the position of the dryer was moved and tilted every hour to get maximum solar radiation.

6. Results and Discussion

The results obtained on each of the two types of solar lumber dryers and two types of solar crop and food dryers will be discussed separately followed by discussion on the design and cost of the dryers.

6.1 External Collector Type Solar lumber Dryer

The results are divided into two sections, the first run on rubber wood, and the second run on thinbaw-kokko.

6.1.1 First Run

The total green volume of the lumber used in this test was 60 cubic feet (about 1.2 tons) of rubberwood (0.56 green specific gravity). The average initial moisture content of the sample boards was 60.2 percent. The average final moisture content attained after 22 days of drying was 8.2 percent. Thus the average daily moisture content loss was about 2.36 percent. The maximum temperature in the drying chamber during this test was 135^{o} F, while the ambient temperature was about 102^{o} F.

These results showed that lumber can be solar dried by an external-collector dryer during the winter in Yezin (19^{o} 47' N, 96^{o} 15' E) to a final moisture content below 10 percent.

No surface checking, warping, distortion, honey-combing or case hardening occurred. There was slight splitting. Some blue-stain and sticker-stain occurred in some of the boards, at the beginning of the drying process. Insect attack occurred in some of the boards at the end of the test..

6.1.2 Second Run

The total volume of thinbaw-kokko (0.45 green specific gravity) tested in this run was about 70 cubic feet (1.4 ton). The average initial moisture contents of the 1-inch and 2-inch sample boards were about 51.4 percent and 32.1 percent, respectively.

After 18 days of drying, the average final moisture content of 1-inch sample boards was 9.6 percent and that of 2-inch sample boards was 12.2 percent. The maximum temperature attained inside the drying chamber was 140° F while the ambient temperature was about 105° F.

No warping, distortion honey-combing or case hardening occurred. There was slight surface check and slight splitting. No discolaration or decay.

The average daily total power consumption by the circulating fans, blower and exhaust fan for both test was about 15 KWhr.

6.2 Semi-Greenhouse Solar Lumber Dryer

The results obtained from the two test runs will be discussed separately.

6.2.1 First Run

The total green volume used in this test was 25 cubic feet of kuthan (0.39 green specific gravity). The average initial and final moisture contents of the sample boards were 67.5 percent and 7.2 percent, respectively. The total drying time was 25 days, thus the average daily moisture content loss was 2.41 percent. The temperature of the dryer ranged from 86°-138° F while the ambient temperature ranged from 68 ° - 104 ° F. Thus the temperature of the dryer was 18° to 34° F higher than that of the ambient air, which showed that the walls and the floor of this dryer were well insulated.

Based on these results, it can be seen that, lumber can be solar dried in a semi-greenhouse dryer during the winter in Rangoon (16° 46' N, 96° 09' E) to a final moisture content below 10 percent.

Drying defects such as surface checking, warping, etc. did not occur.

6.2.2 Second Run

The total volume used was 23 cubic feet of air-dried thinbaw-kokko (0.48 green specific gravity). The average initial moisture content of the sample boards were about 14.0 percent. The average final moisture content attained after 11 days of drying was about 7.1 percent. The maximum temperature attained in the dryer during the drying period was 140° F, while the ambient temperature was about 100° F.

Therefore, solar drying of air-dried lumber to a final moisture content below 10 percent was achieved in less than two weeks.

No significant drying defects occurred but some slight warping and splitting was noticed.

6.3 Semi-Greenhouse Type Solar Crop Dryer and Box Type Portable Solar Dryer

Since these two dryers were tested at the same time with the same materials, results obtained will be discussed together.

Drying times of bananas and coffee seeds in each of the dryers compared to the traditional sun drying are given in the following table.

Table 1. **Comparison of Drying Methods**

Method	Bananas		Coffee Seeds	
	Time (days)	Gain (%)*	Time (days)	Gain (%)
Sun dry	3-4	-	7-8	-
SGH **	2-3	25-30	5-6	25-30
Portable	1½- 2½	40-50	4-5	35-40

* Gain % = Drying period gained in comparison with sun dry.
** SGH = Semi-Greenhouse

In drying bananas, flies and other insects could not enter the dryers, thus it was a more hygenic method than sun drying.

It was not necessary to put out and remove the materials every morning and evening, thus reducing the labor cost over sun drying, particularly in drying coffee seeds.

6.4 Design and Cost of Solar Dryers

Based on this study it was found that design and cost of a dryer can be varied depending on the availability of material, season and locality. If, for example, coffee seed is to be dried during the winter (harvesting period for coffee) at Maymyo (22^o 0'N, 96^o 08'E), the angle of the semi-greenhouse roof should be about 32^o to improve the winter performance. If on the other hand, lumber is to be dried during the summer at Rangoon (16^o 46' N, 96^o 09' E), the angle of the roof should be about 17^o.

The cost of the dryer depends on the construction materials. If bamboo walls and plastic roof are used, the cost of a semi-greenhouse solar lumber dryer will be less expensive. In addition plastic requires substantially lower replacement cost when broken. On the other hand, the efficiency of the dryer will also be decreased because insulation and transmission efficiency are lower than those of plywood and glass.

The efficiency of the semi-greenhouse solar crop dryer can be increased by using a fan (cost about 1,200 Kyats) to circulate the hot air through the drying material. But the cost of the dryer and operating cost will also be increased.

A semi-greenhouse type solar lumber dryer of 2 tons capacity is to be constructed at the FRI, using local materials. The cost of the dryer is estimated at 17,000 Kyats. The average daily total power consumption should be about 8 KWhr. The author estimated that 1 ton of air dried lumber could be solar dried at a cost of not more than 100 Kyats (including costs on maintenance, labor, electric power and wages for the operator).

A conventional kiln of 12 tons capacity operated at a furniture factory of the Timber Corporation, costs about 480,000 Kyats (including 300,000 Kyats in foreign exchange).

7. Conclusions

a. Conclusions drawn from tow different types of solar lumber dryers are:

(1) Green lumber of 1-inch thickness can be solar dried to a moisture content below 10 percent in less than one month.

(2) Air dried lumber of 1-inch thickness can be solar dried to a moisture content below 10 percent in less than two weeks, at a very little cost. Thus, solar drying of lumber preceded by air drying is suitable for conditions in Burma.

(3) For some locations which have heavy rain during the rainy season (e.g. Rangoon), solar drying can be used for eight months. Thus, for these places, air drying under a shed can be started during the rainy season for the species which are difficult to dry.

(4) A solar lumber dryer requires a minimum of capital investment, no energy except for the fans, and operators less skilled supervision than conventional kilns.

b. Based on the results obtained for two different types of solar crop and food dryers, it can be concluded that:

(1) A 25-50 percent gain in time is achieved over the traditional drying method.

(2) The harmful effects caused by dust dirt and insect infestation are greatly reduced and more hygenic conditions are achieved than in sun drying.

(3) Less handling cost is required than in sun drying.

(4) The dangers of incomplete drying caused by sudden rainfalls, high humidities, etc. are reduced.

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