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ISN 24460

498-0265

Cooperative Agreement USAID 492-CA-1707 -T
Project No. 498-0265

Semi-Annual Progress Report
Period covered: September 1, 1982-March 1, 1983

General:

The emphasis on R&D at Los Baños during the period has been on development of fertilizer placement machines and upon grain drying. Dr. Amir Khan joined the staff on September 1 and has been concentrating on development of machines for deep placement of fertilizer. Two research post-doctoral fellows joined last year and each is involved in a grain drying project.

Several interesting models of equipment for deep placement of fertilizer have been developed and are undergoing testing. A deep plunger device for placement of urea supergranules, a vertical auger device for placement of prilled urea, and a wheel device for placement of forestry grade all appear promising. The principal problem will be to develop equipment that is economical and that the farmer will accept.

Contact will continue with the Chinese Academy of Agricultural Mechanization Sciences to exchange information regarding deep placement machines. The Chinese are presently using machines in some provinces for deep placement of urea briquettes. The effectiveness of the placement technique is questioned by many. The Chinese system places the material 3.5 cm deep while research by our Agronomy Department indicates at least a 5 cm depth is necessary.

Two approaches are being followed to develop improved grain dryers. One is through the development of a warehouse type dryer utilizing a furnace for heat which burns rice hulls, cocorut husks, or any other agricultural waste material. A vortex wind machine is used to move air. The building is constructed of straw and mud. Thus, the warehouse is constructed of low-cost local materials and no fossil-based energy is required to move air or provide heat energy.

The second approach is a heated floor dryer. This unit consists of a drying floor heated by hot water which is heated by a straw burning furnace. It is being tested at a cooperating farm in Mindanao. Copies of papers describing the two methods of drying are attached.

The Design group have been redesigning the portable thresher (TH-6) to incorporate some of the features that have been developed by cooperators of the IRRI Industrial Extension program in the Philippines. Although testing has not been completed, the new design

appears to produce cleaner grain and a higher percentage of threshed grain.

IRRI will conduct a course on the Production of Rice under Upland Conditions. The Agricultural Engineering Department has responsibility for the Machinery Component. As a result of the work by the Design group in preparing for the course, there appears to be a need for some tillage and planting equipment for the small farmer. One design engineer has been assigned to this activity.

As a result of requests from Industrial Extension project personnel in Indonesia and Thailand, a two-stage axial flow pump was fabricated and is now undergoing tests. Also, a graduate student will be testing the improved buffalo plow of Thailand along with the IRRI plow and a common Philippine carabao plow.

An Agricultural Engineering Course was presented from December 6-17, 1982. Students included people from the Philippines, Indonesia, Thailand, Bangladesh, Burma, China, Egypt and Korea. From our experiences with the past schools, we decided to increase the time of the course to three weeks in 1983. Our courses in 1983 will be held 25 July to 12 August and 28 November to 16 December.

India

The International Rice Research Institute has nominated an individual to represent us in India. We have not yet received approval from the Indian Council of Agricultural Research (ICAR). We have contacted ICAR and have been assured that the individual is acceptable but formal approval for an expatriate to work in the country requires the clearance from the Ministry of Economic Affairs.

C. W. Bockhop visited ICAR in Delhi on March 4th and visited the site for the project in Tamil Nadu University. We will have adequate shop and office facilities. A reaper and 5 HP power tiller have been sent to Tamil Nadu University and a TH-8 thresher and manual transplanter will be sent soon. Mr. P. Datt, the project engineer, will be posted about May 1.

Philippines

The reaper, introduced in February 1982, is being produced by about 20 cooperating manufacturers. Manufacturers are being surveyed and, although not yet complete, it is believed that at least 250 reapers have been fabricated and sold.

The method of introducing the reaper, through a workshop for interested manufacturers was, we feel, an important factor in the rapid introduction of the machine. By introducing it to all manufacturers at the same time the development in the field was more rapid than through individual contact.

A detailed report on the activities is attached.

Indonesia

The project in Indonesia is making good progress. The introduction of the thresher to the farmers in West Sumatra is an example where the equipment is badly needed because of the shortages of labor at critical times; however, the farmers do not have the money to purchase the needed equipment. At least one manufacturer is leasing the thresher for a percentage of the harvest and is doing very well.

A meeting is planned with the Director of the Department of Agriculture in West Sumatra and staff of the Bank of Indonesia to develop a mechanization program for the farmers. The machine presently being introduced is the portable thresher.

The project in Luwu is nearing completion. There were a number of problems with the project due to hired personnel who had not managed the machinery properly. However, the power tillers were enthusiastically accepted by the farmers and all tractors have been sold.

The following table is a summary of machines fabricated in Indonesia:

Table 1. Summary of machines fabricated in Indonesia.

Province	No. of IRRI coop. manuf.	Hand Tractor	TH-6 Thresher	Water Pumps	Others
W. Sumatra	14 + 1*	4	300	3	
S. Sulawesi	3 + 1*	5	3	2	
S. Kalimantan	3	2	8	40	
Java	7 + 1*	85	265	260	2₤ + 2$
Total	27 + 3	96	576	305	

*Government workshops like the one in Pasar Minggu and Bukitinggi

₤ 2 reapers
$ 2 transplanters } by Pasar Minggu workshop.

A detailed report from Indonesia is enclosed.

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Thailand

The detailed report for Thailand by Ray Fischer is enclosed. Mr. Fischer retired on February 20th and the country was visited by C. W. Bockhop during the week of February 6 to evaluate the project. The visit included 19 organizations and 37 individuals who were acquainted with the project in some way. A detailed copy of the trip report is enclosed. The recommendation that the project be continued was approved by the Director General of the International Rice Research Institute. A name was submitted to the Director of the Department of Agriculture, Thailand, and his nomination was approved. Dr. Billy Cochran of Louisiana State University has been invited to interview for the position.

The project needs to change its focus and direct its work of industrial extension to areas where mechanization is presently lacking. The North Eastern area of Thailand appears ready for a mechanization program. Other people in this area, such as Dr. Charles Alton (USAID representative on loan from USDA) is very interested in cooperating in the Industrial Extension activities.

MA-IRRI INDUSTRIAL EXTENSION PROGRAM FOR SMALL FARM EQUIPMENT

R E P O R T

PERIOD: NOVEMBER 13, 1982 TO FEBRUARY 28, 1983

INTRODUCTION

Progress is evaluated in this report by comparing actual performance (i.e., outputs, achievements, etc.) with the Schedule of Activities presented in the Proposed Workplan for September 82 - September 83.

1. EXTENSION OF REAPER AND POWER TILLER

PROGRESS TO DATE: Twenty cooperating manufacturers have successfully produced prototypes of the reaper and tiller. MA-IRRI engineers are currently providing technical assistance to reaper manufacturers while conducting a survey of problems associated with fabrication, operation, or marketing the reaper and tiller. Improvements to the original designs are being formulated on the basis of the experiences of MA-IRRI and cooperating manufacturers.

PROPOSED PLAN: Complete survey and prepare written report to be presented at the annual meeting of the Philippine Society of Agricultural Engineers. IRRI and the MA-IRRI Program will collaborate in developing a disk plow for the PT5 tiller.

2. EXTENSION OF AXIAL FLOW PUMP

PROGRESS TO DATE: The report on the comparison of axial flow and centrifugal pumps was revised by economists at IRRI, and this report is being prepared for printing. An axial flow pump fabricated from stainless steel is being fabricated for testing in areas of brackish water, such as fishponds.

PROPOSED PLAN: MA-IRRI staff will discuss the pump report and extension of axial flow pump with appropriate agencies and cooperators, beginning in the Bicol region in March. The stainless steel pump will be tested in Iloilo in collaboration with SEAFDEC.

3. DEVELOPMENT AND EXTENSION OF THRESHER

PROGRESS TO DATE: An improved design for the thresher concave has been developed and tested at IRRI, and a patent application is being prepared. Information on the concave design will be sent to cooperating manufacturers.

PROPOSED PLAN: An improved design of the thresher blower will be tested at IRRI. A thresher with the improved concave and blower will be fabricated and taken to the PPC Farm for intensive testing.

4. DEVELOPMENT OF TRANSPLANTER

PROGRESS TO DATE: The two units under intensive testing at the PPC Farm are performing satisfactorily with an average field capacity of 0.2 hectares per day per machine. A cooperating manufacturer with interest in promoting the transplanter in the Cagayan Valley has been trained at IRRI on seeding preparation and equipment operation, and loaned one unit to facilitate fabrication of their first unit.

PROPOSED PLAN: Continue intensive tests at PPC Farm, including the improved transplanter design which should be available in April. Follow up with technical assistance to cooperator fabricating prototype.

5. DEVELOPMENT OF ROLLING INJECTION PLANTER (RIP)

PROGRESS TO DATE: Field trials of the RIP have been conducted in Iloilo and South Cotabato through collaboration with RPTR (IRRI) and the Ministry of Agriculture. The KABSAKA Program in Iloilo plans to order 100 units.

PROPOSED PLAN: The trials results will be analyzed and presented in a report, together with a suggested plan for trials for the next season. Technical assistance will be provided to KABSAKA.

6. DEVELOPMENT OF DRYER

PROGRESS TO DATE: Initial tests of the experimental model of the heated floor dryer (HFD) were completed and are described in detail in the report. The report has been discussed at IRRI and SEARCA. Plans have been made for tests of the HFD during the next wet season.

PROPOSED PLAN: Conduct tests of HFD during wet season. Carry out exploratory study of sterilization technique for reducing deterioration of wet paddy.

7. DEVELOPMENT OF SEED AND FERTILIZER APPLICATOR (SFA)

PROGRESS TO DATE: The prototype SFA was demonstrated to a group of manufacturers, farmers, MA and IRRI staff at Lipa on November 24. The results of field trials indicate the need to improve metering of seeds. Five units are being fabricated at BPI, but progress has been handicapped by poor and slow workmanship.

PROPOSED PLAN: Steps will be taken to improve the workmanship of BPI shop employees. Trials will be conducted in at least five provinces. Design drawings will be finalized after making improvements to metering mechanism.

8. DEVELOPMENT OF LOW VOLUME SPRAYER

PROGRESS TO DATE: Received delivery of ten units of low volume regulator and nozzle from Sri Lanka.

PROPOSED PLAN: Units will be dmonstrated to entomologists, agronomists, engineers, and economists at IRRI in order to assess the potential of the unit and formulate tests.

9. DEVELOPMENT OF FERTILIZER APPLICATOR

PROGRESS TO DATE: Results obtained for trials conducted at five different locations were reviewed in meeting at BPI, and trials for the next season were formulated.

PROPOSED PLAN: Second series of trials will be carried out.

10. PROMOTION OF R&D ON SMALL FARM EQUIPMENT

PROGRESS TO DATE: Gonzalo and Stickney discussed this activity with E. Gianzon who is in charge of coordinating agricultural research within the Ministry of Agriculture.

PROPOSED PLAN: Follow up meetings with Ministry and PCARRD.

11. DEVELOPMENT OF INNOVATION & INVENTION CAPACITIES RELATING TO SMALL FARM EQUIPMENT

PROGRESS TO DATE: The MA-IRRI Program carried out three design contests during this quarter and awarded prizes to the outstanding entries. A detailed report on these contests is being prepared.

PROPOSED PLAN: Prepare to repeat these contests next year.

12. ASSISTANCE TO FORMULATION OF POLICIES ON FARM EQUIPMENT

PROGRESS TO DATE: MA-IRRI representatives attended AMMDA, RNAM, and AMDP meetings on agricultural mechanization policies.

PROPOSED PLAN: Continue collaboration with groups mentioned above.

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13. TRAINING COURSE ON SMALL FARM EQUIPMENT

PROGRESS TO DATE: A two-week training course on agricultural engineering was held at IRRI in December 1982. It was attended by three BPI engineers who are participating in the MA-IRRI Program, one engineer from FSDC /Manila, and one cooperating manufacturer.

PROPOSED PLAN: Prepare for next training course scheduled for July 1983.

14. PROGRAM MONITORING/EVALUATION

PROGRESS TO DATE: Mailings were sent out to all cooperators to ask them to: (a) submit an updated memorandum of agreement; (b) report on their production during 1982.

PROPOSED PLAN: On the basis of these data, files on active cooperators will be updated.

OTHER ACTIVITIES

(1) Field Trips: The Co-Leaders of the MA-IRRI Program visited cooperators and farmers in the following provinces during this period:

November :	Iloilo, Antique
December :	Bukidnon, Zamboanga del Sur, Cebu
January :	Ifugao, Bulacan, Leyte, Samar
February :	North Cotabato, Sultan Kudarat, South Cotabato, Davao, Bukidnon

(2) Field Demonstrations: In February, field demonstrations were conducted in Zamboanga del Sur and Samar. Preparations are now being made for demonstrations in Agusan and Surigao during April.

IRRI-DITPROD INDUSTRIAL EXTENSION PROJECT
P.O. BOX 18/KBYPM. PASAR MINGGU, JAKARTA SELATAN INDONESIA TELEPHONE : 782557

March 17, 1983

To : Dr. J.R. Cowan
IRRI Liaison Scientist

From : V.R. Reddy
Agricultural Engineering Consultant

Subject : Quarterly Report
October through November 1982

T r i p s :

Oct. 13th - Oct. 15th	: To West Sumatera to monitor the progress of extension work.
Oct. 18th - Oct. 21th	: To visit Luwu - Sub Project.
November 19th	: To seed farm Sukamandi with Ir. Zaidir Said.
Nov. 24th - Nov. 26th	: To South Kalimantan to monitor the progress of the extension work.

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During this quarter the programe of activities we have planned to build and test at Tanjung Barat workshop is enclosed herewith. It may be noted from this chart that hand - tractor, new design harrow with leveller, modification of transplanter, thresher along with the manufacture of prototype of reaper 1.0 meter and 1.6 meter is undertaken.

For testing of this equipment, we were able to get permission to use the paddy fields of Sukamandi seed farm centre. Infact this seed farm uptill now has been using huge big tractors and combines for land preparation and harvesting operations. Out of total 3.000 Ha of land, they were able to cultivate only about .750 Ha with their equipment and another 750 Ha were being given on contract. During the fourth five year plan, they want to bring all 3.000 Ha under cultivation and are in search of a suitable farm equipment technology which meets their requirements and which they can manage. In this regard we had submitted a proposal to consider IRRI-type small farm equipment and test it out throughly in their fields. A copy of the same is enclosed.

In West Sumatera, the manufacture and sales of TH 6 threshers are continuing to gain momentum on their own. We are now concentrating to popularise hand-tractors and axial flow pumps in this province. In Kabupaten Sejunjun a kelompok tani has been identified for testing out one hand-tractor with plough/puddler and harrow and one axial flow

pump to cultivate a piece of 12 Hactares during the coming wet season. Local agricultural department officers are being involved to monitor and keep full records of this experiment.

In Luwu, two seasons of land preparation data have been collected and sent to Los Banos for the analysis work. As per the previous agreement between FCC and six cooperator farmers, they will have to opt for the purchase of these hand tractors after a period of one year, which ends by Nov.'82. In this regard, the prices and depreciation were worked out by FCC in consultation with us. Copies of the letters are enlosed herewith. Since these hand-tractors were being sold to the parties, we have specifically instructed that they need to be overhauled and painted up before the wet season begins in December. copies of the written instructions in this regard are being enclosed.

In South Kalimantan, we have noted suddenly the interest for axial flow pumps specially in Kabupaten Hulu Sungai Selatan. Here due to less rain this year, they needed badly pumping up to save crops from several riverlets that criss-cross this district. In swampy areas of this district nearer the coast, they use small boats and water ways to transport vegetables, fruits and other produce. They needed this year to pump up water to transport their produce. One enterprising local small workshop in Puskanegara has manufactured four

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6 " pumps and two 10 " pumps. He has several orders pending . Another manufacturer at banjar Masin Haji Sabli has also produced 6 pumpsets (all 6 " dia) and sold them. In this workshop, industries department has conducted training programme for the manufacture of transmission boxes of IRRI type hand-tractors with the help of a German Consultant from M.I.D.C. TH 6, threshers produced in this shop are to be field tested during the coming harvest season.

PROPOSAL TO TRY OUT IRRI-TYPE SMALL RICE FARM EQUIPMENT
AT NATIONAL SEED PRODUCTION CENTRE-SUKAMANDI W.JAVA

Background Information

*Ir. Soenario has approached this office with a request to try out IRRI small farm equipment technology at Syang Hyang Seri(seed production center), since he is finding both expensive and difficult to cope up with the existing imported farm machinery and equipment at the center. In this reagard the following facts and figures are given about this seed farm.

Total area of the farm is 3000 Ha with round the year irrigation facility. However, at present/able to use only about 1500Ha due to inadequate facilites mainly in terms of equipment and management of the farm. Out of this 750 Ha are being cultivated by the existing imported farm equipment (consisting of tractors ranging from 30 HP to75 HP and big combines) and about 750 Ha are being given on contract for land preparation and harvesting. The contract charges being paid at present for land preparation is Rp.50,000/Ha whereas their own cost (according to their cost analysis) is coming between Rp.95,000 to Rp. 135,000/Ha.

Similarly for harvesting
/ they are having lot of difficulties in operating these big combines when the field is wet. Moreover, their plan is to shift harvesting from the months of March/April to December/January, which means it is impossible to use these big combines during the rainy season.

/ they are

* Director of Syang Hyang Seri

Need for an Alternative Farm-Equipment Technology

Due to the above mentioned problems, the present thinking of the management of this seed farm is to try out few alternatives available during the year '83 and then select and standardise the most suitable and economical farm equipment to bring the entire 3000 Ha under seed production during the 4th five year plan starting from the year '84.

Advantages of Selecting Locally Made Farm Equipment Technology

First of all the cost of equipment will be much less and then the unreliability of supply of spare parts problem (causing excessive down time and expensive maintenance) will not be there.

Secondly it will encourage local manufacturers increasing their local skills and creating more off-farm jobs.

Thirdly this can become demonstration to the surrounding farmers for their adaptation and thereby increasing their productivity and profits and decreasing post harvest losses and drudgery.

It is, however, important that selected equipment are well tested and found suitable under Indonesians conditions.

Since the IRRI-type small rice farm technology is being successfully *introduced in few selected provinces of Indonesia, under the cooperative agreement between DITPROD and IRRI (funded by USAID) since '78, we recomend that this technology be tried out at Syang Hyang Seri during the coming year to find out the economics and its suitability.

* The Progress of IRRI Small Farm Equipment Technology Transfer in Indonesia is enclosed

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Suggested Plan of Action

We recommend the following equipment as a package set be given on lease to atleast two contractors :

I. 2 Hand Tractors (6 HP diesel) with the attachments like plough, harrow, puddler, trailer 3/4 ton cap. and
   1.6 meter reaper attachment
   1 TH6 thresher
   2 Transplanters
   4 weeders

II. 3 Hand tractors (5 HP gasoline) with the attachments like plough, harrow, puddler, trailer 1/2 ton cap. and
   1.0 meter reaper attachment
   1 TH6 thresher
   2 transplanters
   4 weeders

We feel with this equipment it should be possible to cover about 20Ha by each contractor. These contractors maybe paid at the present market rate minus depreciation and interest charges. For example, for land preapartion if Rp.40,000/Ha is being paid when the equipment is owned by the contractor, let him in this case be paid only Rp.15,000/Ha towards fuel, operator, repairs and profit as the depreciation and interest charge comes approximately Rp.25,000/Ha. Similarly it can be calculated for other operations.

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It is important to keep a close watch on the performance of this equipment atleast during the first season and maintain detail records with regards to number of hours used,work done, fuel consumed, repairs etc.

In order to supervise this activity, we suggest a team may be made responsible consisting of a member each from Syang Hyang Seri, BPTP Sukamandi and IRRI-DITPROD.

In this manner we feel a good assessment can be made about the suitability and economics of this technology within a period of one year.

VRR
Oct.3,'82.

Best Available Document

BENGKEL TANJUNG BARAT
OKTOBER - JANUARI 1983

Kegiatan	Vol	Oktober I	Oktober II	Oktober III	Oktober IV	Nopember I	Nopember II	Nopember III	Nopember IV	Desember I	Desember II	Desember III	Desember IV	Januari I	Januari II	Januari III	Januari IV	Specialist
Pembuatan																		
a. Jig Reaper 1,0 m	1																	Trans : Suwardi
1,6 m	1																	Traktor tanga + Reaper = Kasiman
b. Reaper 1,0 m	2 - 1																	
1,6 m	2 - 1																	Thresher = Endon
c. Transplanter	4			PT. Tugas														Pompa air = Endon
d. Thresher modifikasi	1																	Dryer = Endon
e. Dapur sekam	1																	
f. Traktor tangan 6 HP	1																	
g. Garu segitiga	-																	Pameran = Cholid.
Pengujian																		
a. Traktor tangan 6 HP	1								SKMD									Pengujian A - G
b. Transplanter	1						Bekasi			SKMD								di Sukamandi (Sahyang Sr
c. Weeder	3																	
d. Reaper 1,0 m																		
1,6 m																		
e. Thresher	2																?	
f. Dryer dapur sekam+m.tnh	1																	
g. Traktor tangan 4 HP diesel																		
Pompa 6" diesel	2																	
Seminar																		
Transplanter.																		
Gambar kerja																		
a. Pedal Thresher																		
b. Penabur pupuk																		
c. Traktor tangan 3 HP								TRANSLATE										Soehardjo
d. Reaper																		Made Dasnaya.

IRRI-DITPROD INDUSTRIAL EXTENSION PROJECT
P.O. BOX 18/KBYPM. PASAR MINGGU, JAKARTA SELATAN INDONESIA TELEPHONE : 782557

April 6, 1983

To : Dr. J.R. Cowan
IRRI-Liaison Scientist

From : V.R. Reddy
Agricultural Engineering Consultant

Subject : Quarterly Report
January through March 1983

T r i p s :

Jan. 22th - Jan. 26th	: To visit Ujung Pandang to-monitor Luwu Sub-project.
Feb. 24th - Feb. 26th	: To visit Padang to monitor our project extension work.
March 7th	: To visit Sukamandi with Mr. Bart Duff to discuss about workshop consequency project.
March 9th - March 10th	: To visit Ujung Pandang with Mr. Bart Duff to discuss about workshop consequency project.
March 26th - March 29th	: To visit Semarang, Yogyakarta and Klaten to visit cooperative manufacturers Kubota and Kubota Kwik.

Received a very disturbing letter from the project leader of Luwu, regarding the performance of our sub-project in Bone-Bone. Immediately I rushed to Palopo and Luwu. The detail report of the trip submitted to USAID is enclosed herewith.

It may be noted from this report that their letter was highly exaggerated in what they have stated to be various short comings. The majour short coming was that our assistant site supervisor after getting married in October, has not been staying at Bone-Bone and attending the job properly.

While this development has created few irregularities and improper functioning of the office, the interest of the farmers in the hand-tractors has not decreased as reported in their complaint letter. On the contrary the number of farmers showing interest in hand-tractors is continuously increasing. The one manufacturer at Palopo who has been assisted to make two hand-tractor units, have been tested successfully. FCC is anxious to take the role of distributor and provide after sales service, and coordinate the credit required from banks to farmers and also assist manufacture by placing orders in advance.

During Bart Duff's recent visit on March 8, the detail report of this subproject for the first two

seasons was presented. The list of people attended from USAID, Luwu project, BPLPP and DITPROD is enclosed. It has been agreed that under the circumstances, the majour emphasis to be changed from record keeping to the promotion of manufacture and sales of these hand-tractors within Luwu. However, the record collection of land preparation alone from 33 respondents will be continued until the end of the 4th season Sept.'83, by one record keeper who will be working under the supervision of Manager FCC-Bone-Bone. The servicing will be provided by the FCC-on commercial basis. For more details , the detail letter to the head of project Luwu by Dr. J.R. Cowan maybe referred.

Meanwhile two more small workshops were identified in Masseppe and Rappang (in Sidrap district, S. Sulawesi) and were assisted to manufacture TH 6 threshers. After some modifications they will be tested during the coming harvesting season starting from April '83. Also the workshop of DIPERTA at Ujung Pandang has taken up th fabrication of 10 paddy threshers to be distributed to various districts for demonstration purposes. With one gear-box we have sent, this Goverment workshop has built the hand-tractor which was successfully tested at Sidrap. We are planning to assist the workshop in Masseppe to fabricate hand-tractor as the interest in this machine is steadily increasing.

In West Sumatera, the production and sales figures of TH 6 threshers is continuing to increase. The latest count shows 14 fabricators and about 300 threshers in the Province. Now we are focussing our attention to promote hand-tractor in this Propvince. 4 numbers of small hand-tractors gear-boxes have been supplied to three local fabricators for building the hand-tractor and testing with various attachments. Two staff members from IRRI-DITPROD Jakarta have assisted them in fabrication during the 2nd week of March. On the suggestion of Inspector DIPERTA of West Sumatera, we have prepared a note (enclosed) for promoting these hand-tractors on priority basis.

In South Kalimantan, the manufacture and sales of axial flow pumps from two local manufacturers has gone up to more than 30 numbers. During this coming harvesting season, locally manufactured threshers will be tested. We are planning to organise a demonstration of hand-tractor, pump and thresher in one of their districts to be followed up with a meeting consisting of staff from DIPERTA, Perindustrian and Bank Indonesia and BRI.

At Tanjung Barat workshop here, following items have been taken up for fabrication during this quarter

1. Hand Tractor 6-8 HP (Implement)
   - Cage Wheel (modification).....1 pair's
   - Mold Board plow Thai'type.....1 pieces

- Leveller.....1 piece
- Mold Board plow (modification).....1 piece
- Triangle Harrow..... 1 piece

2. Hand Tracktor 4-5 HP
   - Mold Board Plow ..... 2 pieces
   - Transmission Box..... 1 piece
   - Cage Wheel ..... 2 pieces
3. Transplanter..... 1 piece
4. Grain Cleanner..... 1 piece
5. Jig & Fixture
   - Reaper 1,o m ..... 1 piece
   - Reaper 1,6 m ..... 1 piece

During this period we have taken up the testing of hand-tractor with various attachments at Sukamandi seed farm and transplanter at Tanjung Barat workshop. Not yet satisfied with the performance of transplanter which are locally fabricated. . Continuing with modifications and testing work.

THAI-IRRI Cooperative Machinery Project

(Semi-Annual Report for USAID, 1 Sept. '82 - 28 Feb. '83)

A. First half of Third Fiscal Year

The December, 1982 Semi-Annual Report remains an up-to-date status report for this project, with the following exceptions :

1. Anusarn Company, Chieng Mai, has built 600 rotovator attachments over the past six years, including 150 during the calendar year, 1982. The attachment consists of three assemblies of four spring steel blades mounted on each power tiller axle, in lieu of cage wheels. An adjustable depth gage is provided.

The design was furnished by personnel from the Thai-IRRI cooperative project. This has not been reported previously because the production was unknown until it was shown at a demonstration at Chieng Mai on January 19.

2. Work was started on a buffalo powered water pump in mid-January. The engineer and counterpart believe that a unit of this type may be beneficial to farmers, particularly in the northeast. The buffalo would be utilized in the off season, after the paddy fields are worked. The farmers with a suitable water source, such as a shallow well or a stream, would benefit from irrigation with virtually no cost for energy.

Pumps of this type are used in India, Pakistan, and other countries. Formerly they were used in Europe and the U.S. A double opposed piston pump for buffalo power from India looks attractive. It operates at 30 rpm and has a capacity of 7 lit/sec., which will provide 15 cm of water to 1/6 ha in approximately 10 hours of operation.

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3. The Khon Kaen plow firm built 20 improved buffalo plows in the last half of 1982 which increases the 1982 total to 55 units.

4. A Nakhon Sawan firm built 15 improved buffalo plow moldboard assemblies since 1 January, 1983. Ten of them are the narrow upland unit and 5 are the wider paddy plow. Three companies have now started production of this design.

5. It was recently learned that a small shop has started commercial production of the cyclone seeder. The number of units built is not yet known.

B. Review of progress, 1978-1982

It is appropriate to reflect on project progress at this time. The June and December semi-annual reports for the two calendar years compares the numbers of producers and total IRRI design machines built.

	Year			
	Producers		Machines	
	1978	1982	1978	1982
Axial Flow Thresher	10	28	1,919	9,490(a)
Portable Thresher	1	1	16	1
TH-8 Thresher	-	1	-	-
Power Tiller	3	-	122	-
Rotovator att. for Power tiller	1	-	60(est)	150
Improved Buffalo Plow	-	2	-	35
Batch Dryer (2 T & larger)	-	2	-	4
Extendable Lug Wheel	-	1	-	14
Reaper	-	1	-	1
Grain Cleaner	-	1	-	1
Total	14(b)	38		

a. The 1982 production estimate was 28% less than in 1981 because of low farm income and drouth or flood problems.

b. One firm built two items.

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C. Looking Ahead

1. Promotion of New Designs to Farmers and Manufacturers. Eighteen different designs have been furnished to some manufacturers at their request. The axial flow thresher is very well established and the extendable lug wheel for power tillers is built by one producer. The buffalo plow has been introduced by three firms and it is expected to gain momentum in 1983. In addition to one prototype reaper reported, another firm has ordered material for a prototype and a third company plans to produce an initial lot of 5-10 units on a PT-5 power tiller. The 2 ton batch dryer design has been started at two firms and production is expected to expand. Production of the TH-7, TH-8, and portable grain cleaner were limited prototypes during the period. With only seven present development projects not yet completed, it appears appropriate to increase emphasis on promotional and extension activities among farmers and manufacturers.

Purchase of a limited number of nine items from manufacturers who have blueprints should increase the interest of producers in these items. They will be loaned to various organizations who would use them, and demonstrate or loan them for farmer use. The organizations would furnish feedback to the cooperative project. Assuming this activity proves of value, it can be expanded to other designs in the future. The initial program would be within the limit of the machinery component of the third fiscal year budget. Most of the costs are based on quotations received.

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	Machine	Number	Est. Total
1.	Reaper, 1.0 m & PT-5	2	฿ 20,000
	4 HP B & S engine	2	5,000
2.	Reaper, 1.6 m	1	8,000
3.	PT-3	1	7,000
	7 HP B & S engine	1	4,000
4.	Upland Seeder, 3 row	3	10,000
5.	Land Leveler, 2 m	3	6,000
6.	Improved Paddy Plow	10	2,500
7.	Upland Hand Weeder	20	6,000
8.	Paddy Weeder	20	8,000
	Total ($3,340)		฿ 76,500

Distribution is anticipated to :

1. Selected rice and upland crops experiment stations
2. Department of Extension
3. Thailand farmers association
4. Thai-Netherlands I.D.P., Mr. Winai Sri-Amporn, Agricultural Engineer
5. Interested volunteer organizations
6. Other.

2. Forecast for the Future. It is anticipated that most, but not all of the IRRI designs would be accepted in significant numbers by Thai farmers. Continuing the project and increasing the promotional activity, as indicated earlier, should result in several of the designs being commercialized. If the cooperative project was terminated now, it is predicted that only a few designs would find acceptance.

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A UNDP representative recently suggested that there should be a coordinator group, committee, or individual to monitor activities of the three bodies who are now in cooperative farm machinery developments with the Agricultural Engineering Division (AED). The IRRI engineer feels that there has not been a lot of duplicative effort. However, he agrees with the UNDP individual, because the Technical Committee appears to be dominated by one cooperator.

TRIP REPORT
THAILAND
C. W. Bockhop
February 6-12, 1983

OBJECTIVE: To evaluate the Industrial Extension program in Thailand.

Since Mr. Ray Fischer is leaving on February 20th and retiring, the trip was made to evaluate the project, and determine the future course of action with respect to the Industrial Extension program in Thailand.

During the week the attached itinerary was followed and manufacturers and personnel in the Ministry of Agriculture around Korat and Khonkaen in the Northeast area were visited in addition to people in the Bangkok area. A list of persons contacted during the week is attached along with a schedule of visits.

SUMMARY

My visit included 19 organizations and 37 individuals. All organizations had, in some way, been in contact with the Thai-IRRI project. All expressed opinions that the project is needed and should continue.

The organizations in Khonkaen and Korat are especially anxious to have the Industrial Extension project continue. They are just developing their mechanization and need considerable assistance.

As a result of my visit and evaluation I recommend:

1) That the Thai-IRRI project continue.

2) That we immediately recruit someone to replace Ray Fischer.

3) That we develop a new work plan in cooperation with the Thai group when the new man is in place.

DETAILED TRIP REPORT

The project organization includes the following persons at the present time:

Funded by IRRI: Raymond Fischer - Co-Project Leader (Retiring)
Kriengsak Sirichaimanus - Senior Research Assistant
Vacharachai Pumarin - Junior Engineer
Chalit Chuensombat - Technician
Jutaphorn Charoenpravat - Secretary

Funded by Ag. Engineering Division:

Jaruwat Mongkoltanotas - Head of Workshop and Service Section
Chak Chakkaphak - Head of Research and Testing Section and Co-Project Leader
Prasorn Kradang-nga - Engineer
Suphasit Sa-ngiampong - Engineer

When technicians are needed for test and evaluation, they are provided from a pool by Chak Chakkaphak.

During the week we visited 19 organizations including 37 people. All visits were made as scheduled except two on Thursday. We arrived in Bangkok too late on Thursday to visit Dr. Singh of Asian Institute of Technology (I talked to him by phone at night) and a manufacturer of the dryer.

0900 - February 7, - Rice Research Institute.

I visited with Mr. Pornchai Pukkaman, Deputy Director of the Rice Division of the Rice Research Institute.

The Institute is interested in direct seeding for rainfed rice and a weeder for upland conditions.

They are testing the 3-row upland seeder developed by the Industrial Extension group and will need 10 seeders for their various stations. They are willing to provide funds needed to fabricate the equipment but need the technical assistance provided by the Industrial Extension group, especially to assist the manufacturers in the farming areas to produce the needed machines. They are also asking for the upland weeder which the project developed.

The Deputy Director stated that they have been very pleased with the progress of the Agricultural Engineering Division and hoped the work will continue.

1000 H - February 7 - Agricultural Extension Department.

I met with Mr. Veera Piriyapon, Head of the Farm Machinery Sub-Section. This sub-section has been in existence for 3-1/2 years and are just becoming effective in the introduction of needed equipment. They now have 7 mechanization specialists and will have more in the future.

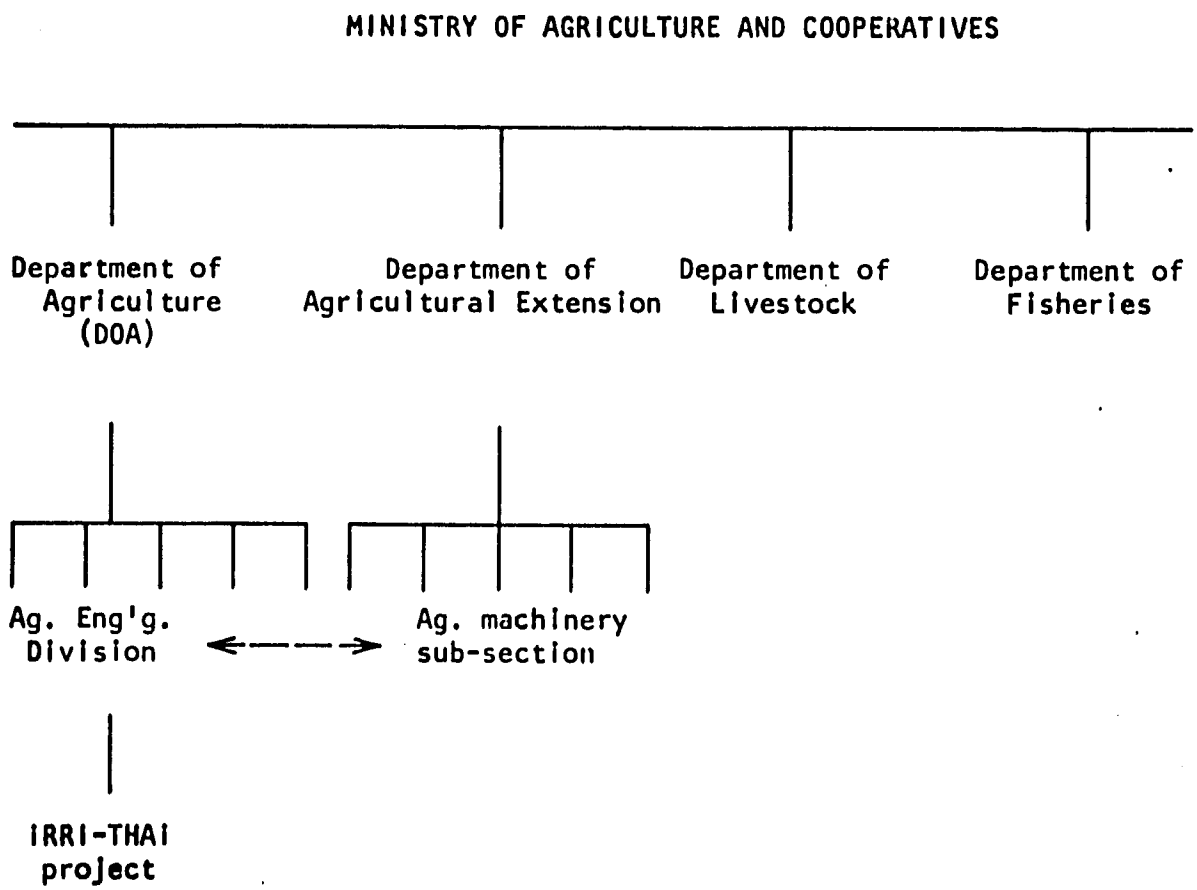
The machinery sub-section has ordered 40 of the improved buffalo plows from a fabricator to use in demonstrations to farmers. They tested 5 plows last year and are satisfied that they are better than the traditional plow.

Three of the engineers in the Extension Department have attended the Agricultural Engineering Course. One attended at IRRI in Los Baños, two in Bangkok at the course in the Thai language conducted by the Thai/IRRI project. The Head of the Department believes the training has been very useful and he would like to have all engineers receive training on IRRI machines.

The Farm Machinery sub-section of the Extension Division is trying to introduce hand operated pumps, weeders, animal plows and a small engine-powered rotovator, all high priority items. It was stated that 600 rotovators (the axle mounted type) were fabricated in 1982.

The Head of the Machinery sub-section stated that they need to be more closely affiliated with the Ag. Engineering research group.

Below is the organization chart of the Ministry of Agriculture and Cooperatives showing the relationship between the Agricultural Machinery Sub-section of the Extension Department and the Agricultural Engineering Division of the Department of Agriculture.



Since the Agricultural Engineering Division is in the DOA and the Agricultural Machinery sub-section is in the Department of Extension, linkages need to be developed between the two. Progress has been made in this and I believe that the Extension group wants to get more involved with the IRRI project. The priorities of the Department of Extension for extension of equipment to the farmers is weeders (hand), animal plows, and rototillers. Six hundred axle-mounted rototillers have been built and sold in the country. The extension engineers are also distributing blueprints of hand operated pump of a Thai design.

The Extension engineers are also interested in the IRRI BD-2 dryer. They believe that drying will become more important in the future.

1100 - February 7 - Agricultural Engineering Division of the Ministry of Agriculture.

I met with Mr. Chak Chakkaphak, Head, Research and Testing Section (Ray Fischer's counterpart), and Mr. Jaruwat Mongkolstanatas, Head of the Workshop and Service Section. Mr. Somnao Rugtrakul, the Director of the Agricultural Engineering Division, was with us a short time but left because he felt ill.

Since these were the people with whom our project has been involved, I asked specifically for their thoughts regarding our activities in the past and what should the direction be in the next two years. Their response is summarize:

1) In the past, there has been emphasis on development of machines. There should be increasing emphasis on extension and getting machines into the hands of farmers.

2) Since machines are location specific, the machines must be selected which will benefit the farmers the most and these should be demonstrated and manufacturers engaged for local fabrication.

3) In the next two years the extension work needs to be concentrated in the Northern Sector where farming is still primitive and improved animal powered tools are needed.

At the present time the FAO has a project with the Agricultural Engineering Division. This project is more involved in upland crops and is scheduled to terminate in 1984.

The group stated that they need to extend training to all their engineers; the Agricultural Engineering course at IRRI and the one in Bangkok in the Thai language have both been helpful. This training needs to be continued. Within two years the Agricultural Engineering Division will have engineers at 5 research stations.

1300 H - February 07, 1983 - FAO Project.

I visited with Mr. Majid Khan, Chief Technical Adviser, Mr. David Howson, Testing, Evaluation and Development Engineer; James Williams, Industrial Extension Engineer; and Adrian Toet, Associate Expert.

The FAO project is concentrating on animal powered machines and upgrading selected manufacturers. The project personnel are designing, testing, and developing the machines and the industrial engineer is assisting selected manufacturers. The project is scheduled to be completed in 1984.

Although the project appears to be duplicating some of our work, I believe there is really no conflict. Our group is trying to institutionalize the Industrial Extension project, while the FAO group are assisting in the research and development but the project will phase out when completed. The FAO are working on machinery for all crops while the IRRI group are concentrating on rice production equipment and rice-base cropping systems.

1500 H - February 07 - Jakpetch Tractor Co., Power Tiller Manufacturer.

I visited with Mr. Suvit Therdteppitak, Managing Director of the firm who is also Secretary of the Agricultural Machinery Crafts of the Association of Thai Industry.

He was very appreciative of Ray Fischer's assistance the past four years, especially in the activity of translating US tractor standards into the Thai language. As a result of Ray's early effort the Association is now embarking on a voluntary standards program. They believe this will benefit the industry and farmers.

The firm is manufacturing power tillers, disk plows, moldboard plows and harrows. His firm needs assistance on industrial engineering problems.

He stated that the Japanese may be coming into the country with an industrial assistance program, but I could not determine what type of program they were contemplating.

0815 H - February 8 - Pramual Kolakij.

I met Mr. Anusorn Boon-it, Manager. The firm manufactures axial flow threshers, a large grain cleaner, and hammer mill. Mr. Boon-it is also in charge of the heavy equipment section of the Agricultural Engineering Division in the Ministry of Agriculture. His wife manages the factory.

He believes that small shops need assistance in improving their manufacturing techniques, in distribution and in marketing. He believes the reaper will become a popular implement in Thailand. Since the second crop is now harvested in the wet season, a dryer is needed.

Mr. Boon-it attended an IRRI Agricultural Engineering course in Los Baños in 1981.

0930 H - February 08 - IRRI Project Staff.

I met with Mr. Kriengsak Sirichaimanus, Senior Research Engineer; Mr. Vacharachai Pumarin, Engineer; Mr. Suphasit Sa-ngiampong, Ag. Engr. Division Engineer; Mr. Prasan Kradang-nga; Ag. Engineering Division Engineer; Mr. Chalit Chuensombat, Technician and Mrs. Juthaporn Charoenpravat, Secretary.

The main purpose of the meeting was to assuage the fears of the group regarding the project's future. They had seen Mr. Argento's report and they were concerned that their jobs would be terminated as soon as Ray Fischer left. I assured them that, for the present, the project would continue and that if we were to decide to terminate the program, we would give them adequate notice so they could relocate.

1000 H - February 08 - Agricultural Engineering Department, Kasetsart Univ., Kamphaengsaen.

I visited with Prof. Akradej Atajinda, Assistant Head of the Department. They have a typical, fairly well equipped shop. They are interested in having some IRRI equipment to use in their teaching program. All the staff are heavily committed to teaching. Ray Fischer has had close contact with them.

1700 H - February 08 - Farm Suwan.

We visited with Mr. Porn Rungchang, Manager of the farm. It is a Kasetsart University farm and is used for both training and research. The cyclone seeder had been tested at the farm and one of the technicians

has fabricated and sold 10 seeders according to the design by the IRRI project engineers.

0800 H - February 09 - Settakit Koarnchang, Manufacturer in Korat.

I met with Mr. Setsamut Tonskun, Manager. Mr. Setsamut attended the Agricultural Engineering course at IRRI in December 1982 and said it had been very helpful to him. The firm produces cement blocks, hammer mills, axial flow threshers and rice mills. In 1981, he sold 3 threshers; in 1982, 45 threshers. He seems to be a conscientious businessman who tries to provide quality equipment.

0930 H - February 09 - Posilaborikarn, Manufacturer of axial flow threshers.

I visited with Mr. Prasert Posila.

He is manufacturing trucks and jute mill parts. He was very complimentary of the Thai/IRRI program. He had been fabricating axial flow threshers but stopped during 1982 because of the depressed agricultural economy.

1300 H - February 09, Chan Thai Lek, Khon Kaen.

I visited with Mr. Chanchai Pisitpaibul.

The firm manufactures plows. He has fabricated 40 of the improved moldboards the past year and has plans to fabricate 200 during the next couple of months. He normally fabricates 50 - 60,000 traditional plow bottoms each year. The improved bottom will sell for 120 - 150 Bahts ($6 - $7 - 1/2). He has a good foundry and most of the plow bottoms are cast but he does make some from polished steel.

He stated that the Thai/IRRI project was very helpful to him and that the improved plow not only provided a new product for him but is helping the local farmers.

1345 H - February 09 - Khon Kaen University, Agricultural Engineering Dept.

I visited with Dr. Winit Chinsuwon, Head of the Department.

The Department includes 11 staff members and they teach 120 students each year.

They would like to cooperate with the Thai/IRRI project and utilize IRRI designed machines. A thresher is needed in their area. The Thai threshers have not yet reached the Northeastern area. Powered equipment is needed to increase cropping intensity in the area.

1500 H - February 09 - Siam Karnyont, Khon Kaen.

The manufacturer fabricates axial flow threshers. They sell large equipment for larger farms but there is a need for small equipment for the upland crops.

1545 H - February 09 - Rice Station, Khon Kaen.

Met with Mr. Pongvut, Head of the Station and Dr. Vanarat.

Near the station the buffalo plow is used extensively. They see a great need for equipment designed for the small farmer.

0800 H - February 10 - Northeastern Agricultural Center, Tha Pra, Khon Kaen.

I visited with Dr. John Raglan, University of Kentucky, Dr. Charles Alton and Dr. Sawat.

The University of Kentucky is cooperating in the introduction of oil crops. Dr. Alton is on loan from the USAID to USAID for this project.

They were very impressed with the equipment developed and introduced by the Thai/IRRI project. Dr. Alton has had the improved plow with farmers. He has ordered 30 from a local shop at 190 Bahts. He stated that the introduction of equipment by the Thai/IRRI program was a classic example of how extension should be done and how equipment should be introduced.

Mr. Alton will be there for 5 years and is interested in working with the Thai/IRRI project personnel.

1200 H - February 10 - Korat Technical College.

We visited with Mr. Anusorn and Mr. Mongkol, staff members in Agricultural Engineering.

The College teaches numerous technical courses and stresses "hands-on" shop work. They have a well equipped shop and were building 10 axial flow pumps based on the IRRI design. They had tested both the IRRI design

and the Thai designed pumps and found the IRRI design more efficient. The pumps will be used on surrounding farms.

They will also fabricate some upland weeders that the Thai/IRRI project had developed. They had the following equipment on display fabricated from blueprints furnished by the Thai/IRRI project: transplanter, diaphragm pump, rotary injection planter, axial flow portable thresher, and PT-3 power tiller. They have used these items in farmers demonstrations.

The College is providing a needed service to the area in the form of technician training, and farmer training.

0800 H - February 11 - UNDP-UNIDO-UN Building.

We visited with Mr. William Millager, Senior Industrial Development Field Adviser for UNIDO.

Mr. Millager is monitoring the FAO mechanization project and is also very interested in the Thai/IRRI project. He expressed interest in Bart Duff's Consequences Research and asked to be invited to the Consequences workshop.

Mr. Millager believed that we were just beginning to show results from the project and that it would be foolhardy to stop now. He stated that the extension work should be intensified.

0915 H - February 11 - NESDB, the National Economic and Social Development Board.

Met with Mr. Sompong, Agricultural Planning.

One member of the National Committee on Agricultural Mechanization reports to the NESDB. The Board, in turn, makes policy recommendations regarding mechanization. This organization is involved entirely with policy development. The Board (NESDB) is very supportive of the Thai/IRRI project because it is involved in small machinery production. The country is trying to reduce the importation of farm machinery.

1100 H - February 11, USAID.

I met with the USAID Director Robert Halligan, and Mr. John Foti, Agricultural Officer.

Mr. Halligan was formerly with the Asia Bureau in Washington, D. C. and he said that it was difficult to see the output from the Thai/IRRI program when in Washington. However, since he came to Thailand he had a different perspective and believed the project should be continued. He expressed the opinion that the USAID people in Washington were perhaps looking at the project with a horizon that is too short and results were expected that could not have been achieved in such a short time. He recommended that the project continue.

1300 H - February 11 - Ministry of Agriculture.

Ray Fischer, Ben Jackson and I met with Dr. Yookti Sarikaphuti, Director General of the Department of Agriculture, and Dr. Tanongchit Wongsiri, Deputy Director General.

Both gentlemen were favorably inclined to the project and wanted it continued. I believe we will receive the full support of the administration.

Dr. Yookti was formerly Director of the Department of Extension. He is very interested in having an increased activity in extension and would like a closer linkage of the project with the Farm Machinery group in Extension.

CWB/hhr
3/01/83

List of people met in Bangkok

February 7, Monday

9:00 Rice Research Institute
Mr. Pornchai Pukkaman, Deputy Director, Rice Division

10:00 Agricultural Extension Dept.
Mr. Veera Piriyapan, Head
Farm Machinery Sub-section

11:00 Agricultural Engineering Div.
Dept. of Agriculture
Mr. Samnao Rugtrakul, Director
Mr. Chak Chakkaphak, Head, Research & Testing Section
Mr. Jaruwat Mongkoltanatas, Head, Workshop& Service Section

13:00 FAO Machinery Project
Mr. Majid H. Khan, Chief Technical Adviser
Mr. David F. Howson, Testing, Evaluation & Development Engineer
Mr. James F. Williams, Industrial Extension Engineer
Mr. Adriaan J. Toet, Associate Expert

15:00 Jakpetch Tractor, Power tiller manufacturer
Mr. Suvit Therdteppitak, Managing Director

February 8, Tuesday

8:15 Pramual Kolakij, Axial Flow Thresher mfgr.
Mr. Anusorn Boon-it, Manager
His post with the Agricultural Engineering Div. is Head, Farm Machinery Section

9:15 IRRI Machinery Project staff
Mr. Kriengsak Sirichaimanus; Senior Research Engineer, Mr. Vacharachai Pumarin; Engineer, Mr. Suphasit Sa-ngiampong; AED Engineer, Mr. Prasarn Kradang-nga; AED Engineer, Mr. Chalit Chuensombat; Technician, Mrs. Juthaporn Charoenpravat; Secretary.

10:00 Department of Agricultural Engineering, Kasetsart University, Kamphaengsaen
Mr. Akradej Atajinda, Assistant Head

17:00 Farm Suwan
Dr. ~~Sumete~~
Porn ~~Runschoon~~ Rungchang

February 9, Wednesday	8:00	Settakit Karnchang, Nakhon Ratchasima (AFT) Mr. Setsamut Tonskun
	9:00	Posilaborikarn (AFT) Mr. Prasert Posila
	12:45	Chan Thai Lek, Khon Kaen (Plow) Mr. Chanchai Pisitpaibul
	1:45	Khon Kaen Univ., Ag. Eng. Dept. Dr. Winit Chinsuwan, Head
	3:00	Siam Karnyont, Khon Kaen (AFT)
	3:45	Rice Station, Khon Kaen Mr. Pongvut, Head Dr. Vanarat
February 10, Thursday	8:00	Northeastern Agricultural Center, Tha Pra, Khon Kaen, - Dr. Charles Alton & Dr. John Raglan.
		Korat Technical College, Mr. Anusorn & Mr. Mongkol
	2:30	AIT. Agricultural & Food Engineering Div. Dr. Gajendra Singh, Chairman (phone in the evening)
	4:00	Panit Borikarn, Pathumthani (Dryer) Mr. Nop Worapanit
February 11, Friday	8:00	UNDP/UNIDO UN Building Mr. William Millager from UNIDO
	9:15	NESDB Mr. Sompong
	10:30	USAID, Mr. John Foti, Head Agricultural Projects Mr. Bob Halligan, Director
	1:00	Dr. Yookti Sarikaphuti, Director General Department of Agriculture
		Dr. Tanongchit Wongsiri, Deputy D-G
		Dr. Ben R. Jackson, IRRI Representative to Thailand

Revised Itinerary for Dr. Bockhop trip to Thailand

Sunday, February 6		Arrive at Don Muang. Single room reserved at New Imperial Hotel.
Monday, February 7	8:15	Dr. Jackson
	9:00	Rice Research Institute Officials
	(a) 10:00	Extension Department, Farm Machinery Section
	11:00	Agricultural Engineering Division
	12:00	Lunch
	1:00	FAO Machinery Project Staff
	2:00	Depart for manufacturers
	3:00	Jakpetch Tractor - Power tiller
Tuesday, February 8	8:15	Pramual ~~Kolakij~~ Bonn-it - Axial flow thresher
	9:15	IRRI Machinery Project Staff
	10:00	Depart for Agricultural Engineering Dept. Kasetsart University, Kamphaengsaen
	1:30	Depart for overnight at Korat (300 kms)
Wednesday, February 9	8:00	Settakit Karnchang - Axial flow thresher & rice mill
	9:00	Posilaborikarn
	9:45	Depart for Khon Kaen (160 kms)
	12:45	Chan Thai Lek - Buffalo plow
	1:45	Khon Kaen University, Agricultural Engineering Department
	3:00	Siam Karnyont - Rice mill & Axial flow thresher
	(a) 3:45	Rice Station, Khon Kaen
		Overnight at Khon Kaen
Thursday, February 10	8:00	Northeastern Agricultural Center, Tha Pra
	9:15	Depart from Khon Kaen
	2:30	AIT. Agricultural & Food Engineering Division
	(a) 4:00	Panit Borikarn, Pathumthani - Power tiller BD-2
		Overnight in Bangkok
Friday, February 11	8:00	USAID
	(a) 9:15	DTEC/NESDB - Mr. Sumetee & Dr. Rungruang
	(a) 10:30	UNDP/UNIDO Miss Natsume & Mr. Millager
	1:00	Ministry officials & Dr. Jackson

(a) Items not in tentative itinerary.

25/1/1983
RCF:jc

Paper No. 8334

DESIGN AND DEVELOPMENT OF A FURNACE FOR EFFICIENT BURNING OF AGRICULTURAL WASTES

By

Dr. Clarence W. Bockhop
Dr. Yong Woon Jeon
Engr. Leonides S. Halos

Agricultural Engineering Department
The International Rice Research Institute
Los Baños, Laguna, Philippines

Paper Presented at the

1983 Grains Post-harvest Workshop

Held

May 3 - 6
Puncak Pass Hotel, P. O. Box 18
Sindanglaya, West Java, Indonesia

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DESIGN AND DEVELOPMENT OF A FURNACE FOR EFFICIENT BURNING OF AGRICULTURAL WASTES

By

C. W. Bockhop, Y. W. Jeon and L. S. Halos

ABSTRACT

The center-tube type furnace was designed to burn efficiently any kind of agricultural wastes such as: rice hull, sawdust, coconut husk and similar materials.

The furnace presents an ideal heat utilization possibility and a burning efficiency up to 98 per cent. It can generate sufficient heat which can be used for multiple application.

The developed furnace can be fabricated from locally available materials: a commercial and oil drum combination or soil bricks.

The drum-made furnace model is very much applicable as a portable unit, while the soil brick-construction is for a fixed installation.

INTRODUCTION

In view of the present energy situation, agricultural by-products, then considered wastes, now represent the most valuable alternative energy resources. The conversion of these abundant fuel supply into clean energy forms should provide opportunity to expand energy base while reducing the pollution now associated with waste disposal.

As the supply of biofuels is expected to increase as agricultural productivity increases, there is a continuing challenge to develop heat-conversion processing units which are usually thought of as furnaces. The complexity and sophistication of such furnaces can vary widely, from the pile of fuel materials in a flat grate, to an inclined-step grate, to a fluid bed furnace. All of these furnaces operate simply by combining fuel and air under the most efficient and controllable conditions to provide heat for some beneficial utilization.

In majority of the combustion type furnaces, some of the combustible gases in the flue gas pass out unconsumed. Many attempts to improve combustion efficiency had been made but the sophistication that goes with the development had limited their application.

An improved, low-technology conversion technique geared towards obtaining maximum energy, along with producing an improved, consistent grade of residue, was therefore the object of this work. Critical furnace design criteria were investigated and results were used as parameters in designing a furnace which can suitably be used to overcome the wide variations in the combustion requirements of various agricultural by-products owing to differences in their physical properties and chemical composition.

MATERIALS AND METHODS

Physical properties and the chemical composition related to the burning characteristics of some agricultural by-products were analyzed. Rice hull, sawdust and coconut husk, which represent the most available fuel materials and assumed to be representative of the different agricultural by-products, as per size and composition, were used in this investigation.

A center-tube furnace was designed, constructed and evaluated on the basis of burning efficiency which will be referred in this text as the capability of the furnace to generate heat and to reduce raw material to the least carbon-containing ash residue. Smoke (flue gases) from the chimney was also observed and noted. Specific performance data were recorded from operations of a circulatory water-heating system and a warehouse dryer where the furnace was used as heat source.

Design and performance parameters included determination of the physical properties related to material- and air-flow in the fuel bed; sustaining kindling temperature; volume change-time relationship and air requirements for satisfactory burning.

Maintenance and repair features as well as design flexibility were considered in the development of the furnace.

Partial result of the investigation was presented in New Delhi, India (Jeon, et al) with specific reference to rice hull as fuel material.

RESULTS AND DISCUSSION

Design Criteria

Physical properties. The most essential physical properties of fuel materials associated with the design of the furnace are: bulk density, porosity, angle of repose and coefficient of friction. These vary from material to material and their moisture contents.

Bulk density is important in the design of hopper and fuel bed related to capacity and flow patterns. Porosity is used in the airflow and heat flow analyses in the system.

A critical flow factor of the material in the hopper and the furnace is dependent upon the angle of friction between the material and the wall of the hopper, the hopper slope, the internal angle of friction, solid size distribution and moisture content.

Fuel bed temperature. To sustain a continuous burning of the fuel material, the fuel bed should be kept at a temperature which approximates the kindling temperature of the fuel materials. Most agricultural wastes burn with temperatures from 300 to 400°C depending on their physical form and chemical constituents.

Volume change- temperature- time relationship. A close observation of the burning characteristics of the fuel materials revealed a significant consideration in furnace design with

reference to volume change, burning time and temperature generated in the burning chamber. These properties define the feeding interval that will sustain a desired temperature at the fuel bed. Design of burning chamber size can be based on the feeding interval, that is, considering how long the chamber should hold the material for burning at the specified temperature.

This rate must be given attention in order that the burning chamber will not be too short to cause consolidation or arching of materials; or too long to cause an obstruction to airflow.

Rice hull burns with about 60% of its volume remaining in the form of char and ash (Fig. 1). This could be related to the high silica-cellulose structure of the rice hull. Coconut husk and sawdust can be reduced to 28 and 25 percent of the original volume, respectively, and will still sustain a temperature of at least 400°C to effect good burning. This result implies that a reasonable time to feed will be such that the volume of material and temperature of the fuel bed will not fall below the values specified.

Air requirements for combustion. The chemical composition of the fuel material has a direct bearing on the determination of the amount of air required for combustion and the amount of the products of combustion. Detailed studies had been done by Singh, et al (1980) using nomograms based on chemical composition and the Ostwald chart specifically for rice husks and groundnut shell.

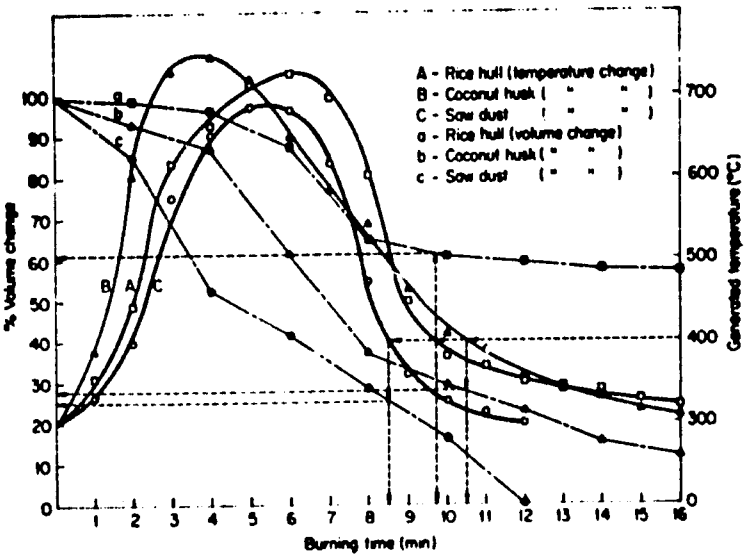

Fig. 1. Temperature and volume change of rice hull, coconut husk and sawdust during burning (Material weight = 120 grams).

The theoretical air requirement and the products of complete combustion were calculated based on the chemical reaction of the different constituents with oxygen during the combustion process. Observations, however, revealed that in general, a certain amount of excess air (65 to 75 percent of the theoretical air, Fig. 2) is necessary to ensure reasonably complete combustion. An undue excess is found deleterious, the effect being more serious when the leakage is at the point at which the air enters

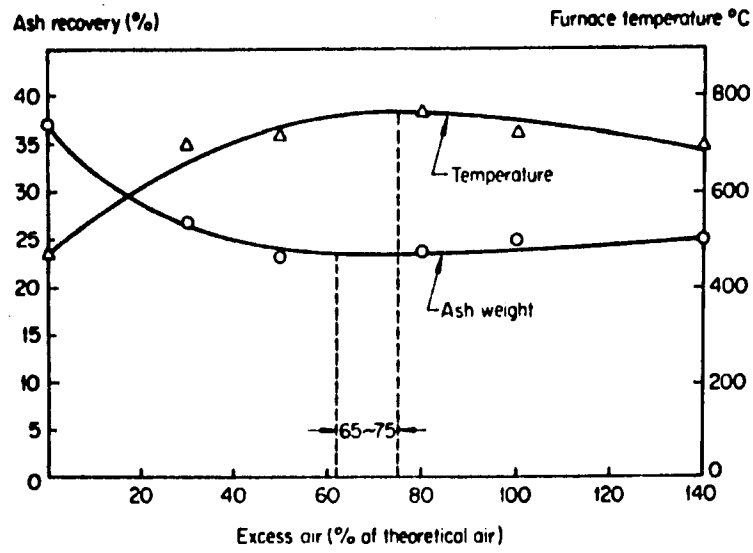

Fig. 2. Effect of excess air on ash recovery and temperature generated.

the system. This causes cooling of the gases below their ignition temperature resulting in a less complete combustion. Heat transmission is also impeded owing to the lowered temperature, and if the chimney draft is employed, the chimney maybe overloaded and the rate of combustion decreased.

Excess air should therefore be supplied in the proper amount and proportion to the system. This can be accomplished by providing a primary and secondary air inlets capable of regulating the air supply during the primary and secondary phases of combustion.

Different materials require different proportions of this excess air (Fig. 3). Rice hull maintains a high burning temperature with a supply of primary and secondary air in almost the same proportion. Coconut husk, on the other hand, needs more primary air as its components break down easily and therefore nearly completes combustion at the primary phase. Sawdust will theoretically behave in the same manner as rice hull.

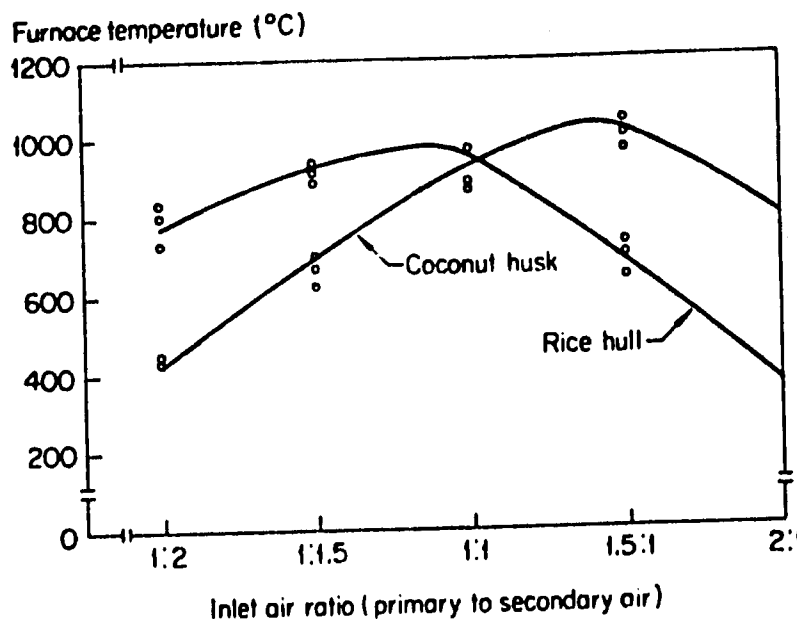

Fig. 3. Effect of primary and secondary air ratio on furnace efficiency.

Exhaust air velocity at chimney should likewise be kept within 70 to 90 m per min in order to allow sufficient time for chemical reaction to take place in the chamber. This could be regulated by proper chimney design in addition to the controlled air inlet.

Design Features

The center-tube furnace is equipped with primary and secondary air inlets, a center mold and a T-chimney for proper supply and control of air required during combustion of the fuel materials.

It was constructed from one- and one-half commercial drum (58 cm dia.) and one oil drum (50 cm dia.) arranged concentric to each other. The center-tube (mold) was designed and constructed from round steel bars (6 cm dia.) which provides proper circulation of air within the fuel bed.

The burning chamber is enclosed by the oil drum and the mold. The lower half of the oil drum is perforated to provide passage for primary air. Secondary air required to complete combustion is supplied through a small pipe (7.6 cm dia.) located at the center of the mold and extending vertically from the bottom of the furnace to the middle of the burning chamber. Burning takes place gradually involving carbonization and gasification processes.

Air moves into the system by natural convection and hence dependent partly on chimney draft. A properly designed T-chimney (15 cm dia.) is provided which gives a good ventilation effect to the system.

The furnace can also be fabricated from soil bricks which should provide alternative for on-farm construction at desired sizes to attain the required heat for any system it maybe coupled.

Figures 4 and 5 show the cut-out view of the drum-made and the soil brick model center-tube furnaces, respectively.

Material burning in the furnace is accomplished in various stages as illustrated in Fig. 6. The fuel bed denoted by C attains a lower temperature than regions A and D. This region exhibits four distinct stages of chemical reaction taking place during the burning process: oxidation, primary reduction, secondary reduction and distillation.

Ash forms near the mold at the top of the burning chamber which gives protection to the chamber from rapid wear due to excessive heat. The fuel material is in itself serving as insulator.

Gases produced due to chemical reaction of the material with oxygen is burned at the region near the top of the mold. This is where complete combustion takes place and where the highest temperature is generated.

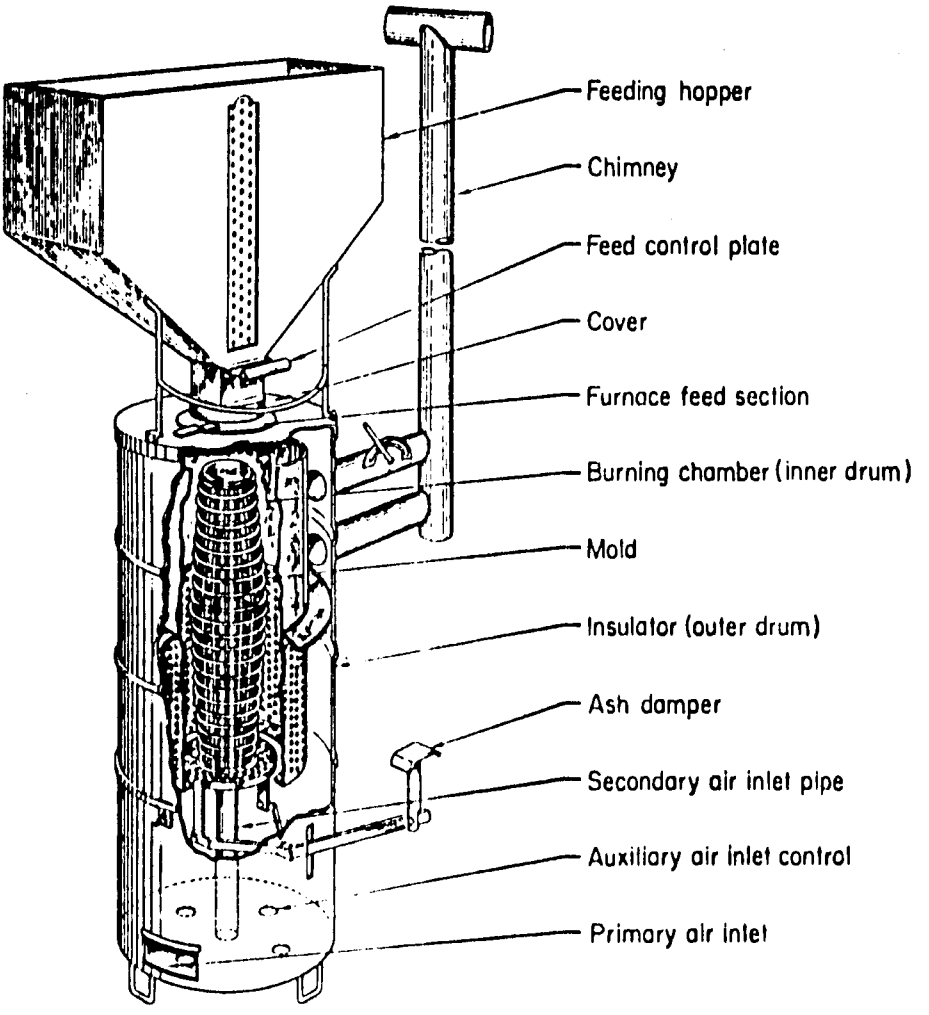

Fig. 4. Cut-out view of the drum-made center-tube furnace.

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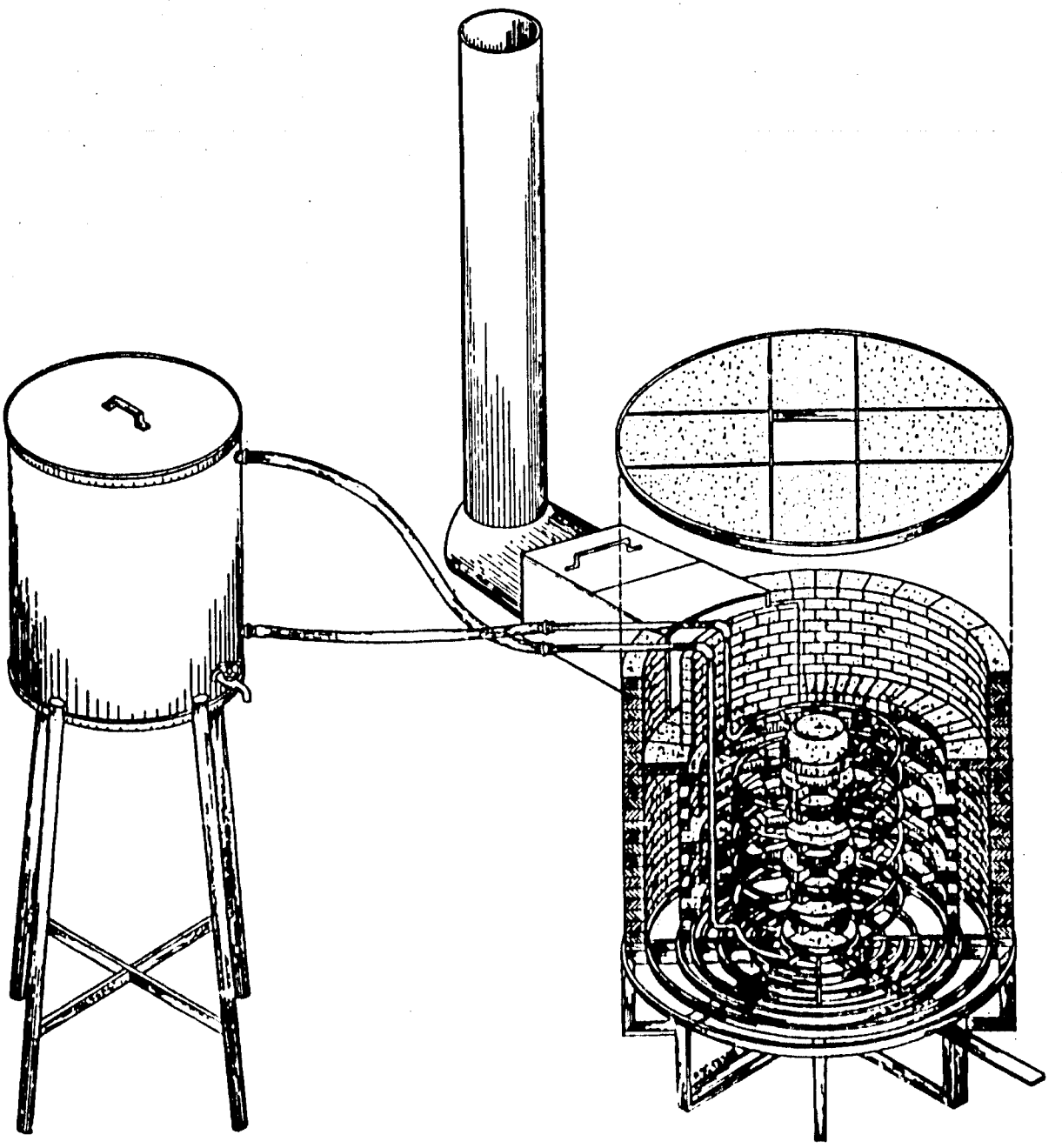

Fig. 5. Cut-out view of the soil brick-made center-tube furnace connected with a circulatory water heating system.

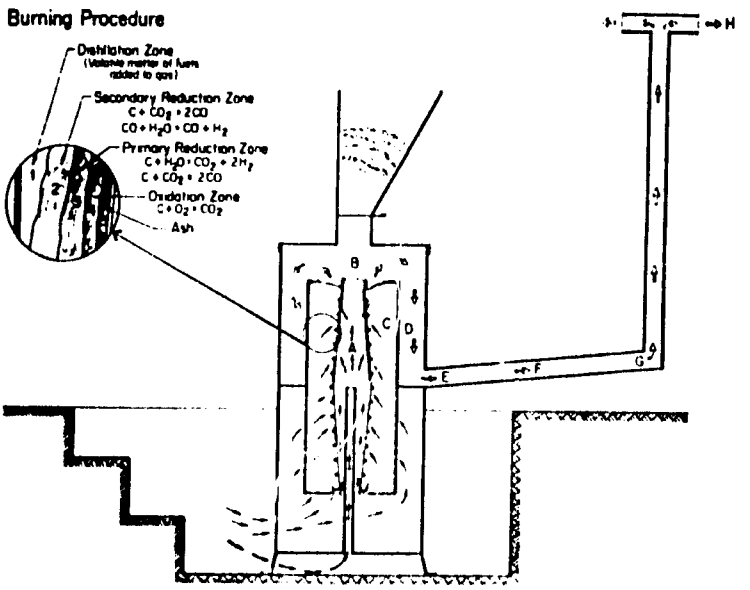

Fig. 6. Burning processes in a center-tube furnace.

Heat and flue gases are passed out through the air jacket, D, at a section above the flange; then out to the chimney.

Performance Features

Burning efficiency. The degree by which the fuel material is burned based on ash recovery varies with the fuel bed temperature and the material moisture content.

For a burning efficiency of at least 90 percent, fuel bed temperature should be maintained at 350, 380 and 400°C for coconut husks, sawdusts and rice hulls, respectively (Fig. 7). These temperatures approximate the kindling temperature of the fuel material at moisture contents below 16 percent; at most 16 percent for rice hull, 15.5 percent for sawdust and 15.0 percent for coconut husk (Fig. 8).

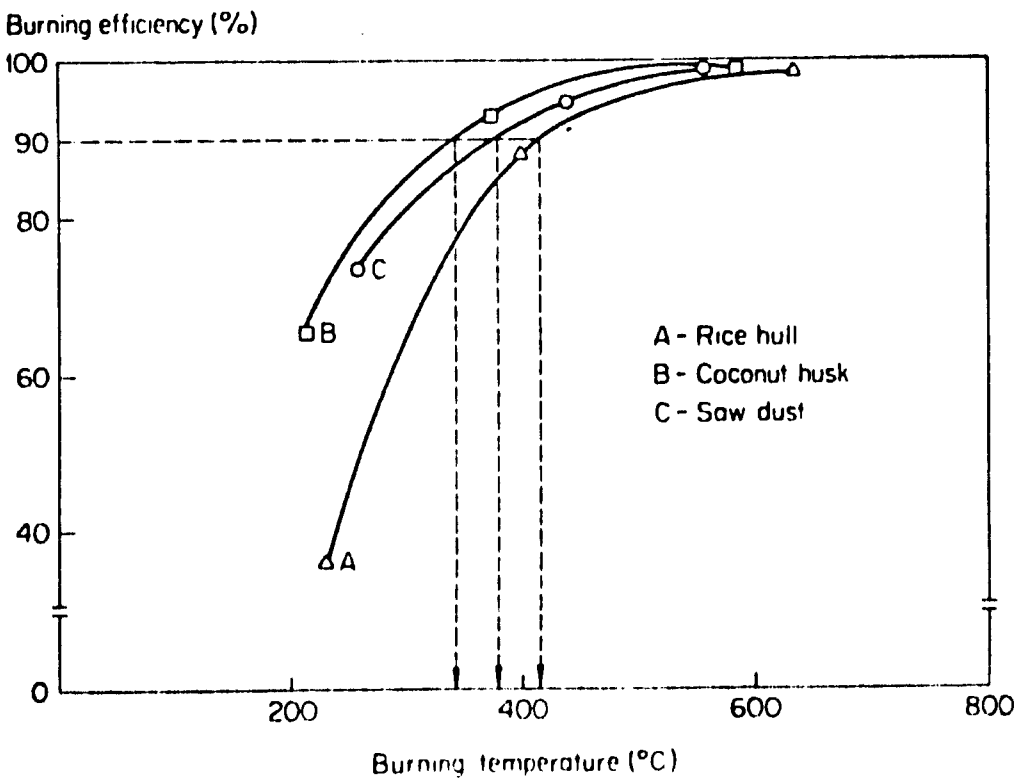

Fig. 7. Effect of fuel bed temperature on the burning efficiency.

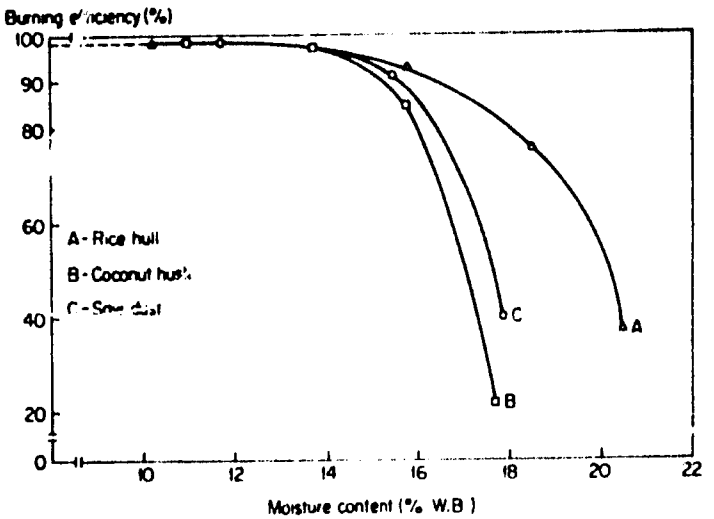

Fig. 8. Effect of material moisture content on burning efficiency.

In general, the lower the moisture content of the fuel material, the higher is the temperature generated at a shorter time, which in turn gives a higher burning efficiency. It takes 5 to 15 min to pre-heat the furnace to the required temperature.

Ash residue analysis gave less than 1.5 percent of carbon which is indicative of a complete combustion. Smoke from the chimney was observed to be whitish and faint, which connotes that most of the combustible gases are consumed during combustion.

Application. An ideal heat utilization possibility was recorded for the furnace. Tests revealed that in a circulatory water heating system, 200 liters of water can be heated 10°C higher in one hour operation of furnace. In a separate test, the furnace was used as indirect heat source for drying. The drum size furnace can supply heat equivalent to a 2 ton/day drying capacity; while the soil brick furnace model has an equivalent drying capacity of 8 ton/day. In effect, the furnace has a heating efficiency of 79 percent which can be derived from Table 1.

Table 1. Comparison of actual (Q_a) and calculated (Q_c) heat energy for paddy drying in a warehouse dryer, kJ/kg of paddy dried.

TRIALS	Q_a	Q_c
1	8.64×10^4	7.18×10^4
2	8.60×10^4	7.03×10^4
3	9.16×10^4	6.65×10^4

SUMMARY AND CONCLUSION

The outstanding feature of the center tube furnace is the provision for a primary and secondary air inlet which is made flexible to be easily adapted for combustion of different fuel materials.

The amount of combustion air required in burning depends largely on the type of firing and the properties of the fuel material. The air capacity should be great enough to ensure that only a very faint trace of exhaust gas can be seen rising from the chimney stack.

It should also be kept in mind that to have a certain and steady combustion, it is necessary to design the furnace so that the drawdown of the heat sink during feeding cannot reduce the temperature below that necessary to ensure good gasification and burning.

The efficiency rating of the furnace developed was found satisfactory, thus the furnace finds multiple application.

A summary of the furnace specification and performance data is given in Table 2.

Table 2. Summary of the furnace design specifications and performance data.

Dimensions	Drum furnace	Soilbrick furnace
Over-all, diameter by length (cm)	58 dia x 122	150 dia x 130
Burning chamber (cm)	43 dia x 140	90 dia x 100
Burning surface (cm^2)	660	980
Ash chamber (cm)	58 dia x 46	130 dia x 30
Feeding hopper (m^3)	0.20	
Chimney (cm)	15 dia x 265	25 dia x 180
Fuel consumption (kg/hr)		
Rice hull	5 - 60	
Coconut husk	10 - 80	
Coconut shell	10 - 80	
Sawdust	5 - 60	
Burning efficiency (%)	95	
Water heating capacity (li/hr)	250 (20-30°C)	
Equivalent grain drying capacity (ton/day)	2 - 8	

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DESIGN AND PERFORMANCE OF A MULTI-PURPOSE DRYER USING NON-CONVENTIONAL ENERGY SOURCES

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Leonides S. Halos, Yong Woon Jeon
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ABSTRACT

A warehouse type dryer using non-conventional energy sources was designed. A center-tube furnace fueled with combustible agricultural residues was developed as heat source for drying and a vortex wind machine was designed as power source for moving air inside the warehouse.

Tests were conducted to find alternative construction materials like soil bricks for furnace and soil-straw blocks for warehouse wall. Water proofing material for the warehouse wall was also found.

A vertical tray drying system was adapted for higher energy efficiency and maximum space utilization.

The drying system was evaluated by drying paddy, corn, coconut meat and fish. Results of evaluation presented in this paper describe the drying phenomena in a warehouse dryer and a physical description of the dried material.

Cost analysis revealed that using the dryer, a ton of paddy will be dried from 25 to 14 percent moisture content at a fee of ₱13.37 to ₱14.08.

INTRODUCTION

Drying of farm crops presents a complex problem especially in the grain-producing regions. Most of these crops are harvested with moisture contents usually in excess of 25 per cent (wet basis), and if it is stored without further drying, the crop will deteriorate due to insect attack, mold growth and respiration which would consequently reduce quality.

Sun drying is a common practice of reducing crop moisture content. The snag, however, is that in tropical countries, like the Philippines, air relative humidity is often high and the sun cannot be relied upon to shine with any consistency at harvest time. Natural drying in the field is possible only during the very dry months of March to May. Because of the high humidity conditions during harvest, it is necessary that there be an added source of heat energy provided to supply the heat of vaporization and an air moving device to blow the heated air through the mass of drying materials. Thus, drying becomes an energy intensive agricultural operation.

Many mechanical dryers had been developed thoroughly but had not been successfully introduced into tropical and sub-tropical regions not only because of climatic differences but also because of the technological gap existing between temperate and tropical and sub-tropical regions and the very small land holdings that tend to be typical of tropical farmers.

On-farm facilities (dryers) can alleviate this critical situation. Recent researches had been geared towards the development of these facilities. Alternative energy sources had also gained a considerable interest in these days of energy crisis. A well-designed grain drying system using non-conventional sources of energy could reduce drying costs as it can be developed along the concept of an intermediate technology wherein the system is simple in construction, low cost, makes use of materials available in the region and can be used for multi-purpose end.

DESIGN CONSIDERATION AND BASIC INFORMATION OF THE DESIGN

Of prime consideration in the development of the dryer is the analysis of the weather condition and the general trend in agriculture of the locality where the dryer will serve. It was assumed that the conditions studied were normal mean values for the tropical regions.

Typical weather conditions at UPLB and IRRI (1970-1980 records) and the general trends in agriculture (Appendix 1) were analyzed. An extensive review of drying literatures and personal interview with farmers were also carried out and resulted to the conceptualization of a drying system which can be described as simple, easy to operate, versatile and economically feasible. Appendix 2 gives a capsuled description of the dryer requirement.

The dryer is a warehouse type which was constructed from locally available materials requiring a simple construction technique. The dryer had been designed to meet requirements for high capacity of a group of farmers operating in a cooperative or village level and to provide multiple utilization for drying and storing different materials in separate lots.

METHODOLOGY

Procedure

Drying literatures were searched and analyzed and were used as baseline information in the development of the warehouse dryer. Design activities were planned and carried out accordingly using the PERT schedule.

A separate activity for the design, development and evaluation of the dryer components was undertaken which gave a basis for the most efficient design feature.

The designed furnace, vortex wind machine and material holding chamber were housed in a structure similar to a warehouse and evaluated based on its potential as a dryer and a store house.

In majority of the tests conducted paddy had been used as drying material. Coconut meat and fish were placed in separate trays and dried simultaneously.

Evaluation Parameters

The inter-relationship of the drying parameters were analyzed in the warehouse drying system. These included evaluation of the ambient and drying air conditions, heat flow and air movement in the warehouse, and the material moisture contents.

The main objective of the experimentation was to examine the feasibility of drying materials in the warehouse where air movement is effected only by natural draft of air and by the suction pressure created by the swirling motion of wind striking the vanes of the vortex wind machine. Heat is supplied in the system by burning rice hull in a center-tube furnace. Other fuel materials like coconut husks and corn cobs were also tried.

The variables considered in the analyses were the fuel material feed rate, temperature distribution, airflow rates and weather conditions. Quality of end products were assessed based on their physical form. Time constrained further analysis of the effect of drying on the chemical composition of the dried materials.

SYSTEM DESIGN DESCRIPTION AND DEVELOPMENT

Warehouse

Existing farm storage buildings are made either of solid concrete wall or concrete hollow blocks and corrugated G.I. sheet roofing.

A conservative construction material for wall from rice straw and ordinary paddy soil (about 50% clay), Fig. 1 and 2, had been adapted in the warehouse dryer to possibly increase system efficiency in terms of energy utilization by minimizing heat and mass transfer through walls while sustaining sufficient strength to support load. The structure rests on a 3-layer concrete hollow block (CHB) foundation and reinforced with round steel bars (1.2 cm dia.).

Soil-straw block mechanical testing revealed compressive and bending strength equivalent to 3.7 and 1.6 tons (per 15 x 15 cm), respectively,which is comparable to a concrete hollow block of the same dimension. Test conducted on coating material revealed that lime-cement-soap water mixture is an excellent water proofing material for the wall. Heat transfer value through soil-straw wall was calculated to be 1.19 kcal/m^2 hr°C (Jeon et al., 1983).

Roof was designed as solar collector. It was constructed from corrugated G.I. sheets with optimum tilt angle of 14 degrees and a collector area of 54 m^2. This gives a mean daily rate of solar energy absorption of 753.96 W/m^2 (8:00 a.m. to 4:00 p.m., solar time).

Material Holding Chamber

Horizontal drying trays (perforated flatbaskets) proved efficient. It allows materials to dry in a manner similar to thin layer drying, however, the problem of loading and unloading restricted its further development especially for drying small grains. The set-up is most appropriate for drying fish and vegetables.

A vertical tray holding bin constructed from wood and mesh wire was tested (Fig. 3). Sundrying tests for a tray capacity of 300 kg of paddy and 400 kg of corn gave a drying rate of about twice that of the floor drying at 7 cm thickness. Consequently, loading and unloading problems are minimized and the drying process resembles that of a counter-flow drying system.

Strip hangers were also designed to hold materials like tobacco (Fig. 4).

A continuous rectangular rail was provided to support the different material holding systems in a hanging position. Rollers enable movement of material from the main drying chamber to the pre-drying chamber without difficulty.

Center-tube Furnace

The center-tube furnace constructed from commercial and oil drums (Fig.5), was modified for higher capacity and longer service life by using soil brick materials (Fig. 6). Soil bricks were constructed from paddy soil and rice hull ash at 4 percent proportion by soil weight. Compressive strength of this proportion (50 kg/cm^2) were found superior over the rests of combinations tested. Coefficient of thermal expansion was found to be $4.8 \times 10^{-7}/°C$ which is lower compared to commercial bricks and concrete blocks.

The center-tube furnace can burn any kind of combustible agricultural residues with minimum adjustment. Due to the provision of adjustable air supply gate, black smoke during combustion was eliminated and ash recovered is almost negligible for coconut husks and sawdust and only about 16 percent by weight for rice hull. The furnace can generate heat requirement for a 10-ton dryer capacity.

Vortex Wind Machine

Features of the vortex wind machine were published in 1982 (PSAE Journal). A modified wind machine (Fig. 7) with inner-side vanes curved outward allows the wind entering the system to move in a smooth circular path at the side of the tower wall creating a more distinct and efficient low-pressure zone for suction.

The furnace chimney positioned directly beneath the wind machine increases the difference of temperatures between the ambient swirling air and the exhausting air resulting to an increased air suction. Tests observations gave a high system efficiency even without the conical frustum venturi.

DRYER SET UP AND THE DRYING PROCESS

The warehouse dryer (Fig. 8) measuring 10 x 5 x 3 m consisted of the material holding chamber, the center-tube furnace and the vortex wind machine. It is divided into two sections based on temperature gradient; the main drying chamber which is adjacent to the furnace, and the pre-drying chamber, which is located farther half-way of the structure.

Two lines of circular flue ducts inclined at 4 degrees which emanate from the furnace are laid under the trail of drying material trays and finally connected to the vertical chimneys located directly beneath the vortex wind machine. The chimneys are provided with dampers to permit variation of warehouse temperature.

Two vortex wind machines are positioned at the top center of the drying chambers. Jute sacks are provided around the tray rail which can be suspended down or rolled up depending on airflow and temperature requirements.

Air inlet doors are located at the bottom of the warehouse wall adjacent to the flue ducts while air vents at the top serve as air inlet when considering solar heat for drying. Openings of these air inlet doors and windows are made adjustable.

Drying proceeds in a manner such that the heated air is moved upwards from around the heat exchangers accross or through the layer of the drying materials. Saturated drying air is

exhausted at the wind machine tower. The pressure drop resulting from the circulating motion of wind entering through the tower blade clearances causes this upward movement of air.

RESULTS AND DISCUSSION

System Design Evaluation

The warehouse dryer is a new concept in drying which provides for higher capacity and multiple utilization. It makes use of non-conventional energy resources. It has an indirect heating feature which accounted for a better quality product.

The set-up resembles a counterflow dryer which allows drying at varied conditions. The rail system for the hangers enables movement of batches around the warehouse without difficulty. The drying/stored material can also be moved or circulated within the tray whenever deemed necessary. The zigzag movement of discharging materials permits mixing within the batch allowing the material to equilibrate. Occasional turning of trays can also be done to expose drying materials to varying conditions.

The design of trays and hangers maybe varied depending on the kind of materials to be dried/stored. The vertical trays allows a faster drying rate and maximum utilization of space, while the horizontal trays minimizes crushing of materials due to packing.

Temperature and airflow conditions can be controlled with the provision of a regulated fuel feed rate, adjustable airflow guide around the rail, air inlet doors and windows, and dampers in the chimney. The system can therefore be operated with low or high temperature allowing the materials to dry uniformly and therefore results to a better quality of products.

Previous investigators reported that high-low temperature drying resulted to an increased capacity and reduced energy consumption in addition to improved quality. A further advantage of the system is the ease in loading and unloading of materials.

Performance Evaluation

Drying conditions. Ambient air conditions recorded in this report were for the dry season harvest, 1983, Los Baños, Laguna and the adjoining locality. Generally, fair weather condition prevailed over the area with average range of relative humidity falling within 65-76 percent. Dry bulb temperature was recorded between 25 and 35°C. Wind blows from the S-W direction at velocities varying from a soft morning breeze to a gust amplitude of 5 m/sec in the mid-day which lasts for at least 3 hours.

Drying air temperature was maintained at 40-42°C for drying paddy and 48 to 51°C for drying corn, coconut meat and fish.

The total air suction rate gave an average of 63 m^3/min for the two wind machines.

Drying phenomena. The drying behavior of paddy, corn, coconut meat and fish materials in the warehouse dryer is shown in Fig. 9. Generally, the constant-rate drying period was not exhibited by the drying materials even the high-moistured corn and coconut meat. It is noticeable that moisture removal proceeds slowly at uniform rate as drying progresses. This can be accounted by the fact that while temperature inside the warehouse is maintained at a certain level, (40-42°C for paddy and 48-51°C for other materials) the air movement is effected by the natural draft of incoming ambient air and the suction created due to the low-pressure zone formed at the center of the wind machine.

Another striking characteristic of the drying curve is that moisture continues to rescind and does not seem to be asymptotic to the equilibrium moisture until after operation is terminated.

Fish drying behavior, however resembles that observed for drying heavy salted codfish (Strømmen, 1980).

Figure 10 reveals material advantage of drying paddy in the warehouse dryer over that of sundried on concrete floor and flat bamboo tray. Sundrying lags 1 to 4 hours behind that observed from warehouse drying. Obviously, this has been caused by the modified drying air condition.

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A characteristic tri-dimensional curve can be derived from observations of the effect of drying temperature and wind velocity on the drying rate of paddy (Fig. 11). It will be observed that temperature does not significantly affect the drying rate at low wind velocities, although in general drying rate increases with an increase in temperature. The effect of wind velocity and temperature is increasingly important at high levels. A high drying rate, however is not always desirable. It may be deleterious to the drying materials especially paddy where thermal stress and moisture diffusivity are critical conditions affecting crack generation.

Quality Assessment

Copra and fish. The quality of copra (dried coconut meat) and dried fish was observed superior over that of sundried materials. Observations however were limited to visual characterization of the dried products. A clean and desirable product smell is attributable to the controlled drying condition in addition to the fact that the dryer has an indirect type of heating system. Results would entail higher quality copra-oil yield and a more nutritious foodstuff.

Paddy. Milling analysis undertaken for the dried paddy revealed that warehouse drying is a potential system which yield comparable milling recovery with that obtained from sundrying technique. Paddy and milled rice analyses results are presented in Table 1.

Note however that from the results it cannot be disclosed that the potential milling yield is attained. Although comparisons were done with the warehouse-dried and sun-dried paddy with other conditions being held constant, there are a lot more factors affecting the milling recovery; variety, degree of maturity, purity, initial mechanical damage resulting from operations prior to drying and to a certain extent the milling system.

Table 1. Milled rice analysis after 24 hours of drying of warehouse-dried and sun-dried paddy (IR-42).

BROWN RICE COMPONENTS	% BY WEIGHT
Immature kernels	19.5
Fermented/chalky/grains	5.6
Damaged grains	1.7
Other varieti	0.5

MILLING YIELD	WAREHOUSE DRIED	SUNDRIED	
		Concrete Floor	Flat Bamboo Tray
Total milling recovery	67.5	65.7	65.2
Head rice	83.6	72.7	69.6

SUMMARY AND CONCLUSION

- The dryer is simple and low cost technology requiring minimum operational maintenance and adjustments.

- The dryer can be constructed from cheaper and locally available materials as rice straw and rice hull ash in correct proportion with paddy soil.

- It is most applicable for drying and storing different materials in one batch in separate lots and maybe used by farmers' groups operating in a cooperative or village level, and rice mill owners.

- In general, the venting rate or airflow rate during drying has more influence on the drying efficiency of the system than any other management variables. The airflow rate control was found more critical than temperature control especially so that the drying operation is highly weather dependent.

- Quality assessment was limited to visual observation of the physical appearances of dried material. For paddy, the determination of broken grain; for some other materials, which were tested to a little extent due to time constraint, observation of mold growth and color changes.

- An intensive aerodynamic analysis of airflow rate in the system had not yet been established due to lack of instrumentation. Results discussed were based mainly on measurements of air velocities and suction rates but the exact behavior of the direction of air movement had not been predicted.

- The concept of this dryer design would obviously be acceptable as intermediate technology but the context of application vary widely as weather condition as well as agronomic practices differ from one region to another; thus may hinder the full adaptation of the dryer design in some strategic locations where the need for dryers and store houses are even more serious.

ECONOMIC ANALYSIS

One of the most important decision that a farmer makes is to determine whether his investment for a dryer will be reasonable. His decision should be based on a sound economic analysis of the system he uses. He takes into account all opportunity costs that will reduce his drying cost with optimum efficiency.

In analyzing the feasibility of investing in a warehouse dryer, two alternatives were considered: (a) construction management is done by the farmer himself, and (b) the farmer hires a master carpenter for the construction. Further, the analysis undertaken considered paddy drying, although the dryer can be used for drying and storing other crops. Cost analysis information are summarized on the accompanying table . It will be noted that using the warehouse dryer, a cavan of paddy (50 kg) can be dried from 25 to 14 per cent moisture content with a nominal fee of ₱0.67 to ₱0.70.

Benefit cost analysis revealed that it is worth investing in a warehouse dryer as evidenced by the benefit cost ratio (BCR) equal 1.8 and the investment can be recouped in 2.04 years (or after drying 2040 tons of paddy). Annual cost is also covered by drying at least 418.2 tons per year. A fair rate of return of investment can also be manifested by the multi-purpose application of the structure.

Basic information used in the calculation of the warehouse operating costs is given in Appendix 3.

Table 2. Cost analysis for the warehouse dryer, April 1983.

CAPITAL OUTLAY		₱ VALUES
Warehouse		7890.28
Furnace		1037.50
Wind machines (2 units)		2130.00
Attachments		6995.,0
Construction labor[a/]		
a. Farmer based		3916.00
b. Commercial-based		7841.00
	Total a.	21969.48
	b.	25894.48

Fixed Cost Per year	a	b
Depreciation[b/]	3024	3024
Interest on ave. cap. inv.[c/]	2021	2610
Repair and maintenance cost, 3%	659	777
Total fixed cost/year	5704	6411
Variable Cost/Batch (7 tons paddy)		
Fuel[d/] rice hull	11.70	
Labor[e/]: loading/unloading	18.00	
dryer operator	24.00	
Total variable cost/batch (7 tons)	53.70	
Total variable cost/ton	7.67	

Annual Utilization[f/]: 1000 tons (. .dy drying only)		
Total variable cost/year	7670	7670
Total fixed cost/year	5704	6411
TOTAL COST PER YEAR	₱13374	₱14081

Note: See Appendix 3 for the superscripts.

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Appreciation is also extended for the guidance and advises of Mr. MAKOTO ARIYOSHI during the testing of the dryer particularly in the selection and set-up of instruments.

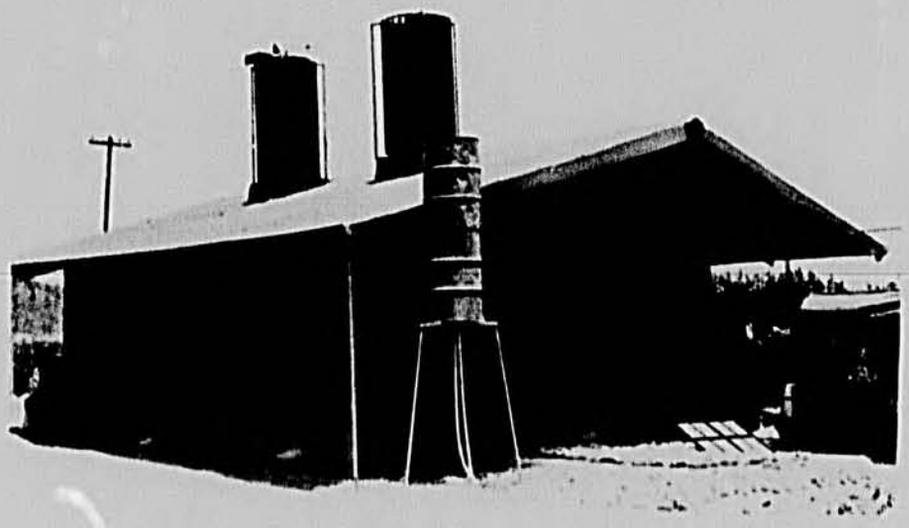


Fig. 1. Warehouse dryer with soil-straw wall.

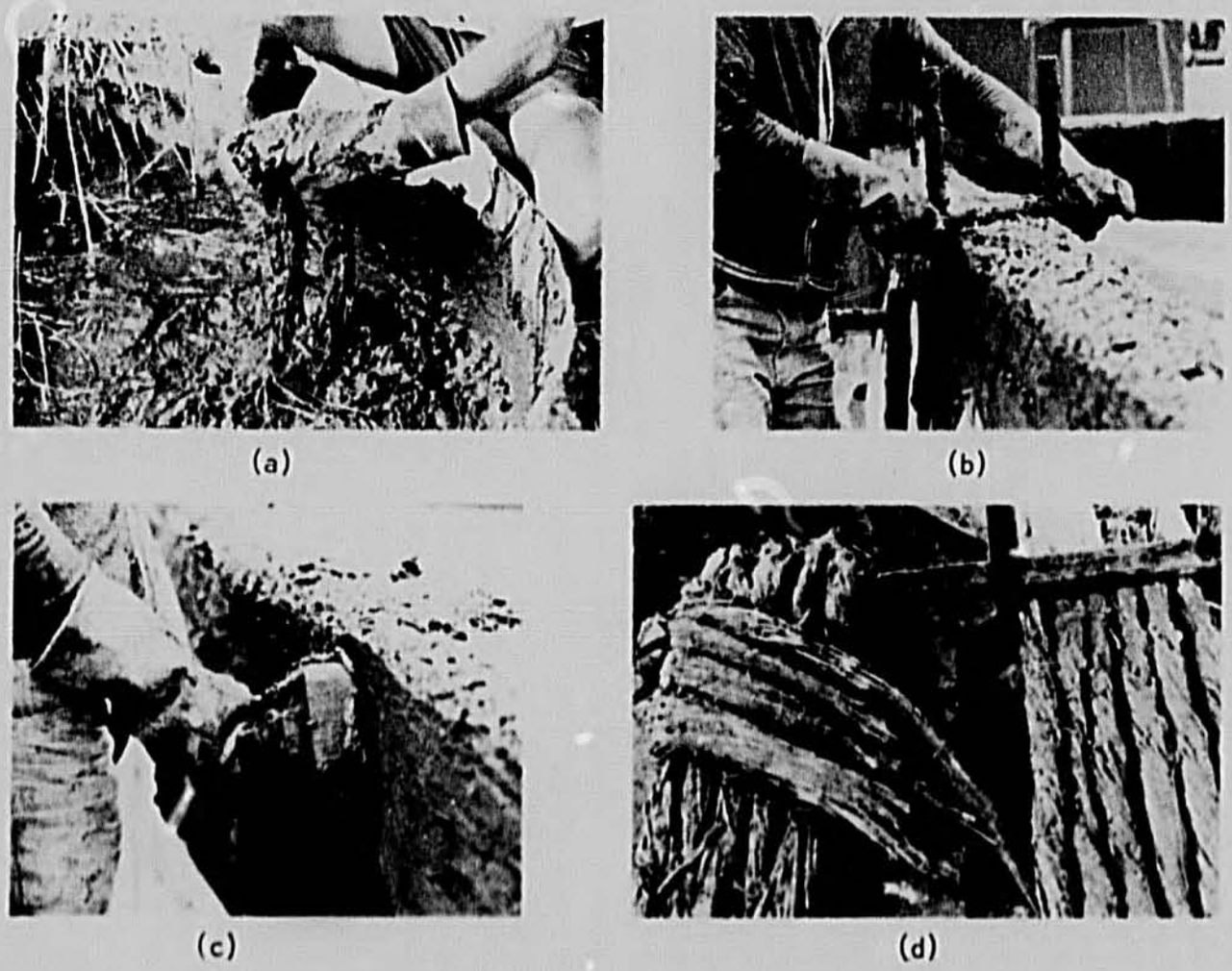
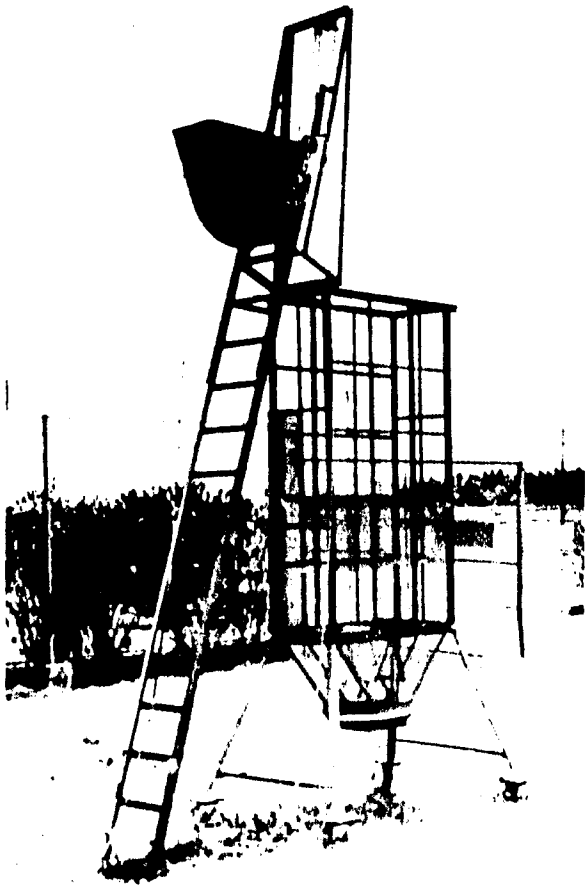
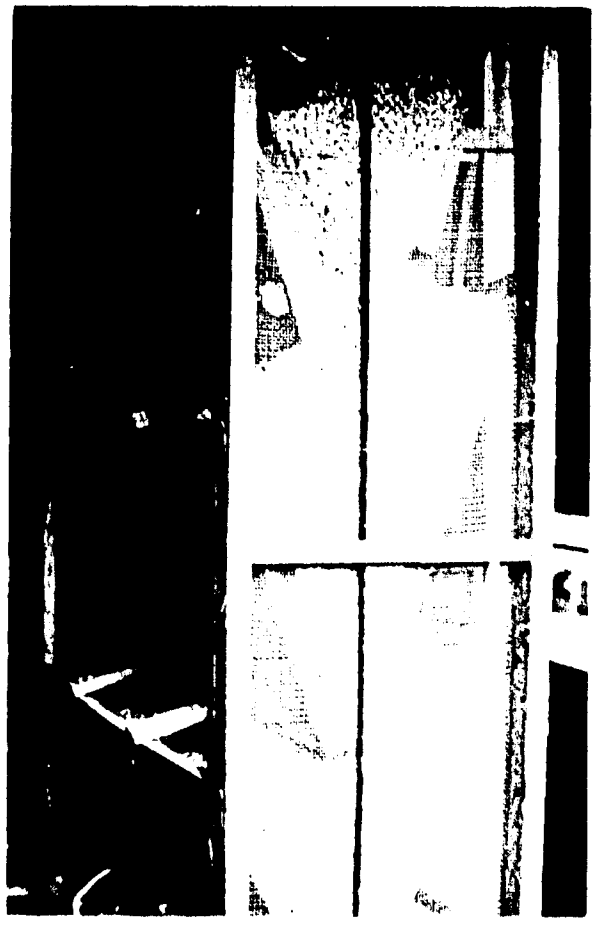


Fig. 2. Steps in constructing the soil-straw wall: a) mixing soil and straw, b) laying, compacting and regulating wall thickness, c) compacting and smoothing sides using a gable, d) methods of straw laying: cross and straight-laying.



(a)



(b)

Fig. 3. Vertical tray holding bin: a) for large size materials like ear corn and b) for small grains.

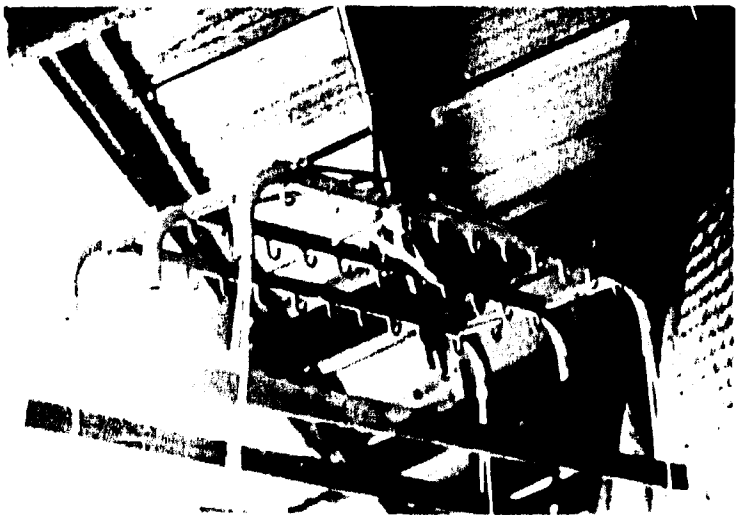


Fig. 4. Strip hangers for holding tobacco and similar material.

Fig. 5. Center-tube furnace constructed from commercial drum.

Fig. 6. Soil-brick made center-tube furnace.

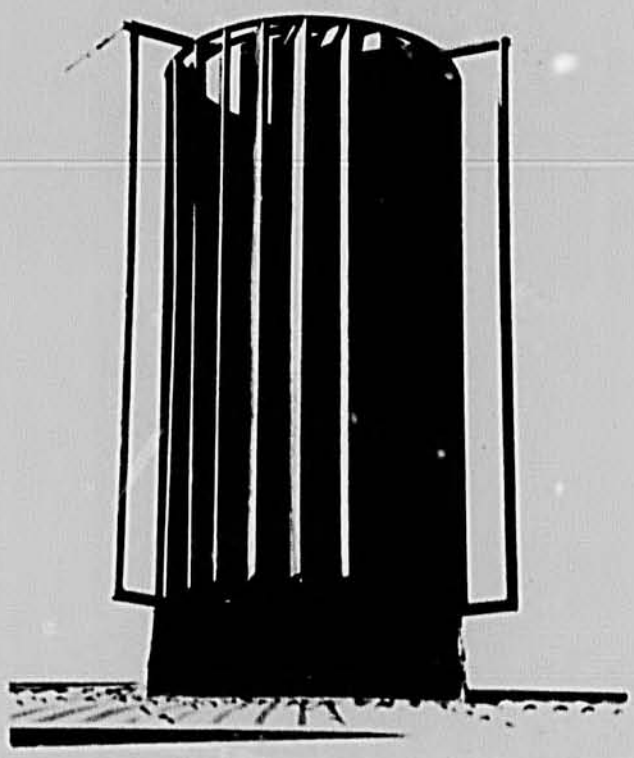


Fig. 7. Modified vortex wind machine.

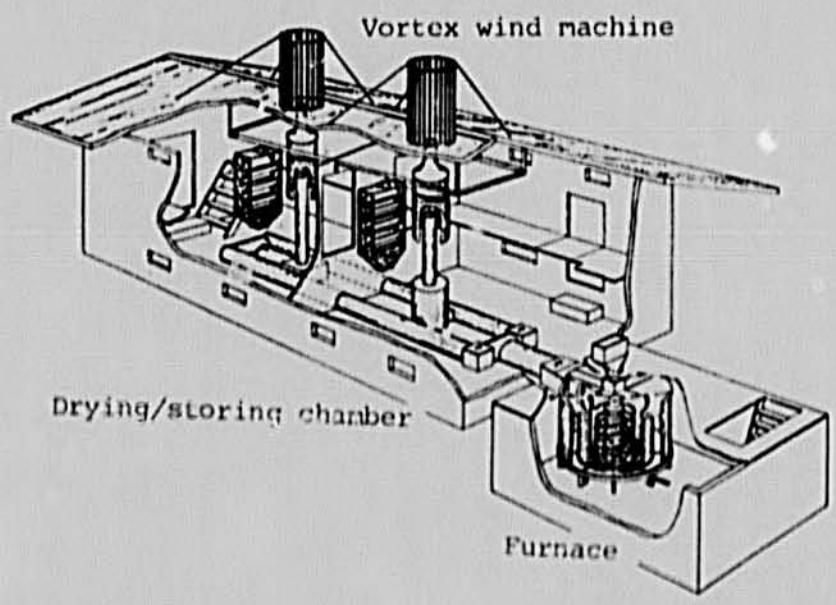


Fig. 8. Cut-out view of the warehouse dryer.

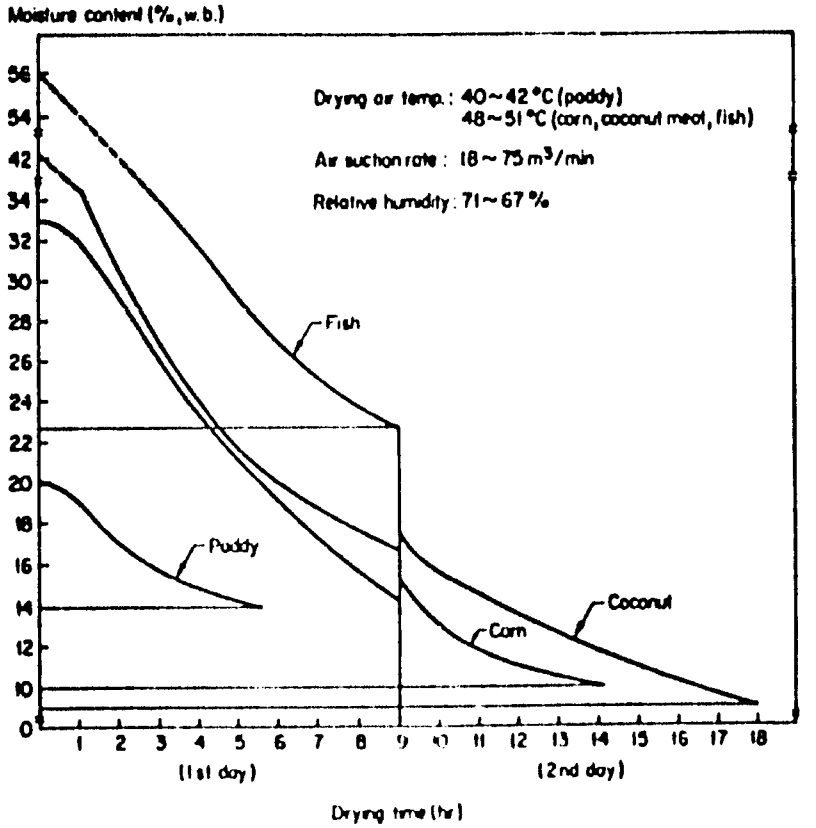


Fig. 9. Drying behavior of paddy, corn, coconut meat and fish materials in a warehouse dryer.

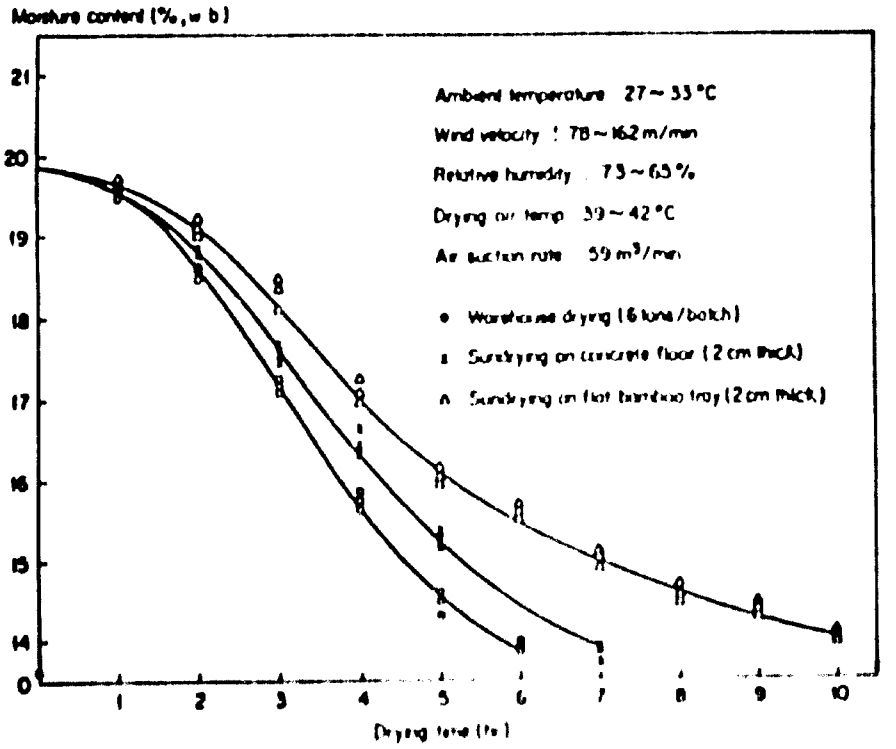


Fig. 10. Drying behavior of sun-dried and warehouse dried paddy.

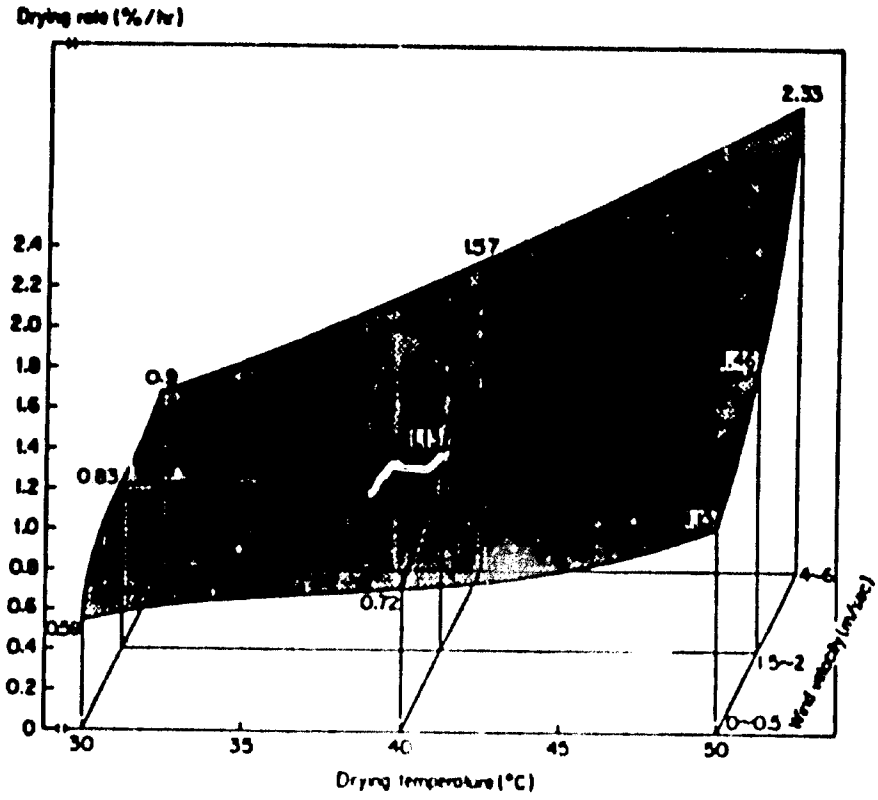


Fig. 11. Drying rate as affected by drying temperature and wind velocity.

Appendix 1. Typical weather conditions and general trends in agriculture (UPLB and IRRI, 1970-1980).

- Mean ambient air temperature : 29.4°C
- Mean relative humidity : 80 percent
- Average wind speed : 1.44 m/s
- Mean annual percent possible sunshine : 50 percent

  Highest (April) : 22.97 mJ/m . day
  Lowest (January) : 10.25 mJ/m . day

- Major crops grown : Rice and corn, with rice as the dominant and staple crop
- Average grain yields : 2.65 tons/ha (rice)
  2.94 tons/ha (corn)
- Harvest seasons

  Wet season : September to December
  Dry season : May to June

- Grain moisture content at harvest : 25 to 33 per cent, dry basis
- Farm size range : 1 to 10 hectares
- Agricultural wastes (i.e. rice hull, coconut husk and shell, sawdust, etc.) are available energy sources.
- Majority of farmers still dry their grains by spreading them on grounds or pavements under the sun
- Electricity is not available in most smaller towns and farms
- Most rural houses and farm storage buildings are constructed with corrugated galvanized iron (Cor. G.I.)sheets roofing materials.

Appendix 2. Basic design characteristics.

- Type : Warehouse type, non-conventional
- Power source : Wind
- Heat source : Sun and/or furnace fueled with agricultural wastes
- Capacity : Up to 8 tons per batch; suited for cooperative or village level operation of a group of farmers or rice mill operators
- Versatility : Use as DRYER and STORE HOUSE for different materials. Holds materials in SEPARATE LOTS
- Technology : Simple, intermediate, within farmers' capability
- Construction materials : Low cost, locally available

Appendix 5. Basic information; Warehouse dryer operating cost.

a/ Labor for construction of the warehouse dryer assumed 2 situations a: farmer based b: commercial based which employed a master carpenter.

b/ Depreciation was computed using the straight-line method and salvage values and life span for each component as follows:

a.	warehouse	:	5% SV - 15 years life
b.	furnace	:	10% SV - 8 years life
c.	wind machine	:	10% SV - 10 years life
d.	attachments	:	5% SV - 3 years life

c/ Interest on average capital investment at 15% interest rate per annum and computed as follows:

$$\frac{IC + SV}{2} \times 15\%$$

d/ Fuel used was rice hull at 21 kgs./hour or 2 bags of ₱0.65/bag (assumed a cost of ₱0.30/bag + ₱0.35/bag transport costs, 9 hrs/batch x ₱1.30 = ₱11.70). (Rice hull is available within 10-km radius of dryer location).

e/ Labor used:

- for loading and unloading, 3 men worked for 2 hours each with a wage rate of ₱3/hour.

- a dryer operator tends the furnace during the drying operation and paid at ₱3/hour.

f/ Annual utilization: 78 days (dryer capacity: 7 tons per batch).

IRRI Saturday Seminar
February 12, 1983

PRELIMINARY TESTS OF A LOW-COST PADDY DRYER UTILIZING RICE HULL OR STRAW[1/]

B. D. Shukla, I. Manalili, R. E. Stickney
and C. W. Bockhop[2/]

ABSTRACT

Throughout rice farming areas in developing countries the most common practice for drying paddy is to expose the grain directly to sunlight. This "sun-drying" method continues to be popular because of its simplicity and low-cost. However, an increasing quantity of paddy is being harvested during the wet season, and in this case sun-drying is often delayed due to clouds and rain. These delays lead to deterioration of the grain quality and induce some farmers to sell without drying. The result is that farmers receive substantially lower prices for paddy which has poor quality or is undried.

This problem has led to the development of a variety of low-capacity paddy dryers. None of the present designs have been widely accepted, generally because the cost is high for a device that it is utilized only when sun-drying is prevented by clouds or rain. The present study is an attempt to develop a simple, low-cost dryer which complements sun-drying and utilizes rice straw or hull as fuel. The basic concept is that the dryer will be used only when sun-drying is prevented by weather, and it will serve to pre-dry paddy to a moisture content (MC) of about 18%, which is adequate for temporarily storing the grain until the weather allows complete drying under the sun.

This report summarizes the initial phases of design and testing of a "heated floor dryer" (HFD). The main components of the HFD are: (1) a furnace in which rice straw or hull are burned to heat water

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1/ The authors are grateful to Mr. Abelardo F. Baclig, Superintendent, PPC Rice Farm, Musuan, Bukidnon for his valuable suggestions and providing the facilities for testing the dryer.

2/ Post-doctoral fellow, Assistant Engineer, Agricultural Engineer and Head, respectively, Agricultural Engineering Department, The International Rice Research Institute, Los Baños, Laguna, Philippines.

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to the desired temperature (e.g., 80°C); (2) a pump for circulating the water from the furnace water-jacket to the drying floor; (3) a metal drying floor heated internally by the circulating water; (4) a roof to protect the floor from rain. By locating the HFD adjacent to a conventional sun-drying floor, it is convenient to push the paddy from sun-dryer to HFD when clouds appear. The system has been designed for small groups of farmers, such as milling and marketing cooperatives, in areas where labor-intensive drying is more appropriate than mechanized drying.

The results of initial tests indicate that grain breakage (percent broken grains) is lower for the HFD than for conventional sun-drying even at HFD temperature of 90°C. The drying rate is related to floor temperature, frequency of mixing ("raking"), thickness of paddy layer, and initial and final moisture content of the paddy. Additional work is needed to: (a) determine the HFD performance for conditions of high relative humidity (e.g., during rain); (b) reduce the initial and operating costs; (c) evaluate farmer acceptance of the design.

INTRODUCTION

Modern varieties of rice are enabling an increasing number of farmers to grow more than one crop per year. In this case the first crop is generally harvested during the wet season rather than at the beginning of the dry season, and farmers often encounter clouds or rain which delay drying of their paddy by the common practice of exposing it to the sun ("sun-drying"). When paddy is not dried within a day or two, the grain quality may deteriorate substantially due to several mechanisms (Ojha 1974, Araullo, et al 1976 and Esmay, et al 1979). As a result of these problems, farmers often receive reduced prices for their paddy either because the quality has deteriorated due to delays in drying or because it is sold without being dried.

Several designs of artificial dryers ranging from simple batch type to sophisticated high volume dryers have been introduced in the Philippines over the past two decades (INSAET). However, none has achieved widespread acceptance for small-scale drying by individual or groups of farmers. The following are possible reasons for why artificial dryers have not been accepted:

(1) Sun-drying has proven to be simple, inexpensive, and convenient technique except during occasional periods of prolonged cloudness and/or rain.

(2) The farmer lacks the necessary capital to purchase and operate an artificial dryer.

(3) The price incentives for drying and grain quality are not sufficient in the Philippines to promote the use of dryers.

(4) Some artificial dryers have not performed satisfactorily in the past, as described by Rawnsley (1968).

Hence, the development of an artificial dryer, suitable and within economic reach of farmers in Philippines, continues to be an unsolved problem. This report describes the initial phases of our attempt to develop such a dryer. To reduce the complexity of the work, we have chosen to concentrate primarily on one particular needy area rather than all the country. The province of Bukidnon in Mindanao was chosen because:

(i) Grain drying is a critical problem due to intensive cropping, inadequate drying facilities, and a long wet season;

(ii) The Ministry of Agriculture (MA) and The International Rice Research Institute (IRRI) Industrial Extension Program for Small Farm Equipment is active in the area; and

(iii) The Philippine Packing Corporation Rice Farm in Musuan, Bukidnon, provides a unique opportunity for conducting accelerated tests of dryer prototypes because paddy is harvested six days per week throughout the entire year.

REVIEW OF PROBLEM AND PRELIMINARY STUDY

The first phase of this work was to discuss paddy drying with: (1) farmers and rice traders in Bukidnon; and (2) manufacturers and researchers (IRRI, IPLB, SEARCA, etc.) (Stickney, 1982).

The principal conclusions were:

1. Rice drying is widely recognized as a critical problem in the Philippines and there are various attempts to increase the capacity of public and private drying facilities.

2. Although the equipment for artificial drying are available for large and medium scale facilities of the National Food Authority (NFA) and private traders/millers, it appears that none of the existing designs for small-scale dryers (less than 15 T/day) are acceptable to farmers.

3. Based on our preliminary economic analysis, a small-scale dryer will not be acceptable unless the drying cost is considerably less than ₱0.20 per kg (₱10.00/cavan).

4. Due to low cost of the traditional sun-drying method, it is expected that farmers will use the artificial dryer only on those days when clouds or rain prevent sun-drying. Consequently, any artificial dryer must be compatible with sun-drying if it is to achieve farmer acceptance.

5. The most essential function of the artificial dryer will be reducing the moisture content of the harvested grain to approximately 18%, thereby enabling farmers to store it for several days until the weather is suitable for sun drying of the grain to a desired final moisture content (approximately 14%).

6. Bukidnon appears to be an appropriate area for preliminary testing and extension of the dryer.

A wide variety of dryers have been designed and tested at different research institutions. In considering these designs, two criteria, fuel source and power source, were considered to be especially important to farmers in the Philippines. Figure 1 presents these two criteria to categorize types of dryers. The level of technology is lowest

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in the lower left hand corner in Figure 1, and increases as one moves upward and to the right. Based on the above criteria, the most promising dryers are encircled by the dotted line in Figure 1 and described below:

1. Warehouse dryer: Jeon, Bockhop, and Halos (1982) developed and tested this innovative type of dryer at IRRI. The work is being continued to reduce the initial cost and the labor required for loading and unloading the dryer.

2. Stirred pan dryer: Chancellor (1968, 1968a and 1971) developed this design which is basically a huge frying pan heated by direct flame of burning rice straw, with the grain being stirred by animal power. There has not been sufficient interest in this dryer to continue the R&D effort.

3. Heated floor dryer: We conceived this design as a possible extension of sun-drying and a modification of Chancellor's concept. The principal attribute is that it is a simple technology which is complementary to the sun-drying technique during cloudy or rainy periods. Moreover, the same labor force for sun-drying could be used for heated floor drying at the time when workers would otherwise be idle due to cloudy or rainy weather conditions.

OBJECTIVES

Based on the information obtained from the critical review of the drying problem in Bukidnon, the development of a heated floor dryer (HFD) project was undertaken with the following objectives:

1. To design and develop a heated floor dryer, using hot water to heat the dryer floor.

2. To establish the relationship between drying rate, floor temperature, relative humidity of ambient air, thickness of grain bed, mixing interval, crack ratio and milling broken percentage of rice.

3. To test the prototype dryer in actual working environment at Philippine Packing Corporation (PPC) Rice Farm.

4. To develop a furnace for the dryer using paddy straw, hull, or other agricultural wastes as fuel.

5. To estimate the economic, social and technical feasibility of the heated floor dryer.

STUDY ON HEATED FLOOR DRYER

The study was conducted in two phases:

1. Model study of heated floor dryer
2. Prototype study of heated floor dryer

1. Model Study of Heated Floor Dryer

Before fabrication of full scale prototype HFD, it was essential to conduct a preliminary test of the most critical aspects of the basic concepts of the dryer. Thus the model of the HFD was tested with the following objectives:

(i) To determine the relationship between operating conditions (floor temperature, initial and final moisture content, drying time, relative humidity of ambient air, mixing interval, grain bed thickness, etc.) and grain quality (crack ratio, milling broken percentage, discoloration, etc.).

(ii) To develop the hypotheses for the design and testing of a prototype of HFD.

Testing the HFD Model:

An experimental HFD model (Figures 2 and 3) was designed and fabricated for the preliminary studies. In general, the dryer had three major components, viz, a kerosene burner was used to heat the water in a tank; hot water was circulated through the floor of the dryer by means of connecting pipes and a pump and the floor was heated to a desired temperature. The model dryer was initially tested at IRRI Engineering Department and then at PPC Rice Farm, Musuan, Bukidnon. The testing procedures of HFD model were:

(1) Water flowing from the tank to floor of the dryer, was measured with graduated cylinder and stop watch.

(2) Initial water and floor temperature, relative humidity (dry and wet bulb temperature) and moisture content of grain were recorded with thermocuples, a psychrometer, and a Cera moisture tester, respectively.

(3) When the water in the tank reached the desired temperature, the pump was started to circulate the hot water through the drying floor.

(4) The floor temperature was controlled by adjusting the flame of the kerosene burner and the flow rate of hot water.

(5) When the floor temperature attained steady state, paddy was placed on the hot floor and the drying operation started.

(6) Since the drying floor had two equal compartments, two tests with different variables were conducted when required.

(7) The variables were the following:

(i) Drying floor temperature: 60, 70, 80, 90 and above 90°C

(ii) Mixing interval: continuous, 10, and 30 min.

(iii) Thickness of grain bed on floor of dryer: 2, 4.5 and 7 cm.

(8) Moisture content of paddy, floor temperature, inlet and outlet temperature of hot water, dry and wet bulb temperature of ambient air, etc. were recorded at subsequent intervals during the drying operations.

(9) Mixing of grains was followed as desired during the drying operation. Mixing was done manually in similar way as was done manually at PPC Rice Farm for sun drying of paddy (Figure 2).

(10) As soon as the moisture content of paddy reached approximately 18%, the total drying time was recorded and paddy was unloaded from the dryer.

(11) A sample of about 250g was collected and cooled before it was placed for sun drying to reduce its moisture content to 13-14%.

(12) The same procedures were repeated for various runs with different variables.

(13) Control samples for comparison were collected from the PPC Rice Farm which were dried from the initial moisture content to approximately 14% by their normal method of sun drying.

(14) Other control samples were dried under the shade.

(15) Crack ratio, milling test and discoloration tests were performed and the results were compared.

Results of HFD model test:

After analysis of samples of paddy with the model dryer, the following results were obtained:

(1) The milling broken percentage were generally below 32% in all the runs, and usually were between 6 and 28%.

(2) The crack ratio and milling broken percentage appear to increase with the drying temperature (floor temperature of the dryer). At 80 and 90°C, the crack ratio and the milling broken percentages were higher than at 60 and 70°C, although the data were more widely scattered at 80 and 90°C.

(3) The drying rate increases with the floor temperature.

(4) The crack ratio and milling broken percentage exhibit a poor degree of correlation.

(5) At lower initial moisture content of paddy, the broken percentage and crack ratio were generally higher.

(6) Mixing interval played an important role during the drying. It was observed that the drying rate increased markedly when the mixing interval was 1 to 2 minutes rather than 10 to 30 minutes.

(7) It appears that the drying rate was not strongly dependent upon the relative humidity of ambient air.

(8) The milling broken percentage were observed to be higher with traditional sun drying at PPC Rice Farm than with the heated floor drying of paddy.

(9) The thermal efficiency (ratio of enthalpy of evaporated water to change of enthalpy of water to drying floor) ranged from 13 to 28% and did not exhibit a clear dependence on floor temperature or paddy layer thickness.

Hypotheses developed: On the basis of the summary of results, following hypotheses were developed:

<u>Hypo-1</u> Our sun drying (dried on the same platform used by the PPC Rice Farm for their sun drying) gives the same breakage as PPC sun drying technique.

<u>Hypo-2</u> Grain breakage increases with increasing floor temperature.

<u>Hypo-3</u> Drying rate increases with increasing floor temperature.

<u>Hypo-4</u> Drying rate increases with decreasing mixing interval.

<u>Hypo-5</u> Grain breakage decreases with decreasing mixing interval.

<u>Hypo-6</u> Grain breakage and drying rate do not depend significantly on relative humidity of ambient air.

<u>Hypo-7</u> Grain breakage with HFD followed by sun drying is not significantly higher than with the PPC sun drying.

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Hypo-8 The HFD functions satisfactorily with wet (high MC) paddy.

Hypo-9 The drying rate is directly proportional to the thickness of the grain layer on floor.

2. Development and Testing of Prototype HFD

Having the encouraging results from the HFD model testing, it was decided to develop a prototype dryer and test the same at the PPC Rice Farm. The dryer was designed and fabricated without trying to minimize cost at this phase of the project. The main emphasis was given to testing its performance and evaluating the principles of operation. The model dryer was of very low capacity and several drawbacks noted during its test were unavoidable. Therefore, the prototype dryer test was necessary before going for a large scale dryer manufacturing.

Fuel and power are the major considerations in minimizing the operational cost of the dryer. The cheapest and most readily available fuel for the farmers would be rice straw and rice hulls. Dr. Jeon is working on the rice hull furnace, and the same could be used for the HFD for heating the water.

A commercial boiler is already available on the market where wood chips, rice straw, rice hulls, etc. are used for heating the water. This boiler was fabricated by the Passat Company of Denmark. It is already in operation for drying the paddy by several rice millers in the Philippines. A similar, but more inexpensive, type of boiler could be developed in future.

The schematic drawing of the HFD, and detailed drawings are presented in Figures 4, 5, and 6. Figure 7 presents overall and close views of the dryer.

Testing procedures of prototype HFD:

The same procedures described for testing the model HFD was followed with the following required modifications:

Preparations before test:

(1) Before proceeding with the experimental tests, all the joints and connections of dryer and boiler were checked thoroughly and if there was any fault, was corrected at once.

(2) The furnace was loaded with the required amount of fuel (wood in this test) and was fired after checking the water level in tank.

(3) As soon as the water temperature in the boiler reached the required level, hot water was circulated to the dryer floor through pipe connections and pump.

(4) A constant desired temperature of the dryer floor was attained before placing the paddy for drying.

Conditioning of paddy:

(1) The IR-56 variety of paddy was used for testing the performance of dryer.

(2) Same day harvested paddy was mixed thoroughly and put in the bags for drying.

Drying for paddy:

(1) The weight of paddy to be loaded on the dryer was adjusted for its initial moisture content in order to ensure that the quantity dried in different runs would be equal at 14% MC. Weight of grain was calculated by the following formula:

$$W_i = \frac{(1-MC_f)\,\rho\, t\, A}{(1-MC_i)} \quad \ldots(1)$$

where:

W_i = Weight of paddy before drying, i.e., at initial moisture content, kg

MC_i = Initial moisture content, in fractions

MC_f = Final moisture content = (14% MC), 0.14

ρ = Bulk density of paddy at 14% MC = 501.28 kg/m^3

A = Drying floor area = 12.05 m^2

t = Thickness of grain bed, m

Thus, for a particular desired quantity of paddy at 14% MC, the weight at its initial MC was calculated and loaded on the dryer for drying.

(2) Mixi . of the grain at a certain interval was performed with wooden takes similar to ones used by the PPC in traditional sun drying of paddy.

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(3) Floor temperature, dry and wet-bulb temperature of ambient air, and moisture content of paddy were recorded with thermocouple wire fixed at the bottom of dryer plate, psychrometer, and Dole type of moisture tester, respectively.

(4) When the paddy approached 18% MC, several samples of about 1.5 kg each were taken at 5 or 10 minute intervals. The moisture content of all the samples were recorded and the one which had approximately 18% MC was selected for sun drying to 14% MC. Other samples were rejected, and the dryer was unloaded for the next run.

(5) Total drying time (from initial MC to approximately 18% MC) was recorded.

(6) The selected sample was placed for sun drying, and when the sample reached 13-14% MC in sun drying, it was sealed in a bags for subsequent quality analysis.

(7) The same procedures were repeated with various runs and different variables. The following were the variables:

(i) Floor temperature: 60, 70, 80, 90°C

(ii) Grain bed thickness: 2, 4, 6 cm.

(iii) Mixing interval: 1, 5, 30 min.

Analysis of dried paddy samples:

(1) About 200 g of each paddy sample was hulled by a laboratory model Satake Huller. The brown rice weight was recorded.

(2) The brown rice was passed through a Satake stone-type polisher and a mixture of brokens and head rice was obtained. It was weighted and recorded.

(3) The head rice and brokens were separated by an indented plate type laboratory model separator. The weights of brokens and head rice were recorded.

(4) The broken percentage was calculated by the following equation:

$$\beta = \frac{b_w}{M_w} \times 100 \qquad \ldots(2)$$

where:

β = Broken rice, %

b_w = Weight of brokens, g

M_w = Weight of polished rice (mixture of brokens and head rice), g

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(5) Six grains of head rice were immersed in one percent (w/v basis) solution of KOH for one hour. The reaction of alkali solution with the rice kernels provides a simple test of the degree of parboiling of the rice resulting from heating during drying by the HFD. After one hour the reaction of alkali with rice kernels was observed and degree of parboiling was recorded as suggested by Juliano (1982).

RESULTS AND DISCUSSIONS

The results are presented in two main headings: performance characteristics of the HFD and quality of milled rice. All moisture content values mentioned in this paper are on wet basis.

1. Drying characteristics

In the model testing of HFD, two factors, floor temperature and grain mixing interval, were found directly related with the drying rate of paddy. Based on those results, it was decided that the thickness of the grain layer on the dryer should be about 4 cm thick, which corresponds approximately to a loading of 20 kg (14% MC) per square meter of dryer floor area. The standard conditions under which the prototype HFD was tested were: the one minute mixing interval; approximately 90°C floor temperature, and 4 cm grain bed thickness. However, several runs were also made for 5 and 30 minute mixing intervals, 60, 70 and 80°C floor temperature, and 2 cm and 6 cm grain bed thickness.

Data on the total drying time in minutes and floor temperature in °C are presented in Figure 8. It is observed that the drying time reduces as the floor temperature increases. The scatter is substantial, most likely because of the differences in initial moisture content of the paddy, MC_i.

To attempt to correct for MC_i, the total drying time was divided by the change in MC , i.e., the difference of the initial and final moisture content of the paddy. Hence, a "corrected" drying time in minutes per unit MC change was obtained and the results are shown in Figure 9. The relation between drying time and floor temperature are observed to be more consistent in Figure 9 than in Figure 8.

If the drying rate is controlled by the vaporization process rather than by heat or mass-transfer processes, then the rate of equation should have the following form:

$$\text{Drying rate} = \frac{k_1}{\theta} = k_2 \exp\left(-\frac{hfg}{RT}\right) \quad \ldots(3)$$

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where:

k_1 and k_2 = Constants

θ = Drying time

hfg = Latent heat of vaporization of water

R = Universal gas constant

T = Absolute temperature, °K

Taking the logarithims of both sides of equation (3), we have

$$\ln \frac{k_1}{\theta} = \left[\ln \; k_2 \; [\exp \; (-hfg/RT)]\right]$$

$$\ln k_1 - \ln\theta = \ln k_2 - \frac{hfg}{RT}$$

$$\ln\theta = \ln \frac{k_1}{k_2} + \frac{hfg}{RT} \qquad \ldots(4)$$

If we substitute $\frac{k_1}{k_2} = C$, a constant in equation (4)

$$\therefore \; \ln\theta = \ln C + \frac{hfg}{RT} \qquad \ldots(5)$$

Differentiating the equation (5) with respect to 1/T, we have

$$\frac{d}{d(1/T)} \; [\ln\theta] = \frac{d}{d(1/T)} \; [\ln C] + \frac{d}{d(1/T)} \left(\frac{hfg}{RT}\right)$$

$$= 0 + hfg/R$$

$$\therefore \; \frac{d}{d(1/T)} \; [\ln\theta] = hfg/R \qquad \ldots(6)$$

Substituting the value of hfg = 9714 cal/mole for water (Prigogine et al 1954) and R = 1.987 cal/mole °K,

$$\therefore \; \frac{hfg}{R} = \frac{9714}{1.987} = 4889 \; °K$$

98

Since, equation (6) is expressed in Napierian base logarithims, and we will utilize the following relationship between Napierian base and Common (base 10) logarithims:

Napierian base log = 2.718 (Common base log)

$$\therefore \frac{d}{d(1/T)} [\log\theta] = \frac{1}{2.718} \qquad \frac{d}{d(1/T)} [\ln\theta] = \frac{4889}{2.718} = 1803.97°K \qquad \ldots(7)$$

$\therefore$ If we plot log θ vs. 1/T, the slope of the curve should be equivalent to 1803.97°K if the rate controlling step of the HFD is vaporization of water rather than heat or mass transfer steps.

The log of corrected time in minutes per unit MC vs. temperature in inverse Kelvin ($°K^{-1}$) was plotted and given in Figure 10. The solid line drawn through the data points in Figure 10 has the slope given by equation (7). Since the curve closely represents the trend of the data, we conclude that vaporization is the rate of controlling step.

An experiment was conducted to find a relation between the total drying time and grain bed thickness at a floor temperature of approximately 90°C and one minute mixing interval. The corrected drying time versus the grain bed thickness is shown in Figure 11. It is observed that the total drying time with respect to a 2 cm layer was approximately doubled and tripled when the thickness was increased to 4 and 6 cm, respectively. However, since the line does not pass through the origin in Figure 11, the drying rate is not exactly directly proportional to the bed thickness.

An experiment was conducted where the mixing interval was varied and floor temperature and grain bed thickness were kept constant as about 90°C and 4 cm, respectively. The relationship between the corrected drying time and mixing interval is shown in Figure 12. It was observed that at 1, 5 and 30 minutes mixing interval, the average total time taken for drying the paddy was 11.39, 17.57, and 25.26 minutes per unit MC respectively. We conclude that drying is accelerated markedly by frequent mixing.

It is believed that the paddy grain directly in contact with the floor are heated effectively by conduction. This heating increases the evaporation of the moisture from the grain. The ambient air in contact with the grain picks up the evaporated water and transports it away by natural convection and/or diffusion processes. By mixing the grain, the cooler, moist grain come in contact with the hot

surface more frequently which increases the evaporation of moisture. Hence, by increasing the frequency of mixing, the total drying time is reduced.

The relation between drying rate and relative humidity of ambient air could not be established in detail because there were few occasions of high humidity during the test period. However, based on limited observations, it appears that the HFD drying rate is not influenced significantly when the ambient relative humidity is high (i.e., about 90% as during rain). The average relative humidity during the tests was about 60%.

2. Milling quality of rice

The most significant aspect of rice milling quality is the proportion of head rice produced (Chancellor 1968). Head rice is defined as whole grains plus brokens with sizes equal to or greater than 75% of whole kernel (Pandya 1971; Sharma and Kunze 1982). Since head rice has a higher market value, drying and milling equipments are designed to minimize breakage of grain. Several terminologies have been used to define the degree of breakage by various researchers (Sharma and Kunze 1982) but, finally all are related with the head rice recovery after the milling. A poor degree of correlation between the crack ratio of brown rice and percent milling brokens was observed when evaluating the model HFD. Hence, the paddy dried with the prototype HFD was tested only for its milling quality and parboiling effect.

The samples were collected before placing the paddy on the HFD and dried separately in the shade. Similarly, the sample in bulk was also taken from the batch of paddy which was to be dried under the sun in traditional way at PPC Rice Farm. This sample was dried carefully on the same drying floor together with the same batch of paddy from where it was taken. The only extra attention was paid with the careful drying operation that the paddy was mixed regularly and was collected when the moisture content was reduced to about 14%. Whereas the traditional sun drying operation was handled by the PPC workers in their own way.

The comparative results of broken percentage corresponding to different methods of drying are presented in Figure 13. The shade dried paddy produced the lowest percentage brokens (6 to 9%) whereas in careful and actual sun dried paddy the ranges were 10 to 49% and 30 to 66%, respectively. The percent brokens in heated floor dried paddy were in the range of 7 to 25%, with no clear dependence on floor temperature. Thus, the paddy dried with HFD produced less brokens than the sun dried paddy. The percent brokens in heated floor dried paddy frequently fall within the range of shade dried paddy. Even in extreme conditions, these brokens were not more than 25%.

There could be several reasons for more brokens in actual sun

dried paddy in compared to careful sun drying. (1) The workers at PPC Rice Farm do not pay much attention to proper mixing of the paddy at definite intervals, thus the drying was not uniform; (2) Tractors are used for spreading and collecting the paddy, and weight and friction between wheel and floor may crack grain; (3) The paddy is often overdried when there is bright sunshine, and; (4) During sudden rain the paddy gets wet and, when redried, cracking occurs.

There was no relationship between the mixing interval and broken percent of milled rice as shown in Figure 14. However, frequent mixing plays an important role in reducing the drying time as shown in Figure 12. Therefore, if rapid drying is desired, it could be done by mixing the grains more frequently without affecting the quality of rice.

The data shown in Figure 15 indicate that grain breakage is not influenced markedly by the thickness of the layer during drying. It is suspected that frequent mixing reduces any possible effect of thickness.

The milling analysis results for samples with a range of initial moisture contents are presented in Figure 16. No clear relation between initial MC and percent brokens grain is observed.

In another experiment, the paddy was dried on the HFD from the various initial MC to a moisture content as low as 12%. As shown in Figure 17, no definite relationship was obtained between the broken percentage and final MC.

The milled rice samples were immersed in KOH solution to determine the degree of parboiling at different floor temperatures. After one hour, the KOH treated samples were examined carefully and no change was observed in any case. Therefore, the paddy dried with HFD was not parboiled to a measurable degree.

CONCLUSIONS

1. The HFD may be used to pre-dry paddy to 18% MC during unfavorable weather; the paddy may be safely stored for final drying to 14% MC when the sun is available.

2. The drying rate increases with increasing floor temperature and increasing frequency of mixing.

3. The total drying times at 4 cm and 6 cm thickness were respectively doubled and tripled in compared to 2 cm thickness of paddy. However, the drying time was not exactly directly proportional to thickness because the intercept of time plotted versus thickness was not zero.

4. The drying process appears to be satisfactory under conditions of high atmospheric humidity (80-90%) as during rainy periods.

5. Grain breakage was substantially lower for the HFD than for the traditional sun-drying method (e.g., 7-25% versus 30-66%).

6. No parboiling effect was observed after drying the paddy with heated floor dryer.

RECOMMENDATIONS

1. Test the performance of the HFD for conditions of high relative humidity of the ambient air (as during rainfall).

2. Test the performance of the Passat boiler using paddy straw and hulls as fuel.

3. Develop a low-cost boiler similar to the Passat boiler.

4. Develop a rake (mixer) which could mix the paddy more frequently and with less labor.

5. Develop and test a full-size HFD using local materials and reducing the initial and operation costs.

6. Perform a detail study of the economic, social and technical feasibility of the HFD.

7. Prepare the drawings and instruction materials of the final design of HFD.

8. Formulate the materials and mechanisms for the promotion and extension of the HFD.

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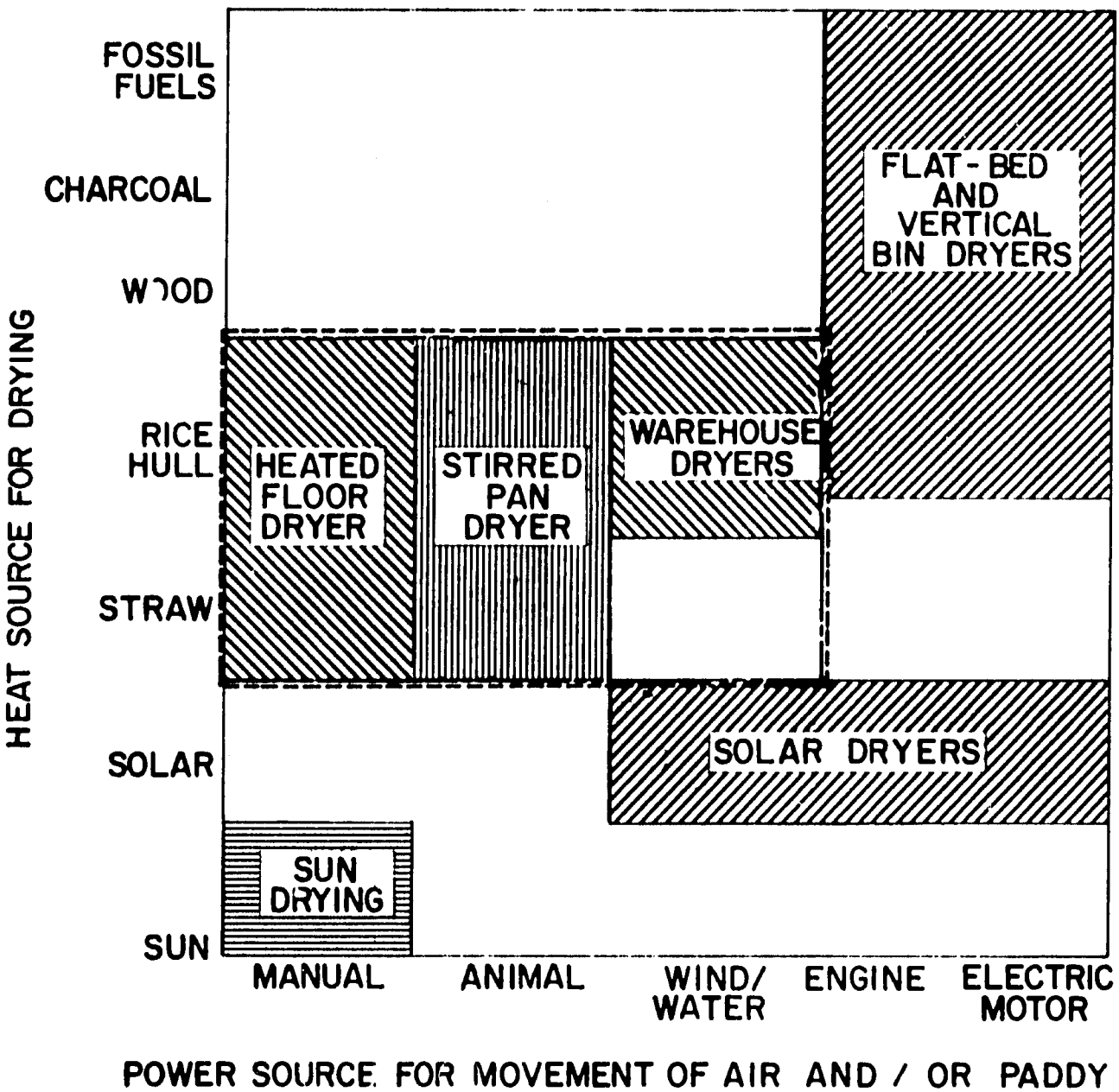


Figure 1. LOW-CAPACITY PADDY DRYERS.

FIGURE 2. VIEW OF EXPERIMENTAL MODEL OF HEATED FLOOR DRYERS.

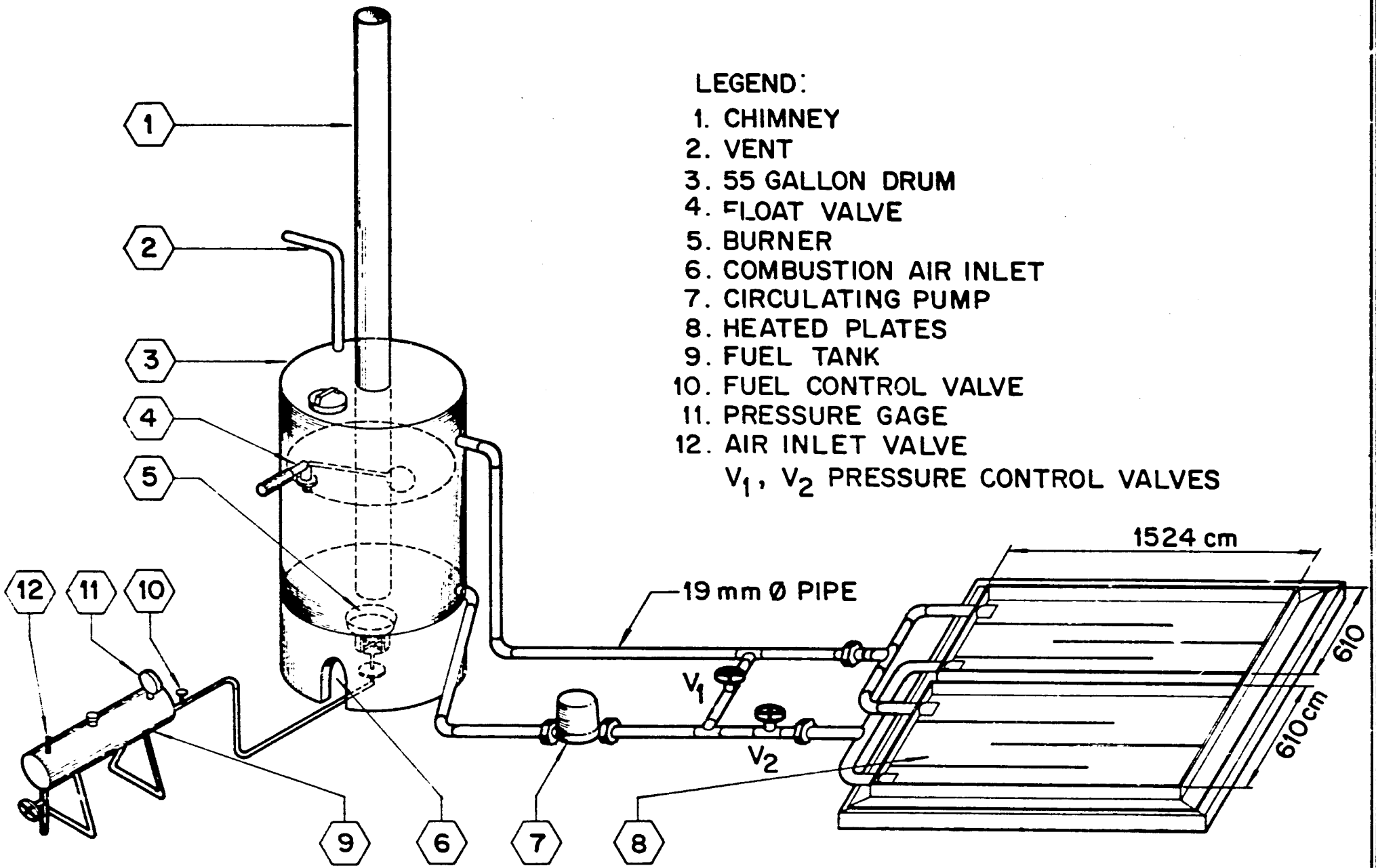


Figure 3. EXPERIMENTAL HEATED FLOOR DRYER

RSC-118'83

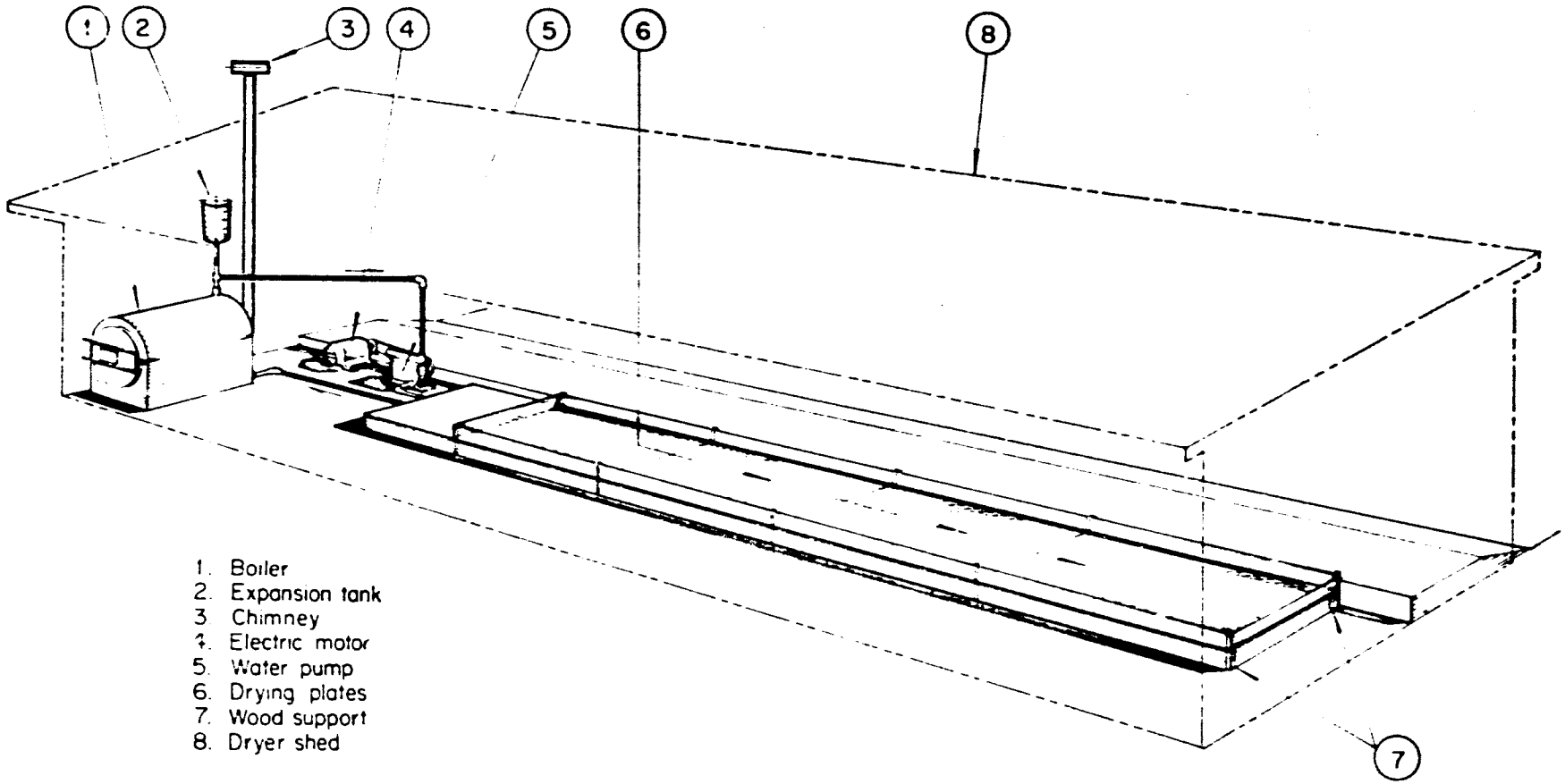
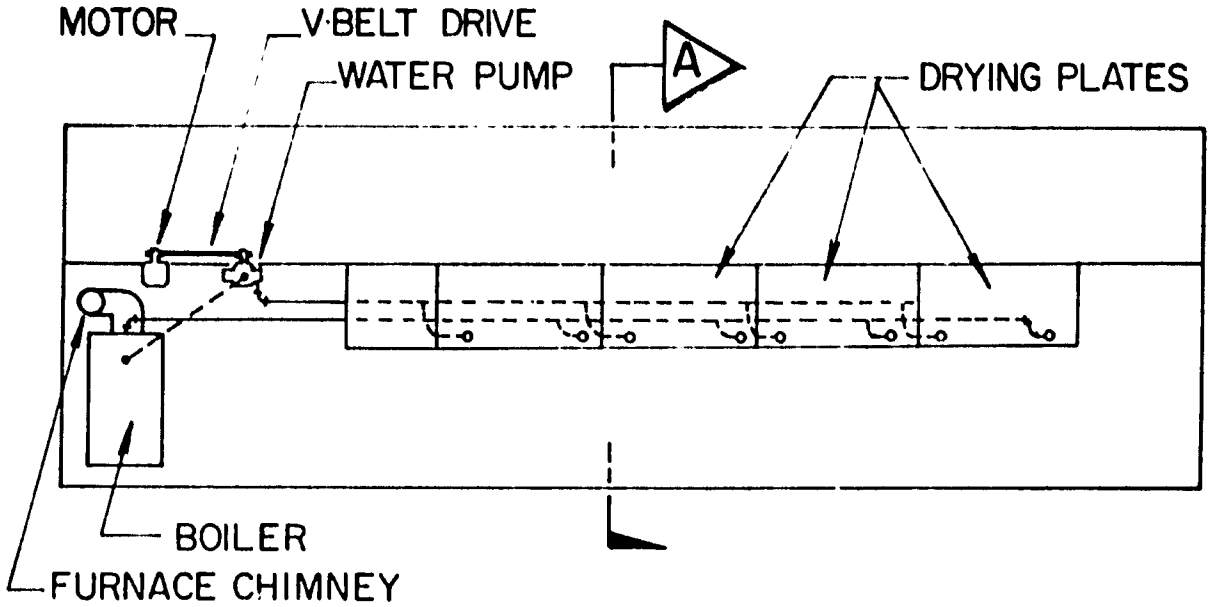
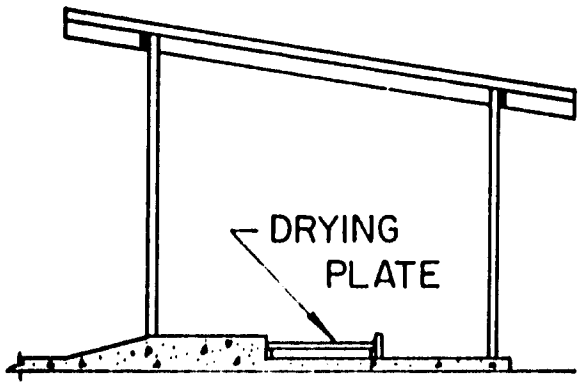


Figure 4 SCHEMATIC DRAWING OF HEATED-FLOOR DRYER



PLAN OF HEATED FLOOR DRYER



SECTION THRU-A

FIGURE 5. LAYOUT OF HFD (PROTOTYPE).

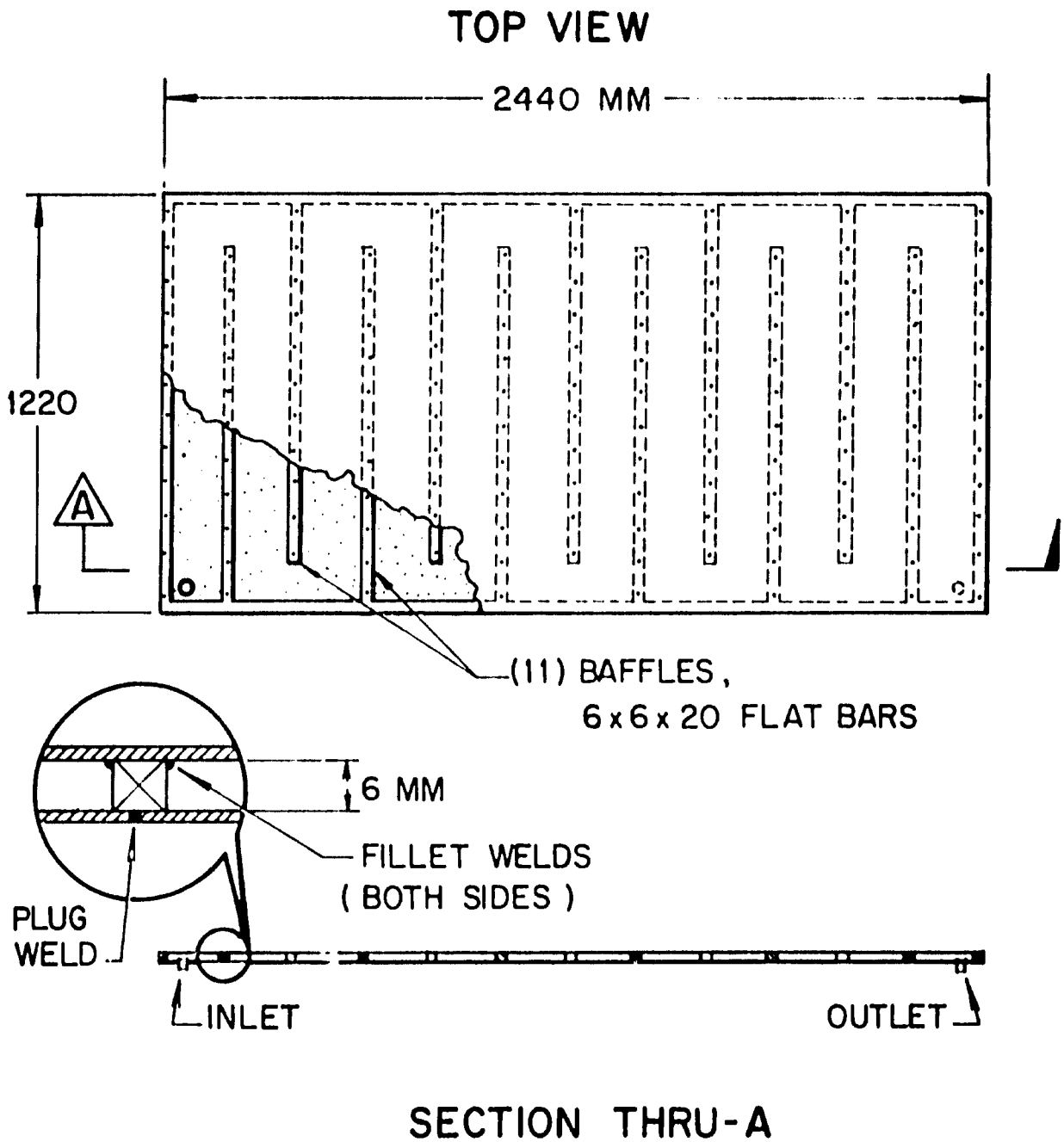


FIGURE 6. DETAILS OF METAL PLATES USED AS DRYING FLOOR.

FIGURE 7. PHOTOGRAPHS OF HEATED FLOOR DRYER PROTOTYPE.

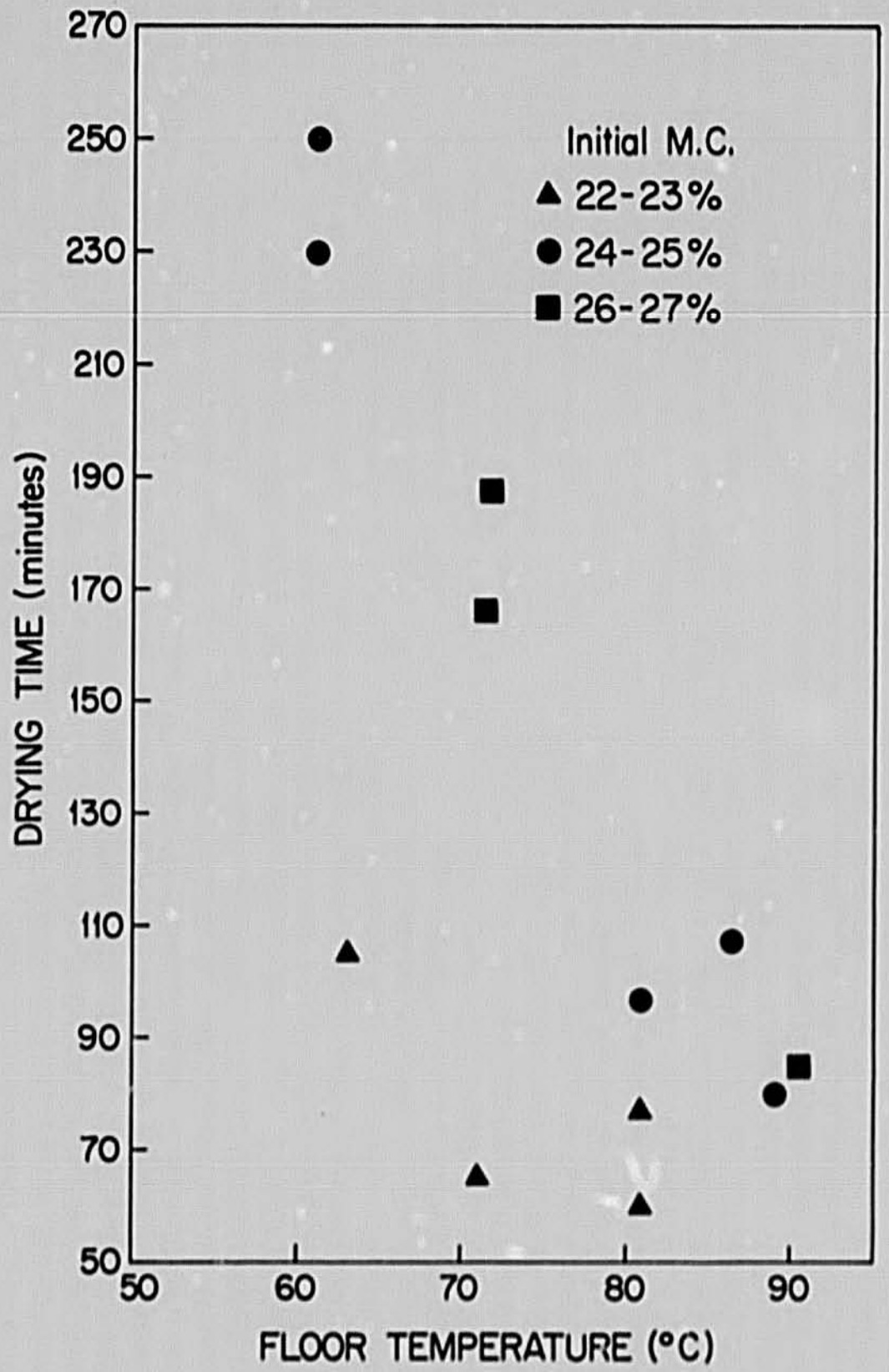


FIGURE 8. EXPERIMENTAL DATA ON DRYING TIME VERSUS FLOOR TEMPERATURE FOR THE HFD (PROTOTYPE). CONDITIONS: INITIAL MOISTURE CONTENT (MC) OF PADDY = 22-27%; FINAL MOISTURE CONTENT = 18%; THICKNESS OF LAYER OF PADDY = 4 CM; MIXING INTERVAL = 1 MIN.

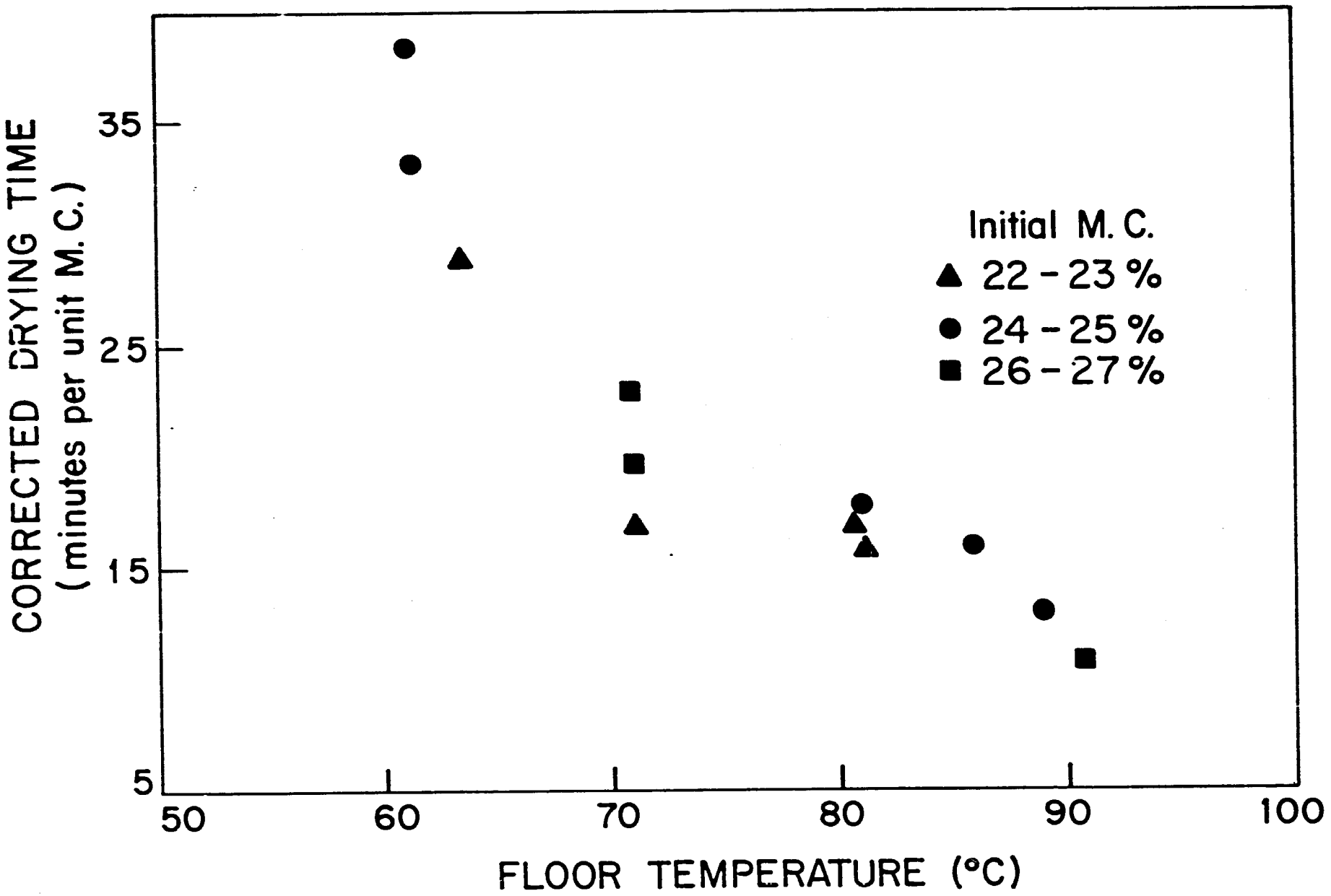


FIGURE 9. APPROXIMATE CORRECTION OF DRYING TIME DATA TO ACCOUNT FOR DIFFERENCES IN INITIAL MOISTURE CONTENT (MC) OF PADDY. DATA AND CONDITIONS ARE IDENTICAL TO THOSE IN FIGURE 8.

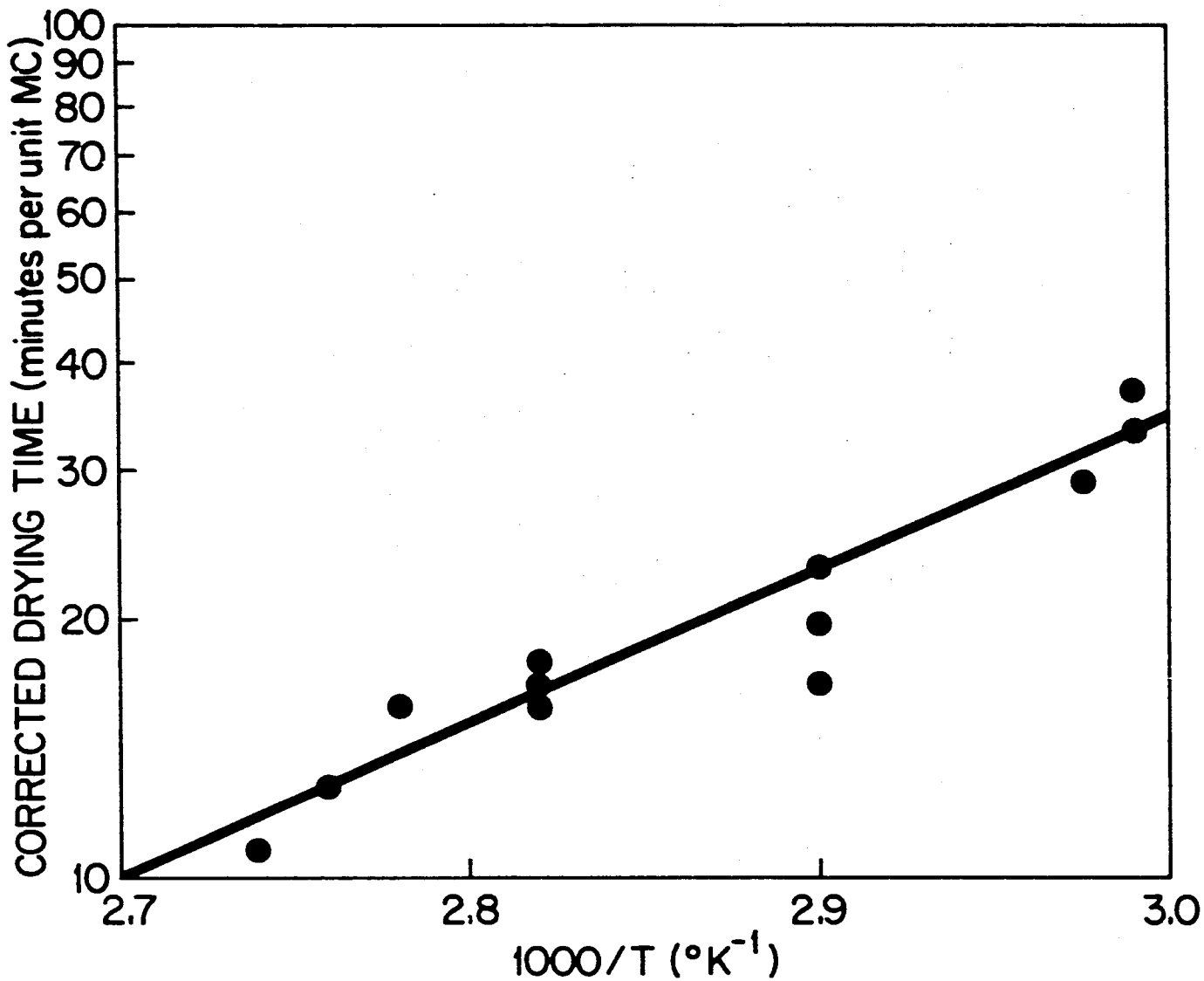


FIGURE 10. SEMI-LOGARITHMIC PLOT OF CORRECTED TIME VERSUS THE RECIPROCAL OF THE FLOOR TEMPERATURE. CONDITIONS ARE IDENTICAL TO THOSE IN FIGURE 8. THE SOLID LINE IS DRAWN WITH SLOPE CORRESPONDING TO THE ENTHALPY OF EVAPORIZATION OF WATER.

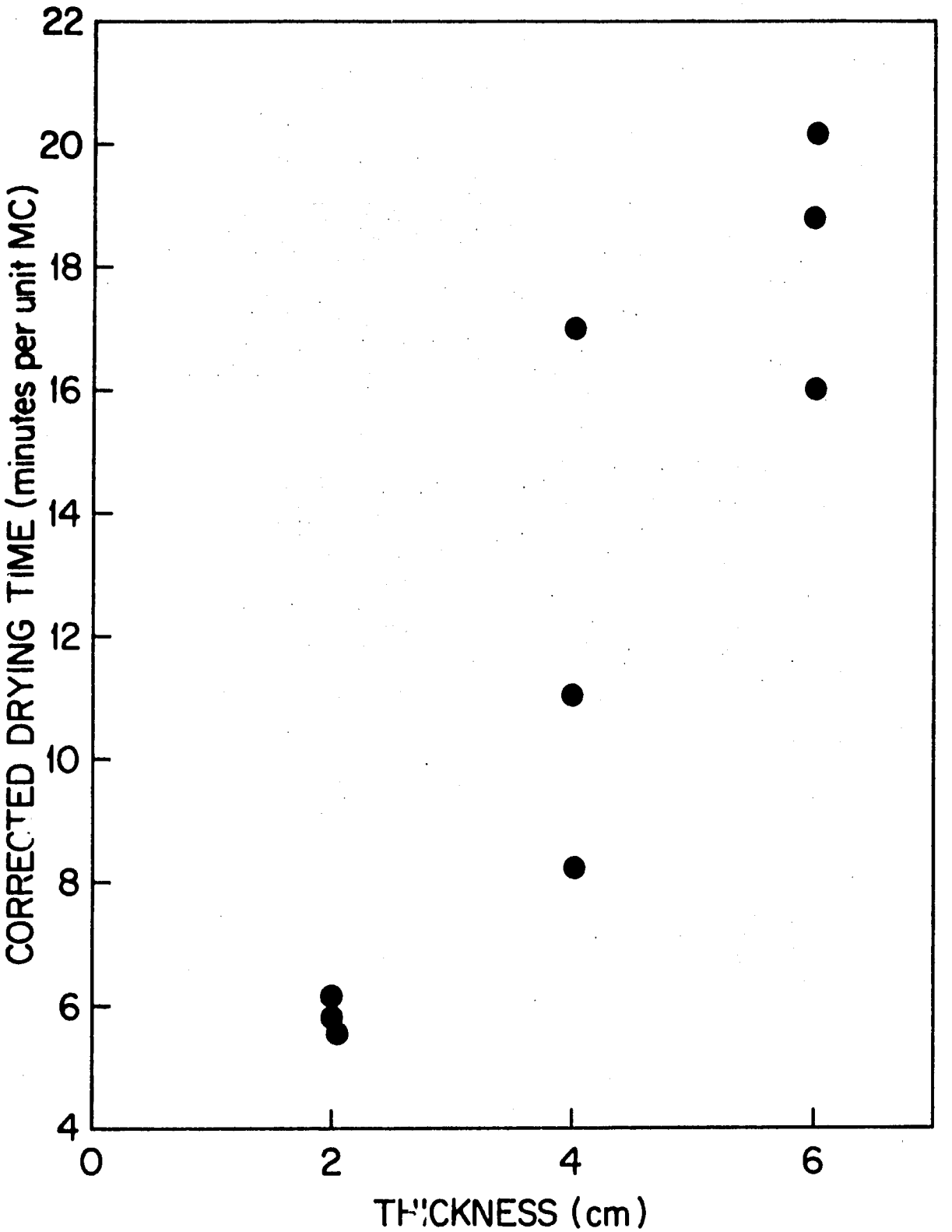


FIGURE 11. EXPERIMENTAL DATA FOR THE DRYING TIME VERSUS THE THICKNESS OF PADDY LAYER ON THE HEATED FLOOR DRYER. CONDITIONS: FLOOR TEMPERATURE ≈ 90°C; INITIAL MOISTURE CONTENT = 23-30%; FINAL MOISTURE CONTENT = 18%; MIXING INTERVAL = 1 MINUTE.

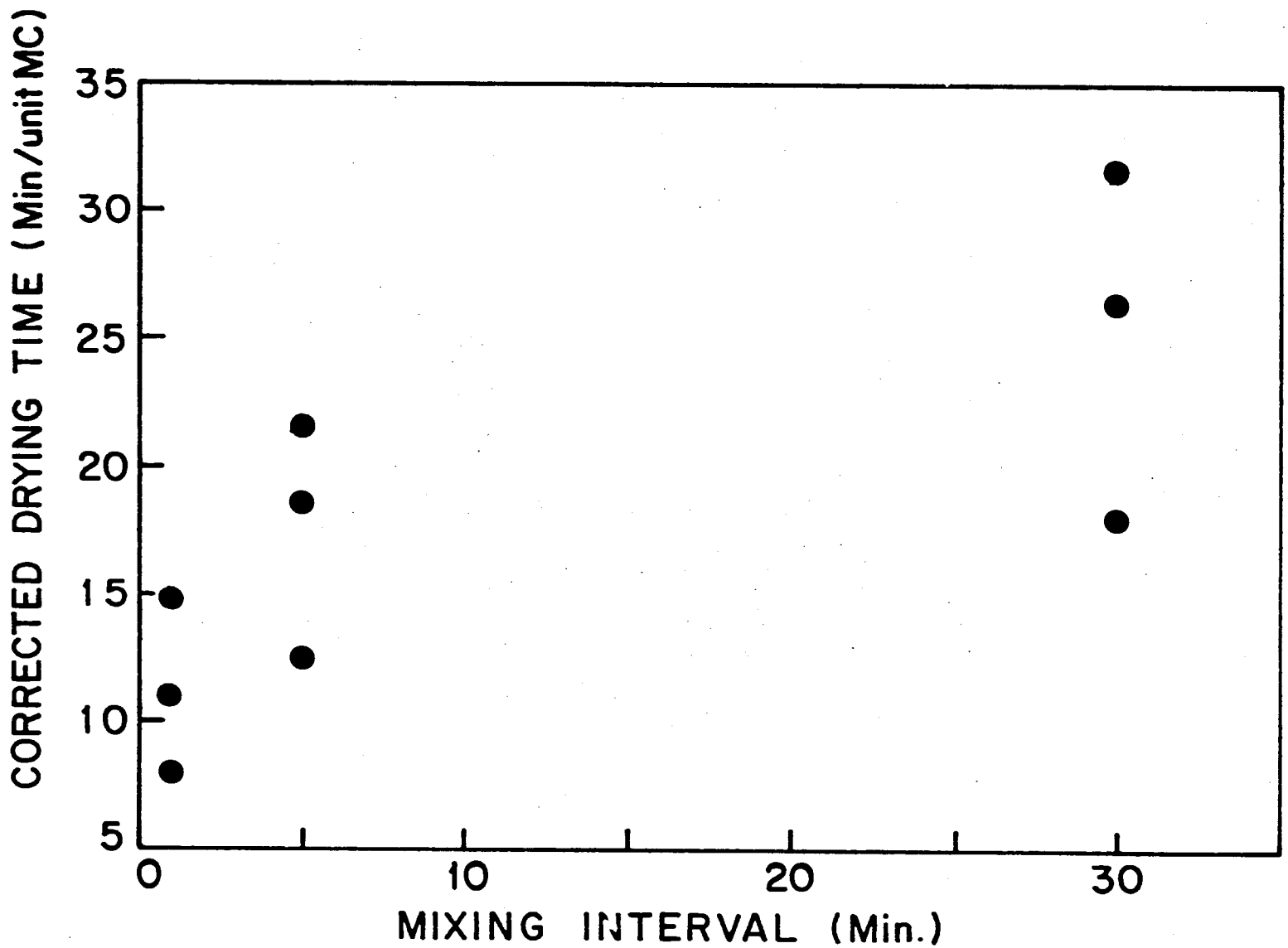


FIGURE 12. EXPERIMENTAL DATA ON THE DRYING TIME VERSUS MIXING INTERVAL FOR PADDY ON THE HEATED FLOOR DRYER. CONDITIONS: FLOOR TEMPERATURE = 90°C; INITIAL MOISTURE CONTENT = 23-30%, FINAL MOISTURE CONTENT = 18%; THICKNESS OF PADDY LAYER = 4 CM.

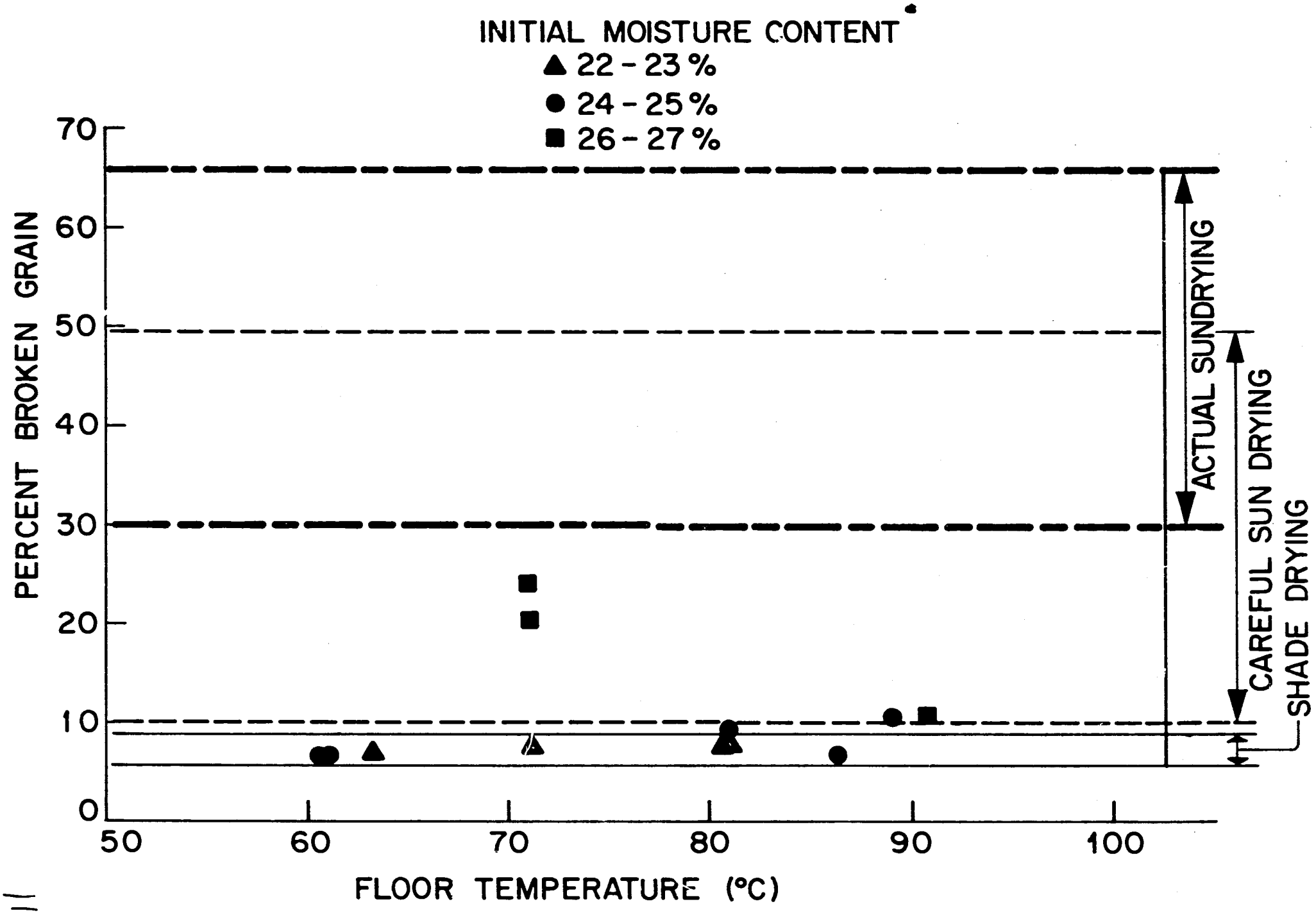


FIGURE 13. COMPARISON OF GRAIN BREAKAGE BY HEATED FLOOR DRYER WITH SUN AND SHADE DRYING.

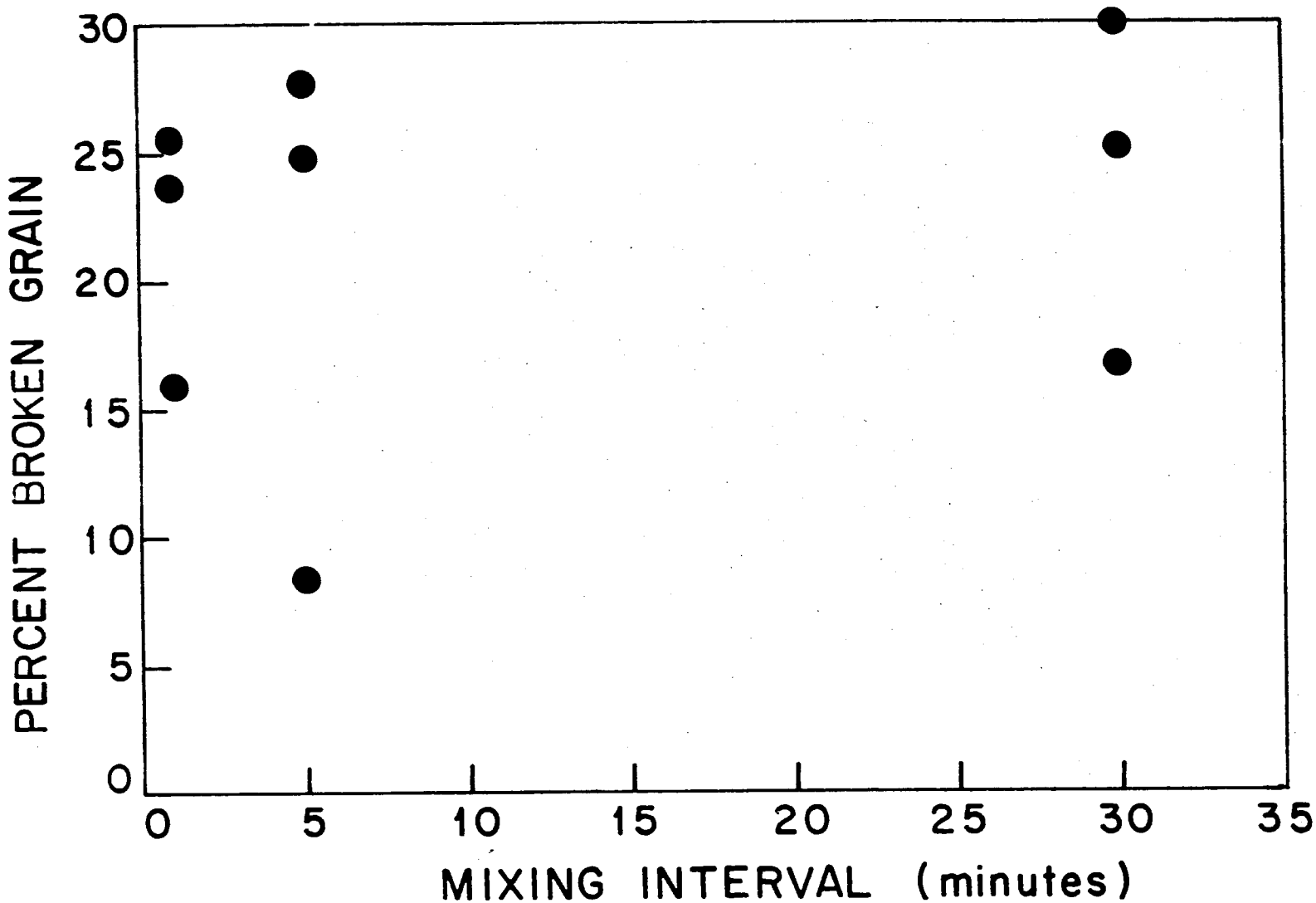


FIGURE 14. EXPERIMENTAL DATA ON PERCENT GRAIN BROKEN VS. MIXING INTERVAL. INITIAL MC RANGE OF 23-30%. GRAIN BED THICKNESS AND FLOOR TEMPERATURE WERE 4 CM AND APPROXIMATELY 90°C RESPECTIVELY.

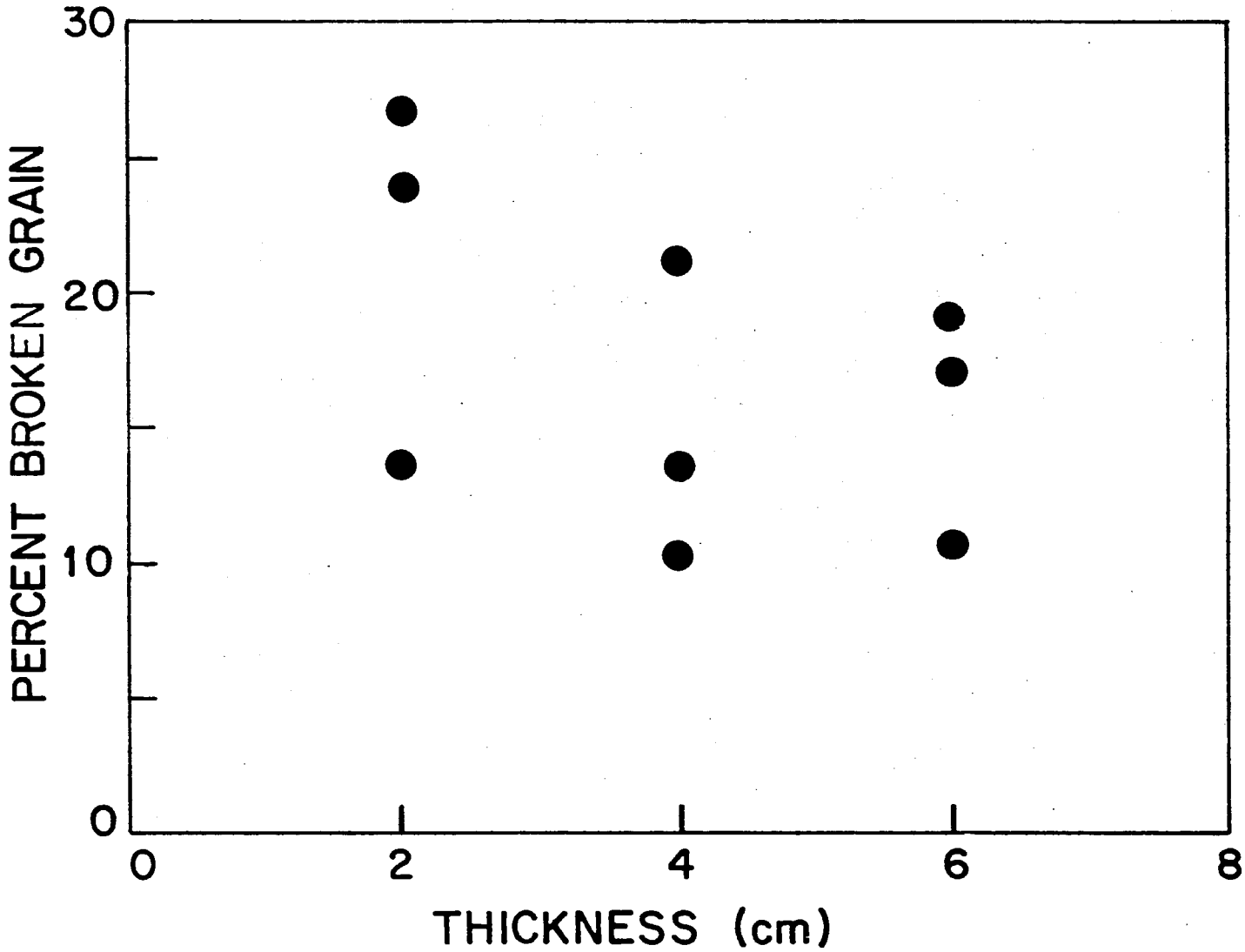


FIGURE 15. EXPERIMENTAL DATA ON PERCENT BROKEN GRAIN VS. GRAIN BED THICKNESS AT INITIAL MC RANGE OF 23-30%. MIXING INTERVAL AND FLOOR TEMPERATURE WERE 1 MINUTE AND APPROXIMATELY 90°C RESPECTIVELY.

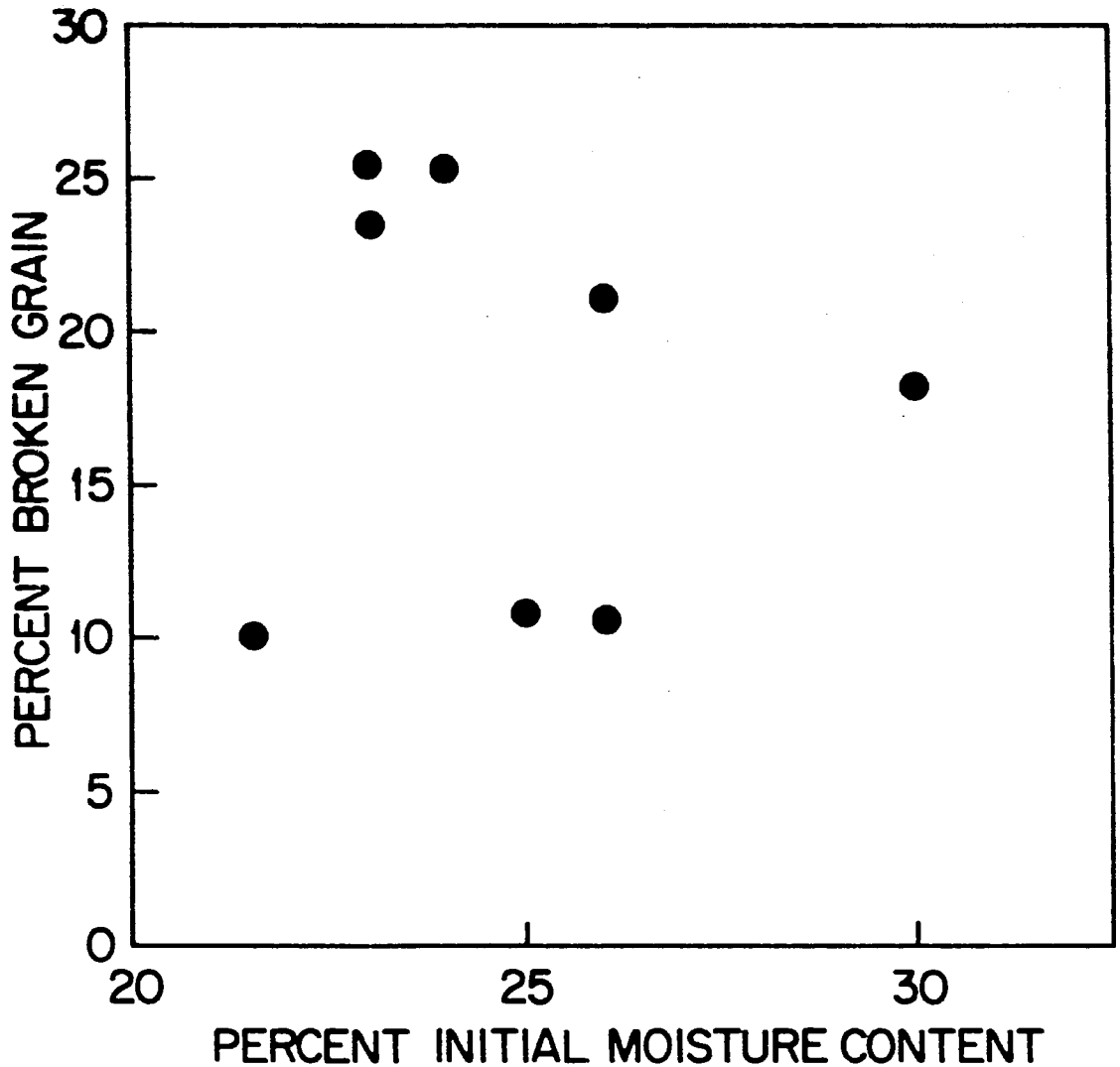


FIGURE 16. EXPERIMENTAL DATA ON PERCENT BROKEN GRAIN VS. INITIAL MC WHERE 4 CM THICKNESS AND 90°C FLOOR TEMPERATURE WERE MAINTAINED CONSTANT.

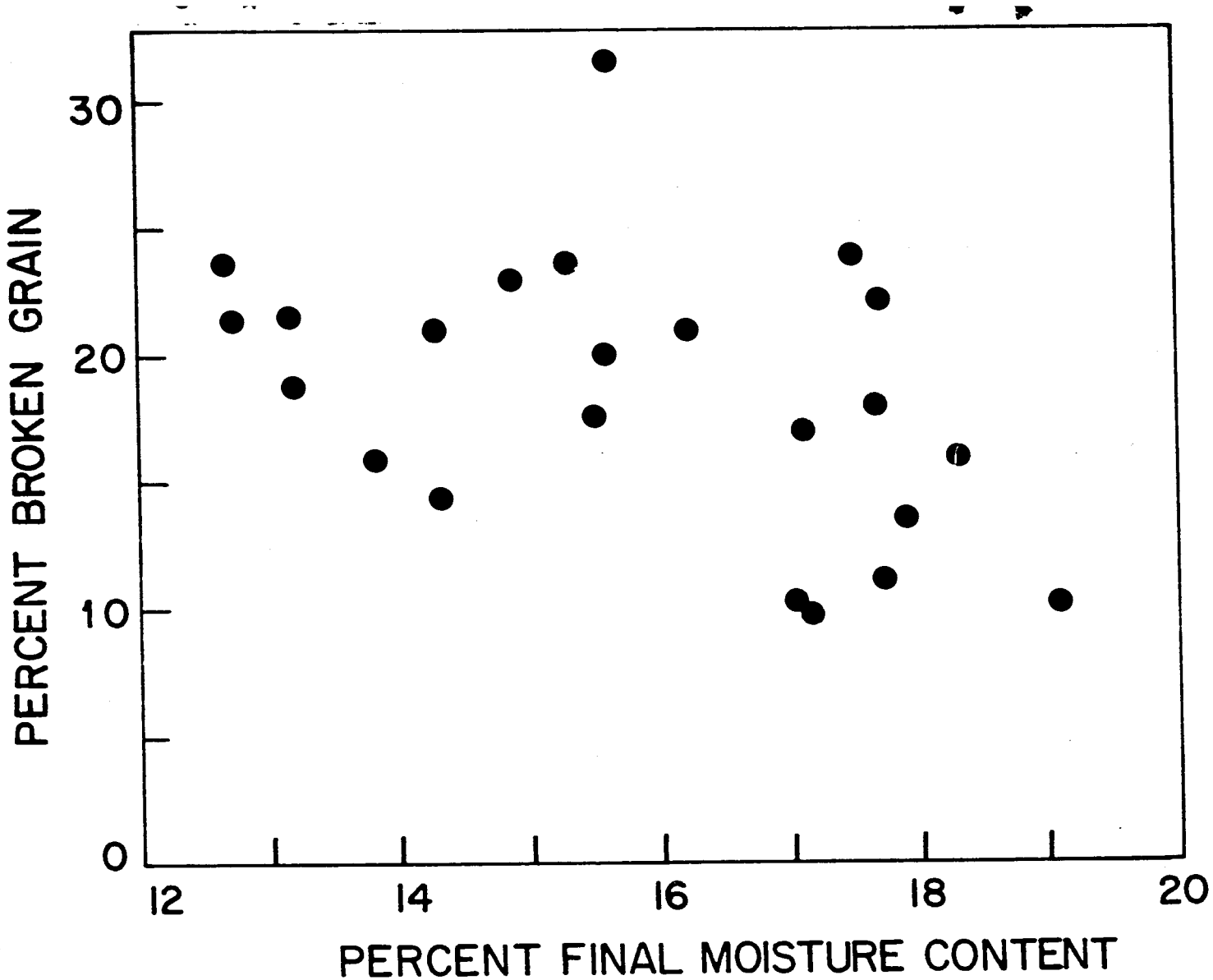


FIGURE 17. PERCENT BROKEN GRAINS VS. PERCENT FINAL MC AT INITIAL MC RANGE OF 26-30% WHERE CONSTANT BED THICKNESS OF 4 CM, 1 MINUTE MIXING INTERVAL AND APPROXIMATELY 90°C FLOOR TEMPERATURE WERE MAINTAINED.