PN-AAS-525
39494

King Mongkut's Institute of Technology, Thonburi
Bangkok 10410 Thailand

SOLAR THERMAL PROCESSES IN THAILAND

A Study on

SOLAR-ASSISTED CURING OF TOBACCO LEAVES

Submitted to the
National Energy Administration
Ministry of Science, Technology and Energy

Under the
Renewable Nonconventional Energy Project
Royal Thai Government
U.S. Agency for International Development

Side View of Solar-Assisted Tobacco Curing System

FOREWORD

Solar thermal energy has been traditionally used in Thailand for many decades for drying crops and salt production. Solar energy applications cover a number of different technologies depending upon the types and places of applications. Some applications have already been commercialized in Thailand, such as solar water heating, photovoltaic generation, etc. Though potentials for solar energy applications are extremely high, a great deal of research and development has to be conducted to make solar energy applications feasible technically, economically and socially.

As a result of the oil crisis in 1973, the 5th National Economic and Social Development Plan identified solar energy as one of the priority areas in the development of alternative energy resources because of its high potential for applications in both rural and urban areas. Solar Thermal Processes has therefore been selected as an area for cooperation between the governments of the United States and Thailand under the Renewable Nonconventional Energy Project (#493-0304).

Solar Thermal Processes is one component of 14 separate components involved in the Renewable Nonconventional Energy Project. Projects carried out include:

Industrial Biogas
Biomass Gasification
Charcoal Improvement
Energy Master Plan Support
Micro-Hydro Project
National Energy Information Center
Pyrolysis of Rice Husks
Regional Energy Centers
Solar Thermal Processes
Solar/Wind Assessment
Stove Improvement
Village Survey
Village Woodlots
Water Lifting Technology

A grant of about US $50,000 was awarded to King Mongkut's Institute of Technology Thonburi (KMITT) by the US Agency for International Development (USAID) Thailand with institutional support from the National Energy Administration, Ministry of Science, Energy and Technology, to conduct research and development on Solar Thermal Processes. The Solar Thermal Processes component is comprised of five sub-components, namely:

Natural Convection Cabinet Drying
Forced Convection Hut Drying
Solar Tobacco Curing
Solar Distillation
Solar Refrigeration

On behalf of the School of Energy and Materials, KMITT, I would like to express my gratitude to USAID for the grant which made the work on Solar Thermal Processes possible. Even with various constraints such as shortages of available time and technical personnel, rigid government regulations, etc., work completed in this component has reached most of its original objectives. In addition to useful results obtained in the component, the Project has stimulated further interest in research and development on solar thermal processes in Thailand far beyond the original scope of the Project.

As leader of the component of Solar Thermal Processes, I would like to thank Mr. John W. Neave and Mr. Mintara S. Watchananai of USAID Thailand, Mr. Prapath Premmani, Mr. Tammachart Sirivadhanakul and Mr. Sompongse Chantavorapap of the National Energy Administration and their colleagues for their tremendous coordinating efforts in spite of a great many tedious government rules and regulations. I am indebted to my co-leader, Dr. Krissanapong Kirtikara and my colleagues, Dr. Surapong Jirarattananon and Dr. Somchart Soponronnarit for their assistance in managing and coordinating the component activities especially during 1983 when I was on leave at the Asian Institute of Technology.

I would also like to thank the sub-component leaders and local experts: namely, Dr. Piyawat Boon-Long of Chiang Mai University, Dr. Sakarindr Bhumiratana, Dr. Ratana (Putranon) Jirarattanarnon, Dr. Somchart Soponronnarit, and Dr. Suradej Chantranuluck of KMITT and Dr. Sanchai Klinpikul of Prince of Songkla University, for their excellent technical input -- the results of which are reflected in this report. Thanks are due to KMITT Vice Rector Dr. Pibool Hungspreug, to KMITT technical and administrative personnel whose contributions greatly helped facilitate this work.

I finally wish to express my sincere appreciation to Professor M.L. Albertson, Ms. Lana Larsen and their colleagues of the Office of Project Management Support for their coordinating efforts and valuable comments that helped to make the report complete and readable.

Dr. Prida Wibulswas
Professor of Energy Technology, KMITT
Leader of the Component on
Solar Thermal Processes

ACKNOWLEDGEMENTS

The study was made possible by a grant from USAID (Thailand) through King Mongkut's Institute of Technology. The research team is indebted to officials of the Thailand Tobacco Monopoly, Mae Jo Experiment Station, for their invaluable advice and cooperation. In particular, thanks are extended to Mr. Narong Nantapan, Mr. Somyot Tadtiam, Weerapan Kiatpakdee, and Prof. Boonyarit Suchinda. Donation of materials from the Microfiber Company and the Petroleum Authority of Thailand are also gratefully acknowledged.

Dr. Piyawat Boon-Long
Assistant Professor
Technical Engineering Department
Chaing Mai University

CONTENTS

Page

EXECUTIVE SUMMARY 9

Acknowledgements 5

List of Tables 13

List of Figures 15

CHAPTER 1 INTRODUCTION

A. Background 19

B. Tobacco Curing Processes 20

C. Energy Usage for Tobacco Curing in Thailand 22

D. Objectives of the Study 23

E. Significance of the Study 23

F. Scope of the Study 24

CHAPTER 2 REVIEW OF LITERATURE 27

CHAPTER 3 DESIGN OF STUDY

A. The System 35

B. The Operation 37

C. Research Workplan 39

D. Data Required 40

E. Data Analysis 41

CHAPTER 4 TECHNIQUES AND PROCEDURES

A. The System's Components 45

B. Measurement Methods 52

C. Data Processing 54

D. Results 59

CONTENTS (continued)

Page

CHAPTER 5 ANALYSIS, DISCUSSION AND EVALUATION OF RESULTS

A. Factors Affecting Energy Usage in Tobacco Curing..... 73

B. Energy Consumption Results..... 74

C. Energy Savings by Solar Heating..... 85

D. Moisture Removed and Calculated Thermal Efficiency..... 88

E. The Role of the Thermal Storage..... 98

F. Quality of Cured Leaves..... 98

G. Economic Aspects..... 99

CHAPTER 6 CONCLUSIONS..... 107

CHAPTER 7 RECOMMENDATIONS..... 111

ANNEXES

A. Spread Sheet Analyses of Results from Experimental Runs..... 115

B. Sample Data-Logger Printout of Raw Data..... 125

REFERENCES..... 129

EXECUTIVE SUMMARY

The project was undertaken to develop a solar-rockbed system for flue-curing of tobacco leaves in Thailand. Its main objective was to maximize the use of solar heated drying air, via a flat plate solar collector and/or rockbed heat storage system, for flue-curing practices.

The solar-assisted tobacco curing experimental prototype system consists of a 3.6 m x 3.6 m x 4.8 m scaled-down (1:4 scale) tobacco curing barn with 1 ton fresh leaves loading capacity, an array of 38.5 sq.m flat plate solar air heater, and a 6 cu.m rockbed unit. Forced convection was induced through the system by one 2-hp and one 1-hp blowers. LPG was used directly as an auxiliary heating fuel.

Experiments with real tobacco leaves using only LPG as fuel were initially carried out. The results from four tests (LPG2-LPG5) produced an average LPG consumption of 0.63 kg, or an equivalent of 28.9 MJ per kg of cured leaves. As fresh tobacco leaves from the off-season plantings were limited in both quality and quantity, only three tests using the solar-assisted system were possible. From the three solar-assisted tests (SOLAR1-SOLAR3), an average LPG consumption of 0.48 kg or 22.2 per kg of cured leaves was achieved. Comparing results of the three solar-assisted test runs with a similar LPG run (LPG5), in which tobacco leaves were harvested from the same field, it was found that an average fuel savings of about 28% was possible. A second method for determining percent fuel savings, by using a fraction of solar heat supplied over the total energy consumed within each run, produced an average value of 16% fuel savings for the three solar-assisted runs.

Moisture removal rates for small samples from LPG4-5 and SOLAR1-3 were monitored. The results were then used as a basis to determine the curing's thermal efficiency. (Thermal efficiency was defined as the equivalent energy required to evaporate moisture from the tobacco leaves over the total energy consumed). The five runs produced an average overall curing thermal efficiency of 40.5%.

This report concludes that solar-assisted tobacco curing is technically viable, and that energy savings in the order of 30-40% over LPG are attainable, given more technical experience, more typical weather conditions, and better tobacco leaves. The usefulness of a rockbed thermal storage unit is still inconclusive, based on limited data obtained from the study. To make a solar heating system more attractive economically, either fuel prices have to increase, or the barn has to be utilized more, for example for drying other regional crops during the off-season for tobacco.

The report recommends that further experiments be conducted, preferably with two identical barns. Also, attempts should be made to test-run the tobacco curing barn as a multiple-crop dryer during the tobacco off-season.

CONCLUSIONS

1. The use of solar heating resulted in energy savings of up to 20% (conservative estimate) in this study with LPG as the main fuel.

2. The authors believe that solar-assisted tobacco curing is technically viable, and that energy savings in the order of 30-40% over LPG are attainable, given more experience, more typical weather conditions, and better fresh leaves.

3. Whether a thermal storage would be useful in a solar-assisted tobacco curing process is still uncertain, due to limited data obtained in this study.

4. Tobacco curing is a complicated process involving many factors. Any energy-usage comparison between any two curing systems should be made on at least two identical curing barns, with similar fresh leaves and curing procedures, under the same weather conditions.

5. From an economic aspect, investment required for the solar heating unit is barely justifiable by the resulting savings in conventional energy consumption, at current prices. To make a solar heating system more attractive economically, either fuel prices have to increase, or the barn has to be utilized more, for example for drying of other crops during the off-season for tobacco.

RECOMMENDATIONS

1. Further experiments should be conducted, preferably with two identical barns.

2. In future experiments, attempts should be made to isolate the effects of solar-assisted heating, rockbed thermal storage, other conventional fuels (firewood and lignite), different types of fresh leaves, and different curing procedures, under otherwise controlled conditions.

3. Serious considerations should be given to test-run the tobacco curing barn as a multiple-crop dryer during the tobacco off-season, to increase its utilization and to make investment in a solar heating system more economically feasible.

LIST OF TABLES

Table	Title	Page
1.1	Summary of requirements of flue cured tobacco.....	22
1.2	Energy consumption by tobacco-curing industry in Thailand.....	22
3.1	Planned time cycle of each component (using LPG as auxiliary heat source).....	38
3.2	Timetable.....	39
4.1	Description of each experiment.....	60
4.2	Summary of LPG consumption.....	62
5.1	Comparison of energy consumption values between experimental runs using LPG only and solar-assisted fuels.	75
5.2	Mae Jo tobacco curing trial runs using LPG as fuel on conventional barns.....	76
5.3	Percent energy saving by SOLAR-1,2 and 3.....	87
5.4a	Thermal efficiency of yellowing stage.....	90
5.4b	Thermal efficiency of color-fixing stage.....	91
5.4c	Thermal efficiency of leaves-drying stage.....	92
5.4d	Thermal efficiency of stem-drying stage.....	93
5.4e	Overall curing thermal efficiency.....	94
5.5	Determination of moisture contents, wet and dry basis from samples of cured leaves.....	101
5.6	Moisture removed from tobacco curing experiment using lignite as fuel on a conventional barn.....	102
5.7	Thailand Tobacco Monopoly (TTM) classification of tobacco leaf grades.....	103
5.8	Grades of cured tobacco leaves obtained from the experiments.....	104

Previous Page Blank

LIST OF FIGURES

Figure	Title	Page
1.1	Conventional flue curing barn utilizing natural air ventilation	21
1.2	Bulk curing barn using forced convection	21
3.1	Four modes of solar-assisted tobacco curing operations	36
4.1	Cross-section view of solar air heater	46
4.2	The rockbed thermal storage cross-section view	47
4.3	The rockbed thermal storage floor plan	48
4.4	The modified prototype tobacco curing barn	49
4.5	Details of damper placement and the four modes of operation	51
4.6	Details of 27 data logger input positions	53
4.7	The data logger system block diagram	55
4.8	The signal flow block diagram	56
4.9	The data analysis and graphic representation block diagram	58
4.10	Run of tobacco curing experiment using LPG, Feb. 15-19	63
4.11	Run of tobacco curing experiment using LPG, Feb. 23-28	64
4.12	Run of tobacco curing experiment using LPG, Mar. 6-11	65
4.13	Run of tobacco curing experiment using LPG, Mar. 14-19	66
4.14	Run of tobacco curing experiment using LPG, April 5-10	67
4.15	Tobacco curing experiment using LPG + Solar, April 17-20	68
4.16	Tobacco curing experiment using LPG + Solar, May 3-7	69
4.17	Tobacco curing experiment using LPG + Solar, May 15-19	70
5.1	LPG Consumption rate of LPG 3, LPG 5 and Solar 3	78
5.2A	Energy consumption rate of Solar 1, April 17-20	79

Previous Page Blank

LIST OF FIGURES (continued)

Figure	Title	Page
5.2B	Cumulative energy consumption of Solar 1, April 17-20....	80
5.3A	Energy consumption rate of Solar 2, May 3-7.....	81
5.3B	Cumulative energy consumption of Solar 2, May 3-7.....	82
5.4A	Energy consumption rate of Solar 3, May 15-19.....	83
5.4B	Cumulative energy consumption of Solar 3, May 15-19.....	84
5.5A	Total and percentage of energy consumed during each stage of curing for LPG 5 and Solar 3.....	86
5.5B	Average hourly rate of energy consumption during each stage of curing for LPG 5 and Solar 3.....	86
5.6	Solar energy contribution in each stage of curing for Solar 3.....	89
5.7	Percent energy savings by solar heat in each stage of curing for Solar 3.....	89
5.8	Comparison of thermal efficiencies between different stages of curing for LPG 5 and Solar 3.....	95
5.9	Moisture removed (per kg of fresh leaves) in each stage of curing for LPG 5 and Solar 1-3.....	96
5.10	Moisture content of every stage of curing for LPG 5 and Solar 1-3.....	97

Chapter 1

Introduction

INTRODUCTION

The vital importance of having adequate supplies of energy and the cost of securing it for the economic well-being of any country is now universally acknowledged. In the agricultural production sector, as in all sectors, the increasing scarcity and cost of fossil fuels has always been a major concern for the past decade. The problem will be even more evident in future years since the demand for energy to produce food will accelerate with the world demand for food. Drying of agricultural produce is one process that is very energy intensive. To alleviate the energy problem, measures are being taken to reduce the energy requirement of the drying of crops. One of these measures is to intensify the use of solar energy, an old practice, which is abundant world-wide.

Thailand and other tobacco-producing countries are keenly aware of the problem of rapidly increasing fuel costs for tobacco curing. The need for energy conservation in tobacco curing, an energy intensive process, and for possible utilization of alternate fuels or energy sources in evident. A reduction in fuel usage per kg of cured leaves would benefit both producer and manufacturer. High percentage of fuel savings would help stabilize production costs and tobacco production would be less dependent on petroleum-based fuels and, hence, less affected by fluctuations in availability of these fuels.

A. BACKGROUND

Tobacco is an important cash crop and a significant foreign exchange earner for Thailand. In 1982, Thailand's tobacco production amounted to 63,100 tons, of which about two-thirds is exported with a total value of US $109.8 million (Bank of Thailand, 1983).

Thai tobacco is well-known all over the world for its excellent characteristics, such as low tar, low nicotine and high sugar. Furthermore, its neutrality makes it very suitable for use in blended tobacco. Four varieties of tobacco are grown in Thailand. These are Virginia, Turkish, Burley and a local variety. Of these four, Virginia tobacco is the most widely grown, with annual production amounting to about 80% of the total.

Tobacco leaves are cured immediately after harvest, usually in local tobacco curing stations. At present, there are approximately 400 stations, mostly situated in northern Thailand. Each station has, on the average, 20-25 curing barns, most of which use firewood as fuel. It is estimated

Previous Page Blank

that in 1982 energy consumption for tobacco curing in Thailand amounted to the equivalent of about 1 million m of firewood (see Table 1.2). This substantial requirement has resulted in a large scale deforestation for the past two decades. The consequences of such deforestation are very serious and wide-ranging, as are now well-known. Clearly, a reduction of firewood wasted in the tobacco curing industry will help alleviated the massive destruction of the forests.

Northern Thailand is under high solar insolation with a daily average of 18.3 MJ/m day (Exell and Saricali, 1975), during the months from December to April which coincides with the tobacco curing period. The potential use of solar energy to provide some of the heat required for tobacco curing in Thailand appears very bright. Works on solar tobacco curing systems in the United States and other tobacco-producing countries have yielded promising results.

B. TOBACCO CURING PROCESSES

There are two tobacco curing methods being employed today by various tobacco growers around the world. The most common method is the classical technique known as flue curing, while the more recent one is by bulk curing. These two methods are illustrated in Fig. 1.1 and 1.2.

All of the existing curing barns in Thailand make use of flue curing technique. This term is derived from the process of drying or curing the leaves in which heat is distributed uniformly by the use of a heat exchanger or flue tubes inside a tightly closed barn. The leaves are loosely hung inside the barn so that easy flow of hot air is permitted. The mode of heat transfer to the leaves is mainly by natural convection. The fuel which may be wood, coal, or fuel oil, is burnt in the burner, and the hot flue gases flow through the metal tubes which act as a heat exchanger. LPG is being tried by some curing stations, where it is burnt directly to heat air inside the barn.

For bulk curing, the leaves are firmly packed, hung or placed in racks. Hot air is driven by fans or blowers through the leaves. The heat source may be gas or oil fired burners.

The process of flue curing involves promotion the yellowing of the leaves and preventing them from becoming brown. This is done by controlling the temperature and relative humidity so that after about four days or 100 hours of gradual increase in temperature and the commensurate reduction in relative humidity, the final product is in the form of golden to yellowish dried leaves with 10 to 20 percent moisture content (wet basis).

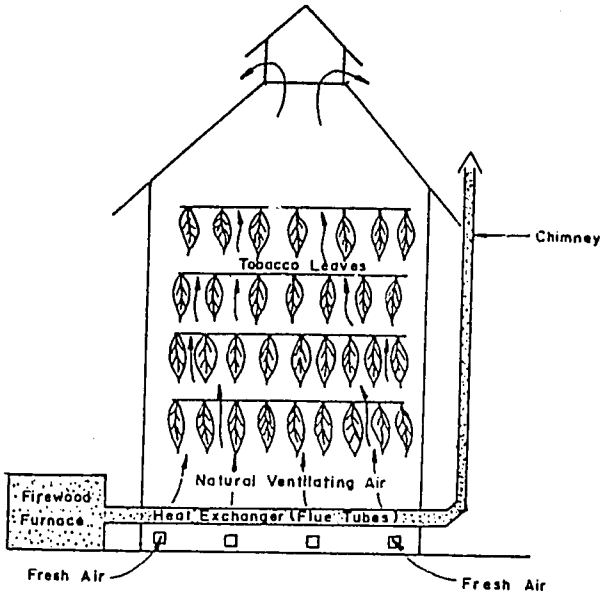


Fig. 1.1 Conventional Flue Curing Barn Utilizing Natural Air Ventilation

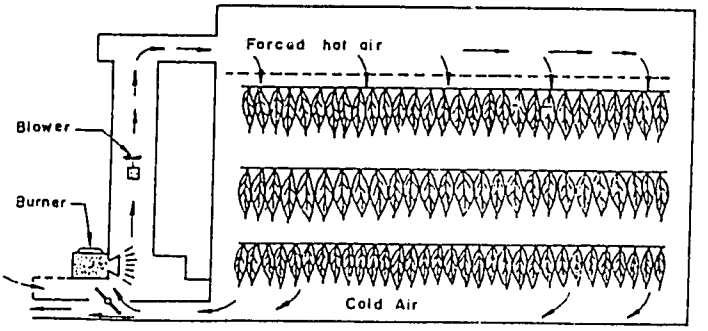


Fig. 1.2. Bulk Curing Barn Using Forced Convection

The temperature and relative humidity requirements of the four stages in flue curing are summarized in Table 1 below.

Stage	Time (hr)	Temperature (°C)	RH (%)
1. Yellowing	24-36	32-43	80-90
2. Color fixing	6-24	45-53	50-80
3. Leaf drying	9-14	55-63	30-50
4. Stem drying	17-25	65-80	20-30

Table 1.1 Summary of Requirements by Flue Cured Tobacco (Necesito, 1978).

C. ENERGY USAGE FOR TOBACCO CURING IN THAILAND

The standard flue curing barns used in Thailand are usually made of bricks or hollow blocks for the four side walls and galvanized iron sheets for the roofing material. The furnace is normally made of bricks and is connected to a metal heat exchanger. The barn's dimension is generally about 6 x 6 m in floor area and 9 m in height. Each curing barn can cure approximately 3,000 kg of fresh tobacco leaves, at 80 to 90 percent moisture content (wet basis), in one curing batch.

Tobacco curing barns in Thailand mainly use wood as the energy source. In some provinces (counties), where deforestation is being checked, the curing operators are forced to use lignite as the energy source. Table 1.2 indicates the estimated total energy consumption by the tobacco-curing industry in Thailand, in terms of wood and lignite equivalent.

	1977	1978	1979	1980	1981	1982
Annual Tobacco Production (tons)	51,800	55,600	59,600	47,200	59,300	63,100
Firewood-equivalent in Fuel (m^3)	859,880	992,960	983,360	783,520	984,380	1,047,460
Lignite-equivalent in Fuel (tons)	362,000	389,200	417,200	330,400	415,100	441,700

Table 1.2 Energy Consumption by Tobacco-Curing Industry in Thailand

Note: From Bamrungwong (1980), 1 kg of cured leaves required 0.0166 cu.m (120 MJ) of firewood or 7 kg (182 MJ) of lignite for energy source.

Clearly, the tobacco curing industry in Thailand wasted an appreciable quantity of firewood annually, and the problem becomes evident when the current fuel requirement by the industry is considered. In 1982, an estimated 3.1 million kg of cured leaves have resulted in 378.6 million kg of water evaporated during curing (the typical wet mass to cured mass ratio is 7 to 1). The thermal efficiency of this process is around 10%.

D. OBJECTIVES OF THE STUDY

This study was undertaken to develop a solar-rockbed system for flue-curing tobacco in Thailand. The objective was to maximize the use of solar heated drying air via a flat plate solar collector and/or rockbed heat storage system in an actual tobacco curing barn.

E. SIGNIFICANCE OF STUDY

The magnitude of conventional fuel savings by solar energy for the tobacco curing industry in Thailand becomes evident when the current fuel requirements by the industry are considered. In 1982, an estimated 63.1 million kg of cured leaves have resulted in 378.6 million kg of water evaporated during curing (the typical wet mass to cured mass ratio is 7 to 1). While the theoretical energy for evaporating this quantity of water is equivalent to 908.6 million MJ, actual fuel requirements of firewood are estimated to be eight to nine times as large, or about 7,500 million MJ (Castro et al., 1980-81, assuming firewood bulk density of 401.7 kg/cu.m at 17.9 MJ/kg). Clearly, any appreciable precentage of fuel savings will significantly reduce the firewood consumption rate by the tobacco curing industry.

This study is expected to have the following immediate impact upon completion of the project:

1. It will demonstrate whether solar energy is technically and/or economically feasible for use as an alternative energy source for tobacco curing and crop drying in the north of Thailand.

2. The thermal performance of a solar-assisted experimental tobacco curing barn will become available from this study. The data from this study can be used as a basis for the future design of solar-assisted tobacco-curing barns and also for the operation of such barns.

F. SCOPE OF THE STUDY

The scope of this study is as follows,

1. A scaled-down experimental tobacco curing barn with a solar air collector and a rock-bed storage will be designed and constructed.

2. A number of actual test runs, about 3-5 batches, of solar-assisted tobacco curing will be carried out between January and May 1984. In addition, tobacco flue-curing using a conventional fuel, LPG or lignite, will also be tested for a few batches before using solar energy.

3. In curing of tobacco using both conventional fuels and solar energy, the consumption of energy during curing, as well as other important thermal parameters such as distribution of temperatures inside the barn, ambient temperature, solar incidence, relative humidity inside the barn, etc., will be monitored and recorded for thermal performance analysis.

4. The site of the experimental solar-assisted tobacco curing barn is at Mae Jo Tobacco Experiment Station, about 17 km west of Chiang Mai City.

5. Results from the tests will be analyzed to determine the technical feasibility of solar-assisted curing by measuring the substitute of conventional energy by solar energy, the thermal performance of the solar air collector and its rockbed storage, and the quality of cured tobacco leaves.

6. An economic analysis to determine the economic feasibility of solar-assisted tobacco curing will also be made.

Chapter 2

Review of Literature

REVIEW OF LITERATURE

Major advances have been achieved (during the past few years) in the application of solar energy for tobacco curing practices. Most of these achievements are reported from studies made on solar-assisted bulk curing systems, where a high percentage of fuel savings by solar energy can be obtained. Bulk curing conditions are easier to regulate and less energy intensive, but suffer from high initial investment when compared with flue curing systems.

However, the majority of the tobacco curing systems in Thailand and other tobacco countries in the region are flue curing systems. Work on solar aided flue curing systems and studies of energy requirements by flue curing tobacco leaves are summarized as follows.

Necesito (1978) made a study on the energy requirement of flue curing Virginia tobacco in the Philippines and the potential use of solar energy. From a total of 600 curing runs, an average wood consumption of 12.14 kg or an equivalent of 217.7 MJ per kg of flue cured leaves was reported. By incorporating advanced cultivation techniques and improvements made on the existing barns, 6 to 8 kg of wood consumption per kg of cured leaves was achieved. Tests to determine the energy equivalent (BTU) required to flue cure a kg of Virginia tobacco using different oil fuel mixtures were made. A mixture of used oil and diesel oil gave the lowest energy consumption rate of 24.3 MJ per kg of flue cured leaves. A study on the potential of tapping solar energy for curing Philippine Virginia tobacco was made by testing different solar-assisted barns and comparing the results with conventional systems. The Taiwanese solar-assisted downdraft bulk curing barn showed marked improvement in fuel utilization by requiring only 22.5 MJ to cure one kg of tobacco leaves. In comparison the average MJ requirement of the other type of curing leaves was two to ten times as large, as summarized below.

1.	Prototype CHB bulk downdraft	58.9 MJ/kg
2.	CHB bulk downdraft crudely assisted with solar heat	54.3 MJ/kg
3.	Prototype black vinyl bulk downdraft	69.0 MJ/kg
4.	Prototype black vinyl flue curing type	156.7 MJ/kg
5.	Farmers flue curing barn	217.7 MJ/kg
6.	Oil fed flue curing barn	70.6 MJ/kg

Previous Page Blank

Castro et al. (1980-81) conducted a study on design improvement and performance evaluation of a low-cost solar-aided curing barn for Virginia tobacco. The aim was to develop a solar curing barn and a solar curing system adaptable to Filipino farmers which will help remedy the fuel problem of the Philippine Virginia tobacco industry. The tested prototype barn's solar heat collector was made up of 57.25 sq.m of galvanized iron walls and roof, which were painted black and provided with a polyethylene plastic cover to trap heat and prevent reradiation and convection losses. The barn was equipped with an auxiliary heating system consisting of a furnace (fuelwood) and flue tube to provide additional heat when solar heat was inadequate. Tests on the thermal behavior of the barn showed that the average solar energy available for curing was 85.3 MJ/hr or a total of 1,023 MJ for the 12-hr period. This is equivalent to the heat that can be supplied by 57.0 kg of wood at 17.9 MJ/kg for the 12-hr period. The percentage of time when solar energy alone can provide the heat requirement ranges from a low of 30.9% to a high of 56.0% during four actual curing test runs. The increase was mainly due to increasing solar insolation and sunshine duration as summer progressed. The fuel to cured leaves ratio reported at 8.97 kg wood per kg of leaves was quite high because the fuelwood was relatively wet (520.94 vs 401.69 kg/cu.m). The four tests produced an average of 39.1 kg of cured leaves per test, with 56.1% grade A leaves, and a low 8.5% of rejected leaves on the average.

Huang (1980) reported on energy in tobacco curing and conclusions made from major research and observations for three types of curing systems - natural convection, forced-air stick curing, and bulk curing. His study showed the following:

1. The average heat energy for all systems was 38.1 MJ/kg, or 3.3 times the theoretical, assuming five kg of water per kg of cured leaves.

2. Bulk curing barns used less energy (29.5 MJ/kg) on the average than the other systems. Even allowing for extra fan horsepower, the bulk system gave a 14% energy reduction in comparison with the overall average.

3. The forced convection conventional barns used the most energy (40.7 MJ/kg). This was blamed in most cases on excessive exfiltration from the units.

4. The natural convection barns average 37.0 MJ/kg, which was an intermediate value between forced convection and bulk curing.

Panlasigui (1980) made preliminary studies of a prototype solar-aided tobacco curing barn which was designed and constructed for the Philippine Virginia Tobacco Administration. Water was used as the absorbing medium of solar energy which in turn was used to heat the barn air via a heat exchanger system. Computer simulation was used to obtain optimum size of the system's components for a barn that would process 3 tons of green Virginia tobacco per flue curing cycle. The simulation was based on the energy requirements inside the barn for a 96-hour curing cycle under a

constant flow of 2,500 cu.m/hr of air and the corresponding temperatures and make-up air required for each stage of the curing processes. The principal components of the system included flat plate collectors made into modules of 4 ft x 6 ft (1.22 m x 1.83 m), a hot water storage tank with a capacity of 10,000 lbs (4,536 kg) of water, a 12 kW electric auxiliary water heater, and a vertical type heating coil heat exchanger. Automatic controls were incorporated to obtain the desired barn temperature set at different stages of the curing process. Results obtained from dry runs were compared with design calculations and extrapolated to actual curing conditions. It was projected that the prototype solar-aided barn can reduce the cost of heating by as much as 75%. However, this has yet to be confirmed by actual tests.

Bamrungwong (1980) made a preliminary study on solar-assisted tobacco curing at Chiang Mai University, Thailand. The experimental flue curing barn was a scaled down prototype, a 3.6 cu.m model, with 2.8 sq.m of flat plate collector area. The natural convection system had no thermal storage and electricity was used as the main heating source. Tests on the prototype showed an average of 14% fuel saving when solar energy was used as a supplementary heat source. It was concluded that solar energy, when available, could be used at all stages of flue curing except the first stage, the yellowing stage where a relatively low curing temperature of 32-38 °C and high RH of 80-95% are required. These conditions were difficult to regulate as the output of the solar collector on an average day showed a higher temperature range and lower RH values than that required by the yellowing stage. The results and conclusions were drawn from a total of three actual curing tests.

Bamrungwong and Apipatanasiripong (1981) made one further curing test on a remodified Bamrungwong's earlier model. The flat plate of the collector was replaced by a black painted rock heat absorber. The 950 kg mass rock bed acted both as a solar energy absorber and a heat storage medium. The rock bed transferred heat to the incoming air by natural convection. Tests on the remodified model showed considerable improvement on quality of the cured tobacco leaves. Also, the rock bed system was found to be easier to regulate to achieve required curing conditions than the earlier model. Data on actual fuel saving by solar energy was not reported.

Phang (1982) made a study on the calculation of a solar air heater and rock bed heat storage system for crop drying, with reference to tobacco curing. A mathematical model was formulated to predict air temperatures obtained in a horizontal flat plate collector, for variations of solar radiation on the collector, and for temperature distributions of air in the rock bed. However, no actual experiment was carried out.

Hirun (1983) assessed the potential of solar energy for tobacco curing in Thailand. Two small solar air-heaters of different design were constructed and their efficiency measured. One collector uses black polyethylene film as the absorber; the other collector uses discarded tin cans. The cans are cut along most of their length into strips and spread

out to face the sun. The base of each can is attached to the bottom of the collector and the whole assembly is painted black. The testing and analysis showed that the use of discarded tin cans as an absorber in a solar air heater significantly improves performance. Based on the experimental result, a preliminary design was made for the solar-assisted flue curing barn of the type commonly found in Thailand. It was estimated that a standard barn of 324 cu.m volume would need about 90 sq.m of collector area. The air heater could supply about 25% of the energy required for flue curing the tobacco leaves. The tin can solar air heater with a 0.25 kW air blower will be relatively inexpensive and ideally suited to supplement all or part of the energy requirement during the day time. Total fuelwood savings all over Thailand could potentially reach 250,000 cu.m of fuelwood per year.

A number of studies on solar-assisted bulk curing barns have been reported. Huang and Bowers (1977) studied the greenhouse bulk curing system with utilization of solar energy as a first priority energy source to cure tobacco in the summer months and to grow greenhouse crops and tobacco seedlings during the remainder of the year. A 30-40% fuel savings was achieved during the two summer curing seasons of 1975 and 1976. Bowers, Huang, and Nassar (1978) experimented on full-scale tobacco cures in midsummer with the U.S. solar barn at the Central Crops Research Station in Clayton (latitude 35° 41' N), North Carolina. The results demonstrated quality tobacco curing with an overall 51% fuel savings as compared with a conventional bulk curing barn under the same curing management. Tabili and Patulingan (1978) reported that official tests conducted for the Taiwan solar barn in the Philippines showed an average energy consumption rate of 21.5 MJ/kg cured leaves, using diesel oil. The energy savings by the solar barn system was 60.46% as compared with the result of prior conventional curing studies in the Philippines. Johnson (1979) made a study on the cross-flow barn design with a solar collector on the roof and a heat exchanger to reclaim heat from the exhaust air. The reported results showed an average petroleum fuel efficiency for 12 cures to be 8.0 MJ/kg cured leaves or 70% fuel savings, assuming 15% moisture content (dry basis) and 90% combustion efficiency. Cundiff (1980) experimented on three bulk curing barns each one-fifth scale of a conventional unit. Each unit is connected to a shed roof flat plate solar collector and rock bed storage. An overall average of 6.7 MJ/kg cured leaves of solar energy and 12.7 MJ/kg cured leaves of supplemented fossil fuel resulted in energy savings of about one-third by solar energy over total heat required. The main drawbacks of these scaled-down systems are high initial investment and lack of year-round utilization. Huang and Toksoy (1983) developed a green house solar system that can be used for bulk curing of tobacco and also for the drying or plant production process so that it can be utilized in agricultural production all year round. Full scale tobacco cures with this system resulted in 47-54% fuel savings over the conventional bulk curing barn. The solar barn can be converted into a greenhouse at the end of curing and drying seasons to accommodate the growing of flowers, vegetables, and various seedlings.

In solar curing of burley tobacco, Walton et al. (1977) proposed a two-stage solar curing system to reduce the fossil fuels needed to provide the proper curing environment. The first stage was solar field curing under direct solar radiation. The second stage was to complete the cure in a solar curing facility using solar energy as the source of heat during curing. They experimentally evaluated the capabilities of the four types of forced ventilation curing chambers:

1) Conventional chamber with metal roof;

2) Solar-transmitting-fiberglass-roof chamber;

3) Solar-collector chamber with no heat storage capability; and

4) Solar-collector-rockbed-storage chamber to reduce high relative humidity during curing.

They concluded that the average daily relative humidity was up to 5 percentage points less in all the solar energy utilizing chambers as compared to the conventional chamber. The solar-collector-rockbed-storage system was superior to the other two solar systems because it provided heat during critical periods of high humidity. The solar-collector-rockbed system supplied enough heat to reduce the relative humidity from the 80-90% range to the desired 65-70% range for 3 days of rainy weather curing without replenishing. A solar burley tobacco curing facility, with a 3-to 4-day heat supply stored in the rockbed, should provide the capability to prevent the 6% tobacco quality loss by using solar heat to lower relative humidity.

Chapter 3
Design of Study

Previous Page Blank

DESIGN OF STUDY

The research team originally decided upon the following approach:

a. The project should be conducted in conjunction with an Experiment Station of the Thailand Tobacco Monopoly (TTM), located at Mae Jo, Chiang Mai. The Experiment Station will be able to supply fresh tobacco leaves for the experiments, as well as expertise in the tobacco curing process based on long experience in the field.

b. The solar collector would be a forced-convection, air heater type. The solar-heated air would be ducted directly into the curing barn together with an auxiliary backup heat (no heat exchanger inside the curing barn).

c. Thermal storage was needed, and would be effected by a rockbed.

The assumptions made were:

a. The solar collector should be able to provide thermal energy to cover the first two stages of curing (yellowing and color-fixing). Thereafter, solar energy would serve as base power supply, in conjunction with an auxiliary heat source.

b. The energy required during the first two stages of curing was 30% of the total energy usage during the curing process. (Suchinda, 1983).

c. The proper size of the rockbed thermal storage, estimated at 0.15-0.25 cu.m of rockbed/m of collector area for residential applications (Hollands, 1981), was also valid for this purpose.

Based on the above, the following design emerged:

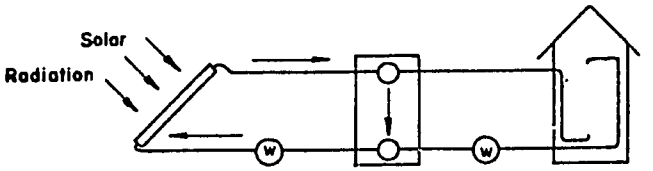
A. THE SYSTEM

The solar-assisted tobacco curing system would consist of the curing barn, the solar collector, the rockbed thermal storage, and an auxiliary heat source. The last component would be either lignite or LPG, although preference would be given to the latter in view of its ease of measurement and more uniform calorific value.

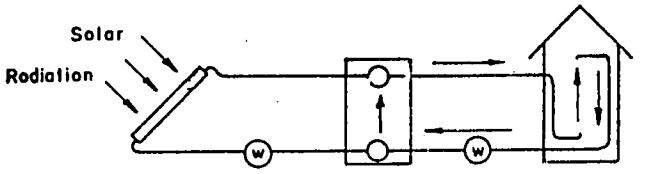
Side views and a diagram of the system are shown in Photo 3.1 and Fig. 3.1 respectively. Four modes of operation are possible:

Mode 1 : Solar-heated air from the collector is used to heat the rockbed thermal storage.

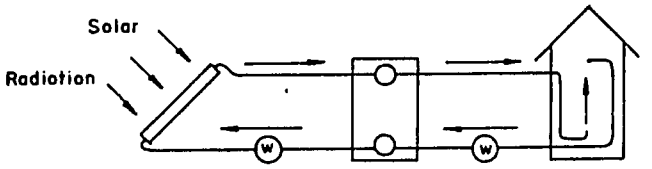
Previous Page Blank



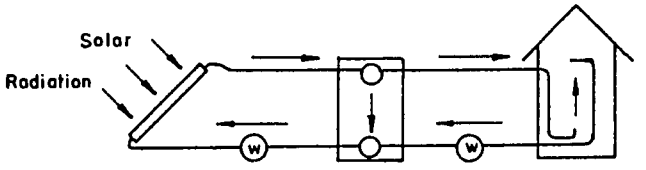
Mode I



Mode 2



Mode 3



Mode 4

Fig. 3.1 Four modes of solar-assisted tobacco curing operation.

Mode 2 : Heat from the rockbed thermal storage is used inside the curing barn.

Mode 3 : Solar-heated air from the collector is directed to the curing barn, bypassing the rockbed.

Mode 4 : A combination of Modes 1 and 2. Solar-heated air from the collector would be directed partly into the rockbed, and partly into the curing barn.

In all modes, ventilation could be provided if required through a fresh-air inlet.

B. THE OPERATION

The planned time-cycle operation of each component is shown in Table 3.1. This was based on the fact that tobacco leaves are usually loaded into the curing barn in the late afternoon, and the curing process commences in the early evening. Furthermore, the curing barn is usually idle for one or two days immediately proceeding the beginning of curing of a new batch*; therefore this idle period could be used for the solar collector to heat up the rockbed. The warm rockbed could then be used during the first night of curing. During each subsequent daytime period, the solar collector would be used to heat the barn. Any excess heat would be directed to the rockbed thermal storage. During most nights, an auxiliary heat source would be needed to supplement the heat from the rockbed, particularly during the later stages of curing in which relatively high temperatures were required. In such a situation, the rockbed would be exhausted of any useful heat first, then shut off. Only then would the auxiliary heat source be activated. Under no circumstances would the rockbed and the auxiliary heat be used at the same time in the recirculation mode, as the auxiliary heat would then be used needlessly to heat the rockbed as well as the load.

Actual operation cycles would naturally depend on the daily solar insolation and the ambient conditions during each experiment. For example, the presence of rainfall or a heavily cloudy sky would affect the output of the solar collector, as well as the output of the rockbed during the succeeding night.

---

* This was to allow time for the previous batch of dried leaves to reabsorb some moisture while still hung inside the barn, to prevent them from breaking and crumbling due to extreme dryness.

Table 3.1 Planned Time Cycle of each component (using LPG as auxiliary heat source)

Day	Time	Component used
1	6 pm - 8 am	Rockbed
2	8 am - 4 pm 4 pm - 8 am	Solar Collector + Rockbed Rockbed (+LPG if necessary)
3	8 am - 4 pm 4 pm - 8 am	Solar Collector + Rockbed Rockbed + LPG
4	8 am - 4 pm 4 pm - 8 am	Solar Collector + LPG LPG
5	8 am - 4 pm 4 pm - 8 am	Solar Collector + LPG LPG
6	8 am - 6 pm	Solar Collector + LPG

C. RESEARCH WORKPLAN

Two types of experiments were planned. The first involved experimental runs with LPG only, to establish the energy consumption pattern during the curing process. This set of experiments would involve three to four batches, consisting of leaves from different parts of the tobacco plant. The second type of experiments, with solar heating and LPG as the auxiliary heat source, would then follow. It would also involve three to four batches of tobacco leaves. The emphasis would be on the maximum possible reduction of LPG usage by means of the solar collector and the rockbed thermal storage. (See timetable below).

Table 3.2 Timetable

Month / Activity	1	2	3	4	5	6	7	8	9	10
1. Design	—	—								
2. Construction			—	—	—	—				
3. Experiments with LPG only							—	—		
4. Experiments with solar heating and LPG								—	—	
5. Data Analysis								—	—	—
6. Report Preparation									—	—

D. DATA REQUIRED

It was determined that the following data were needed, for a meaningful analysis:

From the barn:

a) Temperatures (wet and dry bulb) at various levels;

b) Heat losses from the barn;

c) LPG consumption (hourly);

d) Ventilation flow rates;

e) Weight of fresh and cured leaves; and

f) Moisture loss from leaves during each stage of curing.

From the solar collector:

a) Inlet and outlet air temperatures;

b) Air flow rates; and

c) Collector plate temperature.

From the rockbed:

a) Inlet and outlet air temperatures;

b) Temperature inside rockbed at three different levels; and

c) Air flow rates.

Ambient conditions:

a) Temperature and relative humidity; and

b) Solar radiation intensity.

E. DATA ANALYSIS

The collected data would be used to calculate the following:

a) Energy savings by the use of solar energy;

b) Energy losses during the curing process;

c) Energy consumption during each curing stage;

d) Thermal efficiency of the curing process;

e) Rockbed effectiveness; and

f) Economic aspects.

Chapter 4

Techniques and Procedures

Previous Page Blank

TECHNIQUES AND PROCEDURES

A. THE SYSTEM'S COMPONENTS

The Solar Collector

The collector was an air-heater type, with single glass glazing. Air flowed inside a rectangular cross section channel formed by corrugated metal sheets on the top and a flat sheet at the bottom (Fig. 4.1). The collector area was 38.5 m^2, with a 6.8 m length and 5.6 m width, divided into 8 flow channels each 0.70 m wide. Fiberglass insulation, 0.05 m thick, was placed at the bottom of the collector. Appropriate ducts were constructed to distribute the air flow evenly to all eight flow channels.

The collector design was based on an assumed efficiency of 0.30. The outlet air temperature was designed to be 60°C from an inlet air temperature of 50°C at an air flow rate of 0.47 m^3/s at 10 A.M. on a clear day in January. The orientation was south-facing, with a 30° tilt angle from the horizontal.

The Rockbed Thermal Storage

The rockbed size was 1.8 m x 1.8 m x 2 m in dimension, filled with 0.05 m nominal diameter river gravel. Details of the rockbed are shown in Fig. 4.2 and Fig. 4.3. Ducts were installed in both upper and lower plenums, to serve as air flow channels. Sight glasses were also installed at three different levels, to permit visual inspection of the gravel. The rockbed was insulated with 0.10 m of fiberglass on the sides and bottom, and 0.25 m of fiberglass on top. Four dial-type thermometers were buried in the rockbed for monitoring of its thermal behavior.

The Curing Barn

The research team decided to use a 3.6 m x 3.6 m x 4.8 m tobacco curing barn at the Mae Jo Tobacco Experiment Station as the experimental unit. Necessary modifications were made, including insulation with 0.013 m thick fiberglass sheets, and provision for using either lignite-fired or LPG-fueled modes coupled with solar heat. The barn's loading capacity was about 1 ton of fresh tobacco leaves. A sketch of the barn is shown in Fig. 4.4.

Previous Page Blank

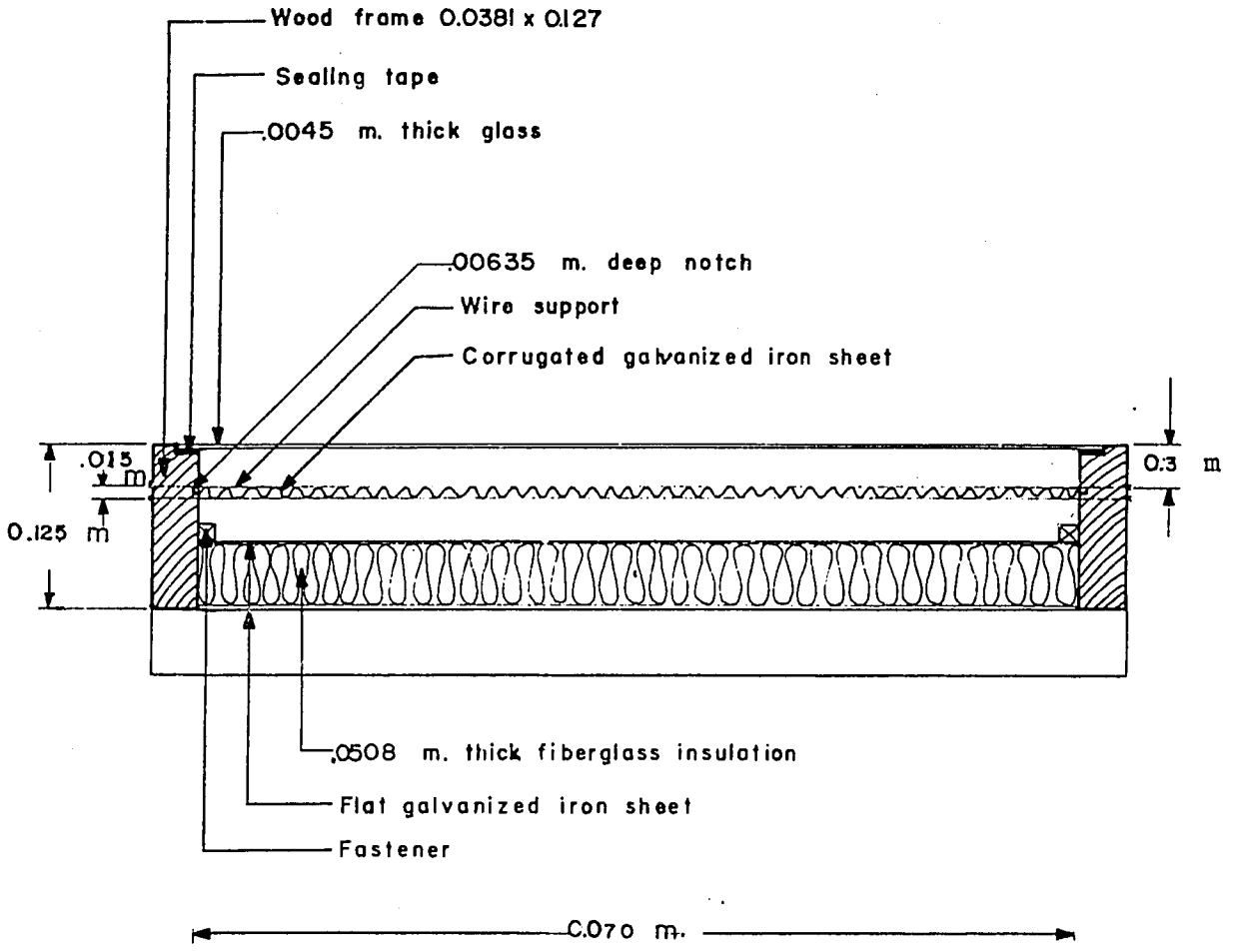


Fig. 4.1 Cross – section view of solar air heater.

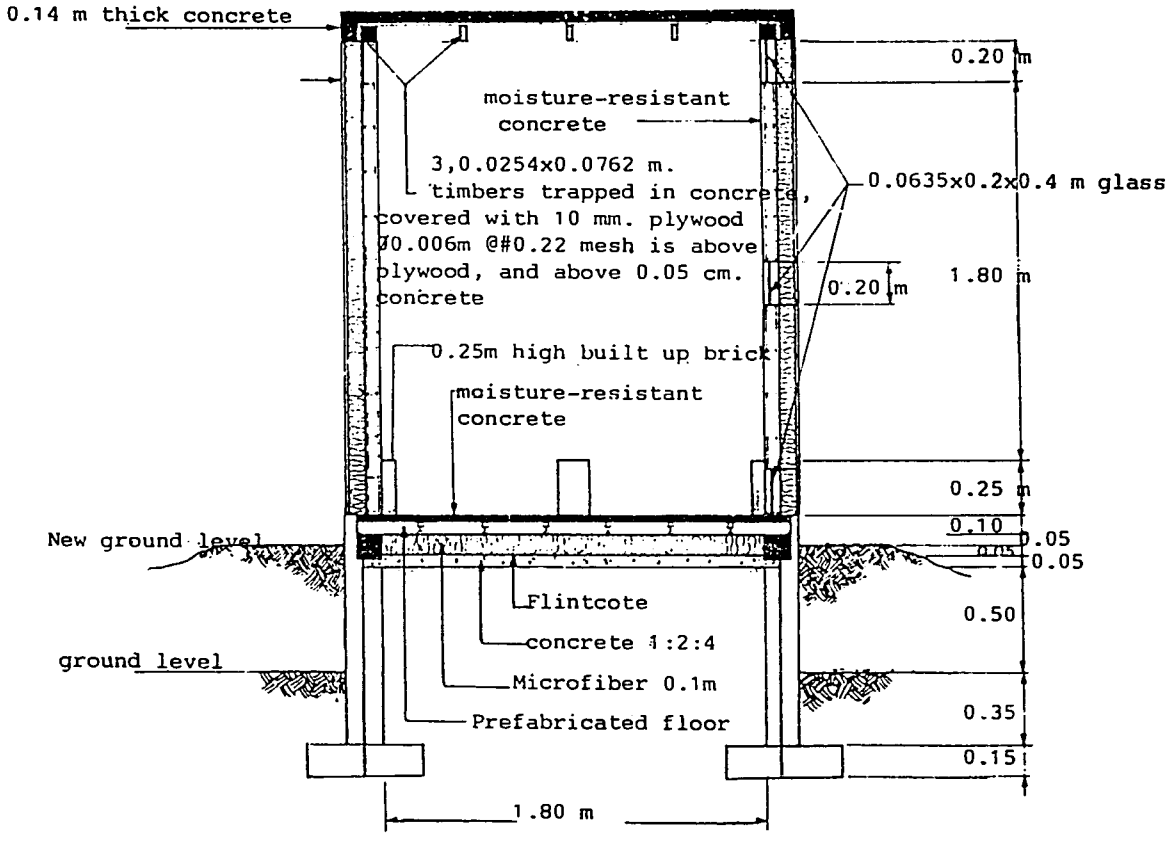


Fig.4.2 The rockbed thermal storage cross-section view.

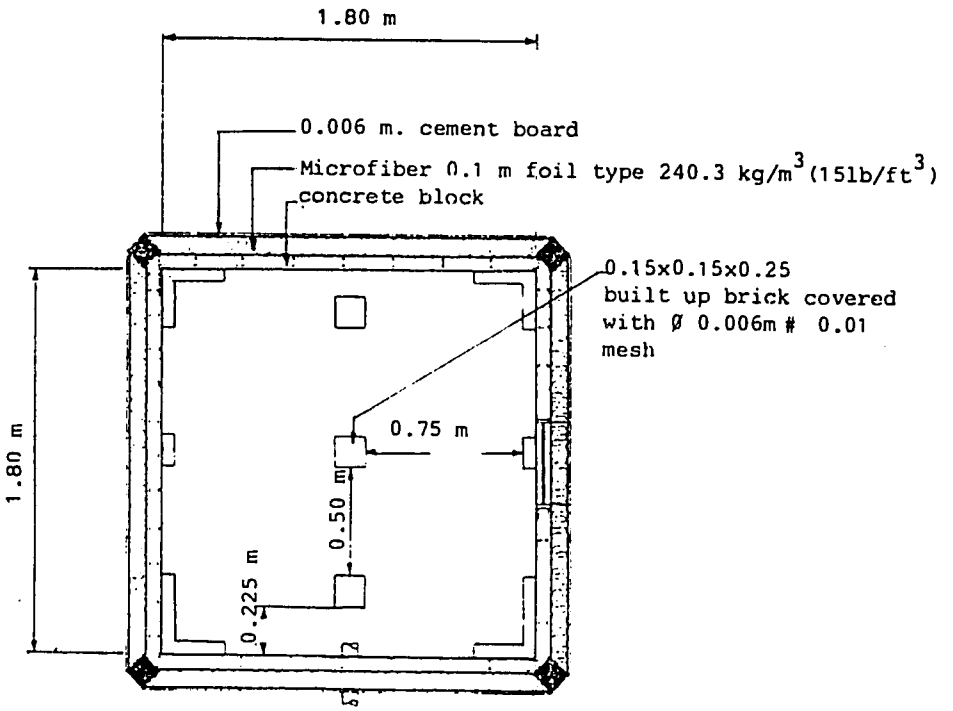


Fig.4.3 The rockbed thermal storage floor plan.

The Air Flow System

The inlet and outlet air from each of the eight flow channels of the solar collector was channeled through the manifolds and onto the inlet and outlet duct respectively. The collector's inlet duct was connected to the return duct from the rockbed thermal storage and the barn. A fresh-air inlet to provide ventilation, when required, was available through an adjustable port of the return duct. The collector's outlet hot air was circulated through the rock bed thermal storage and/or the barn via a 0.75 kW (1 hp) or a 1.5 kW (2 hp) centrifugal blower. The ducts were made of folded galvanized steel sheets, coated with Flintcoat, and covered with 0.05 m thick fiberglass insulation. The main supply and return ducts each measured 0.36 m x 0.36 m in cross-section.

To enable the system to operate in all four modes previously described, several dampers are placed in the ducting. Fig. 4.5 shows the details of damper placement. Manipulation of the dampers for each of the four modes can be as follows:

Mode 1 : Dampers 1, 2, 9 and 10 open. All others closed.

Mode 2 : Dampers 2, 3, 6, 8 and 9 open. All others closed.

Mode 3 : Dampers 1, 4, 6, 7, 8 and 10 open. All others closed.

Mode 4 : Dampers 1, 5 and 8 open. Dampers 2, 3, 9 and 10 partially open. All others closed.

Cost

Cost of the experimental apparatus and testing was as follows:

Solar collector	Baht	55,000	(US $2,400)
Rockbed		15,000	(US $ 650)
Curing barn modifications		7,000	(US $ 300)
Ducting and blowers		46,000	(US $2,000)
Testing (8 batches)		50,000	(US $2,174)
		173,000	(US $7,524)

The above did not include the majority of the cost of insulation (donated by the Microfiber Company), LPG fuel (donated by the Petroleum Authority of Thailand), and fresh tobacco leaves (procured for the Project by the Mae Jo Experiment Station).

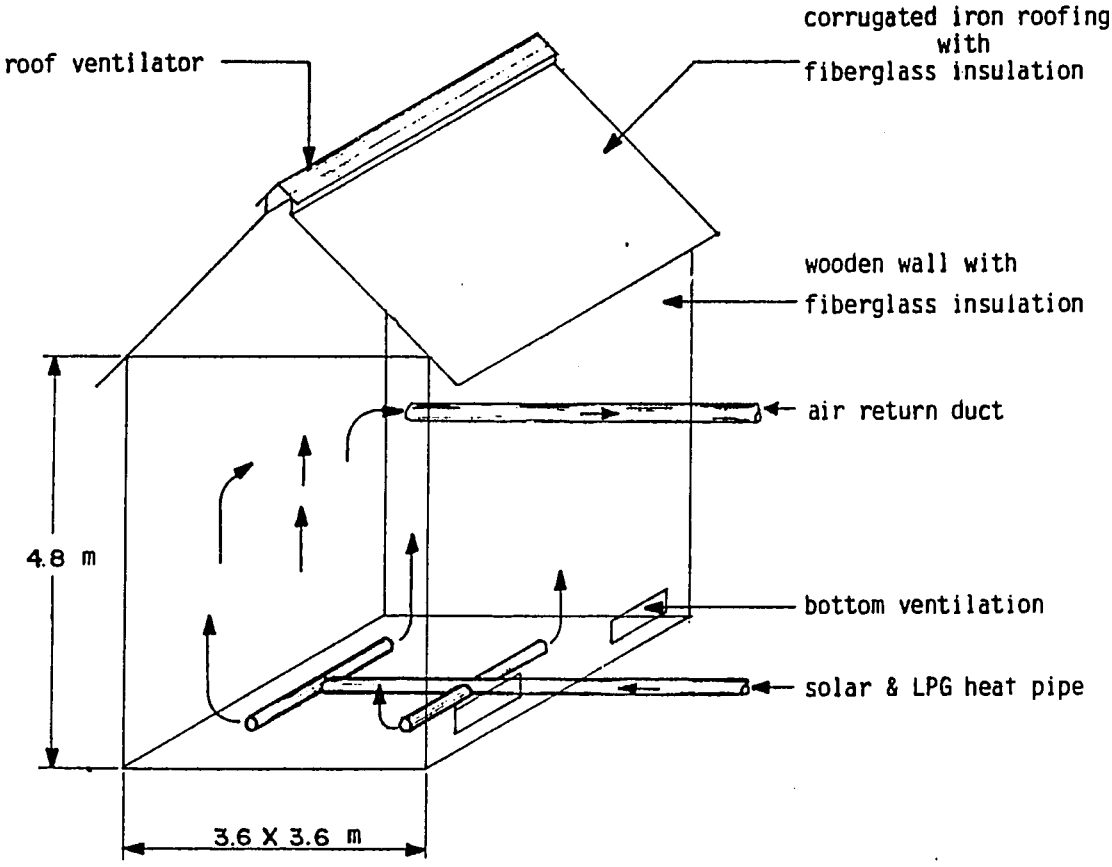


Fig. 4.4 The modified prototype tobacco curing barn

Note : Mode 1 ; Dampers 1,2,9 and 10 were opened. All others were closed.

Mode 2 ; Dampers 2,3,6,7,8 and 9 were opened. All others were closed.

Mode 3 ; Dampers 4,6,7,8 and 10 were opened. All others were closed.

Mode 4 ; Dampers 1,5 and 8 were opened. Dampers 2,3,9 and 10 were partially opened. All others were closed.

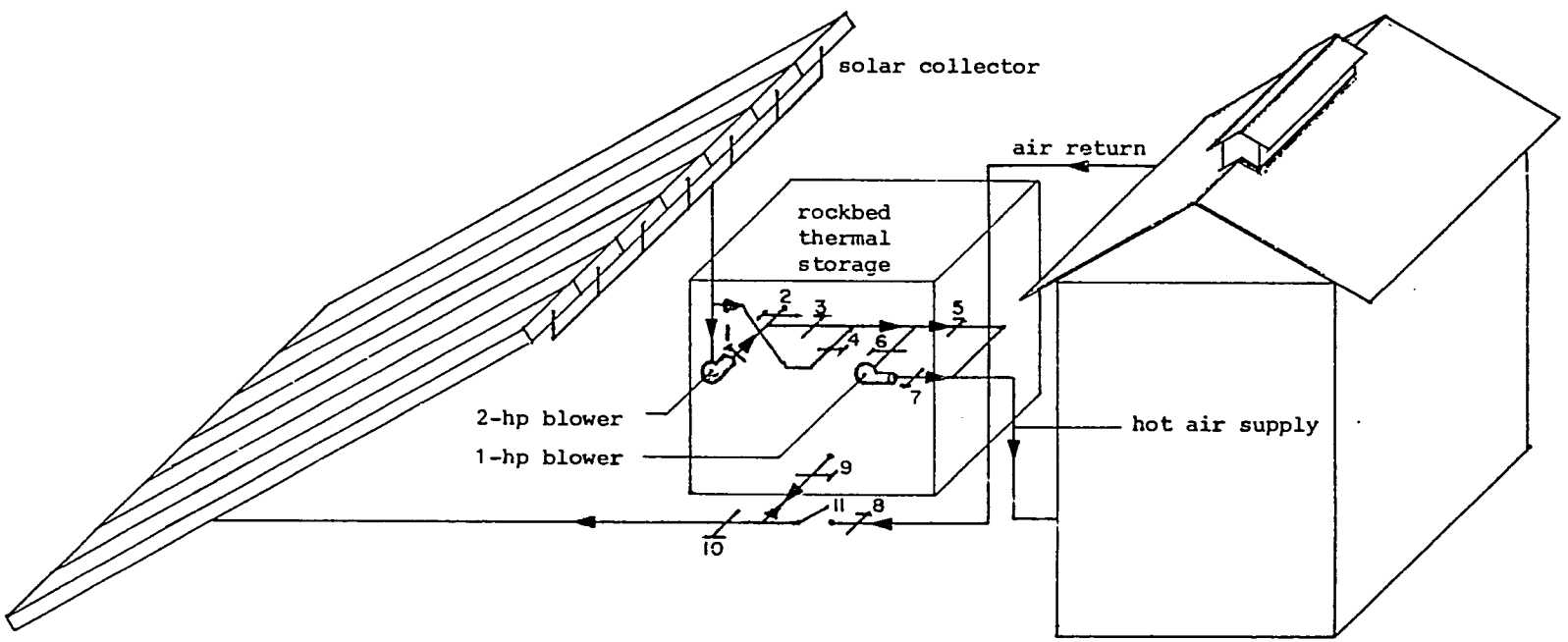


Fig.4.5 Details of damper placement and the four modes of operation.

B. MEASUREMENT METHODS

Temperatures

For a meaningful analysis, 25 thermocouple points connected to a data logger (see Chapter 4, Section C for details) were used to monitor wet and dry bulb temperatures at various levels inside the barn, temperature differences across the walls, inlet and outlet temperatures of the solar collector and the rockbed thermal storage, and ambient temperature. Type T thermocouple wires were used, with ice points as references for absolute values The positions and notations of the 25 thermocouple points are illustrated in Fig. 4.6.

For analysis of rockbed performance, 4 additional dial thermometers (Teddington type KDA/A/20) were used to measure temperature across different depths of the rockbed. The aim was to evaluate the rockbed's charging and discharging thermal performances.

Air Flow Rates

DISA hot wire anemometer (probe type 55P11/bridge type 56C10) was originally used to monitor air flow rates of the solar collector and the rockbed system, as well as discharged air leaving the barn's roof ventilation. Again, a data logger was used to record data from the hot wire anemometer. Due to the delicate nature of the hot wire probes and the limited supply of spare parts, an inclined U-tube manometer was later used instead for determining the solar collector and the rockbed air flow rates.

Heat Flux

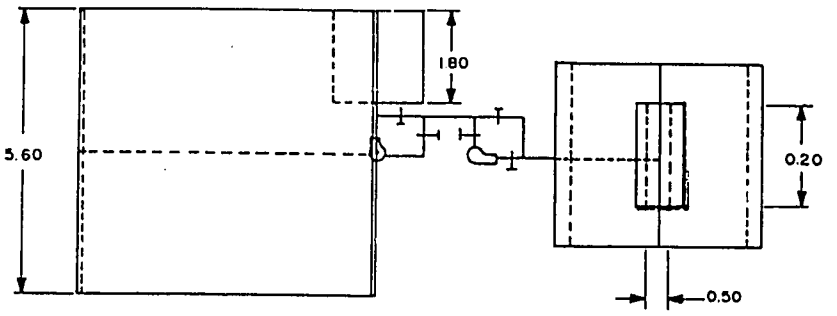
An EKO heat flux probe ($k = 89.07$ w/m^2-mv) connected to a data logger was used to measure heat loss through the barn's corrugated iron roof.

Solar Radiation

A Kipp and Zonen pyranometer model CM5, connected to a Watanabe 2 - channel chart recorder and a Kipp & Zonen solarimeter integrator model CC1, was used to measure the global solar radiation.

Note :

T1	= Dry Bulb Temp at level 1	ΔT17	= Wall temp difference (shade)
T2	= Wet Bulb Temp at level 1	ΔT18	= Wall temp difference (shade)
T3	= Dry Bulb Temp at level 2	T19	= Ambient Temp (shade)
T4	= Dry Bulb Temp at level 3	T20	= Ambient Temp (Unshade)
T5	= Dry Bulb Temp at level 3 (beside)	V21	= Velocity at roof
T6	= Dry Bulb Temp at level 4	T22	= Temp input Collector
T7	= Wet Bulb Temp at level 4	T23	= Temp output Collector
T8	= Dry Bulb Temp at level 5	T24	= Temp rockbed (above)
T9	= Dry Bulb Temp at level 6	T25	= Temp rockbed (below)
T10	= Wet Bulb Temp at level 6	T26	= Dry Bulb Temp at pipe
T11	= Dry Bulb Temp at roof	T27	= Wet Bulb Temp at pipe
Q12	= Heat flux		
ΔT13	= Wall temp difference (Unshade)		
ΔT14	= Wall temp difference (Unshade)		
ΔT15	= Wall temp difference (Unshade)		
ΔT16	= Wall temp difference (shade)		



NOTE: Scale 1:100

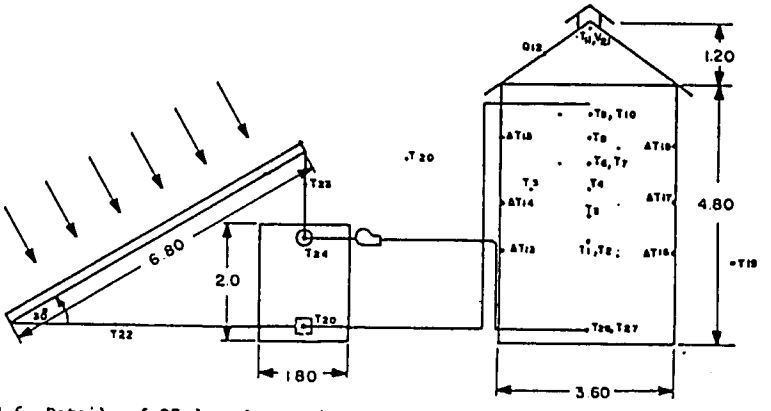


Fig. 4.6 Details of 27 data logger input positions : 25 thermocouple points, a heat flux probe and a hot wire anemometer probe.

LPG Consumption

Liquified petroleum gas* consumption rate was measured by placing the 100 kg LPG cylinder on a scale, and recording the weight reduction every hour.

Weighing Tobacco Leaves

Fresh and cured tobacco leaves were weighed before loading and after unloading respectively. A sample of approximately 10 kg fresh tobacco leaves was weighed every hour to determine the moisture reduction rate during each of the four stages of curing.

C. DATA PROCESSING

Data Logger System Description

The data from the tobacco curing experiments were logged and processed via a data logger/processor system developed by T. Sucharitakul and his colleagues at the Mechanical Engineering Department, Chiang Mai University. The data logger system consists of a Z-80 based microcomputer with 48 kilobytes of memory and 400 kilobyte disk capacity, a Keithley digital multimeter model 173, a 40 channel multiplexer, a custom-made computer interface, and a printer. The microcomputer will select each of the 27 probe channels (Fig. 4.6) by sending a signal to the interface, which in turn will send a signal to the multiplexer, and the signal from the selected probe will be directed to the multimeter input. A time delay of approximately 0.5 second was provided for the multimeter and for the signal settling time. The display of the multimeter was then read into the computer through the interface. Then, the data acquired were converted into the proper unit (millivolt to degree Celsius in the case of thermocouple), stored in the floppy disk, and printed out on the printer. The data logging system was powered by a SOLA MINI UPS uninterruptible power supply unit which was continuously charged by 220 volt 50 Hz power line, or by a Yamaha FF 2800 gasoline powered AC generator in case of power failures. Fig. 4.7 shows the details of a data logger system block diagram.

Signal Flow

The signals from probes (thermocouples, heat flux transducers, and hot wire anemometer) were wired to various input channels of the multiplexer.

---

* LPG supplied by the Petroleum Authority of Thailand (PTT) with a heating value of 46.1 MJ per kg.

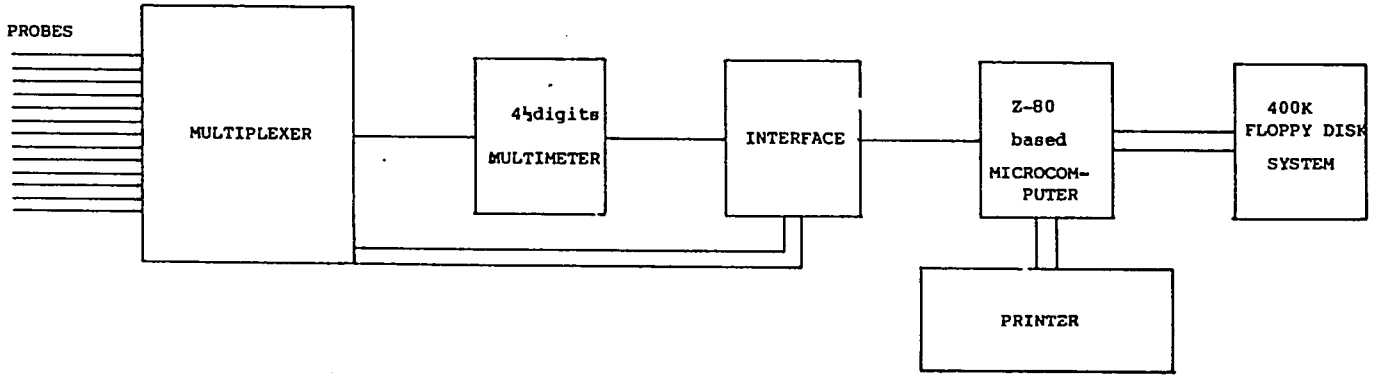


Fig.4.7 The data logger system block diagram.

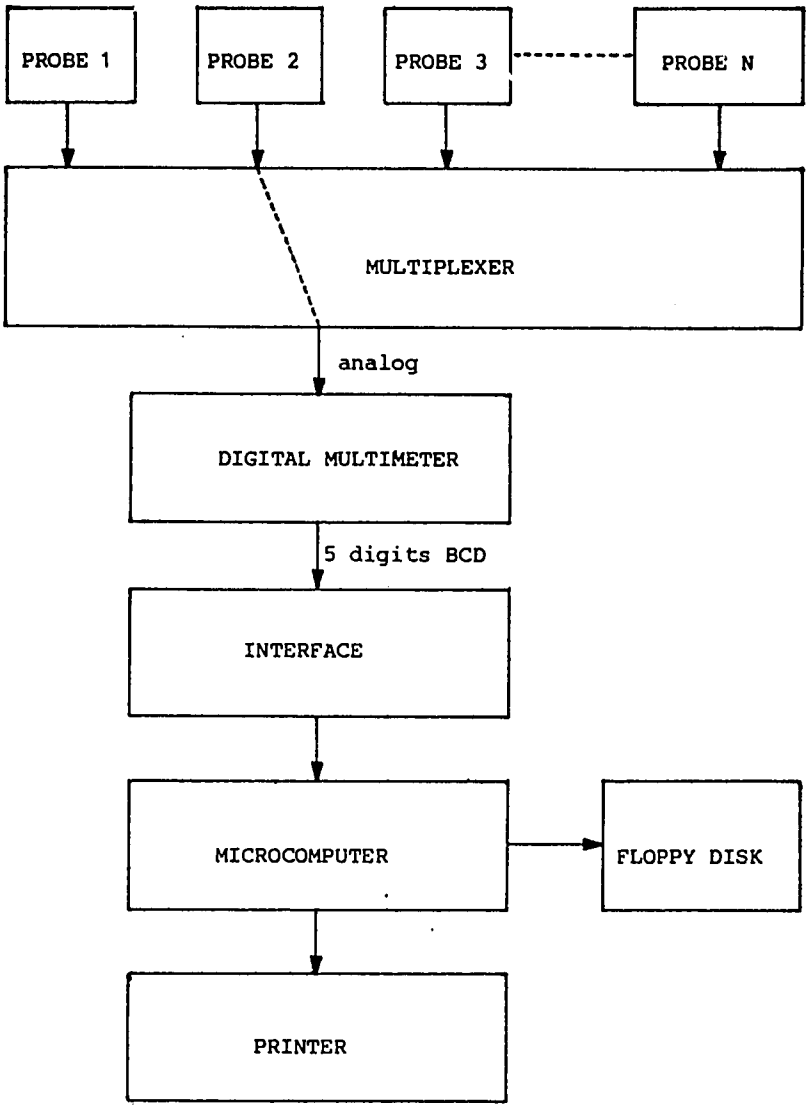


Fig.4.8 The signal flow block diagram.

When a data point was required from any probe channel, the microcomputer signalled the multiplexer to close a pair of relay contacts. Then, the signal from that probe channel will be directed to the multimeter. After a time delay to allow signal settling time lapsed, the microcomputer read the multimeter output into memory in the form of five binary coded decimal (BCD) digits. A program was developed to convert these BCD digits to the appropriate units (degree Celsius, watt per square meter, meter per second). Then, the information was stored in the magnetic disk and the results printed out by a line printer. Fig. 4.8 illustrates how the signal from probe 2 is processed through the signal flow block diagram.

Data Conversion and Storage

The information read from the multimeter was in the form of binary codes decimal units and could be converted into millivolts. These millivolt numbers were then converted, by the software stored in the microcomputer, into the appropriate units. The millivolt to degree C conversions of the thermocouple probes were processed by interpolating thermocouple conversion table stored in the memory. For the heatflux measurement probe and hot wire anemometer data conversion the calibration constant for each probe was used.

Accuracy

The thermocouple sensitivity was approximately 0.039 mV. per degree C and the lowest D.C. Volt scale of the multimeter was 0.01 mV.; therefore, the measurement error of the data logger was 0.26°C. The ice point reference of the thermocouple was maintained between 0.0 - 0.4°C. Hence, when added to the data logger accuracy, the total system accuracy excluding thermocouple measurement error would be 0.66°C throughout the entire temperature range being measured.

Data Analysis and Graphics

Data collected by the data logging system was stored in several short data files. This was so that if any data loss should occur, only a small portion of the data stored would be lost, not the entire file of the experimental run. Each file was no larger than about one hundred data points. When a number of these short files were securely stored, they will be merged into one single disk file and printed out. The print-out will then be reentered into the spread-sheet program of a larger computer (Victor 16-bit microcomputer with 384 kilobytes main memory). The spread sheet was then programmed to perform data analysis. Numerical differentiation was performed to determine LPG consumption rate. Numerical integration was also made to find total solar energy contribution by calculating from the collector's air mass flowrate, collector's inlet temperature, and

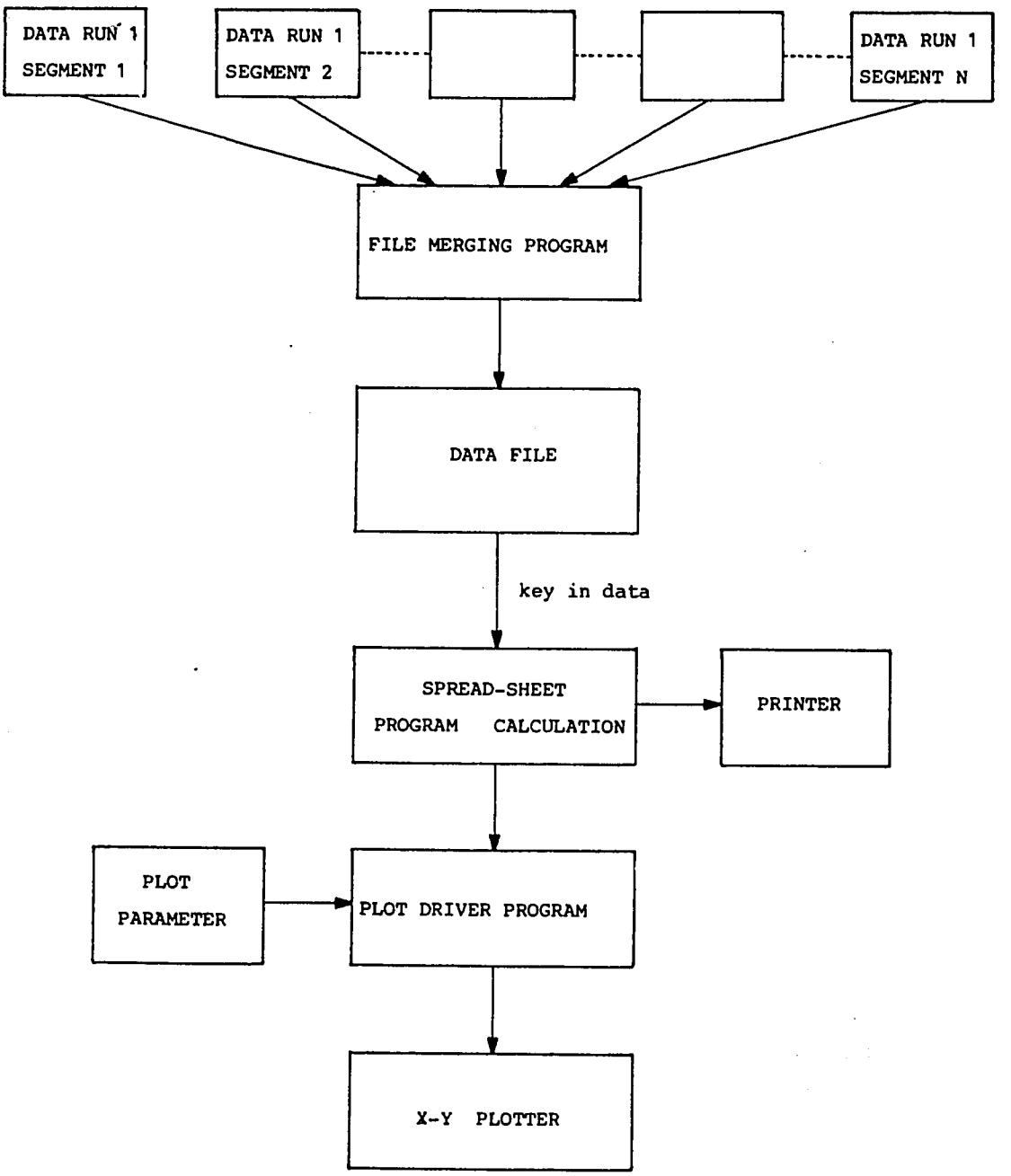


Fig. 4.9 The data analysis and graphic representation block diagram.

collector's outlet temperature. Percentage of energy contribution by the solar collector to the total energy utilization was later computed. A program was then written to extract the calculated information from the spread sheet data files. The extracted data were then used as input into a digital plotter (Watanabe DIGI - PLOT WX4675) to represent the data in graphic forms. Fig. 4.9 shows the flow diagram details of how a set of raw data can be processed into a graphic form. Examples of these raw collected data, spread sheet analyses, and plotter outputs are illustrated in Annex B, Annex A, and Fig. 4.10 - 4.17 respectively.

D. RESULTS

A total of eight tobacco curing runs were conducted during the period February 15, 1984 - May 19, 1984. Each experimental run lasted approximately five days (120 hours), and was continuously monitored. The first five curing runs were fueled by LPG only. The objectives were to establish energy usage patterns during each stage of curing and to familiarize the researchers with the curing techniques involved. The last three curing runs were performed with solar-assisted heating. These later runs were made near the end of the tobacco harvest season. After the third solar-assisted run, it was no longer possible to obtain fresh tobacco leaves, and testing had to cease.

A general description of each experimental run is presented in Table 4.1. LPG 1-5 refers to the first five runs, using LPG heating only, while SOLAR 1-3 refers to the three solar-assisted runs. In general, the major factors which will affect the amount of energy required to flue-cure tobacco leaves are: type of leaves (picked from the bottom, middle or top of the plants), moisture content of fresh leaves (expressed in kg of fresh leaves/kg of cured leaves), curing techniques (which depend on each supervisor), weather conditions, and type of fuel used. Also, leaves from off-season plantings tend to be of lower quality, and therefore more difficult and more energy-consuming to cure. Nevertheless, the experiments have succeeded in reducing the amount of energy required for one kg of flue-cured leaves, from 0.914 kg of LPG (or 42.13 MJ) in the first run to 0.444 kg of LPG (or 20.47 MJ) with solar-assisted heating in the last experimental run.

A summary of all experimental runs is shown in Table 4.2. Included are fresh and cured weight of tobacco leaves, amount of LPG consumed, LPG consumption rate, electrical energy consumed by blowers (in the case of solar heating), and total curing time.

Complete results from all eight experimental runs are presented separately in Appendix A. Graphical representation of each run is presented here as Fig. 4.10 - 4.17. In each graph is shown the following quantities versus curing time:

Table 4.1 Description of Each Experiment

Curing batch	Type and conditions of fresh leaves	kg fresh / kg cured	kg LPG / kg cured	Supervisor	Remarks
LPG 1 (February 15-19, 1984)	Bottom leaves purchased from farmer; high moisture content	7.25	0.914	No. 1	First trial run, coupled with high-moisture leaves, led to high energy consumption
LPG 2 (February 23-28, 1984)	Bottom leaves from test field; lower moisture content	6.20	0.612	No. 1	Fresh leaves in better condition than in LPG 1. Lower energy consumption
LPG 3 (March 6-11, 1984)	Middle leaves from test fields. Normal condition.	5.21	0.552	No. 1	Better leaves, lower moisture, better curing from experience gained.
LPG 4 (March 14-19, 1984)	Middle leaves from test fields.	7.05	0.676	No. 2	High-moisture leaves. Different supervisor.
LPG 5 (April 9-10, 1984)	Middle leaves from off-season field A.	5.76	0.667	No. 1	Well regulated. This run was intended to be a standard for comparison with runs SOLAR 1-3
SOLAR 1 (April 17-20, 1984)	Middle leaves from off-season field B.	5.73	0.539	No. 1	Used both solar collector and rockbed storage. Problems in regulating temperature and moisture. Weather was clear.
SOLAR 2 (May 3-7, 1984)	Top leaves from off-season field A. Lower-than-average quality.	5.32	0.463	No. 3	Used solar collector only. Improved regulation but weather was cloudy and rainy. Little solar radiation. Different supervisor.
SOLAR 3 (May 15-19, 1984)	Top leaves from off-season field B. Harvesting was delayed to allow leaves to attain higher quality.	5.14	0.444	No. 3	Used solar collector only. Rains on two consecutive night led to high usage of LPG during nights, but the days were clear.

- Ambient temperature;
- Wet-bulb temperature at 3 different levels (bottom, middle and top layers of leaves, inside the curing barn).
- Dry-bulb temperature at 6 different levels (for each layer of leaves) inside the curing barn.
- LPG consumption rate (kg per hour per kg of cured leaves).
- Relative humidity of air inside the barn (manually recorded from psychrometer installed at the bottom layer of leaves).

These results are analyzed and discussed in Chapter 5.

Table 4.2 Summary of LPG Consumption

a) Using LPG only

RUN	Fresh tobacco (kg)	Cured tobacco (kg)	LPG Consumed kg total	MJ total	kg/kg cured tobac.	MJ/kg cured tobac.	Av. LPG consumption rate kg/Hr.Kg cured tobac.	MJ/Hr.kg cured tobac.	Curing Duration (Hr)
LPG 1	750	103.4	94.5	4356.4	0.914	42.13	0.011	0.514	82
LPG 2	910	146.8	89.8	4139.8	0.612	28.20	0.00542	0.249	113
LPG 3	1040	199.6	110.1	5075.6	0.552	25.43	0.00468	0.216	118
LPG 4	1178	167	112.9	5204.7	0.676	31.16	0.00512	0.236	132
LPG 5	962	167	111.4	5135.5	0.667	30.75	0.00590	0.272	113
Av. 2 - 5	1023	170.1	106.1	4889	0.627	28.9	0.00528	0.243	119

Note : 1 kg of LPG = 46.1 MJ.

b) Using LPG and Solar Heating

RUN	Fresh Tobacco (kg)	Cured Tobacco (kg)	LPG Consumed kg total	kg/kg cured tobacco	MJ/Kg cured tobacco	Av. LPG consumption rate Kg/Hr.Kg cured tobacco	MJ/Hr.Kg cured tobacco	Electricity Consumed Unit (KW-Hr)	MJ/Kg cured tobacco	Curing Duration (hour)
Solar 1	962	166.0	90.5	0.539	24.85	0.006	0.277	39.90	0.855	92
Solar 2	962	180.9	83.8	0.463	21.34	0.004	0.184	9.10	0.181	103
Solar 3	962	187.3	83.2	0.444	20.47	0.004	0.184	17.61	0.338	102
Average	962	178.7	85.8	0.482	22.22	0.005	0.215	22.20	0.458	99

Note : 1 Unit = 1 kW-Hr = 3.6 MJ

FIGURE 4.10

LPG 1 RUN OF TOBACCO CURING EXPERIMENT USING LPG, FEB 15-19, 1984; MAE JO, CHIANG MAI.

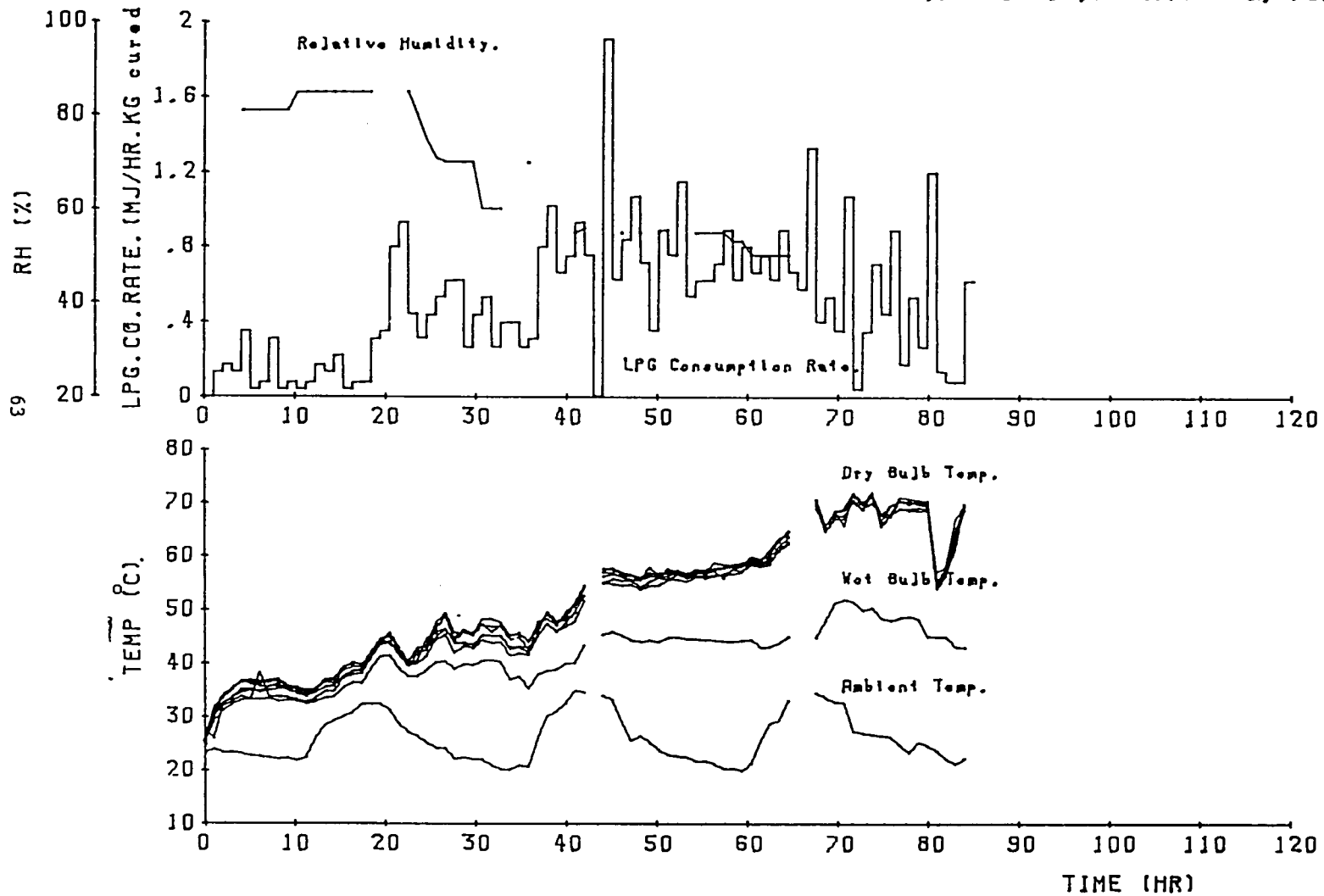


FIGURE 4.11

LPG 2 RUN OF TOBACCO CURING EXPERIMENT USING LPG, FEB 23-28, 1984; MAE JO, CHIANG MAI.

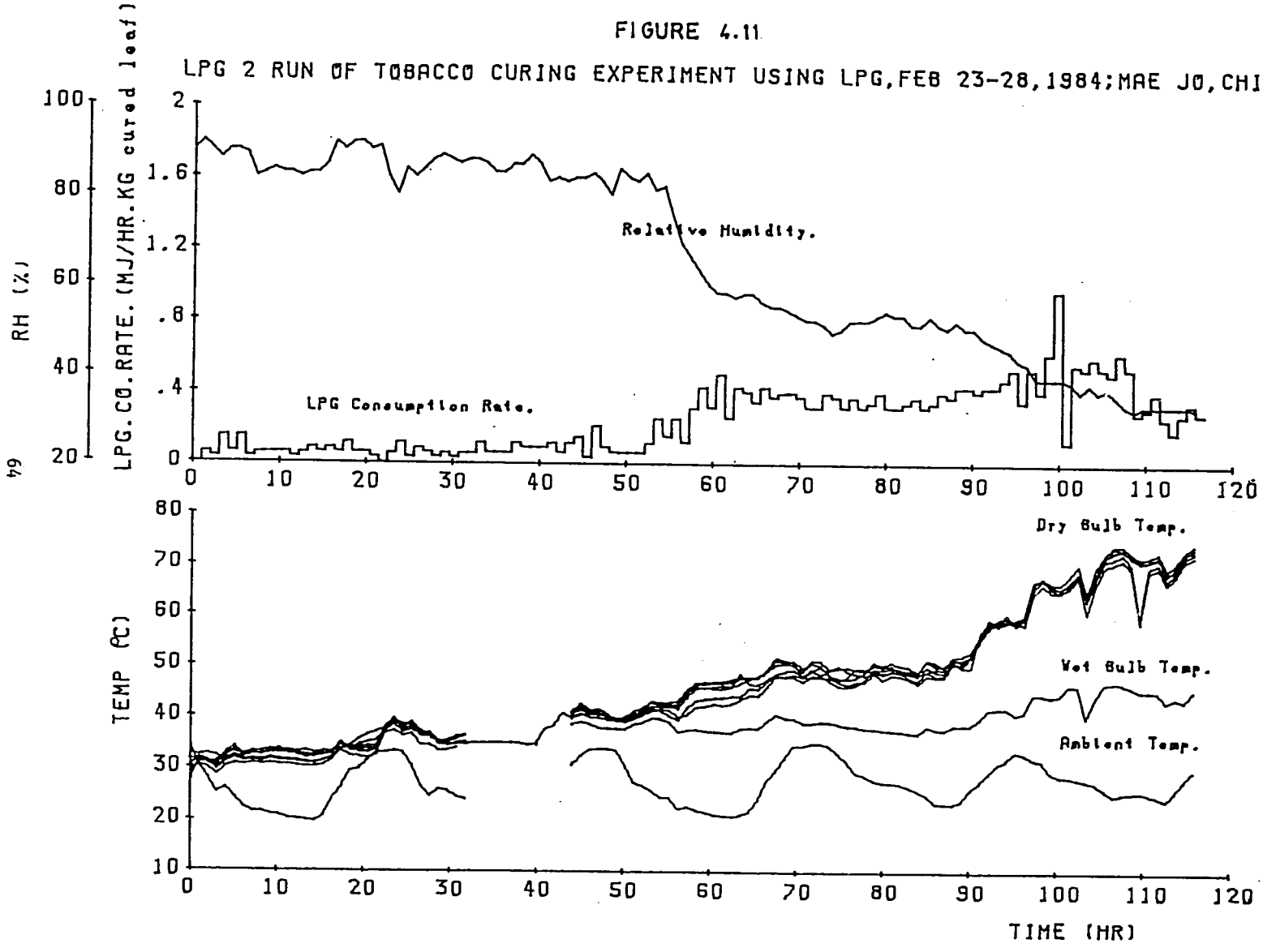


FIGURE 4.12

LPG 3 RUN OF TOBACCO CURING EXPERIMENT USING LPG, MAR 6-11, 1984; MAE JO, CHIANG MAI.

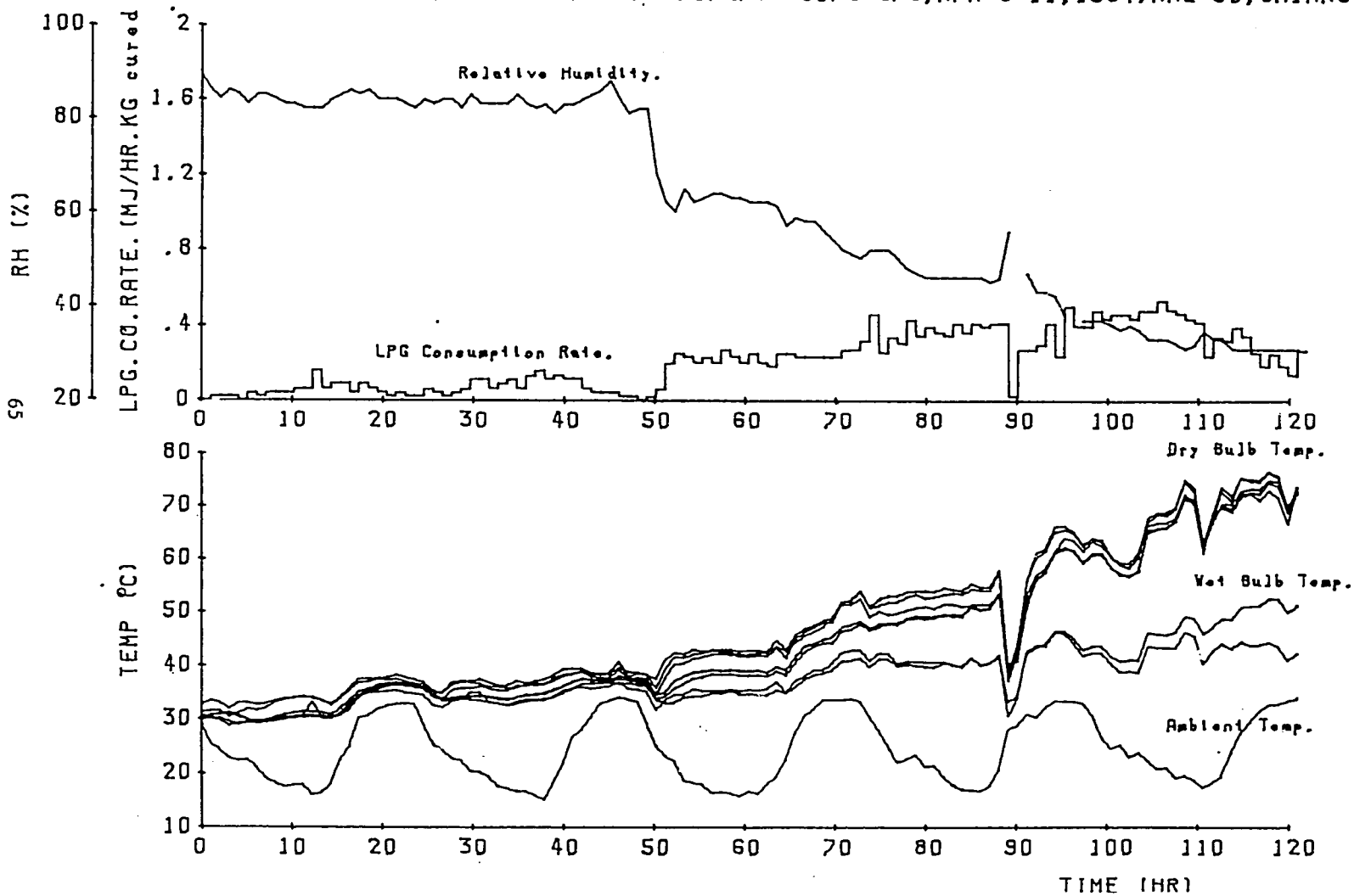


FIGURE 4.13

LPG 4 RUN OF TOBACCO CURING EXPERIMENT USING LPG, MAR 14-19, 1984: MAE JO, CHIANG MAI

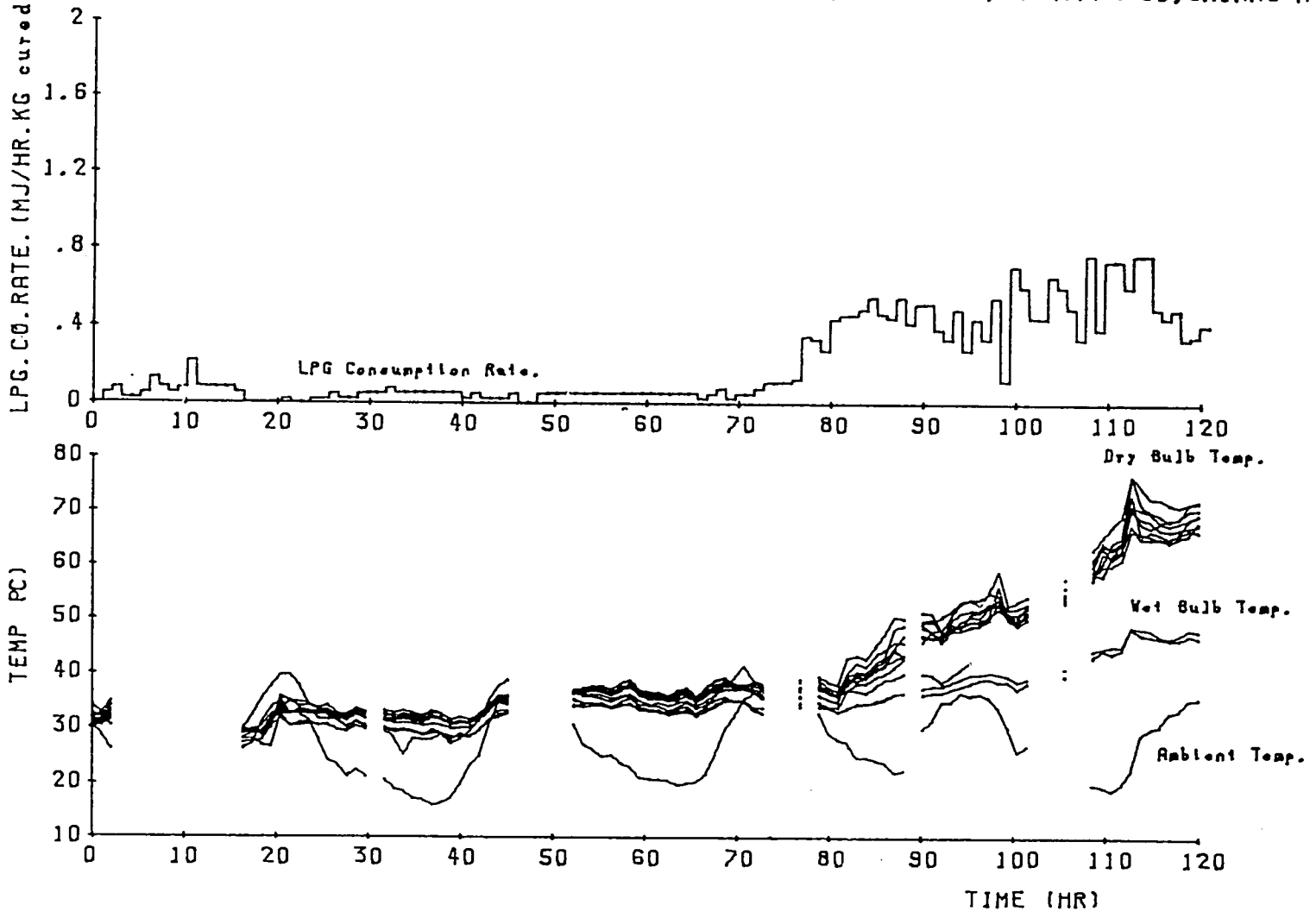


FIGURE 4.14

LPG 5 RUN OF TOBACCO CURING EXPERIMENT USING LPG, APRIL 5-10, 1984; MAE JO, CHIANG MAI

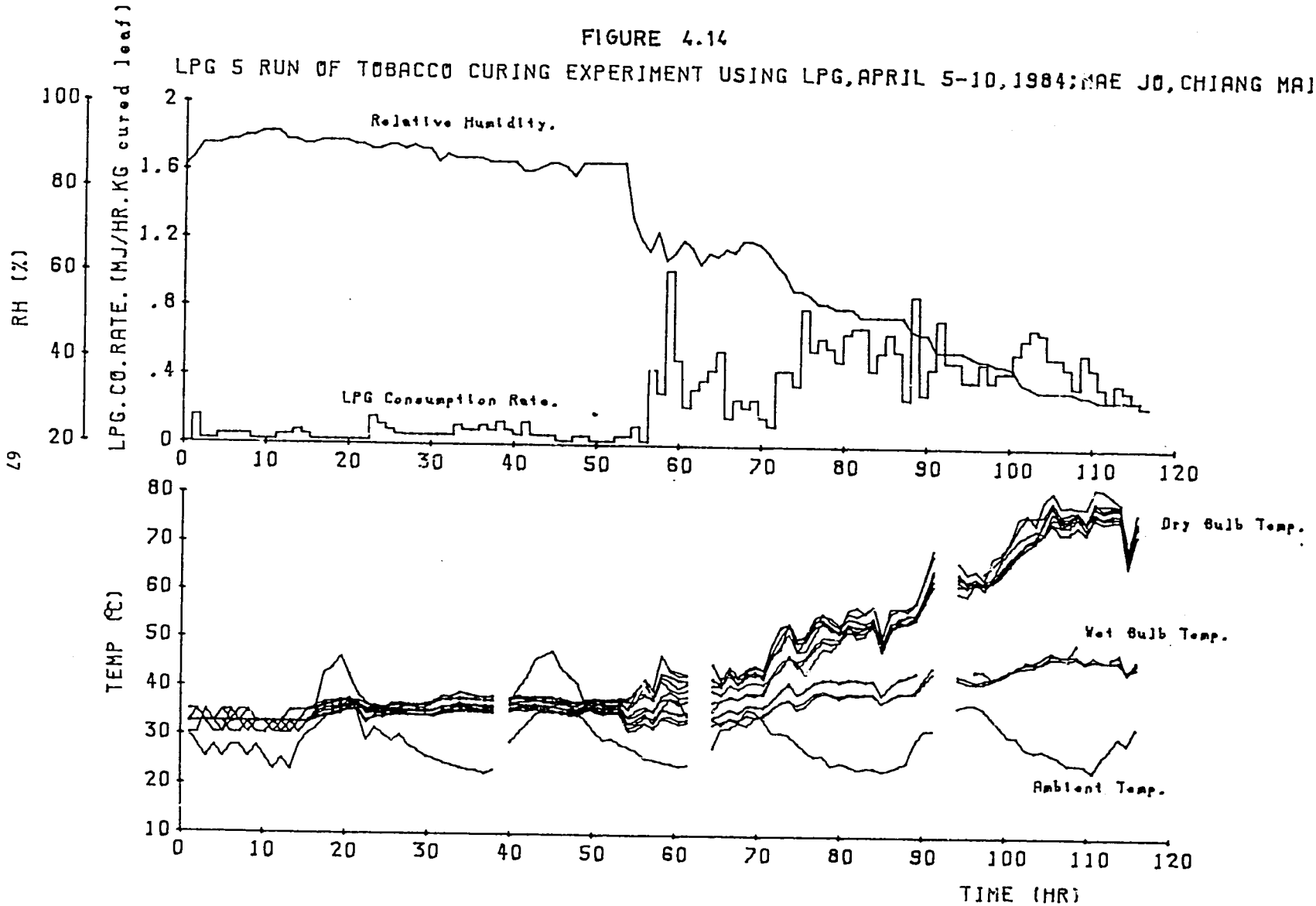


FIGURE 4.15 SOLAR 1 RUN

TOBACCO CURING EXPERIMENT USING LPG+SOLAR, APRIL 17-20, 1984: MAE JO, CHIANG MAI.

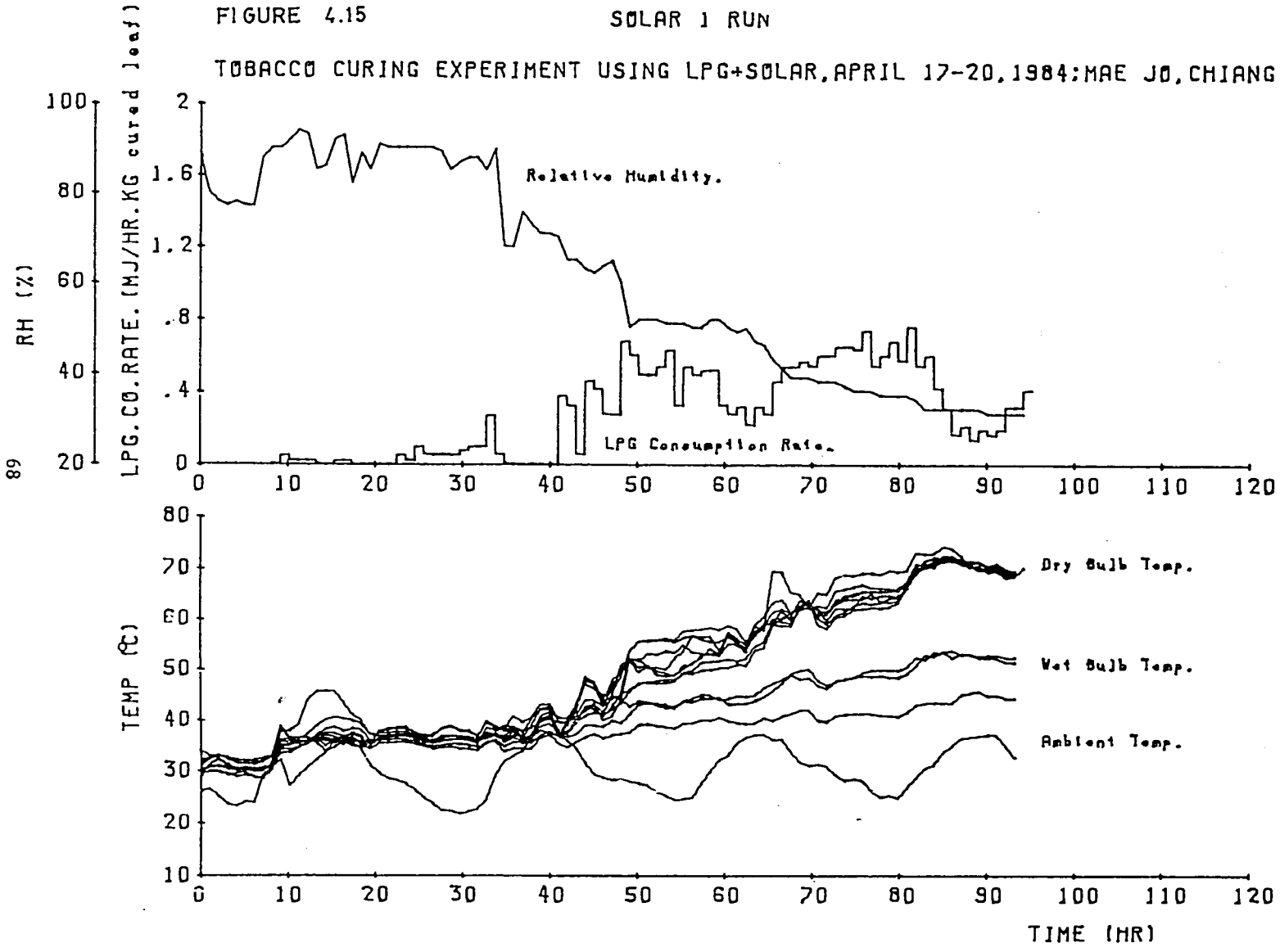


FIGURE 4.16 SOLAR 2 RUN

TOBACCO CURING EXPERIMENT USING LPG+SOLAR, MAY 3-7, 1984: MAE JO CHIANG MAI.

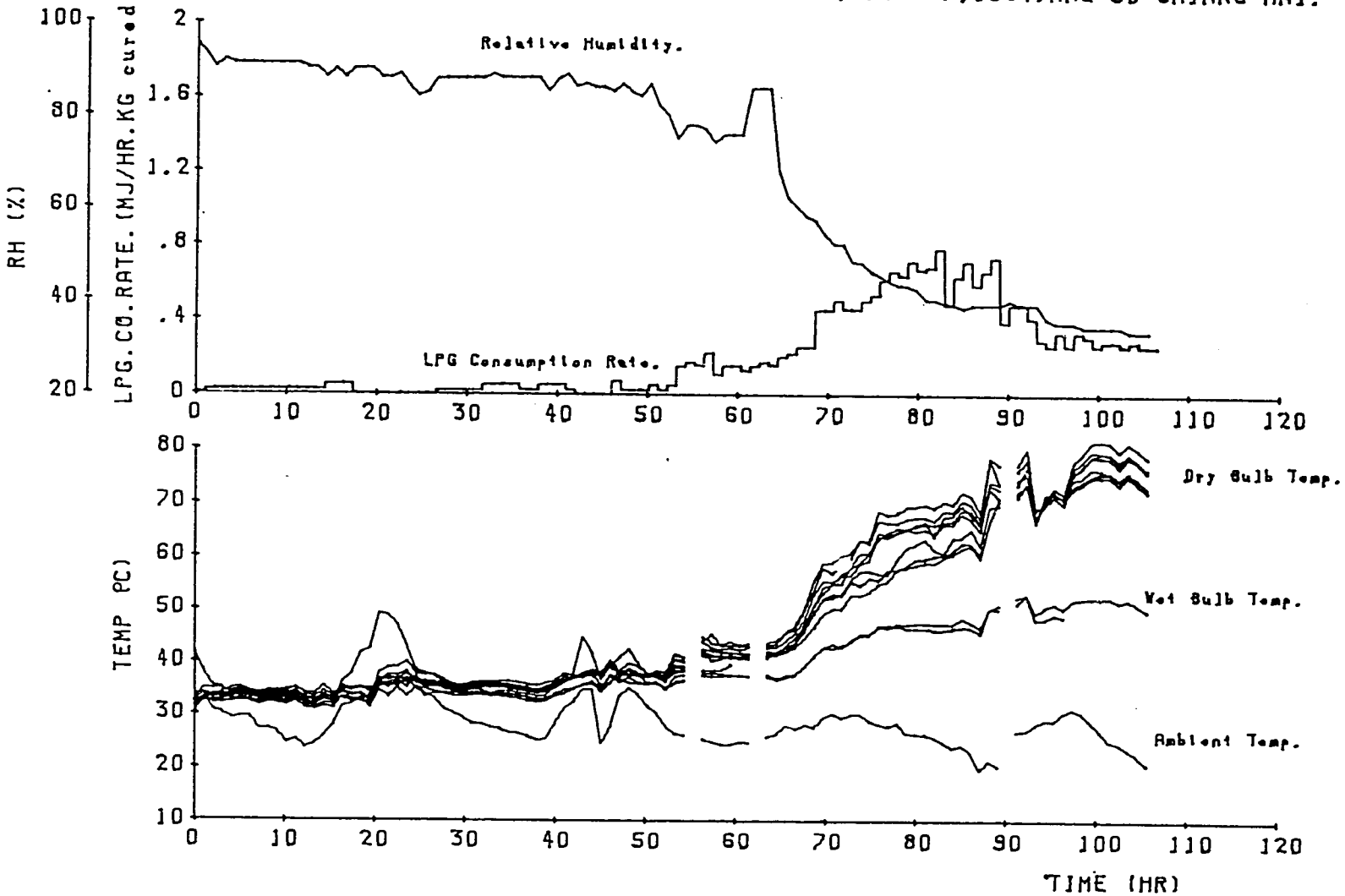
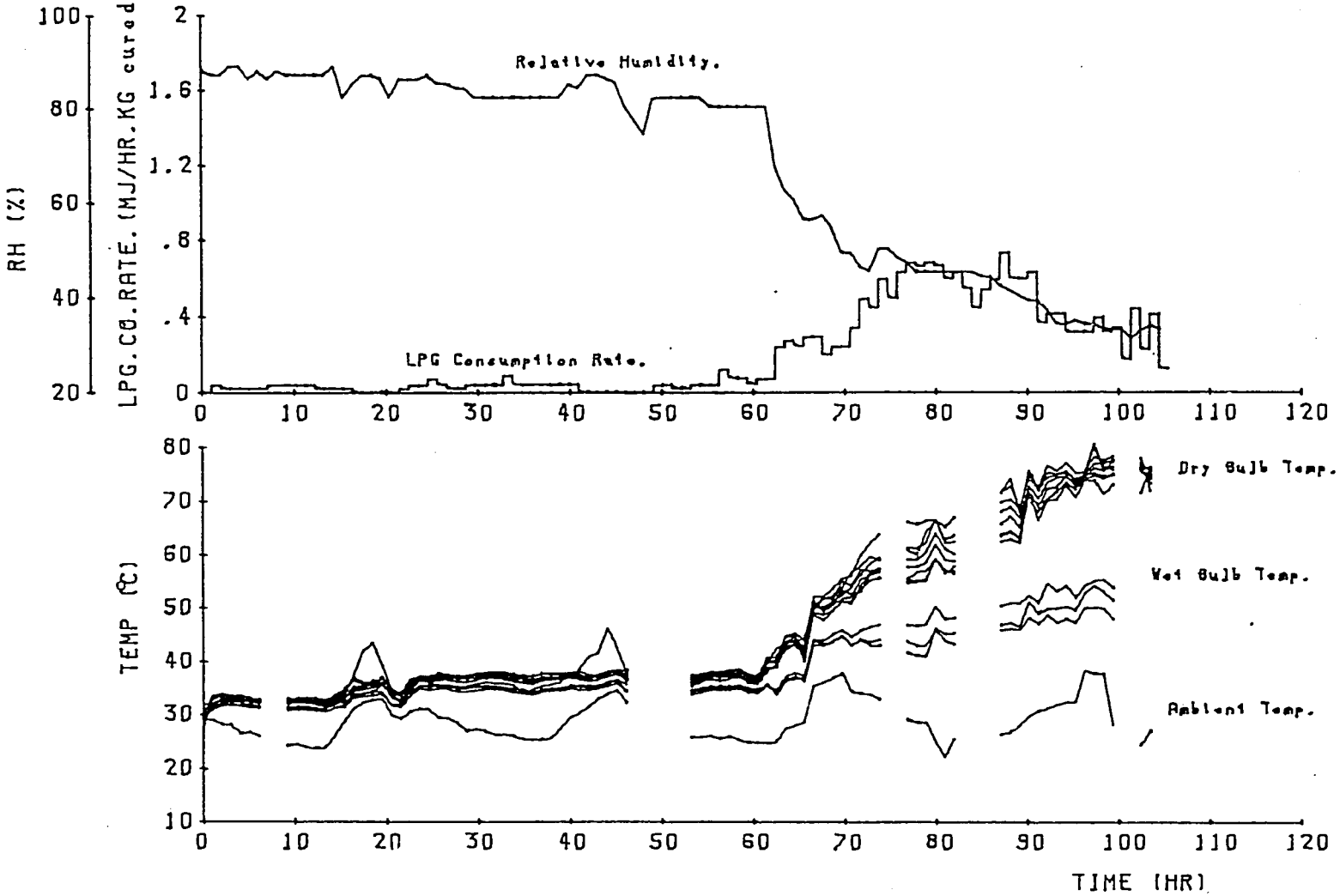


FIGURE 4.17 SOLAR 3 RUN

TOBACCO CURING EXPERIMENT USING LPG+SOLAR, MAY 15-19, 1984; MAE JO; CHIANG MAI.



Chapter 5

Analysis, Discussion and Evaluation of Results

ANALYSIS, DISCUSSION AND EVALUATION OF RESULTS

A. FACTORS AFFECTING ENERGY USAGE IN TOBACCO CURING

The amount of energy needed to fuel-cure any particular batch of tobacco leaves depends on at least the following factors:

1. Condition of the fresh leaves. This includes:

   - Moisture content, which depends on the weather conditions as well as the harvest techniques. (Some farmers water their leaves after harvest, to increase sale weight.)

   - Stage of ripeness. Leaves which are not fully ripe are greenish in color, and require a longer time during the yellowing and color-fixing stages.

   - Type of leaves (whether they are picked from the bottom, middle or top of the plant). Middle leaves are said to require the most energy in curing.

2. Weather conditions. Presence of rain, particularly during the high-temperature stages, will increase energy consumption due to increased heat losses as well as to more humid ambient air.

3. Curing procedures. There are no standard, fixed procedures for curing tobacco in Thailand. Heavy reliance is placed on the supervisor, who will inspect the leaves inside the barn periodically during curing, and issue appropriate commands with regards to the curing conditions to be followed. Hence, each supervisor has his own system, for which the energy required may vary by 10-20%.

4. Type of fuel used. Heating with firewood or lignite, the two most popular methods currently employed, must be indirect (requiring heat-exchanger tubes). Both methods are very energy intensive (120 MJ for firewood and 182 MJ for lignite required per kg of flue-cured tobacco, as reported by Bamrungwong, 1980), and thermally inefficient due to high heat losses from the burner and the heat exchanger stack. Both systems also respond slowly, and an unskilled operator can easily waste much fuel in attempting to increase temperatures too fast. In contrast, direct heating, which is possible with LPG, does not have stack losses,

Previous Page Blank

requires no heat exchangers, shows a quick response, and is less difficult to control. Therefore, by the choice of fuels used, the energy consumption for any particular test is already affected. In addition, if solar heating is used with a direct-heating fuel such as LPG, the savings in conventional energy obtainable by the use of solar energy would tend to be small, since LPG is already an efficient heating method.

In view of the factors described above, precise comparisons between any two experimental runs are very difficult, unless they are conducted concurrently, using two identical barns, with the same batch of fresh leaves, and with the same supervisor. This was not possible with the present experiments. These limitations should therefore be borne in mind in the following analysis.

B. ENERGY CONSUMPTION RESULTS

Total LPG Consumption

A summary of total LPG consumption for all eight experimental runs has been presented in Table 4.2. Data from the first run (LPG 1) shall be disregarded here, since it was the first attempt, using a new barn with inexperienced operators, and using unusually wet fresh leaves (see Table 4.1). In the remaining runs using LPG only, LPG 3 and LPG 5 may be considered well-operated and used as standard runs for later comparison with solar-assisted tests (SOLAR 1-3). However, it must be kept in mind that LPG 3 was run with different leaves from a different field, at a different harvest time from LPG 5. Also, all average values are presented strictly as indicators, as conditions of each run varied with the factors described previously.

In general, the ratio of fresh weight/cured weight ranged from 5.2 - 7.0, indicating that the moisture content of fresh leaves was in the range 80-90% (wet basis). The final moisture content of cured leaves, as determined from small amount of samples, was approximately 20% (wet basis).

The amount of LPG consumed varied from 0.55-0.68 kg/kg cured leaves (equivalent to 25.4 - 31.2 MJ/kg cured leaves), for the runs using LPG only. With solar heating, the LPG consumption dropped to 0.44 - 0.54 kg/kg cured leaves (equivalent to 20.5 - 24.9 MJ/kg cured leaves). Table 5.1 clearly illustrates how these figures compared favorably with those of similar studies previously reviewed in Chapter 2. Also, favorable comparison was obtained between the average LPG consumption of 0.63 kg/kg cured leaves for the four LPG runs, to 0.72 kg/kg cured leaves produced by nine similar LPG runs at Mae Jo Tobacco Experiment Station. (See Table 5.2 for details.)

Table 5.1 Comparison of energy consumption values between experimental runs using LPG only and solar-assisted, and those from similar studies previously reviewed in Chapter 2.

Studied by	Year	Type of cure	Fuel used	Av. energy consumption (MJ/kg of cured leaves)
CMU (Thailand)	1984	flue-curing	LPG	28.9
Necesito (Philippine)	1978	flue-curing	firewood	217.7
Necesito	1978	flue-curing	used oil+ diesel	24.3
Huang (USA)	1980	av. natural convection barns		37.0
Huang	1980	av. bulk-curing barns		30.0
CMU	1984	solar-assisted flue-curing	LPG	22.2
Necesito	1978	Taiwan solar-assisted bulk barn	diesel	22.5
Necesito	1978	CHB, bulk, solar-assisted	kerosene	54.3
Huang	1980	NCSU/BAE solar bulk barn (1975-78)	LPG	15.6 (average)

Table 5.2 Mae Jo tobacco curing trial runs using LPG as fuel on conventional barns
MAE JO TABACCO EXPERIMENT STATION, CHIANG MAI

RUN	DATE	Curing Duration (hr)	Wt. of tobacco Fresh (kg)	Wt. of tobacco Cured (kg)	Fresh:Cured Wt. ratio	Total LPG (kg)	Cons. (kg.LPG) / kg cured leaves
1*	Dec. 16-21 1983	110	3040	438.6	6.93	468.8	1.06
2*	Jan. 19-23 1983	96	4040	459.6	8.79	448.9	0.97
3*	Feb. 8-13 1983	105	3400	548.2	6.20	325.10	0.57
4*	Feb.15-19 1984	93	40.75	509.6	8.01	311.70	0.61
5*	Feb.22-27 1984	111	3730	352.5	10.58	343.10	0.97
6*	Mar.19-24 1984	106	3834	590.0	6.50	309.20	0.52
6*	Mar.19-24 1984	99	3834	569.0	6.74	296.90	0.52
7**	Apr. 27-31 1984	152	3822	535.6	7.14	327.90	0.61
7*	Apr. 27-31	152	3822	506.0	7.55	338.70	0.66
						Average	0.72

Note : * 0.5 inch Microfiber insulated barn
** Aluminium foil insulated barn
Barn's dimensions : 6 x 6 x 6 m.

One important aspect which should be noted is that the use of solar heating seemed to shorten total curing time. The reason for this is the forced-convection nature of solar heating, which produced a higher moisture removal rate from the leaves.

Distribution of Energy Consumption

In Fig. 5.1, energy consumption patterns for the experimental runs LPG 3, LPG 5 and SOLAR 3 are shown together with the solar radiation pattern of SOLAR 3. It can be seen that during the first two stages of curing (yellowing and color-fixing), covering 50-60 hours, little energy was consumed. Solar heating could easily account for all of the energy needed during these stages during the daytime. Also, our previous assumption that these first two stages would use 30% of the total energy to be expended could not be proven. The use of solar heating during the day (SOLAR 3 did not utilize the rockbed thermal storage) visibly reduced LPG consumption rates. It is obvious from the graphs that timing of curing procedures is also important: if the process could be arranged so that the high-energy consuming periods fall as much as possible during the daytime, large energy savings by solar heating could be achieved. As it happened, this timing was managed rather well during the SOLAR 3 test, but unfortunately there were heavy rains during the last two nights (hours 72-84 and 96 onwards), which significantly increased the LPG consumption rate during these hours.

Figs. 5.2, 5.3 and 5.4 show breakdowns of energy usage for SOLAR 1, SOLAR 2 and SOLAR 3, respectively. Three types of energy were expended: LPG, electricity (to run the blowers for the solar collector), and solar energy. In the case of SOLAR 1, the rockbed thermal storage was also used. Figures 5.2A, 5.3A and 5.4A show hourly energy consumption rates as well as solar radiation values, while Figures 5.2B, 5.3B and 5.4B show cumulative energy consumption values together with hourly percentage savings by solar energy.

In terms of solar radiation fluxes, SOLAR 3 was the best experimental run, with consistently high solar radiation and clear days. In contrast, there were mainly cloudy skies during SOLAR 1, and frequent rains during SOLAR 2 tests.

Energy consumed in each stage of curing is presented in Fig. 5.5A and B, for LPG 5 and SOLAR 3. For this purpose, the stages are defined by the curing temperatures as follows:

Yellowing	:	32 - 43°C
Color-Fixing	:	45 - 53°C
Leaf-Drying	:	55 - 63°C
Stem-Drying	:	65 - 80°C

FIGURE 5.1 LPG CONSUMPTION RATE OF LPG 3, LPG 5 AND SOLAR 3

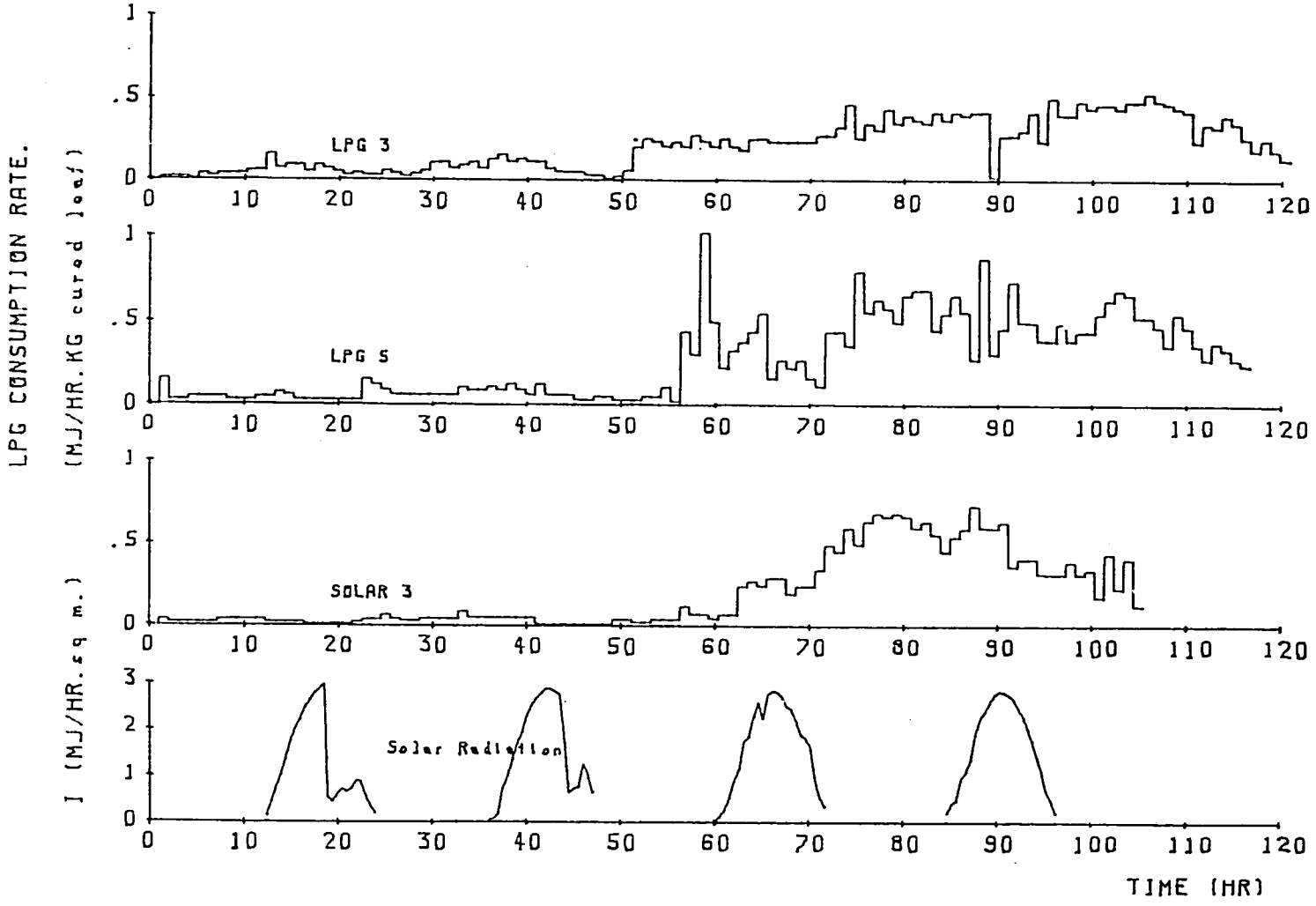


FIGURE 5.2A

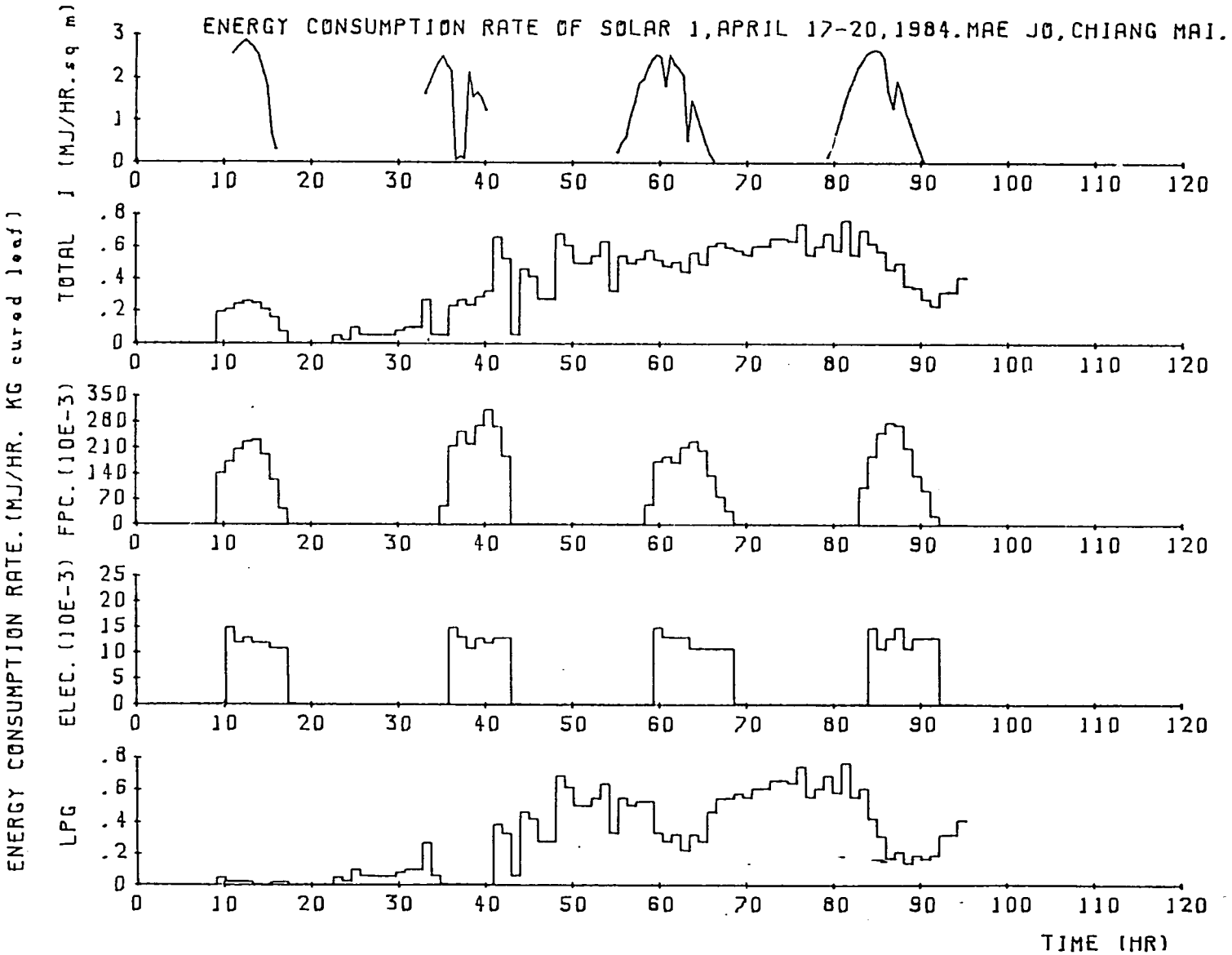

ENERGY CONSUMPTION RATE OF SOLAR 1,APRIL 17-20,1984.MAE JO,CHIANG MAI.
ENERGY CONSUMPTION RATE.(MJ/HR. KG cured leaf)
I (MJ/HR.sq m)
TOTAL
FPC.(10E-3)
ELEC.(10E-3)
LPG
TIME (HR)

FIGURE 5.2B

CUMULATIVE ENERGY CONSUMPTION OF SOLAR 1, APRIL 17-20, 1984; MAE JO, CHIANG MAI.

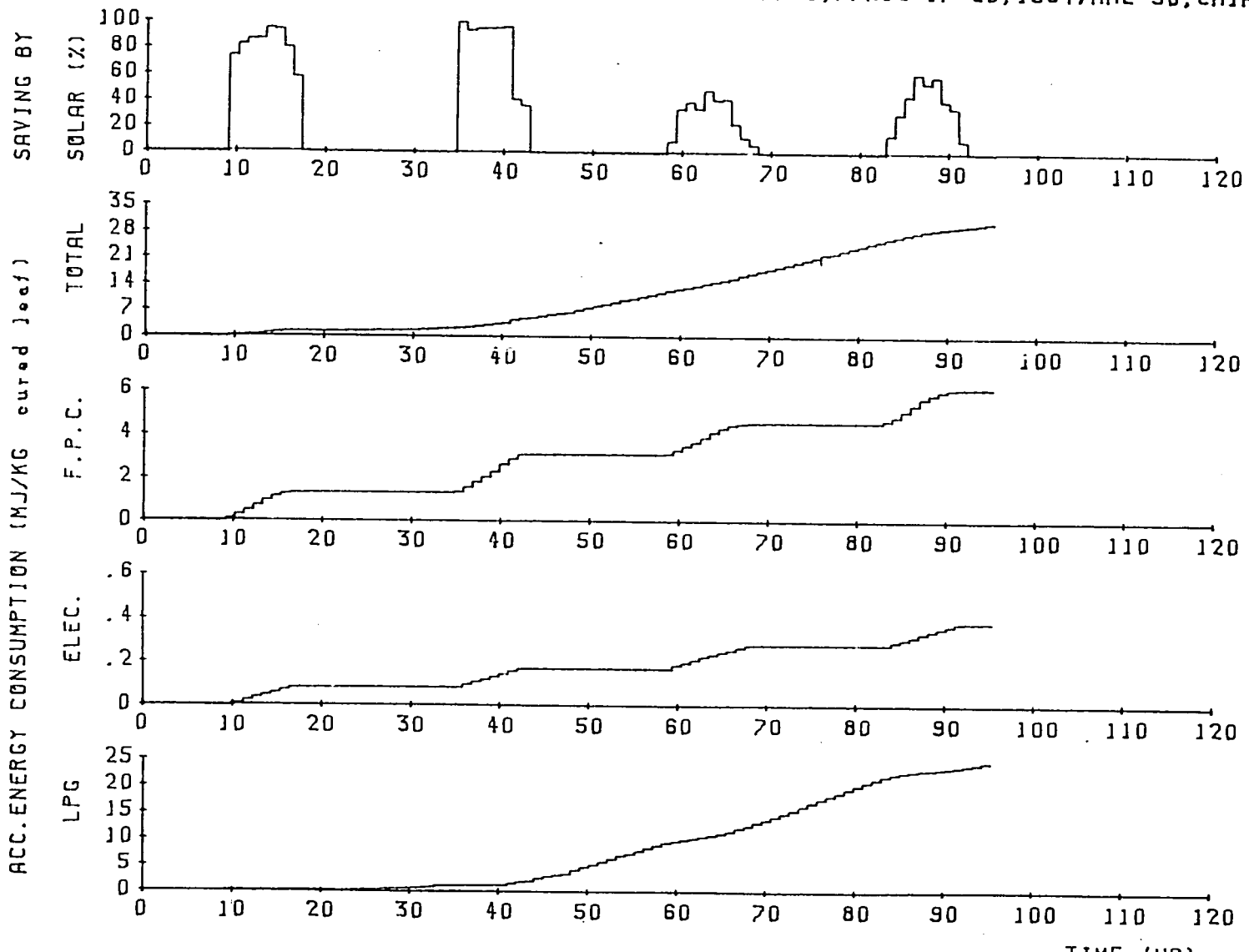


FIGURE 5.3A

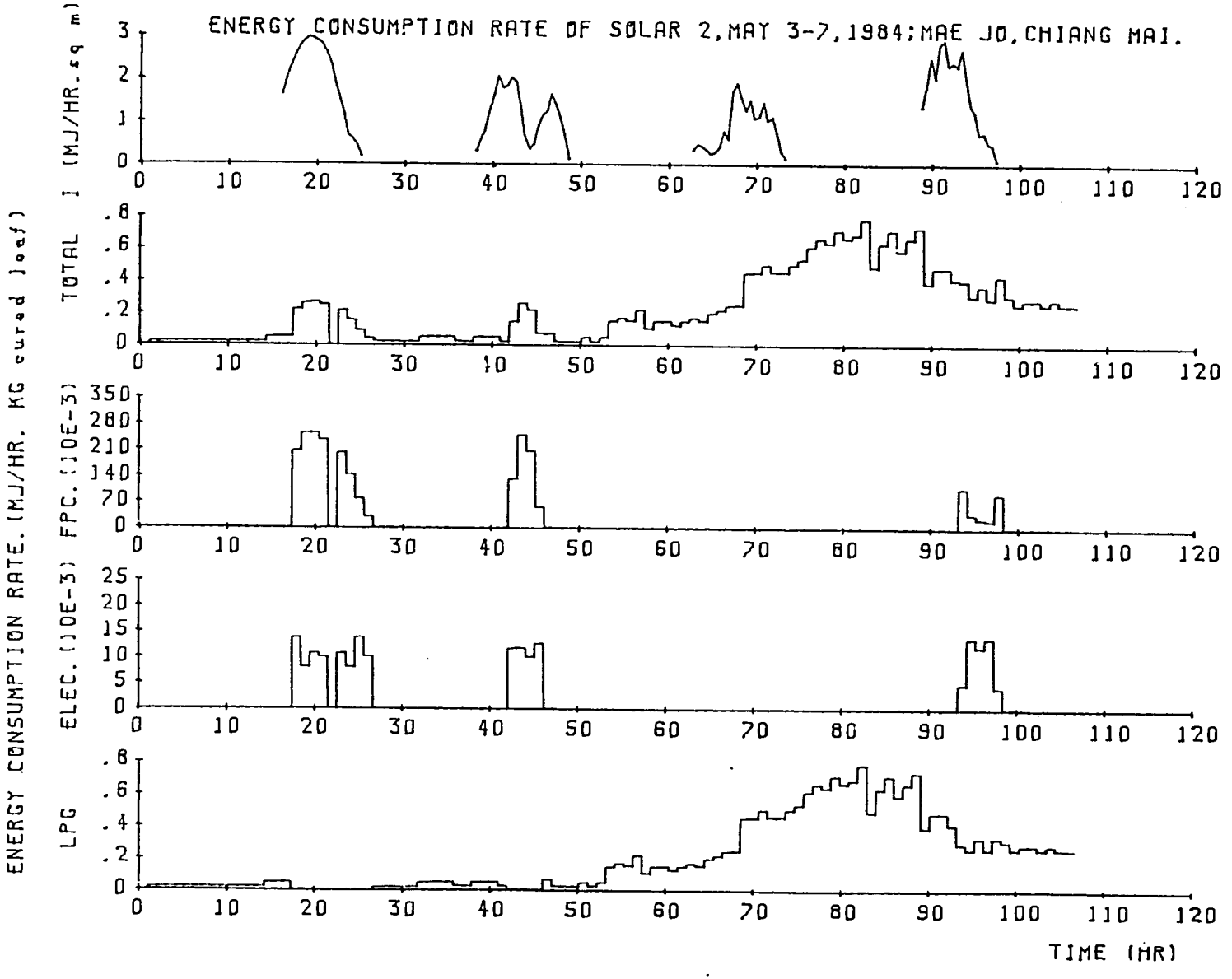

ENERGY CONSUMPTION RATE OF SOLAR 2, MAY 3-7, 1984; MAE JO, CHIANG MAI.
ENERGY CONSUMPTION RATE. (MJ/HR. KG cured leaf)
I (MJ/HR.sq m)
TOTAL
FPC. (10E-3)
ELEC. (10E-3)
LPG
TIME (HR)

FIGURE 5.3B

CUMULATIVE ENERGY CONSUMPTION OF SOLAR 2, MAY 3-7, 1984; MAE JO, CHIANG MAI.

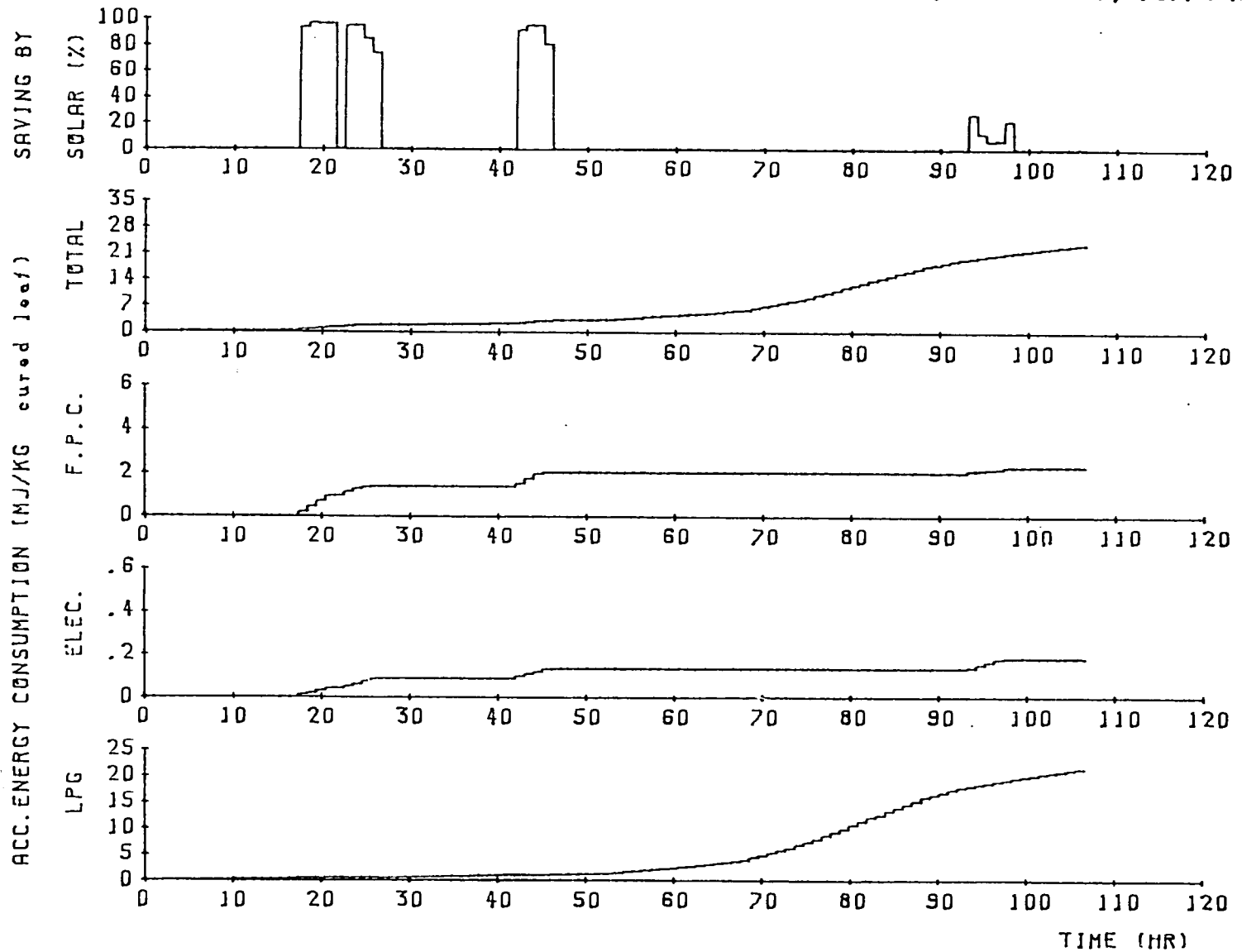


FIGURE 5.4A

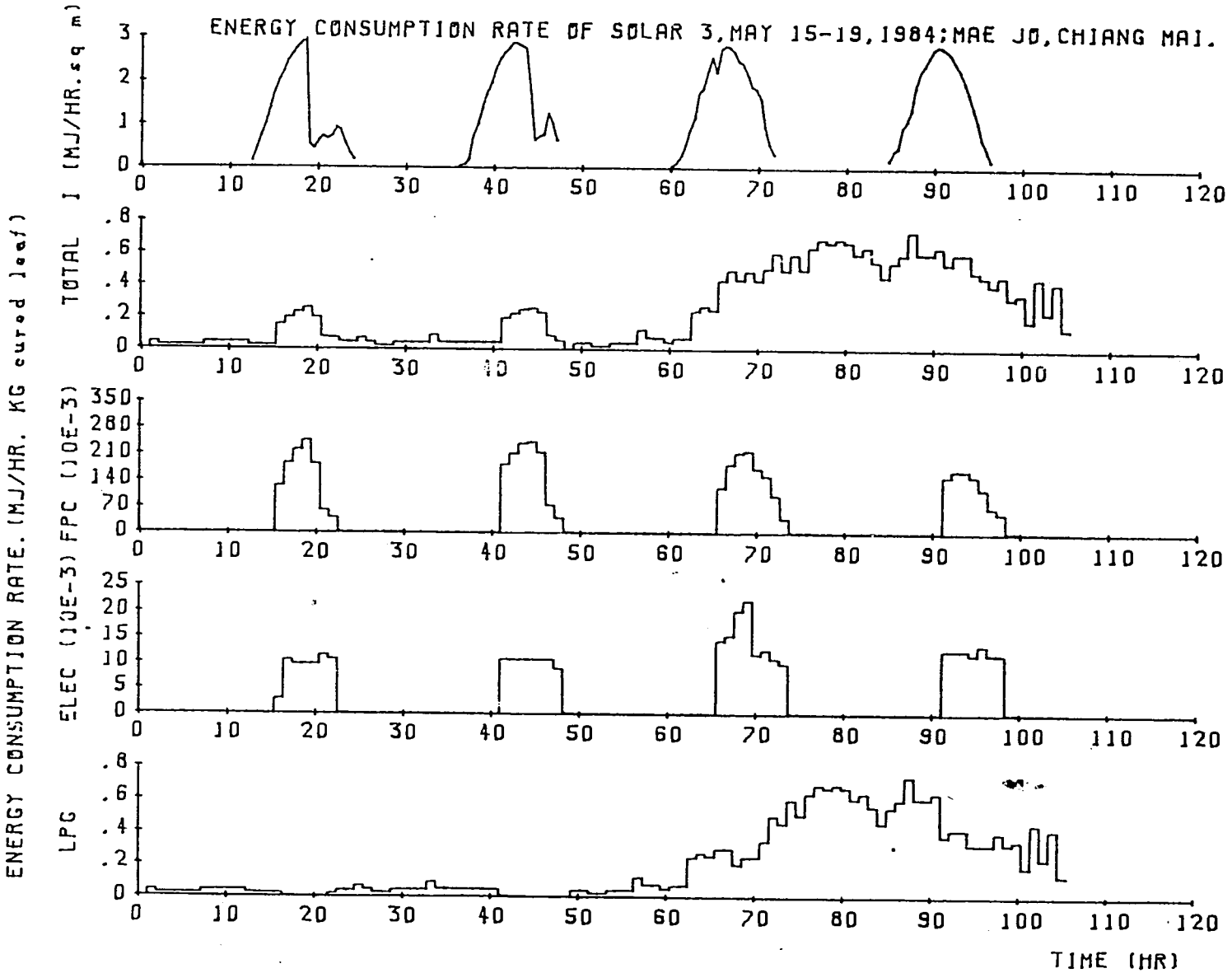
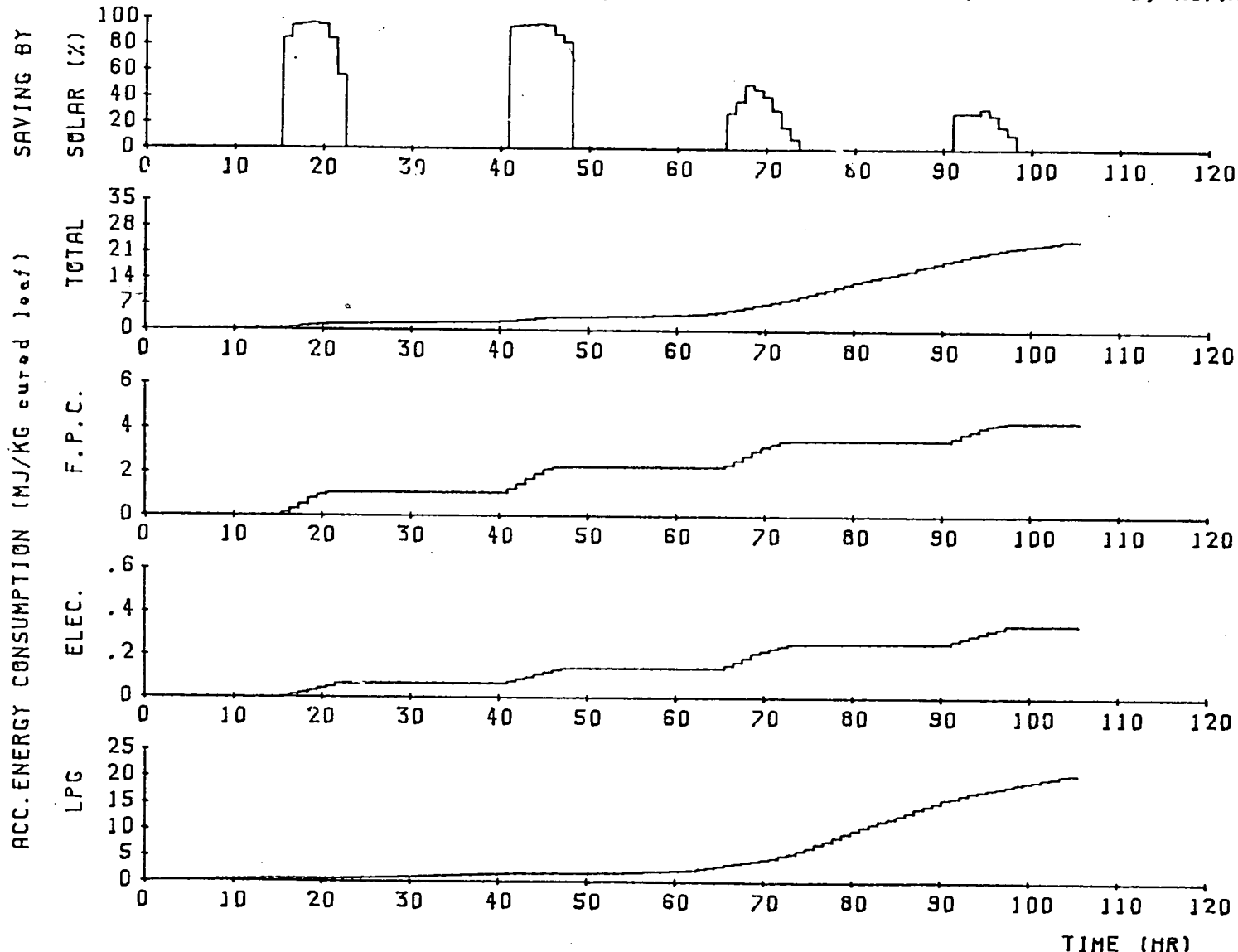

ENERGY CONSUMPTION RATE OF SOLAR 3, MAY 15-19, 1984; MAE JO, CHIANG MAI.
ENERGY CONSUMPTION RATE. (MJ/HR. KG cured leaf)
I (MJ/HR.sq m)
TOTAL
FPC (10E-3)
ELEC (10E-3)
LPG
TIME (HR)

FIGURE 5.4 B

CUMULATIVE ENERGY CONSUMPTION OF SOLAR 3, MAY 15-19, 1984; MAE JO, CHIANG MAI.



The result should be taken only as indicative, since there is overlapping between stages and it would be difficult to define precisely where one stage ends and the next begins. Fig. 5.5A shows actual and percentage of energy used in each stage for the two experimental runs, while Fig. 5.5B shows the average hourly rate of energy consumption in each stage.

C. ENERGY SAVINGS BY SOLAR HEATING

Percent energy savings attributable to solar energy for the three solar-assisted runs are shown in Table 5.3. Two methods were employed in the calculations of percent energy savings:

1. Using LPG 5 as the standard for comparison.

2. Using the fraction of energy supplied by solar heating within each run, over the total energy consumed.

The first method has its drawbacks in that the fresh leaves and the environmental conditions vary from run to run, which affect the results. The second method's drawback is that, while the leaves and the enviromental conditions are the same, reduction in energy consumption due to the different practices inherent in solar heating (e.g. the forced-convection nature of heating) would not be fully accounted for. The best method, of course, is to have two identical barns loaded with the same batch of fresh leaves, run together at the same time, and regulated by the same supervisor. Unfortunately, this was not possible, due to the limited time and funds available.

In any case, calculations by method 1 show that percent savings by solar energy were 19-33% over LPG 5, while those by method 2 indicate a 9.8-19.6% savings. The authors believe that these figures could be significantly increased, with more experience, better control, better fresh leaves, and weather more typical of the normal tobacco curing season (December - March, whereas the solar experiments were conducted during April - May, when sporadic rains began).

It should also be noted that, compared to LPG 5, SOLAR 2 and SOLAR 3 were conducted under a different supervisor. This supervisor was more flexible in his techniques in that he willing to adjust his curing schedules to benefit more from solar heating, without sacrificing the end product's qualities. Therefore, SOLAR 2 and SOLAR 3 showed larger energy

Fig.5.5 A Total and percentage of energy consumed during each stage of curing for LPG5 and SOLAR3

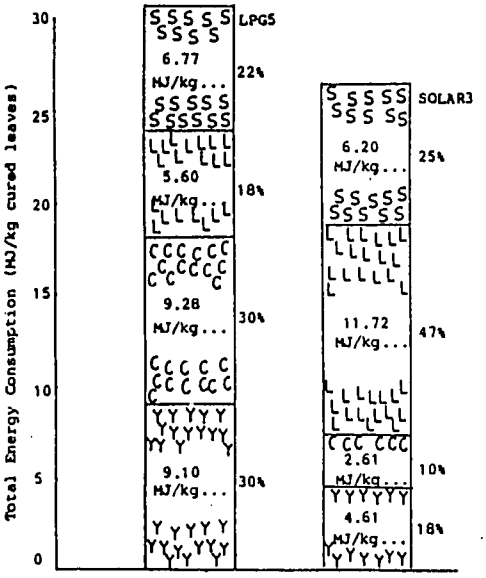


Fig.5.5 B Average hourly rate of energy consumption during each stage of curing for LPG5 and SOLAR3

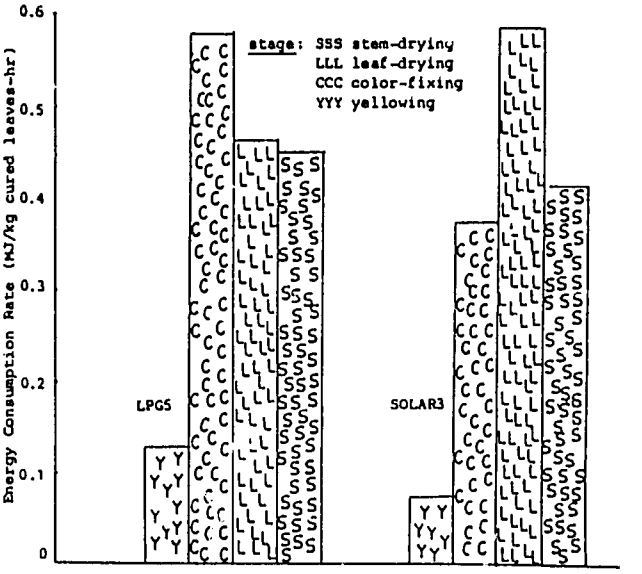


Table 5.3 Percent Energy saving by SOLAR 1, 2 and 3

Method 1.

Run	Total LPG consumed (MJ/kg cured Leaves)	Savings by solar energy (%)
SOLAR 1	24.83	19.25
SOLAR 2	21.35	30.57
SOLAR 3	20.47	33.43
Average	22.22	27.75

Note : Total LPG consumed by LPG 5 = 30.75 MJ/kg cured leaves.

% Saving = (total LPG consumed by LPG5 - total LPG consumed by solar run)/ total LPG consumed by LPG5

Method 2.

Run	Total energy consumed (MJ/kg cured leaves)	Solar energy (MJ/kg cured leaves)	Percent Saving by solar energy (%)
SOLAR 1	31.35	6.14	19.58
SOLAR 2	23.86	2.33	9.76
SOLAR 3	25.14	4.33	17.22
Average	26.78	4.27	15.52

Note : % Saving = $\frac{\text{Flate Plate Collector Energy output}}{\text{Total Energy Consumption}}$

savings by solar heating than SOLAR 1. However, the reader is reminded that SOLAR 2 and SOLAR 3 were run with top leaves, as compared to SOLAR 1's middle leaves, which presumably required more energy in curing. The extent to which these different leaves might have contributed to the energy consumption during the curing process is not yet known.

Fig 5.6 shows the solar energy contribution to each stage of SOLAR 3, and Fig. 5.7 shows the percentage savings in energy due to solar heating for each stage. It is seen that large savings were obtained in the initial stages, where required curing temperatures were relatively low. The contribution of solar energy decreases with increasing temperature. An exception is the stem-drying period, in which case it is believed that due to the period's relatively short duration, and since most of it was in the daytime, the percentage of solar energy contribution is therefore relatively large.

D. MOISTURE REMOVED AND CALCULATED THERMAL EFFICIENCY

For each stage of curing, the amount of moisture removed from the tobacco leaves was recorded, using a small 3-kg batch of samples. The data was then extrapolated to cover the entire amount of leaves in the barn. Thermal efficiency was then defined as the ratio of latent heat of vaporization of moisture from the leaves over input energy during the same period.

Tables 5.4 a-e present the resulting calculations for each stage of curing, for LPG 4-5 and SOLAR 1-3 (moisture removal was not recorded in runs LPG 1-3). It is seen that the thermal efficiency was very high in the first stage, decreasing steadily in subsequent stages, in which high temperature coupled with the need for high ventilation rates led to large heat losses. The overall efficiency, shown in Table 5.24, ranged around 40%.

Thermal efficiencies for LPG 5 and SOLAR 3 are also plotted as shown in Fig. 5.8, for comparison. It is notable that the solar-assisted run shows consistently higher thermal efficiency in all four stages. Two possible reasons for this higher efficiency are the presence of forced convection in solar heating, which increased heat and mass transfer rates between the leaves and the air, and the fact that collector efficiency was not yet included in these calculations.

Fig. 5.9 shows the amount of moisture removed in each stage per kg of fresh tobacco, from the sampling test of the four experimental runs. The moisture content of fresh leaves, cured leaves, and at the end of each stage of curing for all four runs are illustrated in Fig. 5.10 a) and Fig. 5.10 b) in terms of wet basis and dry basis respectively. The moisture content of the cured leaves from the mixed sample of test

Fig.5.6 Solar energy contribution in each stage of curing for SOLAR3

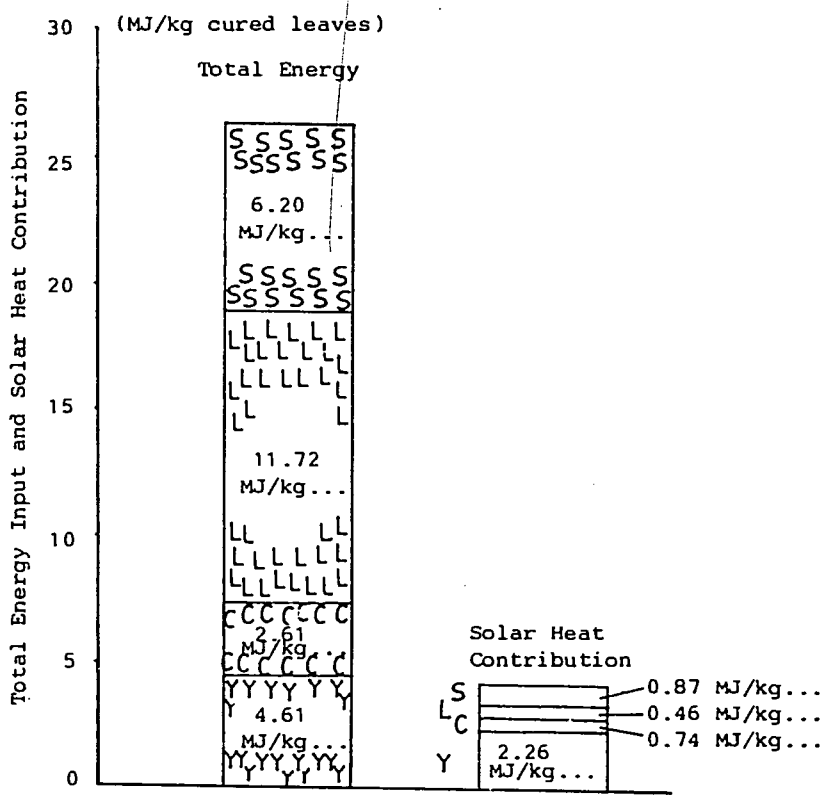


Fig. 5.7 Percent energy savings by solar heat in each stage of curing for SOLAR 3

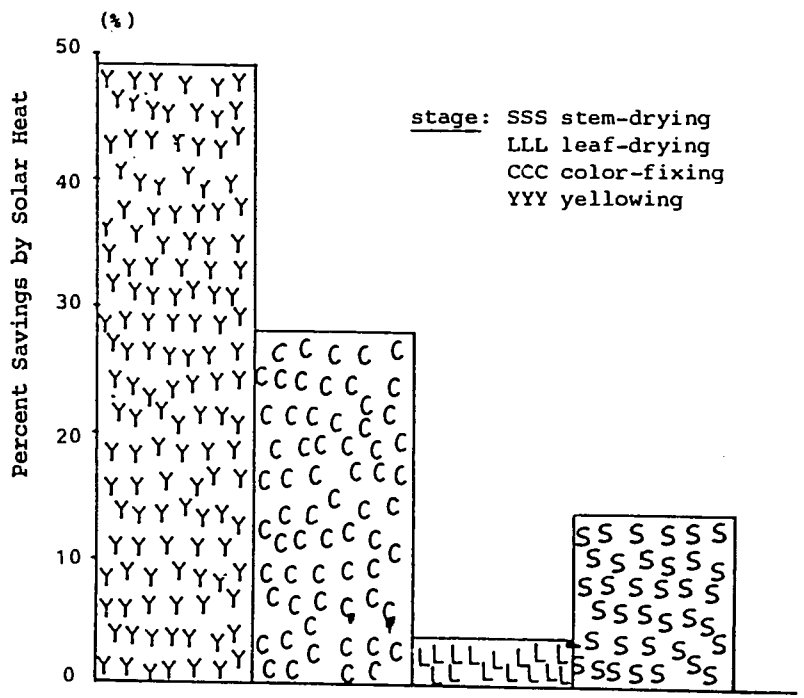


Table 5.4 a Thermal efficiency of Yellowing stage

Run	Curing Duration (Hr)	Energy Consumption (MJ/kg cured leaves)				Moisture Removed		Thermal Efficiency
		LPG	Elec.	Collector	Total	kg moisture/ kg cured leaves	Equivalent MJ/kg cured leaves	(%)
LPG 4	83	7.92			7.92	3.18	7.70	97.2
LPG 5	70	9.1			9.1	3.33	8.06	88.6
SOLAR 1	43	2.46	0.17	3.11	5.74	2.31	5.59	97.4
SOLAR 2	63	3.26	0.13	2.05	5.44	1.94	4.69	86.2
SOLAR 3	60	2.21	0.14	2.26	4.61	1.8	4.36	94.4
						Average		92.8%

Table 5.4 b Thermal efficiency of color-fixing stage

Run	Curing Duration (Hr)	Energy Consumption (MJ/kg cured leaves)				Moisture Removed		Thermal Efficiency
		LPG	Elec.	Collector	Total	kg moisture/ kg cured leaves	Equivalent MJ/kg cured	(%)
LPG 4	12	5.28			5.28	1.20	2.86	54.2
LPG 5	16	9.28			9.28	1.04	2.48	26.7
SOLAR 1	18	7.99	0.06	0.8	8.85	1.82	4.33	48.9
SOLAR 2	7	2.62			2.62	0.8	1.90	72.5
SOLAR 3	7	1.8	0.07	0.74	2.61	0.65	1.55	59.4
						Average		52.3%

Table 5.4 c Thermal efficiency of Leaves-drying stage

Run	Curing Duration (Hr)	Energy consumption (MJ/kg cured leaves)				Moisture Removed		Thermal Efficiency
		LPG	Elec.	Collector	Total	kg moisture/ kg cured leaves	Equivalent MJ/kg cured leaves	(%)
LPG 4	12	6.32			6.32	1.03	2.43	38.5
LPG 5	12	5.6			5.6	0.29	0.68	12.1
SOLAR 1	9	4.5	0.05	0.68	5.23	0.32	0.76	14.5
SOLAR 2	16	10.09			10.09	1.44	3.40	33.7
SOLAR 3	20	11.22	0.04	0.46	11.72	1.55	3.66	31.2
						Average		18.3%

Table 5.4 d Thermal efficiency of stem-drying stage

Run	Curing duration (Hr)	Energy consumption (MJ/kg cured)				Moisture Removed		Thermal Efficiency
		LPG	Elec.	Collector	Total	kg moisture/ kg cured leaves	Equivalent MJ/kg cured	(%)
LPG 4	25	11.64			11.64	0.64	1.49	12.8
LPG 5	15	6.77			6.77	0.10	0.23	3.4
SOLAR 1	22	9.88	0.10	1.55	11.53	0.28	0.65	5.7
SOLAR 2	17	5.38	0.05	0.28	5.71	0.14	0.33	5.8
SOLAR 3	15	5.24	0.09	0.87	6.2	0.14	0.33	5.3
						Average		6.6%

Table 5.4 e Overall curing thermal efficiency

		Total MJ/kg cured.		
Run	Curing Duration (Hr)	Actual Consumption	Energy Required to Remove Moisture	Thermal Efficiency (%)
LPG 4	132	31.16	14.48	46.5
LPG 5	113	30.75	11.45	37.2
SOLAR 1	92	31.35	11.33	36.1
SOLAR 2	103	23.86	10.32	43.3
SOLAR 3	102	25.14	9.90	39.4
			Average	40.5%

Fig.5.8 Comparison of thermal efficiencies between different stages of curing for LPG5 and SOLAR3

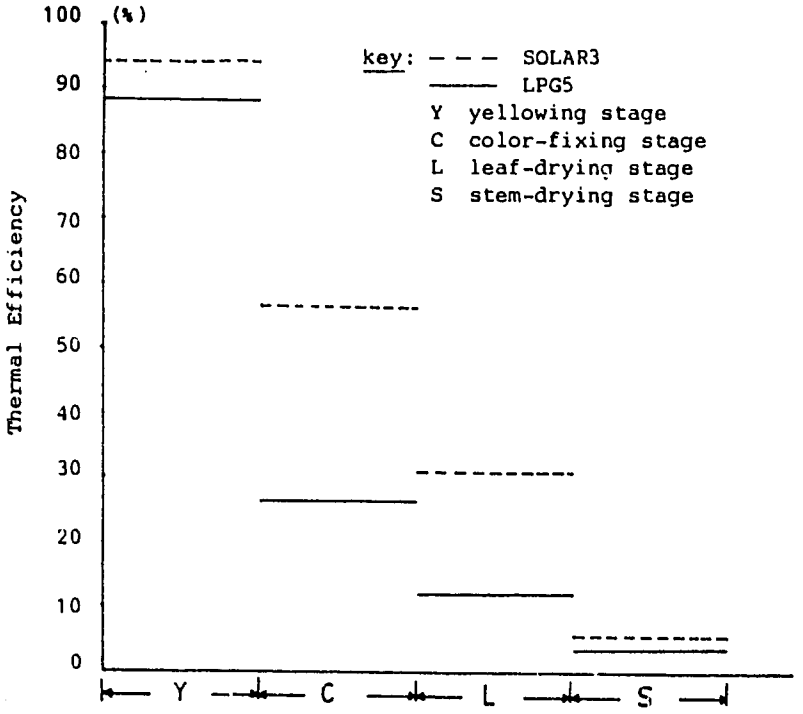


Fig.5.9 Moisture removed (per kg of fresh leaves)

in each stage of curing for LPG5 and SOLAR1-3

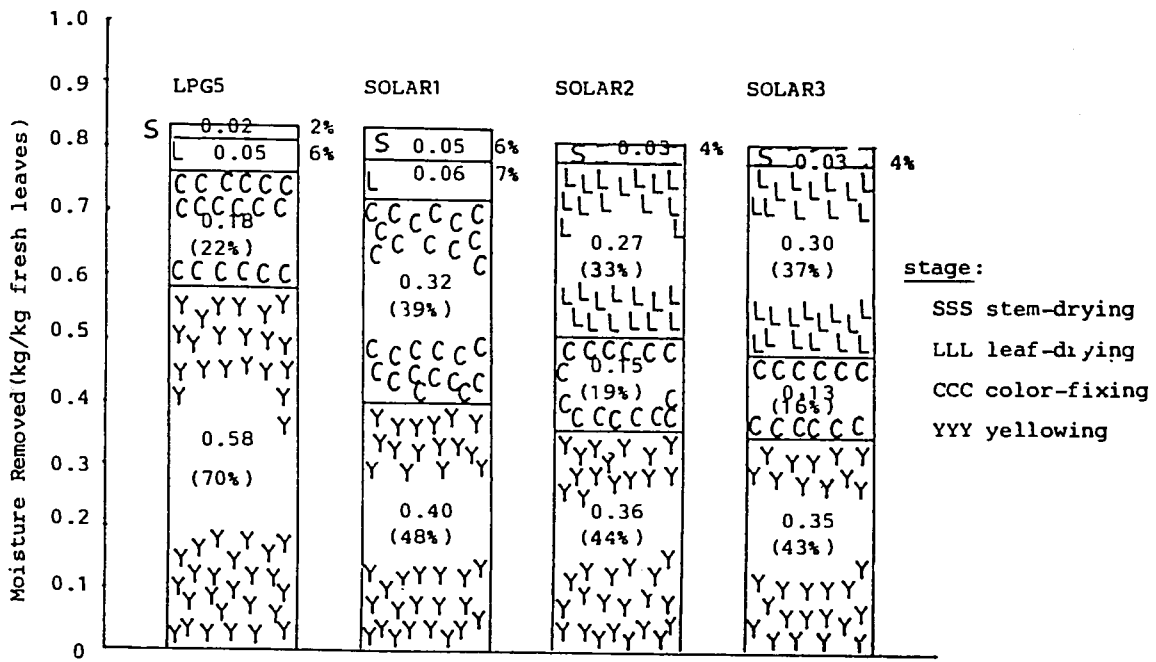
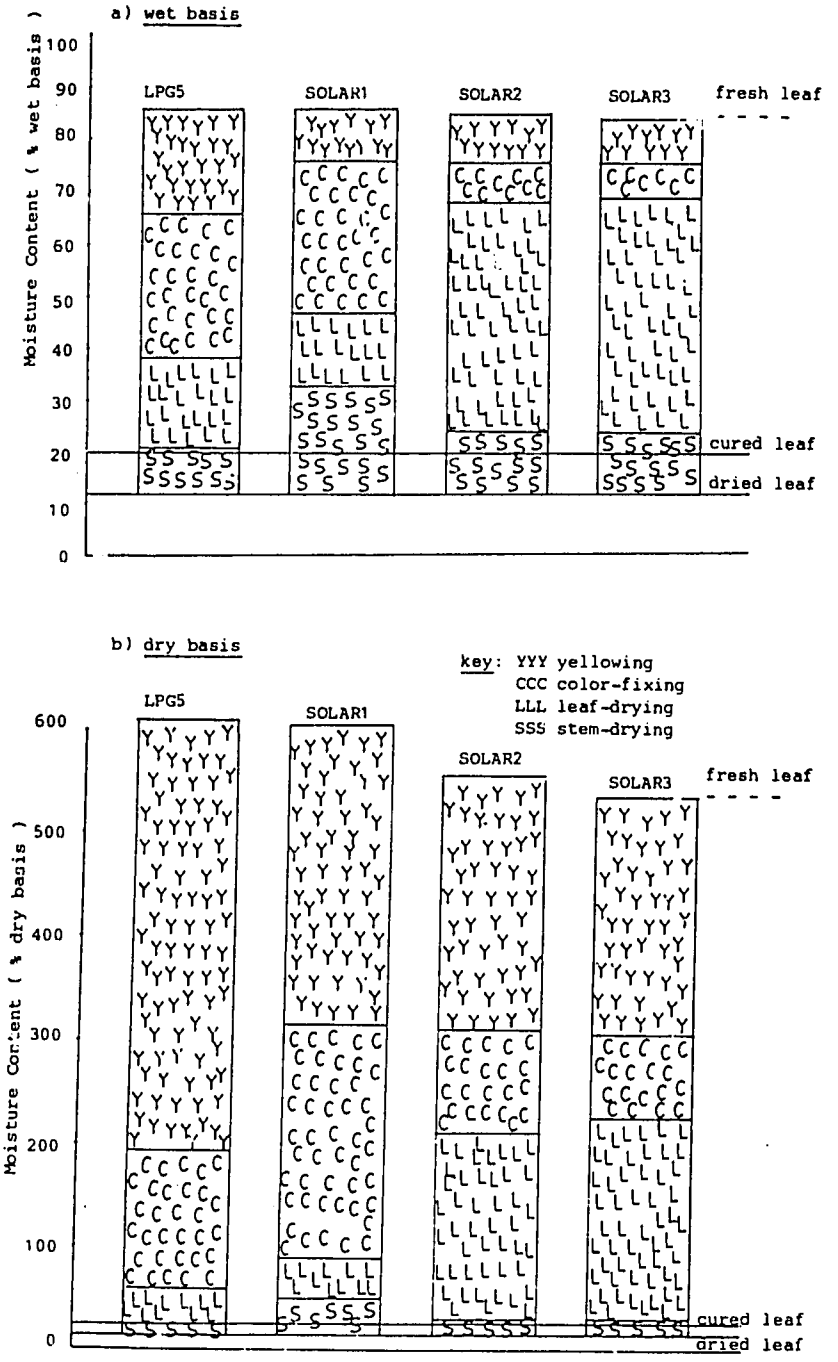


Fig.5.10 Moisture content of every stage of curing for LPG5 and SOLAR1-3



SOLAR 1-3 was determined to be 19.5% wet basis or 24.2% dry basis, as shown in Table 5.5. On a wet basis, the total moisture content of fresh leaves for all four runs differed only slightly (84-86%); however, the fraction of this moisture removed in each stage differed markedly. Again, several factors might have contributed to the differences, not the least of which were different fresh leaves, different curing procedures, and ill-defined stages of curing. However, results for SOLAR 2 and SOLAR 3 are remarkably similar in all four stages. Table 5.6 shows a similar test performed by the Mae Jo Tobacco Experiment Station to determine the percentage of moisture removed from sample of tobacco leaves at three different levels inside the conventional barn, using lignite as fuel. One important discovery was that the percentage of moisture absorbed back by the cured leaves after the final drying stage was found to be 7.9% on an average.

E. THE ROLE OF THE THERMAL STORAGE

Based on data obtained in these experiments, the effectiveness of a thermal storage in flue-curing of tobacco leaves is still uncertain. The rockbed thermal storage was utilized only once, during SOLAR 1 run, during which it was found that the planned scheduling of Table 3.1 could not be adhered to. The reasons were twofold:

1. During the first stage of curing (yellowing), in which a high-humidity and low-temperature condition was required, it was found that the rockbed absorbed moisture from the circulating air thereby making it very difficult to increase relative humidity inside the barn to the desired level.

2. In contrast, during the second stage of curing (color-fixing), which required a gradually-decreasing humidity and a gradually-increasing temperature condition, it was found that the moist rockbed prevented the humidity inside the barn from decreasing according to schedule. In effect, fuel was being consumed to dry the rockbed as well as the tobacco leaves.

As there was little time remaining before the end of the tobacco harvest season, it was therefore decided to exclude the rockbed thermal storage from subsequent experiments, and concentrate on the solar collector only.

F. QUALITY OF CURED LEAVES

Any comparison of performance among the different curing systems would not be complete without considering the end product, that is, the quality of cured tobacco leaves. It is pointless to develop a system which is highly energy-efficient but produces only mediocre cured leaves, which sell at low prices. Toward this end, the research team asked personnel of the Mae Jo Experiment Station to grade the cured leaves according to their standard criteria.

The official classification of tobacco leaf grades, as designated by the Thailand Tobacco Monopoly, is shown in Table 5.7. Major grades run from A to C; grades below C are considered low-quality and priced accordingly. Within each grade, there are several subgrades as seen (4 subgrades in A, 4 in B, 2 in C and 5 in low-quality grades below C). The last four grades (AA, BA, CA, DA) are for loose leaves.

According to the above criteria, tobacco leaves cured in the persent study were classified as shown in Table 5.8. Using LPG 5 as a standard for comparison, it is seen that the average price of cured leaves obtainable declined steadily from SOLAR 1 to SOLAR 3. This is believed to be due mainly to the gradually lower quality of fresh leaves as testing progressed further outside the normal tobacco season. (Fresh leaves for all four runs shown were from off-season plantings.) The authors were assured by the quality evaluators at Mae Jo Experiment Station that the quality of cured leaves obtained from the tests was not out of the ordinary, given the low quality of fresh leaves used.

G. ECONOMIC ASPECTS

The authors strongly believe that the solar-assisted tobacco curing system can be made technically feasible, but its economic feasibility will depend largely on the following major aspects:

- Low initial cost;
- High percentage of energy savings;
- Maximum utilization; and
- Price of conventional fuels.

The authors believe that the initial cost needed to modify a conventional barn into a solar-assisted barn can be considerably lower than the experimental prototype. The final design may include only an array of solar collectors with a simple ducting arrangement, without the return duct, and a blower. To further reduce initial cost, the collector's support structure can be made simpler, or, if possible, the collector can be placed on the barn's roof.

A high percentage of energy savings by solar energy will undoubtedly shorten the pay-back period needed to recover the added investment. With experienced curing operators, standard tobacco leaves, and high solar insolation, at least 30% energy savings by solar energy should be possible.

Maximum utilization of the solar-assisted tobacco curing system is another important aspect when considering the economics of the system. The tobacco curing season lasts about 3-4 months each year, which limit the total number of curing runs to about 15 per year. Normally, during the rest of the year the curing barns are left idle. The economic potential of the solar-assisted system would be greatly boosted if, with some modification and investment, it could be used to dry other northern argicultural products. Such products are longans, soyabeans, groundnuts, chilies, etc.

Lastly, the cost of conventional fuels currently used to cure tobacco is another major aspect to be considered. If prices of firewood, lignite and LPG suddenly increase, the economic feasibility of the solar-assisted tobacco curing system will be improved.

Table 5.5 Determination of moisture contents, wet and dry basis from samples of cured leaves.

Samples		cured wt. (grams)	dry wt. (grams)	wet basis (%)	dry basis (%)
Mixed samples from SOLAR1-3		160.5	129.2	19.5	24.2
Samples from MAE JO test	Bottom level	26.0	20.6	20.8	26.2
	Middle level	35.8	28.0	21.8	27.8
	Top level	34.4	27.0	21.5	27.4
			Average	21.4	27.1

Test site : Department of Mechanical Engineering, Chiang Mai Univ.

Equipment : Electric oven and digital balancing machine

Date : June 1984

Table 5.6 Moisture removed from tobacco curing experiment using lignite as fuel on a conventional barn of 6x6x6 m in dimensions. Mae Jo Tobacco Experiment Station, Chiang Mai.
March 30, 1984

	curing duration (hr)	Bottom Level tobacco weight (kg)	Bottom Level moisture removed (%)	Middle Level tobacco weight (kg)	Middle Level moisture removed (%)	Top Level tobacco weight (kg)	Top Level moisture removed (%)	Average percentage of moisture removed in each stage of curing
Fresh wt.		10.0		11.4		11.3		
Yellowing	44	7.5	36.8	9.4	23.5	9.4	23.8	28.0%
Color-fixing	20	6.2	19.1	7.6	21.2	8.7	8.8	16.4%
Leaf-drying	24	5.0	17.6	5.1	29.4	6.3	30.0	25.7%
Stem-drying	31	3.2	26.5	2.9	25.9	3.3	37.4	29.9%
Total	119		100%		100%		100%	100%
Wt.of dry leaves after final stage of curing (kg)		3.2		2.9		3.3		
Percent of moisture absorbed back by cured leaves after final stem-drying stage.		8.6%		9.4%		7.9%		7.9%(Average)

Note : tobacco leaves from Mae Jo Experiment Station

Table 5.7 Thailand Tobacco Monopoly (TTM) classification of tobacco leaf grades.

Grades	CAL	CAF	BAL	BAF	CBL	CBF	BBL	BBF	CCF	BCF	BG	NIL	NIS	NIG	N2	AA	BA	CA	DA
Major (Grade)	A	A	A	A	B	B	B	B	C	C	low quality					loose leaves			
Prices (Baht/kg)	41.95	44.40	41	43	35.27	36.85	34.40	36	29	28.50	19	17.50	13.50	9.50	9.50	43	37	29	21

Table 5.8

Grades of cured tobacco leaves

obtained from the experiments

Run	Percentage of each grade over total				
	Grade A	Grade B	Grade C	Lower than C	Average Price Baht/kg
LPG5	12.2	61.3	-	26.5	32.1
SOLAR1	9.8	47.7	-	42.5	27.5
SOLAR2	6.4	27.1	4.1	62.4	25.2
SOLAR3	-	33.1	13.4	53.5	18.1

Chapter 6

Conclusions

CONCLUSIONS

1. The use of solar heating resulted in energy savings of up to 20% (conservative estimate) in this study with LPG as the main fuel.

2. The authors believe that solar-assisted tobacco curing is technically viable, and that energy savings in the order of 30-40% over LPG are attainable, given more experience, more typical weather conditions, and better fresh leaves.

3. Whether a thermal storage would be useful in a solar-assisted tobacco curing process is still uncertain, due to limited data obtained in this study.

4. Tobacco curing is a complicated process involving many factors. Any energy-usage comparison between any two curing systems should be made on at least two identical curing barns, with similar fresh leaves and curing procedures, under the same weather conditions.

5. From an economic aspect, investment required for the solar heating unit is barely justifiable by the resulting savings in conventional energy consumption, at current prices. To make a solar heating system more attractive economically, either fuel prices have to increase, or the barn has to be utilized more, for example for drying of other crops during the off-season for tobacco.

Previous Page Blank

Chapter 7

Recommendations

Previous Page Blank

RECOMMENDATIONS

1. Further experiments should be conducted, preferably with two identical barns.

2. In future experiments, attempts should be made to isolate the effects of solar-assisted heating, rockbed thermal storage, other conventional fuels (firewood and lignite), different types of fresh leaves, and different curing procedures, under otherwise controlled conditions.

3. Serious considerations should be given to test-run the tobacco curing barn as a multiple-crop dryer during the tobacco off-season, to increase its utilization and to make investment in a solar heating system more economically feasible.

Previous Page Blank

Annexes

Previous Page Blank

Annex A

Spread Sheet Analyses of Results from Experimental Runs

Previous Page Blank

LPG 1 RUN OF TOBACCO CURING EXPERIMENT USING ONLY LPG,FEB 15-19,1984;MAE JO,CHIANG MAI.

DATE	TIME	BARN TEMP (C) LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5	LEVEL 6	WetBulb Temp(C)	Ambient Temp(C)	RH (%)	LPG.cons.rate. (KG/HR)	(MJ/HR)
Feb.15	21.30	25.2	25.4	25.7	25.2	26.5	27.3	24.7	23.1	-	0.00	0.00
	22.30	30.4	29.9	31.6	31.3	30.6	25.8	29.0	24.0	-	0.30	13.83
	23.30	32.6	32.4	34.0	34.0	33.6	32.1	31.2	23.2	-	0.40	18.44
Feb.16	0.30	33.7	33.7	35.4	35.4	35.0	33.0	32.4	23.3	-	0.30	13.83
	1.30	35.2	34.7	36.7	36.5	36.7	34.0	33.3	23.0	81.0	0.80	36.88
	2.30	35.1	35.0	36.9	36.4	36.1	33.2	33.4	22.6	81.0	0.10	4.61
	3.30	34.6	34.8	36.5	36.1	35.6	38.4	33.3	22.5	81.0	0.20	9.22
	4.30	35.0	35.8	36.8	36.5	35.5	33.7	33.6	22.3	81.0	0.70	32.27
	5.30	35.3	35.6	37.1	36.9	36.3	33.8	[illegible]	22.0	81.0	0.10	4.61
	6.30	35.3	35.0	35.7	35.2	34.9	33.6	33.2	22.5	81.0	0.20	9.22
	7.30	35.6	34.3	35.4	35.1	34.6	33.1	32.9	21.7	85.0	0.10	4.61
	8.30	34.5	33.8	34.9	34.6	34.3	32.6	32.4	22.5	85.0	0.20	9.22
	9.30	34.5	34.7	35.3	35.3	35.1	33.5	32.9	25.9	85.0	0.40	18.44
	10.30	35.6	35.7	37.0	36.7	36.6	34.9	33.7	28.4	85.0	0.30	13.83
	11.30	35.8	36.0	37.2	37.0	36.2	34.8	33.9	29.4	85.0	0.50	23.05
	12.30	37.2	37.6	39.2	39.4	38.8	37.3	35.5	30.2	85.0	0.10	4.61
	13.30	38.5	38.7	40.3	40.1	39.5	38.0	36.5	31.0	85.0	0.20	9.22
	14.30	38.5	39.0	39.6	39.7	39.3	38.2	36.2	32.5	85.0	0.20	9.22
	15.30	41.5	42.0	42.3	41.3	42.2	41.1	39.1	32.5	85.0	0.70	32.27
	16.30	43.9	44.1	44.2	43.7	44.8	43.6	41.4	32.5	-	0.80	36.88
	17.30	44.1	44.2	45.8	45.7	45.2	43.8	41.6	31.2	-	1.80	82.98
	18.30	41.9	41.5	42.9	42.6	42.3	41.5	38.9	28.5	-	2.10	96.81
	19.30	39.8	39.5	40.2	40.0	40.2	39.4	37.4	27.0	85.0	1.00	46.10
	20.30	40.6	41.8	43.0	43.0	42.4	40.1	37.4	26.2	80.0	0.70	32.27
	21.30	44.7	42.7	43.5	43.0	42.6	41.5	38.8	25.0	75.0	1.00	46.10
	22.30	45.8	44.9	47.5	46.7	46.4	44.5	40.3	24.0	71.0	1.20	55.32
	23.30	46.5	46.5	49.5	48.7	48.8	45.5	40.5	24.0	70.0	1.40	64.54
Feb.17	0.30	43.9	43.6	45.6	44.6	44.2	41.8	38.8	22.0	70.0	1.40	64.54
	1.30	43.5	43.9	45.7	46.4	45.9	43.3	39.9	22.4	70.0	0.60	27.66
	2.30	42.6	43.3	45.1	45.4	45.1	42.8	39.6	21.9	70.0	1.00	46.10
	3.30	44.4	45.3	47.1	48.3	47.4	45.3	40.6	21.9	60.0	1.20	55.32
	4.30	43.7	45.3	46.8	48.3	45.7	45.2	40.7	20.8	60.0	0.60	27.66
	5.30	44.0	45.1	46.9	47.5	47.2	45.2	40.2	20.0	60.0	0.90	41.49
	6.30	41.3	42.5	44.3	45.1	45.0	42.9	36.8	20.0	-	0.90	41.49
	7.30	41.9	43.1	44.9	45.5	45.7	43.1	37.6	21.0	-	0.60	27.66
	8.30	41.4	41.7	42.4	43.9	43.8	42.8	35.1	20.5	70.0	0.70	32.27
	9.30	47.8	45.1	45.6	47.3	46.4	45.2	37.9	25.7	-	1.80	82.98
	10.30	48.4	47.5	49.7	49.3	49.6	47.4	38.7	30.2	-	2.30	106.03
	11.30	46.9	45.7	47.7	47.0	47.4	45.9	38.9	31.2	-	1.50	69.15
	12.30	49.7	47.7	48.7	49.2	48.3	46.9	40.1	32.7	-	1.70	78.37
	13.30	50.9	49.5	51.0	51.4	49.7	48.0	40.2	35.0	55.0	2.10	96.81
	14.30	54.6	52.8	54.6	54.6	54.3	51.7	43.5	34.6	56.0	1.70	78.37
	15.30	-	-	-	-	-	-	-	-	-	0.00	0.00
	16.30	56.2	55.0	57.5	57.6	57.0	55.0	45.4	34.0	-	4.30	198.23
	17.30	56.7	55.8	57.5	57.8	56.8	54.8	46.0	33.1	-	1.40	64.54
	18.30	56.1	55.4	56.6	56.8	56.1	54.5	45.2	28.9	55.0	1.90	87.59
	19.30	55.5	55.5	56.4	56.4	56.5	54.7	44.2	25.3	-	2.40	110.64
	20.30	55.5	54.1	55.5	55.8	55.5	53.7	43.9	26.5	55.0	1.60	73.76
	21.30	58.0	55.3	56.8	57.0	56.3	54.5	44.4	25.1	-	0.80	36.88
	22.30	56.2	56.2	56.8	56.4	56.2	54.6	43.9	23.7	55.0	2.00	92.20
	23.30	56.2	55.5	57.0	57.0	57.7	55.7	45.0	22.7	-	1.70	78.37
Feb.18	0.30	57.2	55.7	57.1	57.5	56.9	55.7	45.0	22.5	-	2.60	119.86
	1.30	56.6	55.9	56.1	56.6	56.5	55.2	44.6	22.4	-	1.20	55.32
	2.30	57.6	56.3	56.9	57.0	57.2	56.2	44.5	21.5	55.0	1.40	64.54
	3.30	57.2	56.4	57.0	57.2	56.6	55.8	44.4	21.8	55.0	1.40	64.54
	4.30	58.8	56.4	57.6	57.8	57.4	56.4	44.3	21.0	55.0	1.60	73.76
	5.30	58.4	56.7	57.8	58.0	55.7	56.6	44.0	20.1	55.0	2.00	92.20
	6.30	58.4	57.7	58.2	58.1	57.7	56.7	44.3	20.3	53.0	1.40	64.54
	7.30	58.8	58.2	58.3	58.4	57.0	57.2	44.3	19.7	53.0	1.80	82.98
	8.30	59.4	58.9	60.1	59.9	59.4	58.5	44.5	21.4	50.0	1.50	69.15
	9.30	59.3	58.3	59.3	59.9	58.5	57.9	42.9	25.4	50.0	1.70	78.37
	10.30	61.3	59.2	60.3	61.1	59.9	58.6	43.1	28.8	50.0	1.40	64.54
	11.30	63.5	61.4	63.0	62.9	62.0	61.1	44.0	29.5	50.0	2.00	92.20
	12.30	64.0	62.8	64.6	64.9	63.7	62.5	45.2	33.3	50.0	1.50	69.15
	13.30	-	-	-	-	-	-	-	-	-	1.30	59.93
	14.30	-	-	-	-	-	-	-	-	-	3.00	138.30
	15.30	70.0	69.0	70.3	70.6	70.5	69.5	45.0	34.6	-	0.90	41.49
	16.30	65.6	64.5	65.5	65.5	65.6	64.6	48.1	33.5	-	1.20	55.32
	17.30	68.5	67.1	68.6	68.6	68.3	67.7	51.4	32.7	-	0.80	36.88
	18.30	68.7	67.1	68.8	65.6	69.2	67.8	52.1	32.6	-	2.40	110.64
	19.30	70.5	70.8	71.5	72.0	72.1	70.2	51.5	27.0	-	0.10	4.61
	20.30	69.8	68.5	69.6	70.0	69.8	68.8	49.9	26.7	-	0.80	36.88
	21.30	72.1	72.0	71.5	71.5	71.6	70.2	50.5	26.4	-	1.60	73.76
	22.30	65.4	66.0	66.5	67.7	67.8	67.5	48.4	26.2	-	1.00	46.10
	23.30	67.9	67.9	69.5	69.7	68.0	67.3	47.9	26.0	-	2.00	92.20
Feb.19	0.30	69.2	69.0	70.6	70.5	71.2	70.5	48.6	24.5	-	0.40	18.44
	1.30	68.6	69.0	70.2	70.3	70.8	69.8	48.9	23.2	-	1.20	55.32
	2.30	68.5	69.3	69.8	70.0	70.5	70.5	48.3	25.3	-	0.60	27.66
	3.30	68.6	68.8	69.5	69.1	70.3	69.8	45.0	24.5	-	2.70	124.[illegible]
	4.30	55.0	53.9	54.[illegible]	55.1	56.9	55.5	45.0	23.5	-	0.30	1[illegible]
	5.30	57.0	56.5	57.[illegible]	57.9	58.3	56.5	45.0	22.0	-	0.20	9.[illegible]
	6.30	61.2	62.0	64.5	64.8	67.0	63.0	43.0	21.0	-	0.20	9.22
	7.30	70.0	69.8	69.5	69.7	69.8	68.9	43.0	22.4	-	1.40	64.54

NOTE ; Fresh tobacco leaves = 750 kg
Cured tobacco leaves = 103.4 kg
Total LPG consumped = 94.5 kg (4356.45 MJ)

LPG 2 RUN OF TOBACCO CURING EXPERIMENT USING ONLY LPG, FEB 23-28, 1984; MAE JO CHIANG MAI.

DATE	TIME	BARN TEMP (C) LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5	LEVEL 6	Wet bulb Temp(C)	Ambient Temp(C)	RH (%)	LPG cons. rate (KG/HR)	(MJ/HR)
Feb.23	17.00	31.5	30.2	27.5	30.2	29.0	32.5	28.6	34.5	96.0	0.00	0.00
	18.00	31.4	31.7	31.5	31.9	30.9	32.2	30.4	30.2	97.0	0.20	9.22
	19.00	30.7	30.8	31.0	31.1	31.3	32.6	29.9	27.8	90.0	0.10	4.61
	20.00	29.7	31.0	29.2	30.2	29.4	32.0	28.4	25.0	88.0	0.50	23.05
	21.00	31.4	32.5	32.2	32.8	31.0	31.4	30.2	26.1	90.0	0.20	9.22
	22.00	32.2	33.4	33.2	34.1	31.9	32.3	30.8	24.1	90.0	0.50	23.05
	23.00	31.9	32.4	31.9	32.0	31.1	31.3	30.5	22.3	89.0	0.10	4.61
	24.00	32.7	33.1	32.7	32.7	31.4	31.6	30.9	21.4	90.0	0.20	9.22
Feb.24	1.00	32.4	33.1	32.4	32.4	31.0	31.4	30.6	21.5	89.0	0.20	9.22
	2.00	32.9	33.6	33.2	33.2	31.7	31.8	30.8	20.9	86.0	0.20	9.22
	3.00	32.8	33.3	33.1	33.8	31.3	31.5	30.6	20.8	85.0	0.20	9.22
	4.00	32.7	33.3	33.1	32.7	31.2	31.4	30.6	20.1	85.0	0.10	4.61
	5.00	32.4	33.0	32.9	32.6	31.1	31.2	30.5	20.0	84.0	0.20	9.22
	6.00	31.8	32.4	32.3	32.0	30.8	30.9	30.1	19.8	85.0	0.30	13.83
	7.00	32.0	32.7	32.4	32.1	30.7	30.8	30.2	19.5	85.0	0.20	9.22
	8.00	32.4	33.2	32.9	32.8	31.4	31.3	30.5	20.7	87.0	0.30	13.83
	9.00	32.7	33.0	32.8	32.7	32.1	32.0	31.7	23.9	92.0	0.20	9.22
	10.00	34.6	35.0	34.6	34.5	33.8	33.8	33.4	26.2	90.0	0.40	18.44
	11.00	33.5	33.4	33.8	34.0	33.8	34.3	32.2	29.5	92.0	0.20	9.22
	12.00	33.0	33.2	33.6	34.0	34.6	35.8	32.2	29.9	92.0	0.20	9.22
	13.00	32.8	33.0	33.7	34.3	35.1	36.5	31.6	31.6	90.0	0.10	4.61
	14.00	33.6	33.5	33.8	34.1	35.4	37.1	32.7	33.1	91.0	0.00	0.00
	15.00	37.7	37.9	38.0	37.6	37.2	37.8	36.8	33.1	84.0	0.20	9.22
	16.00	39.4	39.8	39.6	39.2	38.6	39.2	37.4	33.5	80.0	0.40	18.44
	17.00	37.3	37.9	37.6	37.2	36.8	38.5	36.1	33.0	86.0	0.10	4.61
	18.00	38.1	39.1	38.9	38.2	37.6	38.0	34.7	30.3	84.0	0.30	13.83
	19.00	36.2	36.8	36.6	36.2	36.1	37.1	34.4	26.4	86.0	0.20	9.22
	20.00	36.3	36.9	36.9	36.4	36.1	36.4	34.6	24.4	88.0	0.10	4.61
	21.00	34.8	35.1	35.0	34.7	34.7	35.2	33.3	26.0	89.0	0.20	9.22
	22.00	34.9	35.4	35.3	35.0	34.5	34.4	33.5	25.5	88.0	0.10	4.61
	23.00	35.7	36.3	36.2	36.2	35.0	34.7	34.1	24.3	87.0	0.20	9.22
	24.00	36.5	36.5	36.6	36.6	35.2	34.7	-	23.8	88.0	0.20	9.22
Feb.25	1.00	-	-	-	-	-	35.0	-	-	88.0	0.40	18.44
	2.00	-	-	-	-	-	35.0	-	-	87.0	0.20	9.22
	3.00	-	-	-	-	-	35.0	-	-	85.0	0.20	9.22
	4.00	-	-	-	-	-	35.0	-	-	85.0	0.20	9.22
	5.00	-	-	-	-	-	35.0	-	-	87.0	0.40	18.44
	6.00	-	-	-	-	-	35.0	-	-	87.0	0.30	13.83
	7.00	-	-	-	-	-	34.5	-	-	89.0	0.30	13.83
	8.00	34.7	35.0	34.9	34.6	30.1	34.9	33.1	22.4	87.0	0.30	13.83
	9.00	-	-	-	-	-	37.8	-	-	83.0	0.40	18.44
	10.00	-	-	-	-	-	38.5	-	-	84.0	0.20	9.22
	11.00	-	-	-	-	-	41.0	-	-	83.0	0.40	18.44
	12.00	40.6	41.1	41.0	40.7	40.2	39.6	38.6	30.8	84.0	0.50	23.05
	13.00	41.6	42.8	42.4	41.8	40.8	40.7	39.2	32.6	84.0	0.10	4.61
	14.00	40.5	41.3	41.0	40.5	40.0	40.7	38.6	33.9	85.0	0.70	32.27
	15.00	40.7	41.6	41.0	40.7	39.8	40.5	37.8	34.0	83.0	0.30	13.83
	16.00	40.1	40.5	40.2	39.8	39.4	40.4	37.7	33.9	80.0	0.20	9.22
	17.00	39.4	39.5	39.5	39.3	39.7	39.5	37.7	33.5	86.0	0.20	9.22
	18.00	39.5	40.1	39.9	39.6	39.4	39.0	37.5	30.5	84.0	0.20	9.22
	19.00	40.8	41.3	40.3	40.2	[illegible]	39.9	38.8	27.1	83.0	0.20	9.22
	20.00	41.4	42.0	41.4	41.7	[illegible]	40.6	39.1	26.5	85.0	0.40	18.44
	21.00	42.3	43.2	43.2	43.1	42.0	41.5	40.0	25.6	81.0	0.80	36.88
	22.00	42.0	42.9	42.7	42.2	41.3	41.7	39.7	24.3	82.0	0.50	23.05
	23.00	42.1	43.0	42.5	42.4	40.2	41.5	39.0	24.3	75.0	0.80	36.88
	24.00	42.1	43.3	42.6	41.5	39.3	40.0	37.0	22.1	69.0	0.40	18.44
Feb.26	1.00	44.0	45.4	45.1	44.9	42.0	40.6	37.6	22.8	66.0	1.00	46.10
	2.00	45.7	46.8	46.4	46.0	43.4	42.2	37.7	21.9	63.0	1.40	64.54
	3.00	46.0	47.0	46.7	45.8	43.7	42.3	37.3	21.5	60.0	1.00	46.10
	4.00	45.6	47.0	46.8	46.0	43.9	42.8	37.2	21.0	58.0	1.60	73.76
	5.00	45.6	47.1	46.8	46.3	44.0	42.4	37.0	20.8	58.0	0.80	36.88
	6.00	46.0	47.5	47.0	46.0	44.3	42.8	37.0	20.7	57.0	1.40	64.54
	7.00	48.7	48.0	47.8	46.8	44.2	43.7	38.0	21.2	58.0	1.30	59.93
	8.00	46.5	48.0	47.8	47.6	45.8	44.5	38.1	21.9	58.0	1.10	50.71
	9.00	46.3	47.8	48.2	48.1	45.6	44.3	37.9	24.0	56.0	1.40	64.54
	10.00	47.6	49.2	49.5	49.4	47.2	46.1	39.5	27.7	55.0	1.20	55.32
	11.00	48.7	50.5	51.3	51.9	48.3	48.2	40.8	29.8	55.0	1.30	59.93
	12.00	49.2	50.7	50.8	51.2	48.0	48.1	39.9	32.3	54.0	1.30	59.93
	13.00	49.5	50.4	51.2	50.8	48.1	48.6	39.8	34.7	53.0	1.20	55.32
	14.00	48.1	48.9	49.6	47.9	46.9	48.0	38.8	34.6	52.0	1.00	46.10
	15.00	49.6	51.3	50.8	49.3	48.3	47.9	38.9	35.2	52.0	1.00	46.10
	16.00	48.3	51.2	50.2	50.3	48.4	47.8	39.2	35.1	51.0	1.30	59.93
	17.00	49.5	49.4	48.4	48.3	47.2	47.9	39.1	34.5	49.0	1.20	55.32
	18.00	50.3	49.8	47.3	47.6	46.1	47.0	38.6	32.9	50.0	1.00	46.10
	19.00	49.1	50.0	48.0	47.5	45.9	46.3	38.2	31.4	52.0	1.20	55.32
	20.00	48.5	49.4	50.0	47.9	46.5	47.1	38.2	29.3	52.0	1.00	46.10
	21.00	48.2	49.2	49.5	49.1	47.6	47.1	37.7	28.5	52.0	1.10	50.71
	22.00	49.0	49.5	50.4	51.0	49.7	48.8	37.8	27.6	53.0	1.30	59.93
	23.00	47.4	48.5	50.0	50.2	49.5	49.0	37.4	27.1	54.0	1.00	46.10
	24.00	48.5	49.3	50.3	51.0	50.0	49.3	37.3	27.1	53.0	1.00	46.10
Feb.27	1.00	48.3	49.2	49.4	50.2	49.4	48.9	37.2	26.9	53.0	1.10	50.71
	2.00	47.6	47.7	48.7	49.9	49.2	48.7	36.9	26.3	51.0	1.20	55.32
	3.00	46.6	47.1	48.1	48.8	48.7	48.6	36.8	25.6	51.0	1.00	46.10
	4.00	48.4	49.4	50.2	51.5	51.4	49.2	38.4	24.8	53.0	1.10	50.71
	5.00	48.0	48.1	49.0	50.9	50.1	49.8	37.7	23.3	51.0	1.30	59.93
	6.00	48.1	48.5	48.8	49.8	50.2	49.5	37.5	23.2	50.0	1.20	55.32
	7.00	51.0	51.2	51.6	51.7	52.2	50.6	38.6	23.2	52.0	1.40	64.54
	8.00	49.8	50.2	51.0	51.5	52.3	50.9	38.5	24.0	50.0	1.40	64.54
	9.00	50.0	52.1	52.3	52.5	53.2	52.3	38.7	26.2	50.0	1.30	59.93
	10.00	56.8	56.2	55.3	55.8	56.1	55.1	40.0	27.5	48.0	1.40	64.54
	11.00	59.0	59.5	57.8	58.0	58.6	58.1	41.8	29.3	47.0	1.40	64.54
	12.00	58.2	58.7	59.0	59.2	59.6	59.2	42.0	31.1	46.0	1.50	69.15
	13.00	59.0	59.2	59.3	59.4	60.0	60.5	42.0	32.0	45.0	1.70	78.37
	14.00	59.5	58.5	59.0	59.5	58.6	58.2	40.6	33.5	43.0	1.10	50.71
	15.00	58.2	58.[illegible]	59.6	60.4	60.3	60.0	41.2	33.0	42.0	1.70	78.37
	16.00	64.5	65.6	66.1	66.8	67.1	66.7	44.7	31.9	39.0	1.30	59.93
	17.00	66.5	67.6	67.4	67.6	67.9	67.8	44.6	31.5	39.0	2.00	92.20
	18.00	64.8	65.4	66.3	65.7	66.3	65.6	44.1	29.2	39.0	3.10	142.91
	19.00	64.8	64.8	65.3	65.5	66.3	65.6	44.6	28.4	39.0	0.40	18.44
	20.00	65.9	66.2	67.0	67.1	68.2	66.6	46.5	28.3	38.0	1.80	82.98
	21.00	67.8	68.4	68.8	68.8	70.3	68.5	46.2	27.9	36.0	1.70	78.37
	22.00	60.5	62.9	64.0	63.5	64.3	64.8	40.0	27.5	38.0	1.90	87.59
	23.00	66.5	67.7	68.2	68.5	69.8	68.1	44.0	27.1	36.0	1.70	78.37
	24.00	70.1	71.2	72.0	72.2	72.6	71.7	46.8	26.0	37.0	1.60	73.76
Feb.28	1.00	70.8	71.8	73.1	73.2	74.3	74.0	47.1	24.8	35.0	2.00	92.20
	2.00	71.5	72.7	73.6	73.7	74.4	73.5	46.8	25.3	33.0	1.70	78.37
	3.00	69.3	70.2	71.7	71.8	72.7	72.4	46.0	25.6	32.0	0.90	41.49
	4.00	58.7	59.6	70.7	70.9	71.5	71.0	45.1	25.8	33.0	1.00	46.10
	5.00	69.1	70.0	71.1	71.4	72.0	71.2	45.2	25.2	33.0	1.30	59.93
	6.00	70.0	70.8	71.9	72.2	73.9	72.2	45.1	24.6	33.0	0.80	36.88
	7.00	66.5	67.7	68.3	68.2	69.2	68.9	43.1	23.9	33.0	0.60	27.66
	8.00	68.4	69.2	69.9	70.1	70.8	69.2	44.1	25.9	33.0	0.90	41.49
	9.00	71.2	71.9	72.6	72.7	73.2	72.0	43.3	27.9	33.0	1.10	50.71
	10.00	72.2	73.1	73.8	73.9	74.5	73.0	45.5	29.9	32.5	0.90	41.49

NOTE ; Fresh tobacco leaves = 930 kg
Cured tobacco leaves = 146.8 kg
Total LPG consumed = 89.8 kg (4139.78 MJ)

1^G 3 RUN OF TOBACCO CURING EXPERIMENT USING ONLY LPG,MAR 6-11,1984;MAE JO CHIANG MAI.

DATE	TIME	BARN TEMP(C) LEVEL 6 wet	LEVEL 6 dry	LEVEL 5 dry	LEVEL 4 dry	LEVEL 3 dry	LEVEL 1 wet	LEVEL 1 dry	Ambient Temp(C)	RH (%)	LPG,cons,rate. (KG/HR)	(MJ/HR)
MAR.6	18.00	30.2	30.3	29.9	29.9	31.2	30.0	32.6	29.0	89.0	0.00	0.00
	19.00	30.7	30.7	30.6	30.1	31.5	30.0	33.5	25.5	86.0	0.10	4.61
	20.00	31.0	31.0	31.0	30.1	31.5	29.7	33.0	24.2	84.0	0.10	4.61
	21.00	31.1	31.0	31.2	29.4	30.2	28.6	31.7	22.7	86.0	0.10	4.61
	22.00	30.3	30.4	30.7	28.8	31.1	29.2	33.1	22.2	85.0	0.00	0.00
	23.00	29.7	29.7	29.7	29.4	31.0	29.3	33.1	22.5	83.0	0.20	9.22
	24.00	29.5	29.1	29.5	29.4	31.5	29.2	32.6	20.9	85.0	0.10	4.61
MAR.7	1.00	29.8	29.3	29.6	29.7	32.1	29.4	32.9	19.0	[illegible]	0.20	9.22
	2.00	29.8	29.6	30.0	30.4	33.2	29.9	33.5	18.1	[illegible]	0.20	9.22
	3.00	30.1	30.0	30.3	30.9	33.7	30.2	33.9	17.4	83.0	0.20	9.22
	4.00	30.2	30.3	30.4	31.2	34.0	30.4	34.0	17.8	83.0	0.30	13.83
	5.00	30.3	30.6	30.7	31.4	34.2	30.6	34.1	17.9	82.0	0.30	13.83
	6.00	30.3	30.5	30.6	31.2	33.8	33.3	34.1	15.9	82.0	0.70	32.27
	7.00	30.2	30.4	30.6	31.2	33.3	30.0	33.5	16.4	82.0	0.30	13.83
	8.00	30.0	30.4	30.2	30.6	32.4	29.9	32.6	18.0	84.0	0.40	18.44
	9.00	30.8	31.1	31.1	32.0	33.9	31.0	34.1	22.4	85.0	0.40	18.44
	10.00	31.8	32.3	32.4	33.5	35.4	33.0	35.9	25.0	86.0	0.70	9.22
	11.00	34.0	34.3	34.1	35.1	36.9	34.4	37.6	30.3	85.0	0.40	18.44
	12.00	35.2	35.5	35.1	35.6	37.0	34.9	37.5	30.7	86.0	0.30	13.83
	13.00	35.9	36.4	35.5	36.2	37.5	35.0	37.6	31.9	84.0	0.20	9.22
	14.00	36.2	36.6	36.2	36.2	37.2	35.2	37.8	32.5	84.0	0.10	4.61
	15.00	36.4	36.8	36.4	36.3	37.5	35.4	38.3	32.9	84.0	0.20	9.22
	16.00	36.2	36.8	36.5	36.1	36.9	34.8	37.7	33.0	83.0	0.10	4.61
	17.00	36.1	36.5	36.4	35.8	36.4	34.6	37.2	32.7	82.0	0.10	4.61
	18.00	35.5	35.7	35.6	[illegible]	36.4	34.3	36.7	28.7	84.0	0.30	13.83
	19.00	34.5	34.8	34.7	34.0	34.6	32.4	35.1	25.2	83.0	0.20	9.22
	20.00	33.3	33.4	33.4	33.3	34.8	33.9	34.6	24.0	84.0	0.10	4.61
	21.00	33.2	33.8	33.8	35.3	36.8	33.3	36.3	22.5	84.0	0.20	9.22
	22.00	33.6	33.9	34.2	35.8	37.[illegible]	33.8	37.0	22.1	82.0	0.30	13.83
	23.00	35.0	34.0	34.2	35.7	37.0	33.5	36.8	20.2	85.0	0.50	23.05
MAR.8	24.00	35.0	34.3	34.4	36.1	37.5	33.4	36.5	20.0	83.0	0.50	23.05
	1.00	33.0	34.0	34.1	35.6	36.7	33.0	35.9	19.1	83.0	0.30	13.83
	2.00	32.7	33.6	33.8	35.1	36.0	32.7	35.9	17.4	83.0	0.40	18.44
	3.00	32.3	33.4	33.5	35.2	36.1	32.5	35.5	17.0	83.0	0.50	23.05
	4.00	32.8	34.0	34.0	35.9	37.2	33.5	36.1	16.5	85.0	0.30	13.83
	5.00	33.3	34.5	34.6	36.4	36.5	33.7	36.1	16.6	83.0	0.60	27.66
	6.00	33.6	34.6	34.6	36.2	37.1	33.4	36.7	15.7	82.0	0.70	32.27
	7.00	33.7	34.9	34.8	36.5	37.5	33.6	36.5	15.0	83.0	0.50	23.05
	8.00	34.2	35.5	35.4	37.2	38.3	34.3	37.8	18.4	81.0	0.60	27.66
	9.00	34.9	36.2	36.1	38.1	39.4	35.4	38.4	21.8	83.0	0.50	23.05
	10.00	35.7	37.1	37.0	38.5	39.5	35.8	38.5	26.7	83.0	0.50	23.05
	11.00	36.7	37.6	37.6	38.9	39.5	36.0	39.1	28.2	84.0	0.30	13.83
	12.00	36.7	37.3	37.2	37.8	38.4	35.6	38.3	30.5	85.0	0.20	9.22
	13.00	36.8	37.5	37.2	37.6	38.5	36.0	38.2	33.0	86.0	0.20	9.22
	14.00	36.8	37.5	36.9	37.7	38.6	36.2	38.4	33.6	88.0	0.20	9.22
	15.00	36.6	38.2	37.0	39.3	40.8	37.0	39.7	34.2	84.0	0.10	4.61
	16.00	36.7	37.4	37.2	37.3	37.7	35.5	38.6	33.6	81.0	0.10	4.61
	17.00	36.3	37.1	36.8	37.7	38.6	35.4	38.5	33.1	82.0	0.00	0.00
	18.00	36.0	36.8	36.4	37.3	38.2	34.9	38.1	28.9	82.0	0.10	4.61
	19.00	33.5	34.5	33.6	34.4	35.6	31.5	37.3	24.8	68.0	0.30	13.83
	20.00	32.8	35.0	34.3	37.7	39.3	33.7	41.1	23.0	62.0	0.90	41.49
	21.00	33.0	37.2	35.8	40.3	41.7	34.7	42.5	21.9	60.0	1.10	50.71
	22.00	34.2	38.1	36.7	40.5	41.5	34.7	42.1	18.5	65.0	1.00	46.10
	23.00	34.3	38.8	37.7	41.4	42.2	35.7	43.1	18.1	62.0	0.90	41.49
MAR.9	24.00	34.3	39.0	38.0	41.7	42.5	35.2	42.5	17.7	63.0	1.00	46.10
	1.00	35.0	39.3	38.5	42.2	42.9	35.3	42.9	16.3	64.0	0.90	41.49
	2.00	34.8	39.0	38.3	42.3	42.8	35.2	42.9	16.5	64.0	1.20	55.32
	3.00	35.4	39.2	38.5	42.0	42.5	35.6	43.0	16.7	63.0	1.00	46.10
	4.00	34.5	39.0	38.1	41.7	41.9	35.2	42.6	16.6	63.0	0.90	41.49
	5.00	34.7	38.9	38.1	41.6	42.0	35.5	42.8	16.8	62.0	1.10	50.71
	6.00	34.4	39.1	38.2	41.9	42.3	35.3	42.8	16.1	62.0	0.90	41.49
	7.00	34.4	38.6	37.9	41.7	42.4	35.8	42.5	18.1	62.0	0.80	36.88
	8.00	35.5	39.9	39.1	43.4	43.6	37.3	44.8	19.5	61.0	1.10	50.71
	9.00	34.7	39.0	38.1	41.3	42.6	34.8	42.7	22.5	57.0	1.10	50.71
	10.00	36.1	41.7	40.6	45.0	45.8	37.3	44.3	27.4	59.0	1.00	46.10
	11.00	37.6	43.7	42.7	46.4	47.0	38.2	45.7	30.7	58.0	1.00	46.10
	12.00	38.4	44.1	43.7	47.3	47.6	39.3	46.5	32.0	58.0	1.00	46.10
	13.00	38.7	45.0	44.3	48.2	48.5	39.3	47.4	33.7	56.0	1.00	46.10
	14.00	39.3	45.5	44.2	48.2	49.0	40.6	49.8	33.7	54.0	1.00	46.10
	15.00	40.9	47.3	46.6	51.8	52.0	42.5	51.5	33.7	52.0	1.20	55.32
	16.00	41.1	47.7	46.9	52.1	52.3	43.0	51.5	33.8	51.0	1.20	55.32
	17.00	41.5	48.4	47.9	53.8	54.0	43.0	52.6	33.2	50.0	1.40	64.54
	18.00	39.5	46.8	46.5	[illegible]	50.6	40.7	48.9	30.2	52.0	2.00	92.20
	19.00	41.3	47.8	47.3	52.4	51.2	42.4	50.2	27.7	52.0	1.10	50.71
	20.00	41.2	48.0	48.0	53.1	51.9	42.3	49.4	24.8	52.0	1.50	69.15
	21.00	39.8	47.9	47.6	53.0	51.9	40.2	49.8	21.7	50.0	1.50	69.15
	22.00	40.2	48.9	48.8	53.9	52.9	40.8	50.4	22.6	48.0	1.90	87.59
	23.00	39.9	49.3	48.9	54.0	53.4	40.7	50.9	23.5	47.0	1.50	69.15
MAR.10	24.00	39.6	49.1	48.7	53.9	52.5	40.6	51.1	21.0	46.0	1.70	78.37
	1.00	39.7	49.2	49.1	53.8	52.8	40.6	50.6	21.4	46.0	1.60	73.76
	2.00	40.6	49.5	49.6	54.6	53.3	40.7	51.6	19.2	46.0	1.50	69.15
	3.00	40.0	49.2	49.5	54.3	53.6	40.0	51.5	17.7	46.0	1.80	82.98
	4.00	39.7	49.2	49.6	53.9	53.3	39.5	51.0	16.8	46.0	1.60	73.76
	5.00	41.5	51.5	51.0	55.4	54.4	41.6	51.4	16.7	46.0	1.80	82.98
	6.00	40.0	50.3	50.3	54.4	54.0	39.9	51.5	16.6	46.0	1.70	78.37
	7.00	40.5	50.9	50.8	54.7	54.0	40.4	51.5	17.8	45.0	1.80	82.98
	8.00	41.8	53.1	53.6	58.0	57.5	42.3	53.6	20.8	46.0	1.80	82.98
	9.00	33.0	39.0	39.9	58.5	57.8	30.3	36.9	28.2	56.0	0.10	4.61
	10.00	34.5	41.0	41.7	44.0	43.5	34.0	42.0	29.0		1.20	55.32
	11.00	42.3	52.0	50.8	56.0	56.0	42.7	53.3	31.0	47.0	1.20	55.32
	12.00	43.6	56.1	56.4	61.3	60.4	43.8	57.1	30.3	43.0	1.30	59.93
	13.00	44.1	57.7	57.7	62.2	61.7	43.6	58.4	32.3	43.0	1.80	82.98
	14.00	46.5	61.6	61.3	66.2	65.2	46.2	61.5	33.5	42.0	1.00	46.10
	15.00	46.5	62.3	62.1	66.4	65.7	46.0	64.0	35.4	38.0	2.20	101.42
	16.00	44.9	61.5	61.6	65.0	64.8	44.0	63.5	33.4	-	1.70	78.37
	17.00	42.7	59.1	59.3	62.5	62.3	41.7	61.4	32.9	37.0	1.70	78.37
	18.00	43.7	61.0	61.2	64.0	63.8	42.4	63.5	30.5	37.0	2.10	96.81
	19.00	43.6	61.0	61.1	63.6	63.2	42.4	62.4	26.5	37.0	1.90	87.59
	20.00	41.6	58.3	58.4	60.5	60.3	40.3	60.5	24.4	36.0	2.00	92.20
	21.00	40.7	57.1	56.9	58.9	58.8	38.7	59.2	25.3	35.0	2.00	92.20
	22.00	41.1	55.7	56.6	58.5	58.1	38.9	59.1	22.7	36.0	1.90	87.59
	23.00	41.0	57.8	58.0	60.3	60.9	38.6	61.5	23.9	35.0	2.10	96.81
	24.00	46.2	65.6	65.0	67.9	67.1	43.6	66.5	22.1	33.0	2.10	96.81
MAR.11	1.00	45.9	65.8	65.9	68.9	68.5	43.4	67.0	20.6	33.0	2.30	106.03
	2.00	45.7	66.0	66.2	69.0	68.3	43.3	67.0	21.0	33.0	2.10	96.81
	3.00	46.5	67.3	67.6	70.0	69.6	43.5	68.0	19.0	32.0	2.00	92.20
	4.00	49.3	71.3	71.9	75.0	74.5	46.4	72.4	19.5	31.0	1.90	87.59
	5.00	48.8	70.6	71.1	75.2	72.4	45.5	70.0	18.5	32.0	1.80	82.98
	6.00	45.8	63.2	62.1	62.8	62.0	40.2	61.0	17.2	35.0	1.00	46.10
	7.00	47.4	66.5	67.0	68.4	67.4	42.8	68.7	18.3	35.0	1.50	69.15
	8.00	48.8	70.[illegible]	70.5	73.6	72.8	44.1	69.8	19.5	33.0	1.40	64.54
	9.00	48.7	69.4	70.4	71.5	70.6	43.0	[illegible]	23.8	31.0	1.70	78.37
	10.00	51.0	72.2	72.8	75.4	75.2	44.5	71.6	27.4	31.0	1.50	69.15
	11.00	51.2	72.6	73.3	74.9	74.6	43.6	72.5	29.5	31.0	1.10	50.71
	12.00	51.3	72.7	73.1	74.8	74.4	43.8	70.6	32.5	31.0	0.80	36.88
	13.00	52.6	74.4	74.8	76.6	76.3	44.4	72.9	32.8	31.0	1.10	50.71
	14.00	52.5	73.6	74.5	75.4	75.2	43.3	71.4	32.9	31.0	0.80	36.88
	15.00	49.8	68.6	69.8	68.0	68.6	40.8	66.6	32.0	31.0	0.60	27.66
	16.00	51.3	72.4	72.8	73.6	73.3	42.4	72.9	34.0	31.0	1.20	55.32

NOTE ; Fresh tobacco leaves = 1040 kg
Cured tobacco leaves = 199.6 kg
Total LPG consumpad = 110.1 kg (5075.61 M MJ)

LPG 4 RUN OF TOBACCO CURING EXPERIMENT USING ONLY LPG,MAR 14-19,1984;MAE JO,CHIANG MAI.

DATE	TIME	BARN TEMP (C) LEVEL 1 dry	LEVEL 1 wet	LEVEL 2 dry	LEVEL 3 dry (center)	LEVEL 3 dry (off-cen)	LEVEL 4 dry	LEVEL 4 wet	LEVEL 5 dry	LEVEL 6 dry	LEVEL 6 wet	Roof Vent.	Ambient temp. (C)	LPG cons.rate (KG/HR)	(MJ/HR)
Mar.14	18.00	31.8	30.1	33.5	30.8	30.3	33.1	30.1	31.8	32.5	31.3	34.0	30.1	0.00	0.00
	19.00	32.5	30.6	32.0	30.8	30.6	33.3	30.1	31.8	31.8	30.8	37.3	28.4	0.20	9.22
	20.00	34.7	32.0	34.0	32.3	31.5	32.8	31.3	33.2	32.3	31.3	30.1	26.0	0.30	13.83
	21.00	-	-	-	-	-	-	-	-	-	-	-	-	0.10	4.61
	22.00	-	-	-	-	-	-	-	-	-	-	-	-	0.10	4.61
	23.00	-	-	-	-	-	-	-	-	-	-	-	-	0.20	9.22
	24.00	-	-	-	-	-	-	-	-	-	-	-	-	0.50	23.05
MAR.15	1.00	-	-	-	-	-	-	-	-	-	-	-	-	0.30	13.83
	2.00	-	-	-	-	-	-	-	-	-	-	-	-	0.20	9.22
	3.00	-	-	-	-	-	-	-	-	-	-	-	-	0.30	13.83
	4.00	-	-	-	-	-	-	-	-	-	-	-	-	0.80	36.88
	5.00	-	-	-	-	-	-	-	-	-	-	-	-	0.30	13.83
	6.00	-	-	-	-	-	-	-	-	-	-	-	-	0.30	13.83
	7.00	-	-	-	-	-	-	-	-	-	-	-	-	0.30	13.83
	8.00	-	-	-	-	-	-	-	-	-	-	-	-	0.30	13.83
	9.00	-	-	-	-	-	-	-	-	-	-	-	-	0.20	9.22
	10.00	29.6	27.9	29.4	29.1	28.9	28.9	27.2	29.1	28.9	27.9	29.2	26.2	0.00	0.00
	11.00	29.6	27.7	29.1	29.1	28.9	29.1	27.4	29.4	29.6	29.1	32.5	27.7	0.00	0.00
	12.00	28.9	26.7	28.4	28.6	28.9	29.1	27.7	28.9	30.3	29.4	35.4	31.1	0.00	0.00
	13.00	29.9	26.4	30.3	31.3	30.8	31.1	30.3	32.0	32.5	31.5	37.6	33.7	0.00	0.00
	14.00	33.7	32.5	34.5	33.7	33.0	33.2	31.8	33.5	33.7	32.5	39.7	35.2	0.10	4.61
	15.00	34.9	30.1	32.5	32.5	32.5	32.5	30.1	32.5	34.9	32.5	39.7	32.5	0.00	0.00
	16.00	33.7	30.8	32.8	32.5	33.0	33.0	30.3	32.8	34.7	33.5	37.6	32.3	0.00	0.00
	17.00	34.2	31.1	33.0	32.3	32.8	33.0	30.6	32.5	34.5	33.0	34.2	31.1	0.10	4.61
	18.00	33.5	30.3	32.8	32.3	32.5	32.5	30.3	32.5	33.2	31.5	33.0	27.7	0.10	4.61
	19.00	34.2	30.6	33.2	32.5	33.2	33.0	30.3	32.8	33.0	31.3	32.0	24.0	0.20	9.22
	20.00	32.5	29.4	32.0	31.5	31.8	32.3	29.4	31.5	32.0	31.3	31.1	23.2	0.10	4.61
	21.00	32.3	29.1	31.5	31.1	31.3	31.8	29.1	31.1	31.1	29.9	29.9	21.0	0.10	4.61
	22.00	33.7	31.1	33.0	32.5	33.2	33.0	30.3	32.5	32.5	31.3	31.3	22.5	0.20	9.22
	23.00	32.8	29.9	32.3	31.8	32.5	32.3	29.6	31.5	31.8	30.3	29.9	21.0	0.20	9.22
	24.00	-	-	-	-	-	-	-	-	-	-	-	-	0.20	9.22
MAR.16	1.00	33.2	29.9	32.5	31.8	32.5	32.3	29.4	31.5	33.3	29.9	29.4	20.5	0.30	13.83
	2.00	32.5	29.1	32.0	31.3	31.8	31.8	29.1	31.1	30.6	29.4	27.9	18.8	0.20	9.22
	3.00	33.2	29.6	32.2	32.0	32.3	32.5	29.4	31.5	30.8	29.6	25.0	18.3	0.20	9.22
	4.00	32.5	29.1	32.3	31.5	32.0	32.0	29.1	31.1	30.6	29.1	28.1	17.0	0.20	9.22
	5.00	32.0	28.4	31.8	31.1	31.3	31.3	28.4	30.6	30.1	28.6	27.7	16.8	0.20	9.22
	6.00	33.2	29.6	32.8	32.0	31.8	32.3	28.9	31.8	30.6	28.9	27.9	15.8	0.20	9.22
	7.00	32.5	28.9	32.3	31.5	31.8	31.5	28.9	31.3	30.3	28.9	28.9	16.3	0.20	9.22
	8.00	31.1	27.7	31.3	30.6	30.3	30.6	28.1	30.3	29.6	28.1	26.9	17.5	0.20	9.22
	9.00	32.0	28.9	32.0	31.1	31.1	31.1	28.4	30.8	29.9	28.4	28.1	19.8	0.10	4.61
	10.00	31.3	28.1	31.3	30.8	30.6	30.6	28.1	30.6	29.9	28.4	29.4	21.2	0.20	9.22
	11.00	32.5	29.6	32.5	32.3	31.8	32.0	29.6	31.8	31.3	29.6	31.3	25.0	0.10	4.61
	12.00	34.2	31.5	34.0	33.5	34.0	33.7	31.1	33.0	33.0	31.3	34.9	30.3	0.10	4.61
	13.00	35.9	32.0	35.7	34.9	35.7	35.4	32.5	35.2	34.9	33.2	37.6	34.7	0.10	4.61
	14.00	35.9	32.8	35.4	34.7	35.7	35.7	33.0	34.9	35.2	33.5	38.8	34.2	0.20	9.22
	15.00	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00
	16.00	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00
	17.00	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00
	18.00	-	-	-	-	-	-	-	-	-	-	-	-	0.20	9.22
	19.00	-	-	-	-	-	-	-	-	-	-	-	-	0.20	9.22
	20.00	-	-	-	-	-	-	-	-	-	-	-	-	0.20	9.22
	21.00	36.9	34.0	36.6	36.4	36.4	36.4	34.2	36.6	36.6	35.2	36.6	30.6	0.20	9.22
	22.00	37.3	34.5	37.3	36.9	36.6	36.4	33.7	36.6	35.9	34.5	35.7	26.9	0.20	9.22
	23.00	37.8	34.5	37.6	37.3	36.9	36.9	34.2	37.1	36.1	34.5	35.7	26.0	0.20	9.22
	24.00	37.8	34.7	37.6	37.1	36.6	36.9	34.2	36.6	35.9	34.2	35.2	24.7	0.20	9.22
MAR.17	1.00	36.9	33.7	36.9	36.4	35.9	36.1	33.5	36.1	35.2	33.5	34.7	25.2	0.20	9.22
	2.00	38.3	34.9	38.3	37.6	37.3	37.3	34.2	37.6	35.9	34.2	35.7	23.5	0.20	9.22
	3.00	39.0	35.7	38.8	38.0	38.3	37.6	34.7	38.0	36.4	34.5	36.1	22.7	0.20	9.22
	4.00	36.9	33.7	36.9	36.4	35.9	35.9	33.2	36.4	34.9	33.2	34.2	20.8	0.20	9.22
	5.00	36.4	33.2	36.4	35.9	35.2	35.4	33.0	35.9	34.2	33.0	34.0	20.5	0.20	9.22
	6.00	36.6	33.2	36.4	35.9	35.4	35.7	32.8	35.7	34.7	32.8	34.0	20.5	0.20	9.22
	7.00	35.7	32.5	35.7	35.2	34.9	34.9	32.5	34.9	34.0	32.3	33.0	20.3	0.20	9.22
	8.00	37.1	33.7	36.9	36.4	35.2	35.6	33.0	36.1	34.7	32.8	34.0	19.5	0.20	9.22
	9.00	37.0	34.2	37.6	37.1	36.1	36.6	33.5	37.3	35.2	33.0	34.9	20.0	0.20	9.22
	10.00	35.7	32.5	35.7	35.2	34.7	34.9	32.0	34.9	34.0	32.3	33.5	20.3	0.10	4.61
	11.00	37.6	34.2	37.3	36.9	36.1	36.4	33.5	36.6	35.2	33.2	34.5	21.8	0.20	9.22
	12.00	39.0	35.4	38.8	38.0	37.1	37.6	34.5	37.6	36.4	34.2	36.1	25.2	0.30	13.83
	13.00	39.5	35.9	39.3	38.8	38.0	38.3	35.4	38.5	37.3	35.2	38.0	29.9	0.10	4.61
	14.00	38.0	34.9	38.0	37.6	37.6	37.8	34.9	37.6	37.1	35.2	39.3	32.3	0.20	9.22
	15.00	37.8	34.9	37.8	37.3	37.3	37.6	35.2	37.3	37.3	35.4	41.6	35.4	0.20	9.22
	16.00	38.5	35.7	37.8	37.1	36.9	37.1	33.2	36.6	36.6	33.7	38.8	36.6	0.30	13.83
	17.00	37.6	35.7	37.1	36.6	35.7	35.9	32.5	35.4	35.7	32.5	38.0	36.9	0.40	18.44
	18.00	-	-	-	-	-	-	-	-	-	-	-	-	0.40	18.44
	19.00	-	-	-	-	-	-	-	-	-	-	-	-	0.40	18.44
	20.00	-	-	-	-	-	-	-	-	-	-	-	-	0.50	23.05
	21.00	39.0	34.7	37.6	35.9	37.3	37.6	34.2	37.6	36.9	34.0	38.5	35.7	1.30	59.93
	22.00	-	-	-	-	-	-	-	-	-	-	-	-	1.20	55.32
	23.00	38.5	34.9	37.3	36.1	37.6	37.8	34.7	38.0	37.3	34.0	38.8	32.8	1.00	46.10
	24.00	38.3	33.7	36.4	35.2	36.4	37.1	33.7	36.9	36.4	33.7	37.3	28.9	1.60	73.76
MAR.18	1.00	37.8	33.7	36.1	34.7	36.1	36.6	32.8	35.9	35.7	32.8	36.7	27.7	1.70	78.37
	2.00	43.0	37.1	39.7	39.5	37.3	38.0	33.7	38.0	38.8	34.0	40.2	27.2	1.70	78.37
	3.00	43.5	36.9	40.5	38.5	38.3	39.5	34.7	40.2	40.0	34.5	42.1	24.5	1.80	82.98
	4.00	42.6	36.4	40.7	39.5	38.3	39.5	34.5	39.7	39.0	34.7	43.2	24.7	2.00	92.20
	5.00	45.2	37.8	42.1	41.4	39.5	40.7	35.2	41.4	40.9	34.9	43.5	24.0	1.70	78.37
	6.00	47.5	39.0	43.3	42.8	40.1	41.6	35.7	42.6	41.9	35.4	44.7	23.5	1.60	73.76
	7.00	50.1	39.3	48.3	44.8	41.3	44.5	36.4	44.8	42.7	36.4	45.9	21.7	2.00	92.20
	8.00	50.1	40.1	49.0	47.1	42.6	42.7	36.6	42.9	43.6	36.6	45.7	22.4	1.50	69.15
	9.00	-	-	-	-	-	-	-	-	-	-	-	-	1.90	87.59
	10.00	51.3	40.0	49.7	45.9	49.2	46.8	36.1	47.1	48.5	37.3	49.4	29.9	1.90	87.59
	11.00	51.0	39.7	50.1	48.0	47.3	46.4	36.6	46.6	47.6	37.8	49.7	33.5	1.40	64.54
	12.00	47.8	38.3	47.3	45.7	46.9	46.6	36.6	47.1	48.3	37.8	50.6	35.0	1.20	55.32
	13.00	50.8	39.7	48.7	48.0	49.4	48.0	37.3	48.3	49.9	38.5	51.7	35.0	1.80	82.98
	14.00	53.1	41.0	48.7	48.0	48.3	49.0	37.8	49.7	51.3	39.2	53.4	36.6	1.00	46.10
	15.00	53.8	42.3	49.7	48.7	51.0	49.7	38.3	50.6	51.7	39.9	53.8	35.9	1.60	73.76
	16.00	52.7	-	49.4	49.0	51.5	49.9	39.0	50.3	51.7	39.9	53.8	36.4	1.20	55.32
	17.00	55.2	-	50.8	50.1	52.4	50.8	39.2	52.4	53.1	40.3	55.0	35.5	2.00	92.20
	18.00	59.0	-	56.2	53.1	53.8	52.0	38.3	52.7	52.7	39.9	54.3	33.6	0.40	18.44
	19.00	52.4	-	49.9	49.9	50.8	50.6	38.5	51.0	50.6	39.4	51.7	29.9	2.60	119.86
	20.00	53.4	-	49.7	48.7	50.8	49.2	36.9	49.2	50.1	38.3	52.0	25.5	2.20	101.42
	21.00	54.3	-	51.0	50.1	52.2	50.8	38.3	51.5	52.7	39.0	52.9	26.9	1.60	73.76
	22.00	-	-	-	-	-	-	-	-	-	-	-	-	1.60	73.76
	23.00	-	-	-	-	-	-	-	-	-	-	-	-	2.40	110.64
	24.00	-	-	-	-	-	-	-	-	-	-	-	-	2.20	101.42
MAR.19	1.00	57.5	-	53.8	53.6	54.3	53.8	39.5	55.9	53.1	40.9	54.8	22.0	1.80	82.98
	2.00	-	-	-	-	-	-	-	-	-	-	-	-	1.20	55.32
	3.00	-	-	-	-	-	-	-	-	-	-	-	-	2.80	129.08
	4.00	63.0	-	58.9	58.2	57.3	59.8	43.0	60.8	58.2	44.2	61.2	19.8	1.40	64.54
	5.00	65.3	-	60.5	58.0	62.5	63.9	44.5	65.5	59.8	44.7	64.4	19.3	2.70	124.47
	6.00	67.3	-	64.2	61.9	61.7	63.0	43.5	61.0	60.1	45.2	67.8	18.5	2.70	124.47
	7.00	69.1	-	65.3	64.2	63.0	64.6	44.5	62.6	61.2	45.0	63.9	20.0	2.20	101.42
	8.00	76.8	-	76.5	73.2	67.6	70.3	48.5	70.9	66.4	48.7	71.2	22.5	2.80	129.08
	9.00	74.5	-	73.2	65.3	64.8	68.5	47.1	67.6	66.0	48.2	70.3	28.9	2.80	129.08
	10.00	73.3	-	69.8	66.4	64.8	68.0	46.6	66.7	65.1	48.0	69.6	30.3	1.80	82.98
	11.00	72.3	-	69.1	67.8	65.1	68.5	46.4	68.0	64.4	46.8	67.8	30.6	1.60	73.76
	12.00	71.2	-	68.0	64.8	64.2	66.2	46.1	67.3	65.1	46.4	68.5	33.0	1.80	82.98
	13.00	70.7	-	68.9	66.0	65.3	66.7	46.1	68.0	65.8	47.1	68.7	35.5	1.20	55.32
	14.00	71.8	-	70.3	68.5	65.8	67.1	47.1	68.7	66.7	48.2	71.4	35.7	1.30	59.85
	15.00	72.1	-	70.5	69.5	68.0	67.6	46.6	69.4	66.2	47.8	71.8	35.7	1.50	69.15

NOTE : Fresh tobacco leaves = 1178 kg
Cured tobacco leaves = 167.0 kg
Total LPG consumed = 90.4 kg (4167.44 MJ)

LPG 5 RUN OF TOBACCO CURING EXPERIMENT USING ONLY LPG,APRIL 5-10,1984;MAE JO,CHIANG MAI.

DATE	TIME	BARN TEMP (C) LEVEL 1 dry	LEVEL 1 wet	LEVEL 2 dry	LEVEL 3 dry (center)	LEVEL 3 dry (off-cen)	LEVEL 4 dry	LEVEL 4 wet	LEVEL 5 dry	LEVEL 5 dry	LEVEL 6 wet	Roof Vent.	Ambient Temp. (C)	RH (%)	LPG cons.rate (KG/HR)	(MJ/HR)
APRIL,5	18.00	-	-	-	-	-	-	-	-	-	-	-	-	85.0	0.00	0.00
	19.00	32.5	32.5	32.5	30.1	32.5	32.5	32.5	32.5	34.9	32.5	34.9	30.1	87.0	0.60	27.66
	20.00	32.5	32.5	32.5	30.1	32.5	32.5	32.5	32.5	34.9	34.9	34.9	27.7	90.0	0.10	4.61
	21.00	32.5	32.5	32.5	34.9	32.5	32.5	32.5	32.5	32.5	32.5	32.5	25.2	90.0	0.10	4.61
	22.00	32.5	30.1	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	27.7	90.0	0.20	9.22
	23.00	34.9	30.1	34.9	30.1	32.5	32.5	32.5	30.1	32.5	32.5	32.5	25.2	91.0	0.20	9.22
	24.00	34.9	32.5	32.5	34.9	32.5	32.5	32.5	32.5	32.5	30.1	32.5	27.7	91.0	0.20	9.22
APRIL,6	1.00	32.5	32.5	34.9	32.5	32.5	32.5	32.5	32.5	32.5	30.1	32.5	27.7	92.0	0.20	9.22
	2.00	34.9	32.5	34.9	30.1	32.5	32.5	32.5	32.5	32.5	32.5	32.5	25.2	92.0	0.10	4.61
	3.00	32.5	30.1	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	27.7	93.0	0.10	4.61
	4.00	32.5	30.1	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	25.2	93.0	0.10	4.61
	5.00	32.5	32.5	32.5	32.5	32.5	32.5	30.1	30.1	32.5	32.5	32.5	27.7	93.0	0.20	9.22
	6.00	32.5	32.5	32.5	32.5	32.5	33.7	30.1	32.5	32.5	30.1	30.1	25.2	91.0	0.20	9.22
	7.00	34.9	32.6	34.9	32.5	32.5	32.5	30.1	30.1	32.5	32.5	32.5	27.7	91.0	0.30	13.83
	8.00	34.9	30.1	34.9	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	27.7	90.0	0.20	9.22
	9.00	34.9	32.5	34.9	32.5	34.9	32.5	32.5	32.5	32.5	32.5	34.9	30.1	90.0	0.10	4.61
	10.00	35.4	33.2	34.9	34.5	35.9	34.0	33.2	34.0	34.5	33.5	35.4	31.3	91.0	0.10	4.61
	11.00	36.1	34.0	35.9	35.2	36.6	34.7	33.7	34.7	35.2	34.0	42.6	33.2	91.0	0.10	4.61
	12.00	36.4	34.2	36.1	35.4	36.9	34.9	34.0	34.9	35.7	34.2	45.8	34.5	91.0	0.10	4.61
	13.00	37.1	34.9	36.8	35.9	37.3	35.4	34.5	35.4	35.7	34.2	46.1	36.4	91.0	0.10	4.61
	14.00	37.3	35.2	36.9	36.1	36.4	35.7	35.2	36.1	36.9	35.9	42.1	37.6	90.0	0.10	4.61
	15.00	36.6	34.9	36.4	35.9	36.1	35.9	35.4	36.1	37.3	36.4	38.3	34.2	90.0	0.10	4.61
	16.00	34.7	32.3	34.5	34.5	34.7	34.2	32.8	34.5	36.1	35.2	36.4	28.6	89.0	0.60	27.66
	17.00	36.1	34.0	35.9	35.2	34.9	34.5	33.5	34.5	35.4	34.2	35.4	31.5	89.0	0.40	18.44
	18.00	35.4	33.5	35.4	35.2	34.9	34.5	34.0	34.5	35.2	34.0	34.5	29.9	90.0	0.30	13.83
	19.00	36.1	34.5	36.4	35.9	35.2	34.7	34.0	34.7	34.9	34.0	34.9	28.6	90.0	0.20	9.22
	20.00	36.4	34.5	36.6	36.1	35.1	34.9	34.2	34.7	34.9	34.0	34.2	30.1	89.0	0.20	9.22
	21.00	36.1	34.0	36.1	35.7	35.9	34.7	34.2	34.7	34.9	34.0	34.7	27.7	90.0	0.20	9.22
	22.00	35.9	34.0	36.1	36.1	35.4	34.7	34.0	34.7	34.9	34.0	34.7	28.7	89.0	0.20	9.22
	23.00	36.1	34.0	36.4	35.9	35.4	34.7	34.0	34.7	34.9	34.0	34.5	25.5	89.0	0.20	9.22
	24.00	36.9	34.0	36.9	36.6	36.6	34.9	33.7	34.9	34.9	34.0	34.9	25.0	86.0	0.20	9.22
APRIL,7	1.00	34.0	35.2	38.0	37.3	37.3	35.9	34.5	35.7	35.7	34.9	35.9	24.2	88.0	0.20	9.22
	2.00	37.8	35.2	37.8	37.1	37.6	35.9	34.7	35.9	35.7	34.9	35.9	23.7	87.0	0.40	18.44
	3.00	38.8	35.9	38.8	37.8	37.1	36.4	34.9	36.1	36.1	35.7	36.6	23.2	87.0	0.30	13.83
	4.00	38.3	35.4	38.3	37.3	37.3	36.1	34.7	35.9	35.9	35.2	35.9	22.7	87.0	0.30	13.83
	5.00	37.8	35.2	37.8	37.1	37.6	36.1	34.7	35.9	35.9	35.2	34.9	22.7	87.0	0.40	18.44
	6.00	37.6	34.9	37.6	37.1	36.9	35.9	34.5	35.4	35.7	34.7	35.2	22.0	86.0	0.30	13.83
	7.00	38.0	35.2	37.8	37.3	36.9	35.9	34.5	35.7	35.7	34.9	35.7	23.0	86.0	0.50	23.05
	8.00	-	-	-	-	-	-	-	-	-	-	-	-	86.0	0.30	13.83
	9.00	37.6	35.4	37.6	37.1	36.9	36.1	34.9	36.1	36.4	35.4	37.1	28.6	86.0	0.20	9.22
	10.00	38.3	35.7	38.0	37.8	38.3	36.4	35.2	36.4	36.9	35.9	39.7	30.6	84.0	0.50	23.05
	11.00	37.6	35.4	37.8	37.1	37.1	36.1	34.9	35.9	36.9	35.7	42.1	32.5	84.0	0.20	9.22
	12.00	37.8	35.4	38.0	37.3	38.0	36.4	35.4	36.1	37.3	35.9	45.7	34.5	85.0	0.20	9.22
	13.00	37.6	34.9	37.6	36.6	38.0	35.9	34.7	35.7	37.1	35.2	46.6	35.2	86.0	0.20	9.22
	14.00	37.6	34.9	37.6	36.4	38.0	35.9	34.7	35.7	36.9	34.9	47.5	36.1	86.0	0.10	4.61
	15.00	37.6	34.5	37.6	36.9	36.4	35.4	34.7	35.4	37.1	34.7	43.8	36.6	85.0	0.10	4.61
	16.00	36.9	34.2	36.6	35.9	35.9	35.2	34.2	34.9	36.6	34.7	42.1	36.4	83.0	0.20	9.22
	17.00	36.6	34.0	36.6	35.9	36.1	35.2	34.5	34.9	36.4	34.7	40.5	34.5	86.0	0.20	9.22
	18.00	37.1	35.4	37.3	37.1	36.9	36.4	35.7	35.9	37.3	35.7	35.9	32.8	86.0	0.10	4.61
	19.00	37.6	35.2	37.6	37.3	36.6	36.1	35.2	35.7	36.6	34.9	37.3	30.6	86.0	0.10	4.61
	20.00	37.1	34.9	37.3	36.9	36.6	35.4	34.5	35.4	35.9	34.2	36.9	28.9	86.0	0.10	4.61
	21.00	37.1	34.9	37.3	36.9	36.1	35.9	34.5	35.4	36.1	34.9	37.1	29.4	86.0	0.20	9.22
	22.00	37.3	34.9	37.8	37.3	36.6	35.4	34.5	35.4	35.9	34.5	37.3	28.1	86.0	0.20	9.22
	23.00	37.3	32.3	37.6	36.9	35.4	33.5	30.8	32.3	33.7	31.3	35.2	27.4	73.0	0.40	18.44
	24.00	39.5	33.5	39.3	36.9	38.8	34.2	31.3	32.5	35.4	32.5	37.3	26.7	68.0	0.10	4.61
APRIL,8	1.00	40.9	34.7	41.9	41.2	38.8	35.4	32.8	34.0	36.1	32.8	38.5	25.2	65.0	1.60	73.76
	2.00	38.0	32.5	39.5	39.3	37.3	35.2	31.5	33.5	34.9	31.5	37.3	25.0	70.0	1.10	50.71
	3.00	43.0	35.7	46.8	46.6	41.6	37.6	33.7	35.7	38.3	34.0	42.5	24.5	63.0	3.70	170.57
	4.00	42.1	34.9	43.5	43.5	39.5	37.6	33.7	35.4	39.5	34.2	41.2	24.2	65.0	1.80	82.98
	5.00	41.1	34.5	42.3	43.0	38.8	36.4	32.3	37.3	37.8	33.0	39.7	23.7	68.0	0.80	36.88
	6.00	41.2	34.9	42.6	42.6	39.5	37.3	33.0	34.1	38.1	33.5	40.9	24.2	66.0	1.20	55.32
	7.00	-	-	-	-	-	-	-	-	-	-	-	-	62.0	1.40	64.54
	8.00	-	-	-	-	-	-	-	-	-	-	-	-	65.0	1.60	73.76
	9.00	41.9	34.0	45.0	45.0	40.5	37.1	32.5	35.4	39.5	33.7	42.1	27.7	64.0	2.00	92.20
	10.00	40.7	34.9	41.9	41.4	40.5	37.6	33.7	37.6	38.5	32.3	40.2	31.8	66.0	0.60	27.66
	11.00	43.0	35.9	44.5	45.2	43.8	38.5	34.0	38.3	40.9	34.0	43.5	32.0	65.0	1.00	46.10
	12.00	40.9	37.9	42.6	42.3	40.7	37.8	33.5	37.8	39.7	32.8	41.9	33.2	68.0	0.80	36.88
	13.00	43.3	39.6	44.2	43.8	42.6	39.0	34.7	39.3	41.2	32.2	42.8	35.7	68.0	1.00	46.10
	14.00	43.5	36.4	45.0	44.5	43.8	38.5	34.0	39.0	41.4	34.2	42.8	35.2	67.0	0.60	27.66
	15.00	42.6	36.1	43.8	43.8	41.9	39.5	34.5	38.8	40.9	34.9	43.0	33.5	65.0	0.40	18.44
	16.00	47.5	37.8	49.0	49.4	47.1	42.8	35.9	42.8	43.0	36.1	46.6	30.8	62.0	1.60	73.76
	17.00	50.8	35.7	53.1	52.7	48.3	44.3	37.3	44.1	45.5	37.3	49.0	31.0	60.0	1.60	73.76
	18.00	50.1	40.1	51.5	51.5	48.0	46.2	36.6	42.9	46.6	37.8	51.5	30.3	56.0	1.30	59.93
	19.00	49.4	38.7	50.1	50.1	47.6	44.3	35.7	45.2	45.5	36.6	47.6	28.7	56.0	2.90	133.69
	20.00	50.1	40.1	51.5	51.5	48.0	46.2	36.6	42.9	46.6	37.6	50.8	27.1	55.0	2.00	92.20
	21.00	52.9	41.5	54.3	54.8	51.3	48.3	38.5	45.9	49.2	39.2	53.6	25.9	53.0	2.30	106.03
	22.00	53.8	42.1	54.5	55.9	54.3	50.1	39.4	48.5	50.8	39.7	55.5	26.4	53.0	2.10	96.81
	23.00	52.7	42.7	52.9	53.8	52.0	49.4	39.3	48.0	50.6	39.0	54.8	24.5	52.0	1.80	82.98
	24.00	51.5	41.6	51.7	52.7	52.2	49.9	38.0	50.3	50.3	38.5	53.1	24.8	52.0	2.40	110.64
APRIL,9	1.00	53.6	42.2	53.6	54.8	56.6	53.1	39.0	53.8	52.0	39.2	55.9	24.3	52.0	2.50	115.25
	2.00	52.9	42.2	52.9	54.3	57.3	52.0	38.7	50.6	51.7	39.0	57.2	23.4	50.0	2.50	115.25
	3.00	52.9	41.7	53.1	53.6	55.7	52.9	39.0	51.3	52.0	39.2	56.2	23.8	50.0	1.60	73.76
	4.00	53.3	42.0	54.1	55.0	57.6	54.5	39.0	54.5	53.4	39.2	57.6	23.8	50.0	2.00	92.20
	5.00	48.0	38.7	49.0	48.7	51.3	49.7	37.1	47.8	48.7	37.1	50.3	23.1	50.0	2.40	110.64
	6.00	52.7	41.0	52.9	54.1	55.9	53.6	38.3	52.7	52.4	38.5	57.1	23.6	50.0	2.00	92.20
	7.00	53.8	42.4	54.3	54.1	57.1	55.0	39.2	54.3	54.1	39.4	57.1	24.3	50.0	1.00	46.10
	8.00	54.1	42.9	53.8	54.3	56.4	55.5	39.4	55.7	53.8	39.2	57.3	25.2	47.0	3.20	147.52
	9.00	55.5	43.6	55.2	55.7	58.3	55.9	39.4	55.7	54.8	39.9	58.5	29.4	46.0	1.10	50.71
	10.00	59.0	-	59.0	59.9	63.6	59.4	41.5	58.5	58.3	42.4	63.4	31.7	46.0	1.70	78.37
	11.00	64.6	-	64.2	65.1	69.4	64.6	43.5	61.9	63.0	44.7	68.2	31.8	42.0	2.70	124.47
	12.00	-	-	-	-	-	-	-	-	-	-	-	-	42.0	1.80	82.98
	13.00	-	-	-	-	-	-	-	-	-	-	-	-	42.0	1.80	82.98
	14.00	63.5	-	64.2	64.4	66.7	62.8	42.3	60.3	61.9	43.0	-	36.4	42.0	1.40	64.54
	15.00	62.6	-	62.1	62.6	64.2	61.4	41.4	59.6	61.7	42.3	-	37.1	41.0	1.40	64.54
	16.00	62.6	44.0	62.8	63.5	65.1	62.6	41.2	62.8	62.1	41.6	-	37.1	40.0	1.80	82.98
	17.00	62.3	44.0	62.1	62.3	63.0	62.8	41.4	61.0	62.1	42.1	64.6	36.1	40.0	1.40	64.54
	18.00	62.6	42.3	62.8	63.0	67.8	63.9	42.1	63.5	63.3	42.6	66.2	34.2	39.0	1.60	73.76
	19.00	64.2	43.3	64.6	65.1	68.7	65.5	43.0	67.3	64.2	42.8	68.0	32.3	39.0	1.60	73.76
	20.00	66.4	44.2	66.9	67.3	71.2	67.6	44.0	69.6	66.2	43.8	70.9	30.3	38.0	2.00	92.20
	21.00	68.5	44.7	69.4	68.7	75.9	69.1	44.7	71.6	69.1	45.2	74.1	30.1	35.0	2.30	106.03
	22.00	70.0	46.1	70.9	71.2	76.8	71.2	45.0	72.7	71.2	45.7	76.3	27.7	34.0	2.50	115.25
	23.00	71.2	45.9	71.6	72.1	74.5	71.8	45.2	73.6	72.1	45.7	76.3	27.2	33.0	2.40	110.64
	24.00	73.0	47.1	75.6	75.2	79.6	73.0	46.1	73.0	73.0	45.9	76.5	27.2	31.0	1.90	87.59
APRIL,10	1.00	75.0	48.2	78.5	78.7	81.4	75.9	47.5	77.2	75.0	46.8	79.4	26.7	33.0	1.90	87.59
	2.00	72.7	47.1	74.3	75.0	78.1	75.6	47.3	75.9	74.3	46.8	76.3	26.0	33.0	1.70	78.37
	3.00	73.0	47.1	75.4	75.6	78.5	75.6	47.1	75.9	74.3	46.4	77.0	24.7	33.0	1.30	59.93
	4.00	74.5	49.9	76.1	76.8	77.5	77.4	47.5	77.4	76.1	47.1	77.4	24.7	32.0	2.00	92.20
	5.00	72.7	-	75.0	75.0	77.9	74.8	45.9	74.5	73.6	45.7	75.2	24.5	32.0	1.70	78.37
	6.00	76.8	-	79.2	79.4	82.1	77.2	47.3	78.3	75.9	48.4	79.0	23.2	31.0	1.30	59.93
	7.00	75.5	-	77.6	77.4	81.8	76.0	46.1	77.2	75.0	46.1	79.0	26.2	31.0	1.00	46.10
	8.00	76.1	46.8	78.5	78.5	80.3	76.8	45.9	77.9	75.4	46.1	79.0	28.3	31.0	1.40	64.54
	9.00	76.1	47.8	78.3	78.3	79.0	76.8	46.1	77.9	75.6	46.4	78.5	30.6	31.0	1.20	55.32
	10.00	65.8	43.5	66.9	67.8	68.0	70.9	43.8	69.8	70.9	44.2	69.4	28.9	31.0	1.00	46.10
	11.00	72.7	46.4	75.0	74.8	77.0	74.8	45.0	75.2	74.3	45.7	75.4	32.5	31.0	0.90	41.49

NOTE ; Fresh tobacco leaves = 962 kg
Cured tobacco leaves = 167.0 kg
Total LPG consumped = 111.4 kg (5135.54 MJ)

SOLAR 1 RUN OF TOBACCO CURING EXPERIMENT USING LPG+SOLAR, APRIL 17-20, 1984; MAE JO, CHIANG MAI.

DATE	TIME	BARN TEMP (C) LEVEL 1 dry	LEVEL 1 wet	LEVEL 2 dry	LEVEL 3 dry (center)	LEVEL 3 dry (off-cen)	LEVEL 4 dry	LEVEL 4 wet	LEVEL 5 dry	LEVEL 6 dry	LEVEL 6 wet	Roof Vent.	Ambient Temp.	RH (%)	LPG.cons.rate (KG/HR)	LPG.cons.rate (MJ/HR)	F.P.C. To-Ti (C)	F.P.C. ENERGY (MJ/HR)	I (MJ/HR, sq m.)
APRIL.16	24.00	34.0	29.9	32.0	31.1	29.6	29.4	29.4	29.1	29.6	29.1	30.1	26.0	88.0	0.00	0.00	0.0	0.00	-
APRIL.17	1.00	32.7	30.8	32.4	32.4	30.8	31.1	29.'	31.3	30.8	30.1	30.8	26.6	80.0	0.00	0.00	0.0	0.00	-
	2.00	33.1	30.8	32.9	32.9	31.1	32.3	29.7	32.5	31.1	29.9	31.0	25.0	78.0	0.00	0.00	0.0	0.00	-
	3.00	32.5	30.3	32.5	32.3	30.3	30.8	29.1	31.1	30.6	29.4	30.6	23.5	77.0	0.00	0.00	0.0	0.00	-
	4.00	32.0	29.9	31.8	31.3	29.9	30.1	29.4	30.3	29.9	28.6	29.9	23.0	78.0	0.00	0.00	0.0	0.00	-
	5.00	32.0	30.1	32.0	31.5	30.1	30.3	29.7	30.3	30.1	29.2	30.1	24.1	77.0	0.00	0.00	0.0	0.00	-
	6.00	32.0	29.9	31.5	31.0	29.9	30.1	28.5	30.3	29.9	28.7	29.7	23.8	77.0	0.00	0.00	0.0	0.00	-
	7.00	32.5	30.1	32.0	31.8	29.9	30.3	28.4	30.6	30.1	28.6	29.9	29.2	88.0	0.00	0.00	0.0	0.00	-
	8.00	33.1	31.5	32.9	32.9	31.0	31.0	30.6	31.0	31.0	30.3	31.7	30.8	90.0	0.00	0.00	0.0	0.00	-
	9.00	39.0	35.9	38.3	39.0	35.2	34.5	33.6	36.2	36.2	34.3	37.8	32.3	90.0	0.20	9.22	19.1	24.02	-
	10.00	35.9	35.2	36.4	35.7	35.2	35.2	33.7	35.2	36.1	34.2	38.0	26.9	92.0	0.10	4.61	23.1	29.06	-
	11.00	36.4	35.7	36.4	35.7	35.4	35.7	34.7	35.4	36.4	34.7	39.3	29.2	94.0	0.10	4.61	27.6	34.78	2.56
	12.00	36.4	35.9	36.4	35.7	36.1	36.1	35.4	35.7	37.3	35.7	44.0	30.8	93.0	0.10	4.61	30.2	38.14	2.79
	13.00	36.2	35.5	35.9	35.7	36.9	36.9	36.4	36.0	39.0	37.1	45.7	32.3	85.0	0.00	0.00	30.9	38.98	2.76
	14.00	34.7	33.7	35.7	36.1	37.1	37.6	36.4	37.1	40.2	38.3	45.7	33.7	86.0	0.00	0.00	25.3	31.92	2.48
	15.00	36.1	34.7	35.9	35.2	36.4	37.3	35.9	36.6	40.7	38.8	45.7	35.9	92.0	0.10	4.61	16.3	20.50	1.79
	16.00	36.9	35.7	36.4	35.9	36.1	36.6	34.9	36.1	40.2	37.6	43.3	35.7	93.0	0.10	4.61	5.5	6.89	0.30
	17.00	35.7	34.8	35.9	36.2	36.6	37.3	36.4	37.6	39.9	38.3	41.0	35.4	82.0	0.00	0.00	8.1	0.00	-
	18.00	35.5	34.5	35.5	35.2	35.0	36.2	35.0	36.6	39.0	38.0	39.7	34.1	89.0	0.00	0.00	7.9	0.00	-
	19.00	35.5	34.8	35.5	34.8	34.8	35.2	34.1	35.2	36.9	35.7	36.9	31.0	85.0	0.00	0.00	10.9	0.00	-
	20.00	37.8	36.6	37.6	38.0	36.4	36.4	35.5	36.4	36.6	35.9	37.3	29.4	91.0	0.00	0.00	13.0	0.00	-
	21.00	38.5	37.1	38.3	38.0	36.9	36.6	35.5	36.4	36.9	35.9	37.3	28.3	90.0	0.00	0.00	14.7	0.00	-
	22.00	38.5	37.1	38.3	38.7	37.3	36.9	35.7	36.9	37.1	36.2	37.6	28.0	90.0	0.20	9.22	15.1	0.00	-
	23.00	38.7	37.1	38.3	38.7	37.3	36.9	35.7	36.9	36.9	35.9	37.6	27.3	90.0	0.10	4.61	16.1	0.00	-
	24.00	37.3	36.6	37.3	37.1	36.6	36.4	35.2	36.1	36.4	35.7	36.9	26.2	90.0	0.40	18.44	16.7	0.00	-
APRIL.18	1.00	36.9	35.9	36.6	36.4	35.9	35.9	34.7	35.4	35.7	34.9	36.1	24.7	90.0	0.20	9.22	17.5	0.00	-
	2.00	37.1	35.4	36.6	36.6	35.9	35.4	34.2	35.2	35.2	34.7	35.7	23.5	90.0	0.20	9.22	17.8	0.00	-
	3.00	38.3	36.4	38.5	38.5	36.4	35.7	34.5	35.7	35.9	34.9	36.9	22.2	89.0	0.20	9.22	16.5	0.00	-
	4.00	38.8	36.9	39.0	39.0	36.9	36.1	34.7	36.1	36.1	35.2	36.9	22.2	85.0	0.20	9.22	19.0	0.00	-
	5.00	37.8	36.6	37.8	37.6	36.6	36.1	34.2	36.4	36.1	35.2	36.4	21.5	87.0	0.30	13.83	18.3	0.00	-
	6.00	37.8	36.1	37.6	37.6	36.6	36.1	34.2	35.9	35.9	34.9	35.9	22.2	88.0	0.40	18.44	18.8	0.00	-
	7.00	36.6	35.4	36.6	36.4	36.1	35.7	33.7	35.2	35.4	34.5	35.2	22.7	88.0	0.40	18.44	17.3	0.00	-
	8.00	39.7	37.6	39.7	40.0	37.3	36.4	35.7	37.3	36.9	35.4	38.5	24.5	85.0	1.00	46.10	11.9	0.00	-
	9.00	38.0	36.9	38.3	38.5	37.1	37.1	35.9	37.1	37.1	36.1	37.8	29.1	90.0	0.20	9.22	10.6	0.00	1.64
	10.00	38.8	35.4	37.8	37.6	35.7	35.4	33.5	35.9	36.6	34.5	38.3	32.0	68.0	0.00	0.00	28.6	8.74	2.15
	11.00	38.5	36.6	38.5	38.0	38.0	37.1	34.5	37.8	38.8	35.7	40.9	33.0	68.0	0.00	0.00	34.0	36.12	2.51
	12.00	37.3	35.4	36.4	36.1	35.9	36.4	34.2	36.1	37.6	35.4	39.3	34.0	76.0	0.00	0.00	29.1	42.84	2.15
	13.00	40.3	36.6	39.0	36.9	36.6	36.4	34.3	37.1	38.5	35.5	40.6	36.4	73.0	0.00	0.00	36.1	36.79	0.15
	14.00	42.2	38.7	42.2	39.9	40.8	39.7	36.4	40.2	39.7	36.9	43.1	38.0	71.0	0.00	0.00	41.6	45.53	2.15
	15.00	42.7	39.4	42.2	41.0	41.7	40.8	37.1	41.0	40.3	37.8	43.1	37.1	71.0	0.00	0.00	35.4	52.58	1.66
	16.00	39.5	37.1	37.3	36.6	37.8	37.8	35.2	36.9	39.3	36.6	40.2	36.6	70.0	1.40	64.54	24.6	44.69	1.48
	17.00	39.4	37.3	39.0	39.9	37.3	37.3	34.3	37.1	39.2	36.4	40.1	35.7	65.0	1.20	55.32	7.0	31.08	-
	18.00	42.8	39.5	41.9	42.3	40.5	39.7	35.7	39.7	40.9	37.1	43.3	34.2	65.0	0.20	9.22	21.8	0.00	-
	19.00	48.2	42.6	47.8	48.7	41.9	40.9	36.6	42.8	44.0	39.0	47.1	31.3	63.0	1.70	78.37	40.8	0.00	-
	20.00	47.3	43.3	46.8	46.8	43.0	41.6	37.3	41.9	43.8	38.8	45.9	29.1	62.0	1.50	69.15	46.5	0.00	-
	21.00	43.8	39.7	42.6	43.3	41.2	40.9	36.1	40.5	42.6	38.5	44.7	28.4	64.0	1.00	46.10	4.9	0.00	-
	22.00	47.6	40.8	46.6	44.8	44.8	42.2	36.9	42.7	44.3	39.9	45.7	28.0	65.0	1.00	46.10	11.9	0.00	-
	23.00	49.9	44.1	49.4	50.8	43.8	43.4	37.3	45.2	45.0	39.2	40.5	28.3	60.0	2.50	115.25	18.1	0.00	-
	24.00	52.0	42.4	51.7	52.0	52.0	45.7	37.6	46.1	53.6	41.2	53.8	27.7	50.0	2.20	101.42	1.0	0.00	-
APRIL.19	1.00	52.0	43.8	49.2	50.1	51.5	47.1	39.0	47.3	55.5	43.1	55.5	27.3	52.0	1.80	82.98	0.5	0.00	-
	2.00	50.1	43.4	50.8	50.8	53.1	47.6	39.2	47.3	55.5	43.4	55.7	26.9	52.0	1.80	82.98	0.5	0.00	-
	3.00	50.3	42.7	48.7	49.4	52.7	47.6	38.7	47.1	55.7	43.1	55.7	25.7	52.0	2.00	92.20	0.2	0.00	-
	4.00	49.7	42.2	48.5	49.0	53.6	48.0	38.5	47.3	55.7	42.9	56.2	25.0	51.0	2.30	106.03	0.5	0.00	-
	5.00	52.2	42.2	48.7	48.5	53.1	47.8	38.0	47.6	55.2	42.4	55.5	24.1	51.0	1.20	55.32	0.5	0.00	-
	6.00	53.6	43.8	50.1	50.8	54.8	49.2	39.4	49.4	55.2	43.6	57.6	24.5	51.0	2.00	92.20	0.5	0.00	-
	7.00	56.6	44.3	51.3	51.0	53.1	49.0	39.4	49.7	56.6	43.4	57.8	24.6	50.0	1.80	82.98	1.4	0.00	0.25
	8.00	56.2	45.0	52.4	52.7	52.9	49.9	40.1	51.3	55.7	44.3	57.8	27.6	50.0	1.90	87.59	4.4	0.00	0.61
	9.00	56.4	44.8	54.1	53.1	52.7	49.9	39.9	51.5	55.2	44.1	58.3	29.9	52.0	1.90	87.59	11.6	9.41	1.43
	10.00	53.4	43.8	52.7	53.1	52.4	50.3	40.6	51.7	55.2	44.5	57.6	32.2	52.0	1.20	55.32	36.3	29.40	2.00
	11.00	57.3	44.1	56.6	57.1	55.0	50.3	39.7	52.0	56.6	42.9	58.7	33.3	50.0	1.00	46.10	38.8	31.42	2.43
	12.00	55.9	44.8	55.2	55.5	54.8	51.0	39.2	51.5	54.8	43.1	57.8	35.5	49.0	1.20	55.32	35.4	28.56	2.46
	13.00	54.5	44.5	53.8	54.8	53.1	50.6	39.0	52.2	53.6	43.1	55.0	36.6	50.0	0.80	36.88	44.2	35.78	2.56
	14.00	57.3	45.0	56.8	56.8	58.7	53.8	39.3	54.5	57.3	43.8	58.9	37.1	47.0	1.20	55.32	47.4	38.30	2.20
	15.00	58.9	46.4	58.5	59.1	57.5	54.3	40.5	55.5	58.9	44.7	60.5	37.1	46.0	1.00	46.10	41.7	33.77	0.51
	16.00	60.1	47.3	59.6	58.7	69.6	58.7	39.7	59.4	61.4	45.9	63.3	35.9	43.0	1.70	78.37	28.0	22.68	1.12
	17.00	60.1	48.0	59.4	58.5	64.1	60.3	40.9	61.7	62.1	47.3	63.9	36.1	41.0	2.00	92.20	15.5	12.43	0.51
	18.00	61.4	49.2	58.9	58.5	65.1	60.5	41.4	59.6	60.8	49.0	61.0	33.5	39.0	2.00	92.20	7.9	6.22	0.05
	19.00	62.6	49.9	62.1	62.6	64.6	63.7	42.1	61.9	63.7	47.8	62.1	31.5	39.0	2.10	96.81	64.4	0.00	-
	20.00	63.1	50.1	63.4	63.8	62.2	63.1	42.0	62.4	62.9	48.3	62.4	30.8	39.0	2.00	92.20	1.2	0.00	-
	21.00	61.7	47.6	60.1	58.7	65.2	61.3	39.7	60.6	61.7	46.6	62.7	31.3	38.0	2.20	101.42	2.3	0.00	-
	22.00	59.4	46.6	58.7	57.8	64.8	61.0	39.4	60.8	61.0	45.9	62.0	30.6	38.0	2.20	101.42	1.6	0.00	-
	23.00	62.2	47.6	60.8	60.3	68.3	63.1	41.0	62.9	63.8	47.8	65.7	29.0	38.0	2.40	110.64	1.2	0.00	-
	24.00	61.9	48.0	61.4	60.8	68.7	64.4	41.2	63.9	64.6	48.0	66.0	27.9	37.0	2.40	110.64	1.5	0.00	-
APRIL.20	1.00	62.3	48.5	62.6	61.9	68.5	64.6	41.4	63.9	65.1	48.5	66.4	28.4	36.0	2.30	106.03	1.2	0.00	-
	2.00	64.6	49.4	63.3	62.1	69.1	65.5	41.4	63.9	65.5	48.7	66.9	27.9	36.0	2.70	124.47	1.2	0.00	-
	3.00	63.9	49.9	62.8	62.3	69.1	65.5	41.2	65.1	65.3	48.5	66.0	26.0	36.0	2.00	92.20	1.5	0.00	-
	4.00	64.6	49.9	63.3	62.1	68.7	65.5	40.9	63.3	65.3	48.7	66.0	24.7	35.0	2.20	101.42	1.2	0.00	-
	5.00	64.5	49.9	64.1	62.4	69.7	65.7	40.8	63.1	65.7	48.3	65.7	25.2	35.0	2.50	115.25	1.2	0.00	-
	6.00	64.5	49.7	64.3	63.4	69.2	65.7	40.6	63.6	65.7	48.3	65.9	24.5	35.0	2.10	96.81	0.9	0.00	-
	7.00	66.2	50.6	66.4	66.2	69.7	67.3	41.7	67.1	66.9	49.2	67.6	26.9	35.0	2.80	129.08	0.7	0.00	0.15
	8.00	69.9	52.4	70.3	69.2	73.1	69.7	43.1	69.0	69.7	50.8	71.0	28.7	34.0	2.00	92.20	3.0	0.00	0.71
	9.00	70.8	51.7	71.5	71.3	72.7	70.8	43.4	70.6	70.3	52.9	70.3	30.6	32.0	2.20	101.42	14.0	17.64	1.43
	10.00	71.4	53.4	72.1	72.1	73.0	70.7	43.5	71.4	70.3	52.4	70.3	31.3	32.0	1.50	69.15	25.2	31.75	2.00
	11.00	71.4	53.4	71.8	71.8	74.3	72.5	43.3	72.5	72.1	53.6	71.6	33.7	32.0	1.10	50.71	33.5	42.34	2.41
	12.00	71.4	53.8	72.1	72.1	73.8	71.4	43.3	72.5	71.4	52.0	71.6	34.9	32.0	0.60	27.66	37.0	46.70	2.64
	13.00	70.9	52.7	70.9	70.7	72.3	71.8	45.0	71.4	71.4	53.1	70.7	36.4	32.0	0.80	36.88	36.0	45.36	2.61
	14.00	70.0	52.7	70.7	70.9	70.5	70.3	45.4	71.4	70.3	52.9	70.5	36.6	32.0	0.50	23.05	27.6	34.78	1.66
	15.00	70.5	52.0	71.2	71.4	69.8	69.4	45.7	70.9	69.6	52.4	69.8	36.9	32.0	0.70	32.27	18.0	22.68	1.94
	16.00	69.1	52.2	69.8	70.0	69.4	69.6	44.5	70.3	69.6	52.7	70.0	37.1	31.0	0.60	27.66	12.3	15.46	1.17
	17.00	69.4	52.0	70.3	70.8	69.9	69.7	44.8	71.0	69.9	52.7	71.0	36.9	31.0	0.70	32.27	3.0	3.70	0.61
	18.00	68.0	51.1	68.7	69.1	68.2	68.5	44.0	69.6	68.5	52.0	69.6	34.7	31.0	1.20	55.32	0.2	0.00	0.05
	19.00	68.3	51.1	68.5	68.5	68.5	69.0	44.1	69.2	69.0	52.2	68.7	32.4	31.0	1.20	55.32	1.0	0.00	-
	20.00	70.1	-	-	-	-	-	-	-	-	-	-	-	31.0	1.50	69.15	0.4	0.00	-

NOTE ; (1) Fresh tobacco leaves = 962 kg
(2) Cured tobacco leaves = 168 kg
(3) Total LPG consumped = 90.5 kg (4172.05 MJ)
(4) Total energy from solar collector = 1031.52 MJ
(5) Total electricity used = 63.84 MJ
(6) Per-cent savings by solar = 19.58 % (4/(3+4+5))

SOLAR 2 RUN OF TOBACCO CURING EXPERIMENT USING LPG+SOLAR,MAY 3-7,1984;MAE JO,CHIANG MAI.

DATE	TIME	BARN TEMP (C) LEVEL 1 dry	LEVEL 1 wet	LEVEL 2 dry	LEVEL 2 dry (center)	LEVEL 3 dry (off-cen)	LEVEL 3 dry	LEVEL 4 wet	LEVEL 5 dry	LEVEL 6 dry	LEVEL 6 wet	Ambient Roof Vent.	Ambient Temp.	RH (%)	LPG.cons.rate (KG/HR)	LPG.cons.rate (MJ/HR)	F.P.C. To-Ti (C)	F.P.C. ENERGY (MJ/HR)	F.P.C. (MJ/HR sq m.)
MAY,3	17.00	32.3	30.3	31.5	31.3	31.1	32.0	31.3	31.5	32.5	32.0	41.6	33.7	95.0	0.00	0.00	13.0	0.00	-
	18.00	34.0	32.8	33.2	32.5	32.5	33.2	32.5	32.8	34.9	33.0	38.0	33.7	93.0	0.10	4.61	5.5	0.00	-
	19.00	33.2	31.8	33.0	32.5	32.5	33.7	32.5	33.2	34.7	33.2	35.2	30.6	90.0	0.10	4.61	2.7	0.00	-
	20.00	34.0	32.0	33.2	32.5	32.8	33.5	32.0	33.0	34.9	33.7	34.7	29.9	92.0	0.10	4.61	8.5	0.00	-
	21.00	34.9	32.5	34.0	33.2	34.2	33.2	32.3	33.7	33.[illegible]	32.5	33.5	28.9	91.0	0.10	4.61	9.5	0.00	-
	22.00	35.2	33.0	34.5	33.7	34.9	33.5	32.5	34.2	33.7	32.5	32.8	29.4	91.0	0.10	4.61	8.8	0.00	-
	23.00	34.2	32.5	34.0	33.2	34.0	33.5	32.3	33.5	33.5	32.5	33.2	29.4	91.0	0.10	4.61	7.6	0.00	-
	24.00	33.7	32.0	33.2	32.5	33.5	32.8	31.5	32.8	33.0	31.8	32.5	26.9	91.0	0.10	4.61	7.8	0.00	-
MAY,4	1.00	34.5	32.7	33.8	32.9	34.1	33.4	32.2	33.6	33.1	32.4	32.7	27.1	91.0	0.10	4.61	7.0	0.00	-
	2.00	34.3	32.7	34.1	32.9	34.3	33.4	32.0	33.6	33.1	32.[illegible]	32.2	26.4	91.0	0.10	4.61	6.3	0.00	-
	3.00	34.1	32.2	33.6	32.7	34.8	33.4	31.5	33.4	32.9	32.0	32.4	24.3	91.0	0.10	4.61	6.8	0.00	-
	4.00	35.2	33.1	34.5	33.4	35.0	33.8	32.4	34.1	33.[illegible]	32.7	32.9	25.2	91.0	0.10	4.61	6.3	0.00	-
	5.00	33.6	32.0	32.7	32.2	33.8	33.1	31.0	32.4	32.5	31.7	32.0	23.4	90.0	0.10	4.61	6.5	0.00	-
	6.00	32.9	31.5	32.2	31.5	33.6	32.4	30.6	31.7	32.2	31.0	31.5	24.3	90.0	0.10	4.61	7.0	0.00	-
	7.00	34.5	32.9	33.8	32.9	35.5	33.6	31.5	33.1	33.1	32.0	32.7	25.9	88.0	0.20	9.22	4.9	0.00	-
	8.00	33.1	32.2	32.4	32.0	33.6	32.9	31.0	32.0	32.[illegible]	31.7	32.0	27.8	90.0	0.20	9.22	5.1	0.00	-
	9.00	35.2	33.4	35.5	34.8	34.3	34.1	33.4	35.2	32.9	34.8	36.2	31.5	88.0	0.20	9.22	20.7	0.00	1.64
	10.00	34.8	32.2	34.5	34.3	33.6	33.4	32.7	34.3	32.2	32.7	37.8	32.0	90.0	0.00	0.00	45.6	37.45	2.30
	11.00	35.2	32.7	35.2	35.2	33.8	33.6	32.9	34.7	32.4	32.4	41.7	37.9	90.0	0.00	0.00	56.0	46.13	2.76
	12.00	34.0	31.5	34.0	34.0	32.5	32.5	31.5	34.7	32.0	31.5	42.6	33.7	90.0	0.00	0.00	56.1	46.13	2.97
	13.00	35.4	34.7	35.7	35.9	35.9	36.1	35.2	36.4	38.0	36.4	49.2	36.9	88.0	0.00	0.00	51.6	42.51	2.84
	14.00	34.9	33.2	35.2	35.4	35.9	37.1	35.7	36.9	39.0	37.6	48.7	36.4	88.0	0.00	0.00	54.5	0.00	2.58
	15.00	36.4	35.2	36.1	36.1	36.6	36.6	35.2	36.6	39.0	37.3	46.8	36.9	89.0	0.00	0.00	44.6	36.72	1.87
	16.00	34.9	33.2	35.9	36.1	36.9	37.8	36.6	37.8	40.2	38.3	42.8	36.1	86.0	0.00	0.00	31.6	25.87	1.15
	17.00	37.3	35.2	36.9	36.1	36.1	36.4	34.7	36.4	37.6	35.9	38.3	34.9	84.0	0.00	0.00	16.5	13.57	0.58
	18.00	34.9	33.2	34.7	34.9	35.4	35.9	34.7	35.9	37.3	36.1	37.6	33.7	85.0	0.00	0.00	6.2	5.07	0.17
	19.00	35.9	34.0	35.7	35.2	35.4	35.4	34.0	35.7	37.3	36.1	37.1	32.8	88.0	0.10	4.61	3.9	0.00	-
	20.00	35.9	34.0	35.2	34.9	36.6	35.4	33.7	35.2	36.4	34.7	35.9	30.8	88.0	0.10	4.61	1.7	0.00	-
	21.00	35.2	34.0	34.7	34.2	35.4	34.9	33.2	34.7	35.4	34.0	34.9	29.9	88.0	0.10	4.61	1.0	0.00	-
	22.00	35.2	33.7	34.5	34.0	35.4	34.9	33.2	34.5	35.2	34.0	34.2	29.1	88.0	0.10	4.61	1.0	0.00	-
	23.00	35.7	34.0	35.2	34.7	35.9	35.4	33.5	34.9	34.9	33.7	34.5	27.9	88.0	0.10	4.61	1.2	0.00	-
	24.00	35.7	34.1	35.5	35.0	36.2	35.7	33.6	35.2	35.2	34.1	34.5	28.0	88.0	0.20	9.22	0.7	0.00	-
MAY,5	1.00	35.9	33.7	35.7	35.2	36.1	35.7	33.2	35.4	34.9	33.7	33.5	27.2	89.0	0.20	9.22	1.0	0.00	-
	2.00	35.7	33.8	35.4	35.0	36.2	35.7	33.4	35.2	35.0	33.8	34.3	26.9	88.0	0.20	9.22	0.0	0.00	-
	3.00	35.2	33.6	35.2	34.8	36.2	35.5	32.9	34.8	34.8	33.4	34.3	26.2	88.0	0.20	9.22	0.0	0.00	-
	4.00	35.0	33.4	34.5	34.3	35.9	35.0	32.7	34.5	34.5	33.1	33.8	26.2	88.0	0.10	4.61	0.0	0.00	-
	5.00	34.5	32.9	34.3	34.1	35.5	34.8	32.2	34.1	34.3	32.9	33.6	25.5	88.0	0.10	4.61	0.0	0.00	-
	6.00	34.3	32.4	34.1	33.6	35.2	34.3	32.0	33.8	33.8	32.4	33.1	24.8	88.0	0.20	9.22	0.0	0.00	-
	7.00	35.2	32.9	35.0	34.5	35.9	35.0	32.4	34.5	34.1	32.7	33.4	25.2	85.0	0.20	9.22	0.0	0.00	0.33
	8.00	35.9	34.0	35.7	35.7	36.4	36.1	33.5	35.7	34.9	33.7	35.4	28.1	88.0	0.20	9.22	6.8	0.00	0.82
	9.00	36.9	34.0	36.6	36.1	37.8	36.9	34.0	36.6	36.1	34.7	37.1	31.1	89.0	0.10	4.61	26.4	0.00	1.61
	10.00	37.1	35.0	36.9	36.9	37.1	37.1	34.8	36.9	36.9	35.0	37.8	32.4	86.0	0.00	0.00	29.8	24.42	1.79
	11.00	38.0	35.7	37.3	37.1	37.8	37.8	35.5	37.6	37.3	35.7	44.8	34.8	87.0	0.00	0.00	55.1	45.41	2.05
	12.00	38.5	36.2	37.8	37.6	38.3	37.8	35.9	37.6	37.6	36.2	41.5	34.8	86.0	0.00	0.00	45.1	37.08	1.38
	13.00	37.8	34.7	37.6	37.1	37.1	37.1	34.2	37.3	35.4	34.0	36.4	24.2	86.0	0.00	0.00	12.2	9.95	0.35
	14.00	40.3	37.6	40.1	39.2	40.1	39.2	37.3	39.4	35.7	36.2	39.4	27.6	85.0	0.30	13.83	13.5	0.00	0.89
	15.00	38.0	36.4	37.8	37.3	38.0	37.8	35.9	37.3	38.3	37.1	40.8	33.6	87.0	0.10	4.61	32.3	0.00	1.28
	16.00	37.1	35.7	37.3	37.3	37.1	38.3	37.1	38.5	39.7	38.7	42.4	35.0	85.0	0.10	4.61	26.8	0.00	1.38
	17.00	37.6	35.9	37.6	37.1	37.3	37.1	35.7	37.3	39.0	37.6	39.5	33.5	84.0	0.10	4.61	14.2	0.00	0.71
	18.00	37.3	35.7	37.3	36.9	37.3	37.9	35.5	37.1	37.6	35.7	37.6	31.3	87.0	0.20	9.22	4.7	0.00	-
	19.00	38.3	36.1	38.3	37.3	37.8	37.3	35.9	37.6	36.9	35.9	36.9	29.9	82.0	0.10	4.61	1.9	0.00	-
	20.00	37.8	34.5	37.6	36.6	36.9	36.4	34.5	36.1	36.1	34.7	35.9	27.4	80.0	0.20	9.22	13.1	0.00	-
	21.00	41.4	37.3	41.6	40.5	39.3	38.0	36.3	39.0	38.3	37.9	40.5	26.0	75.0	0.60	27.66	58.8	0.00	-
	22.00	40.5	37.6	40.7	39.7	39.0	38.3	36.6	38.5	38.5	36.4	40.0	25.7	78.0	0.70	32.27	53.4	0.00	-
	23.00	-	-	-	-	-	-	-	-	-	-	-	-	78.0	0.60	27.66	-	0.00	-
	24.00	42.1	37.8	42.3	41.9	43.8	44.7	38.3	43.8	41.4	37.3	41.2	25.2	77.0	0.90	41.49	0.7	0.00	-
MAY,6	1.00	42.1	37.8	41.9	40.9	45.4	43.3	38.3	42.3	40.0	37.1	40.9	24.5	74.0	0.40	18.44	1.7	0.00	-
	2.00	41.6	37.6	41.6	40.9	42.8	43.0	38.3	42.1	40.5	37.3	40.9	24.0	76.0	0.60	27.66	1.2	0.00	-
	3.00	41.4	37.3	41.6	40.9	43.0	43.8	39.5	42.6	41.2	37.3	40.5	24.2	76.0	0.60	27.66	0.3	0.00	-
	4.00	41.4	37.3	41.4	40.5	42.8	43.0	-	41.9	40.7	37.3	40.5	24.7	76.0	0.50	23.05	0.0	0.00	-
	5.00	40.9	37.1	41.4	40.7	43.0	43.5	-	42.8	41.2	37.1	40.5	24.5	86.0	0.60	27.66	0.0	0.00	-
	6.00	-	-	-	-	-	-	-	-	-	-	-	-	86.0	0.70	32.27	-	0.00	-
	7.00	41.4	37.6	41.9	41.2	43.0	43.5	-	42.6	41.2	37.1	40.7	25.7	86.0	0.60	27.66	3.0	0.00	-
	8.00	41.4	36.6	41.6	41.1	43.5	44.2	-	42.8	41.6	36.4	41.9	26.4	68.0	0.80	36.88	8.0	0.00	0.51
	9.00	42.9	37.6	43.1	42.0	45.7	45.7	-	44.1	42.2	37.1	42.9	28.0	62.0	0.90	41.49	7.4	0.00	0.35
	10.00	43.6	37.8	44.8	42.9	46.4	47.1	-	45.7	43.4	37.6	43.8	27.1	60.0	1.00	46.10	3.3	0.00	0.30
	11.00	46.1	39.3	46.8	44.7	49.9	50.3	-	48.2	46.4	39.3	47.5	28.1	58.0	1.00	46.10	14.2	0.00	0.82
	12.00	49.4	41.2	49.4	46.8	53.8	55.5	-	52.9	50.8	41.2	50.8	27.4	57.0	1.80	82.98	19.6	0.00	1.74
	13.00	52.0	42.8	52.2	49.2	58.0	58.9	-	55.5	54.3	42.8	53.1	29.4	54.0	1.80	82.98	47.4	0.00	1.58
	14.00	52.4	43.5	53.1	50.3	56.8	59.1	-	55.2	55.0	42.6	55.0	30.3	52.0	2.00	92.20	39.7	0.00	1.53
	15.00	53.1	42.8	52.7	50.1	58.7	60.3	-	56.8	56.6	43.0	55.0	29.1	52.0	1.80	82.98	26.0	0.00	1.15
	16.00	55.7	44.2	55.5	52.9	59.8	61.0	-	58.2	56.6	44.0	58.5	30.1	48.0	1.80	82.98	26.2	0.00	1.6[illegible]
	17.00	57.5	45.4	54.5	52.7	63.3	63.3	-	59.1	58.9	45.2	60.8	30.1	48.0	2.00	92.20	17.1	0.00	0.76
	18.00	57.5	45.4	56.1	53.6	62.6	63.0	-	60.8	59.6	45.2	61.0	28.6	46.0	2.10	96.81	9.4	0.00	0.15
	19.00	56.8	47.1	55.5	55.0	66.9	68.7	-	64.6	63.9	46.8	63.5	27.9	45.0	2.40	110.64	4.4	0.00	-
	20.00	56.6	47.1	57.8	55.5	66.4	67.8	-	64.2	63.7	46.6	64.8	27.4	44.0	2.60	119.86	1.0	0.00	-
	21.00	59.8	47.3	57.8	57.8	66.4	68.2	-	64.8	64.8	47.1	65.5	28.4	43.0	2.50	115.25	0.2	0.00	-
	22.00	61.9	47.3	58.5	58.2	67.3	69.4	-	65.3	65.5	46.4	65.3	26.2	43.0	2.80	129.08	0.0	0.00	-
	23.00	62.6	47.5	59.8	58.7	67.6	69.6	-	64.8	66.0	46.4	66.2	26.0	42.0	2.60	119.86	0.0	0.00	-
	24.00	63.5	47.5	59.8	59.1	67.6	70.0	-	65.3	66.4	46.4	66.7	26.0	40.0	2.70	124.47	0.0	0.00	-
MAY,7	1.00	61.4	47.3	60.5	58.9	66.7	69.1	-	64.4	66.0	45.9	63.7	25.5	40.0	3.10	142.91	0.0	0.00	-
	2.00	60.5	47.3	60.5	60.1	68.7	70.5	-	66.2	66.7	46.1	67.6	24.5	39.0	1.90	87.59	0.0	0.00	-
	3.00	63.7	47.3	61.4	60.8	68.5	69.8	-	66.2	66.9	46.4	68.0	23.5	39.0	2.50	115.25	0.0	0.00	-
	4.00	63.9	48.5	62.8	61.9	70.7	72.3	-	68.2	68.9	46.8	69.8	24.2	38.0	2.80	129.08	0.0	0.00	-
	5.00	65.3	47.5	62.6	62.3	69.8	71.4	-	66.9	68.7	46.6	67.8	22.7	39.0	2.30	106.03	0.0	0.00	-
	6.00	62.1	46.4	60.5	59.8	68.9	68.2	-	64.8	66.2	45.4	65.8	19.3	39.0	2.60	119.86	2.3	0.00	-
	7.00	69.6	50.3	66.7	66.9	78.1	78.5	-	73.6	74.1	50.3	73.0	21.3	39.0	2.90	133.69	0.0	0.00	-
	8.00	70.0	50.1	70.7	70.9	73.8	77.0	-	72.7	73.6	51.0	70.9	20.0	39.0	1.50	63.15	0.0	0.00	-
	9.00	-	-	-	-	-	-	-	-	-	-	-	-	40.0	1.90	87.59	-	0.00	1.84
	10.00	71.4	51.3	72.1	71.8	74.3	77.2	-	73.6	76.1	52.4	73.6	26.7	39.0	1.90	87.59	19.2	0.00	2.05
	11.00	73.8	53.1	73.8	73.6	75.6	80.1	-	76.8	78.1	52.9	76.5	26.9	39.0	1.60	73.76	47.1	0.00	2.92
	12.00	66.4	49.2	65.7	66.4	67.1	68.5	-	67.1	68.9	48.0	67.3	28.1	39.0	1.10	50.71	23.9	19.72	2.41
	13.00	71.6	50.6	71.8	71.2	70.9	70.7	-	70.3	70.0	48.2	70.0	28.9	36.0	1.00	46.10	7.9	6.51	2.71
	14.00	7[illegible].1	51.3	72.1	72.3	73.2	73.0	-	72.3	71.6	49.2	71.4	28.6	35.0	1.30	59.93	5.4	4.34	1.38
	15.00	70.7	50.1	70.7	70.7	71.6	71.8	-	70.9	71.2	48.5	69.8	30.3	35.0	1.00	46.10	4.5	3.62	0.71
	16.00	73.0	52.0	73.2	73.4	75.6	77.6	-	75.4	76.5	-	74.5	31.1	35.0	1.30	59.93	20.7	17.00	0.51
	17.00	73.8	52.2	74.3	74.3	76.8	79.2	-	77.0	77.9	-	75.0	30.1	34.0	1.20	55.32	13.6	0.00	0.1
	18.00	75.0	52.4	75.2	75.2	78.7	81.4	-	78.7	79.6	-	76.5	28.4	34.0	1.00	46.10	7.5	0.00	-
	19.00	75.0	52.2	75.6	75.9	78.5	81.6	-	79.4	79.4	-	76.1	26.7	34.0	1.10	50.71	1.2	0.00	-
	20.00	75.0	52.4	75.6	75.9	78.3	81.2	-	79.2	79.0	-	75.6	24.7	34.0	1.10	50.71	0.4	0.00	-
	21.00	73.4	51.3	73.8	74.3	76.5	79.4	-	77.6	77.2	-	74.3	24.2	34.0	1.00	46.10	0.0	0.00	-
	22.00	75.2	52.0	75.4	75.9	78.5	81.2	-	79.2	79.0	-	75.9	23.2	33.0	1.10	50.71	0.0	0.00	-
	23.00	73.6	50.8	73.6	73.4	77.4	79.8	-	77.6	77.4	-	74.3	22.0	33.0	1.00	46.10	0.0	0.00	-
	24.00	72.1	49.7	72.3	72.7	75.6	78.3	-	76.1	75.6	-	73.0	20.3	33.0	1.00	46.10	0.0	0.00	-

NOTE ; (1) Fresh tobacco leaves = 962 kg
(2) Cured tobacco leaves = 180.9 kg
(3) Total LPG consumped = 83.8 kg (3863.18 MJ)
(4) Total energy from solar collector = 421.5 MJ
(5) Total electricity used = 32.56 MJ
(6) Per-cent savings by solar = 9.76 % (4/(3+4+5))

Best Available Document

SOLAR 3 RUN OF TOBACCO CURING EXPERIMENT USING LPG+SOLAR,MAY 15-19,1984;MAE JO,CHIANG MAI.

DATE	TIME	BARN TEMP (C) LEVEL 1 dry	LEVEL 1 wet	LEVEL 2 dry	LEVEL 3 dry (center)	LEVEL 3 dry (off-can)	LEVEL 4 dry	LEVEL 4 wet	LEVEL 5 dry	LEVEL 5 dry	LEVEL 6 wet	Roof Vent.	Ambient Temp.	RH (%)	LPG.cons.rate (KG/HR)	(MJ/HR)	F.P.C. To-Ti (C)	ENERGY (MJ/HR)	J (MJ/HR sq m)
MAY,15	18.00	29.1	27.9	28.9	28.9	29.1	29.9	28.9	29.1	30.8	29.6	31.8	28.9	88.0	0.00	0.00	4.9	0.00	-
	19.00	33.5	32.0	33.2	32.8	32.0	31.8	31.1	31.8	31.5	30.8	32.0	28.9	87.0	0.20	9.22	2.2	0.00	-
	20.00	34.0	32.8	34.0	33.7	33.2	33.0	32.0	33.0	32.3	31.8	32.8	27.9	87.0	0.10	4.61	0.3	0.00	-
	21.00	33.5	32.5	33.2	33.0	33.0	32.8	31.8	32.8	32.5	31.8	32.5	27.9	89.0	0.10	4.61	0.0	0.00	-
	22.00	33.5	32.3	33.5	33.0	33.0	32.8	31.5	32.8	32.5	31.8	32.5	26.2	89.0	0.10	4.61	0.0	0.00	-
	23.00	33.0	31.3	33.0	32.5	32.5	32.3	31.1	32.3	32.5	32.0	32.5	26.7	86.0	0.10	4.61	0.7	0.00	-
	24.00	32.5	31.3	32.5	32.0	32.5	32.0	31.1	32.0	32.3	31.3	32.0	25.7	88.0	0.10	4.61	1.7	0.00	-
MAY,16	1.00	-	-	-	-	-	-	-	-	-	-	-	-	86.0	0.20	9.22	-	0.00	-
	2.00	-	-	-	-	-	-	-	-	-	-	-	-	88.0	0.20	9.22	-	0.00	-
	3.00	32.5	31.1	32.8	32.0	32.5	32.3	30.8	32.0	32.0	31.1	31.1	24.2	87.0	0.20	9.22	2.0	0.00	-
	4.00	33.2	31.5	33.0	32.8	32.5	32.5	30.8	32.3	32.3	31.1	31.3	24.5	87.0	0.20	9.22	1.2	0.00	-
	5.00	33.2	31.3	32.8	32.5	32.5	32.5	30.8	32.3	32.0	[illegible]	31.1	23.7	87.0	0.20	9.22	0.8	0.00	-
	6.00	33.0	31.1	32.5	32.0	32.5	32.3	30.6	31.8	31.8	30.6	30.8	23.5	87.0	0.10	4.61	0.3	0.00	-
	7.00	32.5	30.8	32.3	32.0	31.3	31.8	30.3	31.8	31.1	30.3	31.1	23.7	87.0	0.10	4.61	0.5	0.00	0.43
	8.00	33.7	32.5	33.2	33.0	32.5	32.5	31.3	32.8	31.8	31.3	32.5	26.0	89.0	0.10	4.61	7.8	0.00	1.02
	9.00	34.7	32.0	34.5	34.0	33.2	33.2	31.3	33.0	33.0	31.8	33.7	28.6	82.0	0.10	4.61	28.8	23.60	1.71
	10.00	35.9	34.0	36.4	35.2	35.2	35.2	33.2	34.5	34.9	33.5	37.3	31.1	75.0	0.00	0.00	42.2	34.84	2.20
	11.00	35.7	34.0	35.4	34.7	35.4	35.2	33.5	34.7	35.2	34.0	41.9	32.3	87.0	0.00	0.00	50.6	41.58	2.61
	12.00	36.1	34.5	35.9	35.2	35.9	35.7	33.7	35.2	35.9	34.2	43.5	32.8	87.0	0.00	0.00	56.0	46.08	2.84
	13.00	36.6	34.0	36.4	35.7	35.9	35.9	34.0	35.7	37.1	35.7	39.0	33.0	86.0	0.00	0.00	41.5	34.09	1.67
	14.00	34.5	31.5	34.5	33.5	33.7	34.0	31.5	33.2	34.7	33.0	34.5	29.6	82.0	0.00	0.00	13.4	10.86	0.61
	15.00	33.7	32.0	33.2	32.3	33.2	33.2	31.1	32.0	33.2	32.0	33.2	28.9	86.0	0.10	4.61	8.7	7.12	0.64
	16.00	36.6	34.2	35.9	35.2	36.1	35.7	33.5	34.5	35.4	33.5	35.4	30.6	86.0	0.20	9.22	12.3	0.00	0.92
	17.00	37.1	35.4	36.9	36.4	37.1	37.1	34.9	36.4	36.6	35.2	36.9	31.1	86.0	0.20	9.22	13.4	0.00	0.53
	18.00	36.9	35.2	35.4	35.9	36.6	36.9	34.5	35.9	36.6	35.4	35.9	30.8	87.0	0.30	13.83	6.8	0.00	0.17
	19.00	37.8	35.4	37.3	36.9	37.6	37.1	34.9	36.4	36.6	35.2	35.2	29.1	85.0	0.20	9.22	2.2	0.00	-
	20.00	37.1	35.2	36.9	36.4	37.3	37.1	34.7	36.4	36.9	35.2	35.4	29.1	85.0	0.10	4.61	1.2	0.00	-
	21.00	36.9	34.7	36.6	35.9	37.1	36.9	34.2	36.1	36.6	34.9	34.9	28.1	84.0	0.10	4.61	1.0	0.00	-
	22.00	37.1	34.9	36.6	35.9	37.1	36.9	34.2	35.9	36.6	34.9	35.2	26.7	84.0	0.20	9.22	1.5	0.00	-
	23.00	37.6	35.2	36.9	36.4	37.6	37.6	34.5	36.4	37.1	35.2	35.7	27.2	82.0	0.20	9.22	2.0	0.00	-
	24.00	37.8	34.9	37.6	36.9	37.3	37.3	34.7	37.1	37.3	35.4	36.1	26.7	82.0	0.20	9.22	2.2	0.00	-
MAY,17	1.00	38.0	35.2	37.3	36.9	37.6	37.8	34.7	37.1	37.1	35.2	35.7	26.0	82.0	0.20	9.22	3.0	0.00	-
	2.00	37.8	34.9	36.9	36.4	37.1	37.6	34.5	36.9	37.1	34.9	35.7	26.2	82.0	0.40	18.44	3.0	0.00	-
	3.00	37.3	34.5	36.6	36.1	36.6	37.1	34.0	36.1	36.6	34.7	35.4	25.7	82.0	0.20	9.22	3.2	0.00	-
	4.00	37.1	34.2	36.4	35.7	36.4	36.9	33.7	35.9	36.6	34.5	33.7	25.2	82.0	0.20	9.22	2.5	0.00	-
	5.00	36.9	34.0	35.9	35.4	36.4	36.9	33.5	35.9	36.4	34.0	34.7	25.2	82.0	0.20	9.22	2.5	0.00	-
	6.00	37.6	34.5	36.9	36.4	36.9	37.6	34.2	36.6	36.9	34.7	35.4	25.2	82.0	0.20	9.22	2.2	0.00	0.05
	7.00	37.6	34.7	36.9	36.6	36.6	37.3	34.5	36.9	36.6	34.9	35.7	25.5	82.0	0.20	9.22	1.0	0.00	0.20
	8.00	37.6	34.9	37.1	36.6	36.6	37.3	34.5	36.6	36.6	34.9	36.1	27.4	82.0	0.20	9.22	7.5	0.00	1.02
	9.00	37.8	35.4	37.6	37.1	37.1	37.6	34.9	36.9	37.1	35.4	37.3	29.4	85.0	0.20	9.22	20.8	0.00	1.69
	10.00	38.0	35.2	37.3	36.9	36.9	37.1	34.5	36.4	36.9	35.4	38.5	30.3	84.0	0.00	0.00	41.9	34.46	2.28
	11.00	37.1	34.9	36.6	36.1	36.6	36.9	34.5	36.1	36.9	35.4	40.9	31.5	87.0	0.00	0.00	48.6	39.89	2.66
	12.00	37.3	35.4	37.1	36.4	37.3	37.1	34.9	36.6	37.1	35.4	41.6	33.0	87.0	0.00	0.00	54.4	44.76	2.87
	13.00	38.0	35.9	37.8	37.1	37.8	37.8	35.4	37.3	37.8	36.1	46.1	34.0	86.0	0.00	0.00	55.1	45.33	2.79
	14.00	38.3	36.4	38.3	37.6	38.0	38.0	35.9	37.6	38.3	36.6	42.3	34.7	85.0	0.00	0.00	48.5	39.89	1.66
	15.00	38.3	34.2	38.0	37.3	36.4	36.6	34.0	36.1	37.1	35.4	37.6	32.0	80.0	0.00	0.00	16.3	13.30	0.71
	16.00	-	-	-	-	-	-	-	-	-	-	-	-	77.0	0.00	0.00	-	7.12	1.28
	17.00	-	-	-	-	-	-	-	-	-	-	-	-	74.0	0.00	0.00	-	0.00	0.61
	18.00	-	-	-	-	-	-	-	-	-	-	-	-	82.0	0.20	9.22	-	0.00	-
	19.00	-	-	-	-	-	-	-	-	-	-	-	-	82.0	0.20	9.22	-	0.00	-
	20.00	-	-	-	-	-	-	-	-	-	-	-	-	82.0	0.20	9.22	-	0.00	-
	21.00	-	-	-	-	-	-	-	-	-	-	-	-	82.0	0.10	4.61	-	0.00	-
	22.00	37.1	34.2	36.4	35.7	36.6	36.9	33.7	35.9	36.9	34.5	35.2	25.7	82.0	0.20	9.22	0.0	0.00	-
	23.00	37.3	34.7	36.9	36.4	36.9	37.3	34.2	36.6	37.1	34.9	36.1	25.7	82.0	0.20	9.22	0.3	0.00	-
	24.00	38.0	34.9	37.3	37.1	37.6	37.8	34.7	37.3	37.3	35.2	36.6	26.0	80.0	0.20	9.22	0.0	0.00	-
MAY,18	1.00	37.6	34.9	37.1	36.9	37.3	37.8	34.5	37.1	37.1	35.2	36.1	25.2	80.0	0.50	23.05	0.0	0.00	-
	2.00	38.0	34.9	37.3	37.1	37.6	38.3	34.7	37.3	37.3	35.2	36.6	26.0	80.0	0.30	13.83	0.0	0.00	-
	3.00	38.3	35.2	37.8	37.3	37.8	38.5	34.9	37.6	37.8	35.4	37.1	25.0	80.0	0.30	13.83	0.0	0.00	-
	4.00	36.6	34.2	36.6	35.9	36.4	37.1	34.0	36.1	36.9	34.7	35.7	24.5	80.0	0.20	9.22	0.0	0.00	-
	5.00	36.6	34.0	36.1	35.7	36.1	36.9	33.7	35.9	36.4	34.5	35.4	24.5	80.0	0.30	13.83	0.0	0.00	-
	6.00	40.7	35.7	39.7	38.5	39.5	40.0	35.4	38.5	38.8	35.4	37.8	24.5	80.0	0.30	13.83	0.0	0.00	0.05
	7.00	40.7	33.5	39.7	39.0	42.3	40.2	33.7	38.8	38.8	34.2	39.3	24.7	67.0	1.00	46.10	1.2	0.00	0.30
	8.00	44.7	36.1	43.3	43.3	43.5	44.5	36.6	42.8	42.8	37.1	42.1	27.4	62.0	1.10	50.71	9.5	0.00	0.89
	9.00	45.2	36.6	44.0	43.8	44.7	44.7	37.1	43.0	43.3	37.8	43.3	27.9	60.0	1.00	46.10	20.1	0.00	1.74
	10.00	43.5	36.9	44.0	42.3	39.5	41.2	35.9	40.5	40.9	36.9	42.3	28.6	56.0	1.20	55.32	28.0	23.04	2.28
	11.00	49.6	43.9	51.1	48.6	50.3	50.1	43.0	49.0	49.9	43.9	52.0	35.4	56.0	1.20	55.32	42.1	34.65	2.20
	12.00	51.8	42.8	49.0	47.3	51.6	49.9	42.8	48.4	49.9	43.7	52.0	36.0	57.0	0.80	36.88	48.9	40.27	2.82
	13.00	51.3	43.5	50.5	49.4	52.2	50.5	43.7	49.4	51.1	45.0	53.5	36.7	54.0	1.00	46.10	50.0	41.21	2.66
	14.00	55.0	44.7	53.3	51.1	53.7	51.6	44.7	51.1	52.4	45.8	55.4	37.7	49.0	1.00	46.10	38.9	32.03	2.41
	15.00	53.8	42.6	52.2	50.6	56.6	52.0	42.6	50.8	53.8	44.2	55.9	34.0	49.0	1.40	64.54	34.4	28.28	1.84
	16.00	57.1	44.0	52.9	54.1	57.8	55.2	44.0	53.4	56.1	45.7	59.8	33.5	46.0	2.00	92.20	22.4	18.36	1.58
	17.00	56.6	42.6	56.1	56.4	59.6	56.1	43.3	55.0	58.2	46.4	62.1	33.5	45.0	1.80	82.98	8.6	6.93	0.56
	18.00	57.3	42.8	57.3	57.1	58.7	56.6	44.0	55.5	59.4	46.8	63.7	32.5	50.0	2.40	110.64	7.2	0.00	-
	19.00	-	-	-	-	-	-	-	-	-	-	-	-	50.0	2.00	52.20	-	0.00	-
	20.00	-	-	-	-	-	-	-	-	-	-	-	-	48.0	2.60	119.86	-	0.00	-
	21.00	55.2	41.4	54.5	55.0	60.8	58.9	43.5	57.5	61.2	46.6	66.0	28.9	47.0	2.80	129.08	1.0	0.00	-
	22.00	56.6	40.7	54.8	54.8	59.6	58.9	42.6	57.5	61.0	46.4	65.3	28.1	45.0	2.70	124.47	0.0	0.00	-
	23.00	56.8	40.5	55.0	55.2	64.2	60.5	42.8	58.5	62.3	46.8	66.2	28.4	45.0	2.40	129.08	0.0	0.00	-
	24.00	59.1	46.1	59.1	59.1	66.2	63.9	45.7	61.9	66.4	50.1	66.4	24.7	45.0	2.70	124.47	0.0	0.00	-
MAY,19	1.00	56.1	44.7	56.6	56.8	61.9	60.8	43.5	58.7	62.6	47.5	64.8	21.8	45.0	2.40	110.64	1.5	0.00	-
	2.00	57.8	45.2	56.6	55.9	62.3	59.8	42.8	58.5	63.5	48.0	66.9	25.5	45.0	2.60	119.86	0.0	0.00	-
	3.00	-	-	-	-	-	-	-	-	-	-	-	-	45.0	2.20	101.42	-	0.00	-
	4.00	-	-	-	-	-	-	-	-	-	-	-	-	45.0	1.80	82.98	-	0.00	-
	5.00	-	-	-	-	-	-	-	-	-	-	-	-	44.0	2.20	101.42	-	0.00	-
	6.00	-	-	-	-	-	-	-	-	-	-	-	-	44.0	2.40	110.64	-	0.00	-
	7.00	62.3	46.6	63.3	63.5	71.4	67.8	45.7	65.5	69.6	50.1	71.4	26.2	42.0	3.00	138.30	2.5	0.00	0.43
	8.00	62.8	47.1	64.2	64.4	72.7	68.9	45.9	67.1	70.3	50.8	74.1	26.7	41.0	2.40	110.64	7.8	0.00	0.94
	9.00	61.9	46.1	62.6	62.8	68.5	66.4	45.7	64.6	68.0	50.6	67.3	27.9	40.0	2.40	110.64	19.2	0.00	1.38
	10.00	71.4	51.0	70.7	70.0	74.1	72.7	48.0	71.8	75.0	52.2	75.6	29.6	39.0	2.60	119.86	40.9	0.00	2.25
	11.00	66.0	48.5	69.1	67.6	71.8	70.0	46.6	68.5	71.6	50.6	72.1	30.6	39.0	1.50	69.15	34.7	28.47	2.58
	12.00	70.0	49.7	70.3	70.3	74.3	73.4	48.5	72.3	75.2	54.5	76.5	31.1	37.0	1.70	78.37	38.8	31.84	2.82
	13.00	70.3	49.7	71.8	71.6	74.9	74.3	46.8	72.5	74.8	52.7	75.2	31.8	34.0	1.70	78.37	37.9	31.09	2.71
	14.00	72.7	50.1	73.0	73.4	75.2	74.5	47.8	74.5	75.4	54.1	77.0	32.3	34.0	1.30	59.93	34.5	28.2[illegible]	2.43
	15.00	70.3	49.2	72.1	71.8	73.6	73.0	46.8	72.5	73.4	51.5	74.8	32.1	35.0	1.30	59.93	26.4	21.73	2.00
	16.00	73.7	52.6	74.7	73.9	74.7	74.5	49.9	74.1	75.0	54.1	75.2	38.1	34.0	1.80	59.93	15.3	12.55	1.38
	17.00	73.7	54.1	75.2	74.7	79.9	76.9	49.9	76.0	78.1	55.0	80.5	37.3	34.0	1.60	73.76	3.4	9.55	0.66
	18.00	70.9	52.6	74.1	73.9	75.2	76.9	49.6	75.4	77.3	55.2	76.0	37.3	33.0	1.30	59.93	4.5	0.00	0.17
	19.00	73.0	51.0	74.8	74.8	77.2	77.6	47.5	76.3	78.1	53.4	75.4	27.7	33.0	1.40	64.54	-33.8	0.00	-
	20.00	-	-	-	-	-	-	-	-	-	-	-	-	33.0	0.70	32.27	-	0.00	-
	21.00	-	-	-	-	-	-	-	-	-	-	-	-	33.0	1.80	82.98	-	0.00	-
	22.00	75.4	75.9	75.6	75.6	76.1	75.7	76.1	76.8	71.3	77.8	-	24.2	33.0	0.90	41.49	6.4	0.00	-
	23.00	73.0	73.8	74.1	74.5	75.9	75.9	75.9	75.2	75.9	71.5	75.6	26.9	34.0	1.70	78.37	-0.8	0.00	-
	24.00	-	-	-	-	-	-	-	-	-	-	-	-	33.0	0.50	23.05	-	0.00	-

NOTE ; (1) Fresh tobacco leaves = 962 kg
(2) Cured tobacco leaves = 187.3 kg
(3) Total LPG consumped = 83.2 kg (3835.52 MJ)
(4) Total energy from solar collector = 811.01 MJ
(5) Total electricity used = 63.68 MJ
(6) Per-cent savings by solar = 17.22 % (4/(3+4+5))

Annex B

Sample Data-Logger Print-out of Raw Data

Previous Page Blank

Sample of Data-logger print-out for experimental run Solar 3

```
FILE NAME                          TOBAC22/MAS:1
START TIME                         05/18/84. 10:08:34
REMARK
BEGINNING CHANNEL                   1
ENDING CHANNEL                      27
NUMBER OF INTEVAL                   1
SPECIFICATION FOR INTEVAL #         1
STARTING TIME                      10:09:00
ENDING TIME                        14:09:00
SECONDS BETWEEN LOGGING             300
SET #      1
 46.5952          39.2619          46.8333          45.1861          45.8837
 45.6512          38.2927          44               45.4186          39.0238
 47.0698          .25641           3.07692          1.02564          4.10256
 15.025           4.35898          3.07692          29.6098          29.6098
 .03184           42.5814          66.8864          47.7675          41.6429
 81.1778          77.8667

SET #      2
 45.1861          38.0488          45.8837          43.2857          46.3572
 45.6512          37.8095          43.2857          45.1861          38.7805
 47.0698          1.53846          1.79487          1.53846          3.84615
 14.025           4.61539          5.38462          29.8537          30.3415
 .01878           43.0476          68.6889          50.3488          41.881
 95.3405          87.9778

SET #      3
 45.1861          38.0488          46.1191          43.0476          47.0698
 45.8837          37.8095          43.5238          45.6512          38.7805
 47.3023          1.02564          2.30769          1.28205          3.58974
 14.275           4.10256          6.15385          30.0976          30.5854
 .01458           43.0476          70.0445          50.1163          41.881
 97.2766          89.9348
 ---------        ---------        ---------        --------         ---------

 ---------        ---------        -------          ---------        ---------
SET #      49
 55.8086          44.9576          54.9576          52.4044          55.3831
 52.4044          44.7448          51.7661          53.8938          46.2342
 86.8725          15.3832          13.8939          12.83            13.2556
 19.8513          13.6811          14.3194          38.1491          39.0002
 .06543           39.0002          77.9363          41.5534          40.064
 105.383          97.7234

SET #      50


END OF FILE TOBAC22/MAS:1
```

Key to Data-logger Print-out

Level 1 dry-bulb temp. (C°)	Level 1 wet-bulb temp.(C°)	Level 2 dry-bulb temp.(C°)	Level 3 (center) dry-bulb temp.(C°)	Level 3 (off-center) dry-bulb temp.(C°)
Level 4 dry-bulb temp.(C°)	Level 4 wet-bulb temp.(C°)	Level 5 dry-bulb temp.(C°)	Level 6 dry-bulb temp.(C°)	Level 6 wet-bulb temp.(C°)
Roof vent dry-bulb temp.(C)	Roof vent heat flux (mv)	Lower level unshaded wall temp. difference (C°)	Middle level unshaded wall temp. difference (C°)	Upper level unshaded wall temp. difference (C°)
Lower level shaded wall temp. difference (C°)	Middle level shaded wall temp. difference (C°)	Upper level shaded wall temp. difference (C°)	Shaded ambient temp. (C°)	Unshaded ambient temp.(C°)
Roof vent air velocity (volts)	Solar collector input temp. (C°)	Solar collector output temp. (C°)	Top level rockbed temp.(C°)	Bottom level rockbed temp. (C°)
Supply duct dry-bulb temp.(C°)	Supply duct wet-bulb temp.(C°)			

REFERENCES

Bank of Thailand, *Monthly Economic Report*, Vol. 1, January, 1983.

Bamrungwong, S., *A Study and Design of a Solar Heating System for Tobacco Curing*, Master's Thesis, Graduate School, Chulalongkorn University, Bangkok, 1980.

Bamrungwong, S. and Apipatanasiripong, C., *Solar-Assisted Tobacco Curing with Black-Painted Rock Heat Absorber*, Special Project, Department of Mechanical Engineering, Chiang Mai University, Thailand, 1981.

Bowers, C.G., B.K. Huang and A.H. Nasser, *Solar Energy Drying and Process Control with Microcomputer*, ASAE Paper No. 78-3537, 1978.

Castro, R.C., G.P. Ariz III, A.T. Austria and A.D. Glova, *Design Improvement and Performance Evaluation of a Low-Cost Solar-Aided Curing Barn for Virginia Tobacco*, PTRTC-MMSU, 1980-1981.

Cundiff, J.S., *A Renewable Resource System for Curing Tobacco*, Proceedings ASAE National Energy Symposium, Kansas City, 1980.

Exell, R.H.B. and K. Saricali, "Solar Radiation Tables for Thailand", *Journal of Science Society of Thailand*, 1, 1975, PP. 185.

Hirun, A., *The Potential Use of Solar Energy for Tobacco Curing in Thailand*, Special Project, Training in Alternative Energy Technology Program, TAET 8th Session, University of Florida, 1983.

Huang, B.K. and C.G. Bowers, *Solar Energy Utilization Using Greenhouse Bulk Curing and Drying System*, Proceedings Solar Crop Drying Conference, North Carolina State University, 1977.

Huang, B.J., *Solar Energy Utilization in Tobacco Curing and Culture*, Proceedings 7th International Tobacco Scientific Congress, Manila, 1980.

Holland, K.G.T., "Rockbed Thermal Storage", in A.F. Janzen and R.K. Swartman, Eds, *Solar Energy Conversion II*, Pergamon Press, 1981.

Johnson, W.H., *Solar Energy and Heat Recycling in Tobacco Curing*, ASAE Paper No. 79-3568, 1979.

Previous Page Blank

Necesito, A.C., *The Energy Requirement of Curing Virginia Tobacco in the Philippines and the Potential Use of Solar Energy*, Proceedings Solar Drying Workshop, Manila, 1978.

Panlasigui, R.A., *Design, Construction and Preliminary Study of a Prototype Solar-Aided Tobacco Curing Barn*, Proceedings 7th International Tobacco Scientific Congress, Manila, 1980.

Phang, K.Y., *Calculation on the Operation of a Solar Air Heater and Rock Bed Heat Store for Drying with Reference to Tobacco Curing*, Special Study No. ET-82-4, Asian Institute of Technology, Bangkok, 1982.

Suchinda, B., Private Communication, 1983.

Tabili, R.G. and R.T. Patulingan, *Summary Data on Three Curing Tests on Taiwan Solar Barn*, Philippine Virginia Tobacco Administration, 1978.

Walton, L.R., W.H. Henson, Jr., S.G. McNeil, J.N. Walker, B.F. Parker and J.M. Bunn, *Curing Burley Tobacco with Solar Energy*, Proceedings Solar Drying Conference, North Carolina State University, 1977.