
PREPARING GRAIN FOR STORAGE

VOLUME I OF

SMALL FARM GRAIN STORAGE

BY

CARL LINDBLAD, PEACE CORPS

AND

LAUREL DRUBEN, VITA

ACTION/PEACE CORPS VOLUNTEERS IN TECHNICAL
PROGRAM & TRAINING JOURNAL ASSISTANCE
MANUAL SERIES NUMBER 2 VITA PUBLICATIONS
MANUAL SERIES NUMBER 35E

FIRST PRINTING SEPTEMBER 1976

SECOND PRINTING,
IN THREE VOLUMES JULY 1977

THIRD PRINTING JULY 1980

VITA

1600 Wilson Boulevard, Suite 500
Arlington, Virginia 22209 USA
Tel: 703/276-1800 * Fax: 703/243-1865
Internet: pr-info@vita.org

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PURPOSE OF THE MANUAL

Small Farm Grain Storage is a set of how-to manuals. Together these volumes provide a comprehensive overview of storage problems and considerations as they relate to the small farmer. The authors recommend the volumes be purchased as a set because the material forms an excellent and complete working and teaching tool for development workers in the field. This grain storage information can be adapted easily to meet on-the-job needs; it has already been used as the basis for a grain storage workshop and seminar in East Africa.

This set of publications retains the purpose of the original volume: to bring together and to communicate effectively to field personnel 1) the basic principles of grain storage and 2) the practical solutions currently being used and tested around the world to combat grain storage problems. Only the format has been changed to:

* reduce printing and postage costs.

* permit updating and revising one volume at a time.

* provide smaller books that are easier to hold and use than the large, single volume.

* make portions of the information available to the user who is especially interested in only one or another of the major aspects of small farm grain storage.

Of course, it is impossible to cover all storage situations in this manual. But farmers who understand the basic, unchanging principles of drying and storing grain are better able to adapt ideas, suggestions, and technologies from other parts of the world to their own needs. This material was prepared for use by those who work to facilitate such understanding.

OVERVIEW OF THE MANUAL

Volume I, "Preparing Grain for Storage," discusses grain storage problems as they are faced by small-scale farmers. This volume contains explanations of the structure of grain, the relationship between grain and moisture, the need for proper drying. One large section contains detailed, fully illustrated plans for constructing a variety of small-scale grain dryers.

Volume II, "Enemies of Stored Grain," is an in-depth study of two major enemies: insects and rodents. Each is discussed in detail with guidelines for 1) defining the size of the problem and 2) protecting grain by both chemical and non-chemical means. This volume includes dose and use information for a variety of pesticides, as well as suggestions for preparing materials to be used in audio-visual presentations.

Volume III, "Storage Methods," contains a survey of storage facilities from the most traditional basket-type granary to metal bins and cement silos. The emphasis in this volume is on improving existing facilities; for example, there are detailed construction procedures for an improved mud silo. Storage in underground pits and sacks also is discussed. There are guidelines for using insecticides in storage situations. The largest silo presented in detail is the 4.5 ton cement stave silo.

THE PEOPLE WHO PREPARED THIS MANUAL

Carl Lindblad served as a Peace Corps Volunteer in Dahomey (Benin) from 1972 to 1975. As a Volunteer, Lindblad worked in programs designed to introduce and popularize a variety of grain storage technologies. Upon his return to the United States, he began the task of pulling together this manual as a consultant to VITA and Peace Corps. At present, he serves as a consultant to a number of international organizations, specializing in appropriate technologies for grain storage -- in the areas of planning, extension and evaluation. He spends much of his time in the field.

Laurel Druben served as an International Voluntary Services, Inc. Volunteer in Laos from 1966 to 1968. While in Laos she was a curriculum planner and a teacher of English as a second language. Subsequently, she worked with a consulting firm evaluating government-funded research and development projects, ran a small education-oriented business, and was a free-lance consultant and proposal writer. Druben, who has worked and lived in India and Micronesia, as well as Southeast Asia, is Director of Communications for VITA.

Many thanks are due to the skilled and concerned people who worked to make this manual possible:

A number of VITA people provided technical review, artwork, and production skills:

Staff assistance -- John Goodell

Section 4, Vol. I materials -- Frederick Bueche

Technical review -- Douglas Barnes, Merle Esmay, Henry Highland, Larry Van Fossen, Harold Willson, Kenton Harris

Artwork -- George Clark, John Goodell, Kenneth Lloyd, Nicholas Reinhardt, Guy Welch

Thanks are extended to the following individuals and institutions that provided invaluable assistance in early stages of work on the manual:

Mary Ernsberger and Margot Aronson, Peace Corps Program and Training Journal, USA

Brenda Gates, Peace Corps Information Collection & Exchange, USA
Tropical Stored Products Center, TPI, Great Britain
Henry Barre and Floyd Herum, Agricultural Engineering Department, Ohio State University, USA
Department of Grain Science and Industry, Kansas State University, USA
Agricultural Research Service, Department of Agriculture, USA
Extension Project Implementation Department, Ministry of Agriculture, Ethiopia

F. W. Bennett, Midwest Research Institute, USA
Supervised Agricultural Credit Programs (SACP), Belize
Peter Giles, Nicaragua
Donald Pfalser, Agricultural Cooperatives Development International (ACDI), USA
Technical Assistance Bureau, US Agency for International Development (AID), USA
International Development Research Center, University of Alberta, Canada
League for International Food Education (LIFE), USA
Institut de Recherches Agronomiques Tropicales et des Cultures Vivrieres (IRAT), France
Post-Harvest Crop Protection Project, University of Hawaii, USA
Agricultural Engineering Service, FAO
African Rural Storage Center, IITA, Nigeria
Institute for Agricultural Research, Ahmadu Bello University, Nigeria
Swaziland Rural Grain Storage Project
Jim McDowell, Food Technology and Nutrition Section, UNICEF, Kenya
Gordon Yadcuik, Centre Nationale de Recherches Agronomiques (CNRA), Senegal
R. A. Boxall, Indian Grain Storage Institute, A.P., India
Siribonse Boon-Long, Ministry of Agriculture and Cooperation, Thailand
Asian Institute of Technology, Chulalongkorn University, Thailand
Merrick Lockwood, Bangladesh Agricultural Research Council
International Rice Research Institute (IRRI), Philippines
Dante de Padua, University of Los Banos, Philippines

THE SPONSORING ORGANIZATIONS

Small Farm Grain Storage is part of a series of publications combining Peace Corps practical field experience with VITA technical expertise in areas in which development workers have special difficulties finding useful resource materials.

ACTION/Peace Corps

Since 1961 Peace Corps Volunteers have worked at the grassroots level in countries around the world in program areas such as agriculture, public health, and education. Before beginning their two-year assignments, Volunteers are given training in cross-cultural, technical, and language skills. This training helps them to live and work closely with the people of their host countries. It helps them, too, to approach development problems with new ideas that make use of locally available resources and are appropriate to the local cultures.

Recently Peace Corps established an Information Collection and Exchange, so that these ideas developed during service in the field could be made available to the wide range of development workers who might find them useful. Materials from the field are now being collected, reviewed, and classified in the Information Collection and Exchange system. The most useful materials will be shared with the development world. The Information Collection and Exchange provides an important source of field-based research materials for the production of how-to manuals such as Small Farm Grain Storage.

VITA

VITA people are specialists who volunteer their free time to answer requests for technical assistance. Many VITA Volunteers have lived and worked in other countries, often as Peace Corps Volunteers. Most VITA people now work in the United States and other developed countries where they are engineers, doctors, scientists, farmers, architects, writers, artists, and so on. But they continue to work with people in other countries through VITA. VITA Volunteers have been providing technical assistance to the Third World for almost 20 years.

Requests for assistance come to VITA from many nations. Each request is handled by a Volunteer with the right skills. For example, a question about grain storage in Latin America might be handled by a professor of agriculture, and a request for an improved planting implement would go to an agricultural engineer. These VITA Volunteers, many of whom have lived and worked in Third World countries, are familiar with the special problems of these areas and are able to give useful, and appropriate, answers.

VITA makes the expertise of VITA people available to a wide audience through its publications program.

HOW TO USE THIS MANUAL

Development workers can use material from this manual in a number of ways:

* Discussions. The manual provides clear presentations of grain storage principles from which you can take material to lead

discussions with farmers and village leaders.

* Demonstrations. There are suggestions for demonstrations and experiments which you might find helpful to illustrate grain storage principles to farmers.

* Leaflets. Some of the material has been prepared in the form of illustrated leaflets which can be used directly by you with a farmer. They may require little or no adaptation by you. But, if you prefer, you can use the structure of the leaflet and substitute photographs specific to your area. The material on rodent control in Volume II is a good example of this kind of leaflet.

* Construction Plans. Many of the construction plans have been simplified so that you will be able to work more closely with the farmer. Some of the plans are fully illustrated. You could add photographs of the work steps showing conditions in your area. It is likely that after you introduce the material, farmers can follow the instructions themselves. The plans are written so that they would be easy to translate into local languages. The Improved Maize Drying Crib in Volume I is a good example of a step-by-step, illustrated presentation.

* Checklists. Some of the material most likely to be useful for small-scale farmers has been simplified and prepared in checklist or hand-out form. This material would lend itself to illustrations or photographs, so it can better fit into the

local situation. The checklists on controlling grain storage insect pests included in Volume II are in this category.

* Examples. The appendices contain examples of leaflets that have been prepared by development workers in several countries. These examples have been included to give you some idea of how the materials in this manual might be organized, illustrated, translated, and presented to reach farmers.

* Sources. Wherever possible, addresses are given so that you can write for more information on a subject.

* Further Information. Other appendices contain information on areas which, although important, cannot be covered fully within the scope of this manual, for example, storage program planning. A bibliography is provided at the end of each volume.

These are some of the aims of Small Farm Grain Storage. You will probably find added uses. While it is not possible to make this manual specific to the situations or culture of your particular area, the information is presented so that you can do this very easily by making additions or substitutions to the material.

Dimensions are given in metric units in the text and illustrations. Conversion tables are provided at the end of each volume.

This manual will grow and change as its readers and users send in additional material, comments, and ideas for new approaches to grain storage problems and better ways to communicate with farmers. Your own ideas and conclusions are welcome. A form has been included for your comments. Please send us the results of your silo or dryer building. Let us know how you used the information and how it could be make even more useful to you. Tell us how you changed a plan to fit local needs.

Your experience will help us to produce manuals of growing usefulness to the world-wide development community.

REPLY FORM

For your convenience, a reply form has been inserted here. Please send it in and let us know how the manual has helped or can be made more helpful. If the reply form is missing from your book, just put your comments, suggestions, descriptions of problems, etc., on a piece of paper and send them to:

GRAIN STORAGE
3706 RHODE ISLAND AVENUE
MT. RAINIER, MD 20822
U.S.A.

1 THE GRAIN STORAGE PROBLEM

INTRODUCTION

Farmers all over the world lose much of their grain after it is harvested. Farmers work hard to plant and grow crops. And often they do not receive good returns for their time and effort. The grain is attacked in the field and in storage by insects, rodents, birds, and other pests. The grain that pests do not eat, they dirty with their droppings and their bodies.

Farmers have lived with these problems for hundreds of years. So they have developed ways to deal with them. Many old ways are wasteful, but a number of the old methods are good and must be kept until they can be replaced or improved.

In recent years, however, the grain storage problem has changed (and, in some cases, temporarily worsened) as steps toward full development have been taken. For example, now there are new seed varieties which grow faster and yield more grain. Farmers plant these new seeds, and this grain is ready for harvesting earlier than it used to be. This grain is ready to be harvested during the rainy season. The farmer has always dried his crops in the sun, but there may be little sun during this season. Also,

it is likely this new variety of grain must not be left to dry in the field: if this grain dries too long in the field, it will shatter (break). But if the farmer brings the grain from the field and stores it before bringing the moisture content of the grain down to 13% or lower, the grain will rot and mold.

<FIGURE 1>

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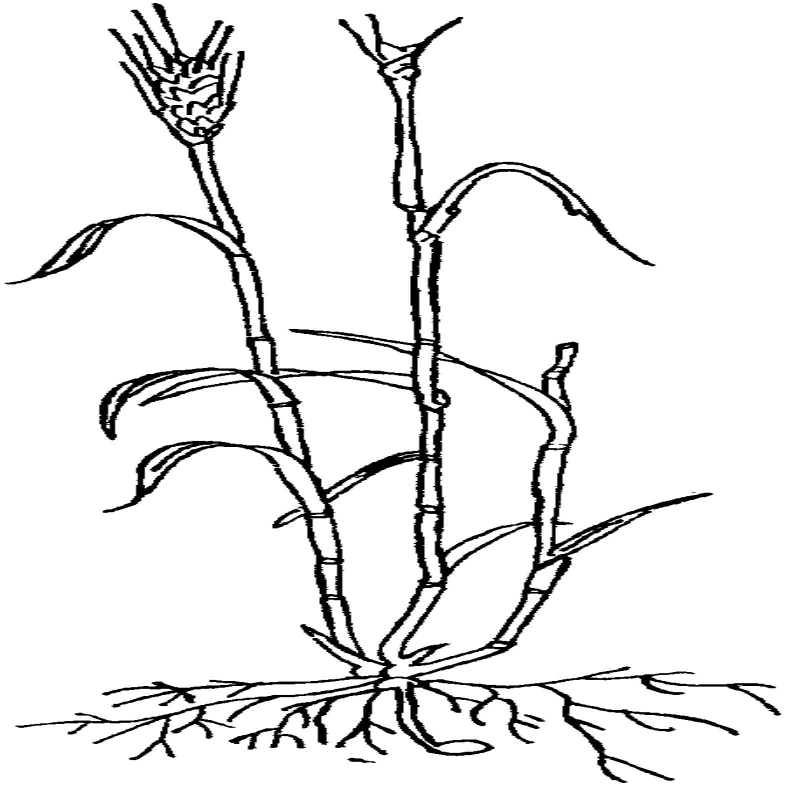

The farmer must find a way to dry his grain, store it safely, and plant another crop -- all in the time he used to spend on one crop. His many old methods must be changed to help with new problems.

<FIGURE 2>

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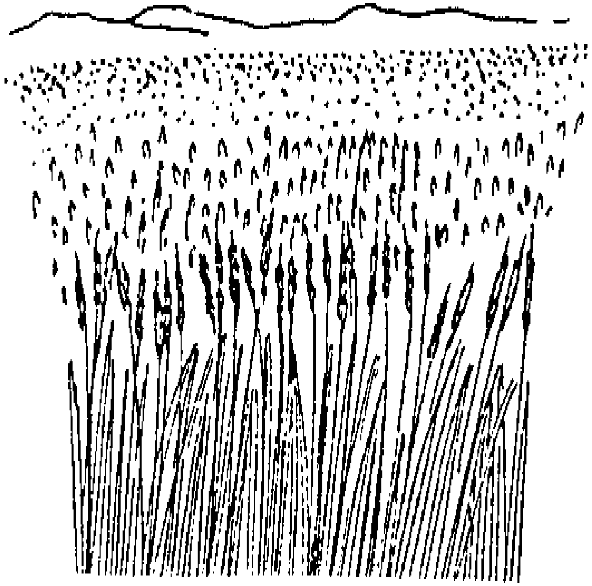

The Problem

The basic question then is how to help farmers protect their grain from attack. The answer must be to give the farmer enough information about harvesting, drying, storing, insects, rodents, and molds so that he can fight the problems successfully. No one can find answers to problems without having enough information about the subject.

Farmers need to know that there are steps they can take to protect their own grain. Perhaps a farmer can save significant quantities of grain by making a simple change in the way he is doing things now. Perhaps there is another way of drying or of storing which fits into his situation well. A farmer needs to be presented with ideas that can be demonstrated, that make sense to him, and that fit into his life easily. This is done

by supplying technology and help which is appropriate. With this kind of help, change for the better is more likely to take place.

The following chapters offer many ideas about the grain storage problem. The materials have been prepared to make them easy for you to use in your work. The manual should help you get information to those who can use it.

GOOD GRAIN STORAGE IS IMPORTANT TO FARMERS

When people in universities and government agencies talk about storage, they are discussing a serious subject. They talk about such facts as these:

* approximately 30% of grain in storage all over the world is being lost because of insects, rodents, and molds.

* improving grain storage would mean less hunger, improved nutrition for the individual, and a higher standard of living and a sounder economy for the nation.

* quality grain for international trade is of increasing importance.

* improper storage of grain leads to weight loss, monetary loss, seed loss, quality loss, food loss.

These concerns are real. And there is a definite need for people to deal with grain storage questions at this level. Many new ideas and plans result from the testing, thinking, and planning being done all over the world by scientists, teachers, and researchers.

But when small farmers talk about grain storage problems, they are talking about their livelihood. And there are some very important reasons why grain storage questions are of concern to them.

Food for the Family

Grain is very likely the single most important thing eaten by the farmer and his family. Whether it is maize, wheat, rice, millet, or sorghum, it is important for his family. The farmer may not think about grain losses and use words like quality and quantity. But he can see that insects, rodents, and molds ruin a lot of his grain, and that there is not as much for his family to eat. He can taste the difference between clean grain and grain which has been damaged by mold. Farmers feel the loss of grain and the need for better storage when they run out of grain for food before the next harvest. Then they must use what little money they have to buy food. Or they must borrow against the next crop and start out in debt.

<FIGURE 3>

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Another food loss is harder to measure. But it is real. Some insects eat out the best parts of the grain. These are the parts which contain the vitamins and minerals which make grain the healthy food it is. The farmer may not see this loss. But he should be told about it. Lack of nutritious food can lead to sickness and more problems.

Seed for Planting

Part of the harvested grain is the seed for the next crop. The farmer must let the seeds rest in a cool, dry place before he plants them. Poor storage of seed grain means that some of the seeds, or many of them, will not germinate (grow) when they are planted. If the seeds are not stored well, the farmer will have to plant many extra seeds to get enough plants. Often seed grains that have not been stored well do not grow well: they may grow at different speeds. This causes problems with cultivating and harvesting the grain.

<FIGURE 4>

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Money to Fill Needs

A farmer usually must buy some of the tools and equipment he needs for home and farm use. He may need to purchase corrugated metal sheets for building, metal pots for cooking, metal tools for farming, or cloth for making clothes. To get items which he cannot make himself, the farmer has to offer money, or he has to barter. Most farmers sell the grain they do not use for food or seed to get money. Or they trade the grain for the things they need.

<FIGURE 5>

51ap04.gif (230x230)

Because of poor drying and storage facilities, farmers cannot keep their grain safely for any period of time. They are forced to sell the grain soon after harvest. The prices are low at this time because no one needs grain. Everyone is harvesting, and there is plenty of grain available. Until the farmer can dry and store his grain safely, he is not going to grow much more than he needs for his family. This lack of safe storage means that total production of grain remains low.

Most farmers will not think in terms of country-wide production. But they will have in mind some things they would like to do if they had more money. Good grain storage can lead to more food, more money, better seed, and a better future.

GRAIN IS A LIVING THING

Grain has certain characteristics which farmers must understand if they are to be able to dry and store their grain well. Here are some of the characteristics of grain which will be discussed:

* Growth of seed grain.

* Protection of the kernel by the seed coat.

* Respiration (breathing) of grain kernels.

* Moisture (water) in grain kernels.

* Moisture movement between grain and air.

Farmers know a lot about planting and growing grain. But most farmers will not think about grain in all the ways listed above. If they do become aware of these characteristics of grain, the reasons for good grain storage are going to make a lot more sense to them. And farmers are going to be able to do more toward solving their own problems.

WHAT HAPPENS TO GRAIN IN STORAGE

Keeping grain safe in storage depends upon a number of things. Moisture, temperature, insects, and molds, for example, all can cause changes in grain put into storage. All factors which are most important to good grain storage are presented in the following paragraphs; some are discussed in greater detail in other places in the manual.

REMEMBER: All of the following points are related to one another.

Insects

<FIGURE 6>

51ap05.gif (230x486)

Insects and their part in grain storage are the subject of another section It is an important section. Insects eat and ruin a lot of grain. Because they grow inside the grain kernels, some insects are not found in grain until after they have done a lot of damage. The section on insects will give information on the major grain storage insects, on where to look for them, and on how to control them.

Insect activity, and the damage which results from this activity, is closely related to temperature and moisture in stored grain. It only take a few insects in the right conditions -- for example, in warm , moist

grain -- to make enough moisture and heat so that large numbers of insects can grow. More insects will make more heat and water, and so on. They create the right conditions for the growth of molds.

Molds

Molds are very small plants. They are so small they cannot be seen on grain, but they are always there on the grain kernels. In warm, moist grain, they will germinate (grow) and produce threads called hyphae. These hyphae push through the seed coats of grain kernels and attack the embryos of the grains. Molds cause damage in a number of ways

* They produce chemicals called enzymes which can stop seeds from germinating and growing into new plants.

* They decrease the quality of the grain for food and for market.

* Some molds produce chemicals which can poison people.

Farmers certainly are familiar with the sight and smell of grain damaged by mold. But they are probably not aware of the conditions that lead to molding, and they may not know what they can do to protect their grain from mold. Helpful information and suggestions are presented later.

Moisture Content (Wetness)

Drying grain, and keeping it dry in storage, is the most important part of good storage. Many problems of grain storage are caused by moisture.

Both grain and air have moisture, and they act together in ways that are important to understand. Therefore, a following section discusses moisture content in grain and in the air; it also explains how moisture in grain and moisture in the air are important to each other.

<FIGURE 7>

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Temperature

There are two temperatures which are important. One is the outside temperature of the air; the other is the temperature of the air and grain in the storage place.

It is easier to store grain in areas where the air temperature is low or never gets too hot. In very cold weather, insects and molds do not grow very quickly, or at all. Seeds do not breathe as much.

In warm places, the grain is warm when it is put into storage. Then, as the outside temperatures go up, the temperature in stored grain is likely to get even higher. When the temperature in the grain goes up, certain things start happening:

* Insects start growing and breeding.

* Mold spores start multiplying.

* Molds, insects, and grains all live and breathe faster, causing heat, water, and carbon dioxide to increase in the stored grain.

Even in this brief look at temperature, it is easy to see the need for keeping grain cool and dry. Keeping storage containers protected from the hot sun is important. Farmers who understand this fact have discovered an important grain storage principle.

Rodents

Rats and mice eat a lot of grain. They can eat the whole kernels of grain sorghum, wheat, and millet. They chew on ears of maize. Rodent damage is the easiest kind of damage to see. Yet farmers may not realize how much damage rodents can do; they may not be aware that rodents spread diseases. Or they may not know what they can do to stop rodents from eating their stored grain. The section on rodents gives information on the habits of rodents, the signs of rodents that a farmer should look for, and some ideas for keeping rodents out of stored grain.

<FIGURE 8>

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Clean Grain and Clean Storage Places

Farmers often do not realize how important it is to clean the place for storing grain. Even grain that is healthy and whole when put into storage can be damaged by insects or ruined by molds if stored incorrectly. Farmers need to know that good grain storage requires planning for a good storage container or place, and careful handling and cleaning of the grain.

<FIGURE 9>

51ap07a.gif (317x317)

Many farmers can improve the condition of their stored grain simply by cleaning and repairing their present grain storage containers and buildings, and by putting only healthy grain into storage. This manual helps spell out the necessary steps for farmers who wish to improve, (1) the quality of the grain they store, and (2) the container into which they put the grain.

GOOD GRAIN STORAGE DEPENDS UPON BETTER DRYING AND BETTER STORING

Improved Drying

As mentioned before, drying is the key to storing grain safely. The section on "Preparing Grain for Storage" covers the importance of careful harvesting, threshing, and moisture measurement before putting the grain into storage. "Grain Dryer Models" presents plans for a number of grain drying methods.

Improved Storing

The manual section on storage discusses methods already being used by farmers, and gives ideas for improving these methods. Also, the section provides plans and construction procedures for a number of grain bins. Each of the storage methods is presented in terms of its possible advantages and disadvantages for use by farmers.

<FIGURE 10>

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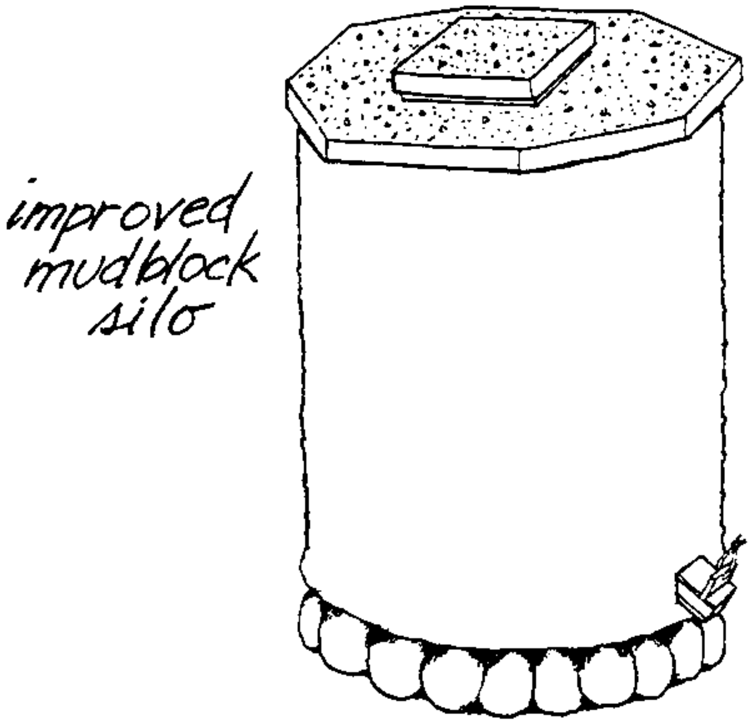


Your Role

You will have to decide how to use the materials in this manual. Some farmers may be ready to make a mud silo; others require information on good storage practices for storing grain in sacks. One village may be ready to make an oil barrel dryer. Another village might like to try solar dryers. These are decisions which you and the farmers in your area must make together. The purpose here simply is to provide information upon which good decisions can be made, and to provide some basic guidelines in important grain storage areas.

The following leaflet provides an illustrated look at what good grain storage can do for farmers.

GOOD GRAIN STORAGE HELPS FARMERS

Suggested Uses: This is a script which could be used to alert farmer to the need for improved storage. Choose the points you feel are most important and have them translated and illustrated as necessary.

* A good crop of grain means plenty of food.

* Farmers work hard to grow their grain. Grain is important.

* A good crop means seed for planting the next crop.

* A good crop means you can buy things for your family and farm.

* But you must have a good place to keep your grain after the harvest. You cannot use all the grain right away.

* It is not good to sell grain right after harvest. The price for grain is lower at harvest time because more grain is available than at other times of the year.

* You cannot eat all the grain. You will want some later.

* Seed grain must be stored safely until planting time.

* A good grain storage place is a place to keep grain safe until you want to sell it, to eat it, or to plant it.

* There are many ways to store grain. Some farmers store grain in sacks. Some farmers store grain in clay jars and in the rafters of their homes. Some farmers store grain in special buildings.

* All grain storage places must protect the grain from insects, mice, rats, and other pests.

* Rats and mice enter open grain storage places easily. They can eat and spoil a lot of grain every day.

* Birds and chickens like to eat grain too.

* Many insects attack stored grain.

* Insects get into grain very easily. Some of them can fly, and some begin eating the grain in the field before harvest.

* Insects lay many eggs. These insects eat and spoil a lot of your grain.

* Insects, rats, and mice eat so much grain that soon there is less for you to sell and eat.

* Insects and rats put the droppings from their bodies on the grain while they are eating. This makes the grain dirty.

You cannot make as much money when you sell this grain.

*** People get sick from eating grain which rats and insects have put droppings on.**

*** Molds also attack stored grain.**

*** Molds are tiny plants. You cannot see these plants. Mold plants float in the air and need warmth and moisture to grow. Mold plants usually are on stored grain even though you cannot see them.**

*** Molds give grain a bad smell and change the color of the grain.**

*** Molds like to grow in warm, wet storage places, so you must keep grain cool and dry.**

*** People can get sick if they eat grain with mold on it.**

*** It is important to keep insects, rats, molds, and other dangers away from your stored grain. Good grain storage means more money and more food.**

*** Your extension worker can help you with grain storage problems. He knows how you can fight insects, rats dangers. He will have ideas on ways you can improve your grain storage.**

The following pictures show how one artist has chosen to present the subject, "Good Grain Storage Helps Farmers." As you can see, he has chosen a certain number of important ideas from the scripts and highlighted them using pictures. Perhaps these pictures will provide you with ideas for illustrating your own leaflets.

<FIGURE 11>

<FIGURE 12>

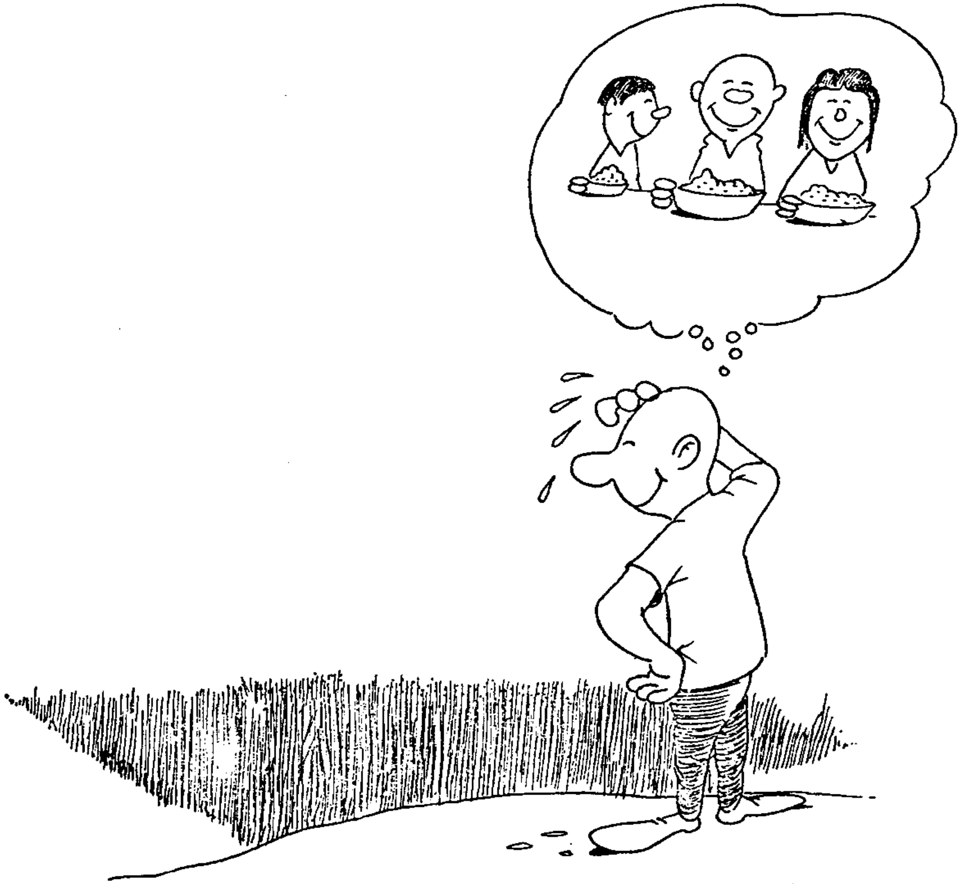
<FIGURE 13>

<FIGURE 14>

<FIGURE 15>

<FIGURE 16>

51ap11.gif (528x528)



I HAVE WORKED HARD, AND IT IS A GOOD CROP. WE WILL HAVE PLENTY TO EAT.

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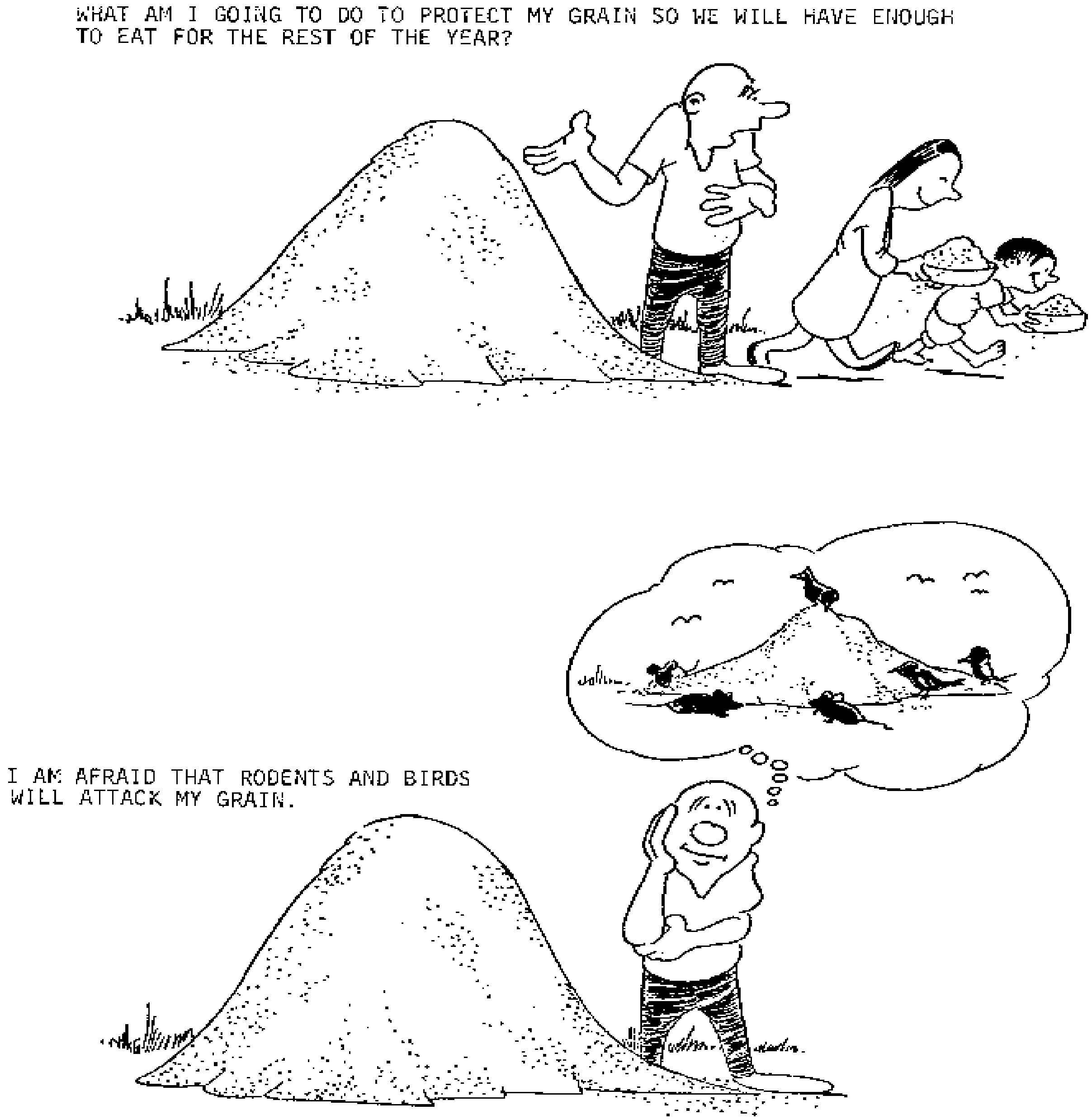

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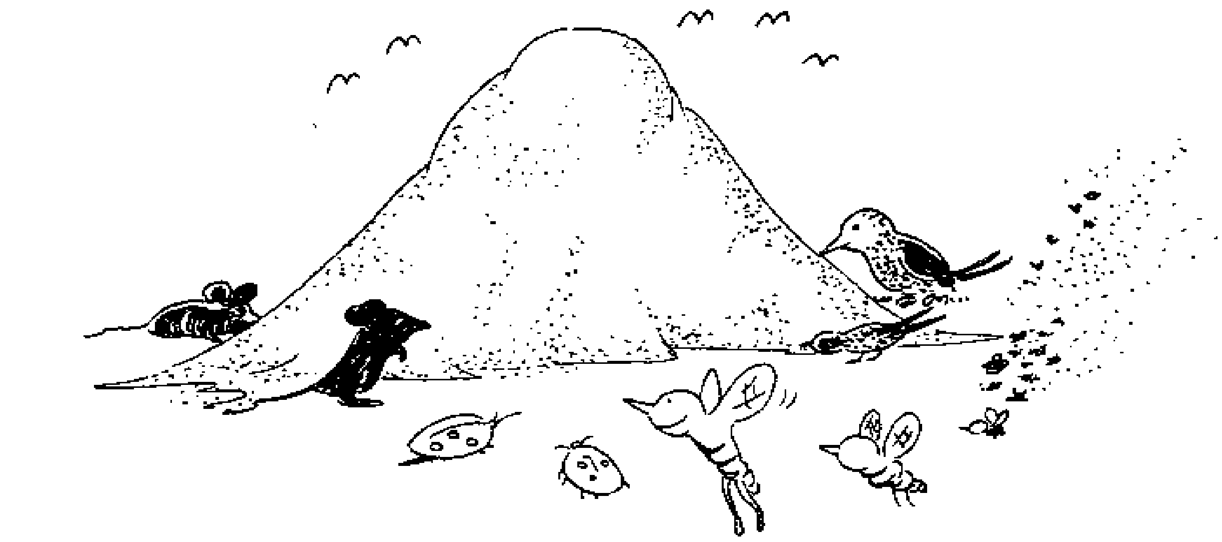

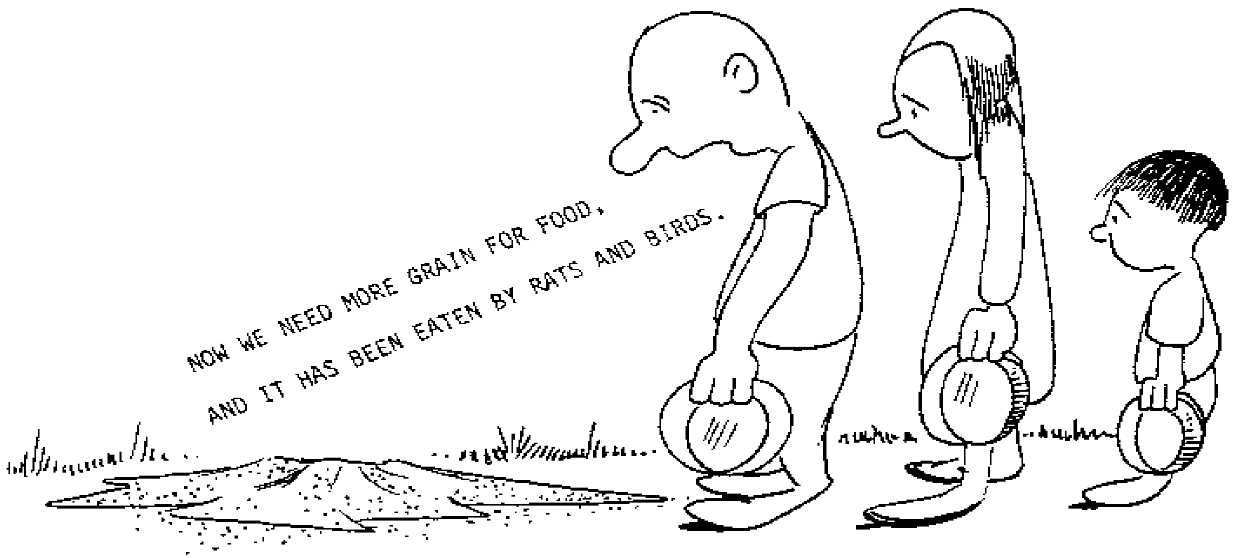

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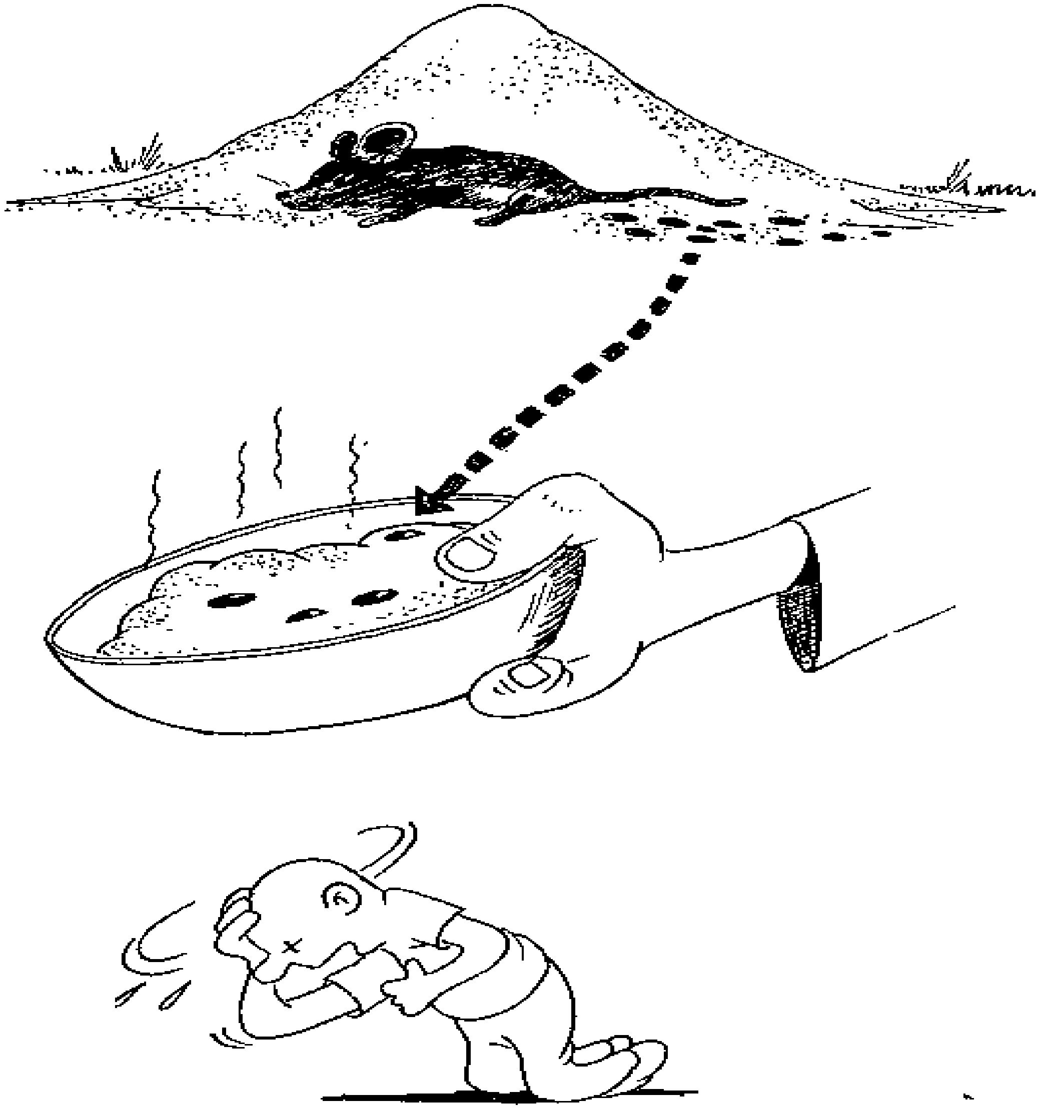

THE GRAIN LEFT BY THE RODENTS AND OTHER PESTS IS DIRTY FROM THE PESTS' BODIES. YOU CAN GET SICK FROM EATING THIS DIRTY GRAIN.

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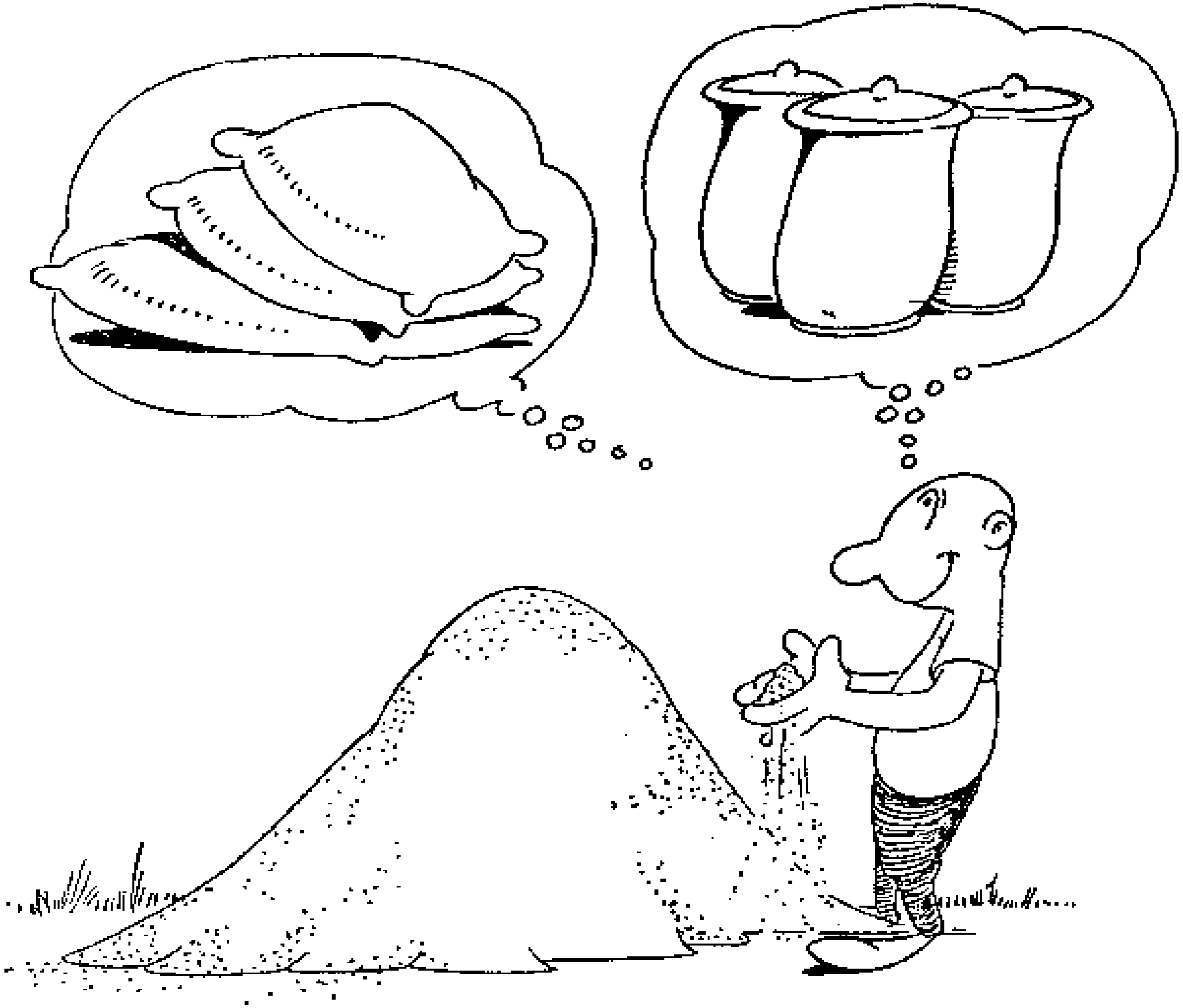
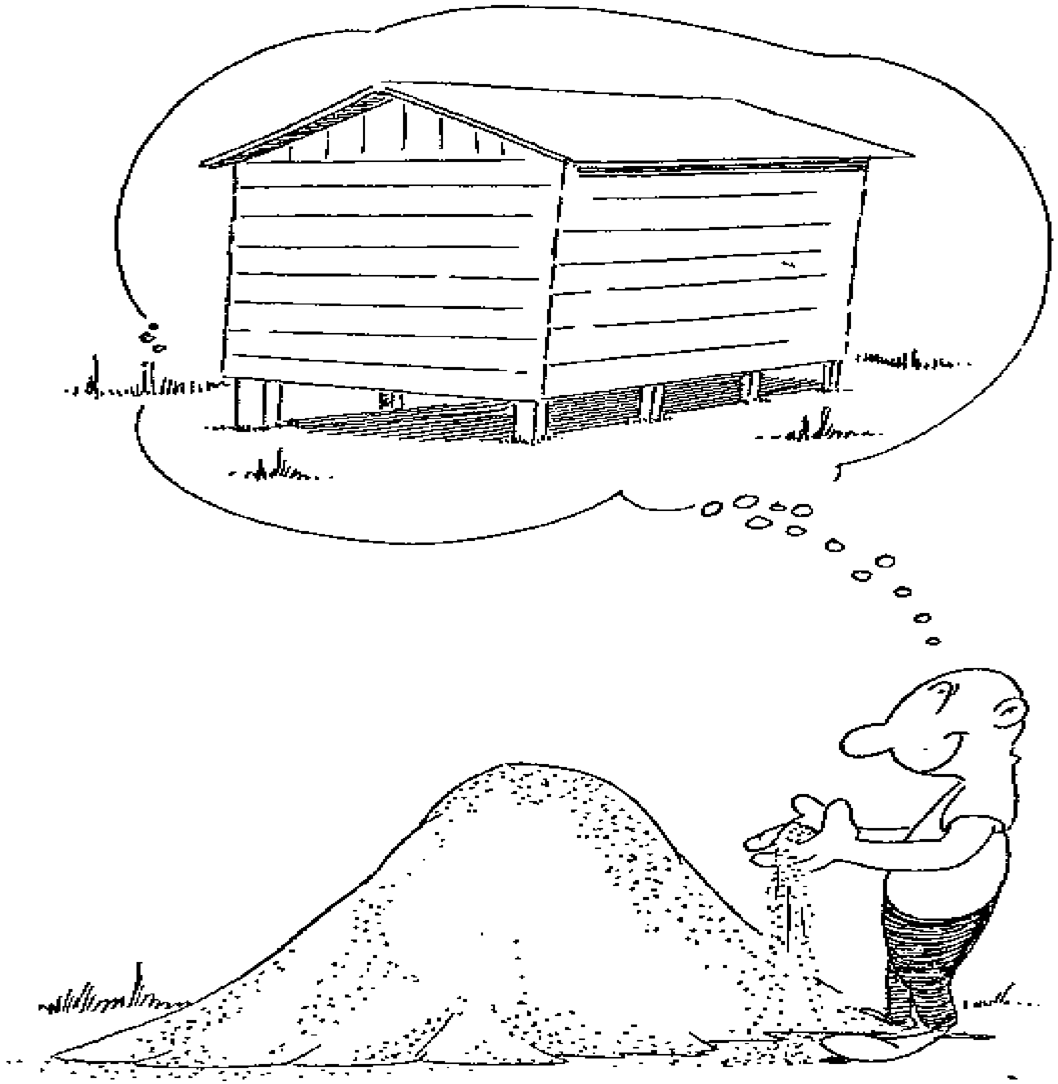


MAYBE I SHOULD PUT THIS GRAIN INTO A GOOD STORAGE PLACE. I COULD STORE THE GRAIN IN SACKS. OR MAYBE I SHOULD STORE IT IN JARS.

51ap16.gif (600x600)



MAYBE I WILL BUILD A SPECIAL BUILDING FOR STORING MY GRAIN. THIS TIME I WILL PROTECT MY GRAIN FROM INSECTS, RODENTS, BIRDS, AND OTHER PESTS.

Illustrations by VITA Volunteer, Guy T. Welch.

GRAIN IS A LIVING THING

The Structure of Grain

Grain kernels are living things. Grain which will be used for seed must be kept alive. Living seeds also store better.

Maize, rice, sorghum, wheat, millet, and so on, are all cereal grains which belong to the same grain family. As you know, these grains do not look alike. Maize is a large kernel with a triangular shape; it has a hard coat and a large, oily germ which is easy to see on one end of the kernel. Sorghum, on the other hand, is a round seed in a brittle or leathery seed coat. The germ is very hard to see.

Although they look different, the grains all share three basic parts: the seed coat; the endosperm; the embryo (germ).

<A RICE KERNEL>

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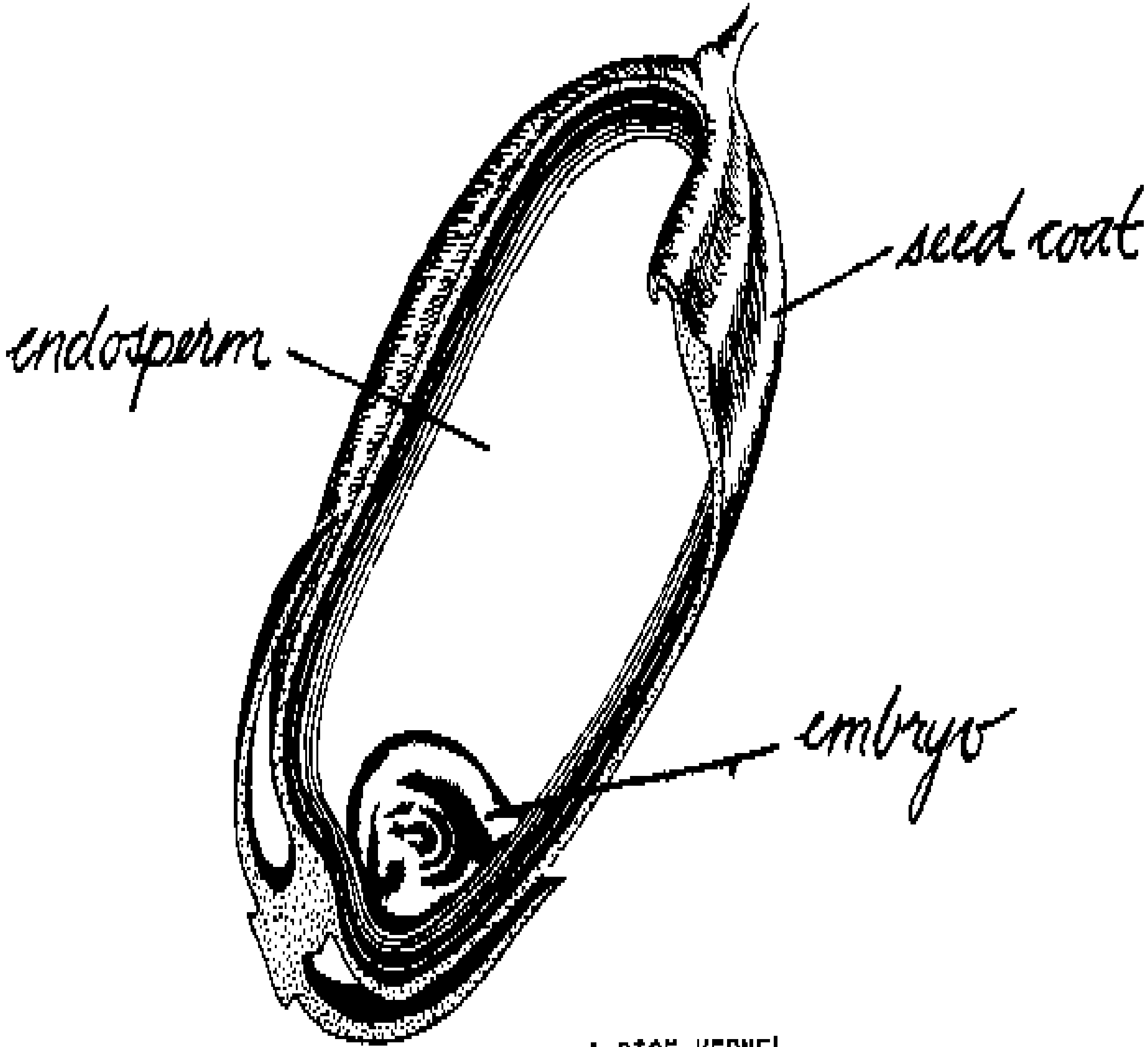


A RICE KERNEL

The Seed Coat

* Surrounds the embryo and the endosperm.

* Protects the grain from attack by certain insects if it is dry and un-cracked.

* Cannot keep out molds and some insects. Those insects which attack the embryo are most dangerous because the seed coat at the embryo is weak.

The Endosperm

* Takes up the largest part of the seed. It is 80% of the kernel volume in most grains.

* Is the seed's food storage place. It is mostly starch and protein.

* Provides food for the developing seed when planted and food for the seed in storage.

* Provides food for farmers and others if the seed is not planted.

The Embryo

* Is the part of the seed which can develop into a new plant.

* Contains most of the protein, fat, and vitamins of the grain.

* Is attacked easily by some insects and by molds. Seed grain which is attacked will not grow into strong plants or will not grow at all. Food grains without embryos do not provide as much nutrition as grains with embryos.

CHARACTERISTICS OF GRAIN AND HOW THEY AFFECT STORAGE

Healthy grain can be kept in storage longer than grain which is broken. The threshing methods used by farmers often damage many of the grains. If the grain is to be threshed before it is stored, the threshing must be done very carefully. Careful handling of the grains helps the grain protect itself from danger. Here are examples of ways in which healthy grains are protected by their structures:

* The husks on maize ears protect the grain from damage during harvesting and drying.

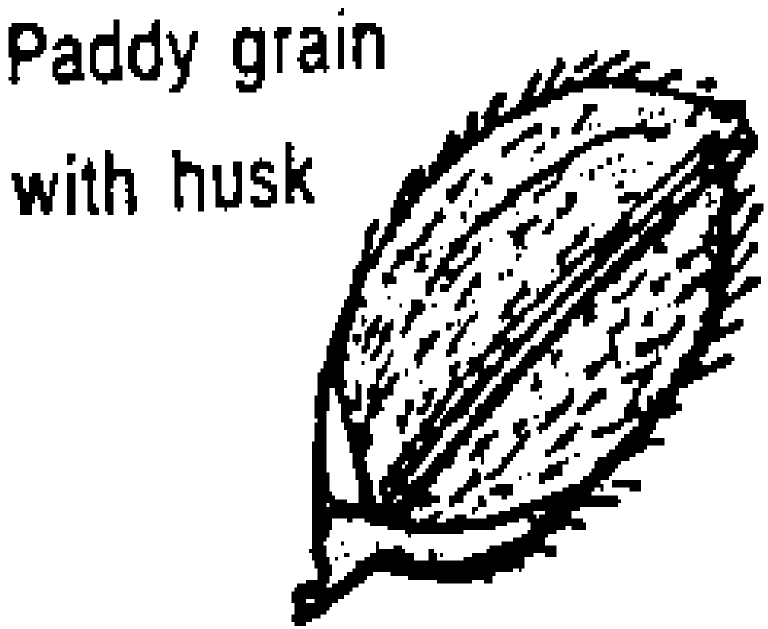
* The husks on rice kernels protect that grain from attack by most insects.

* A hard, dry seed coat with no cracks or splits in it prevents molds and insects from getting into the kernel easily.

* The endosperm of dry grain is hard and is not as easily attacked by insects.

<FIGURE 17>

51ap18.gif (437x437)



Stored rice or wheat or maize, etc., act in one way or another because each has certain characteristics which are affected by the ways it is stored. A farmer should know the characteristics of the particular grain he is storing.

Because there are many kinds of grain, this manual can not talk a lot

about each. Here it is most important to point out that the structure of the grain (the way it is made) plays an important part in what does or does not happen to that grain in storage. The structure of the grain affects the length of time the grain can be stored and the kind of storage container it should be put into. You may want to prepare materials for the farmers in your area which talk directly about the structures of the grains they grow and which storage containers are best for their grain.

Respiration

Grain breathes. Each kernel gets oxygen from the air and burns food from its endosperm. This process gives off heat and and carbon dioxide. This process in grain is called respiration. Respiration is faster or slower depending upon the temperature and moisture in the grain. Respiration is slow when grain is cool and dry. There is only enough respiration to keep the embryo of the grain alive. This process can continue in storage for a long time if the embryo is not attacked by mold, insects, or high temperatures. Slow respiration is important for storage. Growth does not happen at this low respiration level, but seed life continues.

<FIGURE 18>

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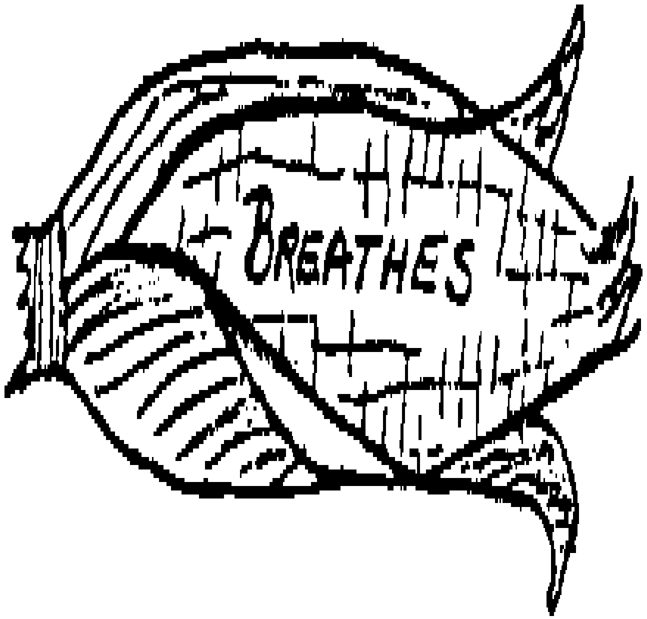

<FIGURE 19>

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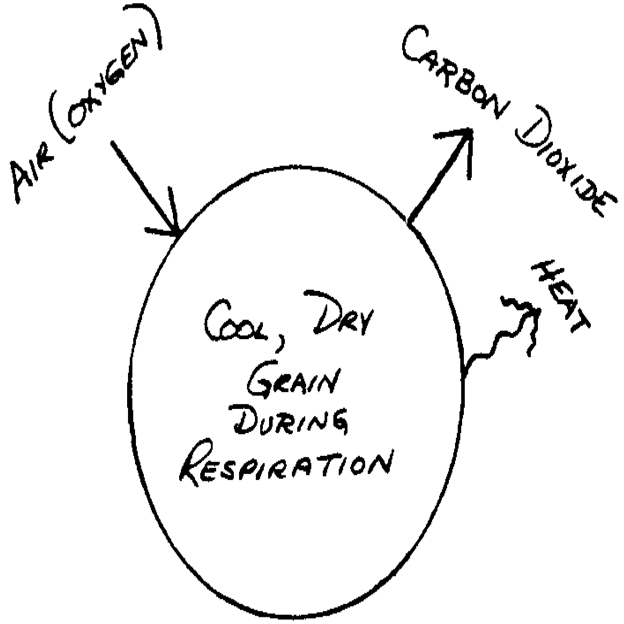
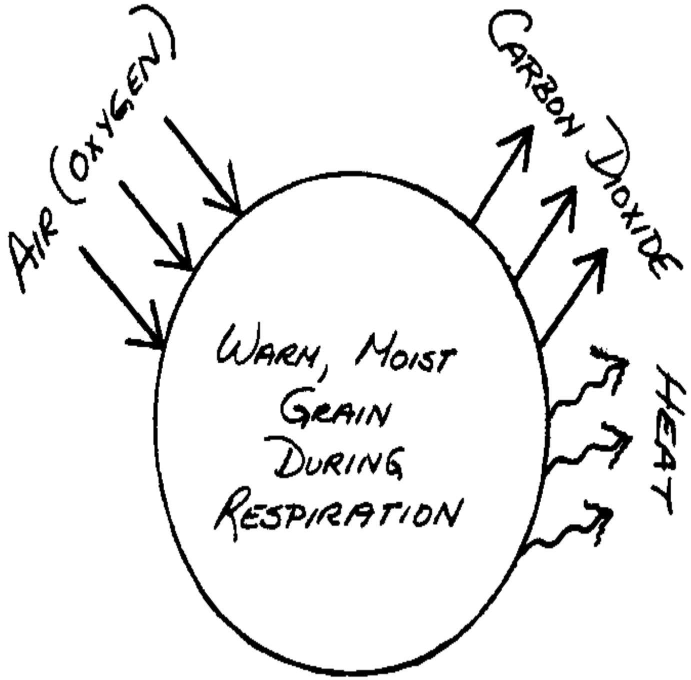


If the stored grain has too much moisture or heat in it, the grain begins to respire faster. When seed grain is planted, for example, it germinates (grows) because respiration has been speeded by water in the ground and the warmth of the soil.

<FIGURE 20>

51ap20a.gif (353x353)



The way that grain, moisture, and temperature work together is important for farmers to understand. Grain put into storage with a lot of moisture in it breathes much faster than dry grain does. This moist grain makes more heat and creates conditions leading to mold growth and insect attack. The farmer who understands this will see the need for storing cool, dry grain.

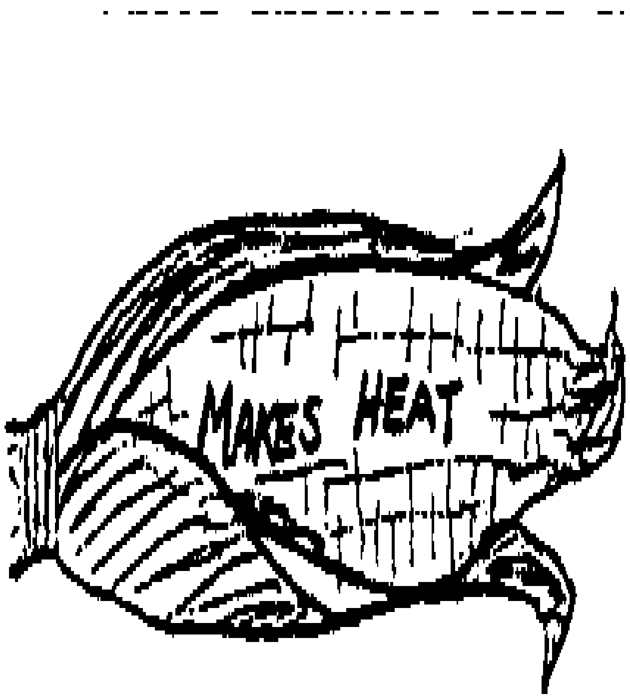
Heat Producing and Heat Holding

Grain produces heat during respiration. If the grain is cool and dry, it respires very slowly and the amount of heat it makes is

very small. But if respiration gets faster for some reason, grain makes more and more heat. Spots of hot air form inside the storage container because the stored grains hold the heat.

<FIGURE 21>

51ap20b.gif (353x353)



The temperature outside the storage container does not have an immediate effect on the grain in large silos, but it can be a problem for the

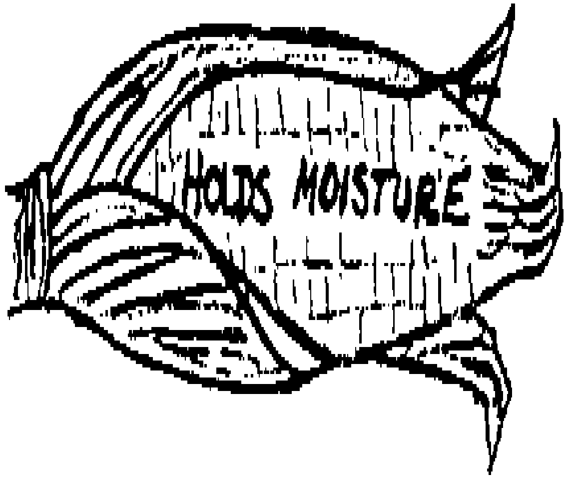
farmer who has a small metal storage bin which stands by his front door and faces the sun for some hours each day. The heat from the sun warms the bin, and this warming spreads to the grain inside. Any insects and molds present in the grain will grow much more quickly.

Moisture

All harvested grain holds a certain amount of moisture. Most of the moisture is inside the kernel; if the grain is very wet, some of the moisture is around the outside of the kernel. Farmers must dry the grain until it only holds about 12-13% moisture if they are to store grain safely. Since moisture and drying are so important, they are discussed more fully in another section.

<FIGURE 22>

51ap20c.gif (317x317)



Grain has other characteristics, such as flow and pressure. These are subjects not particularly important to a small-scale farmer. Mainly he needs to know what the grain looks like inside and what there is about grain that makes it act in certain ways in storage.

GRAIN IS A LIVING THING

Suggested Uses: Select points as needed. Translate and illustrate them for distribution to farmers in your area.

* Each kernel of grain is a living thing. Each grain is a seed.

* A seed can grow into a new plant just like the one it came

from.

* Most of the seed is food around a tiny part of the seed called the embryo. Some people call the embryo the germ of the seed.

* This embryo is the part of the seed that will grow into a new plant.

* One part of the embryo will form the shoot that grows above the ground.

* The other part of the embryo will grow and become the root of the plant. This is the part of the plant that grows under the ground.

* There is a seed coat around the food and embryo. This coat protects the grain from being hurt. Careful harvesting, threshing, and storing will protect the seed coat.

* While they rest, seeds breathe and use the food that is inside them.

* Seeds stay alive and are good for planting and selling if they rest in places which are cool and dry.

* A good grain storage place must be cool and dry. It must protect the grain from insects and other dangers.

* Do not use high heat to dry the grain you are saving to plant with. High heat will kill the embryo.

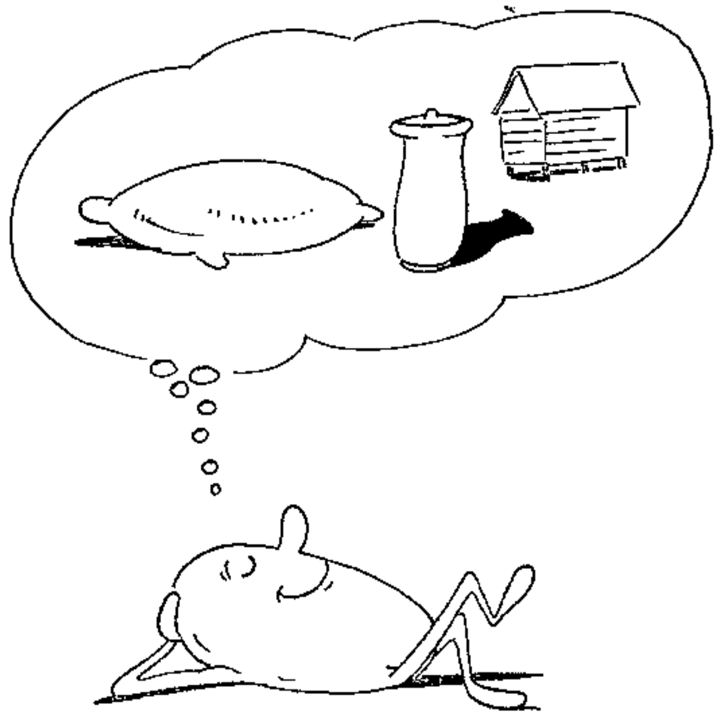
* Store your seed grain separately from the grain you plan to sell or to use for food.

* Check the grain often. Make sure it is dry. Do not let it get too warm. Make sure there are no insects in it. Smell it to see if molds are present.

* Good storage of your seed crop means the next crop will be a good crop. The living grain will grow into a new plant when you put it into the earth.

<FIGURE 23>

51ap22.gif (353x353)



GRAIN, MOISTURE, AND AIR

WHAT MOISTURE IS

Moisture is water or wetness. But moisture is a better word to use when talking about grain storage. When farmers use the word water, they are likely to think of lakes, rivers, wells, or containers of water. They think of water as a liquid which is very easy to see and to measure.

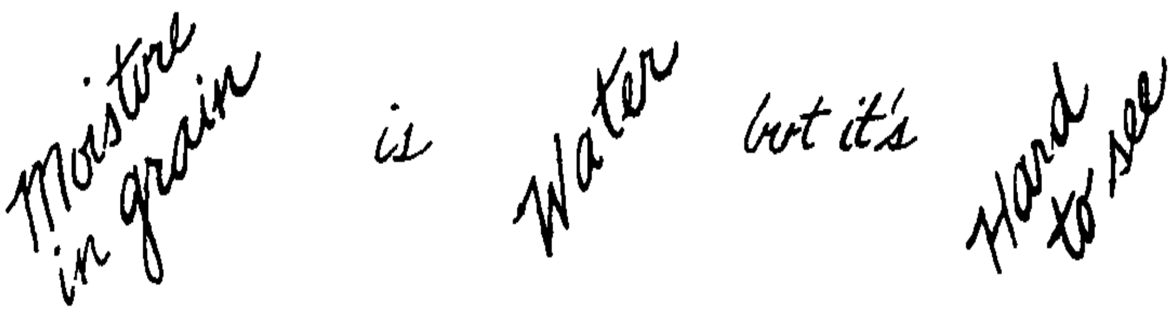
A farmer may not be familiar with the word moisture. Moisture is a good word because it can describe something which is wet or contains water without looking wet. For example, the earth can have moisture and not look wet. A plant does not look wet, but when you crush it, you will feel moisture (wetness) on your hand.

MOISTURE IN GRAIN

Each kernel of grain has moisture inside. But the grain kernel does not look wet when you look at it. The farmer can tell if it is wet by cracking it between his teeth. Wet grain is not hard because the water inside is wetting the seed and keeping it soft, just like pouring water on hard earth makes the dirt soft. When the moisture leaves the grain during drying, the grain becomes harder. The dryer the grain, the harder it becomes.

<FIGURE 24>

51ap23.gif (162x600)



Grains hold different amounts of water at different times: the amount of moisture in harvested grain depends mostly on the time of the harvest. For example, grain harvested in the rainy season may have more moisture than grain harvested in dry, sunny weather.

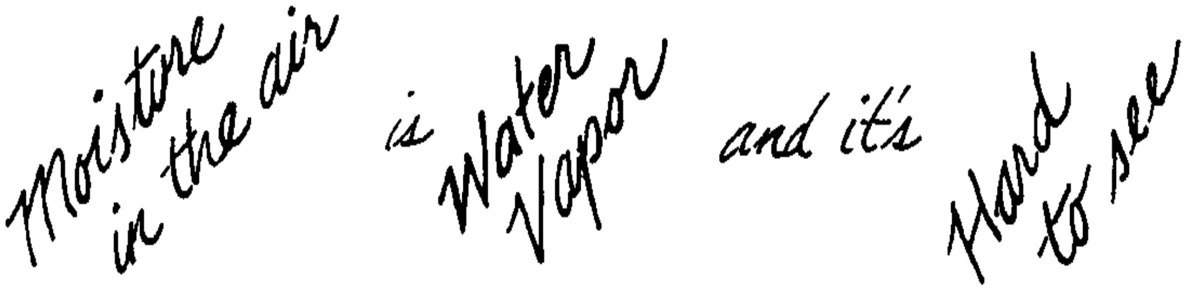
It is important to note that some grains must contain more moisture than others when harvested, if they are to be harvested safely. This is true, for instance, of new varieties of rice. This rice must be harvested before it gets too dry, or much of the rice will shatter or fall off the stalks. Both maize and rice can be harvested when the moisture content in the kernels is in the 20% range. However, maize can be left in the field to dry further before harvesting. Rice must be harvested right away and not be allowed to dry in the field.

MOISTURE IN THE AIR

Air contains moisture also. Of course, the farmer cannot see this kind of wetness when he looks at the air, because the moisture in the air is in the form of vapor.

<FIGURE 25>

51ap24a.gif (162x600)



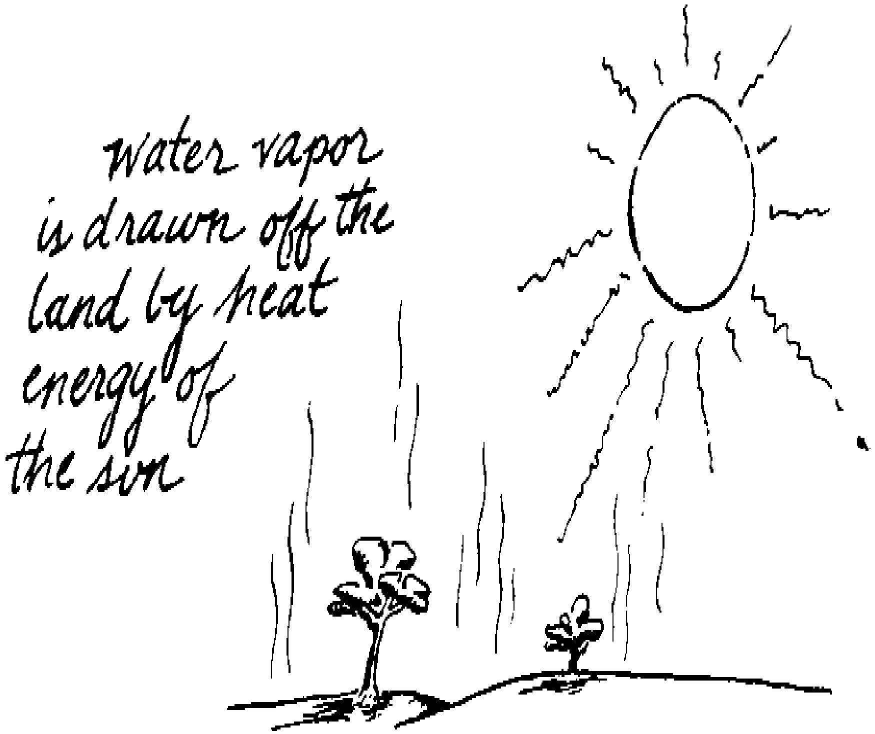
Just as grains hold different amounts of water, air holds different amounts of water. Warm air can hold more moisture than cool air.

On a very hot day, there can be a lot of moisture in the air, When evening comes and the temperature goes down, the air, now cooler, cannot hold all the moisture it held when it was warmer. So the extra moisture falls out of the air and lands on the earth. This moisture from the air is the dew seen in the cool early morning.

As the sun gets higher during the day, the air temperature goes up. The air, now warmer, can hold more moisture. So the dew on the land is taken up by the air.

<FIGURE 26>

51ap24b.gif (437x437)



Relative Humidity

Many farmers will not be familiar with words such as relative humidity. Nor do they really have to be. It is not important to most farmers to understand that relative humidity is a percentage measurement of the amount of moisture actually in the air as compared to the maximum amount of moisture that air at that temperature could hold. Nor do most farmers need to understand that if the moisture content in the air remains the same and the air temperature goes up, the relative humidity goes down.

Relative humidity is a meaningful phrase only to those who can measure it and apply the knowledge to drying times, etc.

Most farmers do not have instruments which measure relative humidity. But they have good information if they understand two facts about air and moisture:

1. Warm air can hold more moisture than cold air.

2. Air at any temperature does not always hold as much moisture as it possibly can. The amount it actually holds changes. When air holds as much water as it possibly can (100% relative humidity), rain is likely.

HOW AIR, MOISTURE, AND GRAIN INTERACT

Scientists say that grain is hygroscopic because it loses or gains (adds) moisture from the air around it. At this point, it would be easy to get involved in a long discussion of moisture and vapor pressure. For example:

Since all things containing moisture have pressure, grain and air have pressure. Grain dries in the sun because moisture vapor is moving from higher pressure in the wet grain to lower pressure in the air, until the grain and the air reach equilibrium vapor pressure.

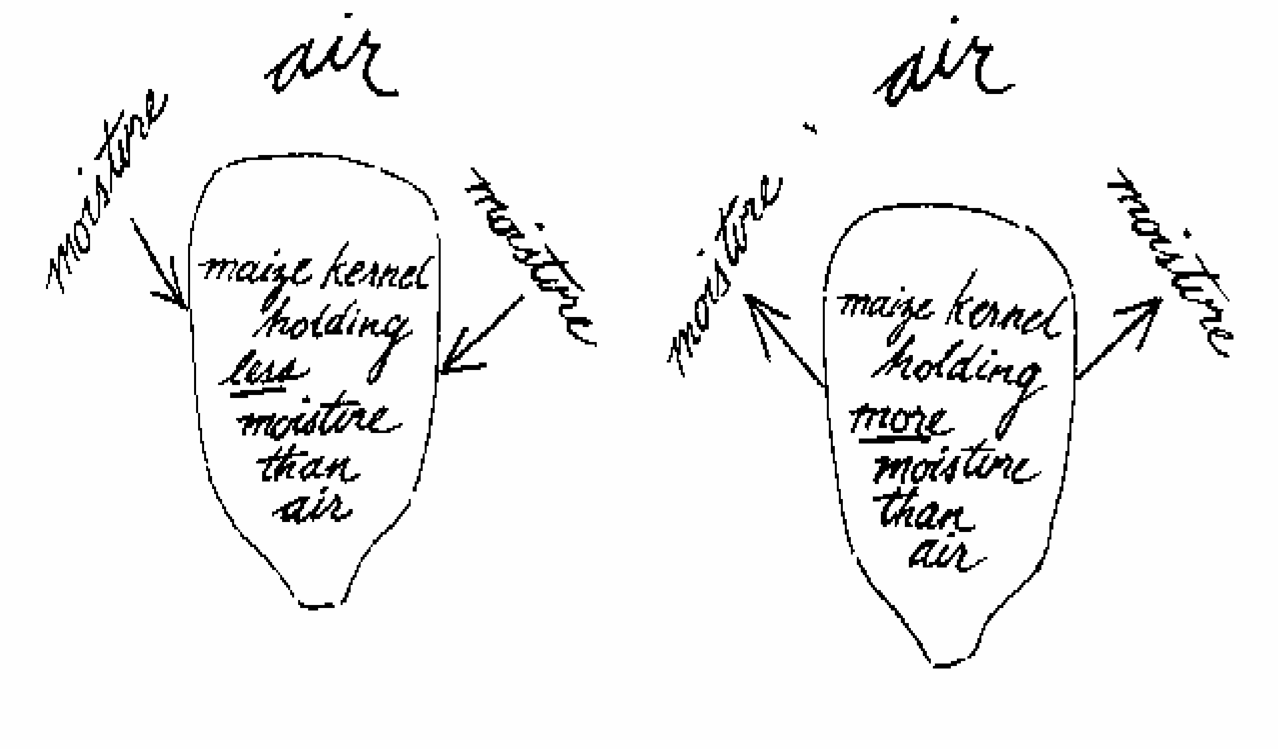
This can be explained somewhat more simply by saying that two things containing water will push that water back and forth until a balance is reached. The more moisture there is, the harder the moisture can push. That is, if there is comparatively more moisture in the grain than there is in the air around the grain, the moisture in the grain will push out into the air.

The key to the drying process, then, is placing grain in the sun or in a drying machine so that the kernels of grain can be touched by warm moving air which has less moisture in it than the grain has. The heat in the moving air will make the moisture in the grain evaporate. The moisture will become water vapor and be absorbed and carried away by the moving air.

It is useful for a farmer to know that drying continues only as long as the air around the grain is able to absorb more moisture from the grain. If the air contains a lot of moisture, the grain is likely to take in that moisture from the air. The farmer should understand this fact because it explains the need to keep dry grain away from moisture and/or air as much as possible. Grain that is not sealed in a closed container will continue to exchange moisture with the air. During the rainy season, for example, grain will take on moisture if left in an open container. In the hot, dry season, grain will lose the moisture again.

<FIGURE 27>

51ap26.gif (353x600)



SAFE MOISTURE LEVELS IN GRAIN

Grain put into storage should not have more than a certain amount of moisture inside its kernels. Although the amount of moisture grain can hold in storage safely can change, depending upon storage conditions, some general moisture-safety percentages have been established.

The chart which follows(*) shows that maize can be stored safely at 13.5% moisture (that is, 13.5% of the total weight of the kernel can be moisture), in air which is 25-30 [degrees] C and has 70% relative humidity (that is, the air at this temperature can hold 30% more water than it is

holding). At this point the kernel of maize and the air are not going to exchange moisture back and forth. This is an equilibrium point. This equilibrium is the condition good grain storage tries to set up, but it is very hard to keep grain stored at conditions which keep equilibrium.

MAXIMUM MOISTURE CONTENT FOR ONE
YEAR (OR LESS) STORAGE AT 70%
GRAIN TYPE RELATIVE HUMIDITY AND 27 [degrees] C
Wheat 13.5%
Maize 13.5%
Paddy Rice 15.0%
Milled Rice 13.0%
Sorghum 13.5%
Millet 16.0%
Beans 15.0%
Cow Peas 15.0%
Remember, the figures above are maximum recommended moisture levels. Generally, farmers should dry their grain as thoroughly as possible.

* From "Handling and Storage of Food Grains in Tropical and Subtropical Areas," by D.W. Hall, published by Food and Agriculture Organization of the United Nations, 1970.

MOVEMENT OF MOISTURE IN STORED GRAIN

Grain which is dry and cool will keep for a long time if it is stored correctly. However, there are a number of bad things which can happen to grain while it is in storage. And moisture is a key part of most of the process of deterioration (spoiling) that can occur in stored grain.

To discuss the role of moisture in the storage container, it is necessary to talk about:

* grain condition

* temperature

* insects, molds, and grain heating.

Grain Condition

The farmer must store only clean, healthy grain which has been dried to safe storage levels.

Broken grains and pieces of straw or dirt increase the chances of storage trouble. And, if the storage container does not keep out moisture or insects, even healthy, clean, dry grain can deteriorate. Trouble is less likely to happen if the grain starts in good condition.

Temperature

There are two kinds of temperature: temperature in the air outside the storage container and temperature of the grain inside the storage container.

Some things to remember about temperature:

* Low temperature is better than high temperature for

grain storage. Insects and molds do not grow at low temperatures.

*** Grain breathes very slowly at low temperatures.**

*** At low temperatures, little heat builds up inside the grain from the living and breathing of insects and molds -- and the grain.**

*** Rising temperatures outside the containers can increase the temperature inside the container -- particularly if the container is not shaded or is made of metal.**

*** Rising temperatures can lead to insect and mold growth. Even in grain that looks clean, insects are almost always there to some degree; mold spores are present everywhere. As the temperature of the grain goes up, these insects and molds will start to grow.**

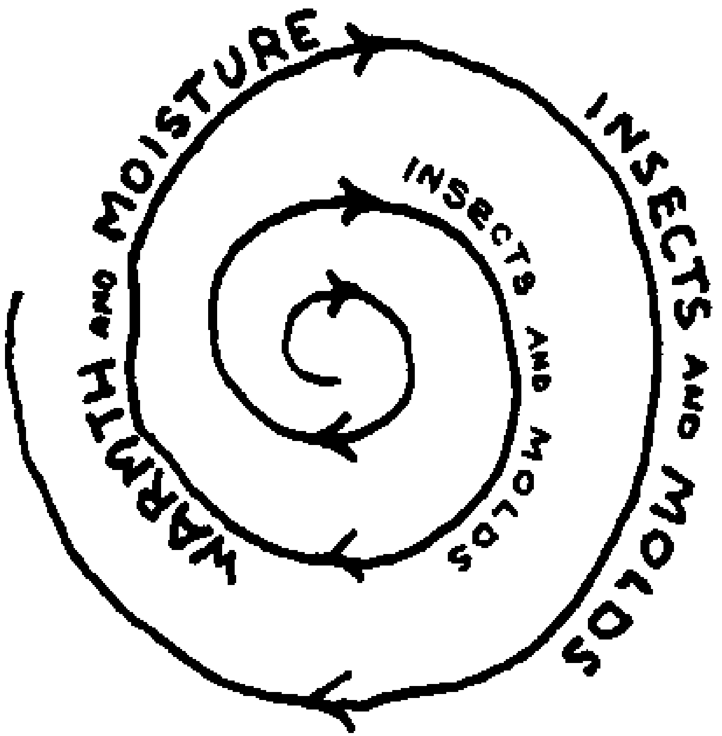
*** As the temperature goes up, molds and insects grow faster. The grain respires more quickly. If the grain contains a lot of moisture, this process goes even faster.**

*** Hot spots can form in areas of the grain where the most**

mold and insect activity is occurring. These hot spots spread and cause great damage and loss of the stored grain.

<FIGURE 28>

51ap28a.gif (393x393)

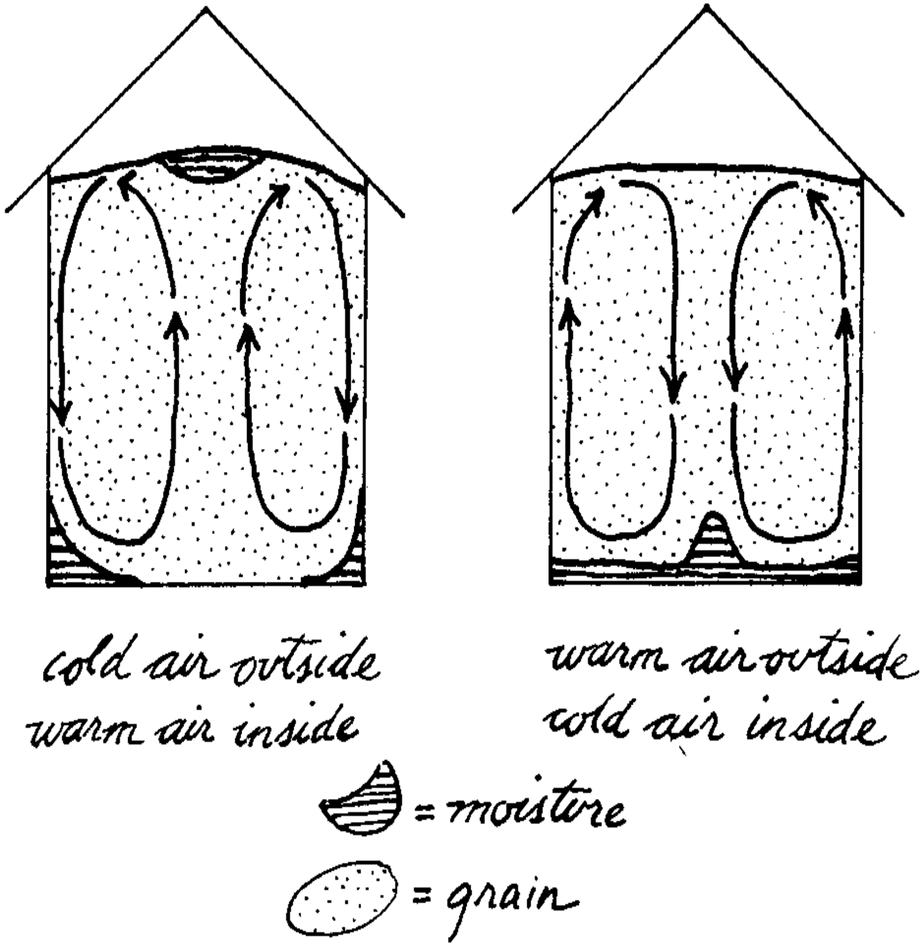


The above points show how temperature and moisture work together. Therefore, grain placed into storage should be as dry and cool as possible. Even then there can be a moisture problem during storage.

This problem often is the result of a difference in temperature between the inside and outside of the storage container. When cool air and warm air mix in the stored grain, the warm air cools and may be forced to lose moisture. This lost moisture becomes water which can be seen at the top and bottom of the storage container. The following drawings show what may happen when there are differences in temperature between the inside and outside of the storage container:

<FIGURE 29>

51ap28b.gif (486x486)



These changes caused by temperature can be seasonal, or they may be daily. This depends upon where the farmer lives. Obviously, it is best to keep stored grain at a relatively constant temperature. The storage section will show various ways of dealing with this problem.

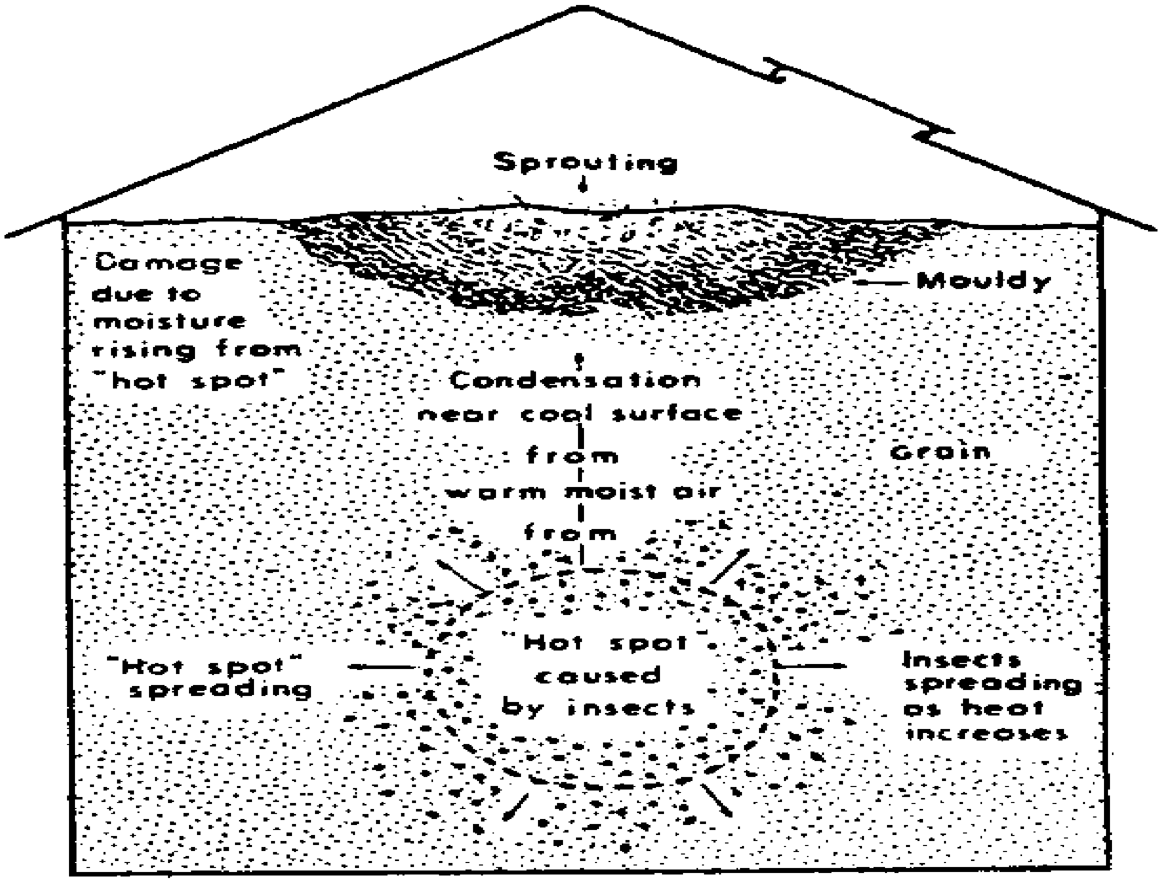
Insects, Molds, and Grain Heating

Remember the dew and how it forms because cold air and warm air cannot hold the same amount of moisture? This same thing is what happens in stored grain when cold air and warm air meet each other because of changing temperatures. The farmer who understands dew will be able to understand how his grain got caked and moldy even if it was dry when he put it inside the storage tin or container.

The pools of water formed by the moisture forced out of the air make the stored grain wet. This wet grain begins to respire at a faster and faster rate. If there are insect larvae and mold spores present, they begin to grow and reproduce. Soon the insects, molds, and grain all are giving off heat. This process produces the hot spots spoken of earlier. When the temperature gets too high, insects will leave the heated spot and go out into the grain mass to find better living conditions. Other trouble spots then can develop.

<FIGURE 30>

51ap29.gif (600x600)



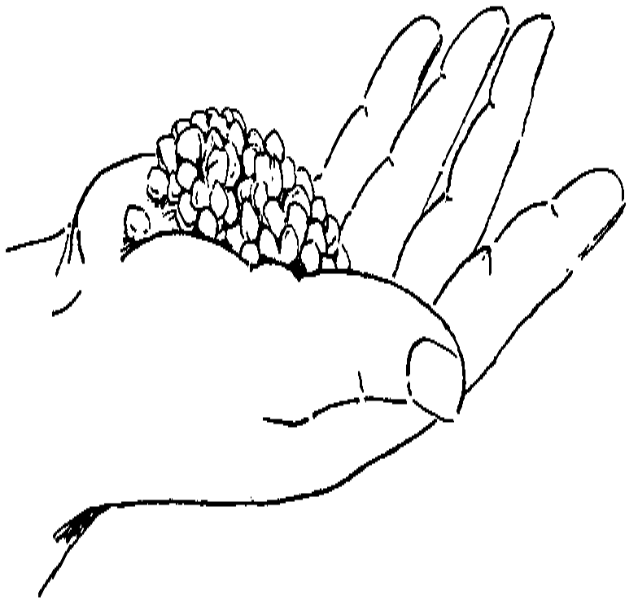
From "Handling and Storage of Food Grains in Tropical and Subtropical Areas," by D.W. Hall, published by Food and Agriculture Organization of the United Nations, 1970.

WHERE YOU ARE NOW

Now the background for the subject of grain storage is complete. If you have been using this manual with a farmer or group of farmers, they now know what grain is in a scientific way; the relationship among grain, water, air, and temperature; and some of the ways grain storage problems occur. In other words, they have some scientific ideas about good grain storage. The next section deals with the subject of preparing grain for storage. That discussion applies some of the ideas from this section.

<FIGURE 31>

51ap30.gif (317x317)



4 PREPARING GRAIN FOR STORAGE

INTRODUCTION

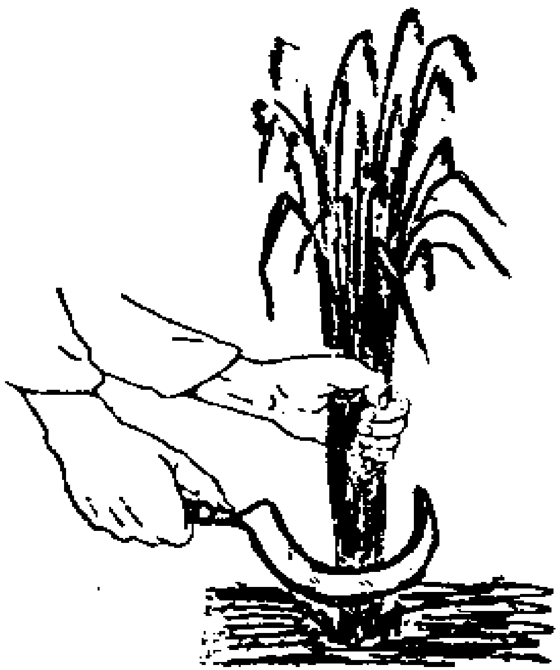
This section discusses the steps a farmer should take to prepare grain for storage. It gives these steps in the order he takes them. Each of these steps is looked at here as an important part of the storage process. Good harvesting, threshing, cleaning, and drying practices are important for the success of any storage method a farmer may use.

HARVESTING AND THRESHING

Some grains, such as new varieties of rice, should be harvested when they contain quite a bit of moisture. Other types of grain, such as maize, can be much drier when harvested. But even when the grain can be allowed to dry in the field, there is often too much moisture in the air, or even rain, and the grain does not lose a lot of its moisture. Therefore, for one reason or another, the farmer has to harvest very moist grain. Then he must somehow dry the grain to about 12-13% moisture content.

<FIGURE 32>

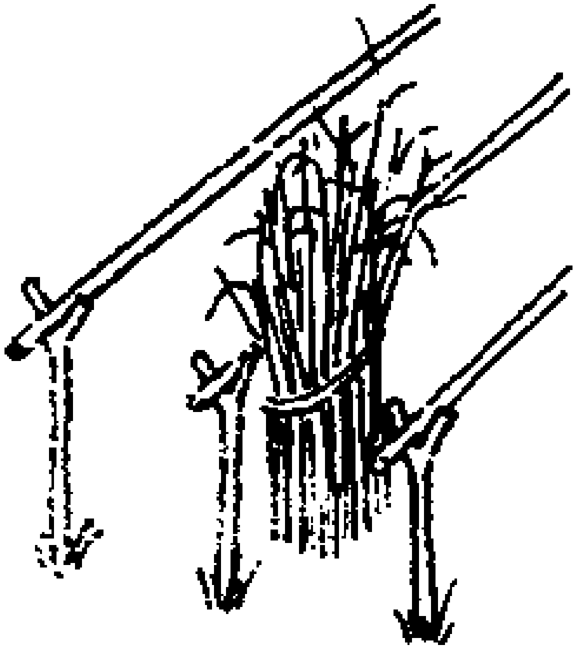
51ap31a.gif (353x353)



If the grain is a variety which can be allowed to dry in the field, and if the weather is good, the farmer can let his grain get as dry as possible while it is still in the field. In some dry, sunny places, it is possible to shock and windrow the grain after cutting it. Wheat, for example, is tied in small bundles that are stacked together side by side. Maize is also often stacked in shocks. This practice allows the grain to dry further. But this practice requires good weather. And rodents, birds, and insects can attack the grain while it is drying.

<FIGURE 33>

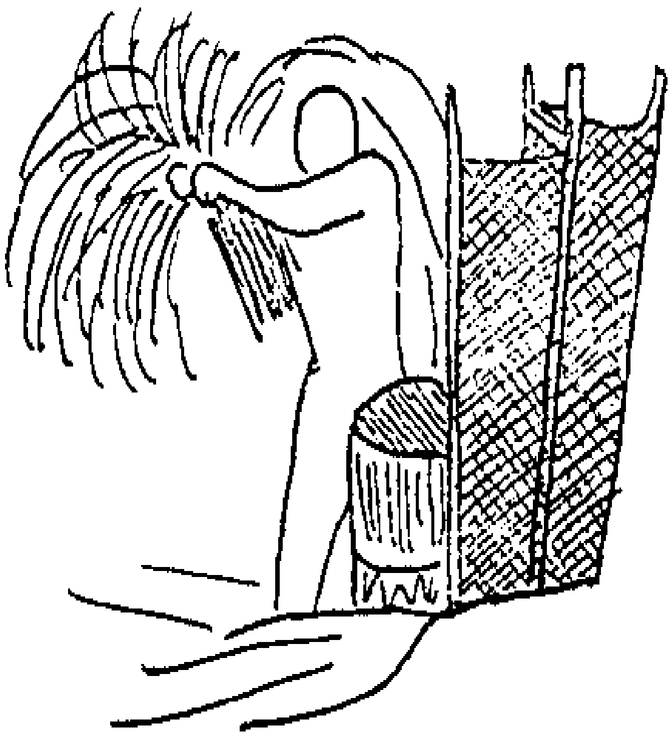
51ap31b.gif (353x353)



Threshing is the separating of grain kernels from stalks and husks. A small-scale farmer usually cuts and threshes grain by hand. When this method is used, farmers must be careful to make sure all weeds and straw are separated from the harvested grain.

<FIGURE 34>

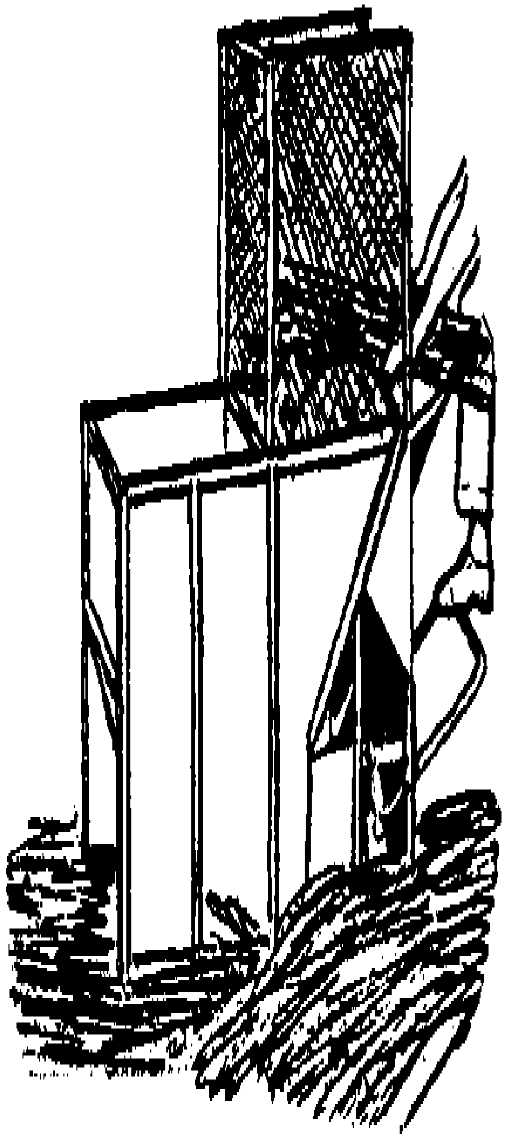
51ap32a.gif (393x393)



There are serious problems in most hand-threshing methods, especially for small grains. A common method uses trampling or beating of the grain to free the kernels. This method often causes cracking of the grain. In addition, unless threshing is carefully done, much of the grain is thrown away with the husks.

<FIGURE 35>

51ap32b.gif (580x580)



No matter what method the farmer uses for harvesting and threshing, he should aim for clean, whole grain. There are machines available which

can harvest and thresh grain at the same time. Most small farmers cannot afford these machines. And for the small farmer, hand harvesting has advantages: it is easier to separate weeds from the grain, and less grain is lost during the harvest.

CLEANING

Clean grain keeps in storage much better than dirty grain. After harvest, grain often contains small amounts of straw, weed seeds, and dirt. These unwanted materials decrease the value of the crop if they remain in the grain. They also cause the grain to deteriorate during storage. Dirt holds moisture, insects, and molds. Dirt also keeps air from moving well through the grain. Dirty grain heats more and deteriorates more quickly than clean grain does.

Insects also must be removed from the grain. Those which eat the grain cause damage in several ways. They destroy much of the grain by eating it. As they grow and multiply, insects produce heat which can cause grain to spoil more rapidly. Grain with a lot of insects in it brings a much lower price than clean grain does.

Most modern harvesting machines get grain pretty clean. They usually blow air through the grain: this removes very light materials such as chaff, husks, and dust. The grain then is sieved. The pieces smaller than the grain kernels are removed by passing them over a fine mesh screen. The larger pieces of waste are passed over a screen that has a mesh size larger than the kernels.

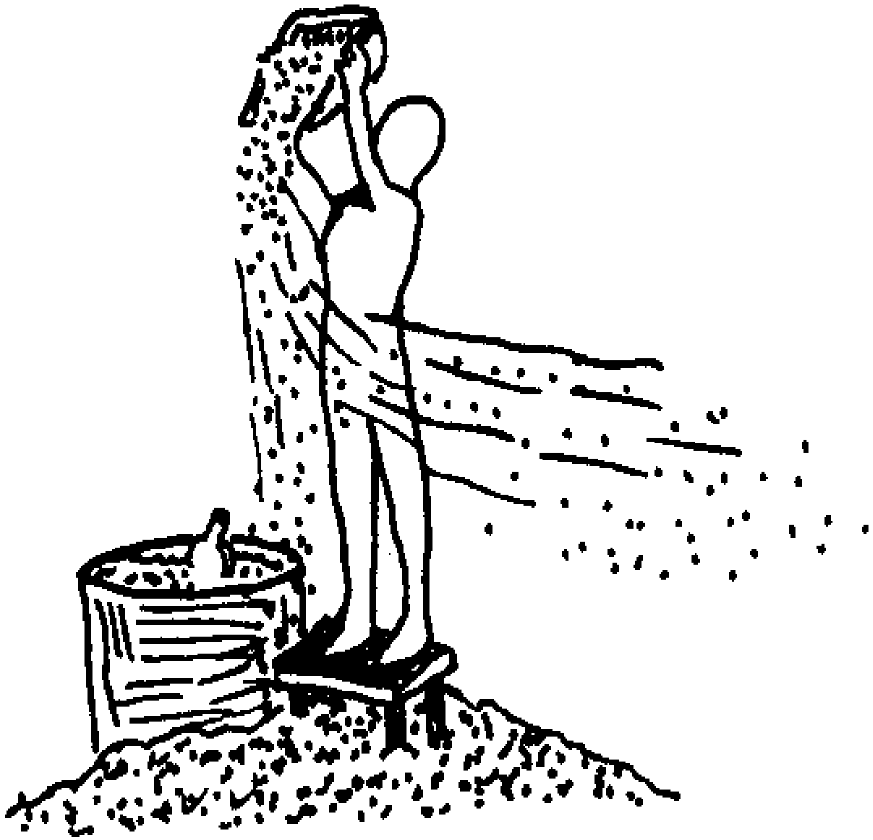
This screening technique can be used even when a machine is not available.

However, it requires screens of proper mesh size. When screens are not available, or when a substitute cannot be found for them, there are other, less effective cleaning methods.

One of the simplest methods of grain cleaning uses the wind: this method is called winnowing. The grain is thrown upward in the wind. As it falls, the lighter pieces -- dust, powder, broken grain -- are blown aside by the wind. But the heavier stones and pieces of earth fall with the grain. For good cleaning, winnowing must be done over and over. Some grain is always lost, and so the method wastes grain. Some farmers place this waste material where chickens can take the lost grain from it.

<FIGURE 36>

51ap33.gif (437x437)



Farmers also should clean their grain each time they move it to a new storage place. If this cleaning is not done, dirty grain from one place may be mixed with clean grain from another. Even grain that has been cleaned quite well before may need cleaning again. Insects do not need a long time to get into grain. Both the insects and their dirt should be removed before the grain is added to grain already in the storage areas.

The farmer should remember that cleaning is important because:

* dirty grain deteriorates more rapidly in storage.

* clean grain does not heat as quickly.

* insects breed faster in dirty grain.

THE NEED FOR DRYING

If moist grain is stored without air moving through it, the grain becomes hot. The grain respires more quickly and gives off more heat and moisture. The grain can be damaged if the heat is too great.

* Heat builds up more quickly in wet grain.

* Molds form rapidly.

* Insects multiply faster.

* Grain can germinate (sprout) while still in storage.

It has long been known that meat, fish, and fruit can be preserved by drying. Dried fish and fruit are widely used for food. These materials do not deteriorate much even when stored for long times. This is because life processes usually occur very slowly when there is little moisture. This is true for grain. Well-dried grain deteriorates only slowly even at fairly high temperatures.

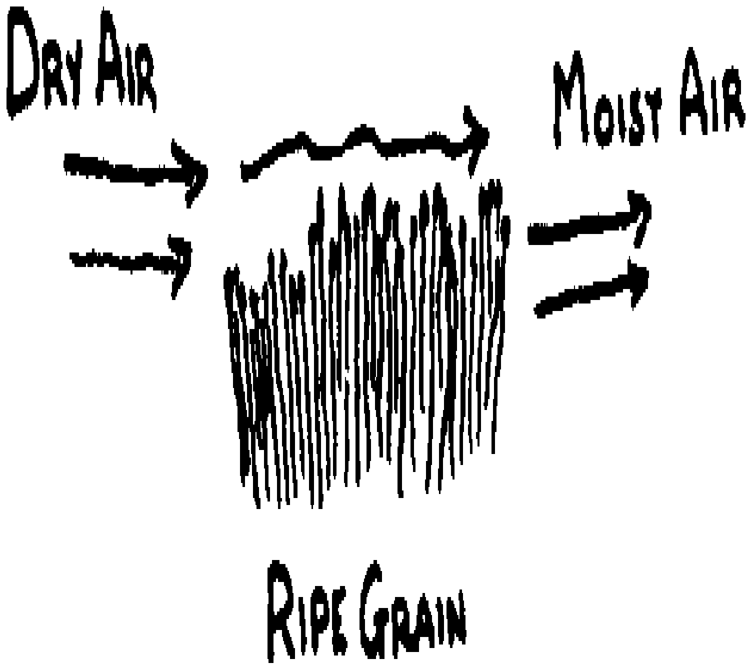
HOW DRYING HAPPENS

In the Field

In order to dry grain, moisture in and on its kernels must be carried away. As the grain stands in the field, the dry air moving past it takes up moisture from the grain. This air, now moist, is then blown away from the grain by the winds.

<FIGURE 37>

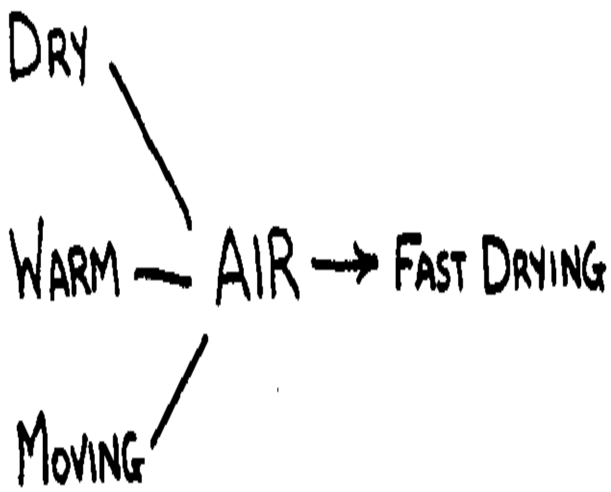
51ap34a.gif (393x393)



The drying process is most rapid if the air does not contain much moisture and if there is a wind. Little drying of the grain occurs if the air contains a lot of moisture, or if there is not much wind.

<FIGURE 38>

51ap34b.gif (256x317)



Hot air passing through the grain usually dries the grain more quickly than cold air does. From the previous section, it is easy to see that there are three major reasons for this:

1. Hot air can hold more water than an equal amount of cold

air can. When dry air blows through the grain, the hotter the air, the more water it can carry away from the grain.

2. Water evaporates more quickly when it is warm. Hot air blowing past grain warms the moisture on the surface of the grain. This moisture leaves the grain more quickly.

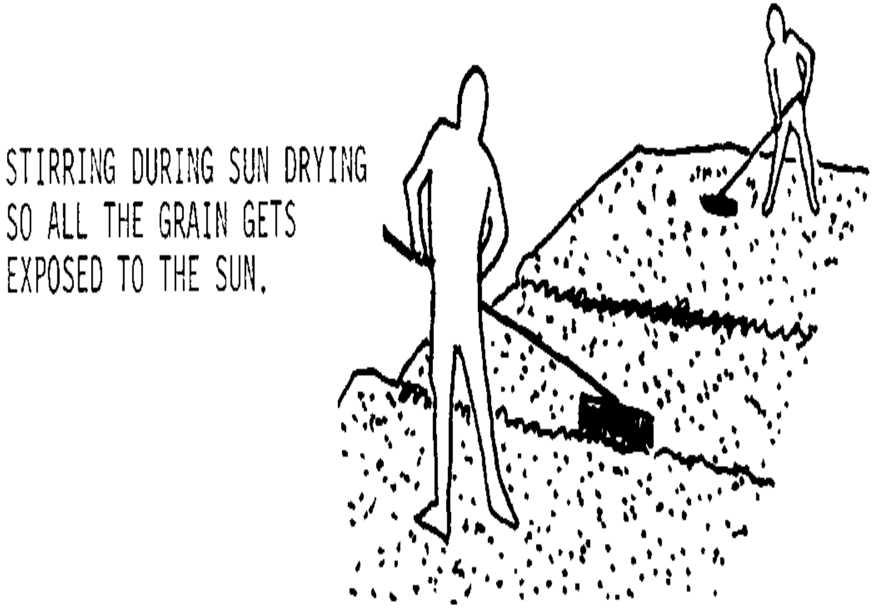
3. Hot air heats the grain itself. Moisture deep inside the kernel moves through the kernel faster at high temperatures. It moves to the surface of the kernel more quickly. When this moisture reaches the surface, it leaves the grain and is taken up as vapor by the air.

After Harvest

The above facts also apply to drying grain after it is harvested. Air must pass through the grain to dry it. Moisture between the kernels and on their surfaces is carried away first. The moisture deep within the kernels must first come to the outside of the kernel. Only then can it be removed by the flow of air. Air must be moving for drying to continue. Only if new, dry air enters the grain can the moist air between the kernels be replaced by air which can take up more water from them. This is the principle behind some drying methods which force cool dry air or warm dry air through the grain to speed drying.

<FIGURE 39>

51ap35.gif (317x437)



Grain drying methods and models are presented in the next section.

It is nearly impossible to dry any grain completely. The last ten percent or so of moisture in the kernel is tightly held by the kernel. It can be removed only with great difficulty. Luckily, grain stores well with this amount of water in it. In some cases, removal of this last water harms the grain.

SAFE DRYING TEMPERATURES

Whatever method a farmer uses to dry his grain, he must be careful not to let the temperature in the drying grain get too high. Too high a temperature causes the kernels of some grains to burst. Temperatures which are too high (when drying maize and rice) cause breaking, cracking, and discoloration of the kernels. This leads to a decrease in milling yield and protein quality. Maize which is used for oil will produce less oil.

Grain used for baking and milling can be dried at temperatures higher than grain to be used for seed. Grain used for seed should not be heated above 40-45 [degrees] C. High temperatures can kill the seed embryo, and the seed will not germinate when planted.

The following are the highest safe temperatures for drying grain.

USE MAXIMUM TEMPERATURE, [degrees] C

Livestock Feed 75
Food for Humans, except rice and beans 60
Milling for Flour 60
Brewery Uses 45
Seed Grains 45
Rice for Food 45
Beans for Food 35

Note Well: The drying temperature depends upon the use of the grain. Drying at lower, rather than highest, temperatures usually gives a better quality dry grain. Also, as a rough rule, lower temperatures should be used for very moist grain than for dryer grain. It is better to take a longer time, and use a lower heat, to dry moist grain than it is to run the risk of parching or burning the grain.

TESTING GRAIN FOR MOISTURE CONTENT

Grain that is too moist will heat in storage. All stored grain should be examined frequently to see if it is heating. Heat build-up deep within the grain is a serious danger signal. Unfortunately, waiting until you can feel the heat in the grain is waiting too long.

Various electrical moisture testing devices are sold. They are seldom available when and where they are needed. Most of them are complicated and expensive. An appendix to this manual contains a discussion of moisture meters. This will show you the kinds of commercial meters which are available.

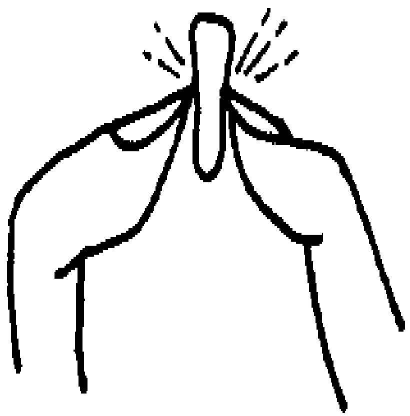
Extension workers should know that grain moisture percentages are calculated in the following way:

PERCENT MOISTURE = weight of completely dry grain
100 x
total weight of wet grain

There are several ways to mechanically measure the amount of moisture in grain in order to make this mathematical calculation. Unfortunately none of these methods are very simple or inexpensive. Fortunately, an experienced farmer can usually tell if grain is dry enough for storage. The method used by the farmer varies from region to region and depends upon the type of grain. However, two methods used by experienced farmers in many places are: (1) pressing the kernel of grain with the thumb nail to see how hard it is (dry grain is hard to press), and (2) crushing the grain kernel between the teeth to make sure it is hard enough (dry enough) for storage. Some people talk of testing to see if grain is dry enough by smelling it for an "off" smell or by rattling grain kernels in a tin can to hear if the dull sound of wet grain has given way to a sharper sound of dry grain.

<FIGURE 40>

51ap37.gif (230x230)



The scope of this first manual edition can not be broad enough to allow us to add specific drying instructions and suggestions for each type of grain. Future editions may be able to do this. If your area is more involved with wheat, and you feel there are additional facts farmers should know, or there are drying methods you have found particularly helpful and would like to share with others around the world, send them in!

If there are plans for threshers and winnowers which could be made and used effectively by others, these also could be included in future editions of this manual.

PREPARING GRAIN FOR STORAGE

Suggested Use: A shortened version of the text. This could easily be illustrated and translated for use by farmers.

* Check the grain in the field before you harvest. Make sure the grain is free of insects and disease.

* Clean old dirt and grain from harvesting tools.

* Remove old grain and dirt from carts or anything used to carry the grain from the field to the storage place.

* Use insecticide on all bins, sacks, and equipment. Remember to ask your extension worker for directions. Always use insecticide carefully.

* Harvest the grain carefully. Do not break the grains. Broken grain will not store well.

* Keep the grain cool and dry between the time you harvest and the time you store it.

* Clean the grain carefully. Insects and molds like to live in harvested grain.

* Sift, screen, winnow, or pick out by hand all dirt, straw, chaff, broken pieces of grain, rocks, and insects.

* These materials hold water. The grain dries better and faster after all the dirt is removed.

* Good drying is very important. Insects and molds like moist grain. Dry grain is harder for them to attack.

* Some farmers dry grain in the field. Insects, rodents, and birds can attack this grain easily. Also, this grain can get wet if it rains. Maize can be dried better in the field if the stalk is broken, and the ear hangs upside down.

* It is better to take the grain out of the field. You can bring the grain to a special drying place and dry it in the sun.

* Keep the grain off the ground while it is drying. Grain picks up moisture from the ground.

* Spread the grain on mats or flat boards to dry in the sun.

* Some farmers spread the grain on large trays. The trays are put out when the sun is shining. The trays are placed under a roof when it rains.

* Insects will leave grain that is in the sun. Insects do not like hot sunlight.

* You must watch the drying grain to protect it from rodents and birds.

* Some farmers like to use open storage places called cribs. These cribs have roofs on them, and they are built on legs.

* These cribs work well for unshelled maize (maize that has not been removed from the cob, or inner part of the ear) or for unthreshed millet, sorghum, or rice. Maize can dry in the crib until it is dry enough for shelling.

* Some farmers build large drying machines to dry their grains.

* The grain is put in the dryer. A fire is lit under the grain to warm and dry the grain.

* Artificial or mechanical dryers can be used by groups of farmers to dry their grain. Your extension worker can tell you about these dryers.

* Test the grain when you think it is dry. The grain must be very dry before you put it in storage.

* Dry grain is hard. It is hard to break it with your teeth.

* Extension workers sometimes use special tools to see if the grain is dry. These tools are called moisture meters.

* When the grain is dry, look for insects again. Turn the grain over with your hand. You can see insects crawling around.

* Sift out the insects. Or spread the grain in the sun.

* Destroy the insects you take out of grain. Burn them. They will go right back into the grain if you do not burn them.

* Put the grain into storage containers before insects

can get into it again.

* Put each kind of grain into a separate container.

* Do not put new grain with old grain. Store new grain separately.

* Use old grain first.

* Store rice with the outer coat on. This coat helps protect the grain from insects and mold. The grain will be good for a longer time.

5 GRAIN DRYER MODELS

This manual already has talked about the need for drying of the grain.

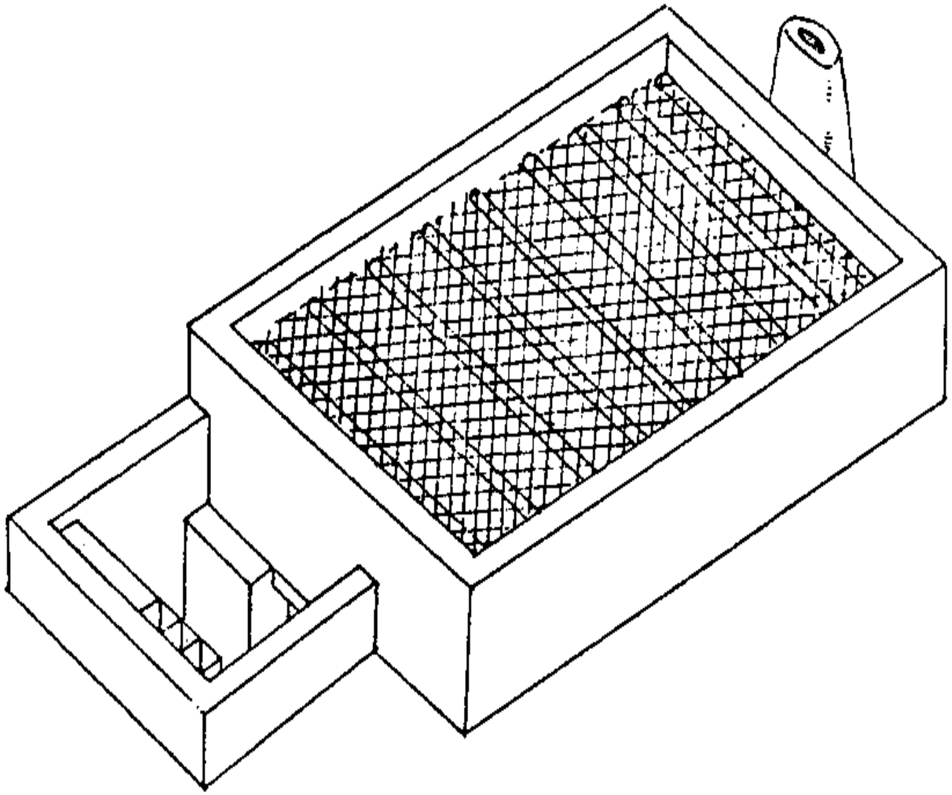
Unshelled maize, rice, millet, or sorghum often is stored in cribs for further drying. The ears, or heads, do not pack tightly. Because the cribs are open to the wind, air moves through the stored grain and dries it. Even so, storage in cribs is more effective in the dry season. The more humid air of the wet season may actually add moisture to the grain. In addition, insects and rodents can cause serious damage to unprotected grain stored in cribs for long periods.

Threshed grains, particularly those with small kernels like millet, dry very slowly during storage. The kernels pack tightly together. As a result, air cannot move easily through the grain. Such grains can be spread in thin layers in the sun for drying. If possible, the grain should be on a screen to let air enter the bottom. The grain should be tumbled (stirred) often and carefully. The grain kernels can crack if they are stirred too hard.

The newer drying methods described here use heated air to dry the grain. Hot, dry air is blown through the grain. These methods dry the grain quickly and well. Most of them require the burning of fuel to heat the air. This fact, together with the cost of building the machine, often limits the usefulness of drying machines for use by small farmers.

<THE PIT OIL BARREL DRYER>

51ap41.gif (486x486)



THE PIT OIL BARREL DRYER

Improved Traditional Methods

A farmer has to think about a lot of things before he can decide which type of drying method to use for his crop. Here are some of the considerations he must keep in mind:

* Does his present method work? If it does, why change it? If

it does not work, why not?

* How much money will he have to spend for a new drying method?

* Would he be able to maintain a new drying machine? Could he fix it? Does he have enough time to operate it?

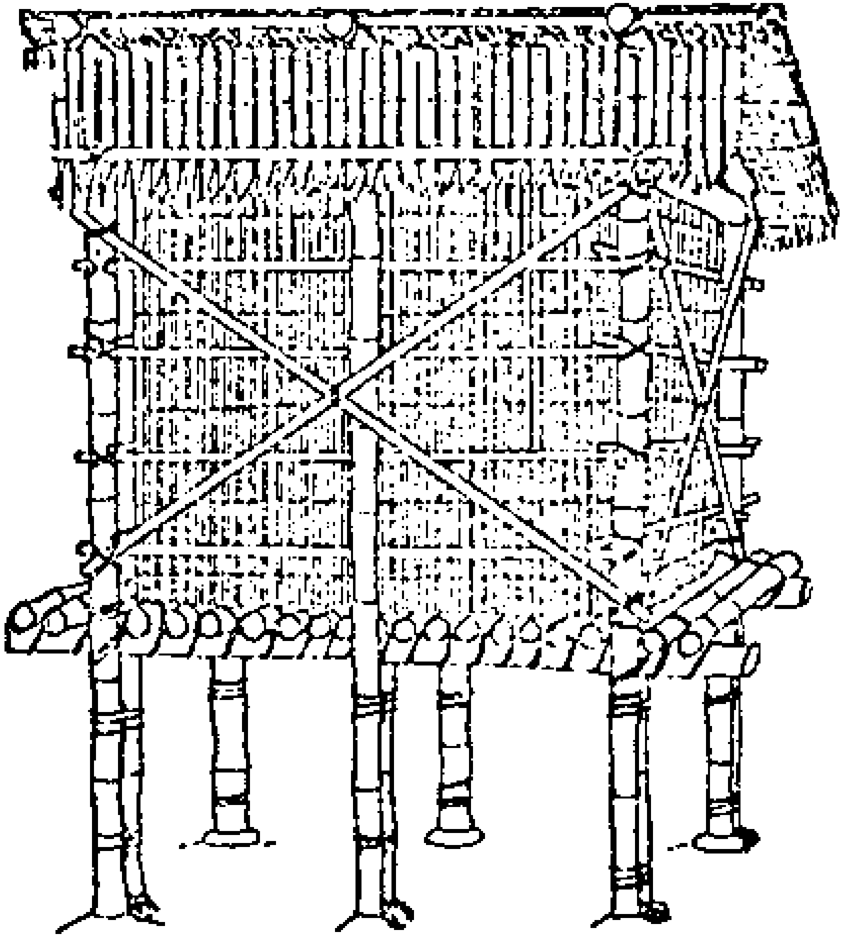
* Would the cost of the dryer be easy for him to get back because of better storage leading to more grain to sell?

* Would it be better to join a group of farmers and pay for the cost of a dryer with a group? Or does the farmer dry enough grain to make use of a dryer by himself?

You will probably be able to help by offering alternatives. For many farmers, an improved method of crib drying for maize or sun drying for smaller, threshed grains, would be a step easily taken. Such a step would insure a much better crop.

<FIGURE 41>

51ap42.gif (486x486)



Here are some ideas for sun-drying grain:

*** Spread the grain in thin layers on trays which can be carried. Stack the trays under sheds or roofs at night to protect the grain from dew or from rain.**

*** Make trays with fine-mesh screening for the bottom. Support**

the trays so they do not rest on the ground. The screening lets dust and straw fall out of the grain. Put the trays on top of each other under roofs or sheds at night and when it is raining.

SUN DRYING USING PLASTIC SHEETS

* Find a plastic sheet. Or use several plastic sheets joined together. You need a sheet about 10m x 3m. The plastic should be at least .004 gauge thick.

* Build a mound of hard-packed earth to place the plastic on. If you use level ground, build a dike of earth around the area on which the plastic will be placed to protect the drying grain from water.

* Make sure there are no rocks, wood and sharp things on the ground where the plastic will go. The plastic tears easily.

* Place the plastic in the prepared place.

* Attach the narrow end of the plastic to straight poles made from bamboo or other smooth material.

* Put clean grain on the plastic. Do not make the grain more than 5cm deep.

* Stir often so the grain will dry faster. Turning and stirring makes sure all parts of the grain are touched by air and sun.

* The rake or other tool used to stir the grain must have smooth, rounded edges. This tool then will not damage the plastic or the grain.

* As the grain dries, moisture from the grain collects on the plastic. After the grain has been drying for two hours, push all the grain to one half of the plastic.

* Let this plastic dry for 5 minutes or so.

* Push all the grain to the other half of the plastic that is now dry and let this half dry for 5 minutes.

* The plastic sheet should be aired in this way every two hours while drying is going on.

* Cover the grain at night. Push all the grain to one end and fold the plastic over as a cover.

* Or place an extra piece of plastic over the grain.

* Remember to put soil, boards, rocks, and heavy things on the corners and edges of the plastic cover to keep it from blowing off.

THE IMPROVED MAIZE DRYING AND STORAGE CRIB

<FIGURE 42>

51ap45.gif (600x600)

THE IMPROVED MAIZE DRYING AND STORAGE CRIB

Maize holds a great deal of moisture inside its kernels and husk. When maize is harvested, the moisture content is high. It must be much drier before it can be put into closed storage containers. If maize is put into a closed container right after harvest, molds cause heavy losses of grain.

Drying Maize

Harvested maize must have air passing around it to dry the kernels. When the kernels are dryer, they can be shelled (taken off the cob) and stored in airtight containers. To dry maize before shelling, some farmers keep the husks on the ears. Then they tie the husks into bunches and hang these bunches in trees. Some farmers hang these bunches on poles set into the ground or put them in the roofs of cooking or living shelters.

Sometimes farmers remove the husks and pile the ears loosely in open-weave basket granaries or in covered crib granaries. These containers partly protect the grain from rain. Storing maize this way allows air to pass over the grain and dry it better. This way of storing the maize while it is drying helps protect the maize from mold.

But insects remain a big problem. They can attack maize drying in cribs easily. Many farmers choose to leave the husk on the maize. This does provide some protection from insect attack -- particularly in traditional varieties of maize where the husk is tight and fits closely over the ear. In newer, hybrid varieties of maize, the husk is smaller and the ear is larger. These varieties are more easily attacked by insects. Maize with the husks left on will take longer to dry because the air cannot pass freely over the ear. Also, the husks are full of moisture -- increasing drying time and the risk of molding.

So, a good way to dry and store maize would:

1) allow the maize to dry without the husks.

2) control insect attack at the same time.

Crib storage, already done in many countries, seemed a good method needing only slight improvement. Therefore, much work and study were done to design improvements into crib storage to allow for both faster drying and effective use of insecticides. Much of the improvement in the crib storage method is based on proper use of insecticides.

Insect Control in Cribs

To reduce losses due to insects, a number of insecticides have been tested for open crib storage. The maize put into the crib must have the husks removed so that the insecticide can cover the whole surface of the kernels.

Apply the insecticide to the maize ears in layers. Put down a layer of ears 20-25cm deep. Dust the layer with insecticide. Put down another layer of ears, and then more insecticide. Continue until the crib is full When the crib is full, put insecticide on the outside walls of the crib to prevent insects from entering.

The wind, rain, and sun all can affect how long the insecticide lasts. You can put more insecticide on the outside of the crib every three to four weeks. Look at the maize in the crib every few weeks to see if the

insecticide is still working. The insecticide put inside the crib will last only four or five months. But while it is working it can reduce the amount of maize damaged by insect attack.

After four months, check the grain moisture level. The maize may be dry enough to shell and store in sacks or bins. The maize is dry when the kernels crack sharply between your teeth and are not soft. If the grain is not dry enough, remove all the maize and put it back into the crib again, layer by layer, dusting with insecticide as you go.

Faster Drying

Keep the crib no wider than 1m. Between 60 and 100cm are good widths for dryer/storage cribs. The narrow width helps maize to dry more quickly. Air cannot move through wider cribs to cool the grain in the middle. The grain in a wider crib will heat, and be attacked by mold and insects.

Rain which wets the grain through open crib walls is not generally a problem. Only the surface of the maize on the sides gets wet, and this dries quickly after the rain stops. This rain causes no increase in moisture content of the grain if there is sunny weather afterwards.

The following plan is a modification of a crib designed and tested by the Nigerian Stored Products Research Institute and the FAO Rural Storage Center at IITA, Ibadan, Nigeria. The plan is for a 2m long crib. It stores 800kg of maize ears (this will give 540 kg of shelled maize). A crib which is 1,50m high, 0 60m wide and 1m long will store 400kg of maize ears (yields 270kg of shelled maize).

Some General Remarks About The Improved Maize Drying and Storage Crib

* Use materials that are easy to find in your local area.

* The crib will work best if it is no wider than 60-70cm.

* A good height for the crib is 2,00-2,25m from the ground to the roof. There is at least 50-75cm between the bottom of the crib and the ground. Most rats cannot jump this high.

* If bamboo in your area is attacked by insect borers, use another local wood for the legs. Make sure the wood is termite proof. These legs must have rat guards put on them.

* The long sides of the crib must face the sun. That is, they should face the east and west. The short sides will then face north and south.

* Make the crib larger by adding more sections. Make it longer. Do not make it wider.

Tools and Materials

This is a guide. You can use what you have available. The frame is bamboo. If bamboo is not available in your area, or if the bamboo in your area is attacked by insect pests, use wood that is resistant to termites or any other pests. Lash it together the same way you would lash bamboo.

For the building frame (all bamboo or substitute):

(a) 3 vertical supports, 3.5m long, with V-notches and lashing slots in one end of each one

(b) 3 vertical supports, 3m long, with V-notches and lashing slots in one end of each one

(c) 2 horizontal roof supports, 2.5m long

(d) 2 horizontal platform (floor) supports, 2

(e) 6 vertical platform supports (with V-notches in one end of each), 1.5m long

(f) 6 notched horizontal width spacers, 70cm long

(g) 25 poles, 95cm long, for the platform surface

For the wall bracing and covering (raffia, small bamboo or other wood):

(h) 8 cross braces (optional if frame is very strong):
*** 4 must be about 2.5m long**
*** 4 must be about 1.70M long**

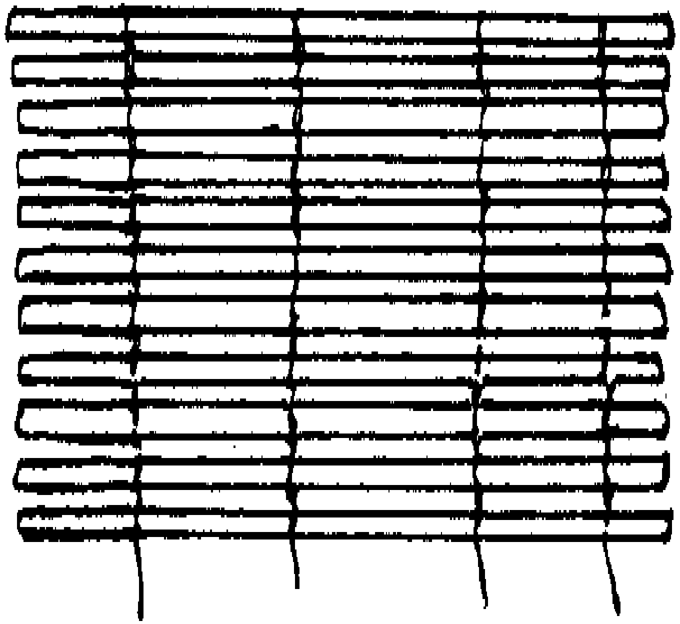
(i) 8 wall supports, 2.25m long

(j) 8 wall supports, 1m long

(k) raffia or other strong slats for the wall covering. Tie these together into a mat. The finished mat should be about 6m long and 1

<FIGURE 43>

51ap48.gif (353x353)



For the roof (all bamboo or substitute, except for purlins, and roof covering and loading cover):

(l) 2 horizontal pieces, 3.25M long

(m) 3 cross pieces, 1m long

(n) 2 angle braces, 1m long

(o) 7 purlins, 3.25m long. Six of these will be lashed across the cross pieces to support the roof covering; one may be attached to the front loading cover.

(p) raffia mat or grass for thatch to cover the roof, and also for the front loading cover. You will need a horizontal piece at least 2.25m long to weave the loading cover material onto -- it need not be bamboo or of a large diameter.

For rat guards (if you need them):

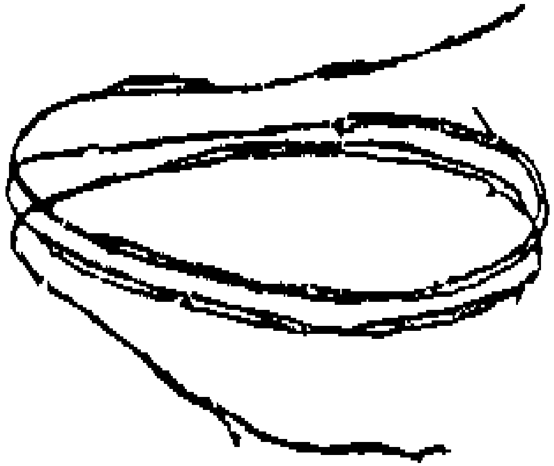
See Section 6, Part 2 of this manual for directions on making rat guards (baffles).

For the lashing material:

(q) You will need plenty of rattan, rope or tie vine for lashing all the wood pieces together.

<FIGURE 44>

51ap49a.gif (317x317)



1. Select a site.

* Find a good site for your storage crib. Keep the crib away from the fields. This stops insects from flying to the drying grain from the fields.

2. Prepare your materials.

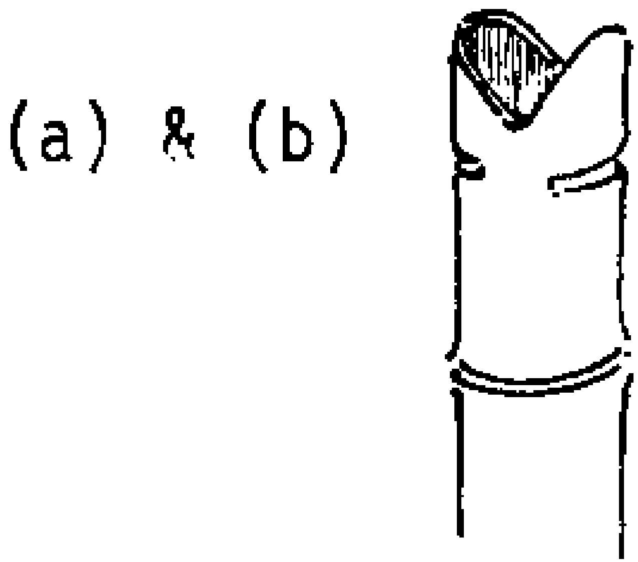
* Collect all the materials you will need.

* Make V-shaped notches in one end of each of the three 3.5m vertical supports (a), and cut some grooves on each side just beneath the notches to provide a hold for

the lashing there. Do the same on one end of each of the three 3m vertical supports (b).

<FIGURE 45>

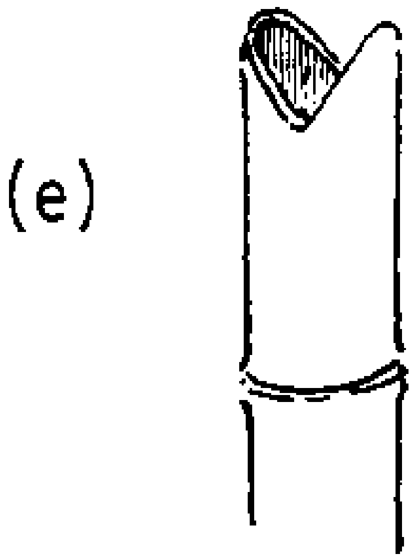
51ap49b.gif (317x393)



*** Make V-shaped notches in one end of each of the six 1.5m vertical support posts (e).**

<FIGURE 46>

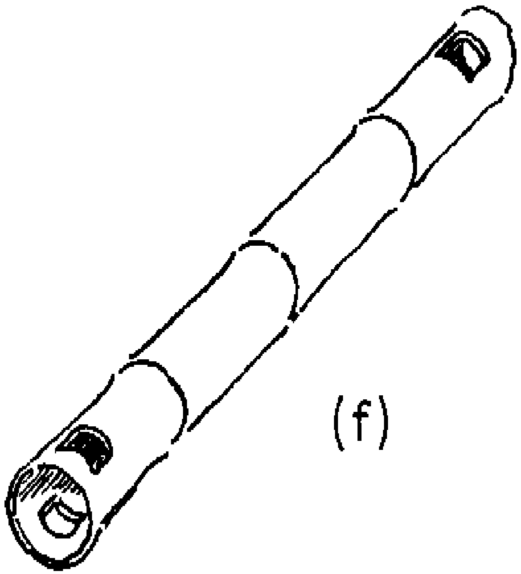
51ap49c.gif (285x285)



* Make holes all the way through each end of all six 70cm horizontal spacers (f).

<FIGURE 47>

51ap49d.gif (317x317)



(f)

* Organize all the pieces, or mark them with the appropriate letters, so you can find them quickly during construction.

3. Make holes in the ground for the legs.

* Mark spots for holes for the vertical supports (legs)(a) and (b) on the ground. Make a mark for the first hole; measure 1m and make another mark. Measure 1m from that mark in the same direction and make a third mark. You should now have 3 marks in a straight line. Each mark will be the center of a hole.

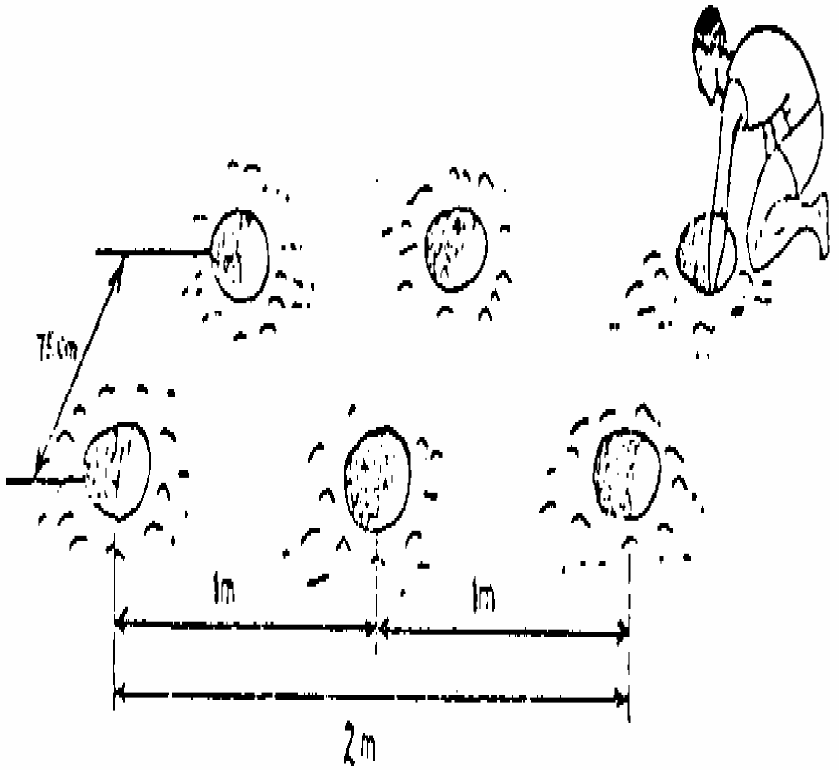
* Make three more marks, each 1m apart, in a line parallel to the first line and 75cm away. Each of the three new marks

should be directly opposite one of the first marks and 75cm away.

*** Dig six holes, each centered on one of the marks. Make the holes 50cm deep and wide enough so that two vertical supports will fit down into each one.**

<FIGURE 48>

51ap50a.gif (437x437)



4. Erect the vertical supports.

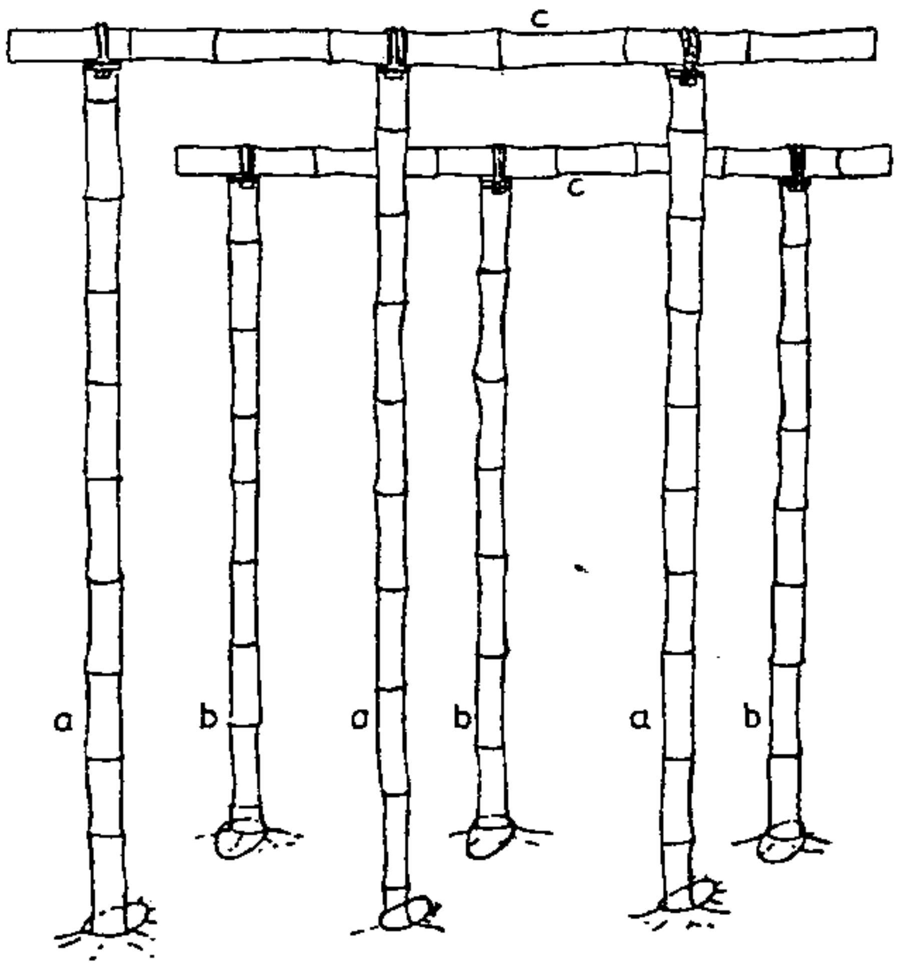
*** Lay the three 3.5m vertical supports (a) on the ground 1m apart, with their ends lined up. Lash one of the 2.5m horizontal roof supports (c) to the notched ends.**

* Lay the three 3m vertical supports (b) on the ground in the same way and lash the other horizontal roof support (c) to the notched ends.

* Place the two assemblies into the holes.

<FIGURE 49>

51ap50b.gif (486x486)



5. Erect the vertical platform supports.

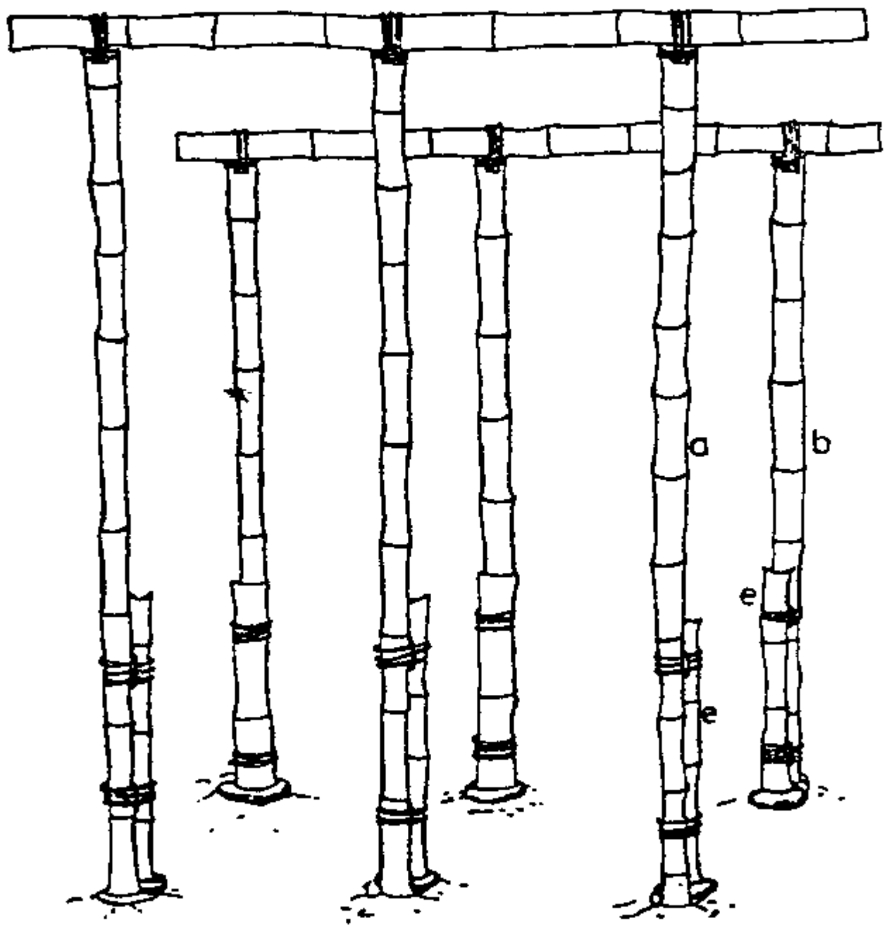
*** Place the vertical platform supports (e) into the holes on the insides of the vertical supports you have placed in the holes. Make**

sure the V-notches are facing upwards.

*** Tie the platform supports to the longer supports temporarily until the next step is completed.**

<FIGURE 50>

51ap51a.gif (486x486)



6. Install the platform support framework and make the structure rigid.

*** Place the two horizontal platform supports (d) in the V-notches of the platform supports.**

*** Lash three of the notched horizontal spacers (f) to the vertical supports (a) and (b), across the width of the crib.**

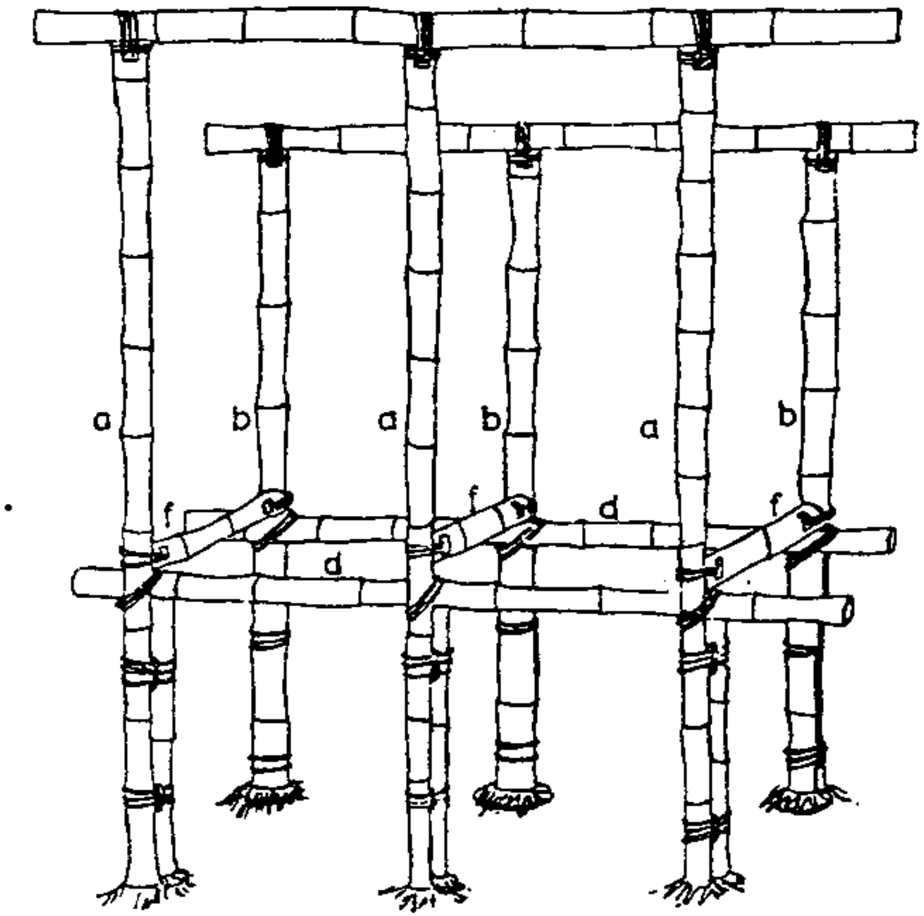
*** Level and square the framework.**

*** Fill the holes around the vertical supports with small stones and soil. Tamp down firmly.**

*** Lash all joints tightly.**

<FIGURE 51>

51ap51b.gif (486x486)



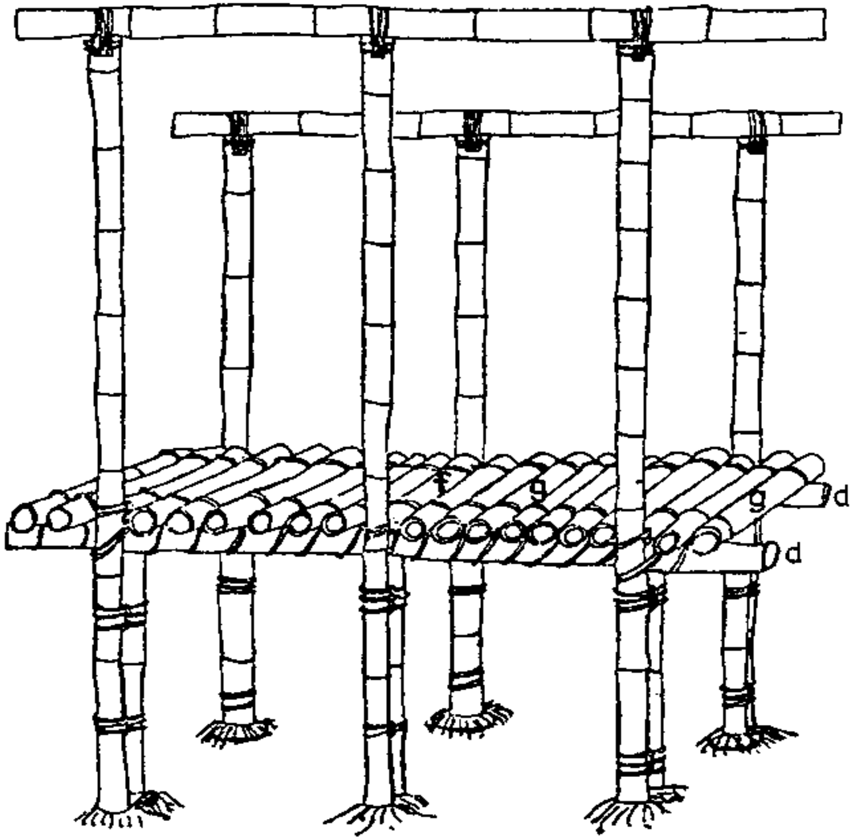
7. Finish the platform.

*** Lash the twenty-five 95cm poles (g) next to each other on the horizontal platform supports. This forms**

the platform.

<FIGURE 52>

51ap52a.gif (437x437)



8. Install the cross braces.

* If you think the frame is not

sturdy enough by itself, lash the cross braces (h) loosely to the vertical supports on the outside of the crib.

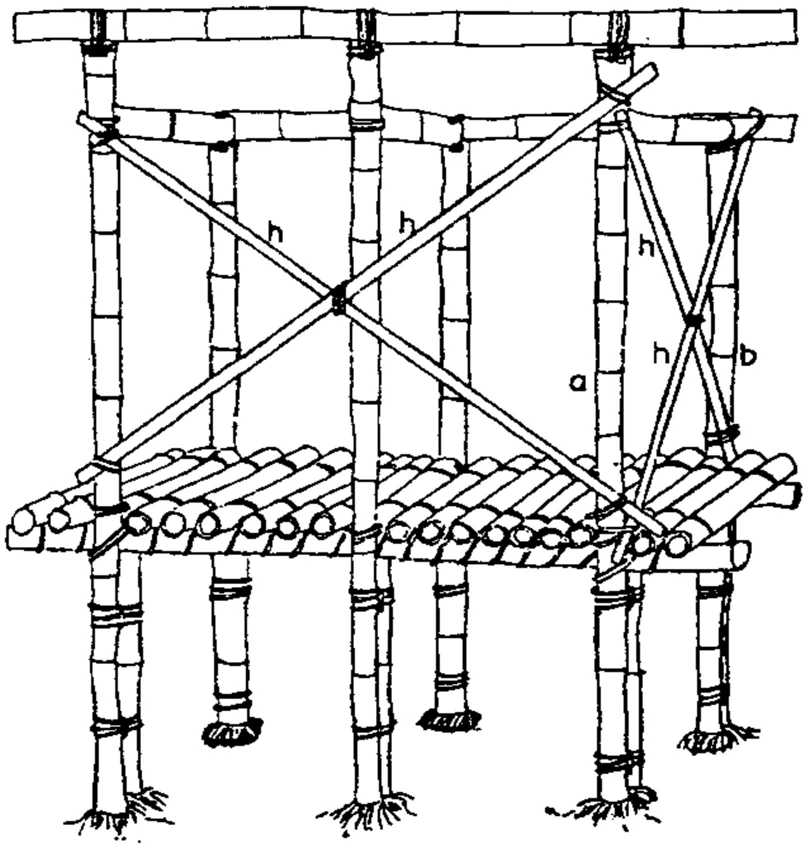
*** The 2 1/2m cross braces are paired on the long sides of the crib, and the 1,70m cross braces are paired on the ends of the crib.**

*** Each brace should extend from somewhere near a top corner to somewhere near the opposite bottom corner. Leave room for a loading cover on the higher side of the crib.**

*** Make sure the frame is straight and even. Lash the braces securely.**

<FIGURE 53>

51ap52b.gif (437x437)



9. Install the wall supports and wall covering.

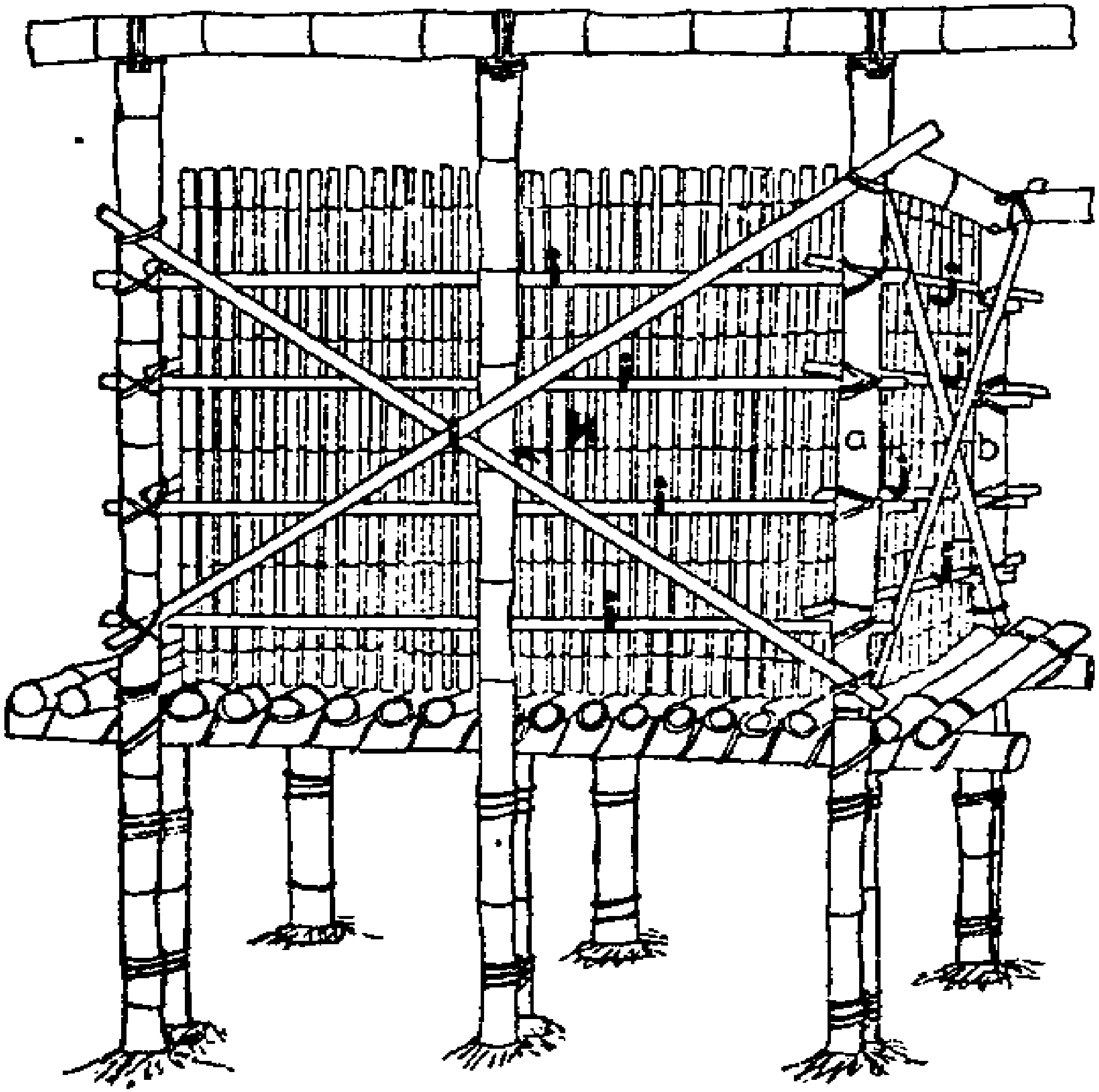
*** Lash four of the 2.25m wall supports (i) to the vertical supports along the inside of one of the long sides of the crib. Lash the remaining four supports to the inside of the other long side of the crib.**

* Lash four of the 1m wall supports (j) to the vertical supports along the inside of one end of the crib, and four of them along the inside of the other end.

* Lash the already-prepared wall covering, 6m x 1.5m (k), to all the wall supports on the inside of the frame.

<FIGURE 54>

51ap53a.gif (600x600)



10. Build the roof.

*** Call the high side of the crib the front and the lower side the back.**

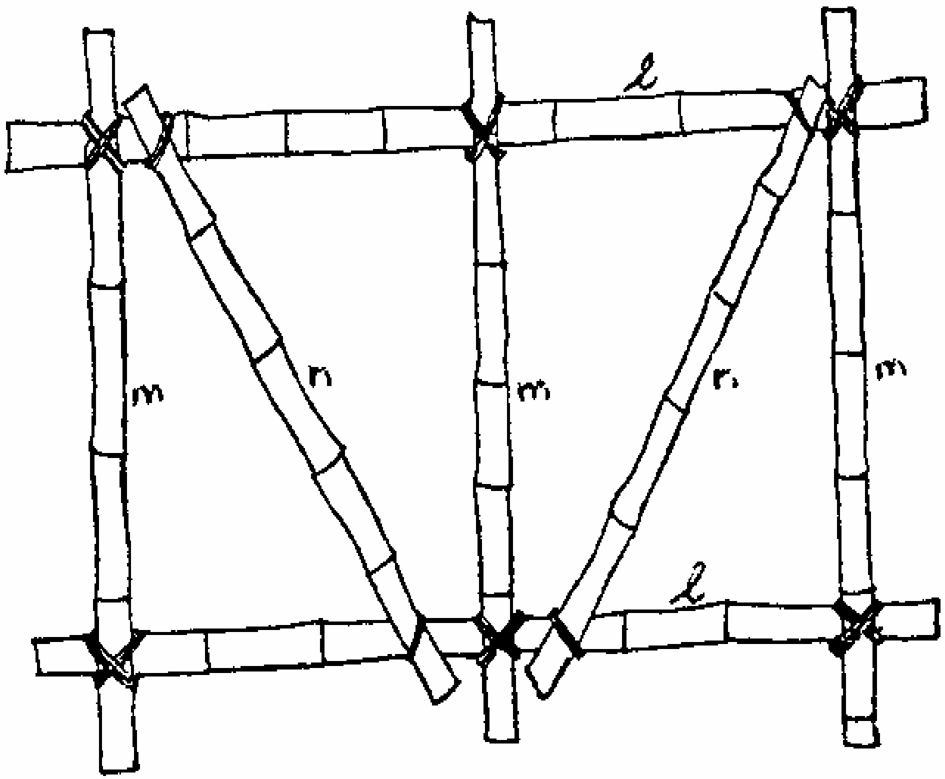
*** Measure the distance between the centerlines of the front and the back horizontal roof supports (c) which are lashed to the tops of the vertical supports (a) and (b).**

*** Lay out the two 3.25m horizontal roof pieces (l) on the ground so their centerlines are the same distance apart as the measurement you have just made.**

*** Lash the three 1m cross pieces (m) on top of the horizontal roof pieces, 1m apart. When the roof is placed on top of the frame, the cross pieces should cross over the ends of the vertical supports of the frame.**

<FIGURE 55>

51ap53b.gif (486x486)



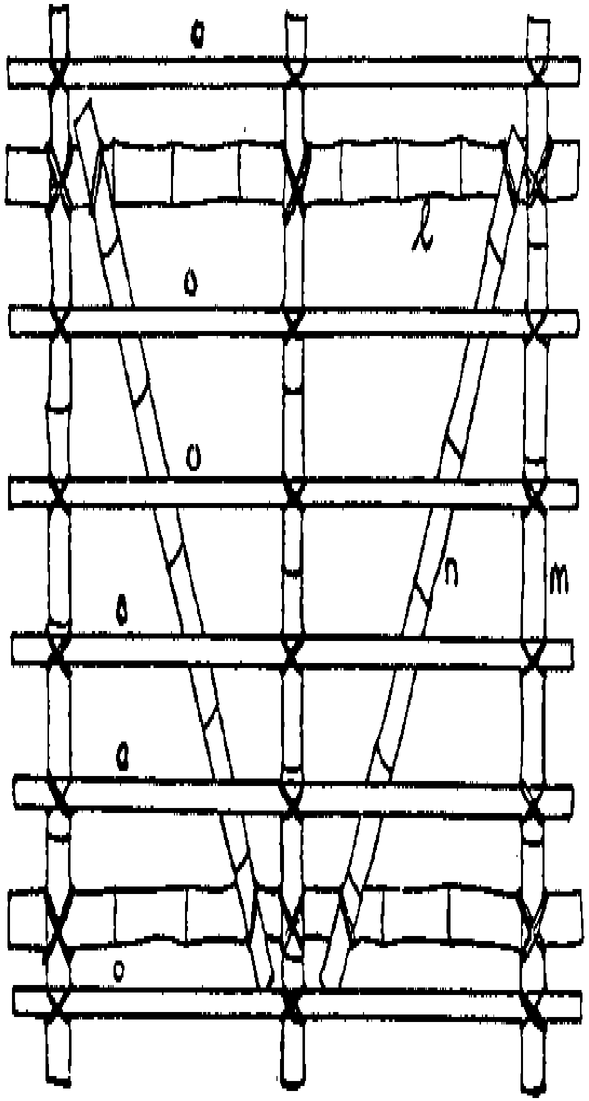
* Lash the two 1m angle braces (n) to the horizontal roof members so that they extend diagonally across the two spaces in the roof frame.

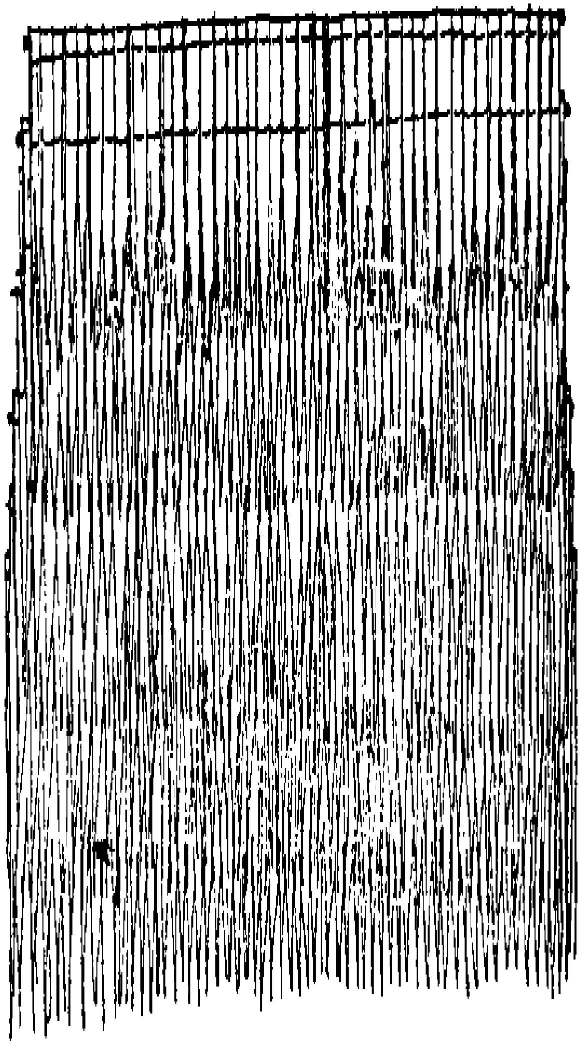
* Lash six 3.25m purlins (o) on top of the three cross braces so that they extend longways along the roof frame. Lash the first and last purlins near the ends of the roof cross braces.

*** Lash raffia mat in overlapping layers to the roof frame.**

<FIGURE 56>

51ap54a.gif (600x600)





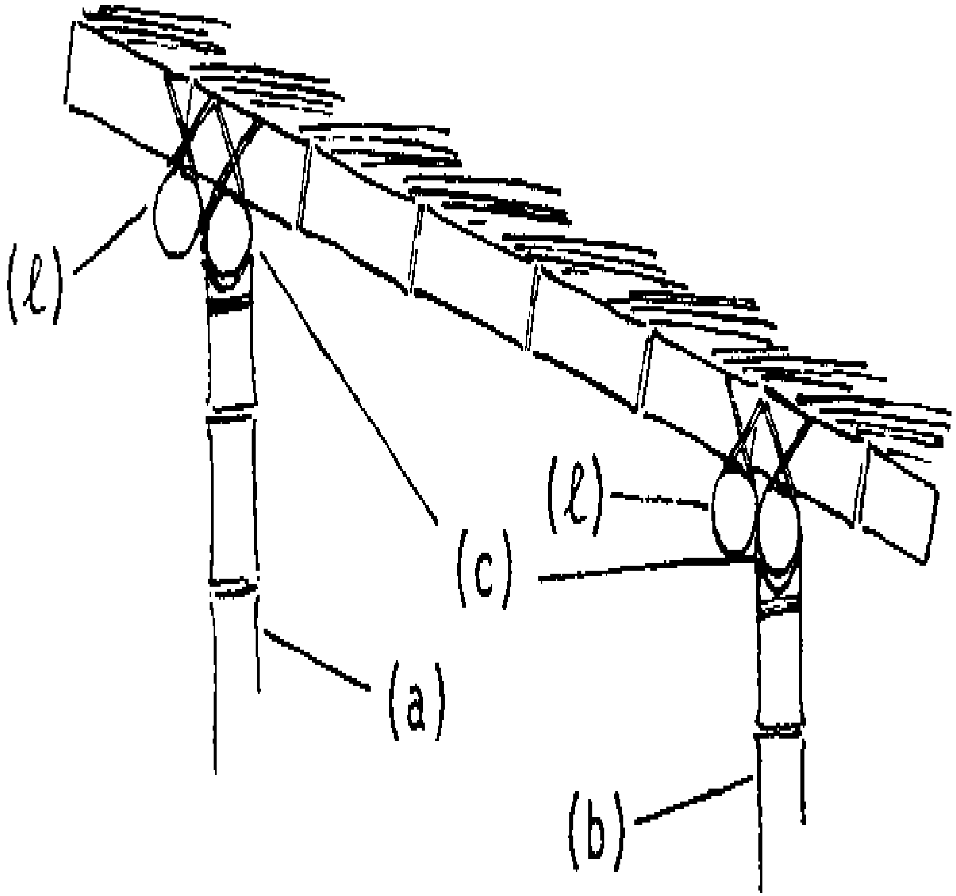
11. Install the roof.

* Place the roof on top of the frame as shown (looking at the end).

* Lash the roof in place.

<FIGURE 57>

51ap54b.gif (486x486)



12. Make and install a front loafing cover.

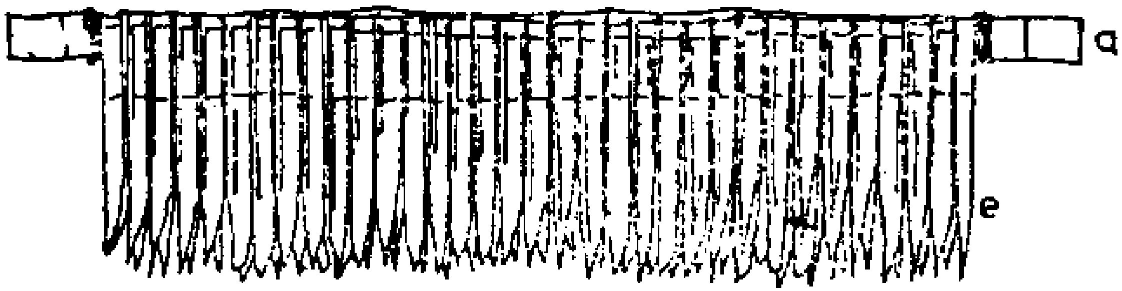
*** Lash raffia mat to a 2.25m long bar to form the front loading cover. The mat should be made large enough to hang**

down beyond the top edge of
the wall covering when the bar
is lashed in place up under
the front edge of the roof.

* Lash the bar holding the raffia mat up under the front horizontal roof piece.

<FIGURE 58>

51ap54c.gif (200x600)

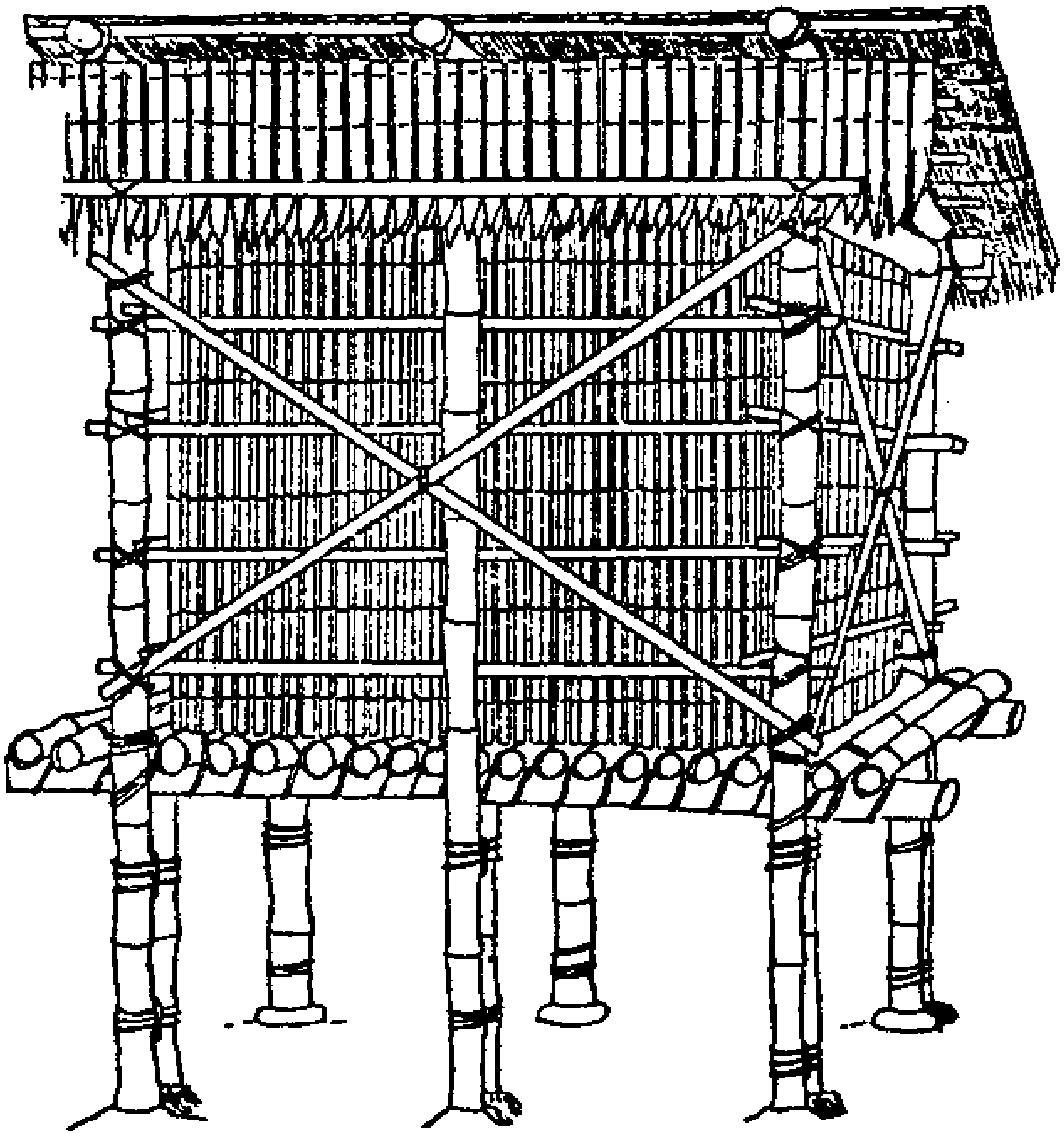


13. The crib is ready for use.

Load the crib. Lash down the bottom corners of the loading cover to the frame during drying and storage.

<FIGURE 59>

51ap55.gif (600x600)



NEWER DRYING METHODS

Some farmers have more money and are more in need of a faster, more reliable way of drying their crops. Controlled drying, or drying with a device which creates heated air for drying, can be very helpful to farmers who are ready and able to make use of newer methods. Used appropriately, these drying methods can help a farmer to:

* harvest earlier and get his land ready for a new crop sooner.

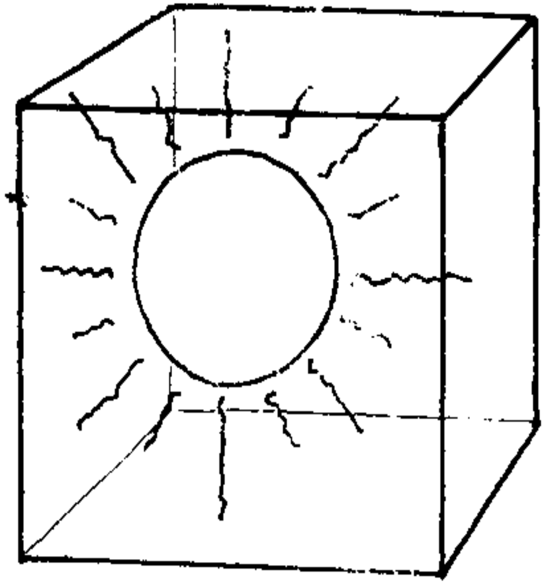
* avoid grain losses to insects, birds, and rodents during long natural drying times.

* store better-prepared grain, keep it in storage longer, and take it out in better condition.

* make more money from the sale of his grain.

<FIGURE 60>

51ap56.gif (317x317)



Four different dryer plans are presented here. Two are made using oil barrels and are heated with a fire. The Philippines Rice Dryer uses a fan and also uses heated air. The solar dryers are three variations of the same idea.

Be Sure a Dryer Will Suit Farmers' Needs

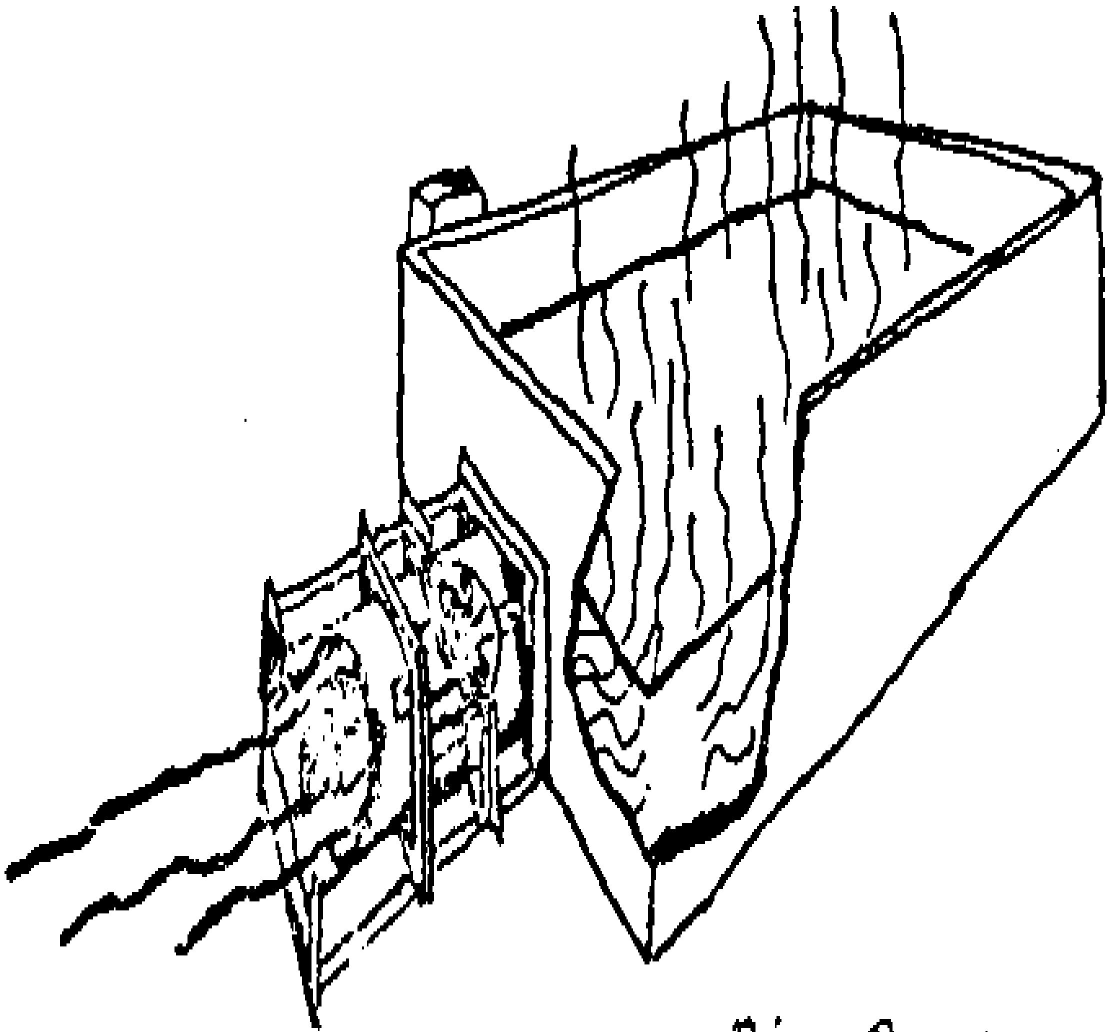
There are several factors which may determine the usefulness of faster drying to farmers in your area. It is not possible to give guidelines for what a farmer could do in every case, but these are some of the basic ones.

The Storage Method. It will not be as useful to build a dryer that dries grain to a low moisture level, and then store the grain in something which will not keep it this dry -- such as cribs, unsealed gourds or baskets, sacks, most kinds of earthen pits, or mud-walled structures which do not have extra protection against moisture. Airtight storage will make the use of these dryers worthwhile.

Type and Condition of Grain. Rice will crack easily in high-temperature drying. Newer varieties of rice must be harvested when they still contain around 25% moisture; since the husks (containing moisture themselves) must be left on while drying, and the rice grains will be tightly packed, a very long time in the dryer would be needed. In the two oil barrel dryer designs, heat is not likely to flow evenly through the tightly packed kernels: and much rice would be damaged by cracking. If fans are added to the oil barrel dryers to force a more even flow of warm air up through the grain, farmers should be able to dry rice successfully. The Philippines Rice Dryer uses this method. It may be difficult or impossible to dry rice in solar dryers. Other grains which also pack tightly, but give up their moisture more easily, and are not so likely to crack and shatter, may be safely dried as long as not too thick a layer is put into the dryer at one time.

<RICE DRYER>

51ap57a.gif (587x587)



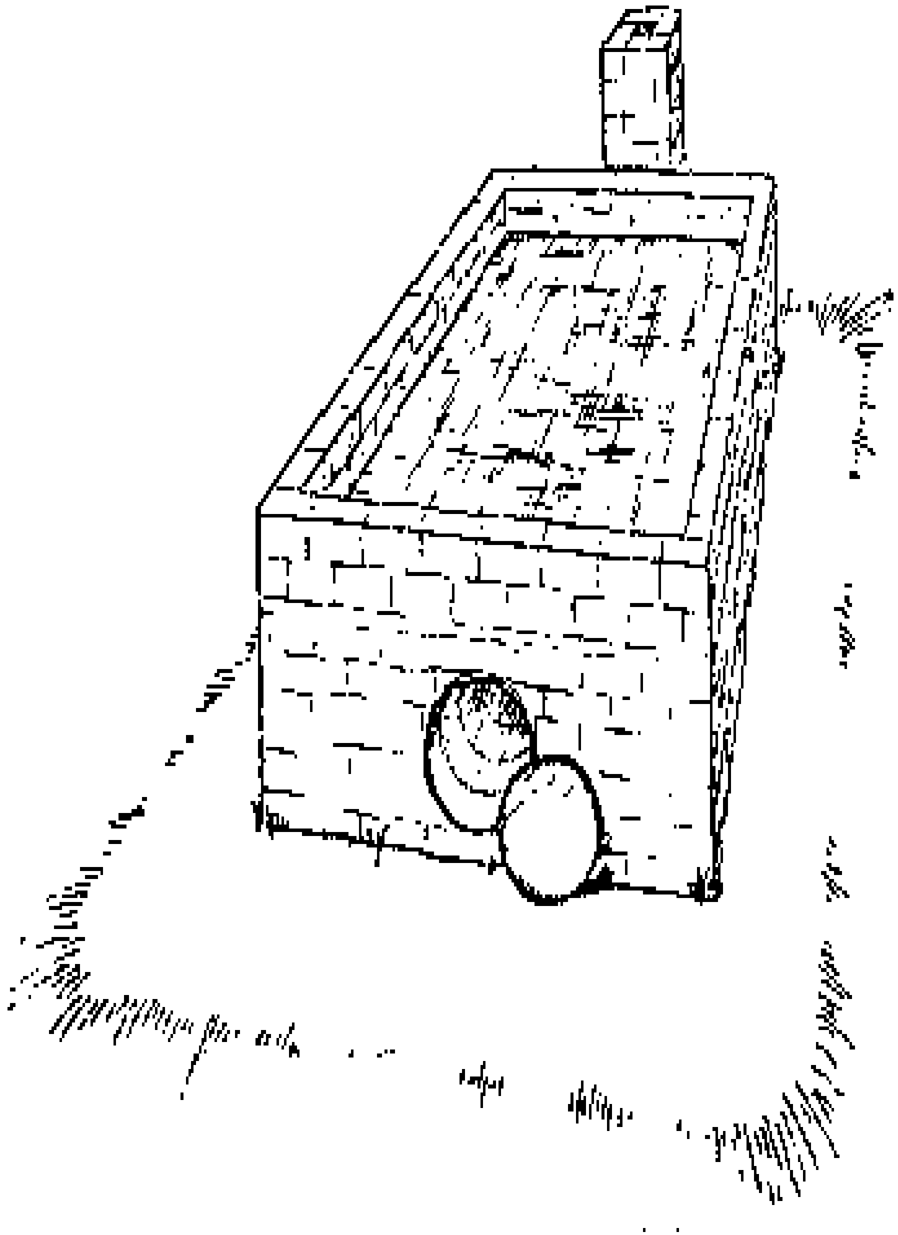
Rice Dryer

Moisture in Grain. Drying very moist grain will take longer. The safest way to dry moist grain is for a longer time at a lower temperature. It would be difficult to avoid overheating portions of the drying grain during a long period of time if the temperature were not kept down. It is difficult to control the drying temperatures accurately in oil barrel dryers without fans and in solar dryers.

Moisture in Air. The weather in your area will affect how long the grain takes to dry. In a wet, cold climate or season, grain will take longer to dry than in a dry, warm place. Heated-air dryers might be very useful where drying must be done in wet or cold conditions which cause farmers to lose grain to insects and molds during long natural drying times. But, at least in the cases of the oil barrel and solar dryers, this must be weighed against problems caused by relatively long drying times in the dryer.

<SIMPLE OIL BARREL DRYER>

51ap57b.gif (600x600)



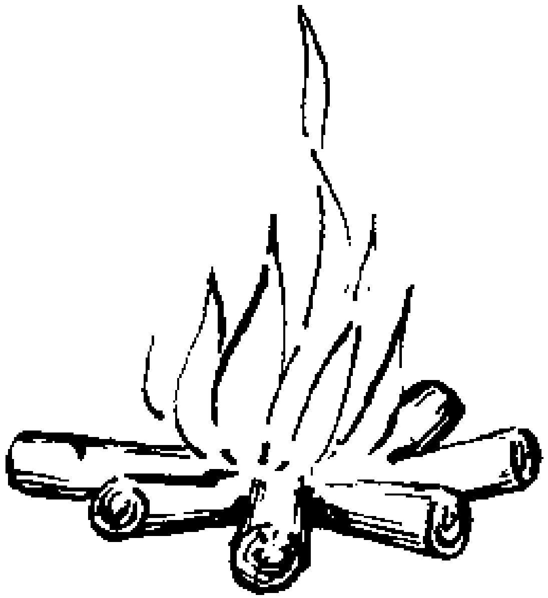
Simple Oil Barrel Dryer

Fuel. What kinds of fuel are available, and how much does it cost? You must know this to determine the

value of heated drying, especially if you expect longer drying times in a dryer. Firewood is not always plentiful -- or even available -- in an area. Even if available, it may be costly. Maize cobs or some other natural fuel may be available. Farmers may have to pay the labor costs for gathering these fuels. Try to be sure farmers will not be spending more on fuel than they will be saving by marketing more and better quality grain.

<FIGURE 61>

51ap57c.gif (317x317)



Other Important Factors. If the grain is to be used to seed, it should not be heated beyond 45 [degrees] C. It will be difficult or impossible to control
the drying of seed grain in these dryers.

Other possible costs, the availability of some materials, and cultural values or local preferences must also be taken into account.

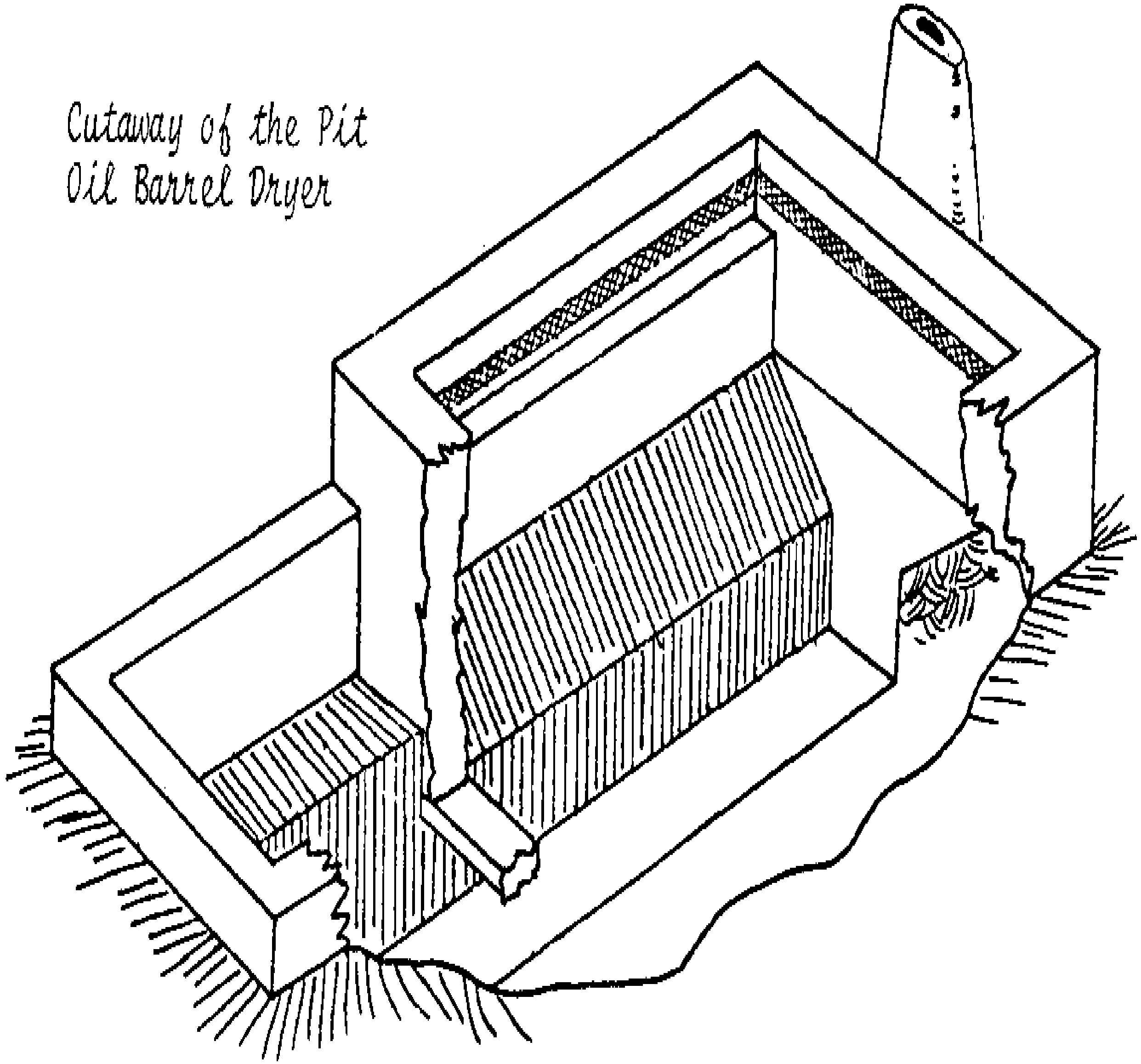
Some Notes on the Dryers

There are many dryers being developed all over the world. But much of this research is being carried out for use in large-scale drying operations. This manual is concerned with the small-scale farmer and his problems. The drying method he chooses must be appropriate for his situation.

The two dryers made out of oil barrels and hand-rammed earth or mudblocks have only one part which may be expensive -- the oil barrels themselves --, but the materials are available almost everywhere. In the Pit Oil Barrel Dryer the barrels are sunk into a pit. The Simple Oil Barrel Dryer is built entirely above ground. They each require mostly simple labor and would be good projects for a group of farmers.

<CUTAWAY OF THE PIT OIL BARREL DRYER>

51ap58.gif (600x600)



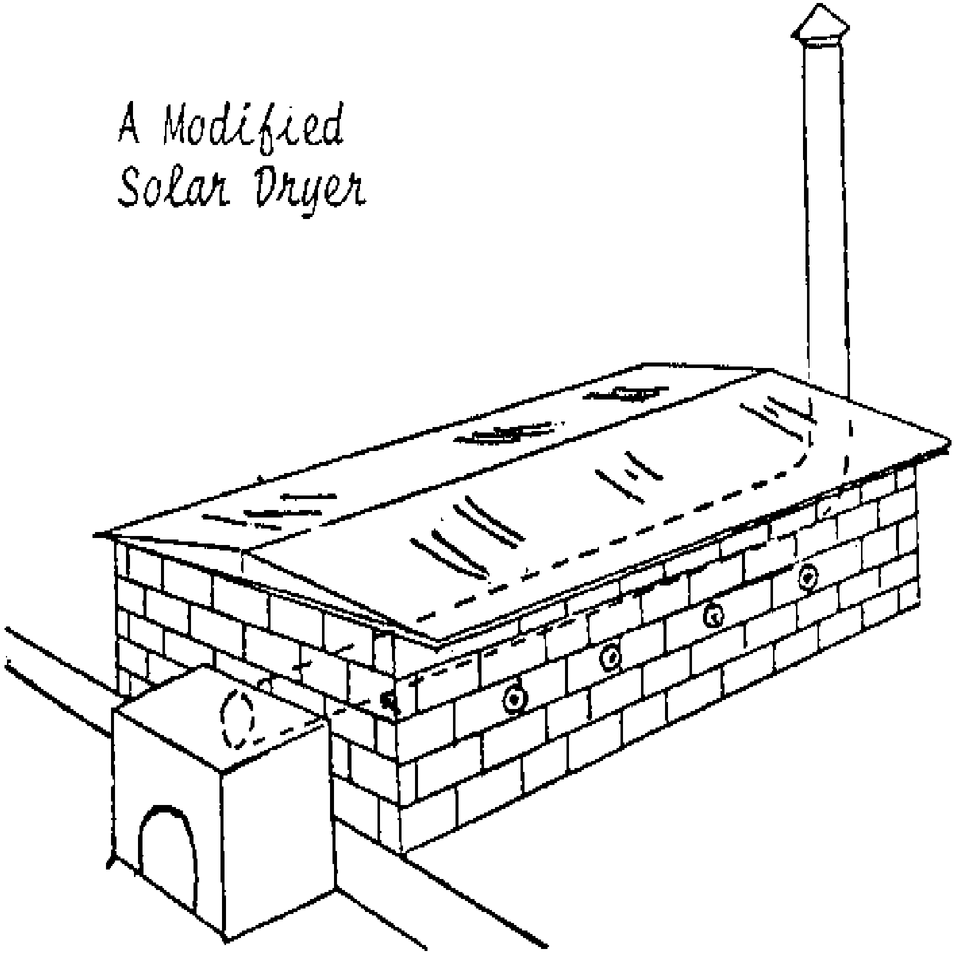
The Philippines Rice Dryer is made from wood and spare auto parts. A fan provides reliable air flow and more even heating. Oil, kerosene

or rice hulls may be used for heating fuel, and a small gasoline or diesel engine, or an electric motor may be used to power the fan. It requires more in the way of materials. Thus it may not be usable by many farmers because of unavailability or high cost of materials. But the plan is included because there are farmers who are interested in this kind of machine, and it does represent a relatively small-scale, appropriate method of drying.

The solar dryers provide faster drying and require no fuel. By enclosing the drying grain, they retain the heat of the sun better than just spreading the grain out in the sun to dry. They require little or no maintenance. Except possibly for plastic sheet or corrugated roofing, all the materials should be available almost everywhere. One of the models' heating capacity can be augmented by adding a fire and a flue under the grain bed.

<A MODIFIED SOLAR DRYER>

51ap59.gif (486x486)



Again it is important to say that these dryers and drying methods are included here to provide good examples of drying choices farmers might be interested in. If a method is not quite right for the farmers in your area, perhaps only a slight change will be necessary. You may discover you can use ideas from one plan in another plan. Let us know if VITA can help make one of these plans more useful. If you know of a plan for a small-scale dryer useful to farmers which is not included

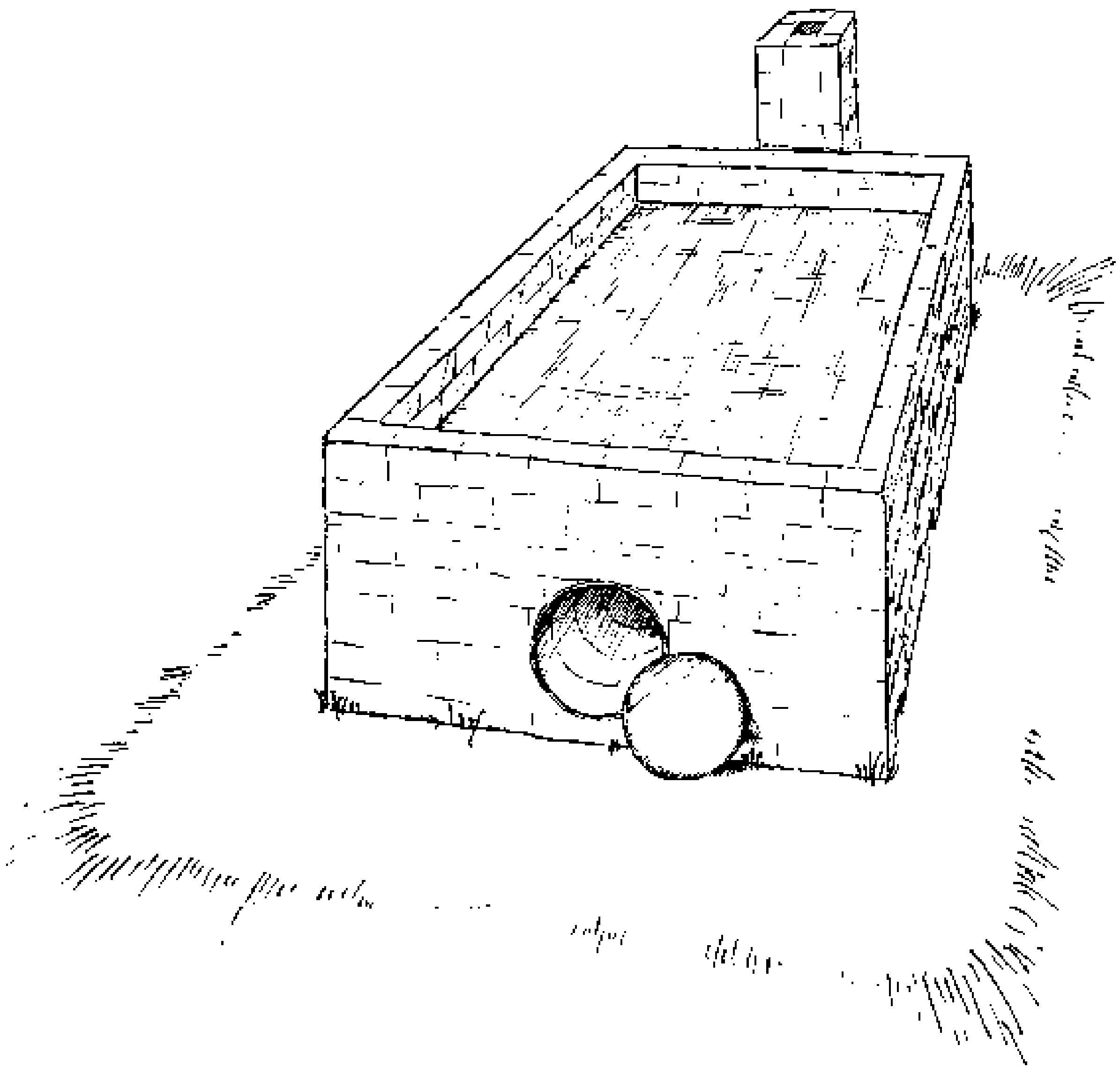
here, send it to VITA for inclusion in the manual.

<A SIMPLE OIL BARREL DRYER>

A SIMPLE OIL BARREL DRYER

51ap61.gif (600x600)

A SIMPLE OIL BARREL DRYER



This design is based on material prepared in 1973 by the Institute for Agricultural Research at the Ahmadu Bello University in Zaria, Nigeria.

It is similar to the Pit Oil Barrel Dryer, but it is easier to build. It rests on the ground so you do not need to dig any pits or trenches.

The drying grain is placed on a screen floor above four oil barrels fastened together. Warm air from the fire -- which is built in the front half of the barrel chamber -- passes through the barrels and out the chimney. This warms the air around the barrels, which rises through the screen floor and dries the grain.

Grain can be harvested without waiting for any drying in the field and during any weather (if you build a shelter over the dryer). Problems of insect and rodent damage during drying in fields or cribs are avoided. Construction materials are easy to find in most places.

It is better for a group of farmers to share in the building and use of this dryer. Make sure there is enough fuel in your area to operate the dryer. Firewood or maize cobs will work well. Placing a fan to force air through the barrels will reduce the amount of fuel needed.

DO NOT USE THIS DRYER TO DRY GRAIN KERNELS YOU WILL USE LATER FOR PLANTING. IT GETS TOO HOT.

In this plan mudblocks are used to make the walls. Hand-rammed earth may also be used without putting it into blocks first. You may substitute an available local material that will be as strong and resistant to wear and heat, such as burned brick. Sandcrete (cement and sand) or concrete blocks will crack with the heat. If banco (earth and water) is already used for construction in your area, the same high-clay-content soil will work well for the dryer. You may mix in cement with low-clay soil to build earthen

walls.

This dryer is made with four barrels. You can build one with more or less barrels. If you make it too much longer you may have trouble getting a good draft from the fire going through them. You should also narrow the width of the dryer somewhat if it is longer, so as not to overload its heating capacity. You can make a shorter dryer wider. A smaller dryer might also be very useful to dry smaller fruit or vegetable crops.

READ THE INSTRUCTIONS THROUGH BEFORE YOU BEGIN

Tools and Materials

*** 4 220-litre oil barrels**

*** about 375 mudblocks, each measuring 15 x 20 x 25cm**

*** wood to make a form for the mudblocks**

*** about 2m of heavy wire, to join the barrels**

*** 3 strips of small-mesh screen, each about 180cm long and a few centimeters wide, to cover joints between barrels**

*** a little cement and some sand to make mortar for sealing the joints between the barrels**

*** 13 6-10cm wide logs for drying floor supports. Cut them about 2m long, equal to the outside width of the dryer.**

* 6.5 or 7 square meters wire mesh, for the drying floor
OR
about the same area of heavy woven mats, plus a total of 10m of wire mesh strips about 20cm wide

* OPTIONAL: materials for making concrete, plus reinforcing rods; or heavy metal bars. These will make reinforcing crosspieces across the barrels in the front and back walls of the dryer.

1. Select and prepare a site.

* Select a site that is well drained and can easily be made level.

* Plan to place the dryer so the chimney will be on the downwind side of the prevailing wind during the season when the dryer will be used most.

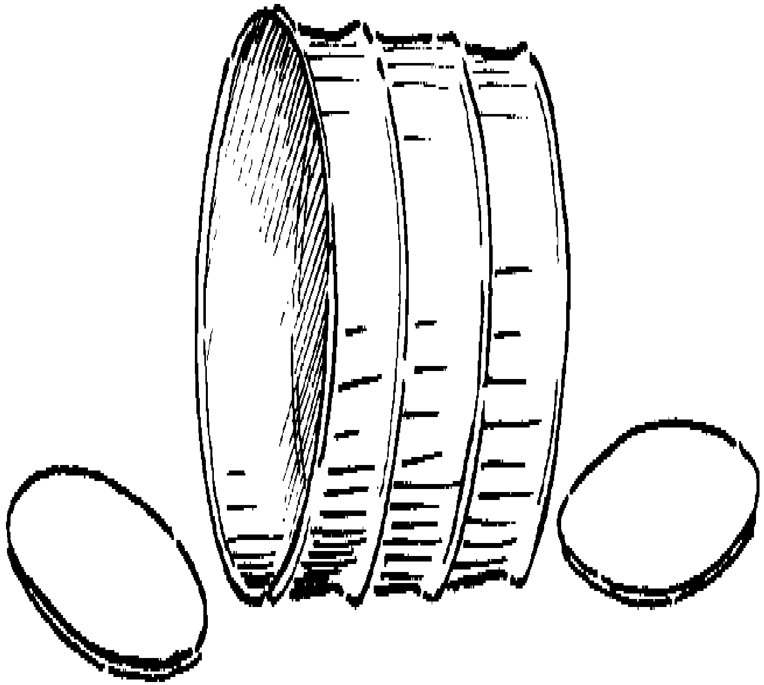
* Build up the ground on the site a little so rainwater will not collect around the dryer. Make it level. Make the raised and level area about 6,50m x 4m.

* Tamp the earth down firmly so it will not shift or crumble under the finished dryer.

2. Assemble the oil drums.

<FIGURE 62>

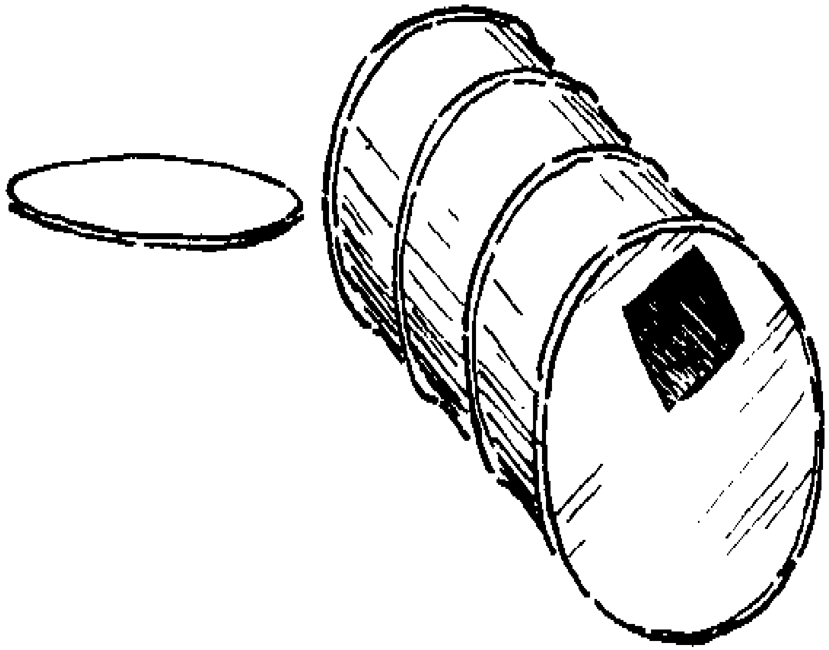
51ap63a.gif (393x393)



*** Cut both ends from three 220 litre barrels.**

<FIGURE 63>

51ap63b.gif (353x437)



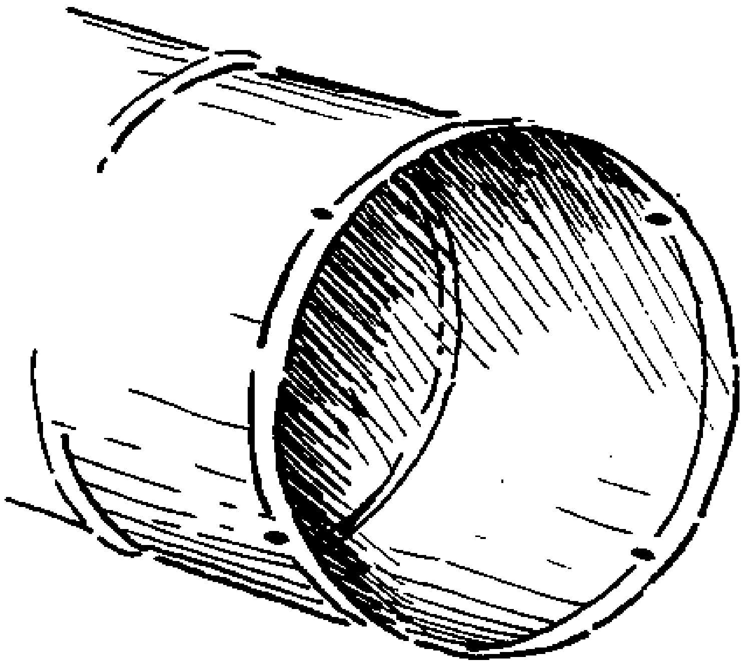
*** Cut one end from a fourth barrel. Cut a hole about 20 x 20cm across near the edge in the other end of this barrel. This will make an opening into the chimney.**

*** Punch four evenly spaced holes around the rim of each barrel where it will join another barrel.**

*** Join the four barrels together by tying pieces of heavy wire through the punched holes. Twist the ends and press them down flat against the barrel.**

<FIGURE 64>

51ap64a.gif (353x393)

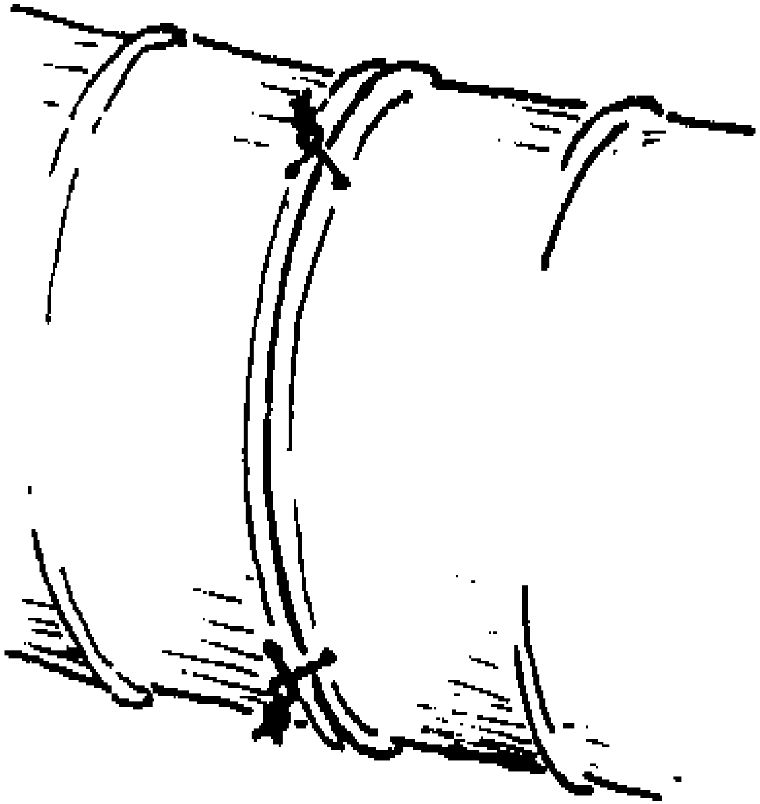


*** Save two of the cut-off barrel**

ends to use later as dampers, one at the front entrance to the barrels and part of the other over top of the chimney hole.

<FIGURE 65>

51ap64b.gif (437x437)



3. Make mudblocks.

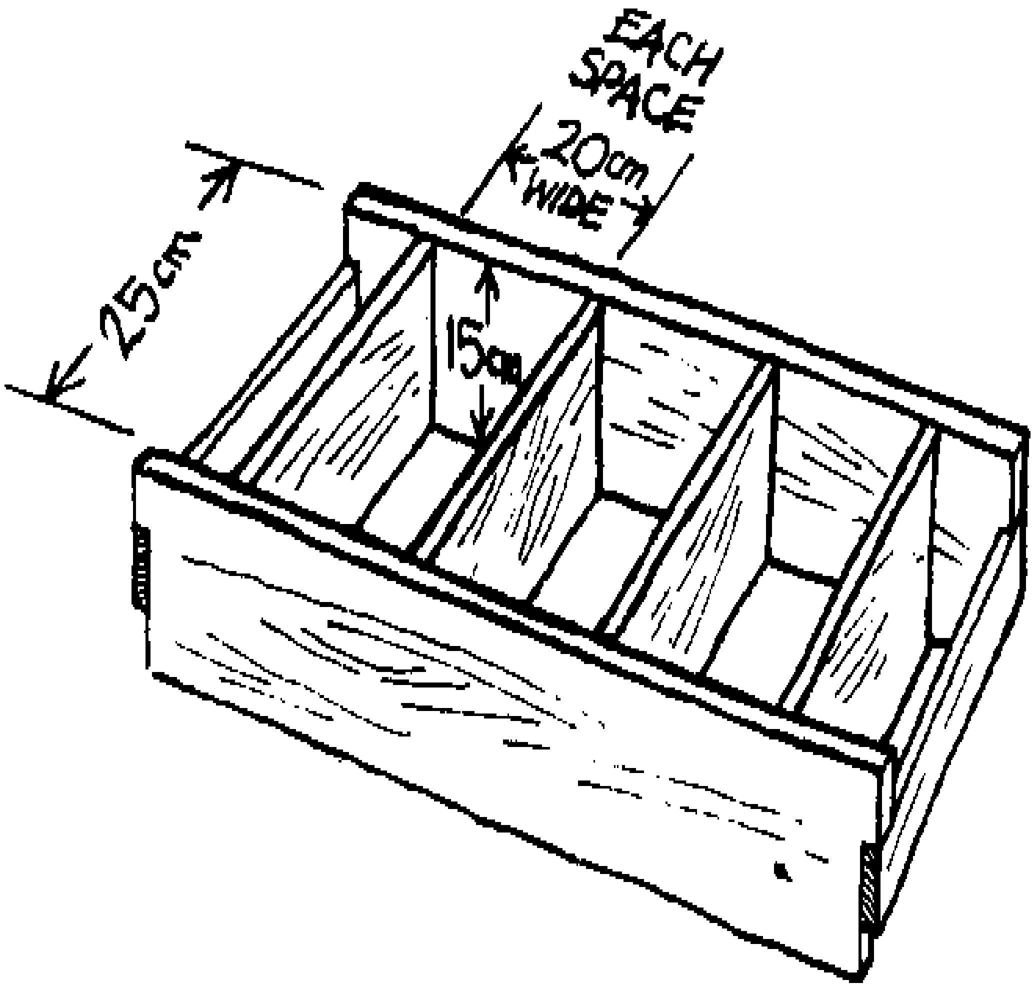
*** Make a form out of wood to mold mudblocks with. One that will make three at a time might be a good size. Make it so**

that each finished block will measure 15 x 20 x 25cm.

*** You will need about 375 mudblocks. Let them dry hard before using.**

<FIGURE 66>

51ap64c.gif (540x540)



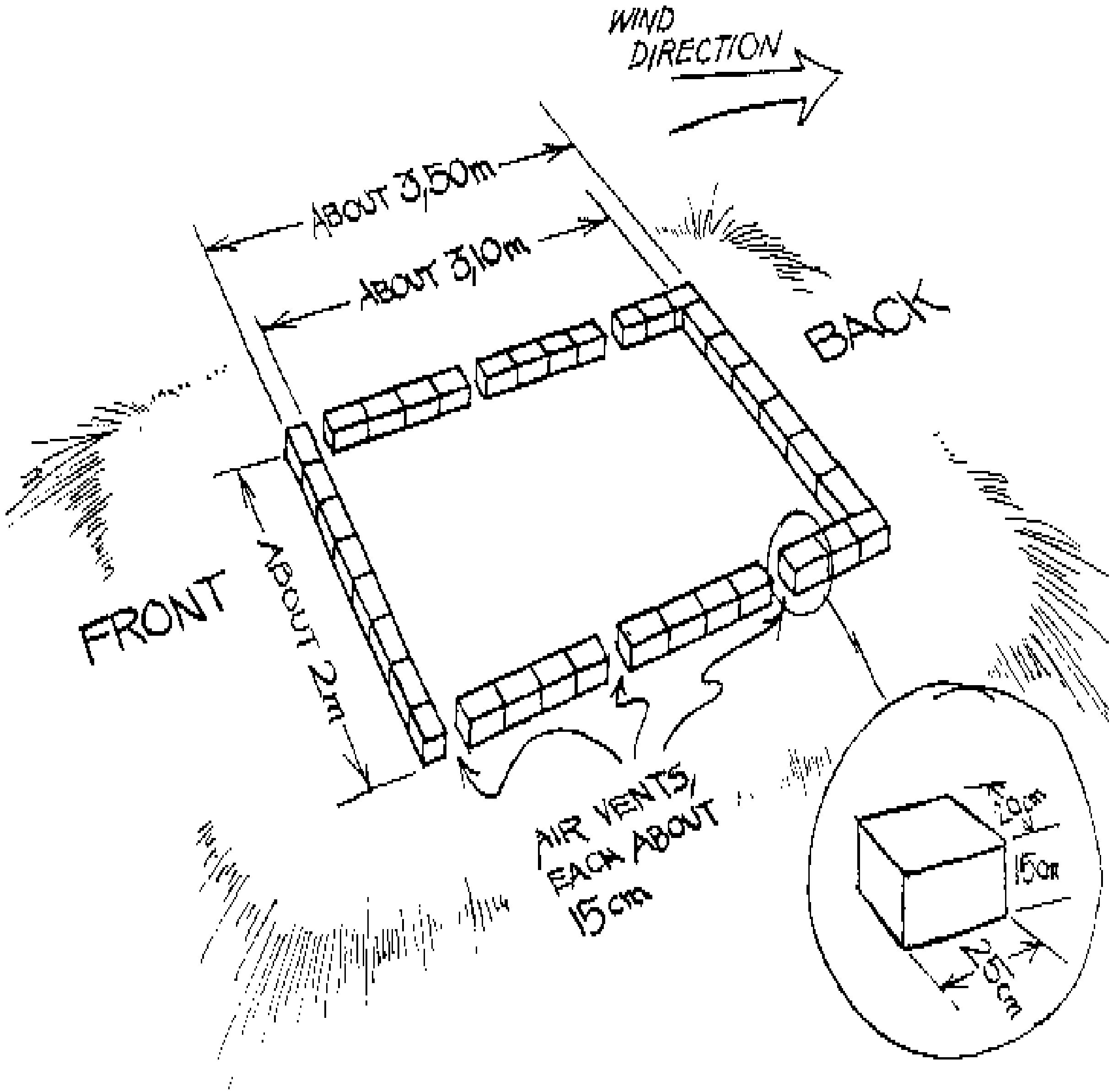
4. Begin the dryer walls.

*** Mark the outside dimensions of the dryer on the dirt foundation you have made. It will be a rectangle measuring about 3,50 x 2m.**

* Call 3,50m the length of the sides and 2m the width across the front and the back. Make your marks so that the front of the dryer will sit back about 2m from the edge of the raised and levelled earth foundation. This will leave about 1m at the back. Leave about 1m on each side.

<FIGURE 67>

51ap65.gif (600x600)



*** Allow for variations in the actual size because of differences in the mudblocks and spaces between them for mortar.**

*** Make a mixture of mortar out of the same material you used for the blocks. Add just enough water so it is not too watery.**

*** Lay down the first layer of mudblocks. Place blocks so that 20cm is the thickness of the walls and 15cm is the vertical dimension.**

*** Mortar between the blocks. Allow about 1cm between blocks for a good mortar joint.**

*** It is important to make the right distance between the front and the back walls. Since the assembled oil barrels will be about 3,45m long, make the distance between the inside edges of the front and back walls about 3,10m. This will allow the ends of the barrels to rest firmly on the first layer of blocks at each end. Later they will be enclosed around the sides by the finished end walls, making a good seal against smoke from the fire leaking around the barrels and passing up through the drying grain.**

*** The three spaces along each side wall will be air vents. When the dryer is in operation cool air will be drawn in through them, warmed, and then rise through the grain to dry it.**

*** Make the air vents each about 15cm across. If you have trouble getting a 3,10m distance between the inside edges of the front and back walls, you may change the size of the vents a little.**

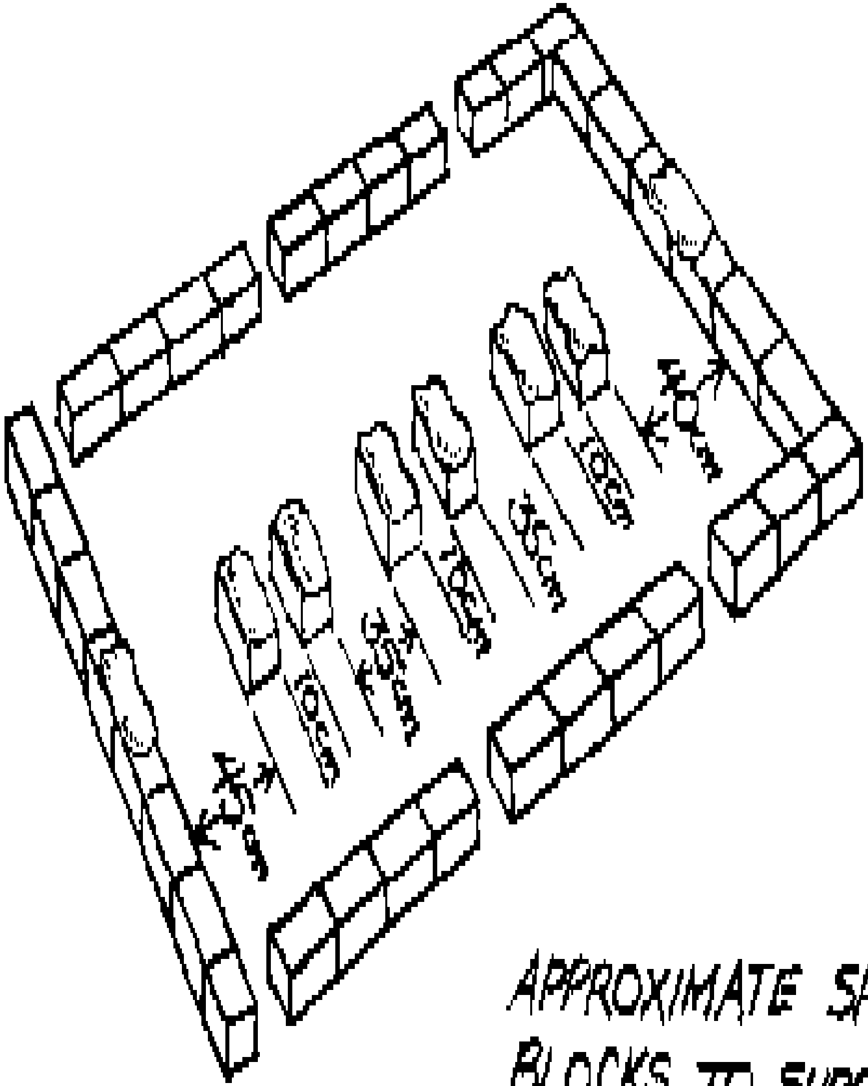
5. Place the barrels.

* Place six free-standing blocks down the middle of the dryer. These will support the barrels. Getting the barrels up off the ground helps air to move around them and also reduces the chance of their rusting.

* Put a layer of mortar on each of the blocks down the middle of the dryer and on the center part of the front and back walls where the barrel ends will touch.

<APPROXIMATE SPACING OF BLOCKS TO SUPPORT BARRELS>

51ap66.gif (600x600)



APPROXIMATE SPACING OF BLOCKS TO SUPPORT BARRELS

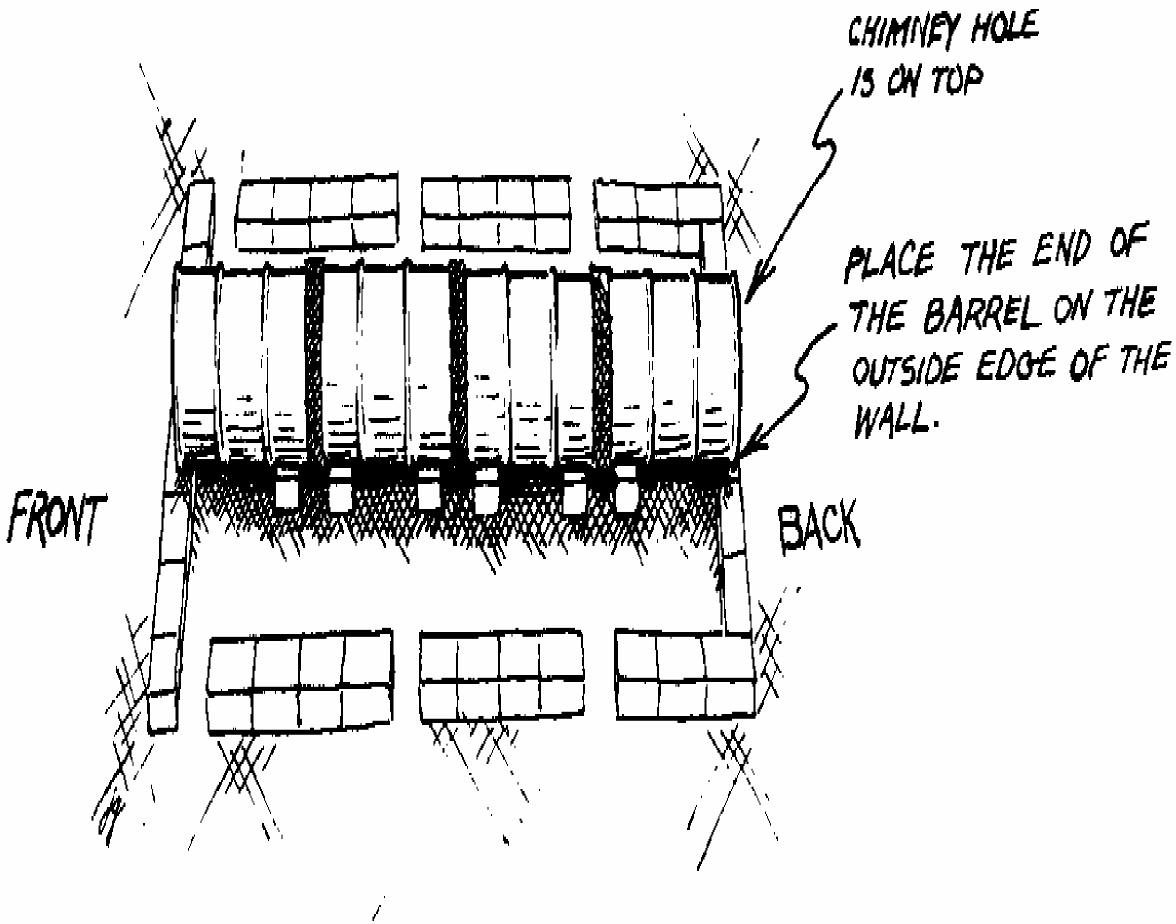
*** Lay the barrels in place on the mortar and brace them temporarily with sticks if they want to roll. Make the chimney end of the**

barrel assembly flush with the outside edge of the back wall. This should cause the front end of the barrel assembly to lie most of the way across the front wall. Make sure the hole that will let smoke into the chimney is on the top of the end.

*** Seal the joints between the barrels. Place a strip of screen around each one and plaster with a mixture of mortar, one part cement to eight parts sand, and water.**
Test the seals at the joints. Light a smoky fire in the first or second barrel from the front and see if smoke escapes anywhere except the hole for the chimney. Don't let it burn long enough to dry the mortar on the joints. Keep the mortar damp until it is hard.

<FIGURE 68>

51ap67.gif (600x600)



6. Continue the walls.

* Lay down five more layers of mudblocks.

* Lay the blocks so that, as much as possible, each block crosses over a joint between blocks in the layer below. This will make the walls stronger.

* The air vents are only as high as the very first layer of blocks (15cm). Span over top of each vent with one full-size block.

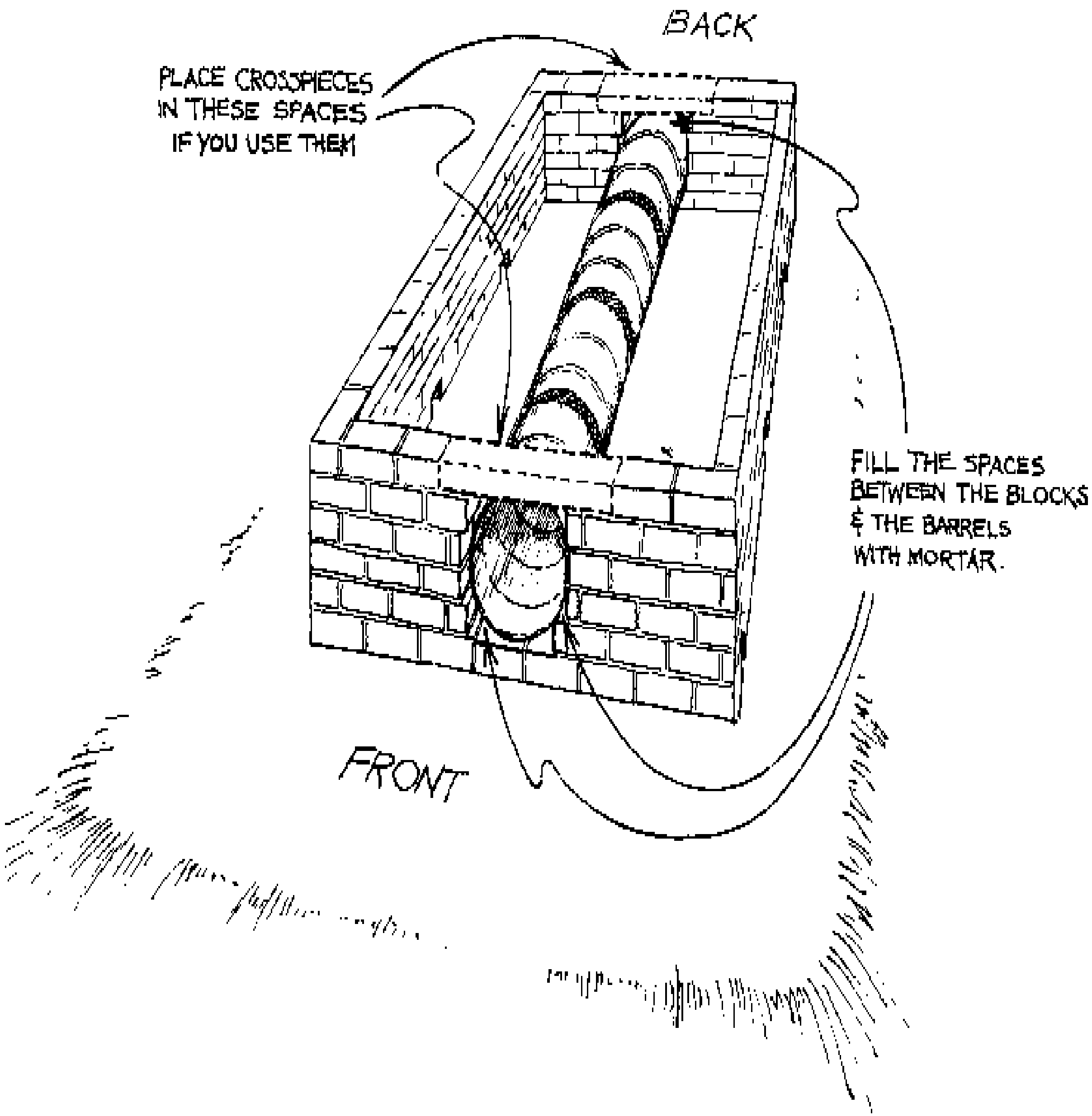
* To make good continuous layers of blocks you will have to cut some blocks into smaller sizes.

* Bring the blocks in the front and back walls as close as you can to the sides of the barrels. Fill in the spaces completely with mortar so there will be no air leaks. For added strength you can mix some cement with this mortar.

* If you think the ends of the barrels are not strong enough to support three or four layers of blocks above them, then make crosspieces out of reinforced concrete or use iron bars to put across the top of the barrel ends. Make them longer than the width of the barrels. Mortar them into place in the wall, and make the tops even with the top surfaces of the walls.

<FIGURE 69>

51ap68.gif (600x600)



7. Make a drying floor screen.

* Prepare screen to the right size for the drying floor. Assemble whatever size sections you have by overlapping about 5-10cm and fastening together with thin wire.

* The overall size should be about 3,30 x 1,80m. This will allow about 10cm on each side to be embedded into the walls.

* Check the size of the screen by stretching it lightly across the top of the dryer. If it overhangs beyond the outside edge of any wall when it is centered, trim it back. If it is too small, add some screen where it is needed. When you are satisfied, set the screen aside.

NOTE: Small-mesh screen is best. But chicken wire can be used. Place straw mats over chicken wire, or other large-hole screen, so grain will not fall through the holes.

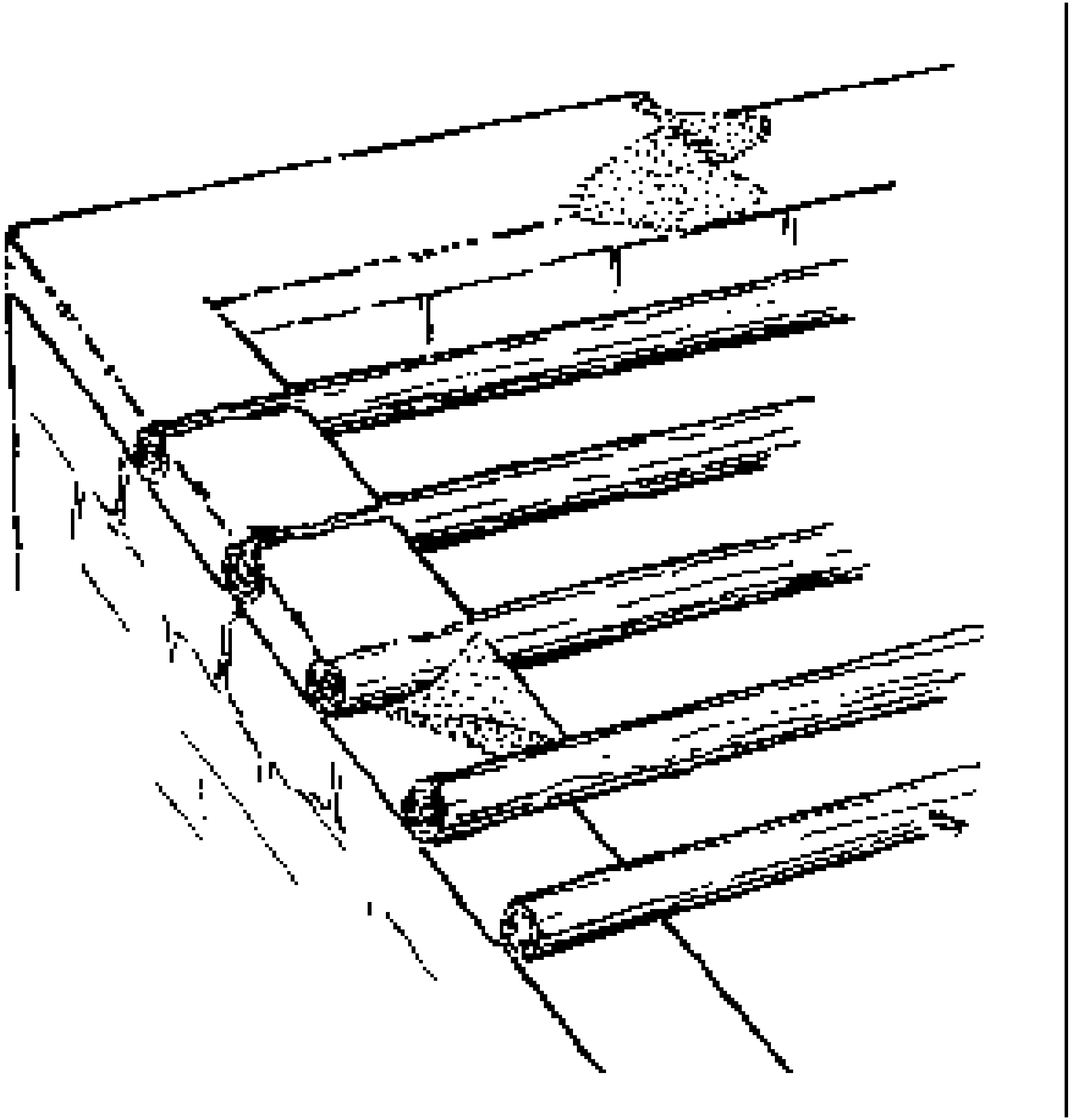
Some kinds of woven mats are very strong. These can be used in place of screen. In some places, screen may be costly. If you use mats in place of screen, it would be best to prepare some strips of metal screen to embed around the insides of the walls and fasten mats to. Then, if the mats later rot or weaken around the edges (or anywhere), there will be something to fasten new mats to.

8. Place the drying floor supports and screen; finish the walls.

*** Put a layer of mortar down on the top of each side wall.**

<FIGURE 70>

51ap69a.gif (600x600)

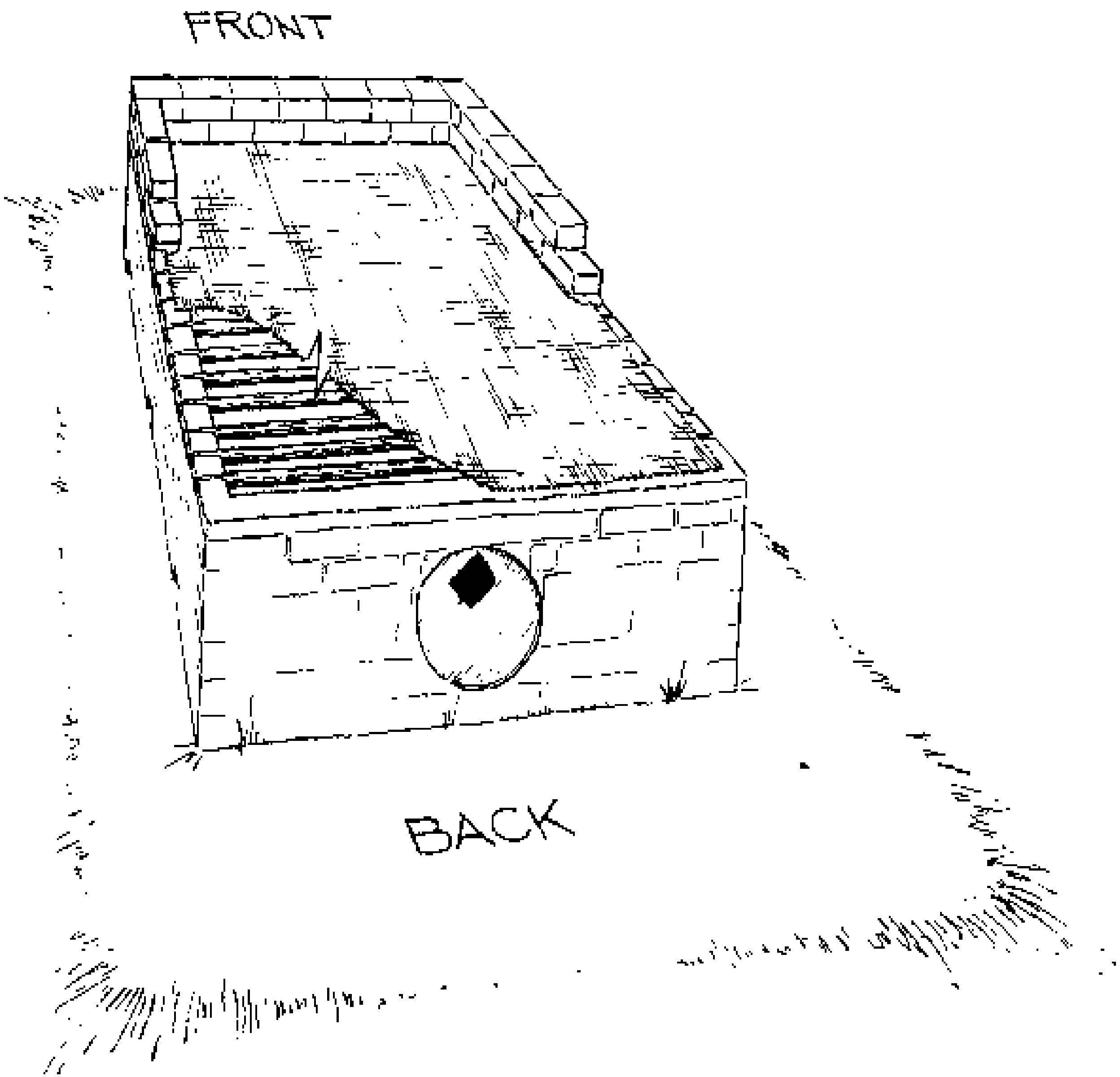


*** Lay the thirteen logs down on the mortar,**

from one side wall to the other. Space them evenly. You should leave about 15cm between each one and between the log on each end and the end wall next to it. The 15cm may be a little different; it will depend on the size of the logs. The log ends should come to the outside edge of each side wall.

<FIGURE 71>

51ap69b.gif (600x600)



*** Fill the spaces between the logs with mortar up to the tops of the logs.**

* Build up the front and back walls and the corners of the dryer to the same height as the tops of the logs.

* While the mortar is still wet on the tops of the four walls, lay the screen you have made in place on top of the logs. Center it so about the same width extends over each wall. Stretch any wrinkles or kinks out of it.

* Place a thick layer of mortar over the screen the width of the wall so that it fills the holes in the screen and gives a good base to lay mudblocks on. Lay mudblocks in the usual way.

* Lay down two layers of mudblocks above the screen. This will make a drying chamber a little more than 30cm deep, which should be plenty for the most bulky grains, such as unshelled maize.

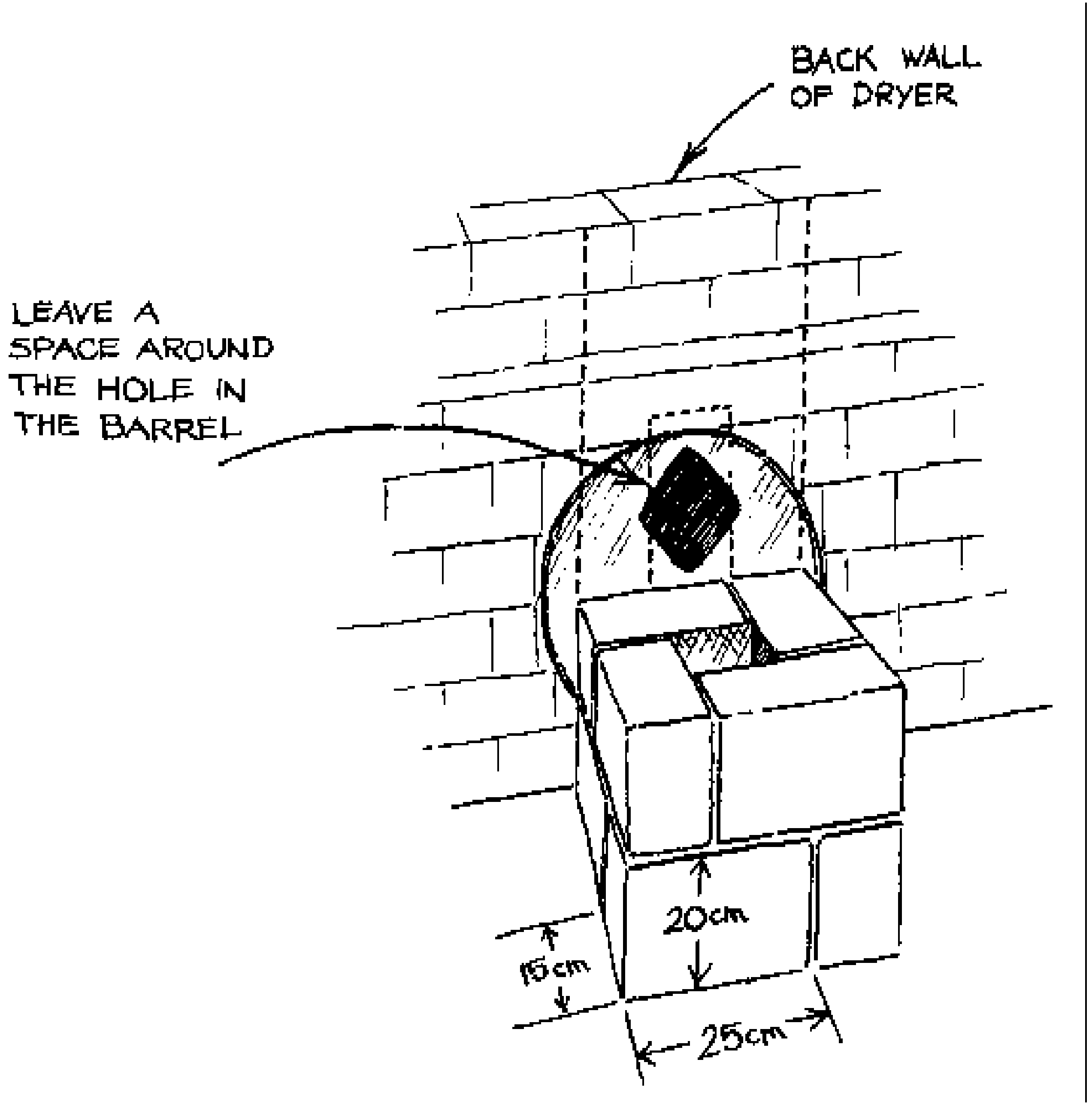
* Smooth any rough spots on the tops of the walls, so no bumps or loose pieces will be knocked into the dryer when it is in use.

9. Build a chimney.

* Build a chimney up against the back wall of the dryer. Center it on the smoke outlet hole cut in the end of the back barrel.

<FIGURE 72>

51ap70.gif (600x600)



*** You can use mudblocks the same size as in the dryer**

walls, and mortar. Position the 20cm edges vertically. This will give about a 12 x 12cm smokehole in the center, which is large enough to allow easy smoke escape, but small enough to keep down heat loss from the barrels.

* Leave a space in the chimney wall against the hole in the barrel end. It will start after two layers of blocks and be about two layers high. Fill in irregular-size spaces in the brickwork with cut blocks or mortar. Center a full-size block over top of the space you have made. Continue laying blocks until the chimney rises at least 1/2 meter above the tops of the dryer walls. This will keep smoke out of the drying grain.

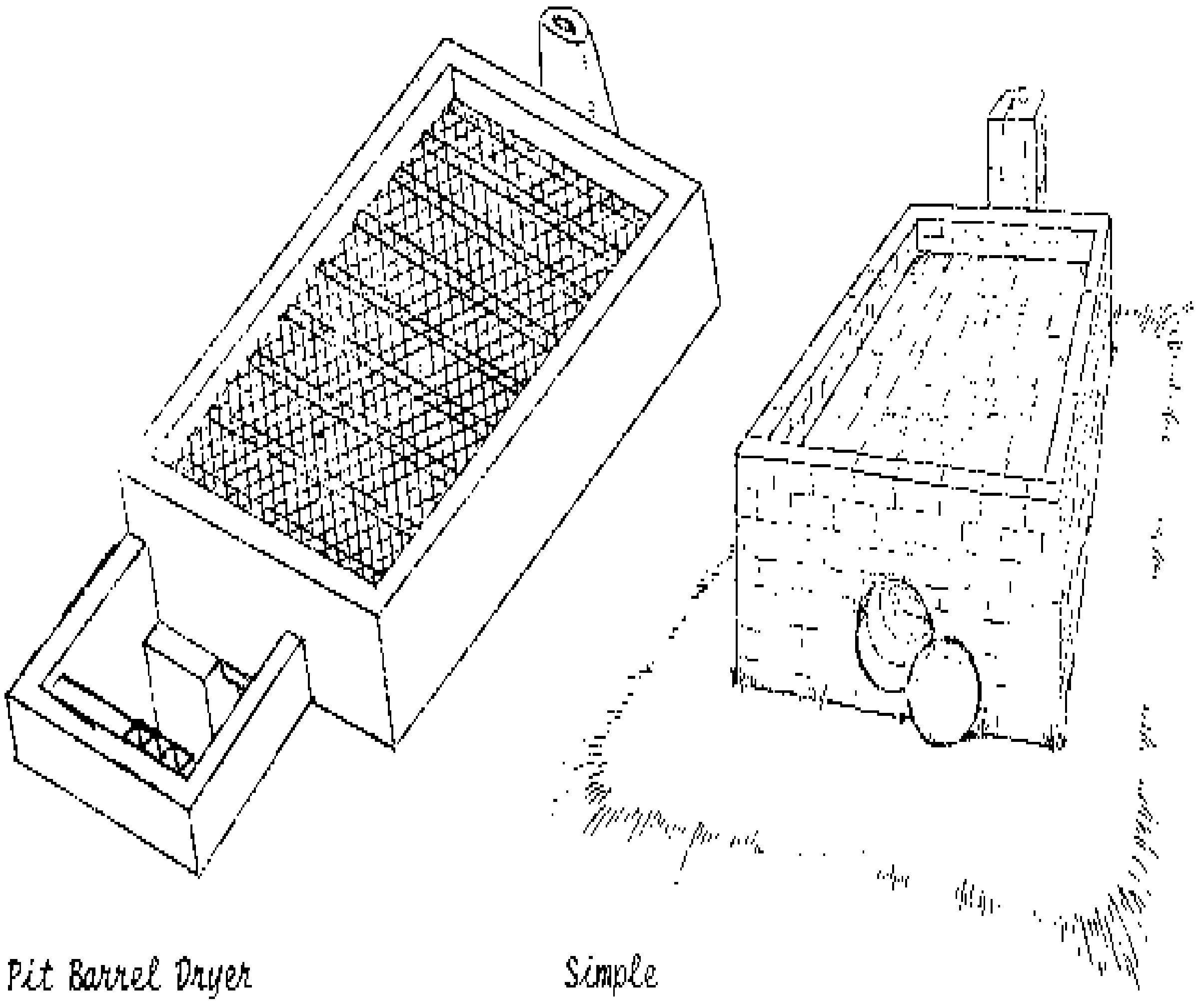
* Make sure the chimney is sealed and free of cracks, so there is only one way for smoke to go: through the hole in the barrel end and out the top of the chimney hole.

INSTRUCTIONS FOR USING THE OIL BARREL DRYERS

<PIT BARREL DRYER AND SIMPLE BARREL DRYER>

51ap71.gif (600x600)

INSTRUCTIONS FOR USING THE OIL BARREL DRYERS



Pit Barrel Dryer

Simple Barrel Dryer

1. A shelter over the dryer will protect it and drying grain from rains. Build an open-sided one to overhang the dryer at least 1/2m on each

side, and more on one side if you wish to have room for storing fuel, a work area, etc.

2. Gather dry wood, maize cobs or other fuel before drying begins.

3. Build the fire in the first barrel or mid-way into the second barrel.

4. Prop one of the cut-off barrel tops against the front opening into the barrels on a block or a rock to adjust a good draft for the fire. A piece of a barrel top can also be placed part-way over the top of the chimney to give you more control of the draft.

5. Watch and control the fire at all times during drying. Do not dry with too large a fire: you may kill or scorch the grain. A medium size fire will give the best distribution of heat.

6. If you have trouble getting enough heat, in the Simple Dryer you may try partly covering the side vents to get a better draft up around the barrels.

7. You can modify the dryers by installing a fan or fans to push a steady flow of air up around the barrels and through the drying grain. The resulting larger volume of less-hot air will dry the grain faster and with little danger of overheating.

8. The dryers will take some time to reach operating temperature while the walls are heating. Continue drying operations day and night to make best use of the heat built up in the dryer. Load it with a fresh batch as soon as the one before is dry.

9. Limit the drying temperature for food grains to 50-55 [degrees] C. The bottom layer of grain should not be too hot to hold in your bare hands. Grains for livestock feed may be dried at higher temperatures. Do not dry rice, beans or any grain to be used for seed in these dryers -- unless you install fans, and even then proceed cautiously. These grains must not be heated to more than 45 [degrees] C.

10. Do not stir the drying grain. Grain in the top layers receives moisture passed up from the warmer grain at the bottom, and gradually releases it as drying is completed. If you stir these wetter kernels down again, they will re-wet the drier kernels that got stirred up to the top -- and drying will take longer. Stir only to release the heat if overheating occurs.

11. Dry grain until the moisture content is about 12%. Grain is dry when a kernel is hard and breaks between your teeth with a sharp crack.

12. Load small grain such as millet and sorghum in a layer 5-8cm deep. Shelled maize and other grains may be loaded up to 10cm, groundnuts up to 20cm, and maize on the cobs up to 30cm.

13. Maize may take one to two days to dry.

14. Do not let dirt build up in the dryer. Do not let the air vents that let air up around the barrels get clogged. Keep the area clean.

15. Check for rust holes in the barrels and for cracks in the joints.

Replace badly rusted barrels and re-seal cracked joints. Smoke leaking into the drying grain will discolor it and change its taste and smell.

16. If you need to get up on the dryer floor while loading or unloading grain, avoid tearing the screen or mats -- do not stand in the spaces between the log supports.

16. If one of the logs supporting the screen in the Simple Barrel Dryer becomes weak or rotted, you will be able to replace it by chipping some of the mortar away from each end, and pulling or knocking it out. Slide in a new log and mortar the spaces around the ends.

THE PIT OIL BARREL DRYER

This dryer is based on a plan prepared in 1974 by American Peace Corps Volunteers in Benin, West Africa. It is called the Oil Barrel Dryer simply because it is made from oil barrels. It actually has received different names depending upon the country where it was used. The first oil barrel dryer was built in Samoa to dry coconut meat. Since then, this dryer has been built and tested in a number of countries, including Nigeria and Benin. The dryer also is known as the Low Cost Bush Dryer and the Brooks Dryer.

Proven advantages of the Oil Barrel Dryer:

* It is useful in areas where grain must be harvested in rainy weather.

* Maize on the cob can be dried without long drying in cribs and use of contact insecticides.

* Construction materials are easy to find in most places.

* Farmers can build the dryer with little assistance or supervision.

* It dries a lot of grain in a short time.

* Grain can be harvested earlier. Because there is less drying time in the field, there is less danger of insect and rodent damage.

Possible disadvantages (depending upon area or situation):

* It is a better dryer for a group of farmers than it is for one farmer. One farmer would not need it very much during a year. Sharing by a group of farmers means more use and less expense to each farmer in building.

* The fuel used in this dryer is often firewood; sometimes maize cobs also are burned. Firewood is becoming harder to get and more expensive in many places.

* There is no fan included in this plan to force air through the heating chamber and the grain bed. Small gas motors needed to drive fans often are very expensive.

* It should not be used for grain which will be used for planting.

* It would be worthwhile to find other economical natural fuels (like maize cobs).

* Banco construction (hand-rammed earth) works only where there is a high clay content in the soil.

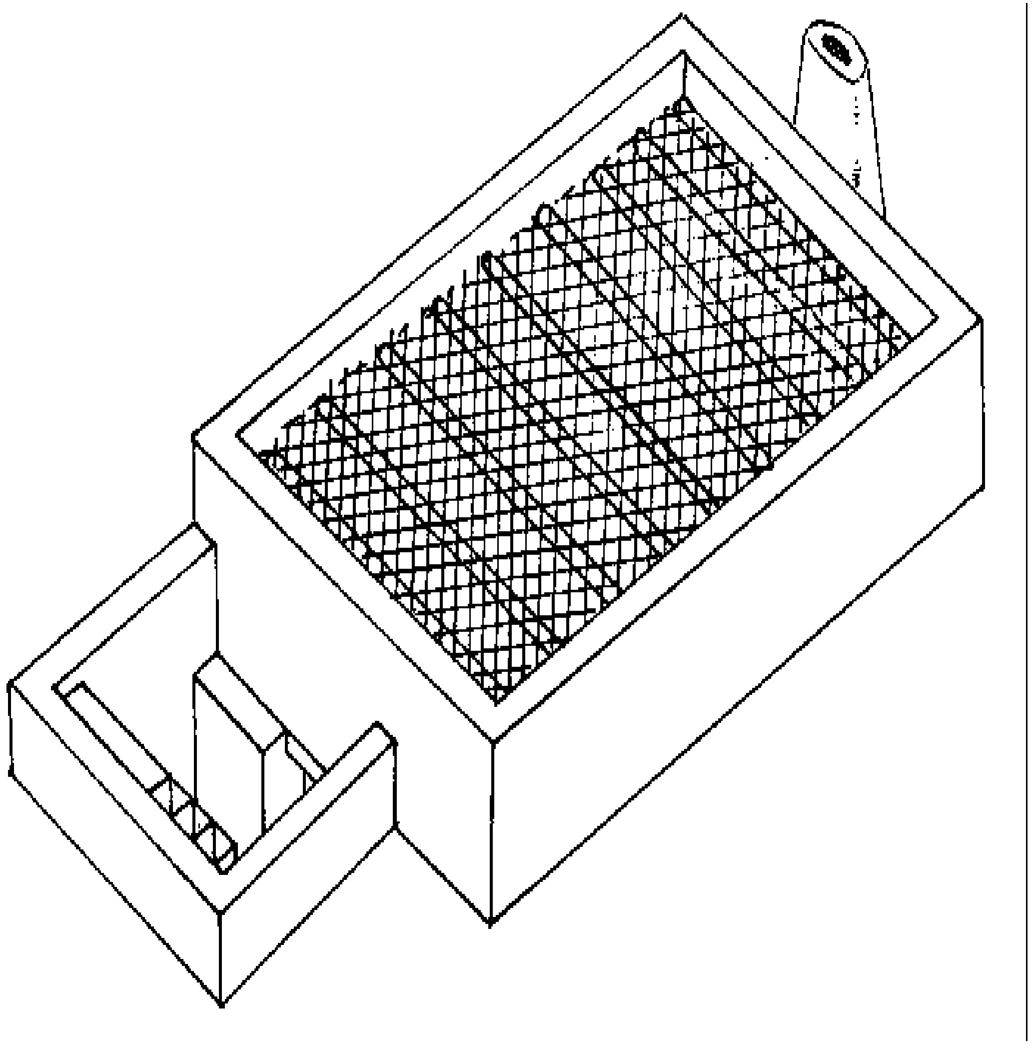
Fans placed to drive the warmed air around the outside of the barrels up through the drying grain would increase the efficiency of the dryer. It will be necessary to find a suitable power source for the fans. In areas where there are many small motor bikes, it might be possible to construct a power drive made from a motor bike which permits temporary hook-up and easy detachment of the bike as a power source.

The dryer is made of hand-rammed earth, known in different areas as banco, terre de barre, adobe, etc. The maize or other grain is placed on a screened drying floor. This floor is placed above a firebox made of three 220 litre metal oil drums joined together end to end.

You may substitute an available local material that will be as strong and resistant to wear and heat as the banco, such as burned brick. Sandcrete (cement and sand) or concrete blocks will crack with the heat. If banco is already used for construction in your area, the same high-clay content soil will work well for the dryer. You may mix in cement with low-clay soil to allow you to build the earthen walls.

<FIGURE 73>

51ap74.gif (486x486)



READ THE INSTRUCTIONS THROUGH BEFORE YOU BEGIN.

Tools and Materials

* 3 oil barrels, 220 litres each

* [9m.sup.2] chicken wire or other screen, or a combination of screen and woven mats

* Iron or steel "re-rod" (reinforcing armature) for lintels. 6mm diameter, 6m long

* Materials for concrete: 25kg cement
1/2 barrel sand
1/4 barrel gravel

* Heavy wire, about 2m

* Thin wire, about 15m

* 10 logs, 8-10cm diameter; 2, 15m long

* 2 strips of small mesh screen, each about 180cm long, and a few cm wide.

* Digging tools

1. Select a site.

* Find a place for the dryer which is high and well-drained. If you dig too near a tree, roots will get in your way and you may damage the tree. If you are in a swampy or drainage area,

water will get into the dryer and wear away the walls.

2. Make 2 lintels.

* The lintels are concrete horizontal slabs which will support the weight of the walls over the barrels.

* Make two forms out of boards or bricks. Line them with paper. The forms should each make a finished lintel which measures 120cm x 30cm x 8cm.

* Cut the re-rod into 6 equal pieces each measuring 1m long.

* Mix concrete in this proportion: 1 part cement
2 parts sand
3 parts gravel.

* Mix sand and cement thoroughly first, then mix in gravel. Then add just enough water to make the concrete thick and smooth, but not watery.

* Pour concrete into the forms up to a level of 4cm and tamp firmly.

* Lay 3 pieces of 1m re-rod on top of the 4cm of concrete in each form. Space them evenly, with the outside pieces about 3cm from the edge.

* Finish pouring concrete into the forms. Tamp firmly and level

off the top surfaces.

* Cover them and keep them out of the sun or cover with grass. Keep them damp for about 7 days by sprinkling three times a day. This slow drying cures the concrete to its greatest strength.

3. Stake out the drying chamber and stoking pit.

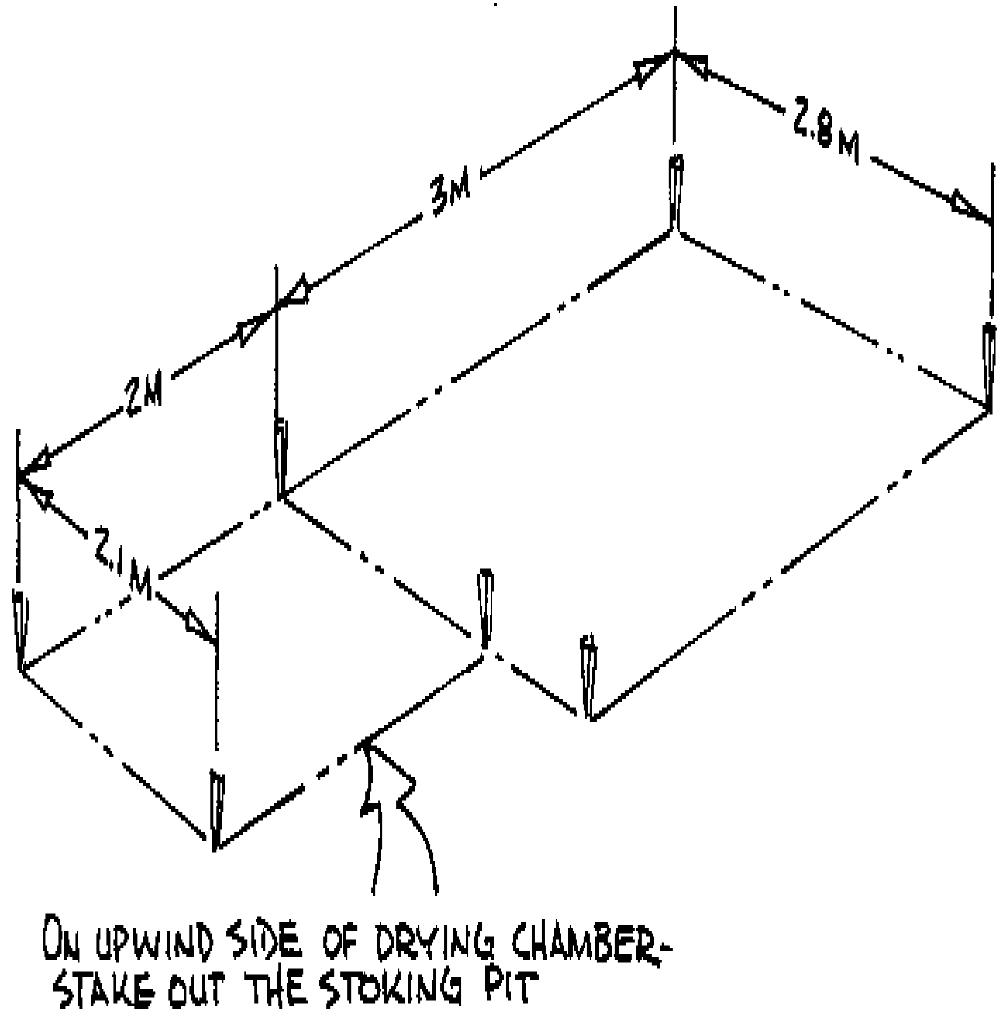
* Stake out the drying chamber, as shown, on the site you have chosen. It will be 2,80m x 3m.

* Make sure the dryer chimney is staked out downwind of the prevailing wind during the season when the dryer will be used most. This is important -- it keeps the smoke from blowing back into the drying grain.

* Stake out the stoking pit against the upwind 2,80m side of the drying area. Make the stoking pit 2m x 2,1m. One of the 2,1m sides should be right next to the upwind 2,8m side of the drying chamber area.

<FIGURE 74>

51ap76.gif (486x486)

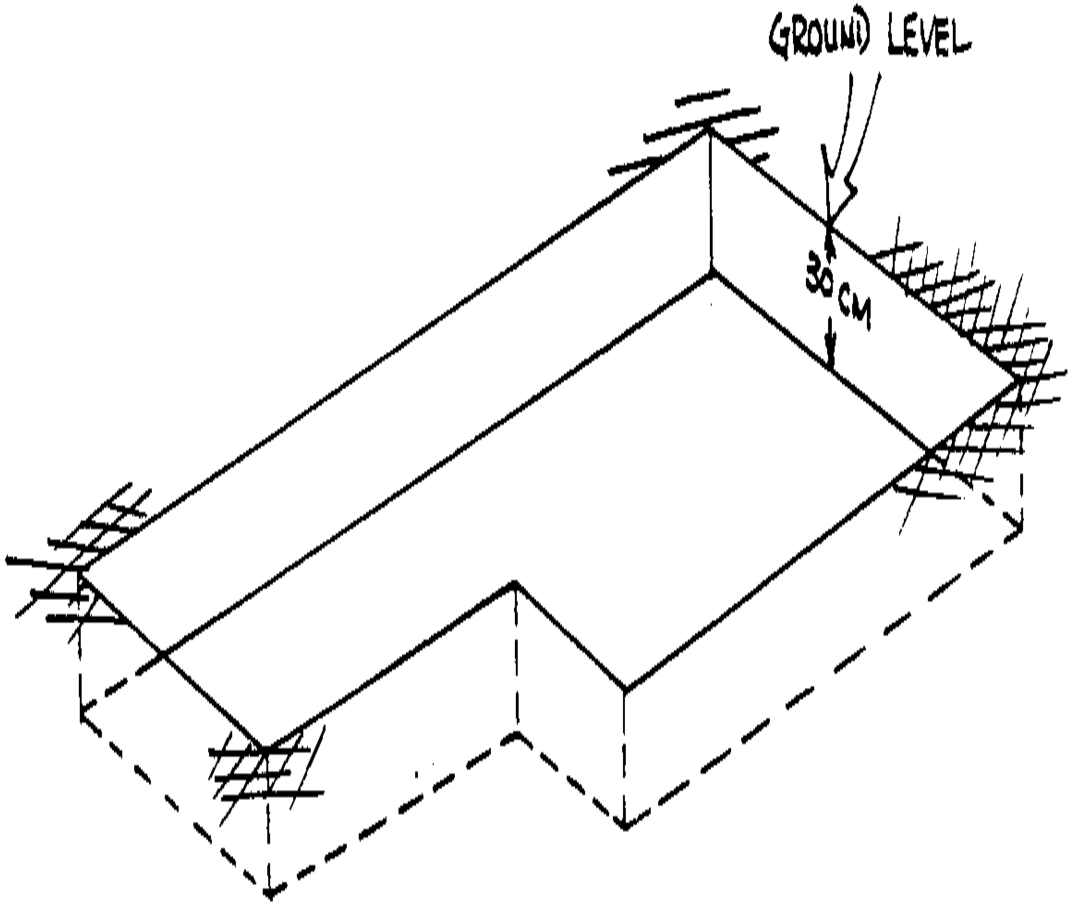


4. Dig top soil out of the staked areas.

*** Dig the staked out areas to a depth where you come to hardpacked earth that will make a good foundation. We will use 30cm in this plan. Pile all top soil to one side so it will not get mixed with the banco when it is later wetted and used to construct the walls.**

<FIGURE 75>

51ap77a.gif (540x540)



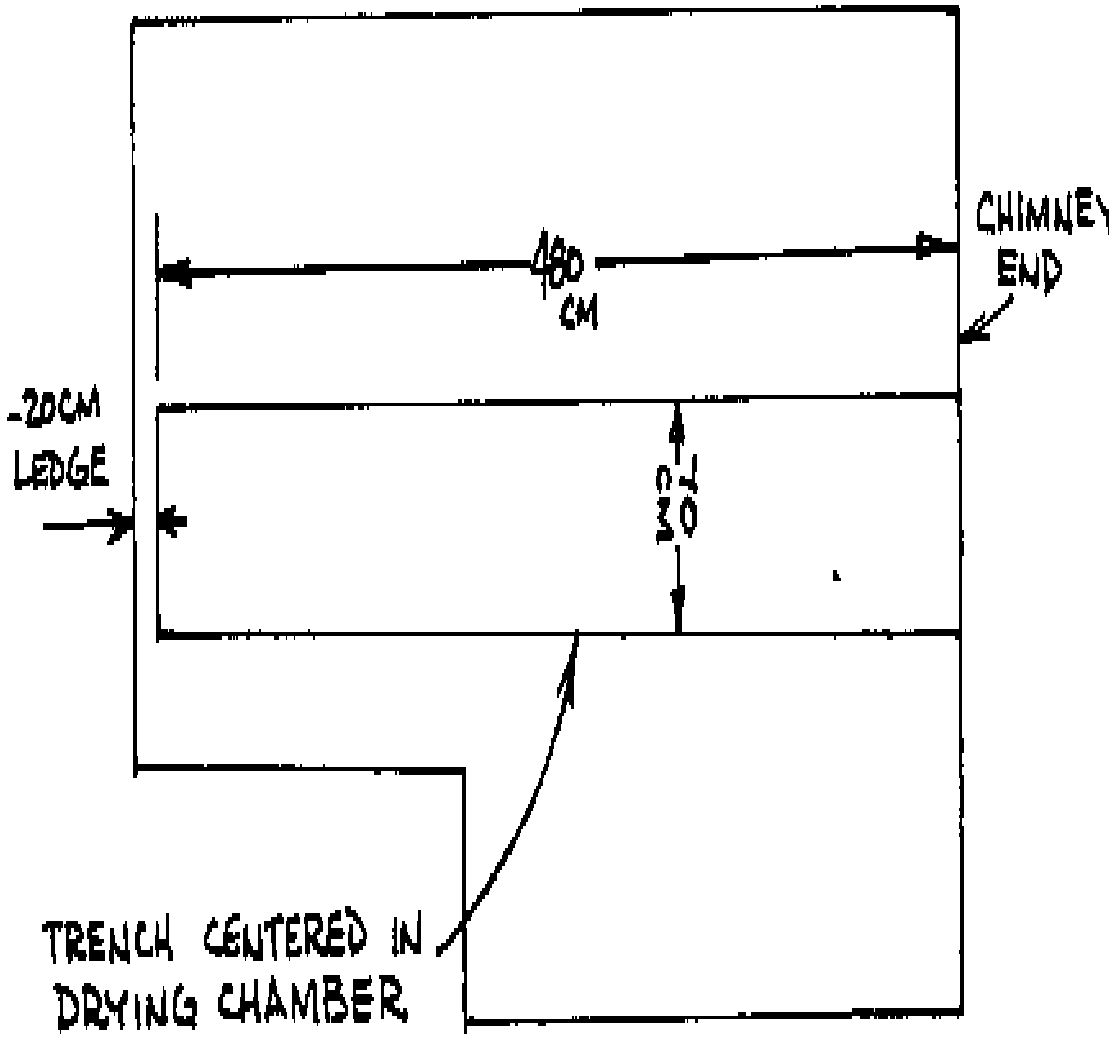
5. Dig a trench in the center of the staked out area.

* Dig a trench centered in the middle of the drying area 70cm wide and 140cm deep -- from ground level. It should extend 4.80cm from the chimney end of the drying area. This will leave 20cm un-dug at the opposite end for a retaining wall for the stoking pit.

* Keep the dirt you remove separate from the top soil you removed before.

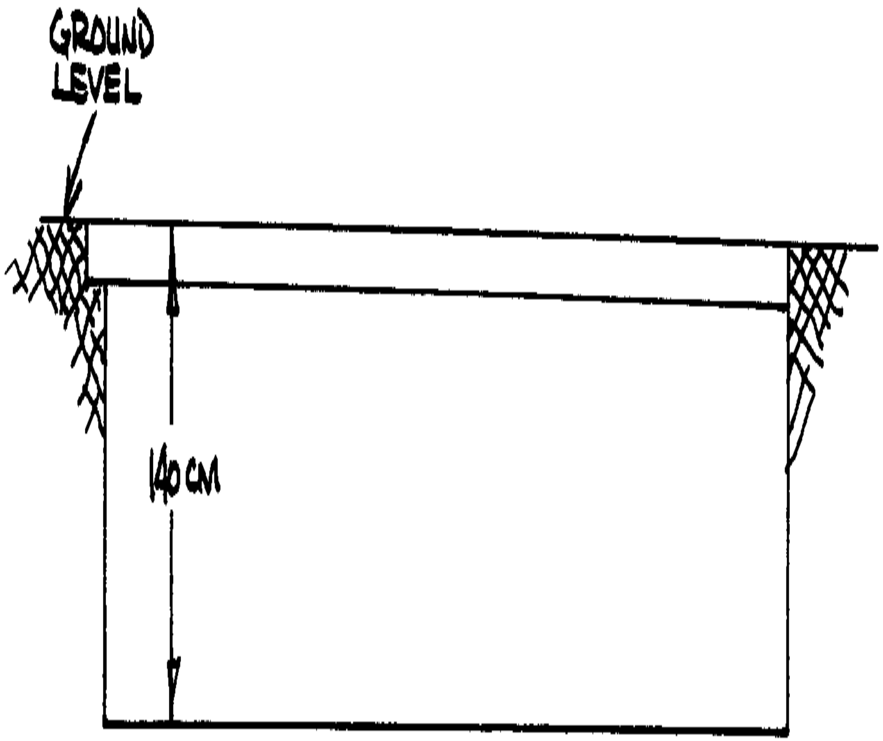
<FIGURE 76>

51ap77b.gif (540x540)



<FIGURE 77>

51ap78a.gif (437x437)



6. Make cut-outs for the lintels.

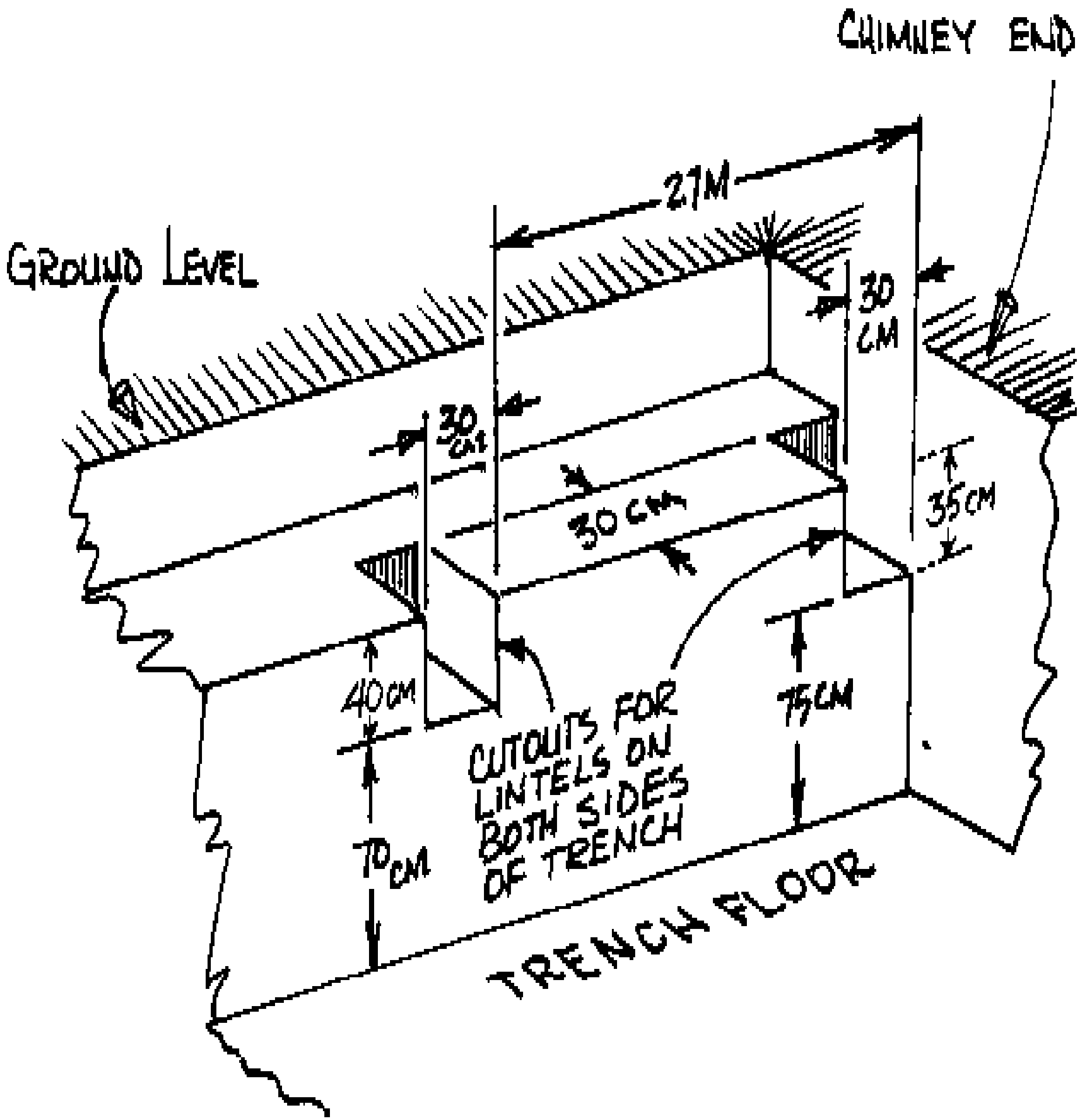
* Mark points at 2,70m and 3m from the chimney end on both sides of the trench.

* Remove the soil between these marks, and extending from the edge of the trench to a distance 30cm back. Dig it down 40cm. This will place the bottom surface 70cm up from the trench floor.

* Make two more slots up against the chimney end. They should be 30cm wide, 30cm long and dug down 35cm, or until the bottom of the slot is 75cm up from the trench floor.

<FIGURE 78>

51ap78b.gif (600x600)



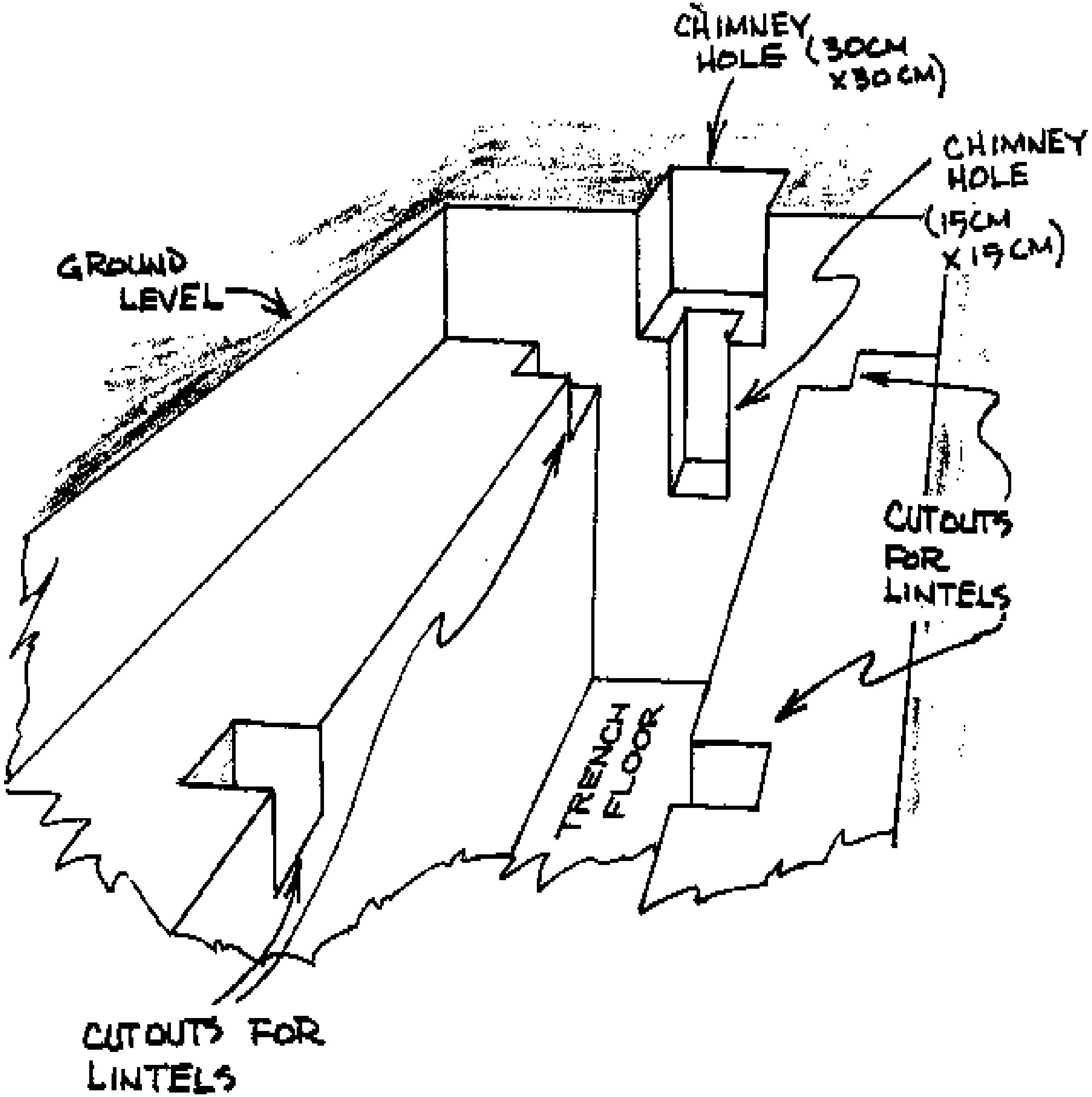
7. Make cut-outs for the chimney.

* The chimney hole should be dug into the soil at the back wall of the drying area. Centered at the end of the drying area, dig out an area 30cm wide, which extends back 30cm beyond the drying area to a depth of 30cm below the ground level.

* Also centered at this end of the drying area, dig another area 15cm wide, which extends 15cm back. This channel will extend below the hole just completed until it is 50cm from the trench floor.

<FIGURE 79>

51ap79.gif (600x600)

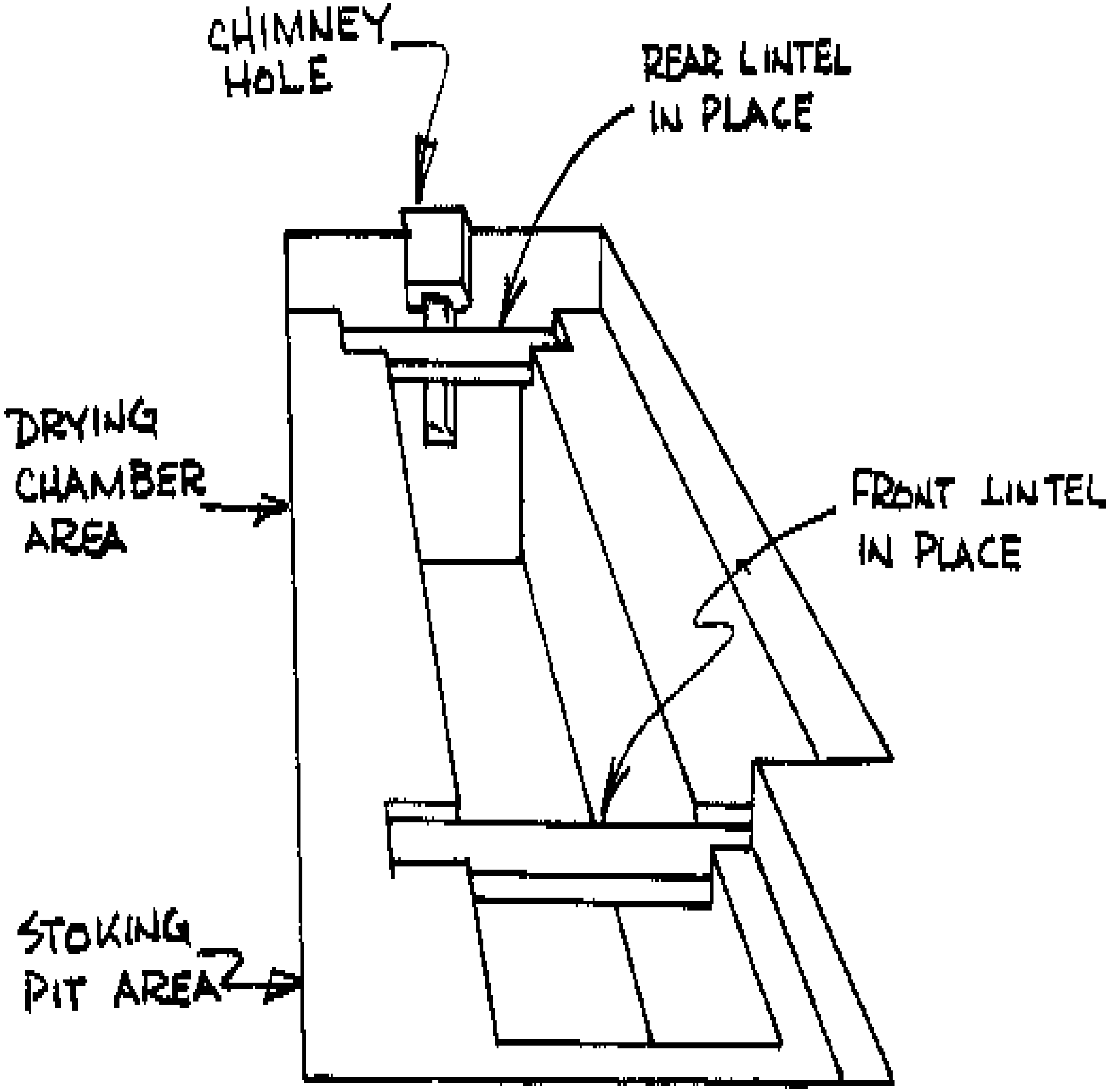


8. Place the lintels.

*** Lay a 5cm layer of banco in each of the four lintel slots. Lower the lintels into place. Make sure they are level, and square with the side walls of the dryer.**

<FIGURE 80>

51ap80.gif (600x600)



9. Build the dryer walls.

* Make the front and back walls -- over the lintels -- 30cm thick.

* Build the side walls up from the floor of the original 30cm deep pit that you have dug out. Make them 45cm thick until they reach a height of 90cm above the base of the front lintel. At this point reduce their thickness to 30cm, leaving a 15cm wide ledge on the inside of each side wall. This ledge will support logs for the drying floor.

* The height you may build the walls in one day will depend on the quality and consistency of the banco.

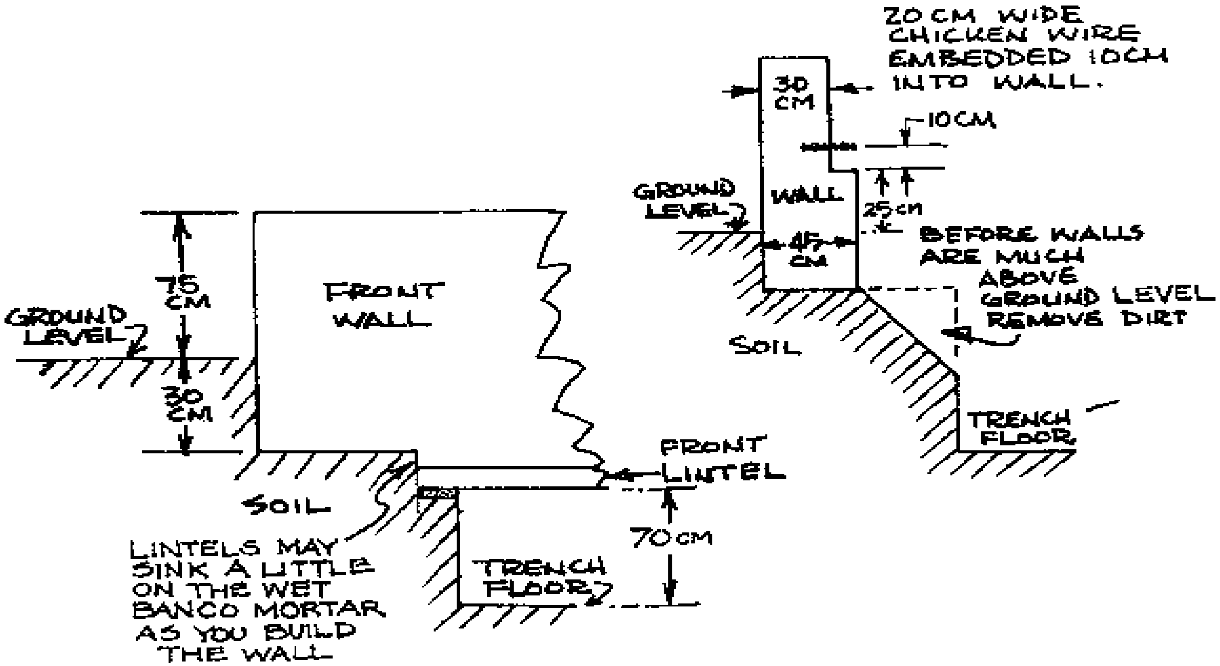
* Before the walls are too high, remove some of the dirt between each side of the oil barrel trench and the side walls. Make a slope on each side of about 45 [degrees] starting at the inside edge of the base of each side wall and extending down to meet the sides of the barrel trench about 40cm above the floor of the trench.

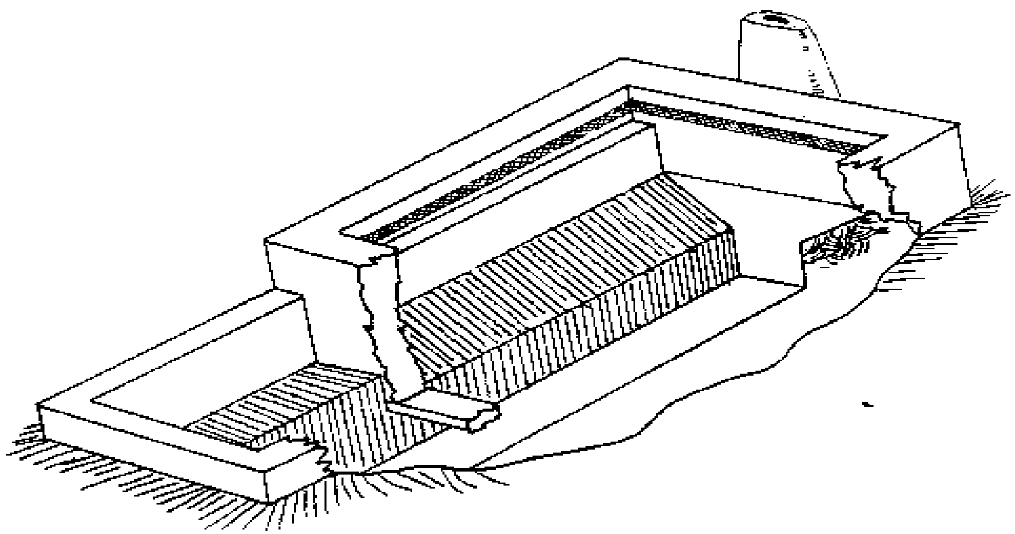
* Embed a strip of chicken wire, or other wire mesh you have chosen to use, into each of the walls, 10cm above the 15cm ledge you have made. Each of the strips is 20cm wide and is as long as the wall it is placed in. 10cm of the wire should stick out flat into the drying area. Later these strips will attach to the drying floor screen.

Continue the front, back and side walls until they rise 40cm above the wire strips. The top of the finished dryer walls will be 75cm above ground level.

<FIGURE 81>

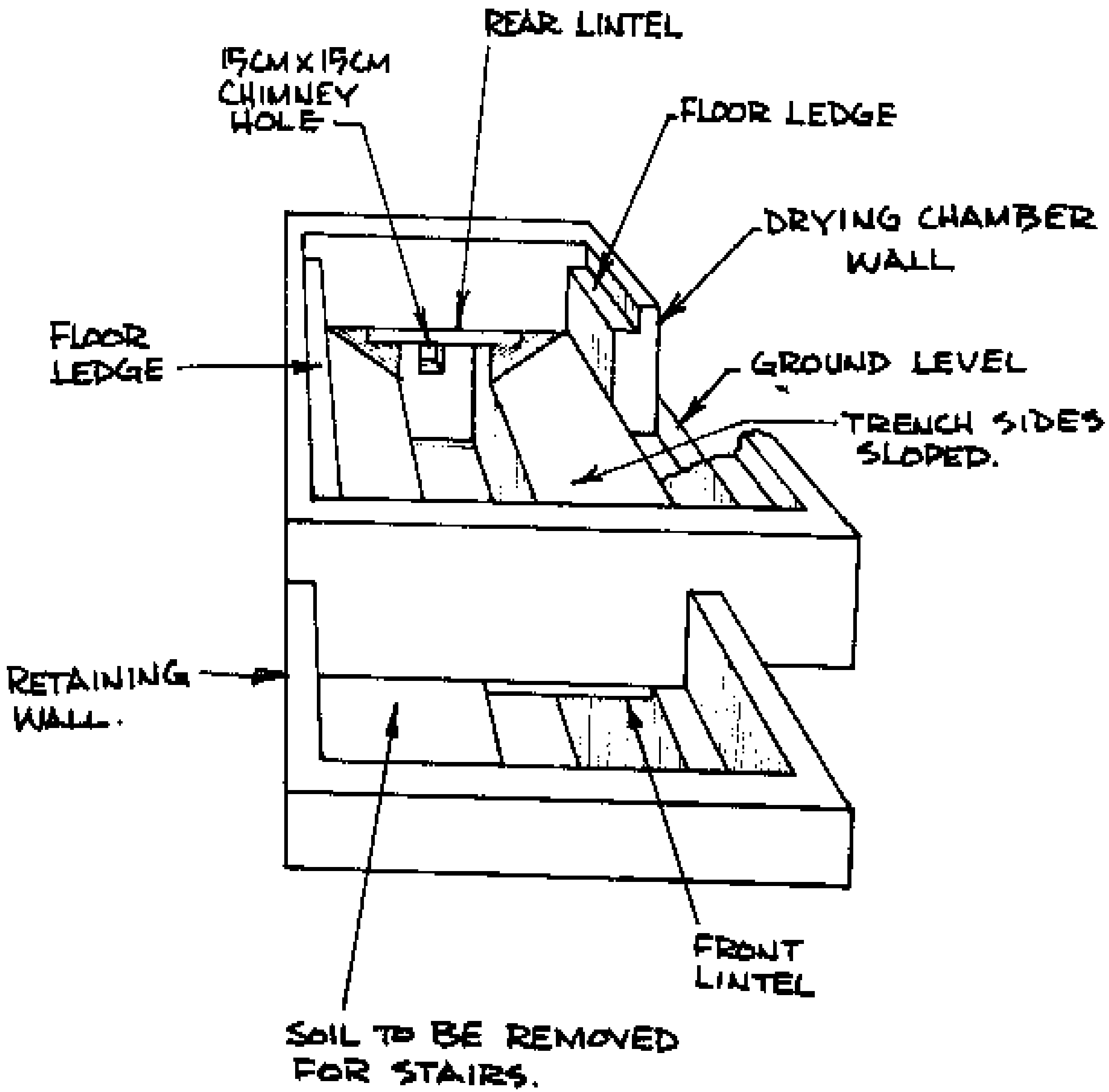
51ap81.gif (600x600)


75 CM
GROUND LEVEL
30 CM
FRONT WALL
FRONT LINTEL
SOIL
70 CM
TRENCH FLOOR
LINTELS MAY SINK A LITTLE ON THE WET BANCO MORTAR AS YOU BUILD THE WALL
20 CM WIDE CHICKEN WIRE EMBEDDED 10CM INTO WALL.
30 CM
10CM
GROUND LEVEL
WALL
25cm
45 CM
BEFORE WALLS ARE MUCH ABOVE GROUND LEVEL REMOVE DIRT
SOIL
TRENCH FLOOR



<FIGURE 82>

51ap82a.gif (600x600)



10. Build a retaining wall around the stoking pit.

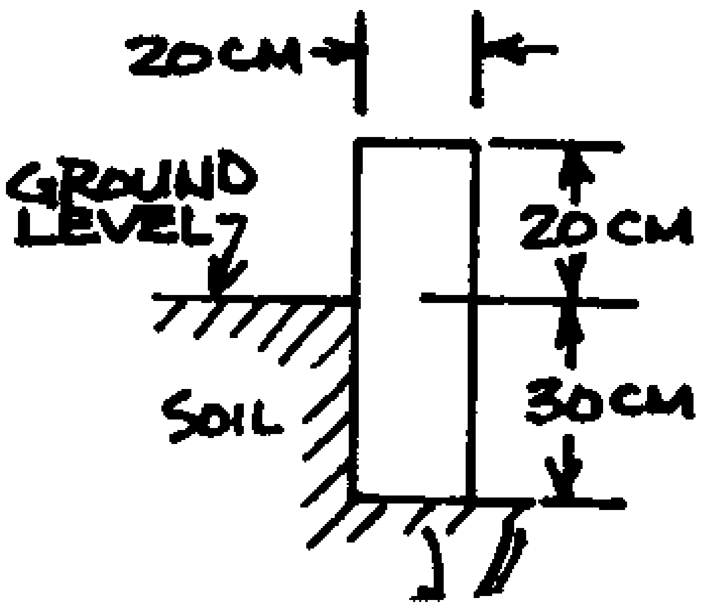
*** The retaining wall protects against erosion and will keep dirt and trash from falling into the pit.**

*** Build the retaining wall up from the floor of the original 30cm deep pit that you have dug out. Build it on three sides of the stoking pit area. The fourth side is spanned by the front wall of the drying area.**

*** Make it 20cm thick. The front wall of the stoking pit will fit exactly on the 20cm ledge you left at the front end of the 140cm deep trench that extends down the center of the dryer and stoking pit.**

<FIGURE 83>

51ap82b.gif (393x393)



* Build all three sides 50cm up from their base. This will bring them 20cm above ground level.

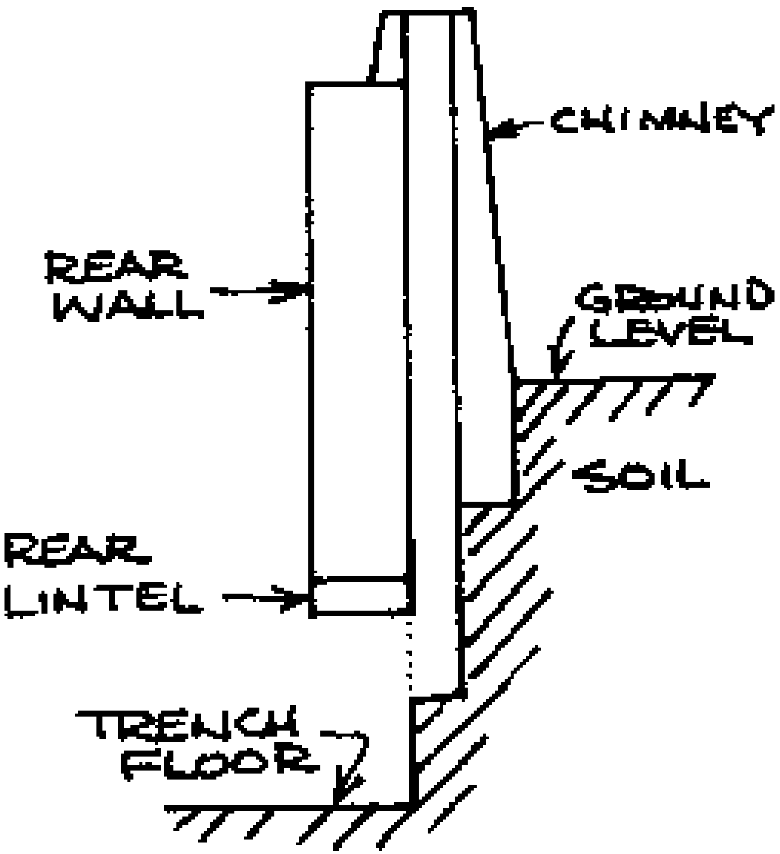
11. Build the chimney.

* Build the chimney walls out of banco up from the bottom of the larger, top hole you have dug out at the end of the dryer. The inside faces of the chimney

walls should be flush with the sides of the lower, smaller hole that is dug into the bottom of the top hole.

<FIGURE 84>

51ap83a.gif (437x437)

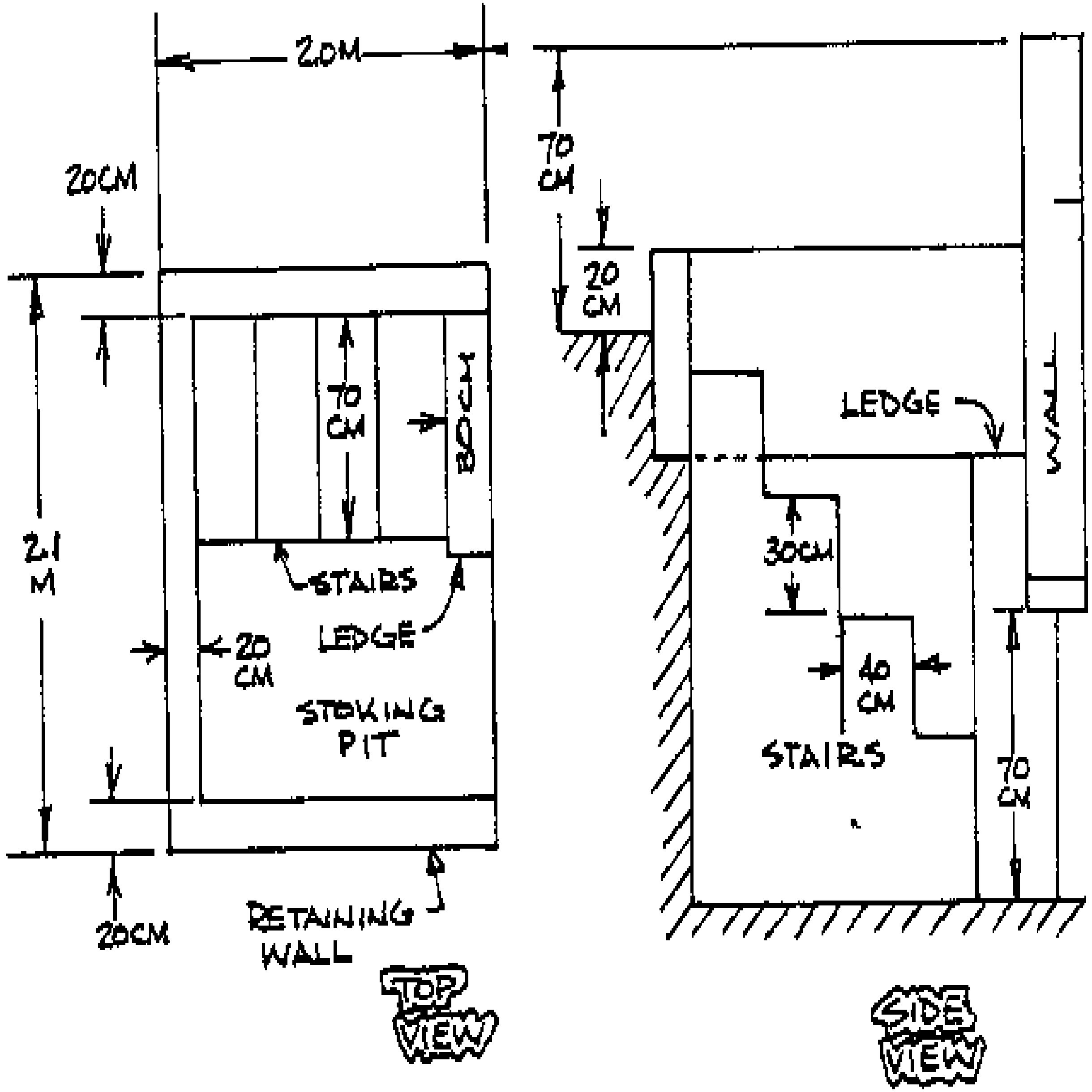


* Extend the chimney 20cm higher than the top of the back dryer wall. As you build upwards, gradually narrow the inside passage of the chimney until it measures about 10cm x 10cm at the top. This will help reduce heat loss.

12. Finish the stoking pit.

<FIGURE 85>

51ap83b.gif (600x600)



* You may excavate any dirt that is left in the stoking pit so that the dirt walls in the front and opposite the stairs

are flush with the inside surfaces of the retaining wall which rests on them.

* Cut stairs in the dirt next to the stoking pit. Make four equal steps each 30cm high and 40cm across.

* Leave a ledge 30cm thick between the lowest step and the front dryer wall, to help brace the dryer wall.

13. Assemble and place the firebox barrels.

* Cut both ends from two 220 litre barrels.

* Cut one end from a third barrel. Cut a hole 20-30cm across near the edge of the other end of this barrel. This will be placed up against the opening at the bottom of the chimney.

* Punch four evenly spaced holes around the rim of each barrel where it will join another barrel.

* Join the three barrels together by tying pieces of heavy wire through the punched holes.

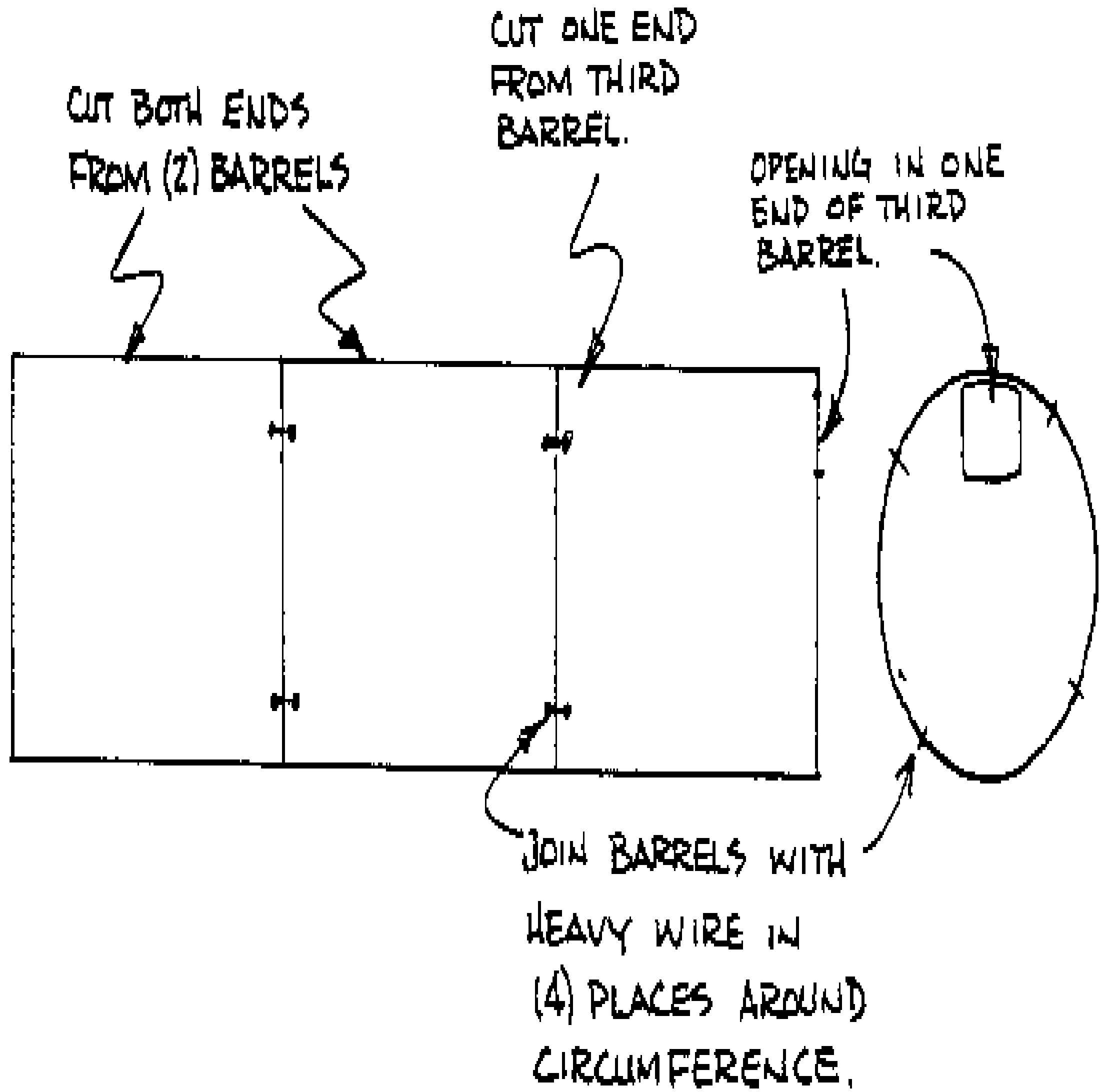
* Locate the barrel assembly in the trench with the small hole in the end of the third barrel placed up against the bottom opening of the chimney.

* Support the barrels on bricks about 10cm above the bottom of the trench. Incline them slightly upwards towards the chimney

for easier smoke escape. This will allow air to circulate all around the barrels and will also prevent rusting.

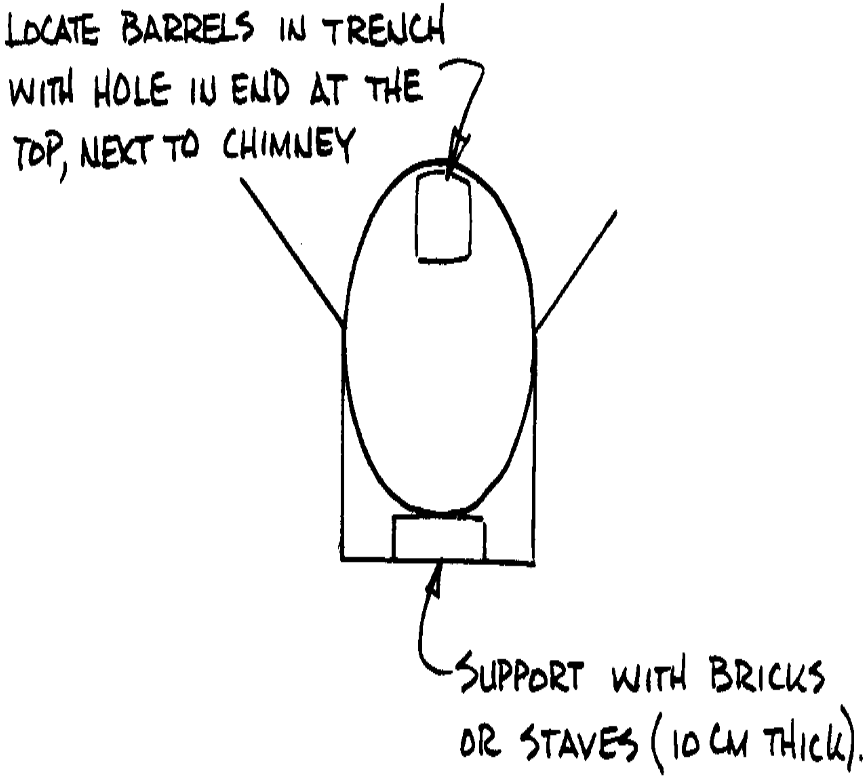
<FIGURE 86>

51ap84.gif (540x540)



<FIGURE 87>

51ap85a.gif (437x437)



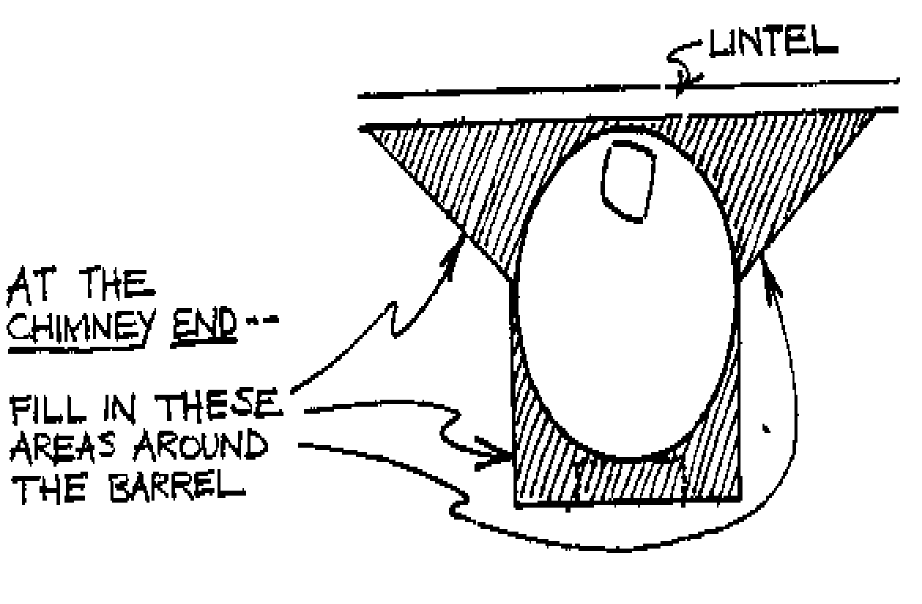
* Seal the joints between the barrels by placing a strip of screening around them and plastering with a mixture of mortar (1 part cement to 8 parts sand).

* Close the trench around the barrel assembly ends under the lintels with banco. Make sure you seal completely around the barrel at the chimney end to prevent any smoke "backflow". Close the front end of the barrel assembly only around the top of the barrel to let cool air enter the drying chamber -- this cool

air is warmed and will rise up through the drying floor and grain.

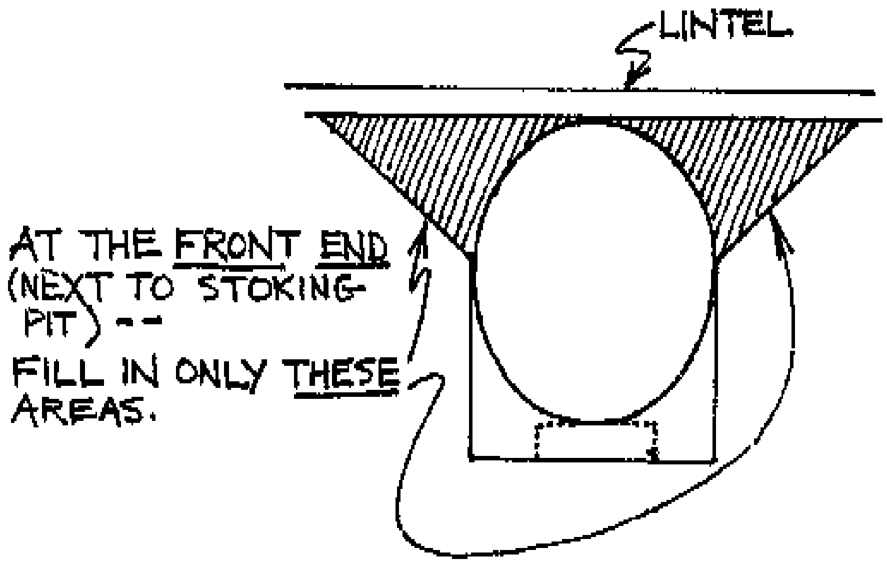
<FIGURE 88>

51ap85b.gif (285x437)



<FIGURE 89>

51ap86a.gif (285x437)



* Test the seals at the joints. Light a smoky fire and see if smoke escapes into the drying chamber. Do not let it burn long enough to dry the mortar on the joints. Keep the mortar damp until it is hard.

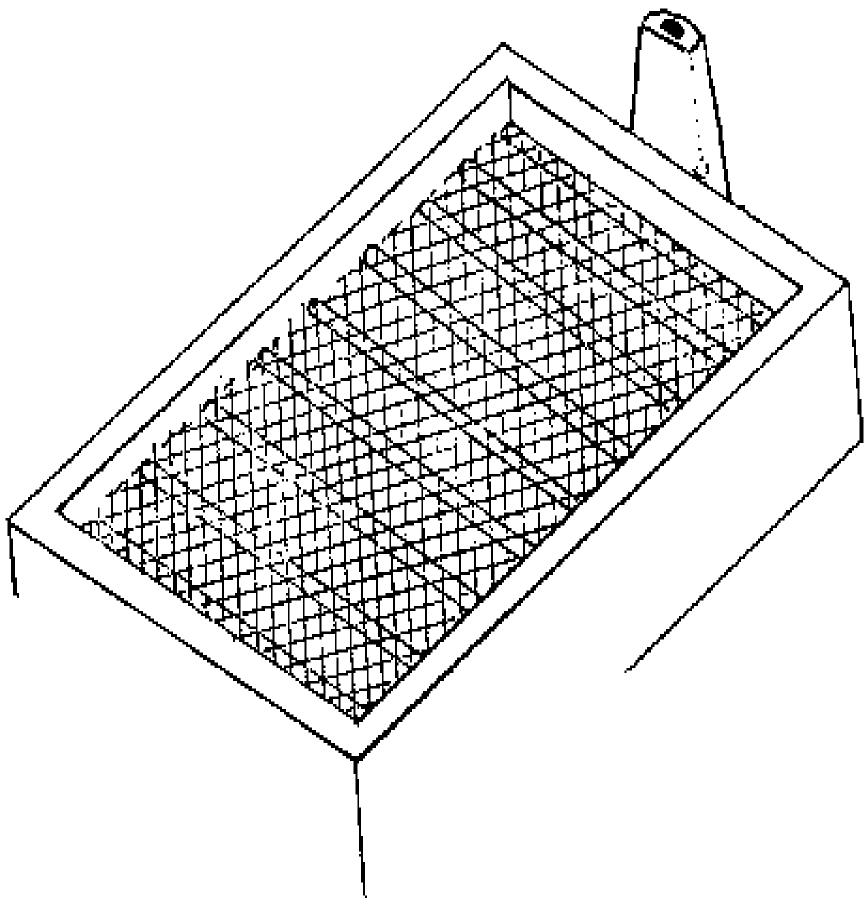
14. Assemble the drying floor supports.

* Use 10 logs of solid wood. The logs should be 8-10cm in diameter and 2.15m long.

* Space the logs evenly across the drying chamber from one end to the other. The log ends will rest on the 15cm ledges in the side walls. Resting the logs on the ledges instead of fixing them in place means they can be replaced more easily if they weaken.

<FIGURE 90>

51ap86b.gif (437x437)



15. Place and fasten screening on top of the log supports.

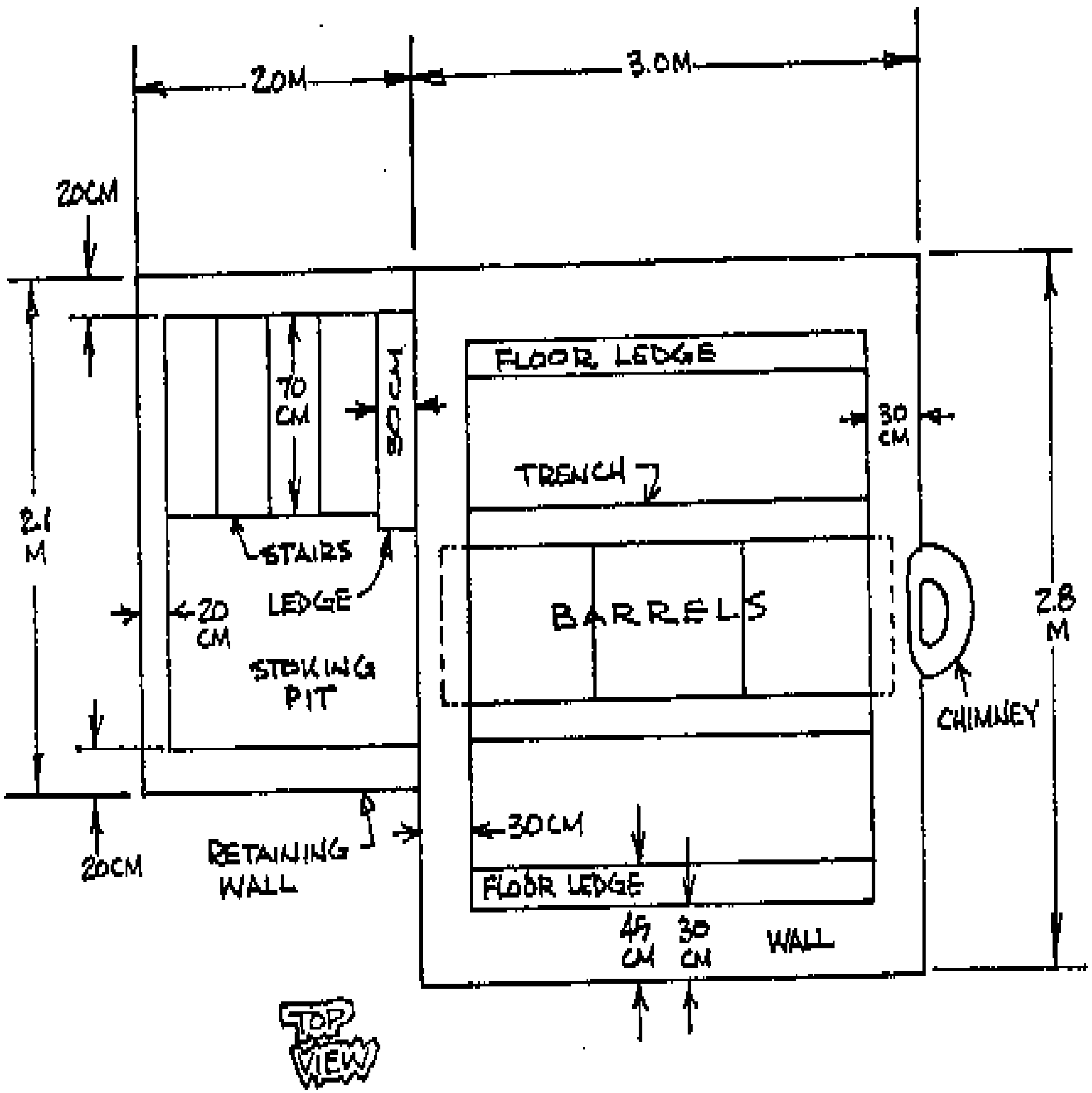
*** Stretch screening across the logs and attach it to the 10cm of wire mesh sticking out from each wall. Make the screening longer than the inside length of the chamber because**

the weight of grain will make the screen sag between the logs. Overlap all sections 5 or 10cm and fasten together with thin wire.

* Small mesh screen is best. But chicken wire can be used. Place straw mats over chicken wire, or other large-hole screen, to keep grain from falling through the holes. Some kinds of woven mats are very strong. These can be used in place of screening. Fasten woven mats to wire mesh strips embedded in the walls the same as you would metal screen.

<FIGURE 91>

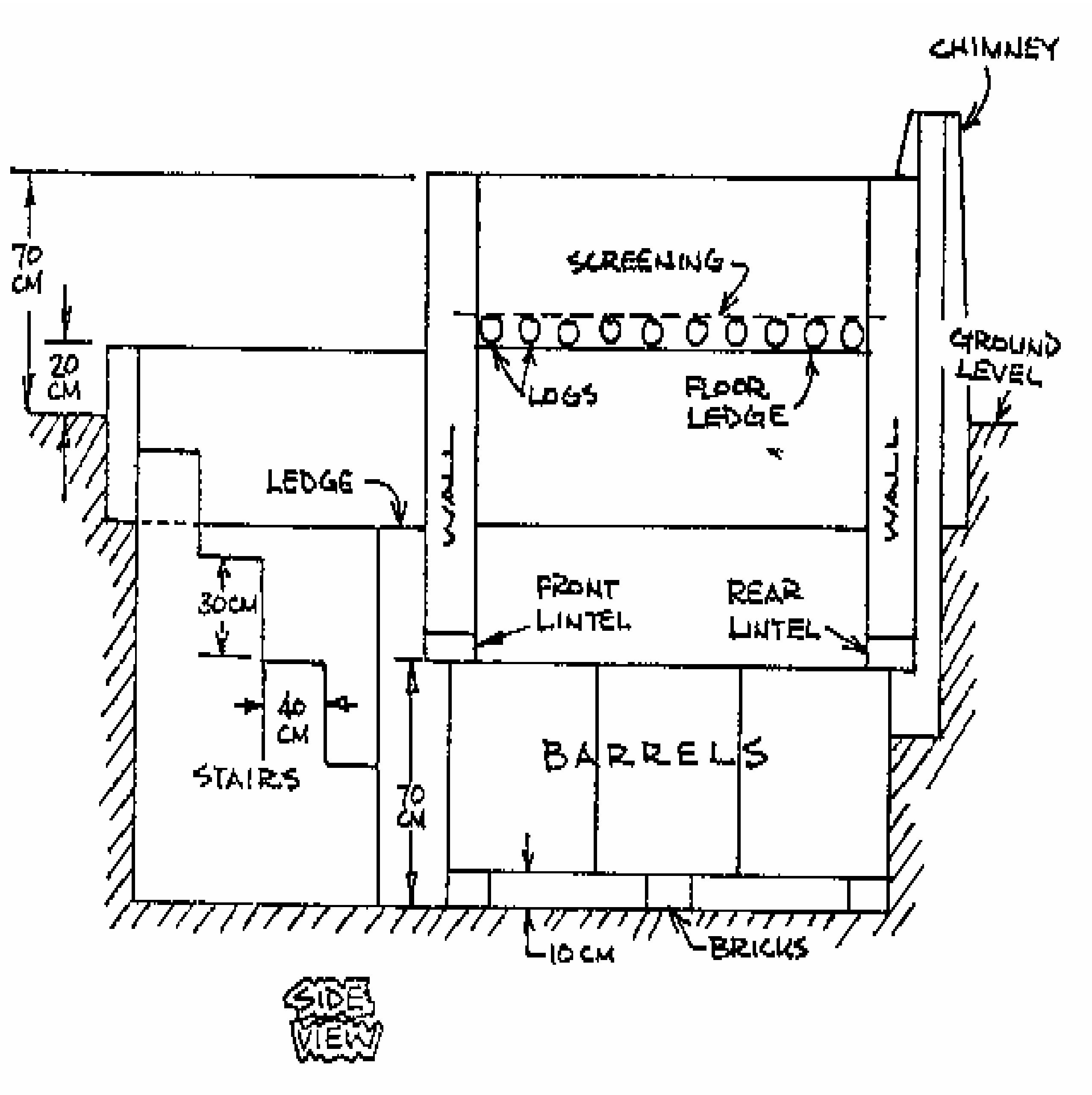
51ap87.gif (600x600)



2.0M
3.0M
20CM
70 CM
80 CM
30 CM
FLOOR LEDGE
TRENCH
2.1 M
STAIRS
LEDGE
20 CM
STOKING PIT
BARRELS
2.8 M
CHIMNEY
20CM
RETAINING WALL
30CM
FLOOR LEDGE
45 CM
30 CM
WALL
TOP VIEW

<FIGURE 92>

51ap88.gif (600x600)



PHILIPPINES RICE DRYER

Scientists working in the Philippines and other rice-growing countries have discovered new kinds of rice seed which grow more quickly. This means the crop is ready for harvest sooner; often a farmer can plant and harvest two crops in the time it used to take for one crop.

However, because the growing time is shorter, the rice is ready for harvest during the rainy season. Before, the rice would not be ready until the rains were finished. The farmer must harvest, but he cannot dry his grain outside in the sun. The problem he faces is simple, and it is a problem for farmers all over the world who must harvest during wet or humid times: how to get the grain dry before it is ruined by insects and molds.

Scientists working at the University of the Philippines and the International Rice Research Institute in Manila, Philippines, have come up with answers. They have designed two versions of a dryer model they feel is relatively inexpensive, simple to make, easy to operate and maintain. We call it here the Philippines Rice Dryer. Each version of this dryer will be discussed separately.

There are advantages and disadvantages to the use of this dryer by small farmers. Advantages are:

* It can be used in the rainy season.

* It uses less fuel than the oil barrel dryer because the fan forces air through the grain and decreases drying time.

Disadvantages:

*** It requires construction using relatively sophisticated materials, tools, and skilled labor.**

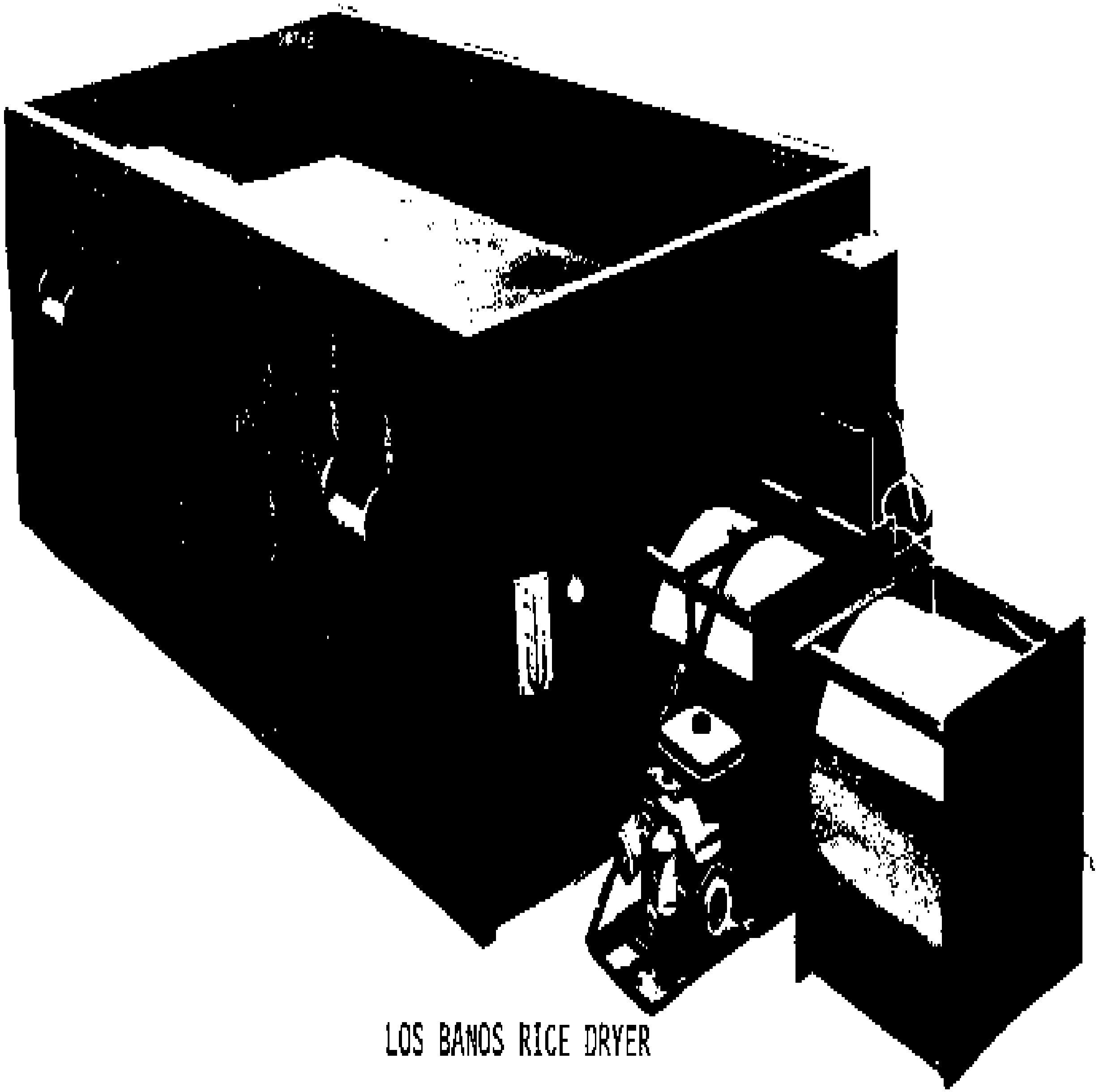
*** It burns fuel which can be costly.**

*** It requires finding and paying for special machinery.**

*** It is practical only for wealthier farmers or a group of farmers.**

<LOS BANOS RICE DRYER>

51ap90.gif (600x600)



LOS BANOS RICE DRYER

The first rice dryer is from the Grain Processing Program of the Department of Agricultural Engineering at Los Banos, Philippines. It has three main parts: a bin which holds the grain (placed on sheet metal with holes) over a container of hot air (plenum); a fan to force air from the plenum through the grain; and a burner to heat the drying air.

A brief description of the major parts of the Philippines Rice Dryer:

Grain holding bin

* Floor area is 1.8m x 3.6m.

* 2cm plywood.

* 5cm x 5cm lumber.

* Perforated sheet metal (sheet metal with holes).

Blower

* 58cm fan adapted from truck radiator fan.

* Pushes 8.5 cubic meters per minute of air against a total pressure of 2.5cm water column.

* Size of the blower is chosen to fit the size of the grain bin.

* No stirring is necessary.

* Mount fan with flange bearings, sheet metal housing.

Reinforce with angle bars.

Engine

* 5 hp gasoline or diesel engine.

* V-belt and pulley.

* A power tiller which has an 8 hp engine can be used.

Burner

* 43 [degrees] C recommended temperature so as not to damage milling quality.

* Developed direct flame kerosene burner. Consists of 3-part iron casing, needle valve between burner and housing, and a double shell sheet metal housing. Uses 1.5 litres of fuel each hour.

Other items

* V-tube manometer to read air pressure at plenum and to set engine throttle.

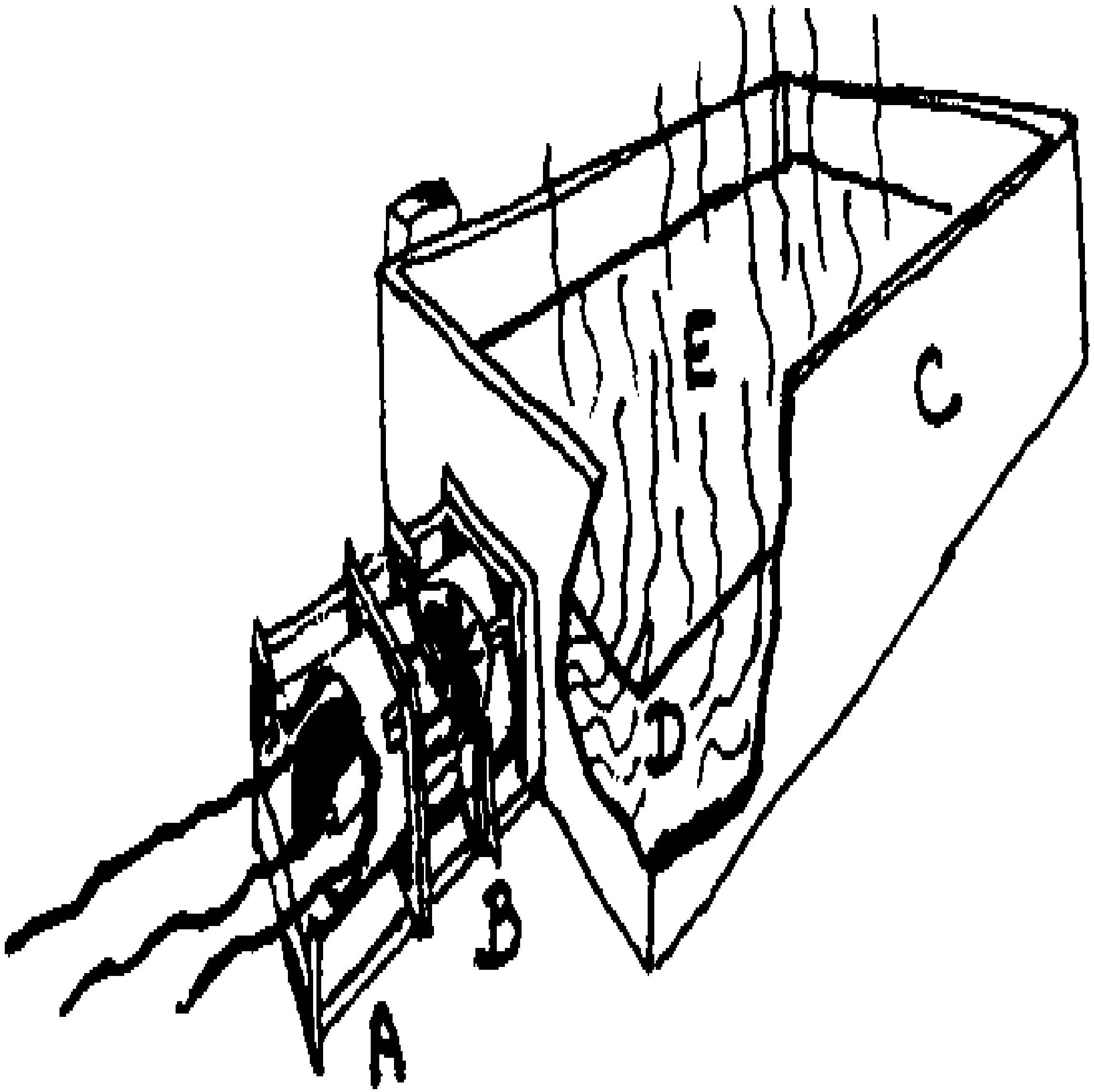
* Dial thermometer to show drying air temperature.

A. Kerosene Burner
B. Fan and Engine

C. Grain Bin
D. Plenum
E. Perforated Metal Floor

<FIGURE 93>

51ap91.gif (600x600)



Notes on Operation of the Dryer

* It takes 2 men an hour to assemble the dryer. This is the final putting together of the pieces. This is the time it takes if the grain bin is already made and all the parts are ready to assemble.

* The dryer must be used under a shed to protect it and the grain from rain.

* The bin holds about 1700kg.

* The manometer is a guide to engine speed: a 2.5cm displacement of the water column shows the engine setting is correct.

* The temperature of the air for drying is adjusted by controlling the flame through the needle valve and by adjusting the distance between the burner housing and the fan intake.

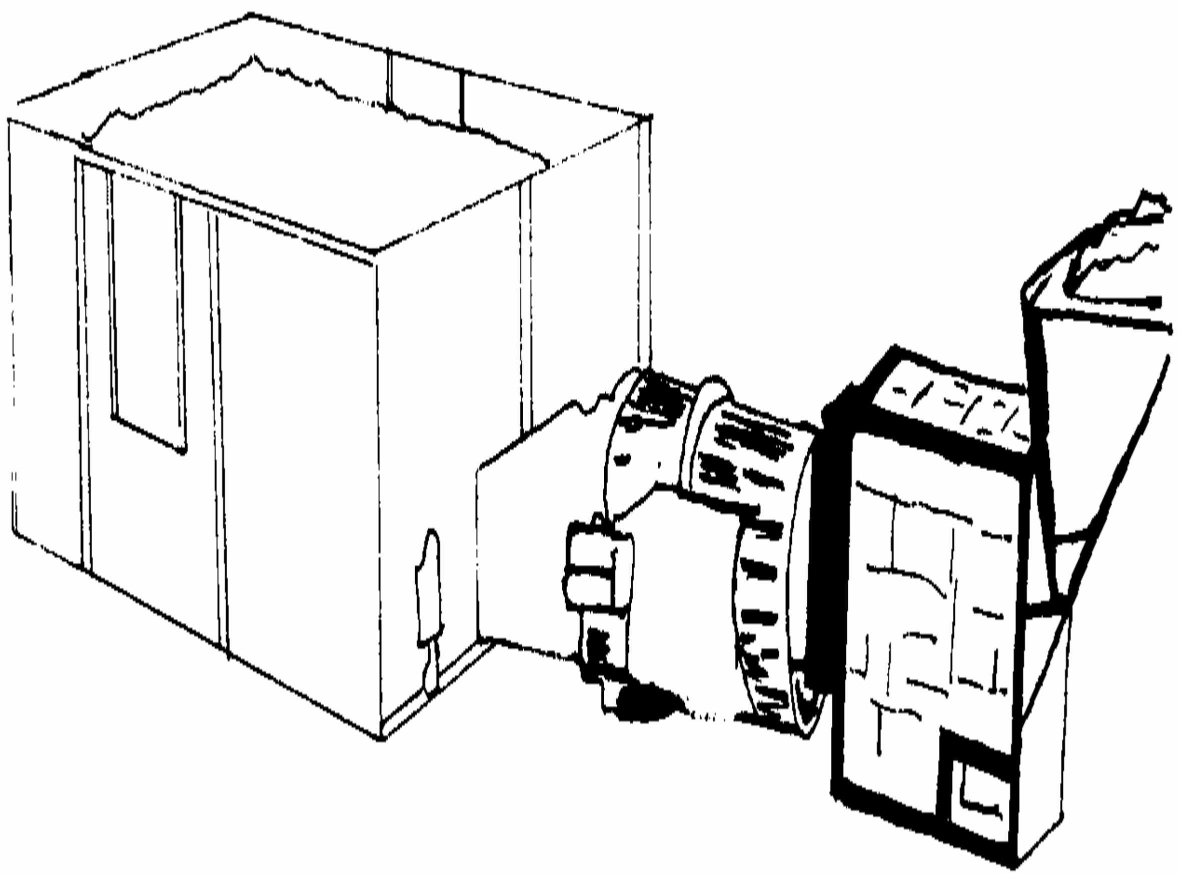
* Drying continues until the top layer of grain is at 14% moisture. (It will take about 8 hours of steady drying to bring moisture down from 26% to 14 or 13%.)

For detailed technical bulletins describing construction and use of the Philippines Rice Dryer contact:

The Project Director
Training of Technicians for Grain Industries
Department of Agricultural Engineering
University of the Philippines at Los Banos
Laguna, Philippines

<IRRI BATCH DRYER>

51ap92.gif (600x600)



IRRI BATCH DRYER

The IRRI Batch Dryer is different from the early University of the Philippines model in 2 important ways:

1. It can use a self-feeding rice hull burner instead of gas or kerosene. This burner uses 3-4kgs of rice hulls per hour or 25kg per ton of rice dried. One ton of rice contains 200kg of rice hulls, so there are plenty of hulls to feed the burner. In other words, one ton of paddy produces enough hulls to dry that same ton of rice kernels.

2. The fan used is a 47cm diameter vane-axial type rather than varying sizes and models of truck radiator plans. The use of a standard fan allows the operator to fix standard drying times.

Other notes on the IRRI Batch Dryer

* Drying capacity is 1 metric ton. It can dry this amount of paddy rice in 4-6 hours depending upon the initial moisture content of the grain.

* The oil burner uses a 3 hp gasoline engine (a 2 hp electric motor can be added to drive the blower). A kerosene burner is installed in the air duct.

* The rice hull furnace has a steel frame and is lined with fire bricks. It consists of a combustion chamber and an ash trap.

* Either heating arrangement can raise the drying air temperature from 29 to 43 [degrees] C at an air flow rate of 30-35 cubic meters of air/min/[m.sup.3] of grain.

* Fuel consumption for the oil burner is 0.75 litres per hour for the gasoline engine and 2.0 litres per hour for the kerosene burner.

* The rice hull furnace burns 3 to 4kg per hour of rice hulls.

This dryer, like the Los Banos Dryer, may be hard to put together: in some areas the materials may be expensive; in other places the equipment is hard to find. These facts make it hard for many small farmers to use such a dryer. A group of farmers, however, would be more likely to be able to use such a dryer cooperatively and profitably. And the dryer can be manufactured locally.

For more information and detailed engineering drawings, contact:

Agricultural Engineering Department
The International Rice Research Institute
P. 0. Box 933
Manila, Philippines

SOLAR DRYERS

PART ONE: CONSTRUCTION

INTRODUCTION

The following plans are based upon a construction manual written by James McDowell as a result of his experiences at the Caribbean Food and Nutrition

Institute in Trinidad. VITA technical artist George C. Clark has provided added illustrations, as well as a simplification of the building procedure of the Model #1 dryer.

McDowell's plans in turn were developed from the ideas and principles of Dr. J. Lawand and associates of the Brace Research Institute, McGill University, Quebec, Canada. Now with UNICEF in Kenya, McDowell has used the dryer to dry grain from 25% to under 12% moisture in one day or less.

Solar Dryers have several possible advantages

* There are no fuel costs.

* Sun drying time is reduced because the heat of the sun is made stronger by covering the drying grain with a double layer of clear plastic film.

* They can be used to dry other crops -- copra, cassava, fruits, vegetables.

There can be disadvantages also

* Temperatures in the dryer may build up to 65-80 [degrees] C. This means that grains such as rice, which crack at temperatures above 50 [degrees] C, or seed grains (which can be dried at temperatures no higher than 40-45 [degrees] C) can be damaged. A farmer has to watch the grain carefully, and, if no thermometer is available, will have to learn by trial and error.

* Dryers are most useful only at certain hours of the day and would be of limited use during long periods of rainfall or very cloudy weather.

NOTES ON THE SOLAR DRYER MODELS

The dryer models here were designed and tested for drying cereal grains, root crops, fruits, and vegetables. The dryer holds 8 to 11kg for each square meter of drying floor. Dryers of the size presented here will dry 18-24kg each day. If a farmer wants to dry more grain, he will have to make a larger dryer or build several dryers.

Instructions and sketches for three versions of a Solar dryer are given in the following pages. These dryers can be made from whatever materials are most available locally. The dimensions given here are for general guidance. You can change the length, width, or depth of these dryers without affecting their efficiency.

The sketches for Models 1 and 2 are based on a useful, practical working size of 2m in length, 1m in width, and 23-30cm overall depth. But changes in area can be made to suit local conditions, and dimensions of materials available. IMPORTANT: The only dimension which should be followed as closely as possible is the thickness of insulation on the Model 1 box-type dryer. Where wood shavings, wood wool, dried grass, leaves, or similar material are being used, a minimum thickness of 5cm should be used. Also, the internal depth of Models 1 and 2 should not be less than 15cm.

MODEL # 1 SOLAR DRYER

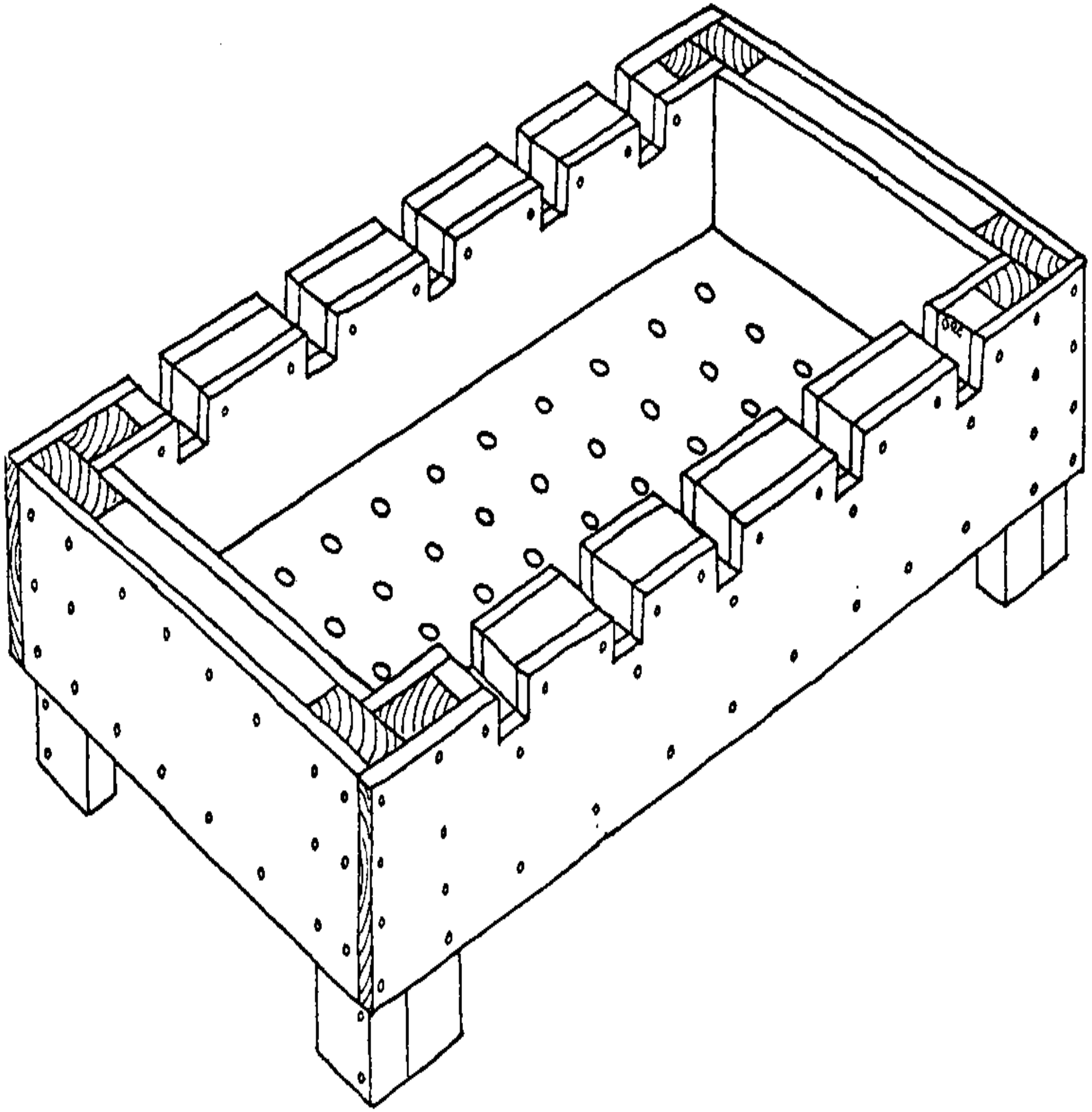
Description

This model consists of an outer box and an inner box. The inner box is at least 10cm less in length and width, and at least 5cm less in depth than the outer box. The space between the boxes is packed with suitable insulating material.

Lower air holes are drilled through the bottom of the boxes (and through spacer boards fitted in the insulation space for this purpose). Slots are cut in the upper edges of the sides of the box to provide upper air outlets. The dryer is supported about 15cm above the ground on four legs (which also form the main corner members for the box)

<FIGURE 94>

51ap97.gif (600x600)



READ THE INSTRUCTIONS THROUGH BEFORE YOU BEGIN

Tools and Materials

* Hammer, screwdriver, tri-square, saw, brace, and 2.5cm wood drill, 2cm wood chisel.

* Wooden planking or plywood for Sides, ends, and bottom of boxes. Use wood from old packing cases if it is available.

* Lengths of timber:

4 pieces 5 x 10cm for legs
4 pieces 5 x 5 cm for legs
13 pieces 5 x 5 cm for the side, end, and bottom spacer strips.

* Insulating material: wood wool, dried grass or leaves, coir fibre, etc.

* Nails and screwnails of appropriate size.

* Flat or matt-black paint or other suitable black staining material, e.g., charcoal, that is not shiny or glossy.

Build the Inner Box

* Check all measurements and markings on the wood before cutting.

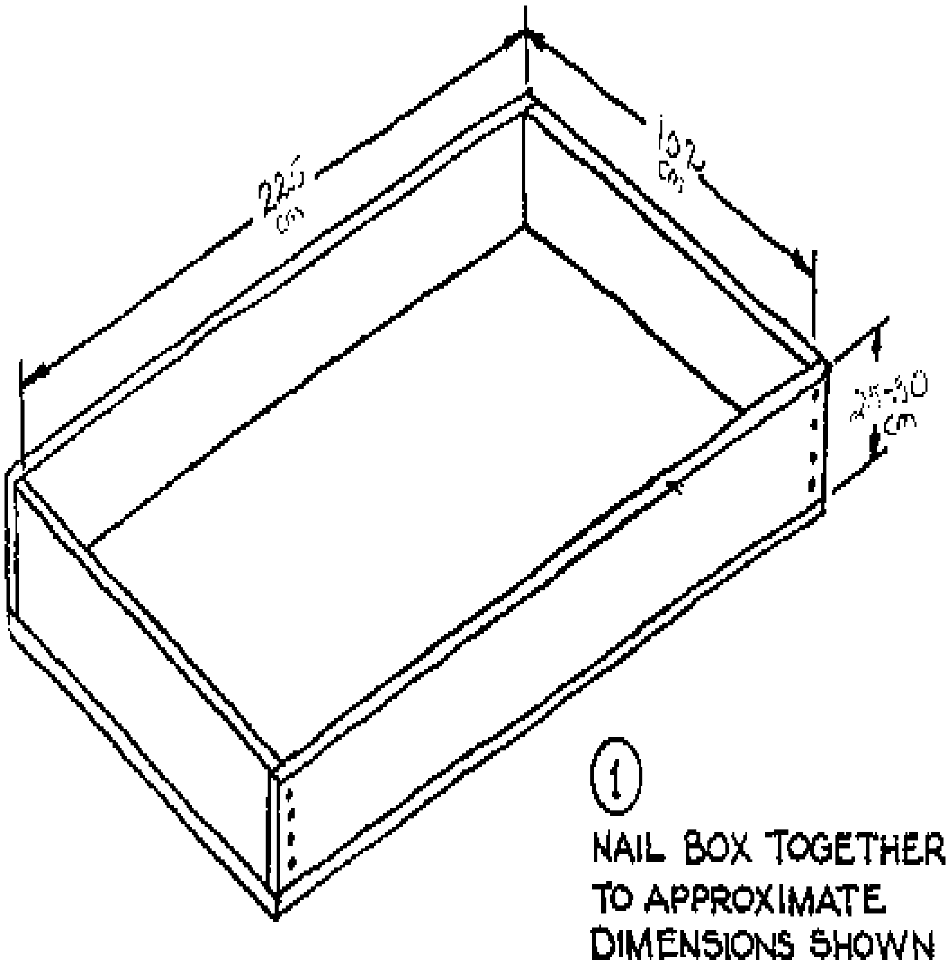
* Cut side and end pieces. These can be one piece of wood, or

you can join narrower planks together to make a box about the right size.

* Put the pieces together. Make sure the nails are completely hammered into the wood.

<FIGURE 95>

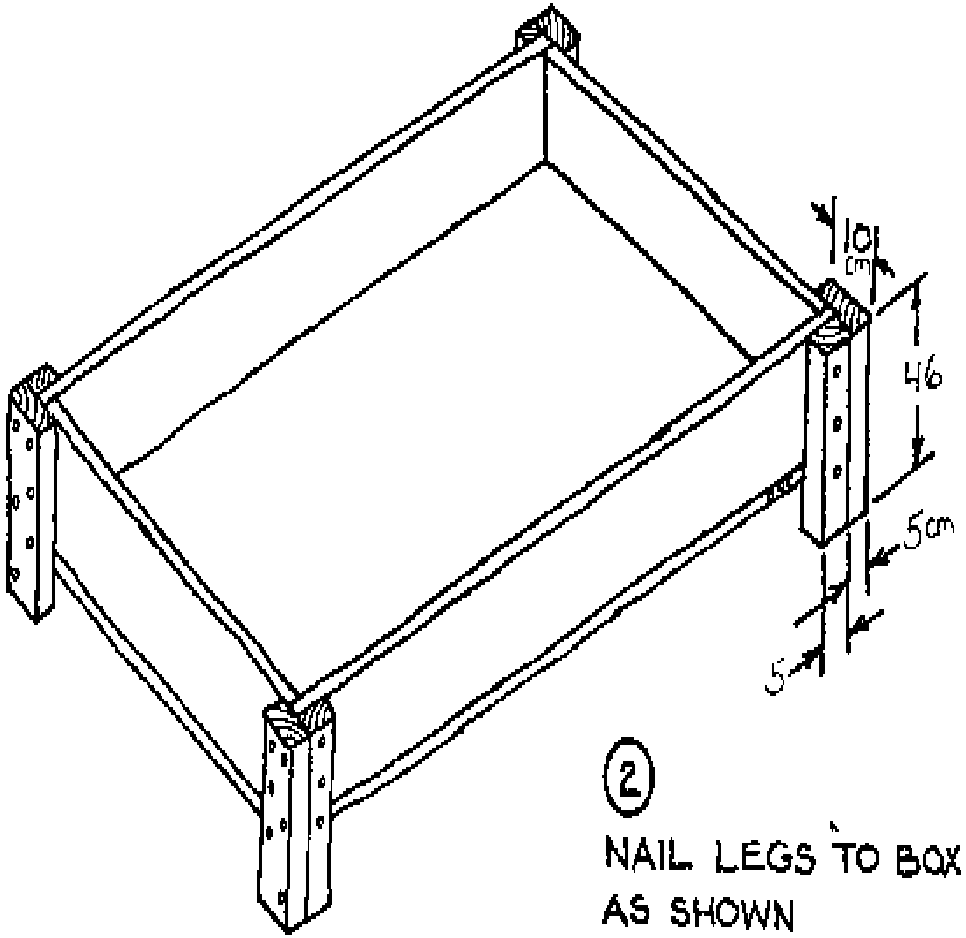
51ap99a.gif (486x486)



* Cut and nail the leg pieces to the corners as shown.

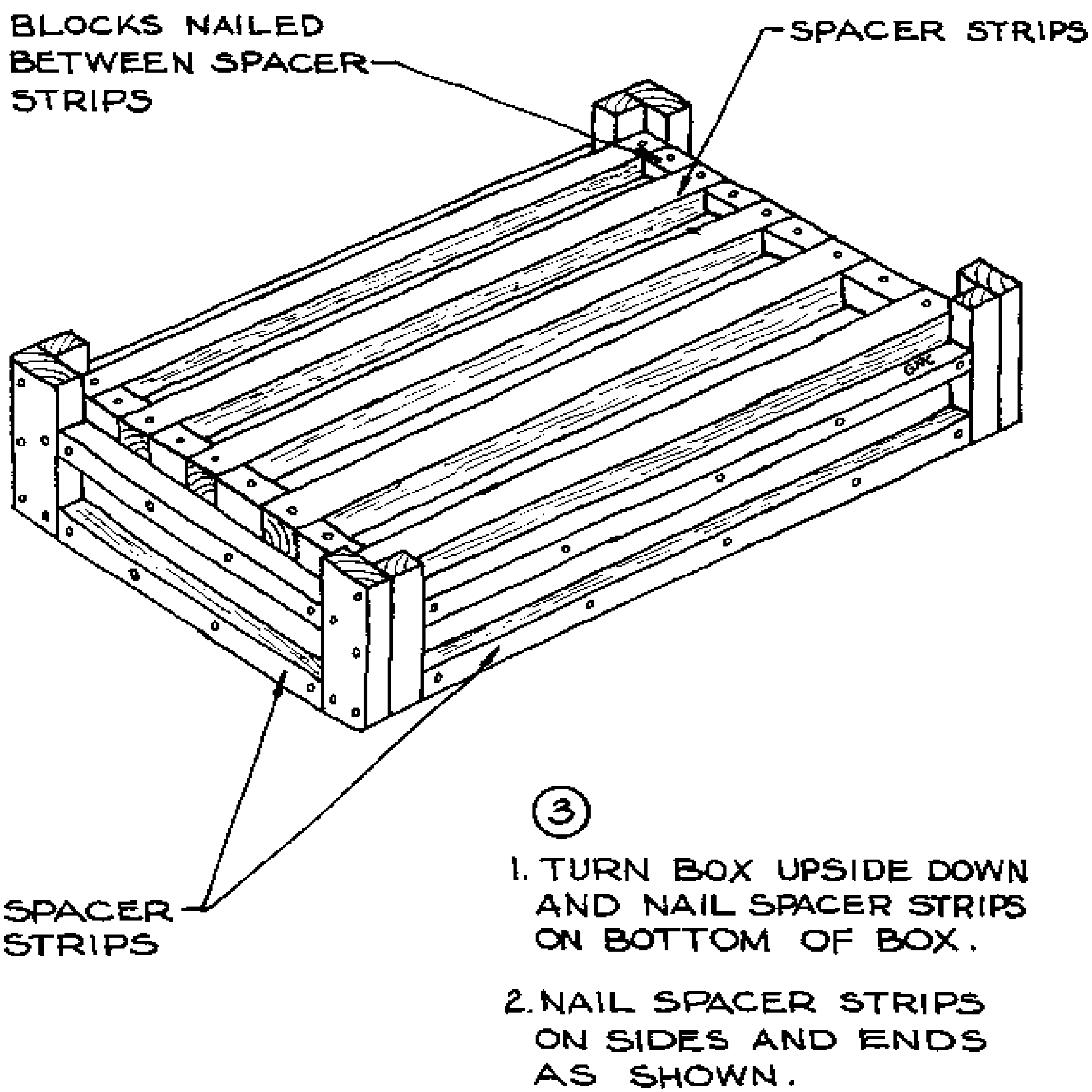
<FIGURE 96>

51ap99b.gif (486x486)

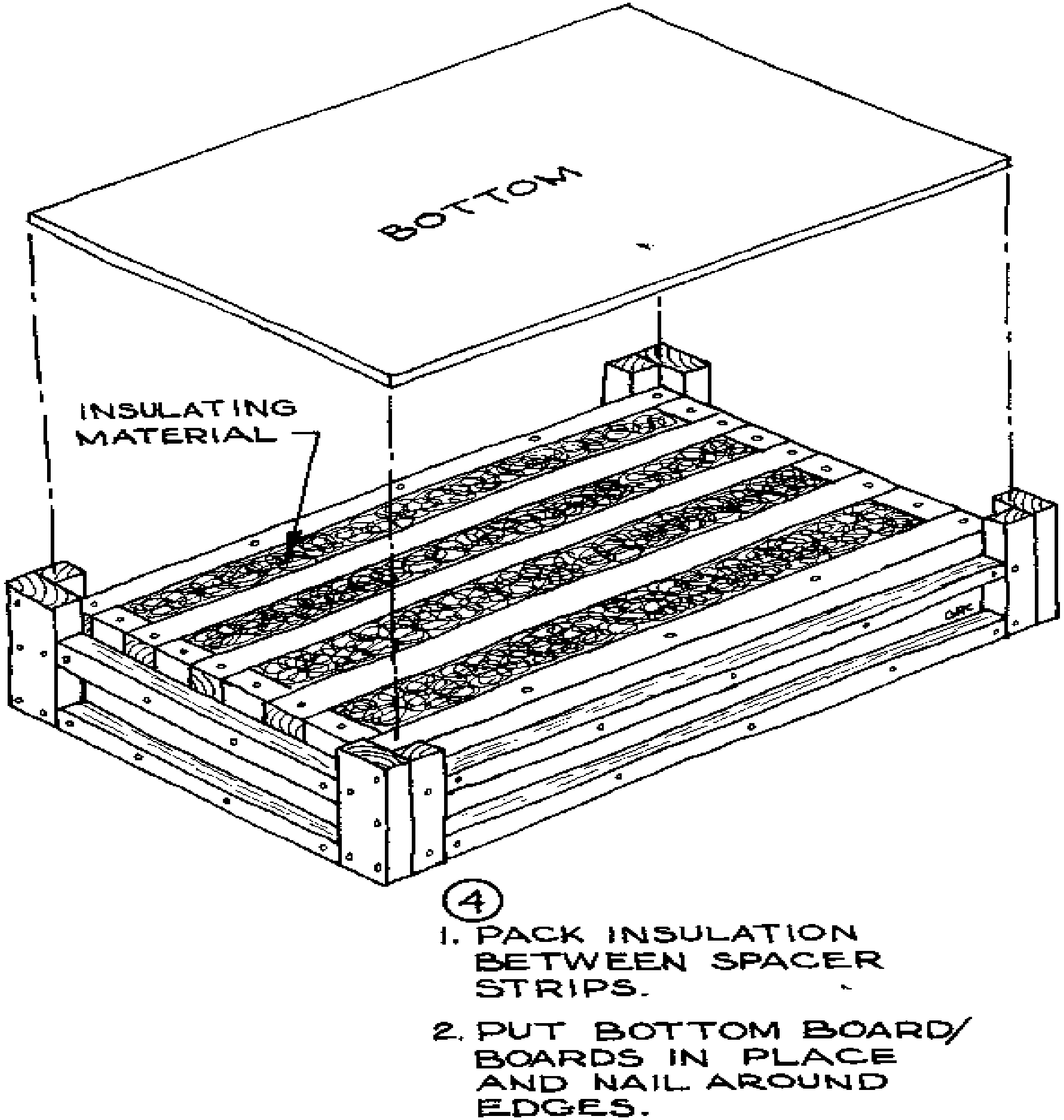


<FIGURE 97>

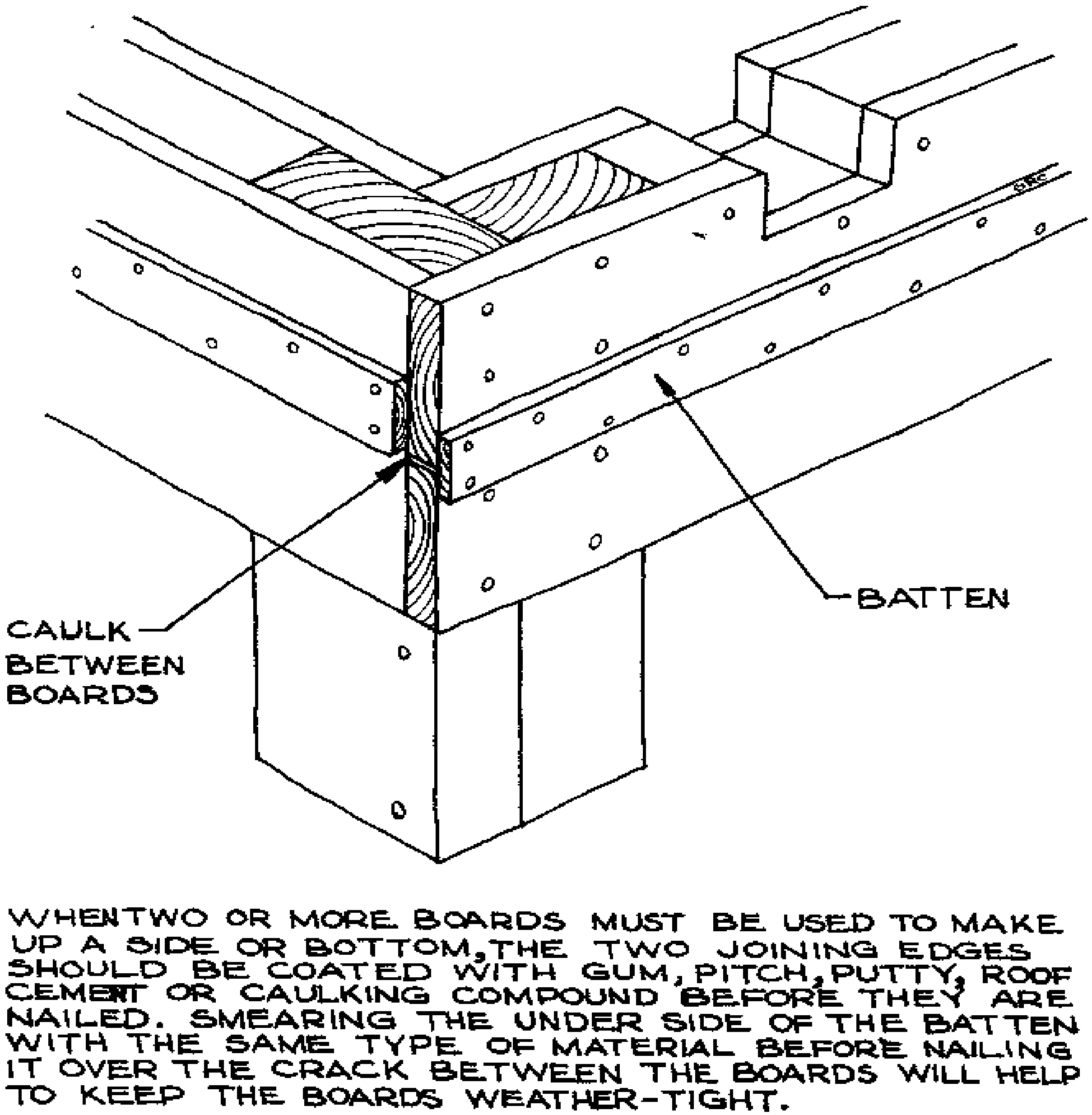
51ap100.gif (600x600)



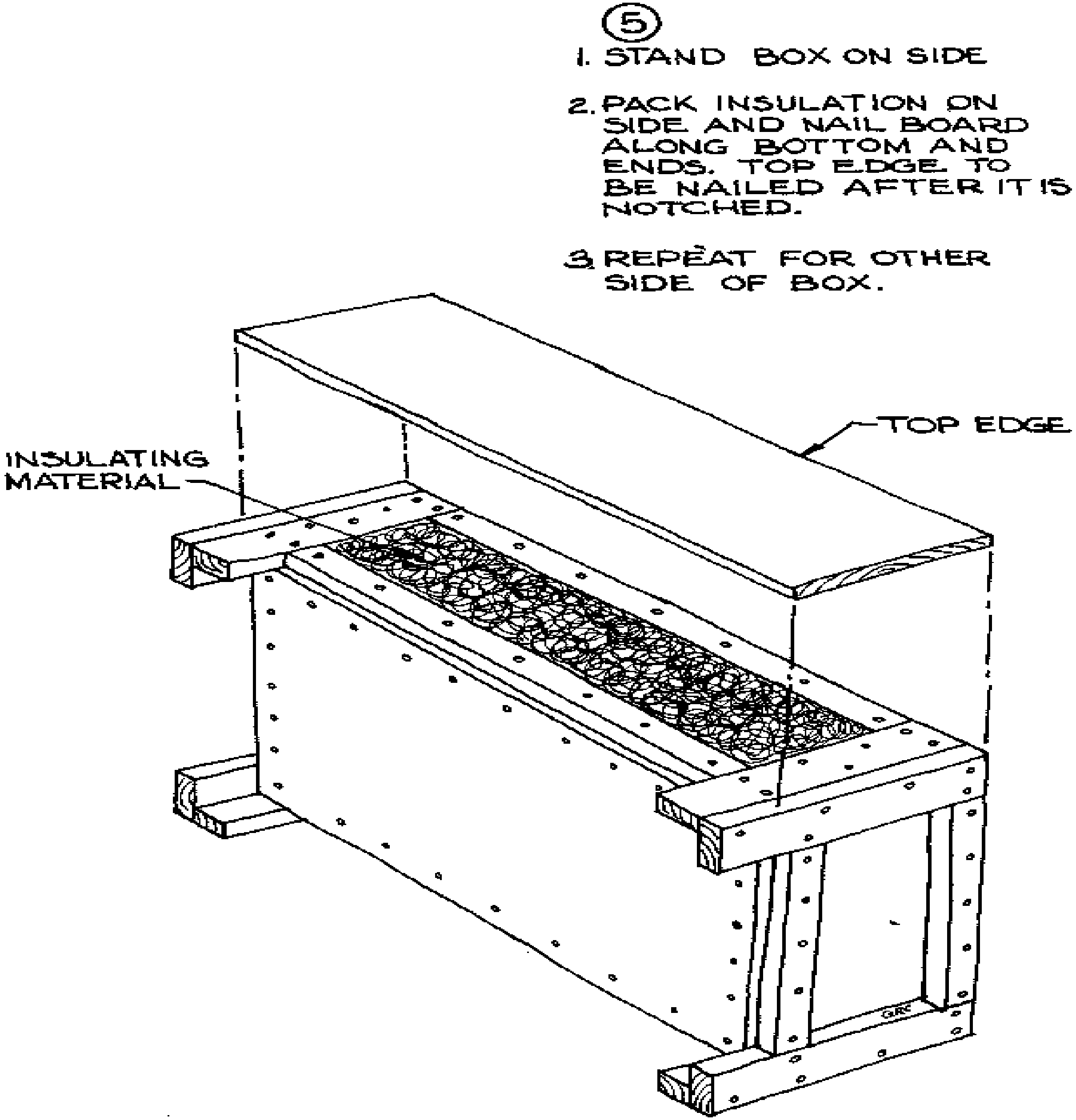
51ap101.gif (600x600)



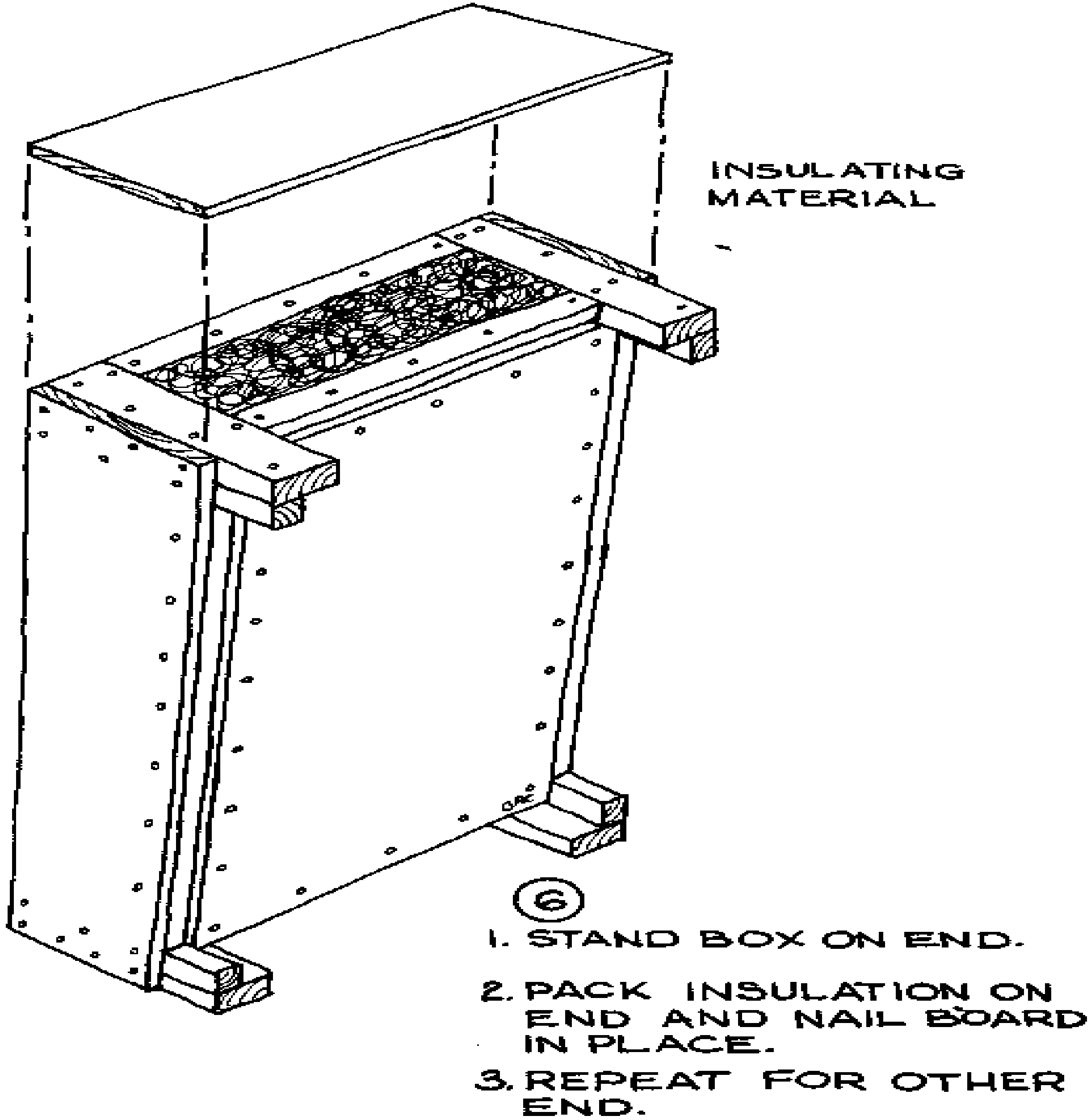
51ap102.gif (600x600)



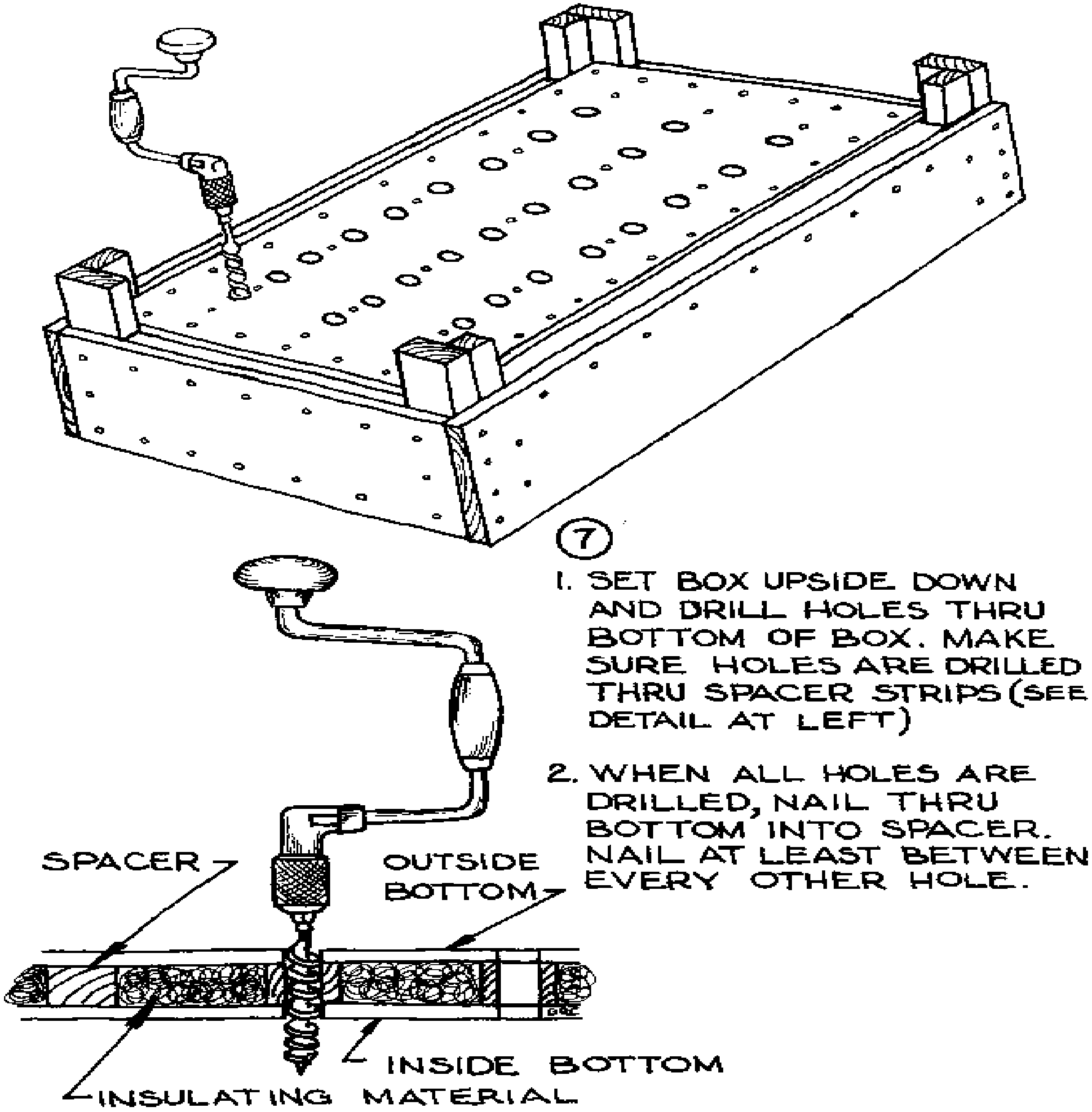
51ap103.gif (600x600)



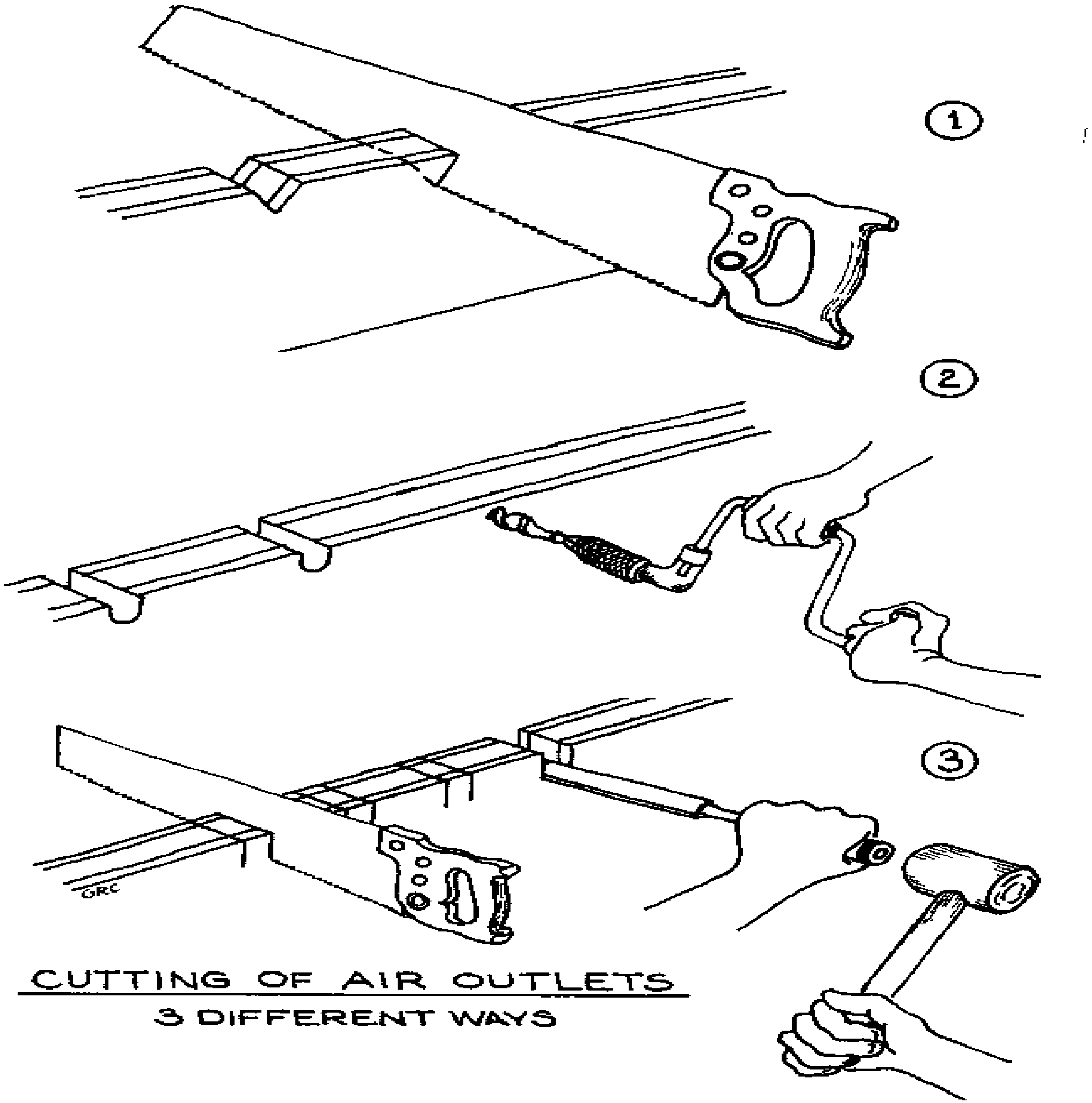
51ap104.gif (600x600)



51ap105.gif (600x600)



51ap106.gif (600x600)



<FIGURE 98>

<FIGURE 99>

<FIGURE 100>

<FIGURE 101>

<FIGURE 102>

<FIGURE 103>

* Make the air outlet slots.

- Mark the position of the air outlet slots on the upper sides.

- Cut out the slots in any of the three ways pictured.

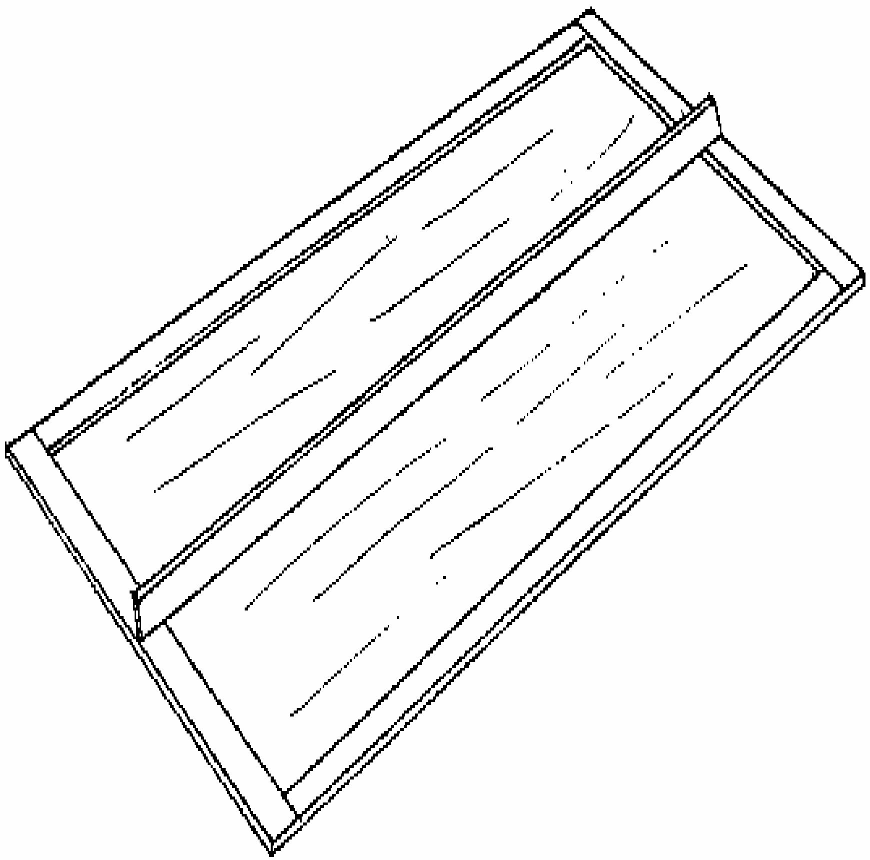
* Paint or stain the inside of the box with a dark color. A flat black is good. It is a good idea to put a wood preservative on the outside if you have it. Then paint the outside with gloss paint or marine varnish -- if you can find them.

CONSTRUCT THE COVER (FOR MODEL 1 and 2 DRYERS)

The same cover is used for both dryers. It consists of a rectangular wooden frame with a central ridge piece. It is covered with a double layer of polyethylene film

<FIGURE 104>

51ap107.gif (437x437)



Tools and Materials

* Saw (preferably tenon saw), screw-driver, sharp knife or scissors, tri square, marking gauge.

* Lengths of timber: about 5cm x 2cm.

* Transparent plastic (polyethylene) film (preferably .127mm or heavier).

* Screws (1.6cm x 8s C.S.).

* Blued tacks (1cm) or large office stapler.

READ THE INSTRUCTIONS THROUGH BEFORE YOU BEGIN

Make the frame so that its length and width are each 8cm greater than the box to be covered. The cover will overlap the dryer box by about 4cm in each direction.

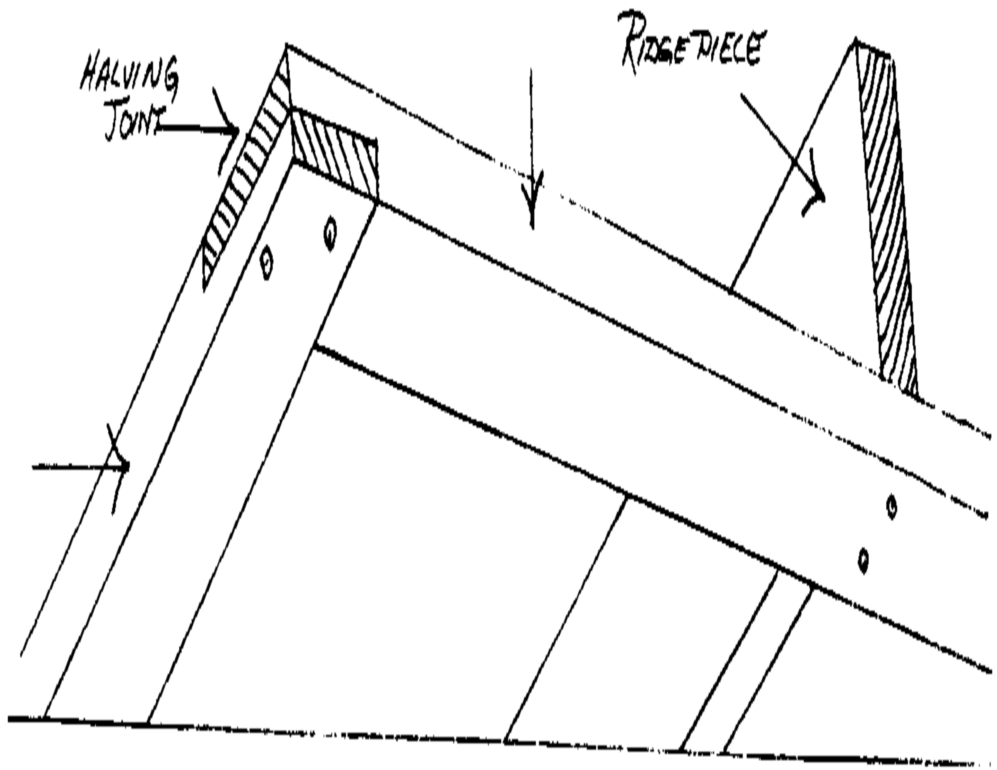
1. Make the Frame

* Cut the pieces for the frame to the right lengths.

* Put them together as shown.

<FIGURE 105>

51ap108.gif (486x486)



* Dry the frame in the hot sun before putting on the plastic.

2. Put the Lower Plastic Sheet on the Frame

* Put the cover on while the wood is still warm and at a time when humidity is low. These precautions are necessary to prevent condensation (fogging) between the

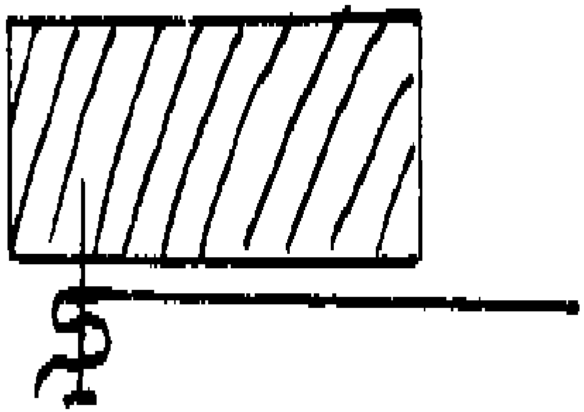
layers of polyethylene.

*** Cut a piece of plastic sheet for covering the lower side of the frame so that it is 8cm wider and 8cm longer than the frame.**

*** Turn the frame upside down and lay the plastic sheet in place. Fold one side of the polyethylene back on itself to form a triple layer seam 2cm wide.**

<FIGURE 106>

51ap108b.gif (317x317)



* Start at the middle of the frame and work toward both ends. Stretch the plastic lightly but firmly lengthwise. Tack or staple through the seam at 8cm intervals to fasten this edge of the polyethylene to the frame. DO NOT OVER-STRETCH THE PLASTIC. POLYETHYLENE WILL "GIVE" AND DISTORT IF FINGERTIPS ARE DUG INTO IT. SUCH DISTORTED AREAS ARE LIKELY TO BREAK THROUGH DURING USE. IT IS BETTER THAT POLYETHYLENE SHOULD BE SLIGHTLY LOOSE RATHER THAN OVER-STRETCHED.

* Repeat this process at the other side of the frame. Stretch the polyethylene across the frame while tacking or stapling.

* Fold similar seams at each end. Tack the ends of the

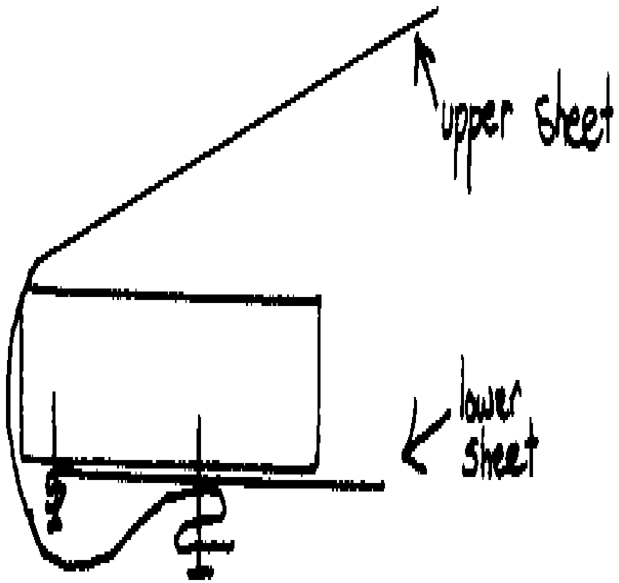
sheet to the frame. Tuck the plastic neatly at each corner. Fasten firmly in place.

3 Put the Upper Plastic Sheet on the Frame

*** Cut a piece of polyethylene sheet for covering the upper side. This sheet, when placed over the frame, should be 10cm wider and 10cm longer than the frame. Turn the frame upside down and, making a triple fold seam as before, tack or staple one edge to one side of the frame so that the seam overlaps the triple seam of the lower sheet.**

<FIGURE 107>

51ap109.gif (353x353)



* Stretch the polyethylene over the ridge and around to the lower edge of the other side member. Make a folded seam and tack or staple in place as before.

* Stretch the polyethylene over one end of the frame, fold and tack as before, cutting away any extra material resulting from the slope from ridge to side member. Tuck the corners of the sheet in neatly, and tack firmly in place. Repeat for the other end of the frame.

4. Attach the Covers to the Dryers

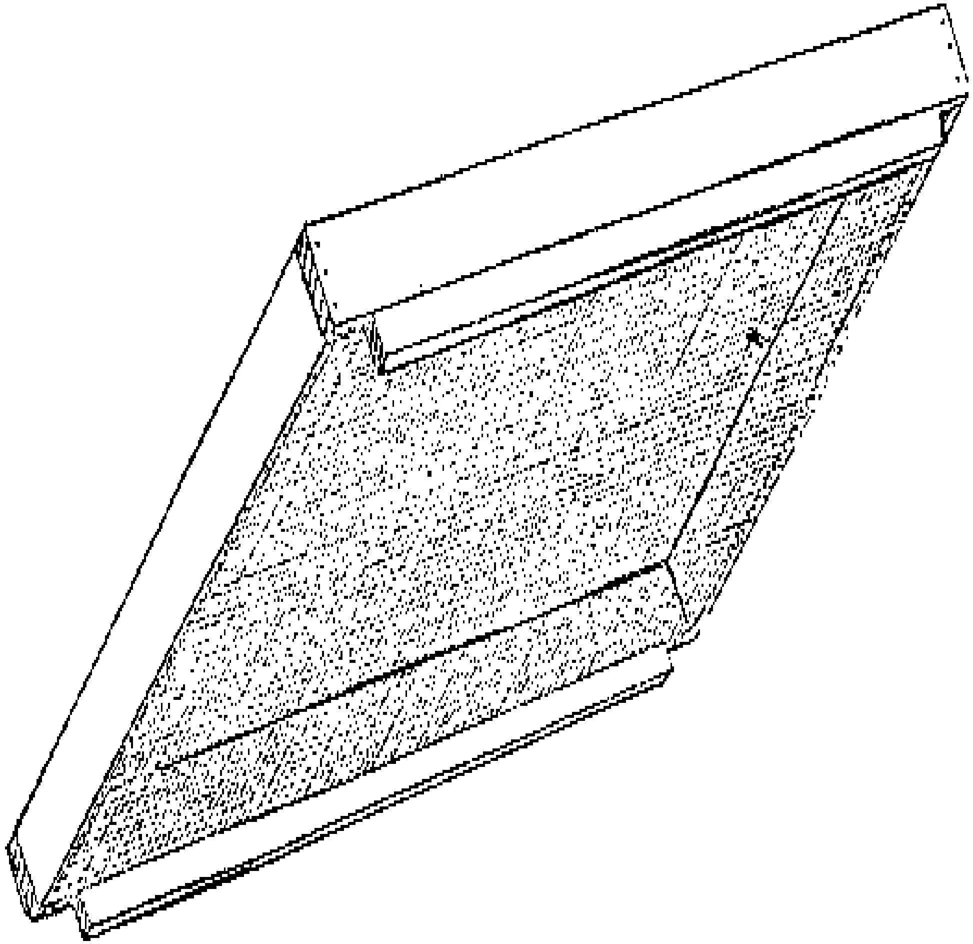
* The covers do not weigh much and are likely to blow off the dryers even in a light wind. The cover can be kept on by fastening hooks of stiff wire to each corner of the cover and swinging these hooks into place around nails or pegs fixed in the sides of the dryer.

* Or, fasten lengths of strong twine or cord to one side of the dryer, draw them tightly across the cover, and tie them to nails or pegs on the other side.

CONSTRUCT THE DRYING TRAYS

<FIGURE 108>

51ap110.gif (486x486)



This is a simple wooden frame with fine wire mesh stapled to its underside. Two support runners are nailed to the underside (over the edge of the wire mesh). If necessary, two small pieces of wood may be tacked over the edges of the wire mesh to hold it in place at the ends. However, folding the edges of the mesh over upon itself before stapling may be all that is needed.

Make two trays, each slightly smaller than 1m x 1m so that it will fit the dryer box well. It is a good idea to make two trays because they are easier to handle than one large tray. Also, using two trays means that grains at two different moisture levels can be dried at the same time.

Simpler trays may be made from local materials. Papyrus reed matting, or a frame with slats of reed or split bamboo, for example, make an excellent support on which material can be dried. Coarse hessian sacking material, or open weave grass or fibre matting stretched on a frame also can be used.

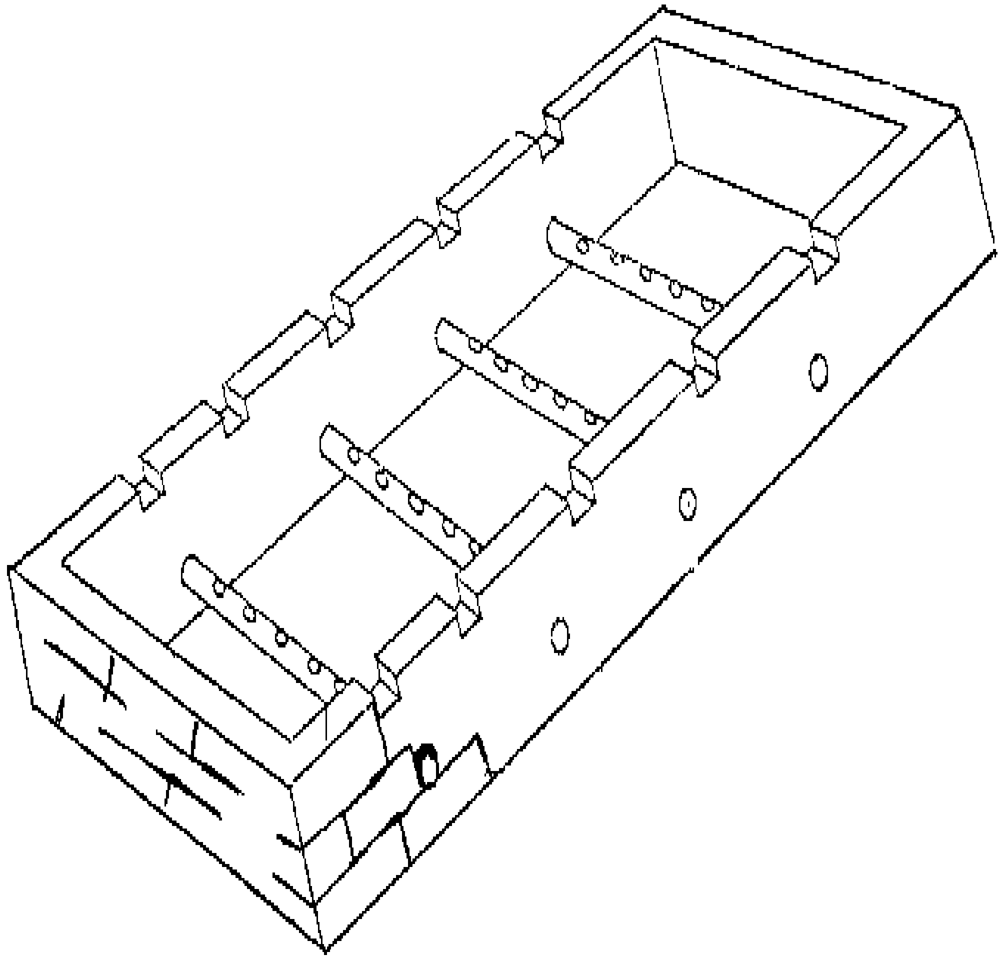
MODEL #2 SOLAR DRYER

Description

This dryer also is for a 2m x 1m dryer. But it is not portable like the Model #1 Solar Dryer. It is built on a permanent location and is made with clay bricks, or similar material. Bricks composed of local earth and cement and compressed by a CINVA-RAM work very well. If hollow bricks are used, the hollows should be packed with dried grass, coir fibre, or other insulating material.

<FIGURE 109>

51ap111.gif (486x486)



Choose a Site

A good place for the Solar Dryer will be

*** high ground which is flat and level. Make sure the location is well drained.**

* out in the open -- not shaded by trees or buildings.

* exposed to the prevailing wind. The end of the dryer should be facing the prevailing wind.

Tools and Materials

* Large knife, axe, or machete

* Coping saw or wood rasp

* 2cm chisel

* Clay bricks or bricks made from similar material

* Mortar or clay for laying bricks

* Thick bamboo (6 to 7.5cm diameter)

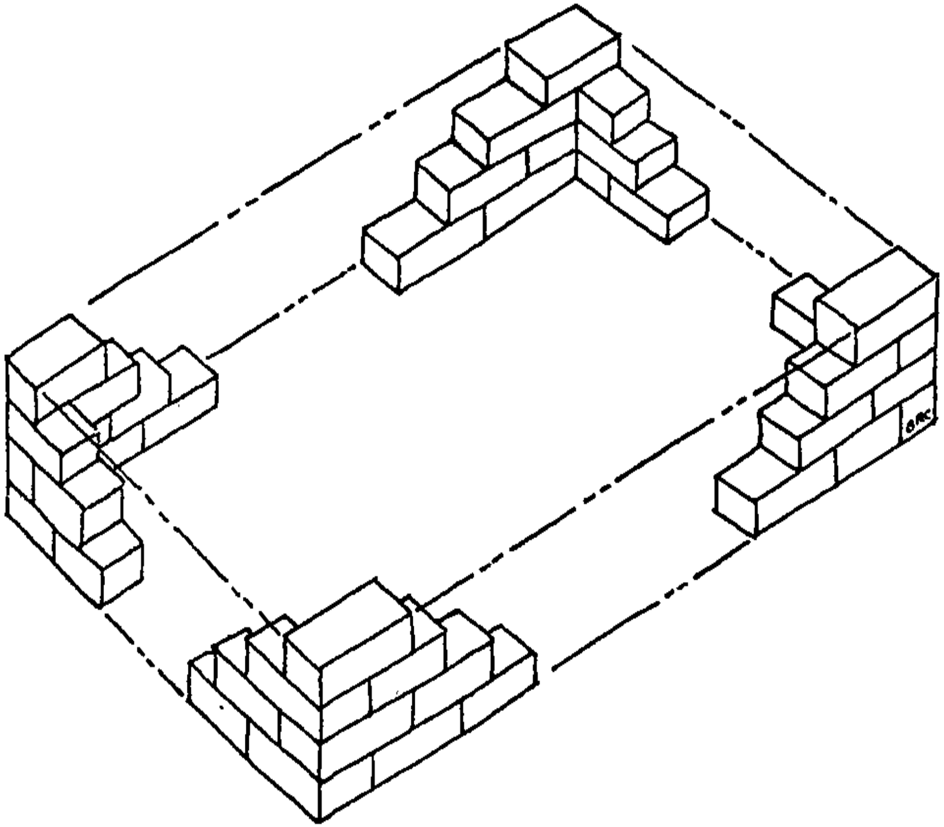
READ THE INSTRUCTIONS THROUGH BEFORE YOU BEGIN

1. Prepare Site

* Lay out dryer size by building up the corner blocks.

<FIGURE 110>

51ap112.gif (486x486)



LAYOUT THE SIZE OF THE DRYER ON THE GROUND AND LAY UP THE CORNER BLOCKS AS SHOWN. FILL IN BETWEEN THE CORNERS TO COMPLETE THE WALLS.

*** Prepare a floor of hard-packed earth or concrete mortar.**

*** Dig a drainage trench around the dryer to protect it from heavy rain. The trench should be 23-30cm wide and 23-30cm deep.**

2. Prepare Bamboo Pipes

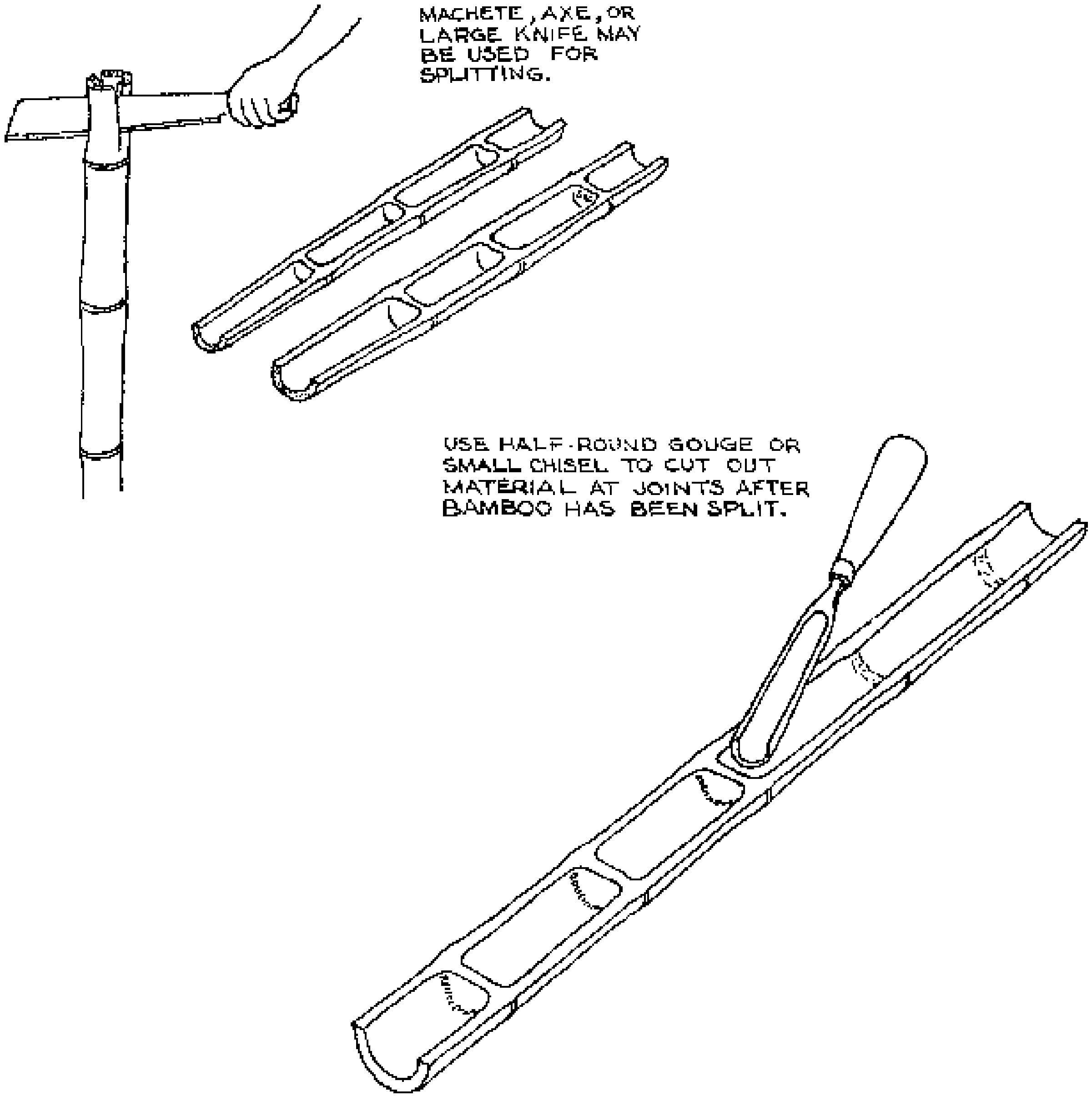
* Choose bamboo of even thickness with as few joints as possible.

* Cut bamboo to the same length as the width of the dryer.

* Then prepare the pipes as follows:

<FIGURE 111>

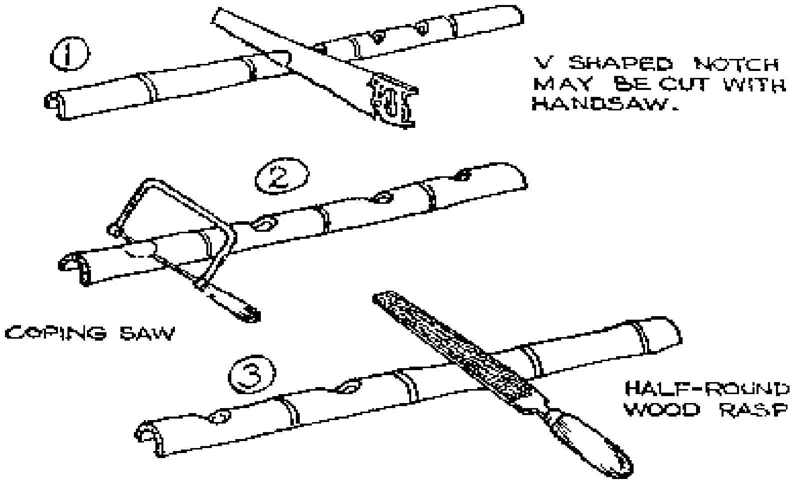
51ap113.gif (600x600)

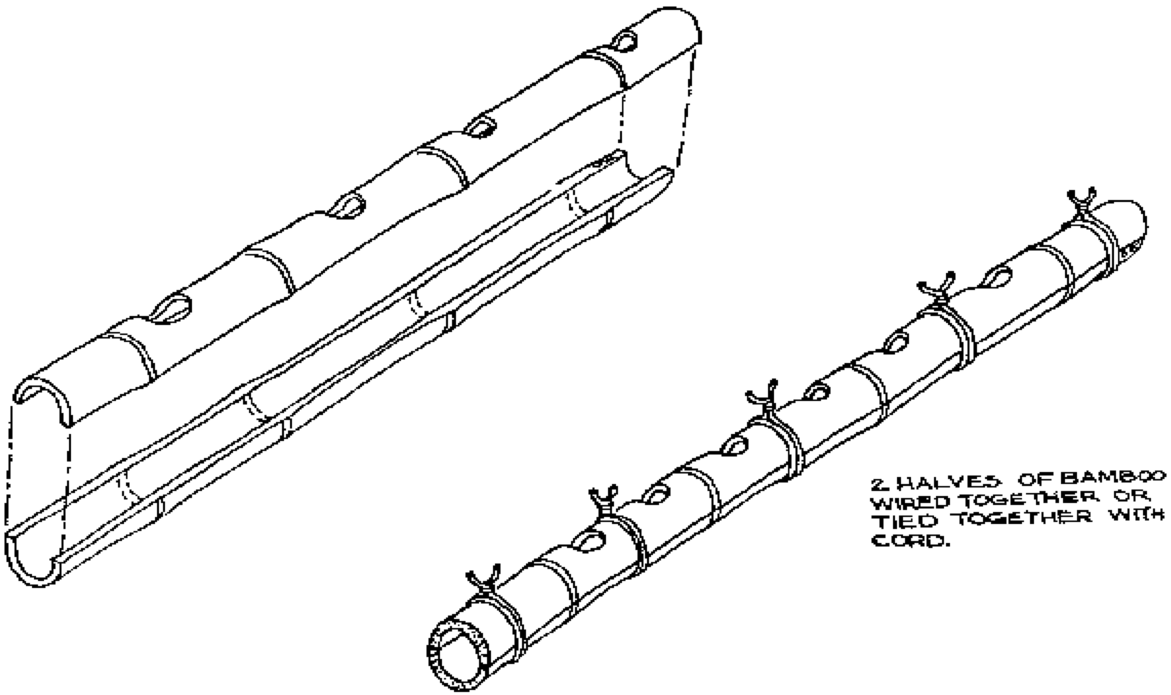


*** Cut holes, about 4cm in diameter, in each pipe. Holes can be made by using one of these methods:**

<FIGURE 112>

51ap114.gif (600x600)



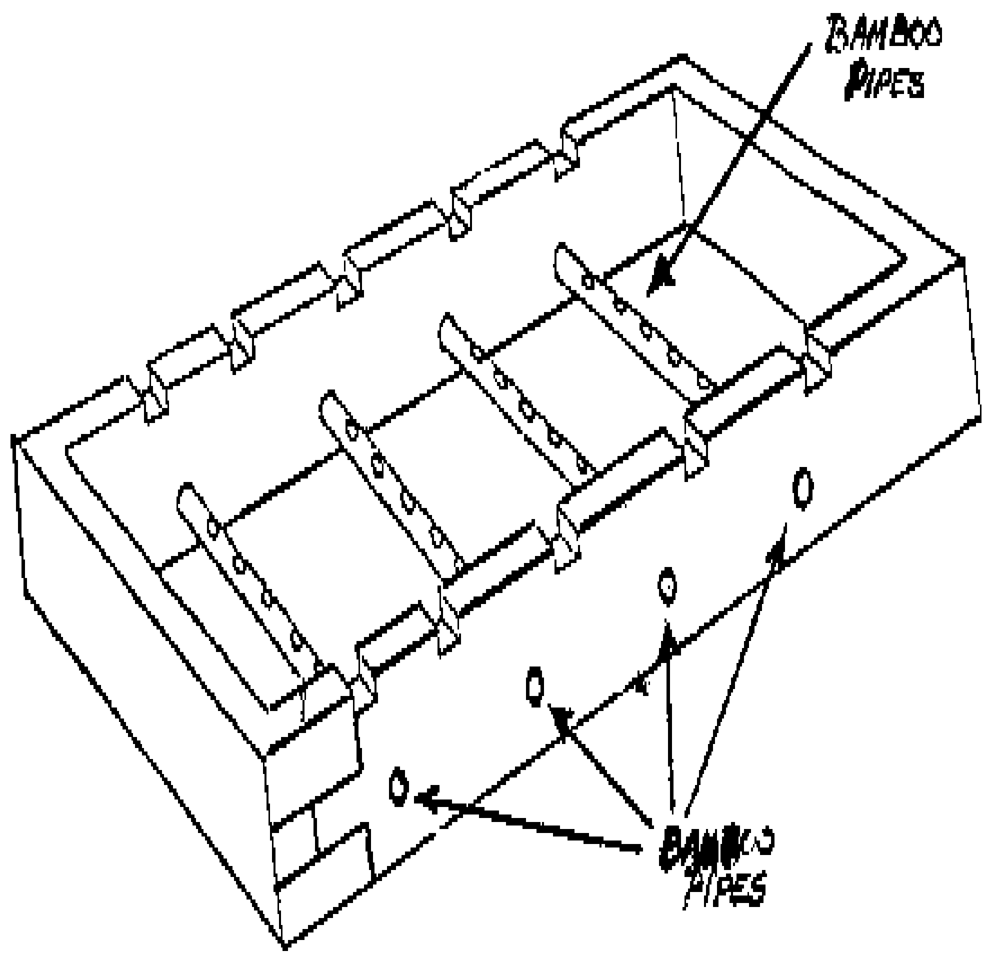


3. Finish the Walls

*** Place the bamboo pipes in position in the second layer. Cut the blocks short as necessary to fit in the bamboo pipes.**

<FIGURE 113>

51ap115a.gif (486x486)



* Put down the third layer of bricks.

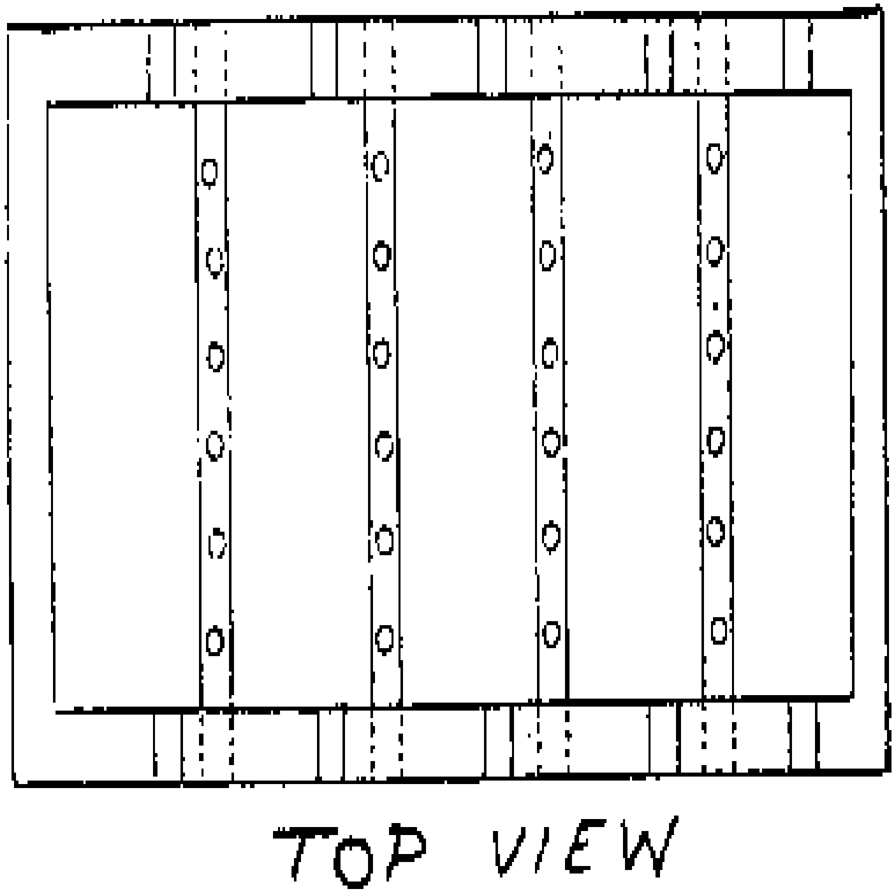
* Pack the holes around the bamboo with mortar or clay.

* Put down the top layer of bricks and cut out the air outlet slots or lay the top layer of bricks leaving one inch gaps as air-outlet holes spaced along the

two sides.

<FIGURE 114>

51ap115b.gif (486x486)



4. Paint the Inside

* Paint the inside of the dryer a dark color. Charcoal, mixed with clay and water may be a good coating.

5. Construct Cover and Drying Trays as for Model #1

MODIFICATION OF MODEL #2 SOLAR DRYER

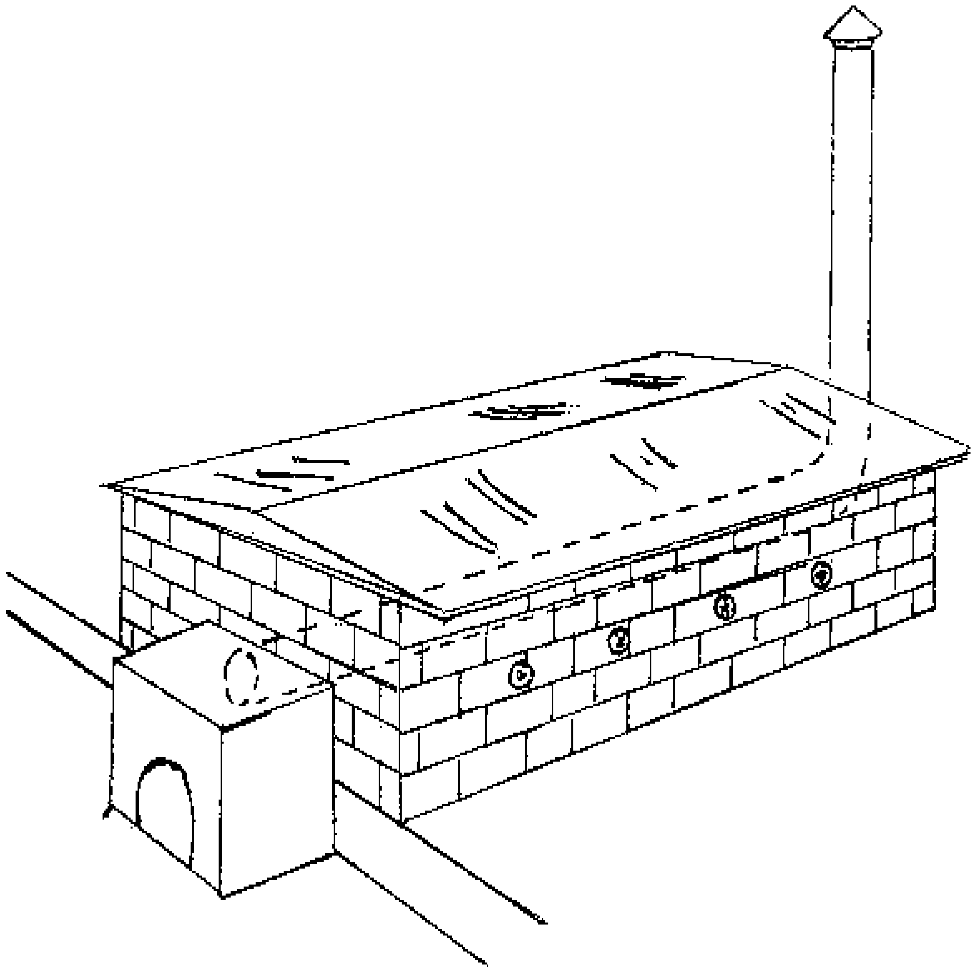
A Dual-Purpose Solar/Fuel-Heated Dryer

It is possible to build solar dryers which can work on solar heat for most of the time, but which can, if necessary, be artifically heated during periods of heavy clouding or rain.

A modification of the Model 2 dryer will allow for this dual-purpose operation. This modification consists of building-in a metal flue pipe which runs through the length of the dryer. This pipe carries the heat from a firebox built at one end of the dryer. When drying has to be done in cloudy conditions, the fire can be lit to provide heat for drying.

<FIGURE 115>

51ap116.gif (486x486)



Either one large, say, 11cm diameter pipe, or a number of smaller pipes can be used. When using smaller pipes, difficulties in constructing a manifold may arise. But it may be possible to adapt an exhaust manifold from an old gasoline or diesel engine for this purpose.

THE ONLY BASIC MODIFICATION NEEDED IN CONSTRUCTING THIS DRYER IS THAT THE WALLS MUST BE BUILT HIGH ENOUGH TO ALLOW THE FLUE PIPE TO PASS UNDER THE

AIR-INLET PIPES.
An increase of 7.6cm (or one brick) in height, should be sufficient. The firebox may be built in clay or brick, or a section cut from an old oil drum may be used for the purpose.

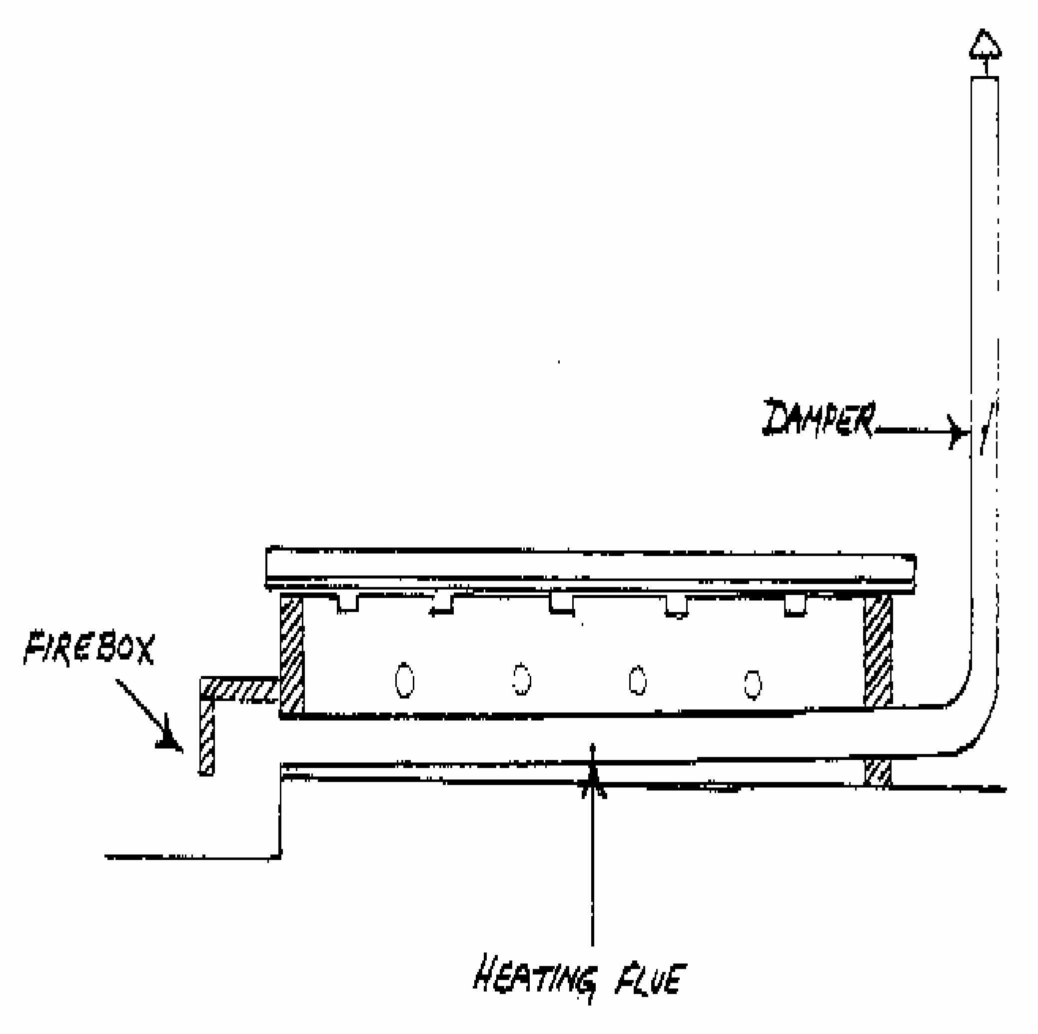
The base of the firebox must be at a lower level than the dryer.

*** Make sure that this area is protected from any flooding which may occur during heavy rains.**

The flue tube running through the dryer should slope upwards towards the chimney to assist draught.

<FIGURE 116>

51ap117.gif (486x486)



When using artificial heat, the movement of air through the dryer by convection will operate as it does when solar heat is being used. However, depending upon the heat given by the fuel being used, it may be necessary to close-off more of the upper ventilation ports.

CAUTION:

* Make sure that the part of the flue pipe passing through the dryer is smoke-proof. If it is not smoke-proof, smoke will flavor the foods being dried. A damper should also be placed in the chimney. This damper must be kept closed when sun-drying is being carried out, or the flue pipe may exert a cooling effect.

* Make sure to site this modification so that the firebox end faces into the prevailing wind. This will assist draught through the flue, and will also ensure that any sparks from the chimney are carried away from the polyethylene cover.

MODEL #3 SOLAR DRYER

Description

This is a simple dryer. It is not as efficient as the other two in conditions where it is exposed to cooling winds, but it will provide more efficient drying than direct exposure to the sun, and will also protect the drying material from rain. It is essentially a "sandwich" Of two sheets of corrugated galvanized iron roofing material placed so that they form a series of tubes. The lower sheet is bedded in insulating material to reduce loss of heat. It is set in a sloping position with one end raised about 15cm higher than the other. This position allows hot air to rise and escape at the upper end, creating a draught of air over the material being dried. The material which is being dried is placed in the hollows of the lower sheet.

There are a number of possible ways of siting and constructing this dryer. It can be permanently sited or made portable. Certain refinements can be added to increase its efficiency. For this reason the construction of a simple portable model will be described first; possible modifications will be described later.

The Portable Dryer

In this model, the corrugated sheets are fastened to a shallow wooden box which contains a bed of insulating material. The box will be about 10cm high and 80cm wide. The dimensions of the box will depend on the final size of the prepared corrugated sheets, so the sheets are prepared first.

Tools and Materials

* Hammer, saw, tri-square, wood chisel, pliers

* 2 sheets corrugated galvanized iron

* Timber for bottom and sides of box

* Nails or coat-hanger wire

* Black paint

1. Prepare the Sheets

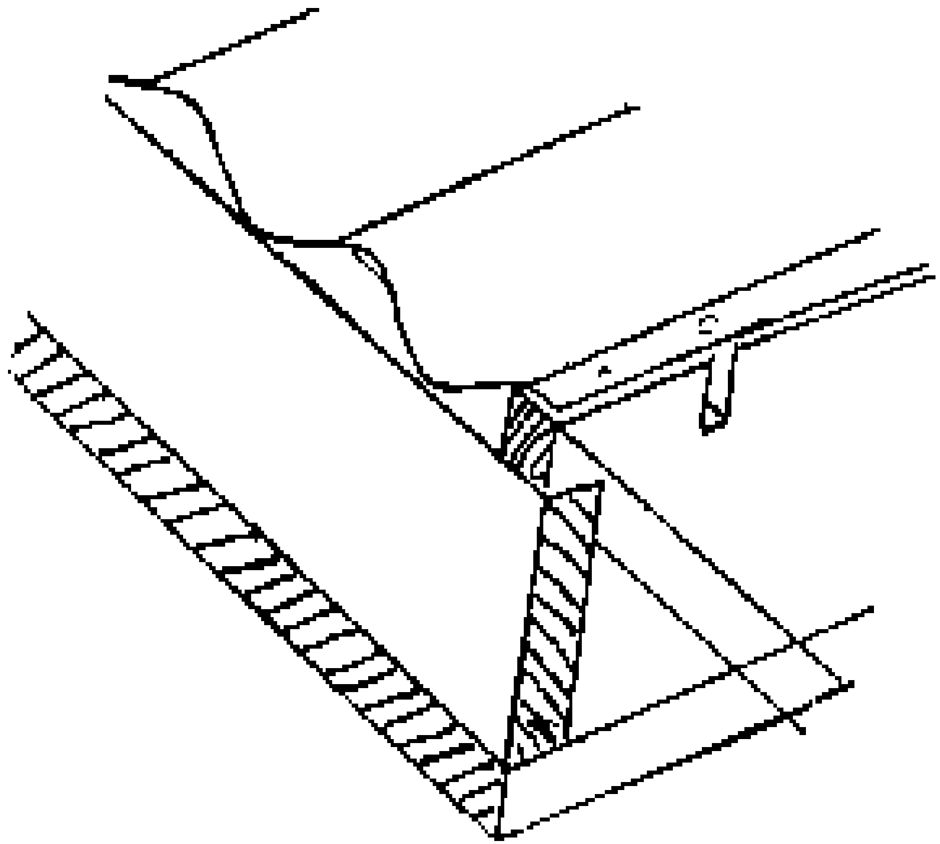
* When purchased, the sheets will be packed closely together. Turn the upper sheet 180 [degrees] so that the sheets are on top of each other. The upper sheet will tend to slip sideways

and will not remain evenly positioned.

* Mark a line along the edges of each sheet about 1cm from the edge. Using pliers, and moving gradually along the sheet, bend the edges down to form flanges which are level with the plane of the sheet. Once the edges have been bent into position, lay each flange along the edge of a piece of wood and beat with a hammer until it is flat and smooth. The sheets will now lie properly together in the correct position.

<FIGURE 117>

51ap119a.gif (486x486)



2. Hinge the Sheets

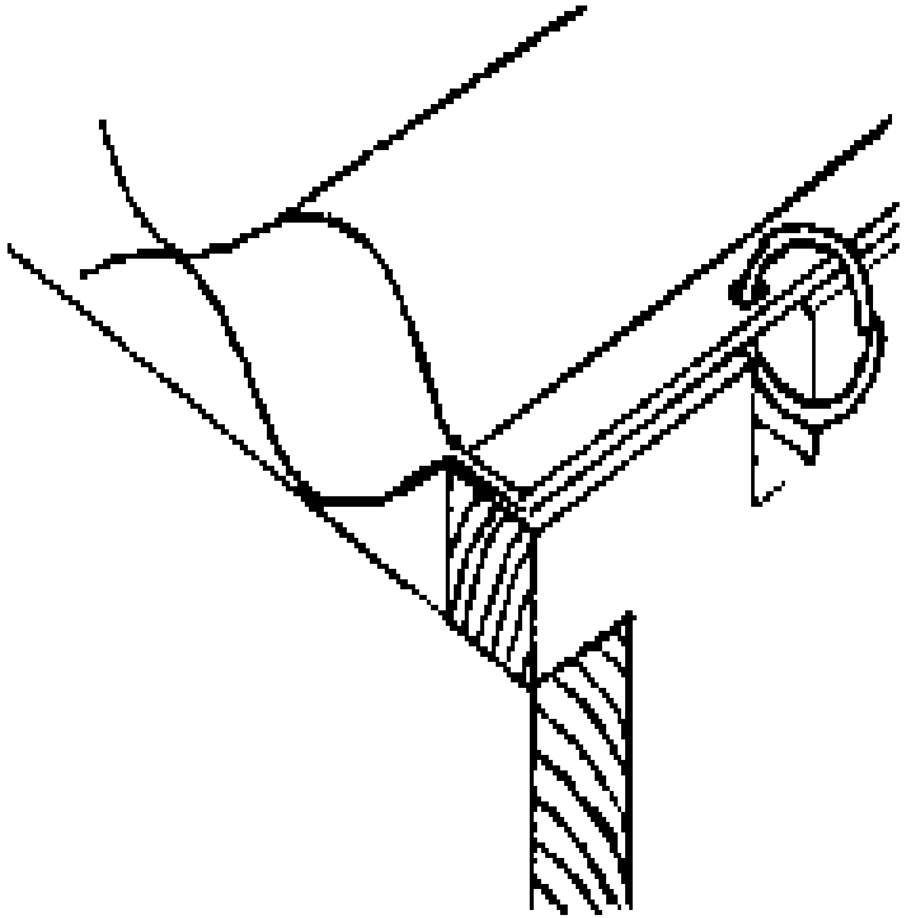
* The sheets must be held together so they can be easily positioned during future use. This is done using wire rings.

* Wind a piece of suitable wire spirally around a 1cm diameter form (e.g., the handle of a wooden spoon) to form 6 loops.

Remove from the form and pull the ends of the wire so that it forms a loose spiral. Cut this spiral with the pliers so as to form a number of rings with overlapping ends.

<FIGURE 118>

51ap119b.gif (486x486)



*** Punch five holes through the flanges at one edge of each sheet, using a nail and a hammer. These holes should be positioned as follows: one hole about 7.5cm from each end of the flange, one hole in the centre of the flange, and two holes midway between these holes.**

Pass the wire rings through these holes and close the

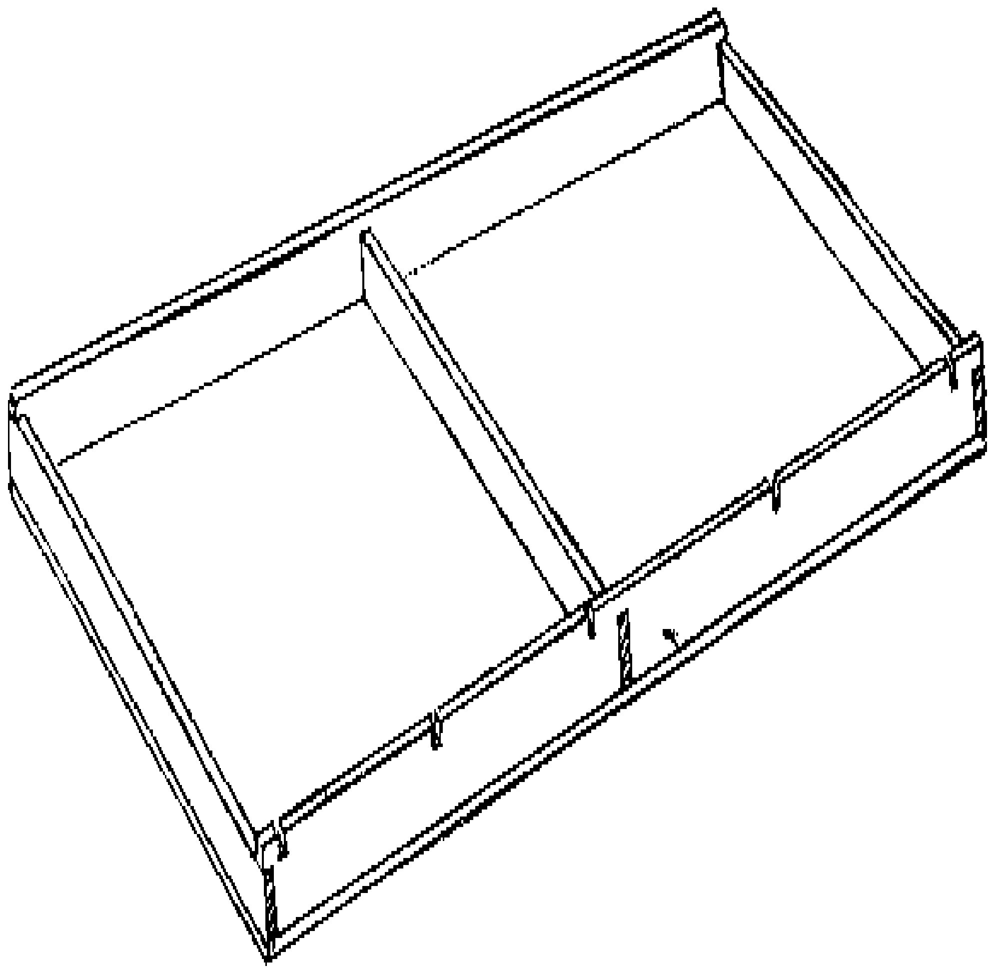
rings by pressing the ends together. This effectively hinges the sheets together and allows accurate positioning.

3. Prepare the Dryer Box

* The shallow support and insulating box can now be constructed to fit the dimensions of the lower sheet of corrugated iron: cut slots in the upper edges of the one side of this box to provide space for the hinge rings.

<FIGURE 119>

51ap120.gif (486x486)



* Pack the box with insulating material, e.g., wood wool, dried grass or leaves, or other similar material.

* Place the corrugated sheets in position and fasten the lower sheet to the frame by nailing through the flanges along each edge and through the points where the sheet contacts the ends of the box and the central support batten.

* Close the openings at each end between the corrugations of the sheet and the wooden frame by filling with cement, plaster or clay.

4. Paint the Dryer

* Paint the upper surface of the top sheet with a flat black paint. Using a suitable primer to be sure of sticking to the metal.

* Treat the wood of the box with preservative, or paint with gloss paint if available.

USING THE PORTABLE DRYER

Siting

* Site with the length of the dryer in a north-south direction, preferably in a position where it is sheltered from the wind.

* Raise one end so that it is 15cm higher than the other.

* Make sure the rays of the sun strike the upper sheet as directly as possible. (The end to be raised will depend on the latitude and season of the year. For example, in latitudes more than 5 degrees north of the equator, the northern end of the dryer should be raised in winter

and the southern end in summer.)

Protecting from Rain

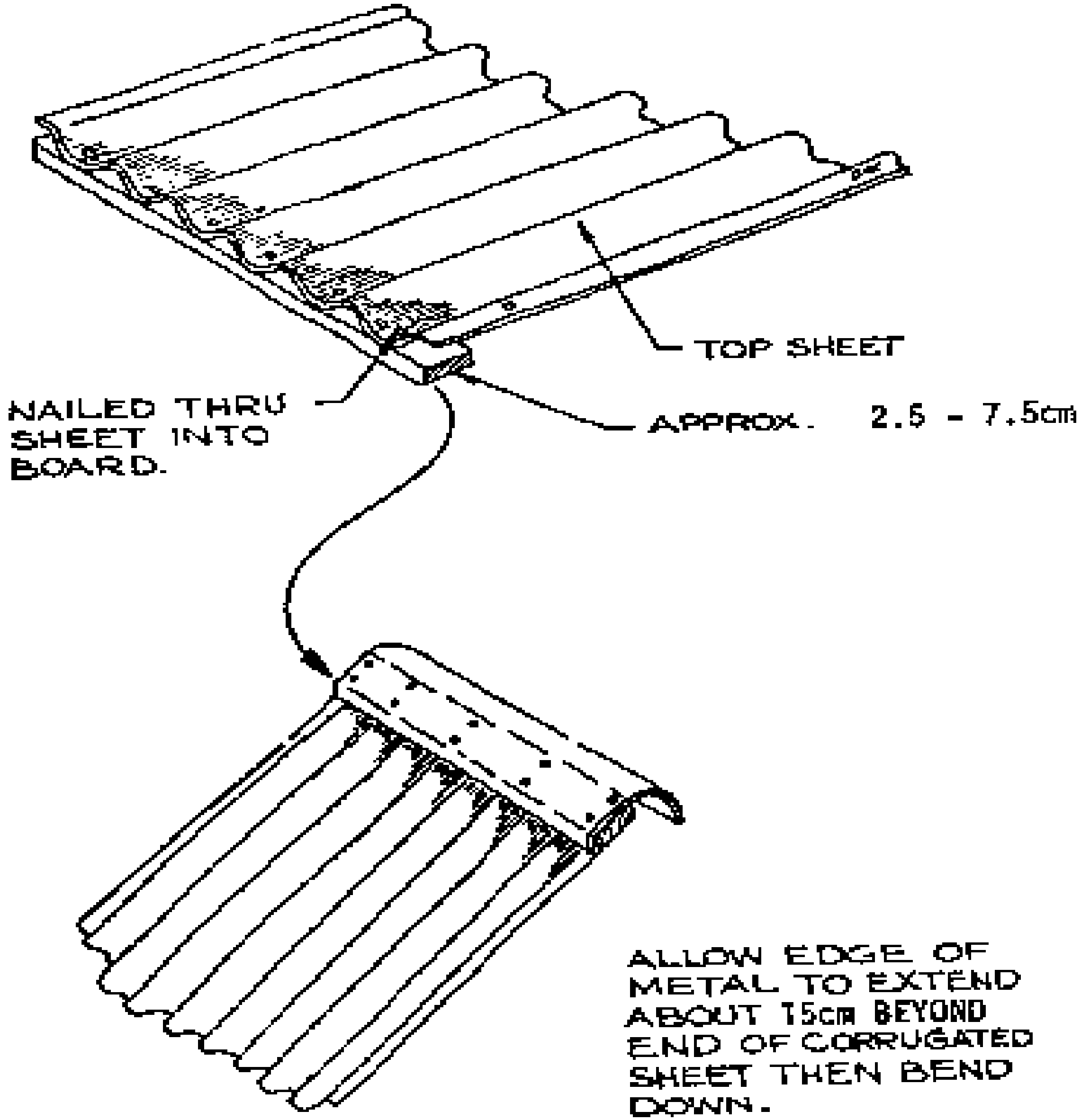
There is a risk that driving rain may enter the upper end of the dryer and wet the contents. It is thus necessary to fit a shelter plate to the upper sheet at this end of the dryer.

* Nail a wooden batten across one end of the upper surface of the top sheet.

* Nail to this wood a strip of metal which is the full width of the sheet, and which will jut out about 15cm beyond the end of the dryer. This metal can then be bent downwards in a gentle curve at its outer edge so as to shelter the open end of the dryer.

<FIGURE 120>

51ap121.gif (600x600)



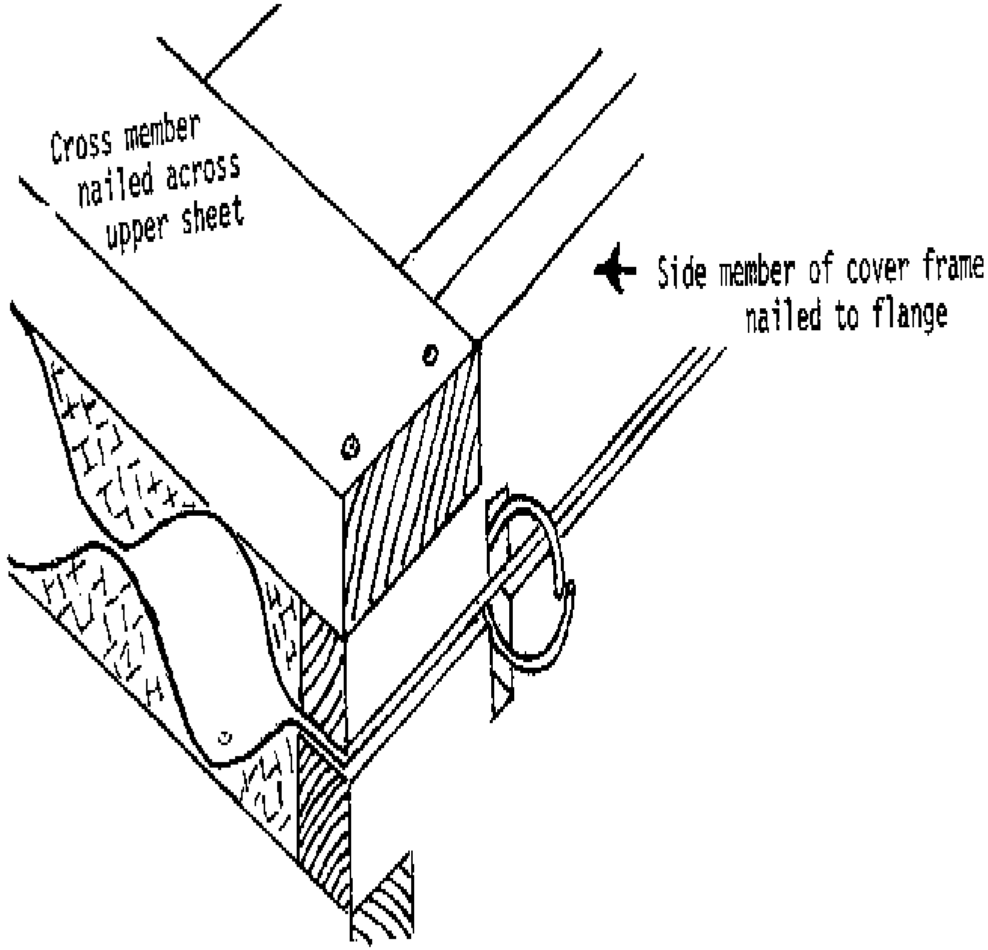
Fitting a Polyethylene Cover

The efficiency of the Model 3 dryer can be greatly increased by fitting a polyethylene cover over the top metal sheet. The plastic creates an insulating air space between the polyethylene and the corrugated sheet.

*** Build a simple wooden frame over the top sheet using two vertically placed battens along each of the flanges, and two joining battens across each end of the sheet.**

<FIGURE 121>

51ap122.gif (486x486)



* Fill the spaces between the corrugations and the end battens with plaster, clay, or cement. Stretch a single sheet of polyethylene over the frame. Tack or staple the sheet in place.

* Keep the slots in the side piece of the frame (necessary to accommodate the hinge rings) as small as possible. They should only be cut enough to allow clearance for the rings.

The polyethylene cover will protect the upper corrugated sheet from the cooling effects of wind and rain. It also insulates the dryer so that higher drying temperatures are possible.

THE PERMANENTLY SITED MODEL 3 DRYER

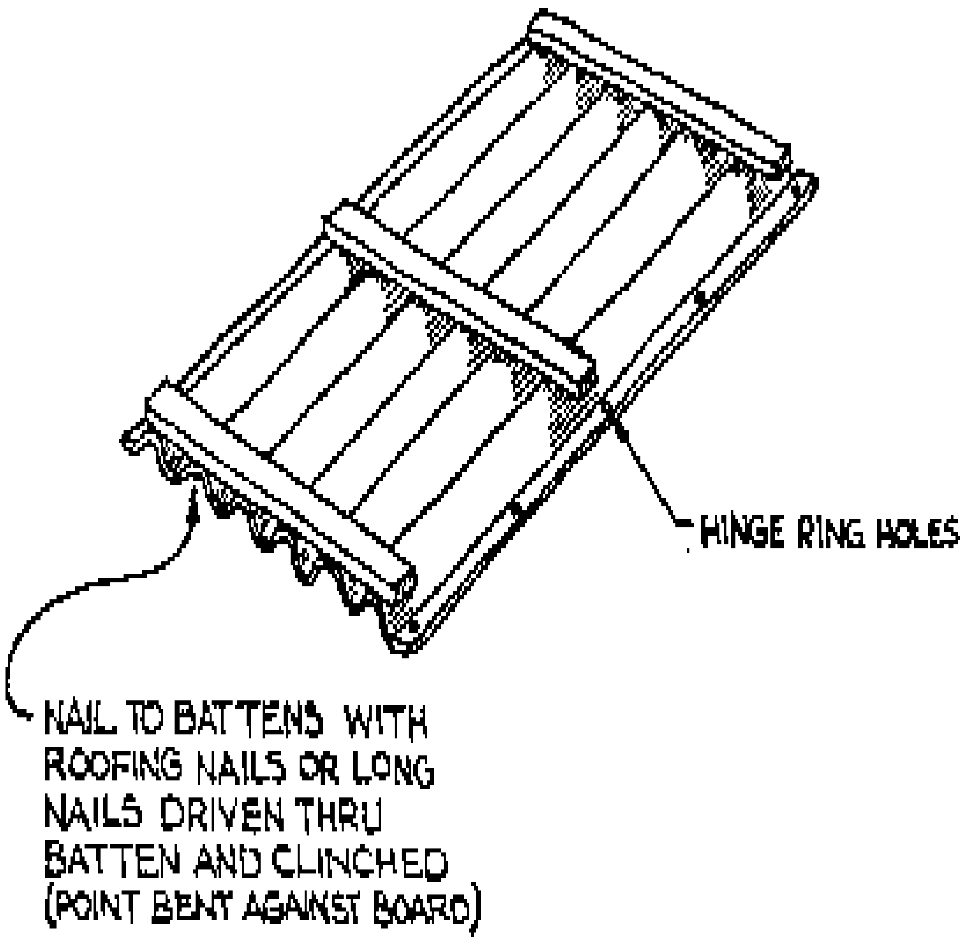
The dryer described above can be permanently sited on a clay platform, thus avoiding the need to construct a support and the lower insulating box. The clay platform will provide insulation. This type is built as follows:

* Flange the sheets and hinge together as described for the portable dryer.

* Nail wooden battens about 4cm x 2cm across the lower side of the lower sheet at each end and at the middle, to provide rigidity.

<FIGURE 122>

51ap123.gif (486x486)



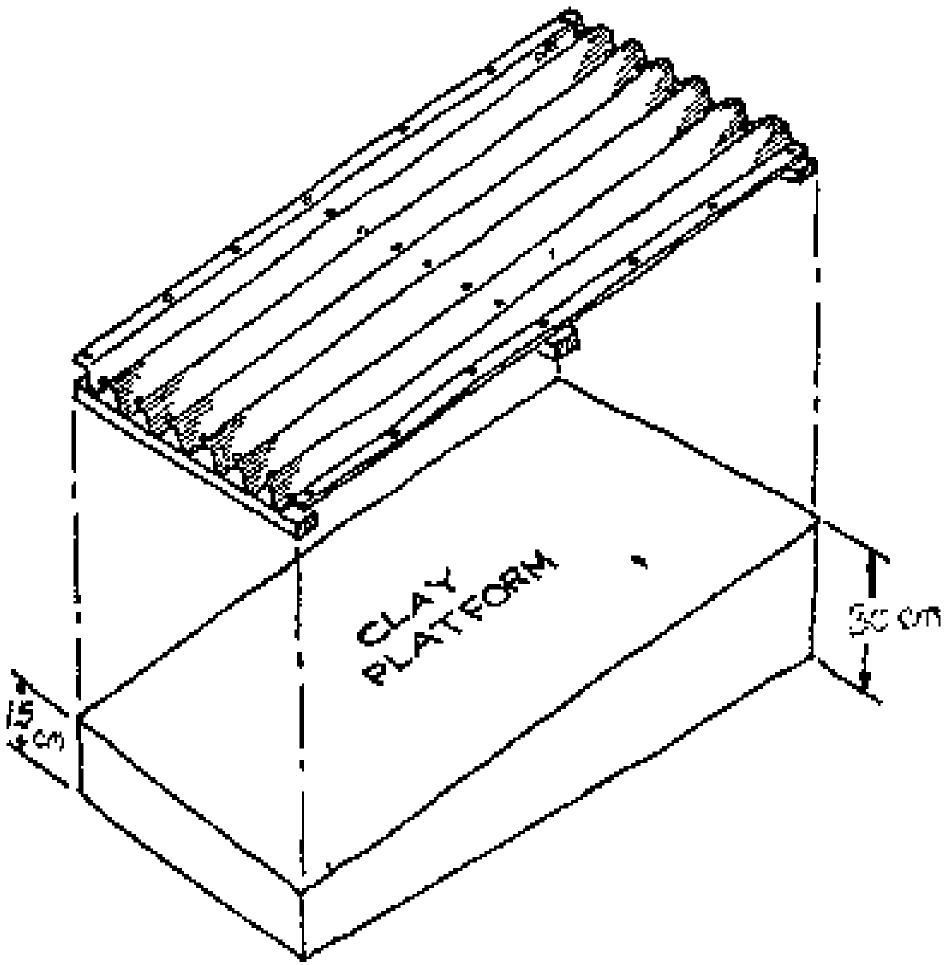
Construct a simple sloping clay platform the size of the lower sheet and 15cm above ground level at one end and 30cm above ground level at the other. Mix large quantities of dried grass or leaves with the clay.

While the clay is still wet and soft, bed the lower sheet in position so that the clay moulds to the corrugations

of the sheet. Allow the clay to harden.

<FIGURE 123>

51ap124a.gif (486x486)

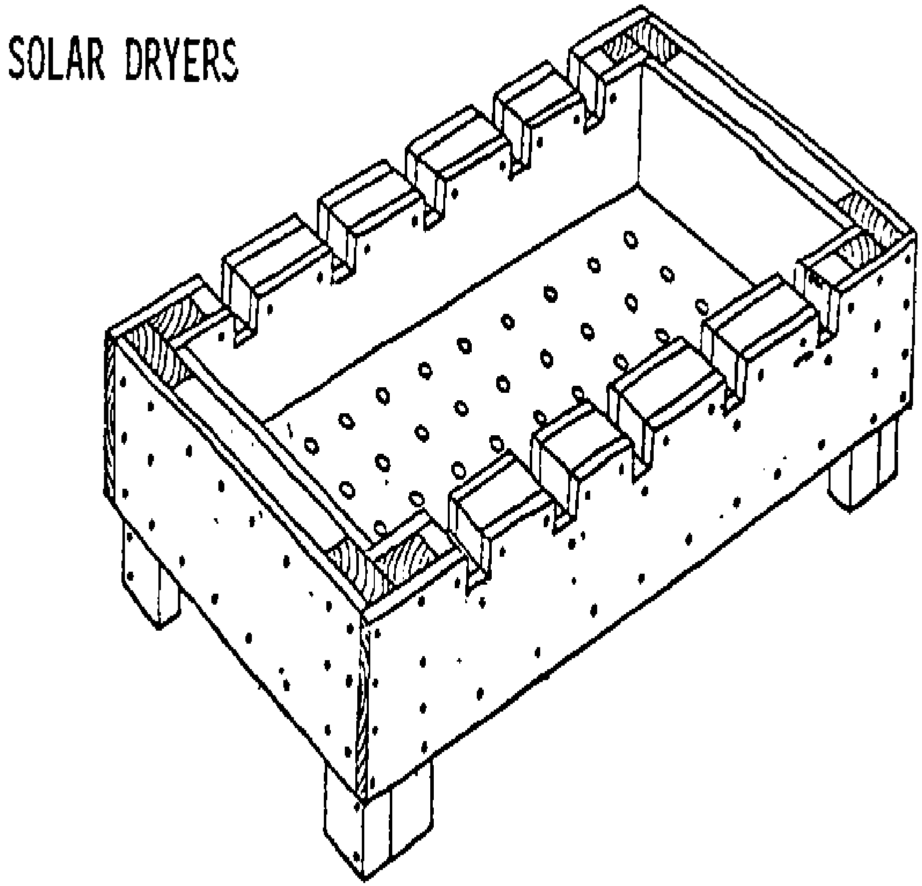


CAUTION: Make sure to site this dryer in a position which will give the

most effective exposure to the sun at the time of year when the most drying is being done.

<SOLAR DRYERS>

51ap124b.gif (486x486)



PART TWO:

OPERATING INSTRUCTIONS

General Instructions

Start drying as early as possible in the day to get maximum exposure to the sun. Once material has been placed in the dryer and the cover placed in position, do not lift the cover until drying is completed for the day: taking the cover off will allow a lot of heat to leave the dryer.

Cleanliness

Brush the dryer out daily to get out dust, and to remove any pieces of dried material spilled from drying trays.

Keep the drying trays clean; wash them often.

Temperature Control

Control the temperature inside the dryer by opening or closing the upper air outlets. Temperature may be measured by putting a thermometer in one of the upper air outlets. When doing this, shade the thermometer from direct sunlight by inserting a card beneath the cover. Temperatures measured in this way will be the maximum (not necessarily the average) internal temperature.

Or, temperatures at the level of the drying material may be measured by drilling a hole through the side of the dryer and inserting a thermometer.

Again, make sure that the bulb is shaded from direct sunlight.

Closing the upper ventilation outlets will increase internal temperatures. However, if moisture begins to collect inside the dryer you must start opening the outlets.

In cases where opening all the upper outlets still results in temperatures which are too high for the material being dried, additional outlets should be cut in the upper edges of the sides.

Shade Drying

Some materials, particularly green vegetables, carrots, plantain and some varieties of sweet potato, may lose color and Vitamin A during direct exposure to sunlight. For these materials, shade drying is useful (but not completely necessary).

To do shade drying, fit sheets of thin metal immediately below the cover. Paint the metal (galvanized sheet or beaten-out tin containers) black on both sides. The size of the metal sheet should be just less than the internal length and width of the dryer. Support the sheet on nails driven into the inner sides and ends of the dryer. Put the nails in not more than half-an-inch below the upper edges of the sides.

Make sure the sheets do not touch the lower side of the polyethylene cover (otherwise their heat may cause it to melt). But the sheets should be high enough so that hot air from beneath the sheet can still escape through the upper air outlets.

When fitted properly, as described above, these sheets will send almost all of the heat they receive to the air inside the dryer, and the internal temperatures are similar to those made by sunlight. Use of metal shading sheets can, in fact, assist drying, since their presence encourages more effective convection air movement through the dryer.

Fogging

If fogging occurs during use, withdraw tacks or staples from a short length at each end of the cover, open up the polyethylene to allow moisture to escape while the dryer is in operation, and then refasten the polyethylene in place.

"Storage" Heating

A simple modification to either the Model 1 or Model 2 dryers, which will enhance efficiency of drying during periods of intermittent clouding or rain, is the placing of a layer of dark-colored (or black-painted) rough-surfaced stones in the bottom of the dryer. These stones should be egg sized or slightly larger.

During periods of sunshine, the stones will become heated. Then when the sun is covered by clouds, the stones maintain the internal temperature by giving up heat to the air.

DRYING GRAIN CROPS

To make sure crops do well in storage, they should be carefully dried, either "in the head" or after threshing, before they are placed in storage.

If dried "in the head," grains should be threshed before storage since closely packed grain is less subject to insect attack.

Groundnuts can be dried either in the shell or after shelling. Storage in the shell provides protection against insect attack.

Shattering sesame may be harvested before pods are quite ripe and dried in trays with very fine mesh bottoms. It will then shatter in the dryer. But since all the seeds will be retained, this method of dealing with sesame has great advantages.

Threshed grains should be spread in a 1cm to 4cm deep layer on drying trays of appropriate mesh size, so as to give a loading of about 7-10kg per square meter. For bulky material such as unthreshed finger millet or sorghum, layers up to 7.5cm deep can be used. For groundnuts in the shell, layers may be up to 5cm deep.

For very small seeds, such as finger millet or sesame, trays with a very fine mesh will be needed. Mosquito netting or tightly stretched hessian sacking would be appropriate.

Appendix A

This Appendix contains some examples of different ways of presenting grain storage information. The examples are from Asia, Africa, and South America, thus highlighting the fact that good grain storage is an important subject all over the world.

GRAIN STORAGE IN MUD CRIBS

The traditional Botswana designs of mud cribs are easy to build and the materials cost very little. By taking more care over some details during construction, you can reduce the risk of insect damage to stored grain.

Issued by the Department of Agriculture, Information Service, Private Bag 27, Gaberones.

BUILDING A MUD CRIB

Choose a place where the ground is firm and well drained, because a crib full of grain is heavy and may sink into soft or wet ground.

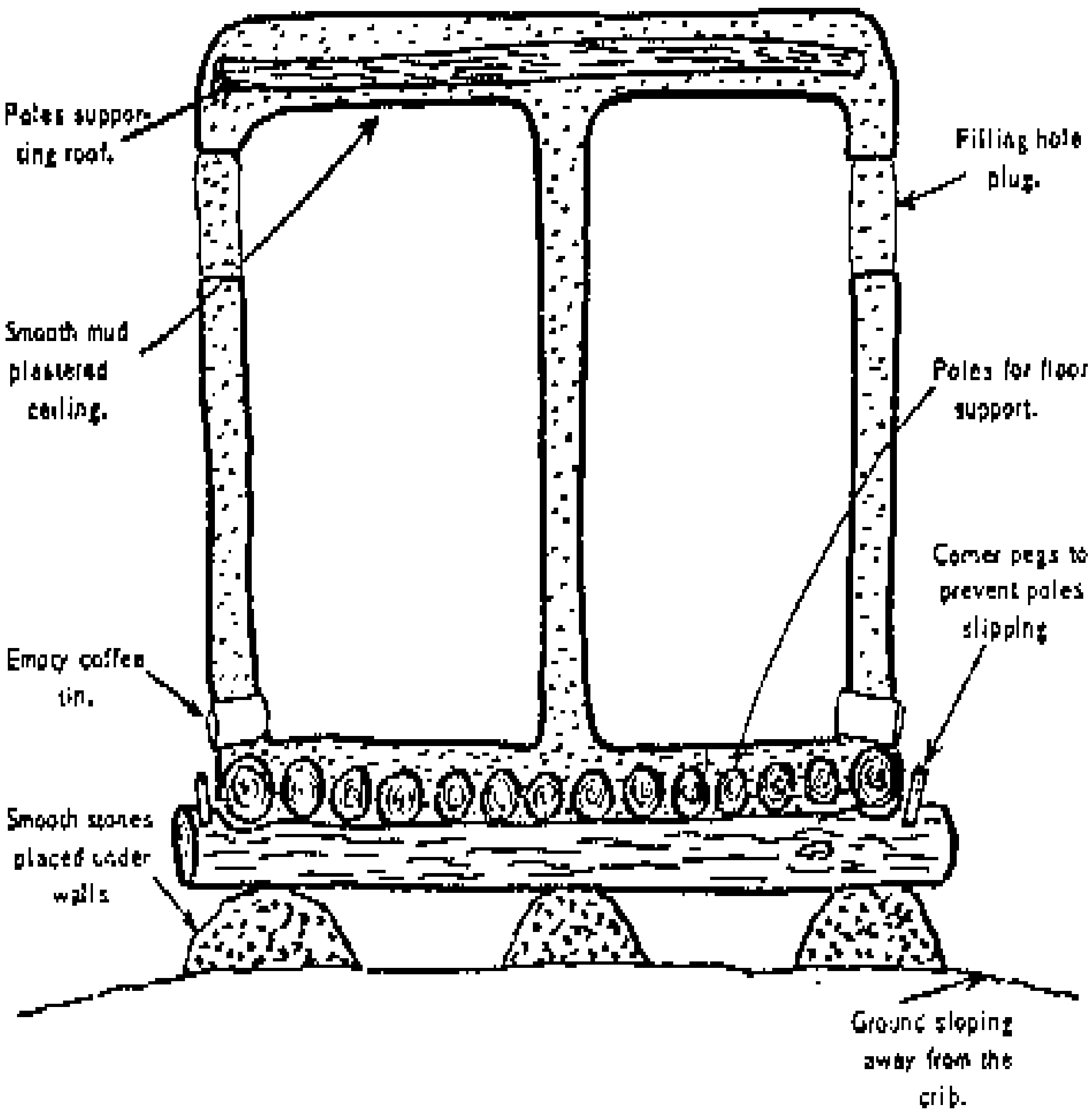
Bring several large, smooth stones and bury them firmly in the ground to form a base.

Use strong, straight poles for the main crib supports and lay them on the stones. Cut notches or fix pegs at the ends of these poles to prevent the floor poles from slipping.

Make a floor of mud and build up the mud walls.
Reinforce the mud ceiling with poles.

<FIGURE 124>

51ap129.gif (600x600)



Make an outlet at the bottom of each compartment to permit easy removal of

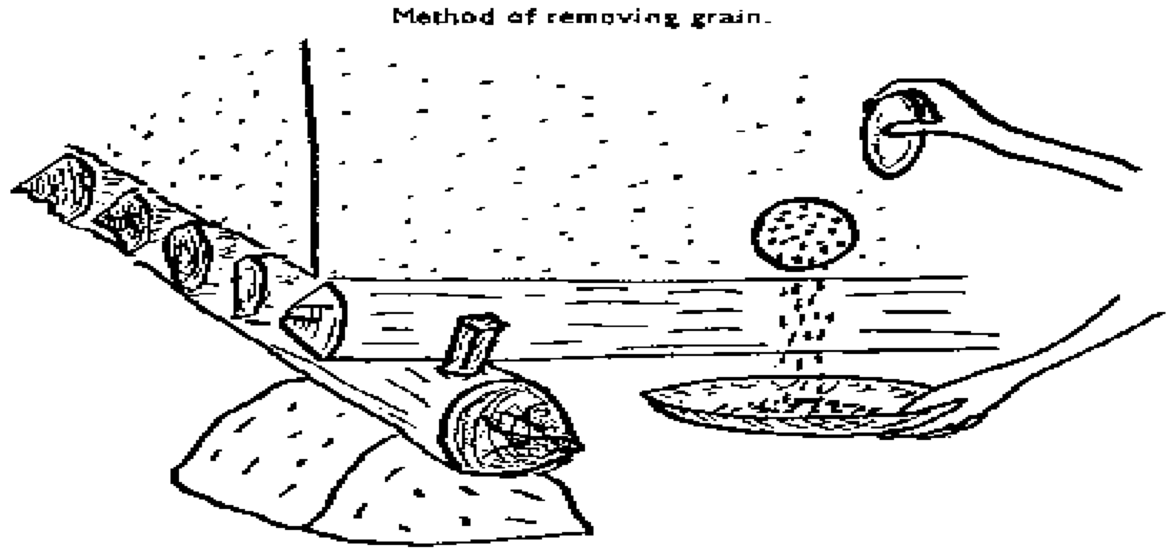
grain. Use an empty coffee or dried milk tin with a lid of the press-in type. First cut out the bottom. then build the tin into the wall at floor level.

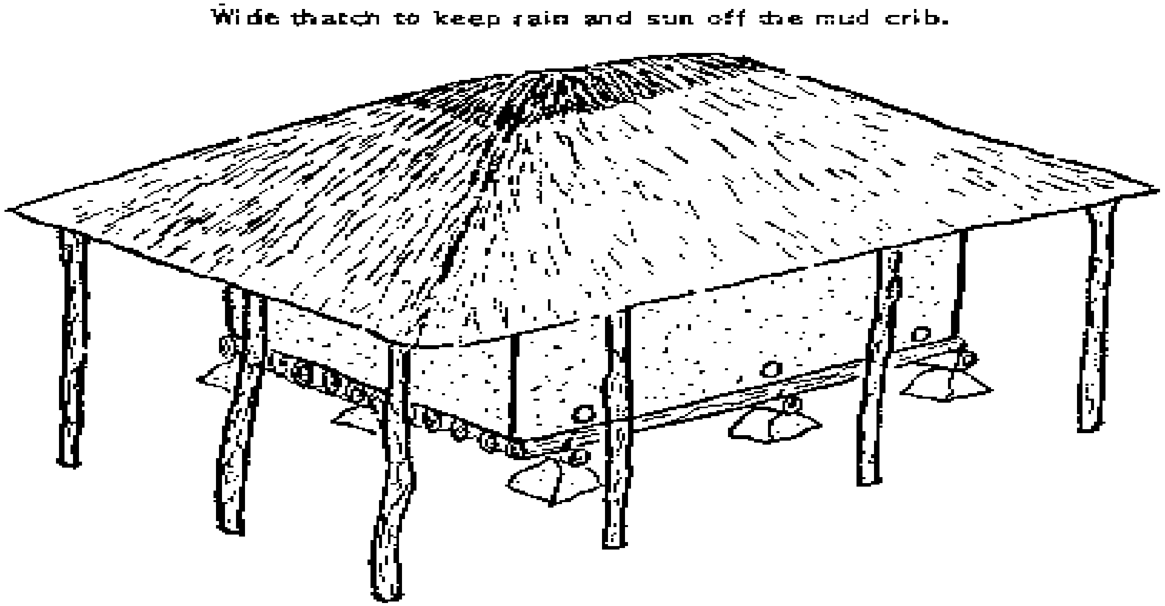
Build the walls right up to the ceiling so that each compartment is completely separate and there is no chance of insects moving from one compartment to the next.

Plaster the inside walls and ceilings. Insects hide in cracks and crevices and in the poles of the ceilings. Therefore plaster the ceilings also, so that there is no gap between the walls and ceilings.

<FIGURE 125>

51ap130.gif (600x600)





Cover the completed mud crib with a thatch roof supported on separate poles. Thatch

should be thick and rain proof especially along the ridge. The roof must also extend well beyond the crib so that rain cannot reach the mud walls, and the hot rays of the sun never shine on the crib.

The plug for filling the crib should be smeared over with mud to make the crib airtight and insect proof. Grain is removed by opening the lid of the tin at the bottom of the wall.

USING A MUD CRIB

The crib should be repaired before each harvest. Mend the thatch and re-plaster over cracks in the walls, floor and ceiling.

Thoroughly clean out the empty crib by brushing. Do not keep old baskets, skins, sacks, etc. on top of the mud crib. These things harbour the beetles that attack grain and it is easy for them to walk into the crib.
Make sure that new grain is always quite dry and has been winnowed or sieved before you put it into a crib. Never mix new grain with old grain remaining from the previous year.

To stop insects damaging your grain, admix Kopthion or Pyrethrum dust (1 packet

of dust
to each 200 lb. of grain.) These insecticides are preferred but the ash from cattle dung or
wood may be used. Mix not less than one bucket of sieved ash with each 200 lb. of grain.

Examine the condition of your grain every 2 months by removing a sample and looking for
live insects. If you find them, remove the grain, winnow it and admix Kopthion or pyrethrum
before returning it to the crib.

CAUTION:

Grain intended for human consumption should be first sieved or winnowed and washed - especially
if it has been treated with insecticide or ash.

If you would like further help, ask your Agricultural Demonstrator.

KEEP THIS LEAFLET FOR FUTURE REFERENCE

Printed by Government Printer Gaberones

HOW TO ....

PROTECT YOUR

GRAIN IN STORAGE

FROM DAMAGE

Distributed through:

SAVE GRAIN CAMPAIGN
(Country Wide Programme)
DEPARTMENT OF FOOD,
NEW DELHI-1.

Apply the 5 Golden Rules:

*** Dry and clean your grain before storing.**

*** Use dunnage to avoid moisture damage to grain stored in bags.**

*** Use domestic bins or improve your storage structure.**

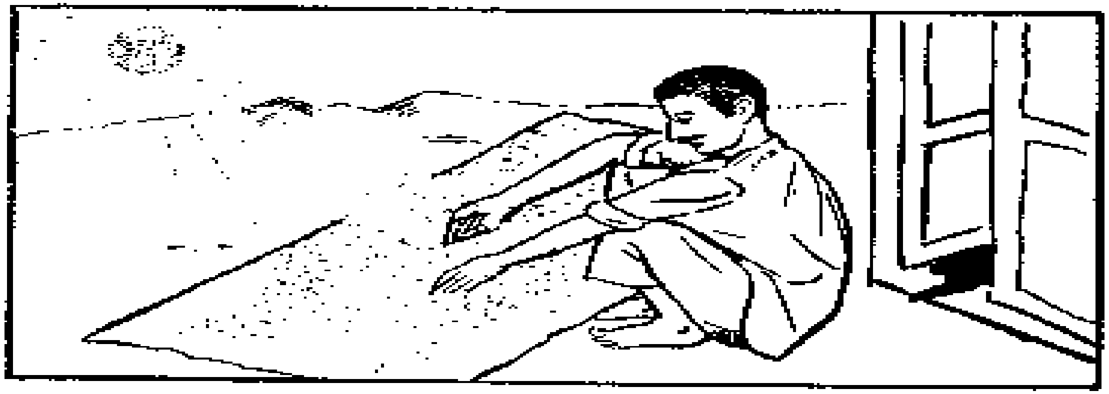
*** Fumigate with EDB ampoules to avoid insect damage.**

*** Use anticoagulant for rat control.**

<FIGURE 126>

51ap134.gif (600x600)

1. Dry and clean your grain before storing.

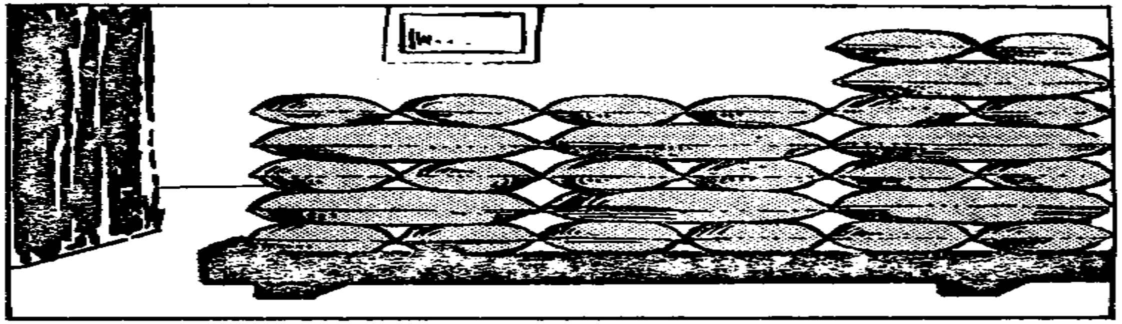


Dry grain stores longer

Clean grain stores better

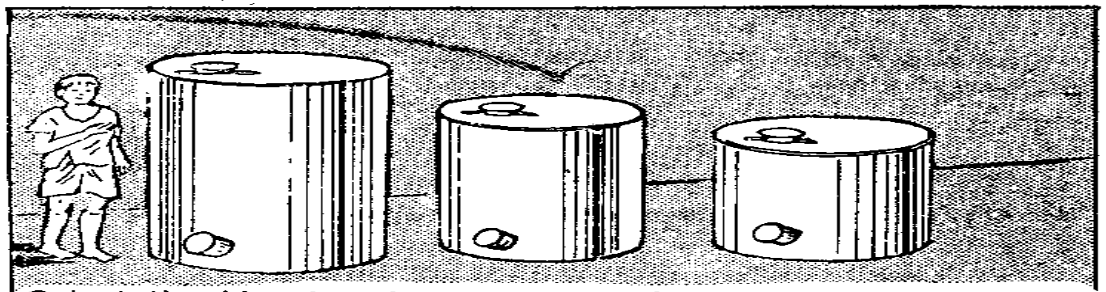
51ap135.gif (600x600)

2. Use dunnage to avoid moisture damage to grain stored in bags.



Wooden crate and bamboo mat prevent moisture pick up from ground.

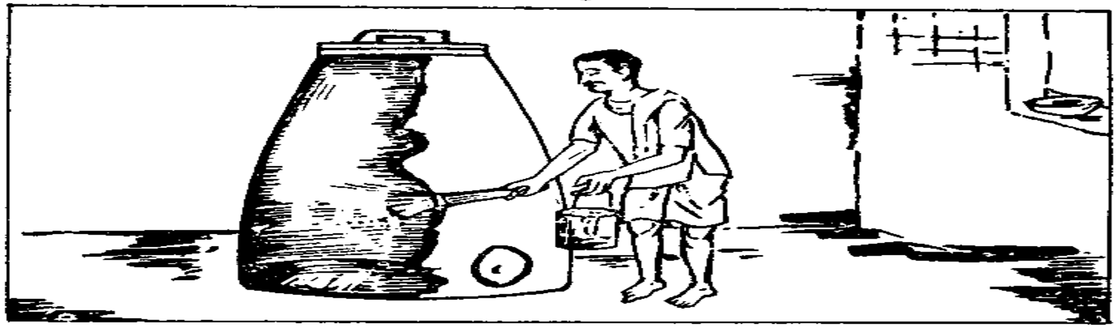
3. Use domestic metal bins.



Select the bins to suit your needs. Improved bins are moisture proof and rat proof. It is easier to fumigate grain in them for insect control.

OR

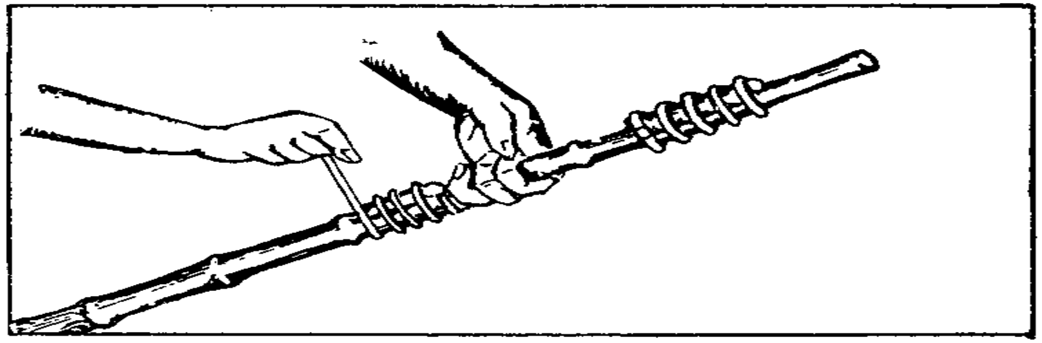
Improve your storage structure



Examine your storage structure before storing grain. Clean it. Attend to cracks and crevices and white-wash it and also make it rat proof and moisture proof as far as possible.

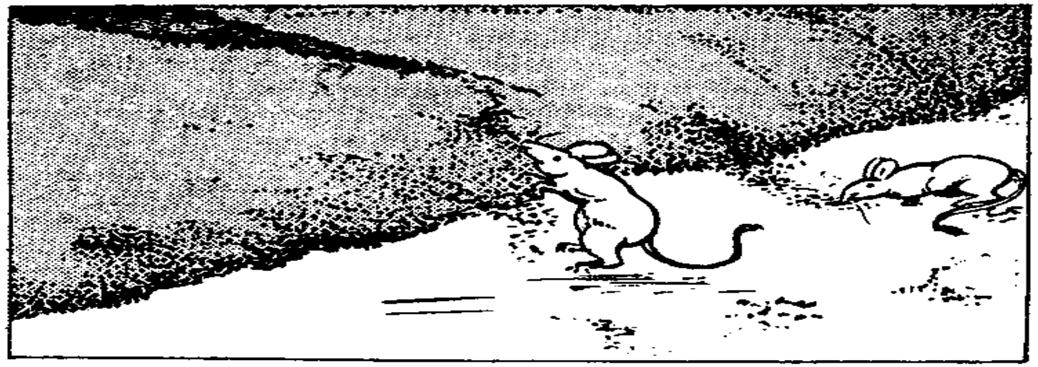
51ap136.gif (600x600)

4. Fumigate with EDB ampoules to avoid insect damage.



Fumigate when the grain is stored. Check periodicaliy and fumigate again if you find live insects.

5. Use anticoagulant for rat control.



Rats damage stored grain and contaminate it with their excreta

<FIGURE 127>

<FIGURE 128>
FOR ADVICE ON YOUR STORAGE

PROBLEMS AND TRAINING

CONTACT ANY OF THE

FOLLOWING PLACES

IN PERSON OR

BY POST:

SAVE GRAIN CAMPAIGN
Department of Food
Ministry of Agriculture
Krishi Bhavan
New Delhi-l.
OR

Post Box No. 10 Post Box No. 7823
Hapur (U.P.) Bombay

Post Box No. 509 Post Box No. 22
Patna (Bihar) Bapatla (A.P.)

Post Box No. 158
Ludhiana (Pb)

Prepared by:
INDIAN GRAIN STORAGE INSTITUTE
HAPUR (U.P)

<FIGURE 129>

51ap139.gif (486x486)

PRESERVE CORN SAFELY IN STORAGE BARNS

MINISTRY OF AGRICULTURE

Division of Stored Products-Extension

Managua, D.N., Nicaragua, C.A.

Preparado por:
Ramiro Lopez
Asistente de Extension de
Productos Almacenados.

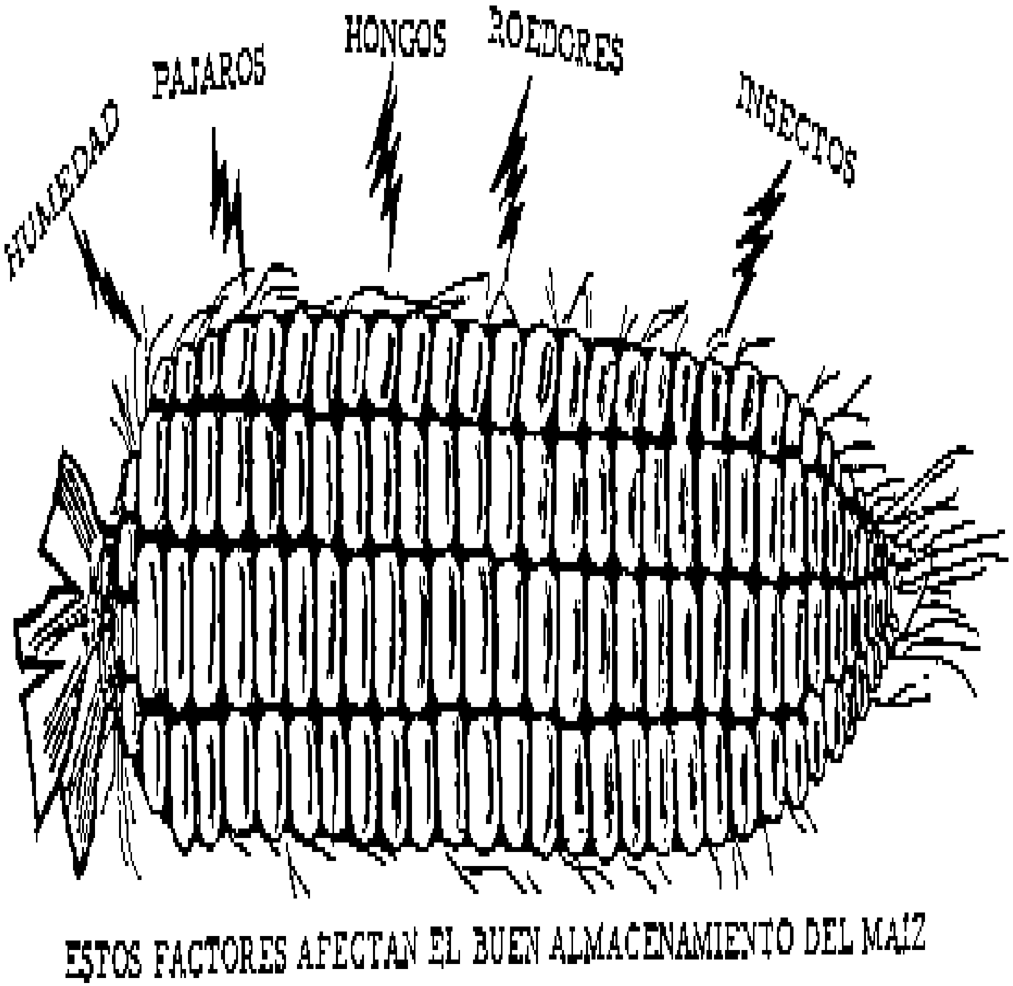
Revisado por: Agro. Francisco Estrada
Jefe de Extension de
Productos Almacenados,
M.A.G.

EVITE PERDIDAS DE SU MAIZ EN LA TROJA.

Cada ano, durante el periodo comprendido entre la cosecha y el momento en que el producto llega al consumidor, el exceso de humedad del grano, el ataque de roedores, hongos, insectos y pajaros, originan perdidas considerables al agricultor y al comerciante.

<FIGURE 130>

51ap141a.gif (486x486)



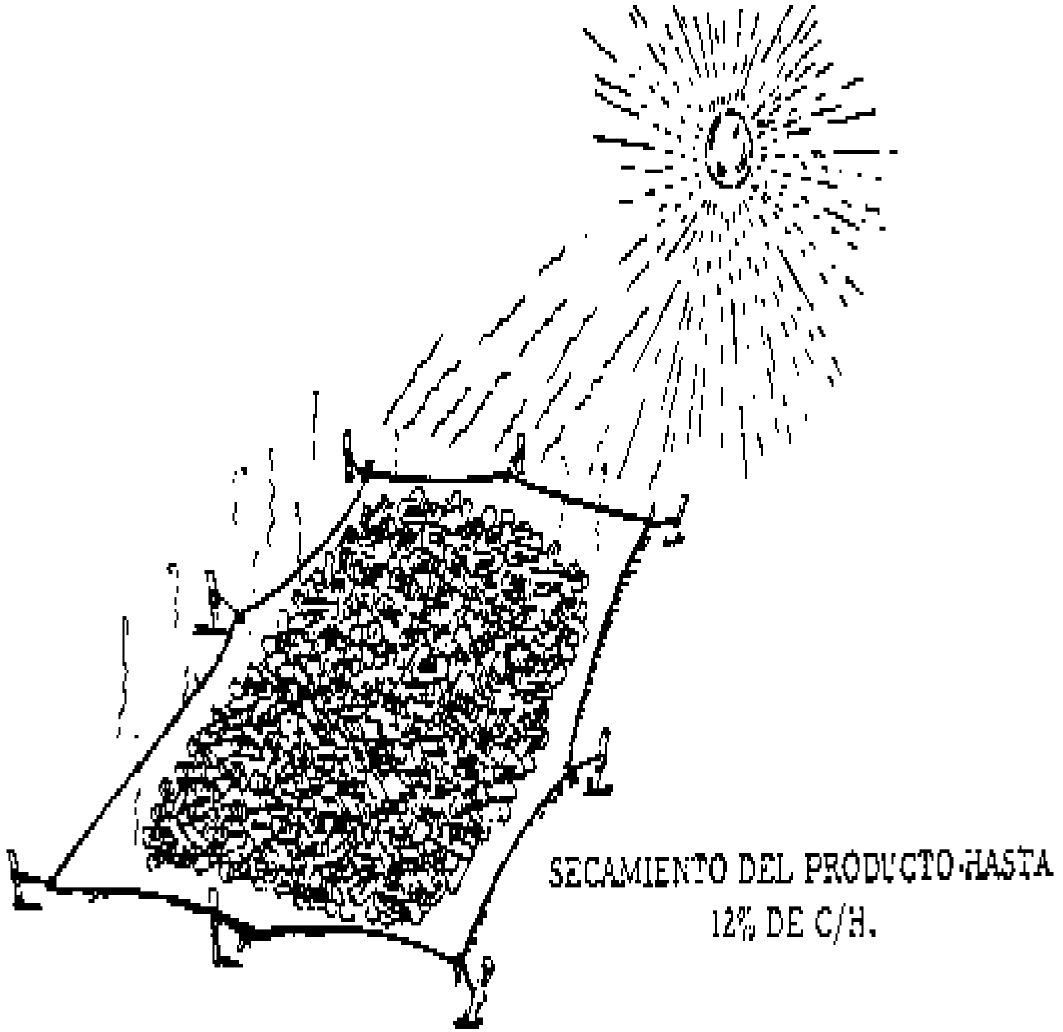
La manera de evitar tales perdidas, es el control sobre las causas antes mencio nadas, mediante un manejo eficiente de los granos, y dandoles una adecuada proteccion durante el almacenamiento.

La humedad, el primero de estos factores, puede controlarse de una manera efectiva, mediante un buen secamiento del grano, antes de guardarlo en el

almacen
o granero; bajando su contenido de humedad hasta un 12% o sea cuando este bien seco.

<FIGURE 131>

51ap141b.gif (540x540)



PREVENT STORAGE LOSSES OF YOUR CORN IN THE BARN

Each year, during the period between the time of harvest and the time when the grain reaches the consumer, there are

considerable losses for the farmer and merchant. These losses are due to excess grain moisture, the attack of rodents, molds, insects and birds.

MOISTURE BIRDS MOLD RODENTS INSECTS

These factors affect the good storage of grain

The best way to prevent such losses is to control the causes by proper handling and adequate protection of the grain during storage.
Dampness, the first of these causes of grain loss, can be controlled effectively by good drying before storage. The safe moisture content for corn is 12% or lower.

DRYING THE PRODUCT TO 12% OR LOWER

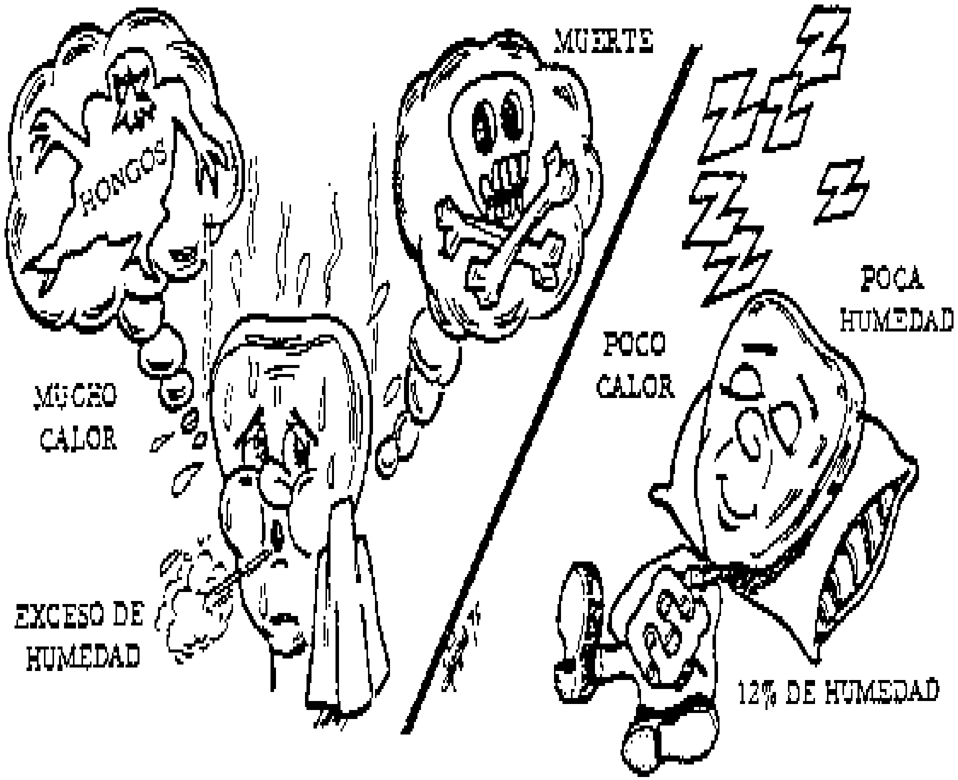
Practicamente, podemos calcular, si la humedad en el grano esta buena para conservarlo, cuando al morderlo, este se quiebra, sin presentar elasticidad y que no este lechoso.

Tambien podemos saber que el grano no esta aun bueno para almacenarse, cuando al introducir la mano entre estos granos, sentimos el calor proveniente de ellos, que por exceso de humedad se encuentra en plena actividad respiratoria; en cambio,

se sentira fresco el grano cuando debido al secamiento, haya disminuido dicha actividad;
entonces los granos estaran reposando y podran ser almacenados, sin mucho riesgo de que se desarrollen hongos, y sin peligro de que se pudran.

<FIGURE 132>

51ap143.gif (393x486)



La humedad y el calor excesivos, son ambientes propicios para que se desarrollen hongos que ocasionaran dano al producto que se almacena.

El dano por roedores puede evitarse en gran parte proporcionando al local de almacenamiento una adecuada proteccion, contra el acceso de las ratas. Tambien manteniendo los alrededores del granero limpio de malezas y desperdicios, ya que estos roedores prefieren no movilizarse por sitios despejados.

Es muy efectivo para su control el uso de raticidas en forma de cebos, de los que se venden en el comercio, tales como Racumin, Zelio, etc.

**No se deben dejar estos cebos al alcance de los ninos ni de los animales domesticos,
porque son productos muy venenosos.**

In practice, we can check the moisture content in the grain which is safe for good storage by biting it. Dry grain is hard, so it will break with a sharp crack, rather than crushing easily like wet grain.

We can also find out if grain is in good condition for storage by touching it. If we feel heat rising from the grain, it is too wet. If the grain is excessively wet, it will respire, producing heat and moisture. On the other hand, dry grain will feel cool. If grain is giving off heat, it should be dried immediately to assure storage without risk of mold development and rotting.

DEATH
MOLD

TOO MUCH LITTLE MOISTURE
HEAT LITTLE HEAT

TOO MUCH 12% MOISTURE
MOISTURE

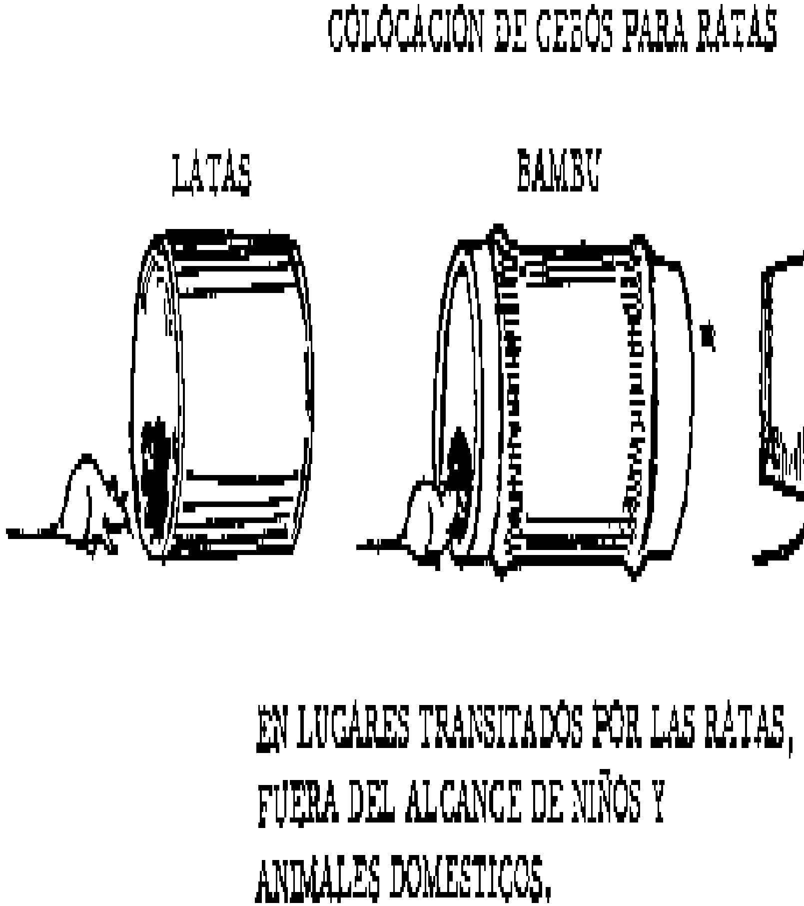
Moisture and excessive heat are favorable conditions for the growth of molds which will damage the grain.

Damage by rodents can be avoided to a large extent by protecting the storage area against the invasion of rats. Also, the surrounding areas of the granary should be kept clean of weeks and garbage as rodents prefer not to move through open, clear areas. The use of pesticides such as Racumin, Zelio, etc., in the form of bait, is effective for control of rodents.

These pesticides should not be Left within the reach of children or pets because they are extremely poisonous products and can cause serious illness or death. Rat poisons should always be used very carefully, following recommended instructions.

<FIGURE 133>

51ap145a.gif (486x486)



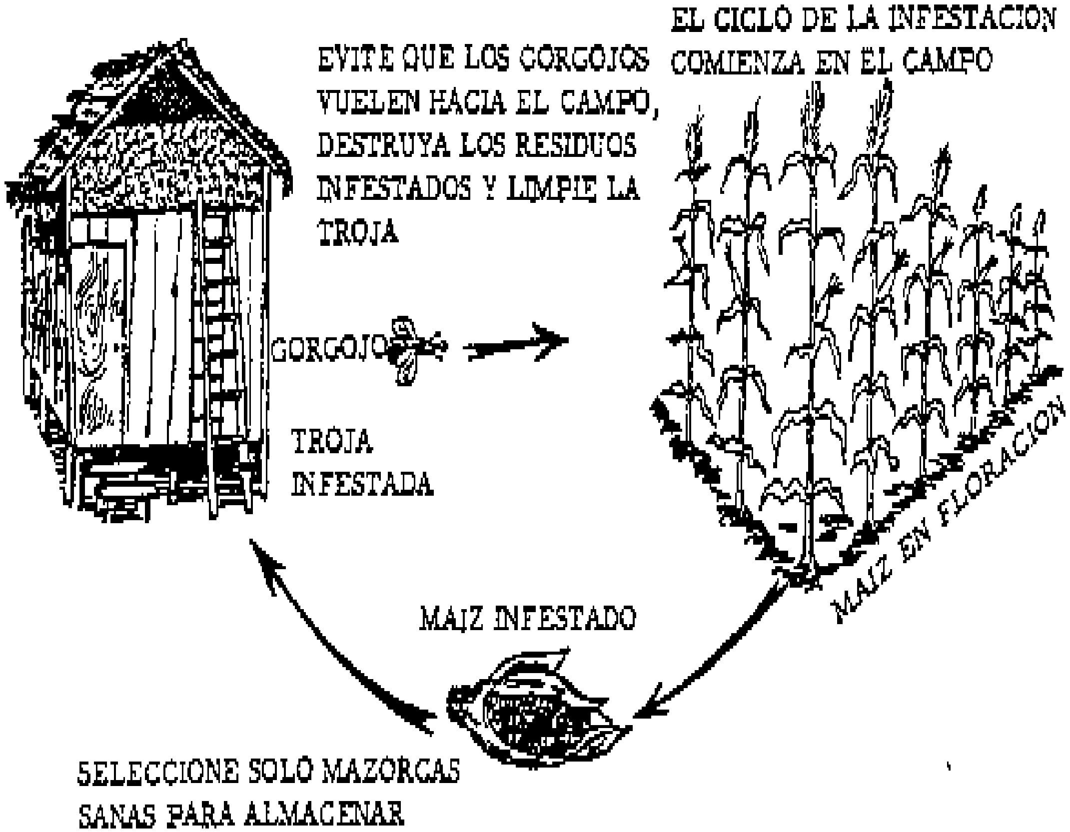
El dano por insectos, es el que generalmente causa mayores perdidas en los productos que se almacenan. Su control se debe ejercer desde el momento en que esta comenzando a florecer en el campo el maiz que se piensa cosechar y almacenar.
En este tiempo en que ya esta espigando el maiz, los insectos pueden estar en alguna troja infestada, cercana al plantio de maiz; vuelan hacia el campo en busca

de nuevo alimento y comienzan a penetrar la mazorca por las aberturas de la tuza:
resultandoles mas facil la penetracion, cuando esta tuza ofrece escasa protection
al grano.

Es por esto que algunas variedades mejoradas, se pican mas facilmente que las variedades criollas, pues estas, generalmente poseen buena cobertura.

<FIGURE 134>

51ap145b.gif (432x534)



PLACEMENT OF BAIT FOR MICE/RATS

CANS BAMBOO BOXES

IN PLACES TRAVELED BY RATS OUT OF THE REACH OF CHILDREN AND FARM ANIMALS

Generally, the greatest losses in stored products are

caused by insect damage. Insect control should be exercised from the moment the corn is beginning to mature in the field through the time when the corn is harvested and stored. Insects may be in an infested barn, near the grain field, flying through the field in search of new food, or already beginning to penetrate the ear of corn through openings in the corn husk. The only natural protection of the ear of corn is the husk, which can be penetrated by insects.

Some of the newly developed varieties of corn have husks which are more easily penetrated than traditional domestic varieties. Extra precautions against insect invasion need to be taken with these newer varieties.

THE CYCLE OF INFESTATION
BEGINS IN THE
FIELD
PREVENT INSECTS FROM
FLYING TO THE FIELD
DESTROY INFESTED REMAINS
AND CLEAN THE BARN

INSECT MATURE CORN

INFESTED BARN

INFESTED CORN

SELECT ONLY HEALTHY EARS OF CORN

FOR STORAGE

<FIGURE 135>

51ap147.gif (600x600)

111 SQUARE YARDS

6 OUNCES (175 c.c.)
MALATHION LIQUID 57%

1 GALLON WATER

In order to prevent infestation in the field, the granary should be cleaned of all the remains of the previous harvest, which may be infested, and these remains burned or destroyed. Next make an application of Malathion liquid of 57% by diluting 17 1/2 spoons (16 oz.) of this insecticide in a gallon of water. Using a sprayer, completely cover the ceiling, walls, and floor surfaces of the granary. With a gallon of this mixture, a surface of 111 square yards can be covered.

APPLY MALATHION LIQUID ON THE WALLS, CEILING AND FLOOR OF THE GRANARY

MATURING CORN

SWEEP AND CLEAN THE GRANARY
CLEAN THE SURROUNDING AREA

BURN THE REMAINS

Al llevar el maiz cosechado hacia la troja o granero, para almacenarlo, se deben seleccionar las mazorcas sanas, evitando guardar mazorcas picadas que infestarian

a las otras mazorcas.

<FIGURE 136>

51ap149a.gif (353x437)

SELECCIONE SOLO MAZORCAS SANAS PARA ALMACENAR

No se debe dejar el maiz ya maduro doblado o sin doblar en el campo, por mucho tiempo, porque queda expuesto a la infestacion de insectos y al ataque de ratas y pajaros, durante un periodo mas prolongado. Se debe proceder a la cosecha, tan pronto como lo permitan las condiciones del ambiente y el contenido de humedad del
grano.

Para proteger al maiz que se va almacenar en trojas, se recomienda aplicar el insecticida Malathion en polvo al 2%. Este se debe aplicar por capas, es decir colocando primero, sobre el piso donde estara la troja, una ligera capa de insecticida, despues se coloca la primera capa de mazorcas, luego otra capa de insecticida, y asi sucesivamente hasta dejar la troja llena a la altura deseada. Las dosis que se recomiendan para el uso de este insecticida estan de acuerdo al tamano de las mazorcas. Asi, tenemos que para los hibridos y variedades mejoradas, como el tamano de la mazorca es un poco grande, hay que aplicar una onza de Malathion 2% en polvo (Triangulo Verde) por cada 100 mazorcas con tuza. Para las variedades criollas, como las mazorcas son mas pequenas, se debe aplicar una onza del insecticida por cada 150 mazorcas con tuza.

<FIGURE 137>

51ap149b.gif (393x486)

When the harvested corn is brought to the barn or granary for storage, the best ears of corn should be selected., avoiding the storage of ears which are already infested with insects, as these insects can easily infest other ears of corn.

SELECT ONLY HEALTHY EARS OF CORN FOR STORAGE

The ripened corn, whether piled on the ground or still on the stalk., should not be left in the field too long because over a prolonged period of time it is exposed to the attack of rodents and birds. The harvest should be carried out as soon as the climatic conditions and moisture content of the grain permit.

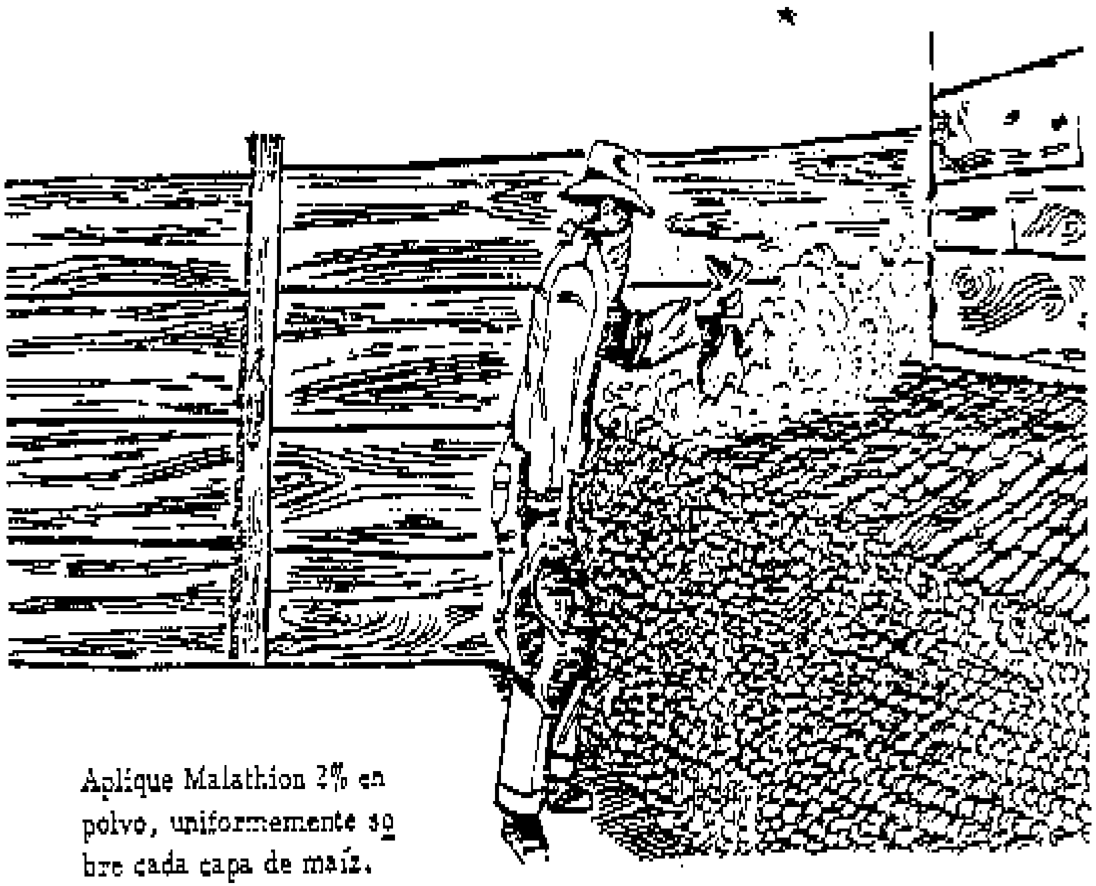
To protect the corn to be stored in barns, it is recommended that 2% Malathion insecticide in powder be applied.

This should be applied in layers. First, dust a thin layer of insecticide on the floor where the grain will be stored. Next, after the first ears of corn are placed, dust another layer of insecticide and so-on until the barn is filled to the desired level. The doses recommended for the use of this insecticide are in accordance with the size of the ears of corn. Thus, we have to apply one ounce of 2% Malathion in powder (green triangle) for every 100 ears of hybrid and newly developed varieties. As the ears of the native varieties are smaller, one ounce of insecticide for every 150 ears should be applied.

Este polvo debe ser espolvoreado sobre la superficie de todas las mazorcas, de modo que las proteja totalmente. Se puede lograr una aplicacion uniforme, utilizan
do una media de tela de Nylon o cualquier bolsa de tela rala, que permita al polvo
filtrarse facilmente hasta las mazorcas.

<FIGURE 138>

51ap151a.gif (437x540)



Se debe aplicar exactamente la cantidad de insecticida que se recomienda y seguir
los metodos indicados, para evitar malos efectos del polvo por una defectuosa aplicacion.

<FIGURE 139>

51ap151b.gif (486x486)

Editado e impreso en la Sección de Publicaciones del SCCA del MAG.

3 M
Junio 1975.

APPLICATION OF INSECTICIDE IN CORN BARNS

POWDER (GREEN TRIANGLE)

FOR EVERY 100 EARS

FOR EVERY 150 EARS

NATIVE CORN HYBRID CORN

This powder should be sprinkled on the surface of all of the ears of corn in a way that totally protects them. A uniform application may be obtained by using a nylon sock or any sack or bag with a loose weave which permits the powder to be filtered easily through to the ears of corn.

Apply 2% Malathion in powder uniformly over each layer

In order to avoid problems caused by the improper application of insecticide, the exact recommended quantity should be used and the indicated methods followed.

Appendix B

This Appendix contains excerpts from an article which appeared in Tropical Stored Products Information in 1971. It is included here to give you some idea as to the types and number of moisture meters which are available. A Table included at the end of this article also lists the names and addresses of the manufacturers and/or suppliers of the meters so that you can write for further information.

The following material is taken from Tropical Stored Products Information, Tropical Products Institute, 1971 VOL. 21

GUIDANCE IN THE SELECTION OF MOISTURE METERS FOR DURABLE AGRICULTURAL PRODUCE

by

T N Okwelogu

Tropical Stored Products Centre (Tropical Products Institute), Slough

Sources of Information

The three principal sources of information available to the prospective user are (1) newspapers, magazines and journals, (2) manufacturers' brochures, and (3) organizations in a position to give unbiased information about moisture meters.

Some newspapers, magazines and journals, which occasionally contain information about meters, include the Financial Times, Electronic Age, and Power Farming. Whilst manufacturers are always helpful in supplying plenty of information about their own range of meters, information about a much wider range of meters will be more likely to be obtained from organizations having unbiased interest in these instruments.
Examples of such organizations are (1) Tropical Stored Products Centre, (Tropical Products Institute),

Slough, England, (2) Grain Storage Department, Pest Infestation Control Laboratory, Ministry of Agriculture, Fisheries and Food, Slough, England, (3) National Institute Of Agricultural Engineering, Wrest Park, Silsoe, Beds, England, (4) Grains Division, Agricultural Marketing Service, United States Department of Agriculture, Agricultural Research Centre, Beltsville, Maryland 20705, USA. Articles on moisture meters sometimes appear in the publications of these and other similar organizations.

Tables I and II give details of some available moisture meters, particularly how they can be obtained and the commodities with which they may be used. These details are based upon information provided by the manufacturers of the meters.

With every piece of information, it is important to ask the question: is this information sufficient for a decisive opinion to be formed about the meter? Where the answer is `no', further enquiries should be made.

Factors to Consider in Making a Choice

It can be seen from Tables I and II that for any specific purpose, several meters can be found, making the problem of choice a real one, indeed. A satisfactory selection is likely to be achieved when adequate thought has been given to the following factors:

1. Meter types and their implications.

2. Characteristics of the commodity.

3. Requirements of the work for which a meter is sought.

4. Business considerations.

Principles and implications of Meter Types

Most manufacturers indicate the principles upon which the action of their meters is based. An appreciation of the implications of such principles will, no doubt, be of considerable value in deciding which of several meters will be the most suitable. The meters commonly used with durable agricultural products fall into five groups, according to the principles of their action:

1. Those involving chemical interaction between calcium carbide and the product water, with the evolution of acetylene gas, the pressure of which is subsequently measured.

2. Those involving heat-drying of the product, the attendant loss being ascribed to evaporated produce water.

3. Those involving the measurement of electrical conductivity (or resistance) of the product, since the value of this property is relatable to the moisture content, within a

suitable range of moisture contents.

4. Those involving the measurement of the dielectric constant of the product (or capacitance of the electrical system of which the product is a component), since the value of this property changes with the moisture content, within a suitable range of moisture contents.

5. Those involving the measurement of that atmospheric relative humidity which is in equilibrium with the product moisture, since, under equilibrium conditions, there is a definite relationship between the moisture content of a product and the ambient relative humidity

Heat-drying methods require a suitable source of power-supply or fuel, which may not be available. Methods based on the evolution of acetylene gas require regular, supplies of fresh calcium carbide, which is not a safe commodity to handle by post, because of the risk of explosion. Meters measuring the inter-granular relative humidity require, firstly, a knowledge of the relationship between the produce moisture content and the relative humidity of the inter-granular air: secondly, a periodic check on their calibrations; and thirdly, in some cases, large quantities of produce which must have remained undisturbed for sometime prior to testing.

The electrical meters are faster, and in the main, less demanding on calibration checks, but require skilled servicing. Also, they give less reliable readings outside the middle region of the range of moisture contents for which they are calibrated. The accuracy of the probe-type electrical meters is affected by variations in the pressure exerted by the produce on the electrodes, while the consistency of the readings of those meters which measure the dielectric constant is affected by inconsistent packing of the sample in the test chamber.

Attention has been focused above on the less favourable features of the meter groups mainly because they are more likely to be overlooked. Information on the merits of any meter will not normally be difficult to obtain, and Tables I and II show the relative merits of the meters discussed in the present article.

Characteristics of the Commodity

The commodity to be tested imposes a number of limitations, and these must be taken into account when considering the use of any meter. Perhaps the best way to do this is to answer questions such as the following.

First, is the chemical nature or any normal pre-treatment of the produce likely to interfere with the use of

the meter? For instance, meters measuring electrical conductivity may not be suitable for produce, like salt-fish, which will become highly conductive when damp. Again, for commodities like dried egg or milk, a heat-drying meter may not be suitable.

Second, is the moisture content to be measured outside the range for which the meter is calibrated? For example, very few electrical meters are known to be suitable for a product like made-tea whose moisture content is normally required to be below 5 per cent, that is outside the range of moisture contents for which most electrical meters are calibrated.

Third, is the milling property of the produce incompatible with the effective use of the meter? For example, commodities like macadamia nuts, palm kernels and copra are not easily ground, while others like cashew nuts (not the kernels) are simply not amenable to grinding.

Fourth, are the unit size and shape of the produce likely to affect the efficient use of the meter? The construction of the meter may be such that it cannot be pushed into floury or powdery produce without hampering the measurement of moisture. Again, larger products like cocoa beans, unshelled groundnuts, cashew nuts and pieces of illipe nuts (Shorea spp.) will present packing problems with some meters.

If the answer to each of the above questions is an unqualified `No', then the meter may be considered suitable for the product. But a `Yes' answer can make all the difference between a meter being chosen or rejected. In such a case, steps should be taken to see what, if anything, has been done to solve the problem, either by the manufacturer or by someone else.

Nature of the Situation Needing a Moisture Meter

In an article of this kind, it is not easy, even if it is possible, to cover all the situations where the use of a moisture meter may be desired. However, such situations are likely to fall into one or the other of the following categories:

1. Knowing whether grain is at the right stage for harvesting.

2. The processing, (eg drying or milling), of foodstuffs.

3. Bulking or packaging produce for storage.

4. Commercial transaction, where moisture content is part of the basis for payments.

5. Produce Inspection Service.

All the above situations require moisture meters which are not fragile, which are consistently accurate within limits acceptable for the particular purpose, and whose performance is little affected by the operating conditions of space, temperature, pressure, light, dust or wind. They also require, to a greater or lesser extent, meters that are simple to operate, portable and capable of taking remote measurements, as with probe-electrodes, or stem hygrometers.

Business Considerations

The purpose for which the use of a meter is usually contemplated is two-fold: to increase or improve productivity, (that is, the flow of goods and services), and to ensure economical operations.

Productivity can be improved by employing a meter which can give results rapidly; a meter for which spares and facilities for servicing and/or calibration are easily available; a meter which does not depend upon sources of operating power that run out, break down, or become short in supply (eg battery, mains supplies, gas, paraffin and other fuel).

Economy of operation implies keeping down to the minimum both capital and operating costs, and/or increasing the return to unit cost. Additionally, the wider the range of commodities that a meter can test, the more economical will be its use. Likewise, the less destructive a test is, the less will be the incidental loss to production, caused by the use of a meter. Although this kind of loss may appear small, it must be realised that its magnitude will depend on how much produce is damaged at each test, and how many times such tests are carried out on a given product.

Conclusions

It should be clear from these discussions that very few meters, if any, can win the top position in every conceivable area of consideration, and that there is no magic formula for choosing a meter. But where a choice has to be made, the final responsibility for it must be that of the buyer.

He must have a knowledge of the commodity to be tested and the accuracy required of a determination of its moisture content the availability of the meter, and the cost of operating it; the conditions under which the meter will be operated: the ease of obtaining spares and facilities for servicing or calibrating the meter: the type of power supply required and available. And when a provisional choice has been made, it is often advisable to obtain the meter on loan for trial before buying.

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(Details from the authors: Standardisation and Testing Branch, Grain Division, Agric. Marketing
Service, USDA, Agric. Research Centre, Beltsville, Maryland).

Table 1 Details of some available proprietary moisture meters(1)

Meters under principles Power supply: Test speed: Accuracy Price rating: Manufacturer/Supplier
of action B Battery + Under 1 min (Within % MC) * Under 50 [pounds]
G Self-generating ++ 1-5 min ** 50 [pounds] - 100 [pounds]
M Mains +++ over 5 min *** Over 100 [pounds]
N None required

CHEMICAL (C)

C.1 Speedy N +++ 0.5 * Thomas Ashworth & Co Ltd
Sycamore Avenue
Burnley, Lancs, England

DRYING (D)

D.1 X17 Agat M +++ 0.3 * A.B.G.L. Jacoby
Box 23014Y, Stockholm 23
Sweden

D.2 Cenco Moisture M ++ 0.2 * Cenco Instrumenten Mij, n.v.
Balance Konijnenberg 40, Post Box 336
Breda, Holland

D.3 Dynatronic IR M ++ 0.2 * Lab-Line Instruments**
Moisture Analyzer International Lab-Line Plaza
Mark II 15th & Bloomingdale Aves,
Melrose Park, Illinois, USA

D.4 ts Crop Tester M +++ 1.0 * Tower Silos Ltd
2 Block Street, Bath
Somerset, England

D.5 Vacuum Moisture M ++ 0.1 * Townson & Mercer Ltd**
Tester Croydon CR9, 4EG, England

ELECTRICAL CONDUCTIVITY (Ec)

Ec.1 KPM Aqua Boy B + 0.2 ** K.P. Mundinger GmbH
D-7253 Renningen, W. Germany

Ec.2 Universal Moisture G ++ 0.2 ***
Tester Burrows Equipment Co
1316 Sherman Avenue
Ec.3 Safe Crop Moisture B,M ++ 0.5 ** Evanston, Illinois, 60204 USA
Tester

Footnotes are explained on p. 28.

Table I (contd)

Meters under principles Power supply: Test speed: Accuracy Price rating: Manufacturer Supplier
of action B Battery + Under 1 min (Within % MC) * Under 50 [pounds]
G Self-generating ++ 1-5 min ** 50 [pounds] - 100 [pounds]
M Mains +++ over 5 min * Over 100 [pounds]**
N None required

ELECTRICAL CONDUCTIVITY (Ec) (contd)
Ec.4 Agil Moisture Meter B + 1.0 - 2.0 * Agil Ltd, Nicholson House
Nicholson's Walk
Maidenhead, Berks, England

Ec.5 Hart Moisture Meter B,M + 0.2 * Hart Moisture Meters, Inc**
K101. K103 400 Bayview Ave, Amityville

N.Y. 11701, USA

Ec.6 `Hydraprobe' B + 2.0 * Coe's (Derby) Ltd
Copra Moisture Thirsk Place, Ascot Drive
Meter Derby, D'E2 8JL, England

Ec.7 Marconi Moisture B,M + 0.5 ** Marconi Instruments Ltd
Meter TF933B Longacre, St Albans
Herts, England

Ec.8 Protimeter B ++ 0.5 ** Protimeter Ltd
Grainmaster Field House Lane
Marlow, Bucks, England

Ec.9 ScotMec-Oxley G + 1.0 ** Scottish Mechanical Light
Industries Ltd
42-44 Waggon Road, Ayr
Scotland

Ec.10 Siemens Moisture B,M ++ 0.5 * Siemens (UK) Ltd**
Meter Grt West House, Grt West Rd
Brentford, Middx, England

DIELECTRIC CONSTANT (Ed)

Ed.1 Cera Tester B + 0.3 ** A/S N. Foss Electric
39 Roskildevej, 3400
Hillerod, Denmark

Table I (contd)

Meters under principles Power supply: Test speed: Accuracy Price rating: Manufacturer/Supplier
of action B Battery + Under 1 min (Within % MC) * Under 50 [pounds]
G Self-generating ++ 1 -5 min ** 50 [pounds] - 100 [pounds]
M Mains +++ over 5 min * Over 100 [pounds]**
N None required

DIELECTRIC CONSTANT (Ed) (contd)

Ed.2 Kappa-Janes B,M ++ 0.5 * Kappa Janes Electronics**
Moisture Meter 27 Stewart Avenue
Shepperton, Middx, England

Ed.3 Burrows Moisture M +++ 0.3 * Burrows Equipment Co**
Recorder 1316 Sherman Ave, Evanston
Illinois 60204, USA

Ed.4 Lippke Moisture M + 0.5 * Paul Lippke K.G. 545 Neuwied**
Meter FK-R-6 PO Box 1760, Germany

Ed.5 Wile B ++ 1.0 * OY Fima Ltd, Helsinki 70
Finland

Ed.6 Super-Matic Foss M ++ 0.3 * A/S N. Foss Electric**
39 Roskildevej, 3400
Hillerod, Denmark

**Ed.7 Transhygrolair B - 1.0 * Les Applications
Industrielles de la Radio
236 Chemin des Vitarelles
Tournefeuille (31) France**

Ed.8 Steinlite Meters B,M ++ 0.3 * Seedburo Equipment Co
618 West Jackson Boulevard
Chicago, Illinois 60606 USA**

**Ed.9 Dole 300 Moisture B,M + - ** Eaton Yale & Towne Inc
Tester Dole Division, 191 E North
Avenue, Carol Stream
Illinois 60187, USA**

**Ed.10 Cae Moisture B + 0.3 ** Canadian Aviation Electronics
Meter Model 919 Ltd, Winnipeg 4, Canada**

Table I (contd)

**Meters under principles Power supply: Test speed: Accuracy Price rating: Manufacturer/Supplier
of action B Battery + Under 1 min (Within % MC) * Under 50 [pounds]
G Self-generating ++ 1-5 min ** 50 [pounds] - 100 [pounds]
M Mains +++ over 5 min, *** Over 100 [pounds]
N None required**

**Ed.11 G-c-Wyndham B + 0.5 - 1.0 * E J Chapman & Co Ltd
Moisture Meter Martley, Worcester, England**

Ed.12 C.D.C. Automatic M + 0.3 *** Compagne des Compteurs (GB)
Moisture Meters Ltd, Terminal House
Hyb 24, Hyb 25 B + 0.5 *** Grosvenor Gdns, London SW1
Hyb 42, Hyb 43 England

INTER-GRANULAR RH (H)
H.1 Dip-Shaft N +++ 1.0 * Abrax Inc, 179/15H Jamaica
Humidity Indicator Ave, Jamaica,
New York 11432, USA

H.2 Quicktest N +++ 1.0 * Opancol Ltd
Models 1 and 2 10/11 Gamage Building
Holborn Circus, London EC1
England

(1) All the information given in this table has come from the manufacturers

- Data not available

NB The exclusion of an instrument from this table does not necessarily imply the author's disapproval of its use with agricultural produce.

Appendix C

WORKING PAPER ON THE

VOLUNTEER ROLE IN GRAIN STORAGE

The following working paper was originally presented at a regional grain storage seminar held in Cotonou, Benin, West Africa, in 1974. The seminar was sponsored by the International Secretariat of Voluntary Services, the UN Food and Agriculture Organization, and the U.S. Agency for International Development.

The seminar's purpose was to encourage the initiation of farmer-oriented storage extension programs through the sharing of practical information and field experiences. It was attended by over 100 participants from nineteen countries in Africa, Europe, and North America. A handbook/report was published, by the German Agency for Technical Cooperation Ltd., which includes all working papers, discussions (summarized), and construction plans for various silo and dryer models reviewed during the seminar. Several of the modified plans presented in this manual are included in the seminar report. It is available from the seminar secretary, Mr. David Dichter. His address is: David Dichter and Associates, Development Assistance Programmes, 9 rue de Vermont, 1202 Geneva, Switzerland.

WEST AFRICAN SEMINAR ON THE VOLUNTEER ROLE IN FARM

AND VILLAGE-LEVEL GRAIN STORAGE

DECEMBER 13-23, 1974

COTONOU, DAHOMEY

WORKING PAPER No. 1

PROBLEMS RELATED TO POPULARIZING NEW FARM-LEVEL GRAIN STORAGE TECHNOLOGY

Carl Linblad
Mark Newman
Roger Vinita
United States Peace Corps
Volunteers to Dahomey (Benin)

Attached to the

Agriculture Service
Ministry of Rural Development
and Cooperative Action

INTRODUCTION

Since 1967, the Agriculture Service of Dahomey and the United States Peace Corps have collaborated in creating, implementing and evolving a farm-level grain storage program in southern Dahomey. One result of this joint program is the actual construction of over two hundred and fifty individual storage units. Another result is seven years of cumulative experience in working through some of the practical day-to-day problems of popularizing new farm-level grain storage technology. This shared experience by two organizations, one a governmental agency and the other an international volunteer agency, forms the basis for this paper.

The authors see the primary purpose of this paper as a presentation of some of the major considerations in the planning and establishment of a farm-level grain storage program. Of secondary importance is a brief history, attached as an appendix, of the collaboration of the Agriculture Service and the Peace Corps in evolving the program.

While the authors' program is limited to Dahomey and primarily one type of storage facility; it is hoped that their practical experience will be of benefit to others initiating similar programs, regardless of the storage method adopted. The paper is not an instruction manual nor a "how-to-do-it" guide to popularizing new techniques in grain storage. Rather, it is a brief discussion, with specific examples based on the author's experience of five major areas of concern in planning a new grain storage project:

1. Assessment of the problem
2. Choice of the improved method to popularize
3. Financial considerations
4. Stimulating interest in improved storage methods
5. The extension and integration of the project into the local infrastructure.

(1) See "Construction Manual for the 4.5 Ton and 2.5 Ton Cement Silo and the Mud Walled Grain Dryer" by U.S. Peace Corps Volunteers, October 27, 1974.

Part I. Assessment of the Problem

The initial phase in the planning of a project to improve grain storage technology is an analysis of the problem from the point of view of the farmer in the particular locality to be served. He is the key ingredient. Any program must be based upon realities as seen by the farmer who will be storing his grain.

In Dahomey, the traditional corn-growing farmer lives in a small village and annually cultivates up to 3 hectares (7 - 1/2 acres) by hand. His annual yield with two growing seasons could be estimated at 600-800 kg/hectare or a total of 1,800-2,400 kg. This is classic subsistence farming, probably not unlike that of most corn-growing farmers in the developing world.

Traditional storage methods. Initially in the consideration, choice and planning of an improved storage program it is advisable to analyze local traditional methods in order to (1) understand their shortcomings and therefore the need for improved techniques and (2) investigate for possible simple, yet effective, improvements. Certainly, minor and effective changes to existing methods of storage are easier to popularize than the introduction of complex and costly alternatives. For example, perhaps improved sealing of traditional granaries or a broad-based program of insecticide treatment could have significant immediate effects.

At any rate, the important point is to think about the traditional methods of storage from the farmer's viewpoint. Does he find that the traditional methods are inefficient? Does the rapid rate of insect multiplication make it impossible to store grain over a long period of time with his traditional method? Do mold growth and rotting present

Problems? What about rodents and birds? How much grain does he actually lose with his traditional methods of storage?

Market Price Realities. As a practical matter, farmers will not be inclined to change their traditional storage methods unless there will be sufficient financial returns from whatever additional labor, time or cash inputs are required by the improved storage techniques. Therefore, the economics of the improved techniques as affecting subsistence farmers must be carefully studied.

Local market price information is needed. What are the prices of grain at harvest time and at the yearly high? Also, does the farmer have large financial demands at harvest time? What are his spending habits? Does he normally have to sell his grain before prices have started to reach their seasonal high? How much fluctuation is there in the price on the local market? Are there other more lucrative markets he can reach easily? Is transportation of his crops to the market expensive or impractical?

There are other economic and market factors to consider. For example, traditionally, grain in Dahomey is sold in markets by volume rather than by weight. This could work against the adoption of improved storage methods. The improved quality of well-stored grain, for instance, could bring few benefits if the farmer not using improved methods can mix a large proportion of his damaged corn with good grain and thus sell it at the same price as well-stored grain.

Similarly, are grain prices keeping pace with inflationary price rise in the cost of the new storage techniques? Also, increased transportation prices, for example, can reduce potential profits. In short, the economies, that is, the practical benefits of a new method, must be thought through from the farmer's standpoint or, it may fail to be accepted because of simple economic realities.

Social Customs and Traditions. Similarly, local customs and traditions should be carefully studied from the farmers viewpoint to see what impact they might have on the introduction of a particular storage technique. The use of insecticides, for example, may require careful planning. If farmers are used to leaving their maize unhusked during storage, will they resist? Will insecticide-treated grain have a changed taste or odor? Is treated grain acceptable by the farmer for his own consumption? Is it acceptable for sale locally? Have there been any bad experiences in the locality as a result of the misuse of insecticides?

Another example of the importance of social customs is the farmer's attitude toward centralization of storage facilities. Does the farmer traditionally build a granary in his field and leave the crops stored there until needed? Would a central storage silo cause him transportation problems? Will he resist co-operative storing because he doesn't want his neighbor to know how much he has produced? Social factors such as these can affect the success of a new storage program.

Having analyzed the problems from the point of view of the farmer, the planning agency or organization must decide upon the scope of the program it hopes to introduce and to what extent it can support the program.

Personnel considerations. The providing of new information and training and support for the introduction of improved storage methods requires considerable personnel. Does the agency have sufficient manpower? Will the personnel need training in the new techniques? Will voluntary extension personnel be needed? To whom will volunteers be responsible? What will their role be in relation to the permanent extension personnel? How will coordination be arranged? Is the organizing agency willing to assign permanent personnel to assure the success of the program? Staffing and training, therefore, are extremely important in planning a new program.

Material Availability. The supply of necessary materials must be assured as well. To what extent is the project dependent upon vital materials which are influenced by outside forces, ie., regional or world shortages, inflation. Cement, insecticides, tin sheeting, re-rod, sand, water, screening, wood ---- are they readily available? Who will be responsible for assuring the supply of needed materials? How reliable is that person or agency? How reliable is the supply? Lack of critical items when needed will undermine the farmer's confidence in the program.

Transportation. Are local transportation facilities available and adequate for the needs of the program? If they are not, provisions for vehicle support must be made. In such a case, decisions must be made as to the use of the vehicles before precedents are set. If farmers are dependent on a project to transport their harvests, this may prevent the development of local transport and cause difficulties when the project can no longer continue such support.

Commercialization. Marketing success of grains stored using improved methods will influence the rapidity with which those methods are accepted. For example, if local market prices do not fluctuate as greatly as those in urban centers, the sponsoring agency may want to consider the planning and support of organized transportation for commercialization. The program should consider the available means of commercialization and look for improvements to enhance the value of the improved storage techniques. For example, the sponsoring agency may want to reward farmers for the improved quality of their grain by introducing some system of quality grading or sale by weight to help popularize their techniques.

The above brief summary includes some of the major factors an agency must evaluate in deciding at what level it is willing to and capable of participating in a program for new grain storage techniques.

Having thus considered the problem, one is better prepared to choose the particular means of improving storage which is best suited for the new program.

Part II. Choice of the Improved Method to Popularize

The choice of an improved storage technique for popularization should result from an analysis of the existing problems. Clearly, the economic factor will weigh very heavily. In dealing with subsistence-level farmers with very limited cash resources, the total cost of construction, repair and utilization of a new technique must be measured carefully against the effectiveness and practical benefit to the farmer. This type of calculation generally requires time for both study and testing of the new method, two factors which are important to the process of choosing a storage technique.

Scientific testing. The importance of scientific testing cannot be over-estimated. Such analysis, before introducing the new storage technique to the farmer, can avoid many problems.

Scientific testing lends authenticity and permits the sponsoring agency to defend confidently such factors as reliability and efficiency. For example, the Institute of Research for Tropical Agriculture (IRAT), in Dahomey, has greatly advanced storage techniques in that country by its testing of many storage methods, among them; local granaries with and without insecticides, cribs, artificial dryers, cement stave and metal silos. The results of these experiments have produced information important to the planning, choice and policy of grain storage programs in Dahomey.

Testing, therefore, is an important step in choosing a particular method of improved grain storage.

Field Experience. Less formal, but equally revealing, is field experimentation. For example, field trials can help to verify the adaptability of local materials as substitutes for more obvious and costly imported materials.

Field tests uncover hidden problems and unanticipated social impediments. They can indicate the level of farmer interest in the proposed new technique.

An example of the value of field tests in Dahomey was demonstrated when they revealed that storage in butyl bags was impractical because common over-filling caused bursting, and rats or sharp objects easily pierced the bag destroying its air tightness. In effect, the field testing of a new technique provides a kind of market sampling of the locality before larger-scale popularization.

The use of permanent extension agents or Volunteers in performing field tests can be effective. In Dahomey, for example, Peace Corps Volunteers performed useful field experimentation in the early years that resulted in much practical information essential to developing the grain storage program here.

Such field experiments must be cearly described as such to farmers to avoid false impressions and to permit adjustments of the program. Thus protected, one can obtain valuable information pertaining to such additional questions as (1) how much training time and supervision is necessary to assure proper construction and/or proper use? (2) can the farmer maintain the technique himself? (3) are special tools required? (4) will the existing agriculture extension system support the new technique?

The final choice of a particular storage method to popularize will be a balance of many of the factors previously discussed in the context of local conditions. To help the reader assess the various grain storage methods presented during the seminar, a "table of consideration" is attached to aid in one's analysis. Participants can fill in any information which they feel is pertinent and valuable to their specific purposes.

Part III. Methods of Financing the Introduction of New Storage Techniques

The organization of the financial aspects of a new program of improved grain storage techniques is essential to the smooth start of the program.

There are several types of financing available from which to choose, among which are included:

1. Direct cash investment by participating farmer
2. Credit financing
3. Price supports
4. Grants

1. Direct cash investment by participating farmer

Cash payment for any improved storage technique is the simplest and most direct method of financing. It requires a minimum of administrative, financial and coordinating burdens for the sponsoring agency. Furthermore, cash programs using the personal financial resources of the farmer can be the method of financing which gives the widest and fastest possible popularization of a program, providing that they are relatively inexpensive and accessible to small farmers.

In countries with an average annual her capita income of less than $100, such as Dahomey, many methods of storage which are relatively low-cost will still be beyond the means of the average small farmer. In this case, high cash requirements can severely limit the scope of a program and the speed of its acceptance.

If the cost of the new technique is too high, the benefits derived from the improvements may be concentrated in the hands of farmers at the highest income level or even with merchants and civil servants who are quick to see the monetary advantages of improved storage methods.

Thus, other methods of financing will have to be considered if the average farmer is to participate in improved storage programs. Later, as a result of his use of improved methods, his increased income may permit him to assume more financial responsibility for additional improvements.

2. Credit Financing

Credit financing can increase the potential availability of improved storage methods to the low-income farmer.

A. Selection of credit recipients is an important consideration. If the project uses financial criteria similar to those used for bank loans, most small farmers will not have sufficient resources or collateral to merit credit. In order to make credit available to those who need it most, without risking a low rate of repayment, it may be necessary to allow repayment of loans in kind or make provisions for a commercialization program for the grain stored.

To participate in a credit program, a farmer should be asked to show his degree of interest in the project, beforehand. This can be judged through the requirement of a cash advance or the supplying of specific materials or labor.

B. The System of repayment of the credit loan should be well-planned before the program begins. Provisions should be made for the eventuality that a certain proportion of the loans will not be repaid sometimes due to circumstances beyond his control, such as crop failure. The terms and requirements of the credit program must be clearly explained to all farmer participants and to all extension personnel to assure that all parties concerned understand the responsibilities being assumed.

3. Price Supports

Another way of financing a program of improved grain storage techniques is by price support contributions by the sponsoring agency. This is a form of gift but it is for the purpose of underwriting the program. For example, it might involve granting a portion of the cash value of construction materials or transportation expenses, the remainder being paid for by the interested farmer or cooperative.

Price supports can provide a valuable alternative to cash and credit financing, especially when there are rapid increases in the prices of building materials or insecticides without equivalent increases in the prices that farmers receive for their produce. Price supports used in conjunction with a cash program can serve to avoid the repayment problems inherent in credit, thus decreasing the administrative burdens of the program.

Un-repayed credit becomes a gift. If a high percentage of reimbursement cannot be assured by a credit program, it might be better to distribute the available financial resources through the use of price supports. This would make it possible to extend the benefits of the program to more people.

A price support program, while limited by the resources available, has many of the advantages of a cash program. The project personnel has a smaller and less complicated administrative work-load than a credit program. Another advantage is that the interest of the farmer is assured by his cash participation.

4. Grants

Grants provide a means of having programs quickly accepted by farmers; their scope is limited only by the financial capabilities of the granting agency. However, grants can present problems to the long-term development of a program. Once the project funds have been exhausted for grant financing, it may be difficult to convince farmers to pay their own money for what others have been given free. In this case, there may be a lag in popularization while farmers wait to assure themselves that no further gifts will be forthcoming.

There is another problem that may result from the donation of a grant: Since the investment by the farmer is minimal, his interest in the upkeep and proper use of the items received may also be minimal.

If grants for the total cost of the storage method are to be given to farmer participants, better results may be assured by careful selection of recipients, thorough explanation of the practical advantages and use of the storage method, followed by continued supervision in its proper use.

Part IV. Stimulating Interest in Improved Storage Methods

There are many methods of popularizing a new storage technique or of stimulating interest in it. The manner in which it is done can directly affect the number of farmers who will choose to try the new technique.

It is best that the program be completely planned before commencing active popularization at the farmer level, in order to avoid confusion or delays. For example, project field agents should be trained and fully informed about the program before they begin discussing it with farmers. The storage method should have been tested. The financial arrangements should be settled and agreed upon. Transportation problems should be resolved. Provisions should be made for the rapid acceptance and expansion of the program. Once all these matters are prepared, than the popularization can begin.

Demonstration Methods

Demonstration of improved storage methods can be very effective in convincing farmers to adopt the new method for themselves. Demonstration models should be highly visible and built to attract a lot of attention. Possible locations for demonstration sites are: near the home of an individual farmer, at farmers' cooperatives, at agricultural youth clubs, at agricultural expositions or on publicly owned land.

Important considerations in attracting the farmers' attention are:
Is the location easily seen? Is adequate, easily interpreted information provided? If it is built for an individual farmer, is he well-respected? Will he use the site? Are there local personnel available who can explain the method? Will the site be attractive and well-maintained?

On Farm Demonstrations

Because of some traditional farmers' reluctance to adopt new methods, the initial demonstration sites may need to be built on a total gift or price-supported basis, perhaps with a guarantee to reimburse any losses in the event of failure. However, when the demonstration site is installed as a gift, recipients may have little stake in its success. Since the purpose of a demonstration site is to spread the knowledge of good results, special care should be taken that such sites are well chosen to reduce problems of mis-use or abandonment. It is a good idea for the selection of farmers for demonstration sites to be done with the aid of local agricultural extension or government authorities. Additionally, close supervision and careful explanation of storage techniques will held to assure good results and positive propaganda.

Agricultural Expositions

The high visibility offered by agricultural fairs presents an excellent opportunity for display, explanation and discussion of demonstration models. An explanation in the local language by a farmer already convinced of the method through personal experience and success can greatly increase the impact of an agricultural fair demonstration. Follow-through is increased by handing out simple flyers which briefly explain the storage method and give names and addresses to contact for more detailed information and assistance.

Demonstration Sites on Public Lands

Sites near market places, health clinics or local agricultural offices can be very effective demonstration locations. Since this type of site generally has no single owner or person responsible for its operation, assurance should be made in its planning to provide for continued and proper use because an unused storage unit can be a bad advertisement. Increased credibility and effectiveness can be provided by assistance of local agricultural extension agents in demonstration site operation and information dissemination and by inviting local farmers to participate in all aspects of its use. Whenever possible, transportation of interested farmers to a demonstration site can increase its impact.

Use of Radio and Newspapers

For more widespread popularization purposes, agricultural radio programs and newspapers can be used. Since these methods lack the visual impact and opportunity for questions provided by actual demonstration sites, explanations must be clearly and convincingly focused at the level of knowledge of the prospective users, preferably in the local language or with simple self-explanatory diagrams and pictures.

Conclusion

With all of the above methods for creating interest through demonstration and information dissemination, emphasis should be placed on the practical benefit of the new storage method and all popularization efforts should be designed for high visibility and comprehension at the level of the farmers for whom the project is aimed.

Part V. Integration into the Local Infrastructure

A grain storage program can have a more lasting and broader impact if it is closely integrated with agricultural extension services, farmers' organizations, local craftmen and the local marketing structure. Additionally, such integration can reduce the program's organizational and logistical responsibilities. For example, the management of insecticide supplies might be turned over to merchants' or farmers' organizations. Craftmen, once trained in storage construction skills, can take over further training through apprenticeship of younger craftsmen. Agricultural agents can supervise drying, treatment and storage. Involvement at all levels of the agricultural, economic and social sectors will help bring about an integration which hopefully results in adaptation of the storage method.

Coordination with other related projects can also extend the long-range effect of a grain storage project. For example, a broader more effective base might be gained by joining forces with grain commercialization programs or improved production projects which encourage the use of fertilizers, improved seeds and/or animal traction. This type of coordination can provide complementary benefits for other sectors of activity as well.

To achieve real and continued integration, one of the project's conscious goals must be just that, integration. Contact between project coordinators through regular meetings or frequent interchange can held to keep communication going and to facilitate cooperation. In addition, competent and thorough training will increase the value of the project extension workers' contribution toward integration. Training sessions can be held "on site" for direct experience or, in the case of large groups, short instruction courses can be incorporated at local training institutes or schools.

Given the temporary nature of third-party developmental aid, a project relying on this type of support cannot expect to have long-term duration if integration into existing infrastructures is not undertaken. The sooner integration begins, the less is the risk caused by the eventual or sudden loss of outside project support, local participation and local adaptation.

APPENDIX

Brief History of the Grain Storage Program of the Agriculture Service of Dahomey and the U. S. Peace Corps

It was in 1967 that the Agriculture Service of Dahomey under the Ministry of Rural Development first asked for U.S. Peace Corps volunteers to assist it in implementing a new program of grain conservation at the farm level in southern Dahomey. Problems with grain storage had always been acute in Dahomey.

The vast majority of maize produced annually in Dahomey is grown in the southern half of the country where there is constantly high humidity and temperatures which foster rotting as well as the multiplication of maize-consuming insects. The traditional method of storage in southern Dahomey is in loosely-woven palm thatched granaries raised on wooden stilts. The only real protection against attack by rodents and insects is offered by the husk on each ear of maize, resulting in 30% average loss of the 300,000 tons approximate annual production. The estimated value of maize lost annually to the combined effects of insects, rodents and rot is a minimum of 600,000,000 CFA (about $3million).

The idea behind the original request was to introduce to individual farmers the use of the insecticide, Phostoxin, with steel drums and butyl sacks furnished by the Office of Agricultural Commercialization of Dahomey (now S.O.C.A.D.) under a grant by US AID.

Thus, the initial impetus to the project was aimed at popularizing a new storage technique at the farm level. It also entailed assessment of traditional systems of storage and experimentation with a variety of potential improved methods of storage. One of these methods was the cement stave silo, adapted from larger models used in the United States, and the mud-walled Brooks dryer, developed at Ibadan, Nigeria, and adopted by the Institute of Research of Tropical Agriculture (I.R.A.T.) at Niaouli, Dahomey.

Since the process of artificial drying and storage in a new type of silo was experimental, and the results could not be guaranteed, the majority of the expenses of constructing the first units for individual pilot farmers were paid for by the U.S. Embassy Self-Help Fund.

Over the first few years, the Agricultural Service and the Volunteers constantly tried modifications in the design of the silos and dryers. During this period of experimentation Dahomean Agricultural extension agents and local officials offered their help and advice. Cumulative results of field testing did indicate to the Agricultural Service and the Peace Corps that the Cement stave silo merited carefully controlled scientific experimentation to determine its reliability of performance.

By 1971, it was clear that (1) farmers in Southern Dahomey were ready to accept new methods of storing corn, (2) the earthen dryer was effective and had potential for popularization, and (3) there were two types of silos -- cement stave and sheet metal (the latter developed by I.R.A.T.) which appeared promising for farm level storage.

At this point, it was decided by the Agricultural Service, the

Peace Corps and I.R.A.T. that controlled tests should be performed. Accordingly, an experiment was installed at the I.R.A.T. station at Niaouli. Twelve cement stave silos and twelve sheet metal silos were built and placed under a large shelter. The silos were filled at the end of October, 1971, periodically tested and emptied in June 1972. They were then refilled with new maize in November, 1972, similarly tested and emptied in May, 1973. The results of these trials demonstrated that both types of silos, if treated with insecticide, store maize extremely well. It was determined that maize dried to a moisture content of 12% and treated with any of a variety of insecticides could be stored in cement stave silos for at least six months with average losses of not more than 3 percent.

During this time, volunteers had been working with local agricultural officials to popularize and build silos and dryers for interested farmers who could afford the units which had an average cost of $70-$80 (without expensive tin roofed shelter). It was after the I.R.A.T. tests that the director of the Dahomean Agricultural Service decided to officially adopt this system, and the National Cereals Commission of Dahomey committed 5 millio CFA ($20,000) for the credit construction of 100 storage units for individual farmers each consisting of a 4.5 ton cement stave silo, an earthen dryer, and a tin-roofed shelter. The first ten units were built in the region of Sakete, under the supervision of a technical agent of the Agricultural Service and a Peace Corps Volunteer. These completed units were officially accepted by the Minister of Rural Development and Cooperative Action in June, 1974, and work has been authorized on construction of another twenty in the three southern provinces of Dahomey.

The National Cereals Commission has established criteria for the 100 farmers who are to receive this credit. The participants must:

1. be a farmer
2. cultivate at least two hectares (5 acres) of maize per year
3. reside in the district where the silo is to be built
4. be recognized by local agricultural agents as a progressive and cooperative individual
5. be willing to sign a contract for the repayment of the loan
6. make a 10,000 CFA ($40) cash advance as an indication of serious intent.

The loan is to be paid off in six equal annual payments at 2% interest. Payment can be made in cash or the equivalent value of maize at a pre-determined value of 25 cfa/kg (the average price of maize at the time of harvest has been from 6 to 10 cfa/kg).

Over the years, the collaboration has grown between the Peace Corps and the Agricultural Service and particularly its Division of Crop Protection which has a supervisory role with respect to the volunteers. Requests for and assignment of volunteers is handled through these offices. A volunteer with experience in the program in Dahomey has traditionally been designated as "Coordinator" by the Dahomean officials and Peace Corps staff, and he acts as a liaison between the grain storage volunteers in the field, the Peace Corps staff in Cotonou, and the government agricultural officials in Porto-Novo. The Peace Corps, besides furnishing volunteers, has helped find outside funding for program related projects.
Appendix D

BIBLIOGRAPHY

The information in this manual is not and can not be complete. The information presented here cannot be immediately applicable or appropriate to all regions or to every storage need. You may well require further technical assistance in adapting these materials and others to your grain storage situation. Some of that help can come from books; much, from organizations and people.

The Tropical Products Institute (TPI) may already be a familiar name to you. This agency does a great deal to gather and distribute information worldwide on grain and grain storage problems. Materials from the TPI library have been of great value in the preparation of this manual.

Peace Corps and VITA are grateful to TPI for its permission to reprint that agency's bibliography of materials on the various aspects of farm-level grain storage.

Tropical Products Institute

G64 Crop storage bibliography (with particular reference to the storage of durable agricultural produce in tropica and sub-tropical countries)

Mrs. S.M. Blatchford and A.J. Wye

This bibliography has been produced by the Tropical Products Institute, a

British
Government organization which helps developing countries to derive greater benef
its
from their renewable resources.

Requests for further information on this subject should be addressed to:

Tropical Stored Products Centre
(Tropical Products Institute)
London Road
Slough SL3 7HL
Bucks.

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Conversion Tables

Simple methods are given here for converting English and metric units of measurement. Following these is a series of useful conversion tables for units of area, volume, weight, pressure and power.

LENGTH CONVERSION

The chart in Figure 3 is useful for quick conversion from meters and centimeters to feet and inches, or vice versa. For more accurate results and for distances greater than 3 meters, Equations: use either the tables in Figure 2 or

the equations. 1 inch = 2.54cm
1 foot = 30.48cm
The chart in Figure 3 has metric divisions = 0.3048m
of one centimeter to three meters, 1 yard = 91.44cm
and English units in inches and feet = 0.9144m
to ten feet. It is accurate to about 1 mile = 1.607km
plus or minus one centimeter. = 5280 feet
1cm = 0.3937 inches
Example: 1m = 39.37 inches
= 3.28 feet
An example will explain how to use 1km = 0.62137 miles
the tables. Suppose you wish to find = 1000 meters
how many inches are equal to 66cm. On
the "Centimeters into Inches" table look
down the leftmost column to 60cm and then
right to the column headed 6cm. This
gives the result, 25.984 inches.

Inches into centimeters FIGURE 2
(1 in. = 2.539977 cm.)

inches	0	1	2	3	4	5	6	7	8	9
0 cm.	2.54	5.08	7.62	10.16	12.70	15.24	17.78	20.32	22.86	
10	25.40	27.94	30.48	33.02	35.56	38.10	40.64	43.18	45.72	48.26
20	50.80	53.34	55.88	58.42	60.96	63.50	66.04	68.58	71.12	73.66
30	76.20	78.74	81.28	83.82	86.36	88.90	91.44	93.98	96.52	99.06
40	101.60	104.14	106.68	109.22	111.76	114.30	116.84	119.38	121.92	124.46
50	127.00	129.54	132.08	134.62	137.16	139.70	142.24	144.78	147.32	149.86

60	152.40	154.94	157.48	160.02	162.56	165.10	167.64	170.18	172.72	175.26
70	177.80	180.34	182.88	185.42	187.96	190.50	193.04	195.58	198.12	200.66
80	203.20	205.74	208.28	210.82	213.36	215.90	218.44	220.98	223.52	226.06
90	228.60	231.14	233.68	236.22	238.76	241.30	243.84	246.38	248.92	251.46

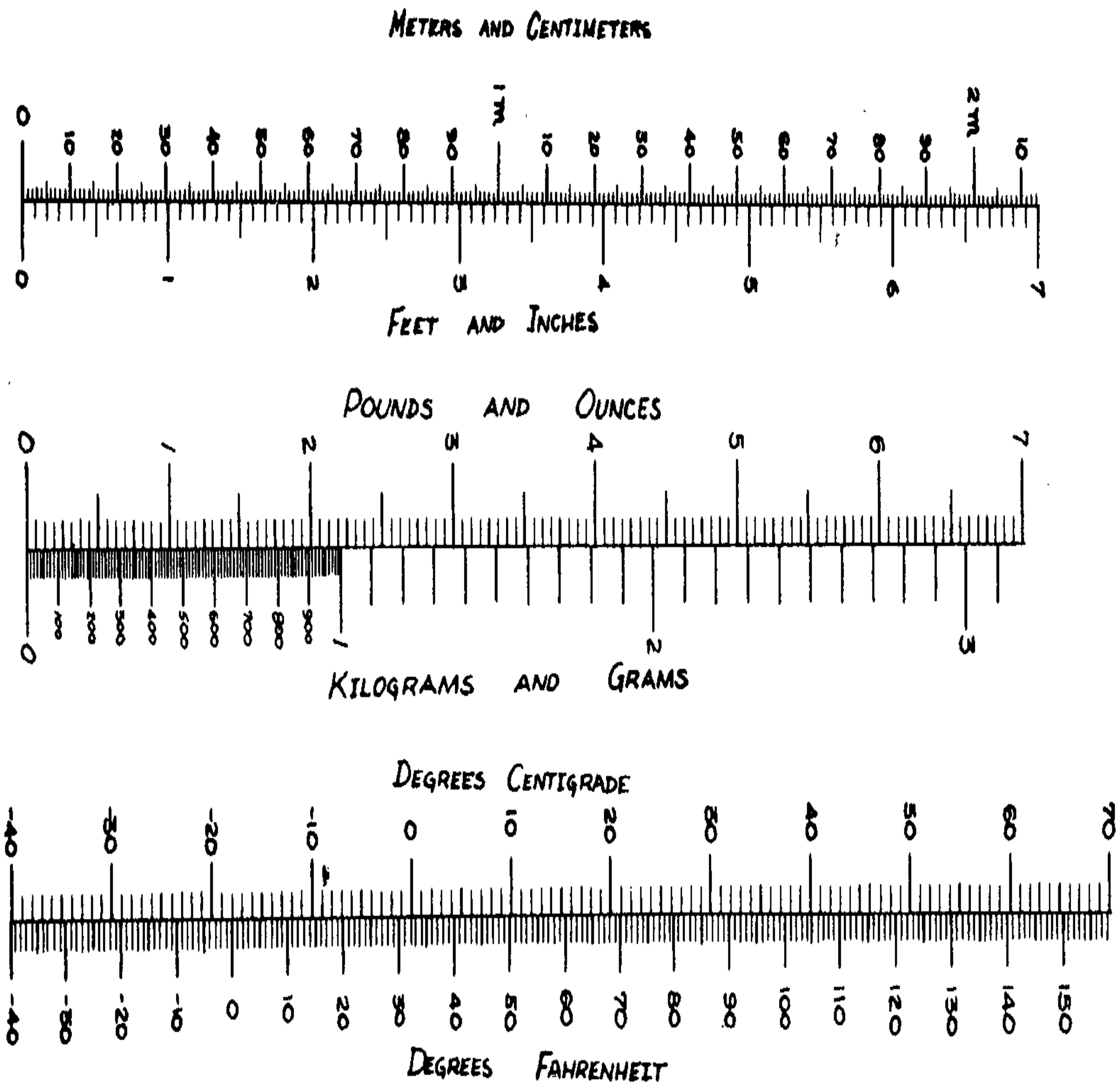
Centimeters into inches

(1 cm. = 0.3937 in.)

cm.	0	1	2	3	4	5	6	7	8	9
0	inches	0.394	0.787	1.181	1.575	1.969	2.362	2.756	3.150	3.543
10	3.937	4.331	4.724	5.118	5.512	5.906	6.299	6.693	7.087	7.480
20	7.874	8.268	8.661	9.055	9.449	9.843	10.236	10.630	11.024	11.417
30	11.811	12.205	12.598	12.992	13.386	13.780	14.173	14.567	14.961	15.354
40	15.748	16.142	16.535	16.929	17.323	17.717	18.110	18.504	18.898	19.291
50	19.685	20.079	20.472	20.866	21.260	21.654	22.047	22.441	22.835	23.228
60	23.622	24.016	24.409	24.803	25.197	25.591	25.984	26.378	26.772	27.165
70	27.559	27.953	28.346	28.740	29.134	29.528	29.921	30.315	30.709	31.102
80	31.496	31.890	32.283	32.677	33.071	33.465	33.858	34.252	34.646	35.039
90	35.433	35.827	36.220	36.614	37.008	37.402	37.795	38.189	38.583	38.976

<FIGURE 140>

51ap199.gif (600x600)



WEIGHT CONVERSION

The chart in Figure 5 converts pounds and ounces to kilograms and grams or vice versa. For weights greater than ten pounds, or more accurate results, use the tables (Figure 4) or conversion equations. See "Length Conversion," Figure 2, for an example of the use of the tables.

On the chart, notice that there are sixteen divisions for each pound to represent ounces. There are 100 divisions only in the first kilogram, and each division represents ten grams. The chart is accurate to about plus or minus twenty grams.

Equations:

1 ounce = 28.35 grams
1 pound = 0.4536 kilograms
1 gram = 0.03527 ounce
1 gram = 2.205 pounds

FIGURE 4

Kilograms into pounds
(1 kg. = 2.20463 lb.)

kg.	0	1	2	3	4	5	6	7	8	9
0	lb.	2.20	4.41	6.61	8.82	11.02	13.23	15.43	17.64	19.84
10	22.05	24.25	26.46	28.66	30.86	33.07	35.27	37.48	39.68	41.89
20	44.09	46.30	48.50	50.71	52.91	55.12	57.32	59.53	61.73	63.93
30	66.14	68.34	70.55	72.75	74.96	77.16	79.37	81.57	83.78	85.98
40	88.19	90.39	92.59	94.80	97.00	99.21	101.41	103.62	105.82	108.32
50	110.23	112.44	114.64	116.85	119.05	121.25	123.46	125.66	127.87	130.07
60	132.28	134.48	136.69	138.89	141.10	143.30	145.51	147.71	149.91	152.12
70	154.32	156.53	158.73	160.94	163.14	165.35	167.55	169.76	171.96	174.17
80	176.37	178.58	180.78	182.98	185.19	187.39	189.60	191.80	194.01	196.21
90	198.42	200.62	202.83	205.03	207.24	209.44	211.64	213.85	216.05	218.26

Pounds into kilograms
(1 lb. = 0.45359 kg.)

lb.	0	1	2	3	4	5	6	7	8	9
0	kg.	0.454	0.907	1.361	1.814	2.268	2.722	3.175	3.629	4.082
10	4.536	4.990	5.443	5.897	6.350	6.804	7.257	7.711	8.165	8.618
20	9.072	9.525	9.979	10.433	10.886	11.340	11.793	12.247	12.701	13.154
30	13.608	14.061	14.515	14.969	15.422	15.876	16.329	16.783	17.237	17.690
40	18.144	18.597	19.051	19.504	19.958	20.412	20.865	21.139	21.772	22.226
50	22.680	23.133	23.587	24.040	24.494	24.948	25.401	25.855	26.308	26.762
60	27.216	27.669	28.123	28.576	29.030	29.484	29.937	30.391	30.844	31.298
70	31.751	32.205	32.659	33.112	33.566	34.019	34.473	34.927	35.380	35.834
80	36.287	36.741	37.195	37.648	38.102	38.555	39.009	39.463	39.916	40.370
90	40.823	41.277	41.730	42.184	42.638	43.091	43.545	43.998	44.452	44.906

TEMPERATURE CONVERSION

The chart in Figure 1 is useful for quick conversion from degrees Celsius (Centigrade) to degrees Fahrenheit and vice versa. Although the chart is fast and handy, you must use the equations below if your answer must be accurate to within one degree.

Equations:

Degrees Celsius = 5/9 x (Degrees Fahrenheit -32)

Degrees Fahrenheit = 1.8 x (Degrees Celsius) +32

Example:

This example may help to clarify the use of the equations; 72F equals how many degrees Celsius?

72F = 5/9 (Degrees F -32)

72F = 5/9 (72 -32)

72F = 5/9 (40)

72F = 22.2C

Notice that the chart reads 22C, an error of about 0.2C.

Conversion Tables

Units of Area

1 Square Mile = 640 Acres = 2.5899 Square Kilometers

1 Square Kilometer = 1,000,000 Square Meters = 0.3861 Square Mile

1 Acre = 43,560 Square Feet

1 Square Foot = 144 Square Inches = 0.0929 Square Meter

1 Square Inch = 6.452 Square Centimeters

1 Square Meter = 10.764 Square Feet

1 Square Centimeter = 0.155 Square Inch

Units of Volume

1.0 Cubic Foot = 1728 Cubic Inches = 7.48 U.S. Gallons

1.0 British Imperial Gallon = 1.2 U.S. Gallons

1.0 Cubic Meter = 35.314 Cubic Feet = 264.2 U.S. Gallons

1.0 Liter = 1000 Cubic Centimeters = 0.2642 U.S. Gallons

Units of Weight

1.0 Metric Ton = 1000 Kilograms = 2204.6 Pounds

1.0 Kilogram = 1000 Grams = 2.2046 Pounds

1.0 Short Ton = 2000 Pounds

Conversion Tables

Units of Pressure

1.0 Pound per square inch = 144 Pounds per square foot

1.0 Pound per square inch = 27.7 Inches of Water*

1.0 Pound per square inch = 2.31 Feet of Water*

1.0 Pound per square inch = 2.042 Inches of Mercury*

1.0 Atmosphere = 14.7 Pounds per square inch (PSI)

1.0 Atmosphere = 33.95 Feet of Water

1.0 Foot of Water = 0.433 PSI = 62.355 Pounds per square foot

1.0 Kilogram per square centimeter = 14.223 Pounds per square inch

1.0 Pound per square inch = 0.0703 Kilogram per square centimeter

(*) at 62 degrees Fahrenheit (16.6 degrees Celsius)

Units of Power

1.0 Horsepower (English) = 746 Watts = 0.746 Kilowatt (KW)

1.0 Horsepower (English) = 550 Foot Pounds per second

1.0 Horsepower (English) = 33,000 Foot Pounds per minute

1.0 Kilowatt (KW) = 1000 Watts = 1.34 Horsepower (HP) English

1.0 Horsepower (English) = 1.0139 Metric Horsepower (cheval-vapeur)

1.0 Metric Horsepower = 75 Meters X Kilogram/Second

1.0 Metric Horsepower = 0.736 Kilowatt = 736 Watts

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