
Volume III Of Small Farm Grain Storage

VITA 1600 Wilson Boulevard, Suite 500 Arlington, Virginia 22209 USA Tel:
703/276-1900 . Fax: 703./243-1865 Internet: pr-info@vita.org (<mailto:pr-info@vita.org>)

TABLE OF CONTENTS

INTRODUCTORY

The Purpose of the Manual The People Who Prepared This Manual The Sponsoring Organizations How To Use This Manual

Introduction Feedback Storage Principles Finding a Good Storage Place & Illustrations Cleaning and Repairing Your Storage Place & Illustrations Storing Grain in Basket Granaries Instruction Sheet for Storing Grain in Baskets Storing Grain in Sacks Mixing Grain and Insecticides for Sack and Small-Container Storage Treating Stacks of Bagged Grain -- Recommended Insecticides and Dosages Storing Grain in Sacks: Summary Airtight Storage Storing in Gourds and Baskets Storing Grain in Underground Pits Storing Grain in Plastic Sacks, and Illustrations Storing Grain in Metal Drums Storing Grain in Metal Bins Sheet Metal Silo Fumigation of Small Quantities of Stored Grain: in Plastic Bags under Plastic Sheets and in Small Metal Containers or Silos Storing in Earthen Structures The Indian Pusa Bin Improved Mudblock Silo How to Use Your Mudblock Silo Ferrocement for Grain Storage An Overview of Grain Storage Uses for Ferrocement: Thai Ferrocement Silo (Thailo) Ferrocement-lined Underground Pits and Other Ferrocement Grain Structures Storing Grain in Cement/Concrete Structures Brick Grain Storage Silo The 4.5 Ton Cement Stave Silo Instructions for Use of the Cement Stave Silo Concrete Block Square Silos for Cooperative Storage.

BIBLIOGRAPHY

CONVERSION TABLES

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 made 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.

<FIGURE 1>

INTRODUCTION

Each farmer has some method of storing his grain. Any improvement in this storage method must be made by steps the farmer sees as the right ones for his situation or need. A farmer who stores his grain in sacks in a corner of his house may not be ready to build a cement silo. Because this farmer is afraid that thieves will take his grain, he may not want to build any type of storage container outside his house.

For this farmer, trying a different drying method, or cleaning his storage bags, or improving a stacking arrangement, or adding insecticides to sacked grain could be a large, first step toward improved storage.

If a farmer is complaining about insects and rodents eating his stored grain, you have an opening to say, "Let's do something about that problem." But if the farmers in your area feel, "It's always been that way, and there is nothing we can do about it," your first job is to convince the farmer that there is something he can do about his problems.

Only you can introduce the material from this manual because you know the area where you work. Hopefully, the earlier parts of this manual have provided a lot of helpful information and material. If a farmer is not ready to make improvements in his storage method, perhaps you can find the material in this manual to put together leaflets which would help show what change could do for him. One convinced farmer may be all it takes to get things started.

Change only begins when farmers believe that new ideas and technologies can be helpful to them. They may start out by making only small changes in the method already being used. But the important point is that something different is being tried. Then, when the farmer sees an improvement in the quality of his stored grain, you have an opening to say, "Now perhaps you would like to try a storage method that can do even more for you." Perhaps that is the time to suggest a metal drum or a mud silo.

You know from your work that change seems to be accepted very slowly. It is good to keep in mind the fact that for a farmer who has always done things the same way, adding a small amount of insecticide to a sack of grain is a large change. It is very easy to give people more than they want or are ready to receive.

This section of the manual brings together all the grain storage information which was introduced earlier:

- * It discusses and shows some traditional storage methods and gives specific directions for improving these methods. Some of these methods are sack, basket, and pit storage.
- * It gives plans for, among others, mudblock, ferrocement, oil-drum and cement-stave silos.
- * It describes other storage possibilities to give some idea of the range of methods in use.

This section, together with the earlier parts of the manual, ought to help you to help farmers define their choices. To provide even more information, there are some valuable appendices to the manual:

STORAGE PRINCIPLES

Whichever kind of storage method a farmer uses, there are certain principles upon which every method is based. Every storage container, no matter what it looks like or what it is made of, should:

- * keep grain cool and dry.
- * protect grain from insects.
- * protect grain from rodents.

All storage methods try to do the above three things. But to do these things requires the following good storage practices:

1. Drying grain well (to 12-13% moisture content) before putting it into storage.
2. Putting clean grain only into containers which have had all old grain, dust, straw, and insects removed.
3. Keeping the grain cool and protected from large changes in outside temperatures. This can be done in a number of ways -- by using building materials which do not easily pass on changes in outside temperatures to the stored grain, by keeping or building storage containers away from direct sunlight, by painting the containers white.
4. Protecting the grain from insects by following rules for cleanliness and drying, by applying insecticide and/or by putting the grain into airtight

storage.

5. Waterproofing the buildings and containers as much as possible. This is done both by the way the building is constructed and by applying materials which keep water from soaking into the building material. Storage buildings should be built on well-drained locations. They should not be placed where they will be flooded by ground water run-off during heavy rains.
6. Making sure containers are rodent-proofed in all possible ways.
7. Checking the grain regularly while it is in storage to make sure it is not infested, and following recleaning instructions to destroy insects, if they are found when the grain is checked.

A farmer who has these seven points firmly in mind will know why a particular silo or storage method has been built or changed in a certain way. And he can then do much to improve his own storage facility by applying the knowledge to his own problems.

The ideas and suggestions for storage methods which follow in this section, no matter how different they look, all require that these seven steps be taken if they are to be successful.

FINDING A GOOD STORAGE PLACE

SCRIPT # 1

Suggested Use: This script and the one which follows contain some of the important points to remember about finding, cleaning, and repairing storage places. VITA Volunteer artist Guy T. Welch has provided illustrations of some of these points to give some ideas on ways this material can be presented through pictures.

- * Rats, mice, birds, insects, and mold destroy a lot of grain. It is not easy to keep these dangers away from your grain. But you can do a lot to keep them away.
- * Fix a good place to put your grain before you bring it from the field.
- * The place for grain storage is very important. Grain storage places must be built on well-drained ground, so the building or container does not get flooded or take on too much moisture from the ground.
- * Most insects and molds like warm, wet places.
- * A good storage place is cool and dry.
- * Grain storage is easier if you live in a cool, dry land. Grains are easier to protect.
- * But insects and rodents can attack even in these places. Farmers must protect the grain from these pests wherever they live.
- * Some farmers store grain in large clay jars with thick walls.
- * Some farmers use metal drums for grain storage.
- * Some farmers in warm places put grain in buildings with thick mud, plaster, cement, or thatched walls and roofs. Thick walls help to keep the hot air out. Thick walls help to keep the grain cool.

- * Some farmers store grain under the ground. Grain stored under the ground is kept cool by the earth.
- * You can put grain storage containers or jars on rocks or wood. This keeps the containers off the ground. Air can get under the container. This air cools the grain.
- * You can build storage rooms or buildings on posts. This keeps the floor off the ground. Water from the earth can not get the floor wet. Air can pass under the storage building to cool the grain.
- * There are many ways to store grain.
- * Remember that the storage place must keep grain cool and dry.
- * Remember that the storage place must be clean and free of insects and rodents.
- * Your extension worker can help you find a way to store grain that is good for you.

<FIGURE 2>

<FIGURE 3>

<FIGURE 4>

<FIGURE 5>

<FIGURE 6>

CLEANING AND REPAIRING YOUR STORAGE PLACE

SCRIPT # 2

- * Your storage room or building must be clean. Insects live and have families in dirty places. Rats, mice, and other pests like dirty places too.
- * Take away and burn or compost all dust, old pieces of grain, dirt, straw, and chaff from the storage place.
- * There should be no cracks and holes in the floor, ceiling, or walls. Insects and rodents use these holes to get in.
- * Fill and seal all cracks and holes.
- * Seal large holes in wooden storage places with sheet metal, flattened tin cans, or pieces of wood. Concrete and plaster make good sealing material for plaster, brick, and concrete buildings.
- * Put paint or whitewash on the walls and floors of the storage area. This paint helps close up very small holes. Insects like these small holes.
- * Do not use any poison until you talk to your extension worker.

- * Put mesh wire over large openings and windows. This will keep out rats, chickens, and birds.
- * The roof must keep rain from coming in. The grain must be kept dry.
- * Mend all holes and openings in the roof.
- * Clean the outside area around the storage place.
- * Clean out the containers that you put the grain in.
- * Bags or sacks for storing grain must be shaken.
- * Bags or sacks should be boiled in hot water and dried in the sun. Mend any holes you find in the bags.
- * Check with an extension worker for information on poisons to kill insects and rodents.
- * The extension worker will know what poison to use. He will know how to use the poison.
- * Always remember that many poisons can kill animals and people.
- * Use insecticide on the inside and outside of your storage area.
- * Put insecticide on all cracks and small places where insects like to live.
- * Put out traps for rodents.
- * A good storage place is free of insects and rodents. It is clean and dry.

<FIGURE 7>

<FIGURE 8>

<FIGURE 9>

<FIGURE 10>

<FIGURE 11>

STORING GRAIN IN BASKET GRANARIES

Grain has been stored in basket-like containers made of grass, reeds, bamboo strips, or small branches for thousands of years. The particular building material depends upon the plants available near a farmer.

These basket granaries are so traditional and widely used that it does not seem necessary to include a plan for making them. There are almost as many different kinds of baskets as there are villages making them, and the skills for this kind of

work are passed on within families. What this manual will present is some suggestions for improving basket granaries so that grain stored in them is more protected from insects and molds.

To increase the protection of grain kept in baskets:

- * Keep the basket off the ground. Make a strong platform upon which the basket can sit. The shape of the platform will depend upon the shape of the basket. Putting the basket on a platform prevents moisture from coming through the ground into the basket. The platform also offers more protection from rodents.

<FIGURE 12>

- * Make sure the basket is well-protected from the rain. If it is a grass or reed basket, keep it in the house or some other dry building. If it is woven of material which can be kept outside, make sure the roof thatch does not let any rain into the grain.

- * Place rodent baffles (guards) on the legs of platforms which support the baskets. These prevent rodents from climbing or jumping into the baskets. (The rodent proofing section contains information on making rat baffles.)

- * A tin can, with a plastic-cover that can be put on and taken off easily, makes a good emptying chute (see the picture below). Cut the bottom out of the can and fit the open end of the can into the lower part of the basket. This makes it unnecessary to take off the cover each time grain is taken out.

- * Baskets can be plastered inside and outside with mud, clay, or cow dung. Covers should be tight and sealed with plaster of the same material. It is important for farmers to realize that grain holding a lot of moisture, whether threshed or freshly harvested, should not be placed in baskets which have been plastered in this way. Plastering makes the basket much more airtight. Moist grain needs to have air passing through to dry it. If moist grain is put into storage without enough air, it will mold and rot quickly.

<FIGURE 13>

INSTRUCTION SHEET FOR STORING GRAIN IN BASKETS

This instruction sheet includes some directions for using insecticide in basket storage. You should include the names of insecticides available in your area which are appropriate for use with grain being stored in baskets. (Malathion and Pyrethrum are mentioned.)

You may want to use the information to make two instruction sheets: one explaining good basket storage without insecticide; the other, with use of insecticide. Also, you may want to illustrate the sheets if you hand them out to farmers in your area who use basket granaries.

<FIGURE 14>

CLEAN THE BASKET AND THE AREA:

- * Make sure the area around the basket is clean. Baskets should always be kept inside a building unless the baskets have been built for outside use.
- * Place the basket on a platform so that it will not pick up moisture from the ground.
- * Clean out all grain dust and broken grains if the basket has been used before.
- * Mend any holes in the basket. * Plaster basket with mud, clay, or cow dung if storing very dry grain.
- * CLEAN AND DRY THE GRAIN CAREFULLY.

IF YOU HAVE INSECTICIDE:

- * Dust the inside of the basket with insecticide. Do this carefully so any insects will be killed.
- * Mix the dry grain with insecticide before you put it into the basket. To mix the grain and insecticide, you must:

Place the dry grain on a plastic sheet, clean floor, or hard-packed ground.

Sprinkle insecticide over the grain. Use 1 packet (4 oz.) of Malathion or pyrethrum dust for each 100 kg of grain.

Mix the grain and insecticide with a shovel until they are mixed very well.

IF YOU DO NOT HAVE INSECTICIDE:

- * Mix burned cow dung or wood ashes with the grain.

PUT THE GRAIN INTO THE BASKET. MAKE SURE THE COVER FITS TIGHTLY.

OPEN THE BASKET AND CHECK THE GRAIN EVERY TWO MONTHS. IF YOU FIND INSECTS:

- * Winnow, sieve, or place the grain in the sun.
- * Clean the basket.
- * Add more insecticide or ashes.
- * Put the grain back and replace the cover tightly.

WHEN YOU REMOVE THE GRAIN FOR FOOD, WASH IT CAREFULLY. INSECTICIDES CAN LEAVE MATERIAL ON THE GRAINS WHICH IS NOT GOOD FOR PEOPLE TO EAT.

STORING GRAIN IN SACKS

Putting grain in sacks (bags) is a very old method of storing. Storage sacks are made of woven jute, hemp, sisal, local grasses, cotton -- whatever material is available in the area. Sacks are relatively expensive as they do not often last for more than two seasons. Sacks do not give a lot of natural protection against insects, rodents, and moisture. But sack storage has some advantages for the small farmer, and there are things farmers can do to protect their sacked grain.

<FIGURE 15>

The Advantages of Sack Storage for Farmers:

- * Grain stored in sacks made of fibers can have a little higher moisture content than grain put into airtight storage. If the sacks are properly stacked, air can move through the sacks to dry and cool the grain.

<FIGURE 16>

- * Sacks are easy to label. Farmers can label old grain sacks and new grain sacks to keep them separate. Seed grain can be marked and kept separately from the other grains.

- * Sacks are easy to move around. And sacks or parts of sacks can be used as they are needed.

- * Sacks can be stored in a farmer's house - no special buildings or containers are needed.

- * Farmers in a village may decide to build a shed to hold the grain belonging to all the village's farmers. It is easy to mark sacks so that each farmer's grain can be found simply.

Grain stored in fiber sacks is easily attacked by insects, rodents, and molds. Often these attacks are worse because a farmer has no all he can to protect his grain sacks.

CONTROLLING MOISTURE AND PREVENTING MOLDING IN SACKED GRAIN

- * Dry the grain well. Although grain can contain about two percent (2%) more moisture for sack storage than for airtight storage, the grain should be as dry as possible.

Check the grain every two weeks. Suggest to the farmer that he make checking his grain part of a weekly or bi-weekly routine. Put his hand into a sack of grain to check for heating. He can smell the grain and look for dark kernels: signs of mold. If these signs are found, he should dump out the grain and dry it again.

- * Waterproof the walls and roof of the building where the grain is stored.

STACK THE SACKS ON PLATFORMS RAISED OFF THE FLOOR. This keeps sacked grain from taking moisture from the floor. Farmers can make these platforms out of whatever materials they have. If no wood or bricks are available to make a platform, the ground can be covered with plastic sheets. The raised platform is better than the plastic because it also allows air to flow under the sacked grain.

<FIGURE 17>

* Stack the sacks in a neat manner. Leave space between the sacks so that air can move freely between the sacks.

<FIGURE 18>

CONTROLLING INSECT ATTACKS ON SACKED GRAIN

* Mend cracks in the walls, roof, and doors of the building where grain is kept. This mending keeps insects from getting in and out of the building through the cracks.

<FIGURE 19>

* Remove and check sacks of grain left from the last harvest. The farmer should take them outside before he cleans the storeroom. This grain should be winnowed, sieved, and spread out in the sun for a time before it is put back into the bags. If the grain is sieved, light a fire and burn all the insects found, so they will not move right back into the grain.

* Clean the room well before placing the sacks inside. Make sure there is no dust, dirt, and old grain left. Sweep walls and ceilings as well as the floors. Some farmers may want to burn a small, smoky fire in the room to drive out insects, if they are not going to use insecticide to protect the inside of the building.

<FIGURE 20>

If Insecticide Is Available

* Apply insecticide to the storage building. You can recommend DDT, Malathion, and Lindane for use on buildings and instruct the farmer on use of these three poisons. There also are other insecticides that can be used on buildings.

* Dust insecticide on the sacks before the grain is put in. (Or the insecticide can be put on the bags as they are stacked. There is a page attached to the end of this section which gives instructions on applying insecticides as you stack grain.) Malathion is a safe insecticide for a farmer to use for this purpose -- it is safe for him to use and safe for his grain. Brush the sacks with a stiff brush and then shake them well. Brush both the outside and the inside of the sack. Put Malathion on both the inside and the outside of the sack.

* Mix the grain with insecticide before it is placed in bags. Use only clean, dry grain. See the end of this section for instructions on mixing grain and insecticide for sack storage.

If Insecticide Is Not Used

* Clean the sacks carefully. Shake the sacks well. If sacks are made of a material which can be placed in hot water, boil the sacks or dip them in very hot water. Dry the sacks in the hot sun. If sacks can not be placed in water, brush them well and place them in the sun. Make sure both the inside and the outside get exposed to the sun.

<FIGURE 21>

* Use only clean, dry grain. The grain should be checked. It should be free of insects (the easily seen adults, at least).

* Mix ash from cattle dung or wood or fine sand with the grain if insecticide is not to be used. Use one, 10-liter bucket of ash for each 100kg of grain.

* Stack the sacks carefully (as shown earlier). The platform holding the sacks must be placed away from the walls because there are insects which live in wood and thatch which will move to the stored grain.

<FIGURE 22>

* Check the grain regularly. If no insecticide has been used, a farmer may have to dump the grain out, get the insects out, and re-bag the grain every two months or so. If Malathion is used, that insecticide possibly will have to be reapplied after four months of storage.

CONTROLLING RODENT ATTACKS ON SACKED GRAIN

* Keep the area around the sacks clear of dirt, broken grains, grain dust, and trash. This clearing makes it harder for rats and mice to find home and food near the stored grain.

<FIGURE 23>

- Cover and repair holes that rodents might use to get into the building where the grain is stored.

- Keep the sacks off the floor. This does not stop rats and mice from attacking the grain. but it does make cleaning, poisoning and baiting, and looking for rats and mice easier.

- Move the stacks if rodents are seen. Then use traps and poisoned baits near the pathways and rodent holes. (See the section on rodent control for more information on using traps and poisons to control rodents).

<FIGURE 24>

KEY POINTS FOR SUCCESSFUL SACK STORAGE

- * Sacks and buildings which are clean.
- * Dry grain which is free of insects. * Good shelter which keeps out rain, insects, rodents, and birds.
- * Careful checking of the grain while it is in storage.

The following pages include:

- * Instructions which can be given to farmers to aid them with mixing grain and insecticides for sack and small-container storage.
- * Instructions for adding insecticide while stacking layers of grain bags.
- * Sample material for a leaflet which could be made to illustrate proper sack storage through pictures. MIXING GRAIN AND INSECTICIDES

FOR SACK AND SMALL-CONTAINER STORAGE

The following insecticides and dosages are recommended for direct mixing with grain:

- Malathion. Use 120 grams of 1.0% dust for each 200kg of grain.
- Lindane. Use 120 grams of 0.1% dust for each 200kg of grain.
- pyrethrum. Use 120 grams of 0.2% pyrethrins plus 1.0% piperonyl butoxide dust for each 200kg of grain.

If you can find Malathion, for example, only in 2%, 5%, or .5% mixtures, you will have to adjust the strength of the insecticide. For example, if you are using 2.0% Dust, you need to use only 60 grams of 2.0% Dust per 200kg.

- * Apply the insecticide to one half sack of grain at a time.
- * Empty one half of the grain from a sack onto hard-packed earth, a plastic sheet, or clean floor.
- * Put 60 grams of insecticide dust on the grain.
- * Turn the grain over and over with a shovel. Make sure the grain and insecticide are well-mixed.
- * Empty the other half of the sack on top of the grain you have just mixed.
- * Put the rest (the other half -- 60 grams) of the insecticide on the grain.
- * Mix very well.
- * Put the grain back into the sack and close it tightly.

REMEMBER: THE GRAIN MUST BE DRY BEFORE THE INSECTICIDE CAN BE USED. INSECTICIDES DO NOT WORK AS WELL IF THE GRAIN IS TOO MOIST.

TREATING STACKS OF SACKED GRAIN

RECOMMENDED INSECTICIDES AND DOSAGES

There are two ways to apply insecticide to stacks of sacked grain:

1. Layer by Layer

Spray or dust each layer of sacks with Malathion or Lindane as the stack is being built.

Malathion -- 25 grams of 2.0% Dust per sack or 50 grams of 2.0% Dust per square meter
Lindane -- 25 grams of 0.5% Dust per sack or 50 grams of 0.5% Dust per square meter

2. Stack Treatment

Build the stack first. Then spray all four sides and the top surface of the stack. Use Dispersible Powder formulations of Malathion and Lindane at the dosages recommended for spraying storage buildings.

When this treatment is finished, apply a band of insecticide around the bottoms of the stacks to control crawling insects. Malathion is best for this job, though where it is not available, Lindane or DDT may be used. **STORING GRAIN IN SACKS**

Suggested Uses: This is an easy-to-read summary of the important things to remember for good sack storage. Pick out the points that best fit your situation and use them with farmers in your area. They are simply worded and can easily be pictured by using drawings or photographs; they can be translated easily.

- * Grain is often stored in sacks. Sacks are also called bags.
- * Sacks are made of different things.
- * Sacks are easy to put away. You can store them in a corner of the house.
- * You can put grain sacks in a special storage building.
- * Sacks are easy to carry.
- * Each sack can be labeled to show what is inside.
- * Put your name on each sack. It is easy to show which grain belongs to you.
- * Insects, rats, and molds can attack grain kept in sacks.
- * You can protect the sacks from these dangers. You must start before the grain goes into the sack.
- * Clean your storage area well.
- * Make sure there is no dust, old grain, straw, or trash in the storage place.
- * Mend holes in the roof, floor, or walls.
- * Check for cracks. Insects hide there.
- * Make sure rain and water from the ground can not get the grain wet.
- * Put rat guards on the legs of storage containers or buildings.

- * Ask your extension agent about insecticides you can use.
- * Shake out old storage sacks.
- * Put old sacks in boiling water, if possible.
- * Dry old sacks in bright sunlight.
- * Mend holes in the sacks.
- * Spray or dust the sacks with insecticide.
- * Spray or dust the building with insecticide.
- * Make sure the grain you put into the sack has no insects in it.
- * Put only clean, dry grain into sacks.
- * Some insect poisons can be put into the sack with the grain. This protects the grain from insects for some time. Ask your extension agent before you do this. Some poisons can poison the grain.
- * You can add sand and ash to the grain in the sack. Insects do not like these materials.
- * Poison is better than sand and ash. But sand and ash are better than putting the grain in with no protection.
- * Close all sacks tightly.
- * Put each kind of grain in a separate sack.
- * Place grain sacks off the ground.
- * If you have many sacks, stack the sacks well. Leave room between the sacks. Air in the room will cool the grain better if there is room between the sacks.
- * Do not stack sacks against the walls. Insects and termites get into the grain from the walls.
- * Check the sacks often. Look for insects. Smell for mold. Look for wet places.
- * If you find insects or mold, dump the grain out of the sack and leave it in the sun. Sieve the grain.
- * Clean the sacks again.
- * Put the grain back into the sacks immediately after cleaning.

REMEMBER: THERE ARE POISONS WHICH YOU CAN ADD TO THE SACKS OF GRAIN AND OTHERS WHICH ARE TO BE USED ONLY ON NON-FOOD LIKE COTTON.

THESE POISONS CAN BE DANGEROUS.

DO NOT USE POISON BEFORE YOU TALK WITH YOUR EXTENSION WORKER.

AIRTIGHT STORAGE

INTRODUCTION

Insects can still grow and reproduce in very dry grain. Grain dried to a 12 or 13% moisture level will not mold, but can still be very good food for insects.

The moisture level in grain has to be 9% or less to slow down insect development. Very high and very low temperatures also slow down insect growth. But most farmers will have trouble getting their grain below 12% moisture and in using temperature to control insect development. They often do not have the special equipment necessary to do these things.

More and more farmers do use insecticides to control insects in grain. But some insecticides are dangerous; some are expensive; sometimes they are not available; and there is increasing concern about using chemicals of any kind on food products.

HOW IT WORKS

Airtight storage simply means putting grain into containers which keep air from getting into the grain. Some air is let into the container at the time the grain is put into storage. But after the container is sealed, no more air enters. The respiration of the grain and any insects in it uses up all the oxygen. Insects need oxygen to live. They die without it. Any molds present which require oxygen also will die.

You can show farmers how airtight storage works by putting some insects and grains on a very smooth surface and turning a glass over on top of them. Make sure the glass is tight against the surface. Seal it with wax or some other material. Or seal some grain kernels and insects in a glass jar. Cover the jar with a screw-on lid or a plastic sheet. Just make sure no air can enter the container!

Wait for a while. The insects will begin to move more slowly. Finally, they will die. How long it takes for the insects to die will depend upon the number of insects, the amount of grain, and the size of the glass container.

You can speed up the experiment by placing a lighted candle under the glass container. The flame on the candle requires oxygen to keep burning. The flame will use up the oxygen in the container quickly. When the oxygen is gone, the flame will go out. Soon, the insects will die.

The lack of oxygen, which kills insects, does not seem to hurt the grain or to keep seed grain from germinating when it is planted.

Successful airtight storage depends upon a number of things:

* Building containers which are airtight. This means using materials which do not let air flow through them, for example, metal, plastic, concrete. These containers must be checked to make sure there are no cracks or holes. Sometimes a farmer will see light coming through cracks in a large container. If the container is a gourd, for example, he can check for cracks by filling it with water to see if there are any leaks. All cracks in storage containers should be sealed for good protection. In addition, it

is usually a good idea to coat or paint the entire outside (and sometimes the inside) surface of the container with tar or oil-based paints (they are waterproof and also do not let air pass through).

For a farmer who cannot afford to buy these materials, there may be local trees and plants which produce materials useful for waterproofing.

- * Sealing tightly the holes for putting grain into the container and for taking grain out. Tar, wax, or pieces of rubber cut from old tires, and inner tubes can be used for this.
- * Filling airtight storage containers to the top is important. Full containers, which are sealed against air, can kill insects in a few days. But if the container is not full, the insects take a lot longer to die. And before they die, they may damage a lot of grain.
- * Keeping the storage container closed. Unless the airtight container is quite small, farmers probably will want to store the grain they use for food separately. The storage container holding the food grain is opened often. Every time a container is opened, more air containing oxygen enters the stored grain. This added air and frequent opening encourages insect growth.

Some of the storage methods used for thousands of years have been based loosely on the principles of airtight storage. A farmer might not call his method airtight storage, or be able to tell you why it works. He stores his grain this way because it keeps his grain pretty safe, and he has been doing it this way for many years. Many of these methods are basically good. Improvements can make them more airtight and, therefore, increase their ability to protect grain.

CHOOSING A METHOD OF AIRTIGHT STORAGE

A farmer has to decide what he needs his storage method to do, and, then, he must figure the costs of each method. Some of the methods, such as metal drums and plastic sacks, cost more money. But they are definitely airtight when used correctly and are very likely to make up their costs by good storage of grain. Other methods, such as the Improved Mudblock Silo, are harder to make airtight, take longer to build, and require more upkeep. But they can hold large amounts of grain, and they can be made with local materials.

Airtight storage is something farmers who store dry grain should work toward. (REMEMBER: IF THE FARMER IS STORING GRAIN WHICH HAS A MOISTURE CONTENT OVER 12-13%, HE SHOULD NOT USE AIRTIGHT STORAGE. Grain which has a high moisture content should be stored so that air can pass over the kernels.)

The rest of the material included in this section describes storage methods which are quite airtight and waterproof or can be made so by making the various improvements described here. This material should serve as a useful guide to some of the storage possibilities that are available to small-scale farmers.

STORING IN GOURDS AND BASKETS

Gourds are the hard, dried outside cases (skins) of certain fruits or vegetables (they are members of the squash family). They are found in many places and are used for storing small amounts of grain. Grain for planting is often stored in gourds.

Scientists are working to discover ways of making gourds effective airtight containers for grain that has no more than 12-13% moisture in it. Here are some of the findings:

- * Linseed oil or varnish painted all over the outside of the gourd makes it almost airtight.
- * The stopper or cover for the gourd has to be sealed well.
- * Pitch and bitumen are easier for farmers to get and seem to make the gourds airtight.
- * Any thick substance which will stick to the gourd will work very well. There are probably local materials which can be found and made to seal the gourd. It is likely that some of the materials found for waterproofing soil would be useful to seal the gourds. If the material stays sticky and does not dry, sprinkle sand or earth all over it.

<FIGURE 25>

If gourd-shaped vessels made of clay or other local materials are available in your area, perhaps these can be made airtight in the same way.

Baskets made of local materials also can be made more airtight. Cover the baskets inside and out with mud plaster. Make sure the cover closes tightly. The outside of the basket can then be coated with a waterproofing or sealing-material.

Possible advantages: Disadvantages:

- * Useful for storing seed grain * Gourds do not hold large amounts and smaller quantities for food. of grain.
- * Easy to get to the grain and to check for insects.
- * Easy to label, so the farmer knows what kind of grain is in each container.

STORING GRAIN IN UNDERGROUND PITS

Farmers store grain in underground pits (holes) in many parts of the world. Pits are used for storing threshed sorghum and maize. They also are used for wheat, peas, and beans. In areas where pit storage is used, it has served farmers well as a way of avoiding theft of the grain (because the pits are hidden). Also, because the pits are dug deep into the earth, they keep the grain cool. In addition, some pits are relatively airtight.

However, pit storage is generally not a storage method to encourage a farmer to adopt. If a farmer is looking for a storage method, he is more likely to get airtight storage by using oil drums, plastic sacks, etc.

<FIGURE 26>

DRY PITS

There are many, many kinds of pits. The pits themselves are not always airtight or waterproof. Therefore, some farmers line the pits with straw to absorb moisture from the earth or from leaks in the covers. The straw gets damp and becomes moldy. These molds use up any air in the storage pit, so that any insects present in the grain die. Often in underground storage pits, the grain at the top and around the sides of the pit is moldy. The main part of the grain, however, stores well.

WET PITS

In some areas, farmers build wet pits. During the rainy season, the water in the ground may rise right into the pit. The grain in this case is full of water. But the grain respires more quickly when wet and uses up the oxygen. Insects and molds requiring oxygen die. Often these wet pits are built where cattle are kept because cow dung uses up oxygen as it decomposes. The grain kept in wet pits may ferment (sour) and thus is not good for seed. But often it seems to store better than grain kept in drier pits.

IMPROVING PITS

The question to keep in mind here is whether or not an improvement in the traditional pit is wise or necessary. A farmer who does not open his pit often may have very light losses from insects and molds. In this case, making improvements may not be necessary.

However, in areas where farmers have lost a lot of grain stored in pits due to insects and molds, it may be a good idea to offer several suggestions for improving the pit storage. Pit storage can be made more safe by improving the covers, building shelters over the pits, or by using a lining in the pits.

Replacing Covers

Pit storage usually can be improved by replacing wood and mud covers with metal or plastic covers.

- * Use one large sheet of metal or plastic to cover the entire area.
- * Make a hole in the middle of the large sheet. This is, so grain can be taken out. Cover the smaller hole with a piece of the same material.
- * Seal the entire cover with a mixture of mud or dung or with bitumen.

Building Shelters

Some farmers build shelters over the pit stores. The shelters should be movable so that when the sun is shining, the pit can be exposed for drying. The shelter should be used when it rains. The problem with this type of shelter is that the farmer cannot keep the place of the pit a secret and the grain may be taken by thieves.

Improving Pit Linings

The other area where pits can be improved is the lining used in the pit.

Straw and Mat Lining

- * Put down a layer of straw on the pit floor. Cover the straw with mats made from bamboo or local grasses.
- * Line the walls with straw and matting as well.
- * Pour in dry grain to the top of the lining.
- * Continue placing the lining and pouring the grain until the pit is full.

<FIGURE 27>

Advantages: Uses local material and costs nothing. Stores grain much better than an unlined pit.

Disadvantages: Does not protect the grain as well as the following methods.

Plastic Bags

- * Place very dry grain in plastic sacks.
- * Seal tightly as shown.
- * Store sacks in the pit.
- * Seal the pit well.

<FIGURE 28>

Advantages:

Airtight if the bags are well sealed.

A farmer can remove part of the grain easily without letting air and moisture into the rest of the grain.

Disadvantages:

May be expensive or hard-to-get.

Plastic Lining

- * Line the pit with large plastic sheets or with plastic bags cut open to make sheets.
- * Make sure the edges of the plastic sheet lie over each other.
- * Fill the pit with clean, dry grain and seal tightly.

Advantages: Gives good protection from moisture if the plastic is sealed.

Disadvantages: Can be damaged easily.

Plastic may be expensive, unavailable, and hard to replace.

Using Plastic Lining and Plastic Bags in Large Pits

- * Lay plastic sheets or cut-open plastic bags on the floor.
- * Fill a number of plastic bags with very dry grain and put these against the sides of the pit.
- * Pour dry grain into the space between the floor and the tops of the sacks.
- * Put another layer of filled plastic sacks against the walls on top of the sacks already in the pit.
- * Fill the space with grain.
- * Continue placing plastic sacks against the sides and pouring in grain until the pit is full.
- * Cover the top of the grain with plastic.
- * Seal the pit

<FIGURE 29>

Advantages: Keeps most of the grain very well.

Stores large amounts of grain.

Disadvantages:

May be hard to find plastic.

May be expensive.

Loses some grain because it falls down between the bags and the walls of the pit.

Concrete Linings

There has been work done on various concrete linings for underground pits. Because this method requires more labor, material and money, it is not as easy for a small farmer to use. However, it will be outlined in more detail in the part of this manual which discusses ferrocement. **STORING GRAIN IN PLASTIC SACKS**

Plastic bags make good airtight storage containers.

- * Use plastic bags which are .20 to .25mm thick (500-700 gauge).
- * Make sure there are no holes in the plastic. Even the smallest hole will cause problems.
- * Some insects can puncture plastic when trying to escape from the sack. But this can be stopped by putting a cloth bag of tightly woven cotton inside the plastic bag. The cloth is added protection.
- * Use grain which is very dry.

* Add insecticide to the grain. It can take a week or more for insects to use up the oxygen which is in the bag.

* Fill the sacks and seal them tightly.

* Store the filled bags off the ground on a smooth surface so that they will not be punctured by the floor or anything sharp.

Advantages: Plastic bags are easy to store.

Plastic bags are easy to move around.

They provide good protection against insects.

Plastic bags make good containers for fumigating small quantities of grain.

Disadvantages: Plastic can be torn or punctured easily.

They are generally good for only one year and must be replaced after that because small holes have been made in them.

Rodents can eat through plastic.

Plastic bags are expensive in some area.

The following leaflet, prepared by VITA artist Ken Lloyd is designed to show farmers a good procedure for storing dry grain in plastic sacks.

<FIGURE 30>

<FIGURE 31>

<FIGURE 32>

STORING GRAIN IN METAL DRUMS

In many parts of the world, 220-litre oil drums are available and not too expensive. If farmers in your area can find oil drums, this is a storage method which may be a good improvement.

Sorghum, maize, millet, cowpeas, and groundnuts are among the materials which can be stored successfully in these drums. The grain should be dry (12% moisture or less) when it is put into the drum.

<FIGURE 33>

Here is the procedure for using a drum:

* Make sure the drum is clean and dry inside.

* Check for holes. Holes in these drums can be plugged with wax.

* Pour clean, dry grain into the drum through the small top opening. Use a wide-mouth funnel to help with this job.

- * Shake the drum to let the grain settle; then fill it again.
- * Make sure the drum is full.
- * Screw the cap on tightly. If the rubber ring on the inside of the cap is missing, smear the cap with grease.

Each drum holds about 660kg of grain.

Advantages: Provides good airtight storage control of insects.

Protects the grain from rodents.

Works well for seed grain; does not seem to hurt the ability of the seed to germinate.

Is available in most areas and is not expensive.

Makes a good container to fumigate grain in.

Disadvantages: Has a small opening for filling and emptying.

Special clamp-on lid is sometimes available. But this lid does not create airtight conditions and insecticides must be used.

Works best when grain is being stored 5 months or more.

Has to be kept out of sunlight to prevent moisture changes and heating in the stored grain.

Can rust and must be repaired carefully for airtight storage to be continued.

<FIGURE 34>

STORING GRAIN IN METAL BINS

Metal bins are being tried for small-scale use in many parts of the world. In some areas, farmers can buy metal bins in different sizes. They are sometimes expensive, and they rust in moist areas. Often a farmer needs to be a member of a credit program to get the money to buy this type of metal silo or bin. Then he repays the money for the cost of the bin. Hopefully, the bin pays for itself by reducing losses to the stored grain due to attacks by insects and rodents.

Metal bins can also be built quite easily: but the farmer must know how to weld and work with metal. Or someone with these skills must be able to help.

CHARACTERISTICS OF METAL BINS

- * Built above the ground -- either on platforms or on cement bases when kept outside. The metal bottoms will rust because of contact with ground water if the bins are on the ground.
- * Rounded in shape to hold the pressure of the grain better: a square bin would have more seams and be more likely to break open.

* Painted white or stored out of the sun because metal conducts (passes on) heat very well.

<FIGURE 35>

Advantages of Metal Bins

- * Good control of insects, molds, and rodents if bins are well-made, well-sealed, kept off the ground, and out of the sun.
- * Small metal bins are lightweight and may be moved easily.
- * A metal bin may pay for itself out of the farmer's increased profit. This is true (for all improved storage methods) only where initial costs are not too high or a good credit program is available.

Disadvantages of Metal Bins

- * Metal sheets for building the silo are more expensive than most locally available materials, or, in some areas, cement.
- * Construction of a bin requires special equipment to cut and weld the metal and people trained in working with metal.
- * Metal rusts quickly in hot, wet places. Sheet metal for bins must be galvanized or painted regularly to protect the metal from rusting. This is another cost to the farmer.

Blacksmiths and people with metal-working experience, who might be interested in making bins to fit local needs, should be encouraged to try to do so. Experimenting with various designs will give information which can help you decide what kind of metal bin will work best in your area.

The following information on various metal bins is provided to give some idea of what types of bins are available. Wherever possible, an address is included so that you may write for further information.

CIRCULAR STEEL BIN

The bin shown here is very useful for storing small quantities of grain indoors. It can be made in four sizes, ranging from 500kg to 3 tons. The chart included here gives the dimensions for each size of circular steel bin.

<FIGURE 36>

Description

- * Opens at the top for filling and has a spout at the bottom for emptying.
- * Has a flat top and bottom made of plain Mild Steel sheets.
- * Has circular sides made of corrugated Mild Steel sheets.

- * Comes in 4-6 pieces which can be put together on site. The bin can be taken apart when not in use and put back together when it is needed again.
- * Prevents uneven temperatures within the bin by building-in a special arrangement.
- * Uses neoprene washers with bolts to make the bin airtight.
- * May be used for fumigation, as required.
- * Can be made in any small sheet-metal workshop.
- * Stores grain to be used for seed safely.

Capacity Height (cm) Diameter (cm) Gauge Steel Sheet

500kg 125 80 28

1 ton 165 100 26

2 ton 210 124 24

3 ton 210 150 24

For further information on this and other bins which might be of use to small farmers in your area, please write to:

The Grain Storage Research & Training Center Department of Food Government of India Hapur, Uttar Pradesh India

METAL BINS FOR HOME USE

A "Save Grain Campaign," begun in India in 1965, resulted in a number of metal bins which were designed specially for use in the home and on a small farm.

<FIGURE 37>

Two styles of bins are pictured here. Each bin is pictured in two sizes. The following chart shows how many kilograms of paddy, maize, or wheat each size of bin can hold.

CAPACITY PADDY(*) MAIZE(**) WHEAT(***) Cubic Meters kg kg kg

0.42 230 300 315 0.68 375 485 510 0.82 450 580 615 1.35 745 960 1015

(*) Approximately 550kg per cubic meter (**) Approximately 710kg per cubic meter (***) Approximately 750kg per cubic meter

The specifications and technical drawings for these bins are available in booklet form from:

Save Grain Campaign Ministry of Agriculture Department of Food Krishi Bhavan New Delhi, India SHEET METAL SILO

This silo was developed by the Institute of Tropical Agriculture Research in Benin (formerly, Dahomey), Africa. It is a good example of an easily made metal storage container.

The model below is made of sheet metal, 1 mm thick, welded together at the seams. It has two openings, one for filling at the top of the bin and one for emptying at the bottom. The cost of the 3 ton model shown here is about \$175 (U.S. currency) when manufactured in small numbers.

<FIGURE 38>

FUMIGATION OF SMALL QUANTITIES OF STORED GRAIN

Fumigants are insecticides in the form of gas. This gas can kill adult insects living outside the grain kernels and larval stages living inside the kernels. Once the gas disappears from the grain, there is no more protection against insects.

BECAUSE FUMIGANTS ARE GASES, THEY MUST ONLY BE USED IN CONTAINERS THAT WILL NOT LET ANY OF THE GAS GET OUT. THIS GAS CAN KILL HUMANS AND ANIMALS AS WELL AS INSECTS.

<FIGURE 39>

The easiest and safest fumigant to use is Phostoxin. In many areas, Phostoxin is relatively expensive. You can buy it in the form of tablets or pellets. These formulations only start to turn into gas when they are taken out of their containers and placed in the air. When the moisture from the air touches the tablets, the gas begins to form. Phostoxin containers must always be tightly sealed when not being used.

<FIGURE 40>

It is not a good idea for a farmer to use Phostoxin himself -- unless he has used it before, and you are sure he understands the use of this fumigant. But you should know how to use Phostoxin so that you can instruct and help the farmer fumigate his grain.

So the following pages present fumigation procedures which will be most helpful to the small-scale farmer: fumigation for stacked grain sacks; fumigation in plastic bags; fumigation in small metal bins, silos, and oil drums.

REMEMBER: WEAR GLOVES WHEN YOU USE PHOSTOXIN.

KNOW WHAT TO DO IN CASE OF AN ACCIDENT.

KEEP ALL PEOPLE AND ANIMALS AWAY FROM THE AREA WHERE FUMIGATION IS BEING DONE.

FUMIGATING GRAIN IN PLASTIC BAGS

- * Use 1 pellet of PHOSTOXIN for each 100kg of grain.

Tablets contain more poison than pellets; 5 pellets are equal to 1 tablet. If you cannot find pellets, you can cut one tablet in 4 pieces. Therefore, one tablet will fumigate 4 bags of grain. CUTTING PHOSTOXIN TABLETS IS DANGEROUS AND MUST BE DONE VERY CAREFULLY.

You must be sure there are no little pieces of the tablets lying around after you cut. If there are pieces, drop the pieces into a large pail of water which has soap in it. Do this outside in the open air. The gas will cause bubbling in the water. When the bubbles disappear, you can throw the mixture away.

- * Use heavy gauge (500 gauge) plastic bags.
- * Make sure the bags have no holes or tears. Mend any holes with tape.
- * Fill a bag with grain.
- * Put the pellet of Phostoxin in an unsealed envelope or piece of paper and place the packet on top of the grain in the bag.
- * Close the bag and tie as shown.

<FIGURE 41>

- * Place a warning on the bag so no one will touch or open the bag.
- * Leave the bag as it is for at least 5 days. It is even better to keep the grain in the bag tightly sealed until it is needed. Gas cannot protect against new attack, but once fumigation has killed any insects present, the plastic bag will maintain airtight storage conditions which will control insects.

NOTE: PHOSTOXIN may be expensive and may not be available in all areas. Check with your extension agent for information on other insecticides which might be useful for you to use on your stored grain.

FUMIGATING SACKED GRAIN UNDER PLASTIC SHEETS

- * Use PHOSTOXIN.

3 tablets per 25 45kg bags or 1,125kg of sacked grain

OR

15 pellets per 25 45kg bags or 1,125kg of sacked grain.

- * Use fumigation on bags made of jute or fiber. If using plastic bags, make sure the bags are open before fumigation begins.

- * Stack the sacks on the floor on a sheet of plastic, unless the floor is concrete. Do not fumigate directly on the ground because the soil will be temporarily poisoned by the fumigant. If the fumigating is being done outside, stack the sacks on a large sheet of plastic. Make sure the plastic is larger than the grain stack on all sides.
- * Take a 500 gauge plastic sheet. The sheet must be large enough to cover the stack completely and be held to the ground tightly. If necessary, you can overlap and tape smaller sheets together to make a large enough sheet.
- * Check the sheet to make sure there are no holes in it. You can do this by holding it up to the light. Mend any holes or tears with tape.
- * Spread the right number of tablets around the sacks. Spread the tablets around so that they do not touch each other.
- * IMMEDIATELY COVER THE STACK WITH THE PLASTIC SHEET.

<FIGURE 42>

- * Make sure the edges of the sheet are sealed tightly. Use loose sand, sand bags, poles, etc. to hold the sheet down.
- * Keep the doors and windows open if you are fumigating inside a building. (This is of course true only when you are fumigating under a plastic sheet inside a building -- not when you are fumigating an entire building. In this case, you would want to close the doors and windows tightly.)
- * Do not let anyone enter the fumigation area.
- * Leave the stack under fumigation for at least 5 days. Some PHOSTOXIN users prefer to remove the sheet while wearing a gas mask. But a gas mask is not necessary, if you follow these simple suggestions: lift the plastic sheet at one corner using a long pole. This means that if there is any gas still under the sheet, it will not hit you in the face when you lift the cover. Leave the stack as it is, with the one corner lifted up, for 1 or 2 hours.
- * Remove the plastic sheet after 1 or 2 hours if there is no strong smell.

NOTE: One characteristic of PHOSTOXIN which makes it relatively safe for farmers to use is the very strong smell associated with PHOSTOXIN. The smell, which starts being released almost immediately, is a good warning to users because the smell is noticeable before the gas reaches a poison strength which can kill or hurt people.

FUMIGATING STORED GRAIN IN SMALL METAL

CONTAINERS OR SILOS

- * Use 3 tablets or 12 pellets of PHOSTOXIN for each 4,400kg.
- * Make sure the emptying chute and filling holes are sealed. A thick coating of grease will make a good seal.

* Check to make sure bolt holes and seams of a water-tank bin are sealed. You can seal these with bitumen or melted wax if you are not sure they are tight.

* If the grain level in the bin is no more than 6m, you can spread the tablets only on top of the grain.

* Spread the tablets as you pour in the grain only if the grain can be sealed up within 4 hours. Remember to place the tablets in an open envelope. In a larger silo, you can build up the grain to a level of 5m and then start putting in tablets. Continue putting in grain and tablets until finished. Start counting 4 hours from the time the first tablets are put in.

* Seal the manhole just as soon as all the grain and tablets are inside.

* **MAKE SURE THE MANHOLE IS TIGHTLY CLOSED. USE A THICK COATING OF GREASE, WAX, OR CEMENT MORTAR TO SEAL IT.**

* Leave the silo unopened for at least 5 days. If the grain is not needed, keep the container sealed until the grain is needed.

WARNING! YOU MUST HAVE THE MANHOLE SEALED WITHIN 3 or 4 HOURS OF ADDING THE FIRST TABLET OF PHOSTOXIN. PHOSTOXIN GAS CAN KILL.

NOTE: Metal drums are good containers in which to fumigate grain. Simply drop in the correct number of pellets for the size drum, seal it tightly, and wait for 5 days.

STORING IN EARTHEN STRUCTURES

Farmers for thousands of years have been storing grain in bins and other containers made of clay. Earth is available and easy to use.

More recently, there has been interest in improving mud granaries to make them more airtight and waterproof. This is especially important in areas where insecticides are hard to get and where there is a lot of rain.

The Pusa Bin, which is discussed here, was developed in India. It is made of mud bricks. The walls are made by sealing a layer of plastic sheet between two layers of mud bricks. The mud bricks protect the plastic from holes. The plastic keeps air and moisture out.

<FIGURE 43>

Advantages:

- * It is an airtight storage structure.
- * The materials are often available locally.

Disadvantages:

- * Plastic sheets are sometimes hard to get or expensive.
- * It must be protected from rain by a separate roof.
- * Sealing the plastic sheets may be a problem for a farmer.

THE IMPROVED MUD BLOCK SILO

The other plan presented here is the improved mud silo, and is based on a plan prepared in Ghana. VITA artist George Clark provided the illustrations.

<FIGURE 44>

The silo is made of mud bricks. This silo was improved by plastering and painting the walls. Plaster is usually composed of cement, lime and sand. Mud plasters also can be used. Both mud and plaster may not stick to the brick walls for long periods of time. Mud plaster sticks better for a time, but heavy rains can wash it away. Efforts have been made to mix the mud with a stabilizer such as cement, or bitumen; this seems to work. Also, to make the plaster stick better, small stones can be added to the mud used to make the bin walls.

Local material also can be used to paint and coat the outer walls. Some materials which can be tried on the walls are:

asphalt resins organic oils ox-blood paints

These coatings last only a year or so, but they are cheap, available, and easy to put on. See Appendix D for information on how to find and use local materials to waterproof soil construction. When looking for a coating for an improved mud silo, the farmer should remember he is looking for a material which:

- * is water-repellant.
- * sticks to the walls.
- * lasts long enough so he does not have to re-apply often.

The improved mud silo presented here has the following advantages and disadvantages:

Advantages

- * The materials are cheap.
- * Airtight storage can be achieved or nearly achieved. If the farmer is not sure the silo is airtight, he can add insecticide to the grain.
- * The emptying chute allows small amounts of grain to be taken out without unsealing the top of the bin.
- * It can be made in a number of sizes.

Disadvantages

- * It requires regular painting or whitewashing.
- * It may not be water-tight to prevent grain rewetting.

Since these earthen structures seem to be more easily made by small farmers than the metal bins, the construction plans are given in more detail. The mud silo presentation includes a set of instructions for use of the silo. THE INDIAN PUSA BIN

<FIGURE 45>

The Pusa Bin was developed in India by members of the Agricultural Research Institute in New Delhi. It is relatively simple and inexpensive to construct and maintain. This bin is double-walled all the way round -- including the floor and roof -- with a separating layer of plastic sheet. The plastic protects against moisture and keeps air from entering the stored grain.

Protect the bin from rain. If the bin is not erected under a shed and it rains often, it will require too much repair and rebuilding, and the grain may get wet and mold. However, complete shading from the sun is not necessary because mud walls do not hold heat. This is one advantage of a mudblock structure over a metal bin.

In India, rats cause great storage losses. For this reason, in this plan the bottom 50cm of the outside wall and the first layer of the floor slab are made of fired, or "burned," bricks. These bricks are harder than un-fired bricks, like mudblocks, and rats and mice cannot gnaw through the bin walls or burrow up underneath the floor to get to the grain. Another way to keep out rats and mice is to use sheet metal over whatever kind of non-hardened material you use, in the same places.

This plan uses an insulating layer of plastic sheet. The Pusa Bin is airtight and waterproof only if the plastic sheet is made and used correctly. The plastic sheet used should be at least 700-gauge thickness, to resist tears and punctures.

If plastic sheet is not available or if it is too expensive, some other form of waterproofing will be needed in warm rainy areas. Check out what is available locally. Tarfelt -- heavy paper impregnated with tar -- can be used. Experiment with bricks containing cement. Try painting the bin with asphalt, coal tar or any other local waterproofing substance. Remember, the bottom of the bin must be waterproofed to stop migration (seeping of moisture from the earth below).

This plan is for a 2 metric ton bin. You may vary the size of the bin to fit your needs. Make sure you build a strong enough roof support frame for larger bins.

READ THE INSTRUCTIONS THROUGH BEFORE YOU BEGIN

Tools and Materials

* mudblocks and mud mortar for the walls. If you make blocks 10 x 10 x 20cm you will need about 900-1000 of them.

* wood to make a form for making mudblocks

* fired, or "burned," bricks, concrete blocks or bricks of some other hard, rat-proof material for the floor and lower 50cm of the walls. You will need about 250 of them. OR some sheet metal to cover mudblocks for the same purpose. You will need 6-6.5 square meters, allowing for overlapping of sections. If you use sheet metal instead of hard bricks, add 250 mudblocks to the number given above.

* cement mortar if you use fired bricks

- * about 9 square meters of 700-gauge plastic sheet for moisture-proofing the bin. Or the same area of tar-paper, or a suitable amount of waterproofing material to give a good, thick coating or several coatings.

- * a piece of iron bar to heat and seal seams in the plastic

- * wood or another strong material for making a roof support frame

- * sheet metal or plastic pipe for an emptying spout. Coated wood will also work.

- * some wax or similar material to seal some joints

- * mud for making roof slabs

1. Select a site.

- * Choose a place that is as high and dry as possible. It is better to build up the earth a little for extra protection against collecting rainwater. Level and firmly tamp down the earth.

- * Make the foundation area at least 1.5 x 2m.

2. Make mudblocks.

- * Use the hard earth beneath the topsoil to make mudblocks. If the soil in your area does not have a high clay content, you may be able to mix a little cement in with low-clay soil to make good mudblocks.

- * A wood form can make several mudblocks at a time.

- * If you use blocks measuring 10 x 10 x 20cm you will need about 900-1000 mudblocks. If you are going to use sheet metal instead of fired bricks to protect against rats and mice, add 250 more.

3. Make the floor of the bin.

- * Lay down a platform of fired bricks or other hardened bricks, and cement mortar, measuring about 120 x 160cm. OR Lay down a layer of sheet metal and place a layer of mudblocks and mud mortar on top of it, to the same measurements. Use flattened kerosene tins or any available sheet metal. Overlap all the pieces. Make the outside edges stick out about 15cm beyond the outside edges of the block platform that will be laid on top of it.

- * Allow about 1cm thickness of mortar between either kind of brick, for a good bond.

- * Place a layer of plastic over the bricks, or whatever waterproofing material you are using. It should extend a few centimeters beyond each edge of the layer of bricks.

- * Lay down a layer of mudblocks and mortar on top of the plastic, the same size as the first brick layer.

<FIGURE 46>

4. Build the inner walls.

- * The inner walls may be made entirely of mudblocks and mortar.
- * Make the outside edges of the walls the same as the outside edges of the floor.
- * Build an emptying spout into the first layer. Form something like galvanized tin into a tube about 9 or 10cm in diameter, or use a plastic pipe the same size. Fit one end flush against the inside of the wall. Make it long enough to extend past where the outside edge of the outer wall will be. You may tilt it downwards slightly towards the outside for easier exit. Mortar it into the wall. You will need a tight-fitting cap on the end of the spout.
- * Lay the blocks so that each one crosses over a joint between blocks in the layer below it. This will make the walls stronger.
- * Build the walls to a total height of about 160cm -- but wait until installing the roof support frame (next step) before putting in the final layer.

<FIGURE 47>

5. Install a roof support frame.

- * Use wood that is naturally termite proof, or coat it with something to protect it against these and other insects. Metal or reinforced concrete bars can be used, but they will be more expensive. The roof must have strong support: use the best available material.
- * Use four pieces as long as the distance between the outside edges of the inner wall -- two pieces about 120cm and two about 160cm. Wood should have at least a 5 x 5cm cross section.
- * Form the frame in a double-cross pattern. Interlock wood joints. One of the corner spaces should measure about 50 x 50cm, for a manhole entrance.

<FIGURE 48>

* Position the frame on top of the next-to-last layer of blocks in inner wall. Raise the ends up on some mortar so the top surface of the frame will be at the same height as the top surfaces of the final layer of mudblocks.

<FIGURE 49>

* Mortar the frame and the blocks for the top layer of the wall into place. Make a smooth top surface on the walls.

6. Build the inner roof.

- * Make mud slabs 5cm thick for the inner roof.

- * You may make one or more to cover each space in the support frame, depending on how strong the slabs are. They will have to support another layer of mud slabs the same thickness when the bin is complete. It would be best to extend them to the outside edges of the inner wall for firm support. Sections of tightly stretched wire mesh fastened to the support frame would provide extra support for the slabs.

- * Position the slabs on mortar applied to the support frame and the tops of the walls. Leave the 50 x 50cm manhole open.

- * Fill any spaces between the slabs with mortar.

7. Plaster the inside.

- * Plaster the insides of the walls and the roof, and the surface of the floor with a smooth coating of mud or mortar. This will leave no place for insects or dirt to lodge.

8. Make and install a plastic cover.

- * Measure the outside dimensions of each of the four walls and the roof.

- * Cut pieces of plastic sheet to cover each of the five surfaces. Each piece should be cut a little larger than the surface which it will cover -- at least 5cm overhang on each edge. The bottom edges of the sides must reach a few centimeters beyond the plastic sticking out from the floor.

- * Fasten the pieces together in a box shape. Keep in mind the right arrangement of pieces so that when the cover is placed over the bin it will fit.

- * Seal the edges of the plastic together with a heated piece of iron bar. Lay one edge over another and pass the iron over them. Make sure the iron is not too hot: it should not melt the plastic, but just seal it together. Make sure you have a good seal. Practice making seams on small scraps of plastic first. Find the right temperature for the iron.

<FIGURE 50>

- * Make sure there are no rough edges of blocks or mortar on the walls or roof that will damage the plastic.

- * Pull the cover all the way down over the inner structure of the bin. If it is too small you will have to re-make it; you may be able to re-work the seams. It does not matter if the cover is too large.

- * Cut a hole in the plastic around the emptying spout. Seal it to the spout with something like soft wax. This should make an air- and water-tight seal.

- * Seal the bottom edges of the wall pieces to the edges of the plastic in the floor.

- * Cut a diagonal slit through the plastic across the manhole.

9. Build the outer walls.

<FIGURE 51>

- * Begin the walls from the earth foundation. Build them right up against the plastic over the inner walls.

- * Use fired bricks or other hardened bricks and cement mortar for the lower 50cm of the outer walls

OR Use mudblocks and mud mortar instead, building them up on the metal sticking out from under the floor. Cover them to a height of 50cm with overlapping pieces of sheet metal. Mortar or otherwise securely fasten the metal in place. Make a good joint with the metal sticking out from under the floor.

- * Continue the outer walls with mudblocks and mud mortar. Build them up to the top surface of the inner roof. If there is any difference in height, fill with mortar.

10. Build the outer roof.

- * Place 5cm-thick mud slabs over the plastic sheet on top of the inner roof, mortaring them in place, out to the outside edges of the outer walls. They may be any size across, as long as they are strong.

- * Do not cover the manhole. Make a separate mud slab to fit over it.

- * Fill in spaces between the slabs with mortar.

11. Finish the bin.

- * Plaster the outer roof and sides with a smooth layer of mud or mortar.

- * Let the entire structure dry thoroughly. This will take about thirty days. Leave the manhole cover off during the drying.

- * A coat of whitewash put on after drying would help reflect the sun's heat and add further waterproofing.

- * Build a shelter over the Pusa Bin to protect it from the rains. Make it at least a half meter larger than the bin on all sides, and high enough to give plenty of room to load grain and get in and out the manhole. There is no need to enclose the sides of the shelter.

12. Prepare and use the bin for storage.

- * When the bin is dry, clean the inside thoroughly. Light a small, smoky fire to drive off insects. Take both of these steps each time you get ready to load an empty bin.

- * Dusting the inside surfaces of the bin with insecticide, and also the grain, will protect the grain better.

- * Cover the manhole when you have put your grain into the bin. Seal it with extra mud or mortar for more protection.

- * Always close the cover of the emptying spout tightly after using.

- * Check the grain periodically.

- * Store only grain which is dried to 12-13% moisture content in the Pusa Bin.

IMPROVED MUDBLOCK SILO

READ THE INSTRUCTIONS THROUGH BEFORE YOU BEGIN

Tools and Materials

- * Rocks about 20-25cm across for the foundation of the silo.
- * Flat rocks, as wide across as possible, to lay across the foundation.
- * Sand for concrete and mortar.
- * Small stones to mix in with the concrete.
- * 2 bags of cement.
- * Trowel or a similar tool to work the mortar and plaster mixes.
- * Different sizes of wood boards. The sizes are shown in each part of the instructions where you will use them.
- * Earth to make mudblocks.
- * Nails (1.8-2.4cm long).
- * Pitch, tar, or other waterproofing material.

Select a Site

- * Find some solid ground on which to build the silo.
- * High ground is best.
- * Make sure the silo is built in a place where the ground underneath it will not wash away during a rainy season.

<FIGURE 52>

13. Make a Form to Mold Mudblocks

- * Use wood boards about 2.5cm thick.
- * You will need: 2 boards 46cm x 10cm 4 boards 10cm x 15cm
- * Line the 2 long boards up side by side. * Nail the 4 small boards crossways between them. Place the small boards so that the distance between the 2 long boards is 15cm. Leave 10cm space between each of the small boards. Place the first small board about 2.5cm in from the ends of the long boards. This should leave about the same amount of space on the other end.
- * Make handles. Use 2 small pieces of wood 2.5cm thick that are 15cm long and about 5cm wide. Nail one across each end of the box.

14. Make Mudblocks

- * Mix earth and water to make the same kind of mud you use to build any building.
- * Wet the form.
- * Fill the form with mud.

- * Pack the mud tightly into the form.
- * Take any extra mud off the top.
- * Lift the form carefully off the mudblocks.
- * Dry the blocks in the sun.
- * Make about 300 blocks.

<FIGURE 53>

15. Make Frame "A" for the Outside of the Topslab

- * To make this topslab you must make 4 wood frames. Later you will pour concrete into these frames.

<FIGURE 54>

- * Prepare: 2 boards, 2.5cm x 5cm x 1.2m 2 boards, 2.5cm x 5cm x 1.1m 4 boards, 2.5cm x 5cm x 51 cm
- * Nail the 4 longer boards together. Butt the ends of the 1.1 m boards up against the ends of the 1.2m boards. When the frame is lying on the ground, the 2.5cm edges of the boards should be facing up.
- * Nail these cross pieces in place from the inside. The 2.5cm edges of these boards should also be facing up when the frame is lying on the ground.
- * Cut the ends of the 4 short boards at a 45 degree angle. Then they will fit easily across the corners of the large square frame.

<FIGURE 55>

16. Make Frame "B" for the Manhole

- * Prepare: 2 boards, 2.5 x 8cm x 45cm 2 boards, 2.5 x 8cm x 40cm
- * Cut part of the face off each end of the 4 boards. This will make a slanted face.
- * Nail the 4 boards together. Face the slanted sides outward. Butt the ends of the 40cm boards up against the ends of the 45cm boards.

<FIGURE 56>

17. Make Frame "C" for the Collar

- * Prepare: 2 boards 2.5cm x 2.5cm x 53cm 1 board, 2.5cm x 2.5cm x 56cm 1 board, 2.5cm x 2.5cm x 66 cm
- * Nail the 4 boards together. Butt the ends of the 56cm board up against an end of each of the 53cm boards. Butt the other ends of the 56cm boards up against the 66cm board. Leave 5cm of the 66cm board sticking out on one end.

<FIGURE 57>

18. Make Frame "D" for the Manhole Cover

- * You will need: 2 boards, 2.5cm x 5cm x 61 cm 2 boards, 2.5 x 5cm x 56cm
- * Nail the 4 boards together. Butt the ends of the 2 shorter boards up against the ends of the 2 longer boards.

<FIGURE 58>

19. Mix the Concrete and Pour it into the Wood Frames

- * Mix the concrete in a proportion of: 1 part cement (out of the bag) 2 parts sand 3 parts small stones

Remember to mix the dry ingredients first. Then add the water, a small amount at a time until the mixture is correct.

- * Cover a flat place on the ground with empty cement bags or sheets of heavy paper or plastic. These will keep the concrete from sticking to the ground.
- * Wet the empty bags or whatever you are using. This will keep the concrete from sticking to them.
- * Put Frame A on top of these.
- * Place Frame B in the middle of Frame A. Make sure each side of Frame B is the same distance from each side of Frame A. The thin edges of Frame B should be facing down.
- * Begin pouring concrete mix into the space between Frame A and Frame B. The open space inside of Frame B will be the manhole.
- * When you have poured in about half the thickness all the way around, lay in the metal rods.
- * Pour the rest of the concrete mix over the rods.
- * Make sure the rods are in the concrete. They should not show through the concrete. If you do this right, the rods will help make the concrete much stronger.

<FIGURE 59>

- * Level the concrete even with the top of Frame A. Frame B will stick up 2.5cm above the wet concrete.
- * Place Frame C around Frame B on top of the wet concrete. The space between the two frames must be the same on every side.
- * Pour concrete mix into the space between Frame B and Frame C. Make the top of the concrete level with the tops of the 2 frames. This will form a collar for the manhole cover to rest on.
- * You are now ready to use Frame D to make a separate piece. This will be the manhole cover.

- * Place Frame D on some empty cement bags or sheets of heavy paper or plastic.
- * Wet the empty bags or whatever you are using.
- * Pour concrete mix into Frame D. Level off the top of the concrete to the top of the frame.
- * Leave all the frames around the concrete for at least 3 days. The concrete will become even stronger if you can leave it for several more days.
- * While the concrete is drying, put water on it 3 times each day at morning, noon, and night. Putting water on the concrete like this will make it harden evenly and not crack. This is called "curing."
- * When the concrete is Cured," remove the wood frames. Remove them carefully, so you can use them again.

<FIGURE 60>

1. Make the foundation

- * Draw a circle on the ground where you want to build the silo. Make the circle 1.2m across.
- * Place the 20cm or 25cm rocks around the circle just inside the edge, and inside the circle. You may fill in the larger spaces with smaller rocks to give more support. The air spaces between the rocks will let air move through the foundation and will keep moisture from collecting.
- * Place flat rocks on top of the circle of rocks. This will make the top more level.
- * If you cannot find good flat rocks, you may use concrete blocks. Place them the same way as you would the flat rocks. Place them so they come right up to the edge of the circle of rocks, or overhang slightly.
- * Make some mortar by mixing 1 part cement and 5 parts sand together. Add enough water to make a workable paste.
- * Put mortar over the flat rocks or blocks. Fill all open spaces. Make the surface as smooth as you can. This will cement the top of the foundation into a solid piece.
- * Find the center of the foundation.
- * Mark off a 91 cm diameter circle from the center. This is the inside diameter of the silo.

1. Build the Grain Chute (Optional)

- * Use hard wood about 2.5cm thick.
- * Prepare: 1 board, 2.5 x 15 x 30cm -- for the top of the chute. 1 board, 2.5 x 15) (25cm - for the bottom of the chute. 2 boards, 2.5 x 10cm that are 25cm long on one edge and 30cm long on the opposite edge. These are for the sides of the chute. 1 board, 2.5cm thick, at least 13cm wide, and 20cm or 25cm long. This is for the sliding door in the chute.

- * Place the edge of the sliding door board on one of the side boards 5cm in from the short straight end. Trace the width of this edge onto the side board. Make a groove. Remove the wood between the 2 lines you have traced to a depth of about 6mm. Make each surface of the groove as smooth and as straight as you can.
- * Repeat this process on the other side board. The groove should be in the same place on each side board.

<FIGURE 61>

- * Cut the top board into two pieces. One piece should be 5cm long. This will fit the space between the front of the chute and the beginning of the groove for the sliding door. Match the edge of the remaining piece with the far end of the groove. Cut the length of the top piece as needed to match the length of the side piece.
- * Nail the top and sides and bottom of the chute together.
- * Trim the width of the sliding door board so that it will slide through the opening in the top of the chute down the grooves.
- * You may have to trim the long sides of the opening too if the sliding door is too thick. The sliding door should move freely up and down but should not be too loose.
- * Cut the bottom edge of the sliding door at an angle so that only a thin edge will touch the bottom of the chute. This edge will face the outside of the silo. This will make it easier to keep grains from lodging under the closed door which might let air and moisture and insects into the silo.
- * Paint the chute and the sliding door with pitch or tar or some like material to protect it from insects and moisture.
- * Drive a few nails into the chute near its slanted end. They should stick out a couple of centimeters. The nails will help anchor the chute into the walls of the silo.

1. Begin the Walls

- * Make mortar the same way you did for the top of the foundation. It is better to mix smaller amounts until you know how fast you can use it. Do not use mortar that has gotten too dry because it will not be as strong.
- * Lay down a layer of mortar all around the inside edge of the circle you have drawn on the top of the foundation. Make it about 10cm wide.
- * Place about 18 mudblocks in a circle on top of the mortar. Leave a space for the chute, including the nails that are sticking out from it.
- * Place the chute in the space you have left. The slanted end of the chute should be even with the inside surfaces of the blocks next to it and straight up and down. This will make the chute tilt down away from the silo wall.

<FIGURE 62>

- * Fill the spaces between the mudblocks and the spaces between the mudblocks and the chute with mortar.

* Lay down a layer of mortar on top of the circle of mudblocks.

* Place the second layer of mudblocks on top of the first. Place each block so that it lays across the space between the blocks in the first layer. This will make the wall stronger. You may have to cut blocks to fit next to the chute. Do not leave a large space that will have to be filled with mortar next to the chute.

* Continue putting on mortar and mudblocks in the same way until you have laid down 4 layers of mudblocks altogether.

1. Make a Slanted Floor

* Use sand or soil to make a slanted floor. This will help the grain move towards and out of the chute. If the chute is not used, this slant will not be needed.

<FIGURE 63>

* Pack the sand or soil down hard.

* The floor should be 30 cm above the bottom of the chute at the place opposite the chute. The floor near the chute should be even with the bottom of the chute.

* Make a mix of plaster. Use 1 part cement (out of the bag) to 3 parts clean sand (mix dry). Use enough water to make a smooth mix. Do not make it too watery.

* Plaster the slanted floor and the inside of the mudblock wall. Make sure you cover all the surfaces completely.

* Plaster carefully around the chute.

* Smooth the plaster well after you put it on. This will make cleaning easier and will leave fewer spots for insects to hide in.

* Keep the plaster damp until it is hard.

* Put loose sand on the floor after it is dry. This will keep drops of mortar and plaster from sticking to the floor as you continue working.

1. Finish the Walls

* Tie a string to a small stone. You will use this to check the straightness of the walls as you build them.

* Put down 3 or 4 layers of blocks. Use mortar and arrange the blocks the same way you did for the first 4 layers.

* Hold the string at the top end, with the stone hanging down from it at the other end.

* Hold the string out about 5cm from the top of the silo wall. The silo wall is straight if the distance between the string and the wall is the same from the top to the bottom.

* Continue adding layers of blocks the same way as you did before. Check every 3 or 4 layers for straightness.

* The finished silo wall should have about 14 layers of blocks.

* Mix some plaster the same way you did for the slanted floor and the inside of the first 4 layers of mudblocks.

* Plaster the inside and the outside of the silo wall. Remember to put the plaster on very smooth.

1. Place the Topslab

* When the mortar and the plaster in the silo wall are dry and strong, you are ready to place the topslab on top of the silo.

* Make sure that Frames A, B, and C are removed from the concrete topslab.

* You will need people to help you put the topslab in place.

* Mix some fresh mortar (1 part cement, 5 parts sand, and water).

* Place a layer of mortar all around on top of the silo wall.

* Put the topslab down on top of the mortar. Many people can lift the topslab together. One person can stand inside and help. He can get out through the manhole.

* Remove the cover from Frame D and place.

<FIGURE 64>

1. Whitewash the Silo

* Apply a coating of whitewash to all the outside surfaces of the silo. The manhole cover and all areas of the topslab and walls should be covered.

* Whitewash closes small openings in the cement.

* Whitewash helps keep the silo cooler inside. It is important to keep the grain cool and dry.

- * Whitewash will also make your silo look nice.

HOW TO USE YOUR MUDBLOCK SILO

<FIGURE 65>

- * Put only clean, dry grain into your silo.
- * Wet grain will rot in the closed silo. It will get moldy.
- * Wet grain will make the silo wet. The silo walls will crack if they get wet. Your grain will be no good.
- * Dry your grain in the sun.
- * Keep the grain in the sun or in the dryer until it is dry.
- * Test the grain when you think it is dry. Put one grain between your teeth. Dry grain is very hard to break with your teeth.
- * Remember, if storing maize -- put kernels into the silo right after you remove them from the cobs. Do not let maize stay on the cobs after you remove the maize from the drying place.
- * When the grain is dry, take the cover off the manhole. Put the grain into the silo right away. Fill the silo to the top.
- * Stir the grain in the silo with a large stick. This helps the grains settle.
- * It is good to add an insect poison to the grain before you close the silo. Insects are always present in grain. Insect larvae live inside the kernels where they can not be seen. Talk to your extension worker about what poison to use and how to use it.
- * Remember, poisons can kill animals and people. Do not use them before you talk to an extension worker.
- * Put the cover on the manhole as soon as possible. Flying insects can enter the grain if the cover is not on the manhole.
- * Put mud all around the cover so nothing can get into any cracks between the cover and the manhole.
- * Make sure the sliding door in the wooden chute closes tightly.
- * Make sure there are no cracks around the chute.
- * Put mud over the chute to protect it from rodents and insects.
- * Keep the area around the silo clean. Rats do not like to live where it is clean.
- * Check your silo often. Put new plaster on any cracks you find. It is important to find the cracks and put plaster on them right away.
- * Keep the silo white. The white color keeps the silo cool. Put on new whitewash when the silo needs it.

- * You may have to use the chute to take out small amounts of grain to sell or eat. Make sure you close the sliding door carefully. Do not leave it open. Reseal it with mud. If theft is a problem, the chute can be omitted and grain will be removed from the top of the silo.
- * Do not leave grains scattered on the ground. These grains will attract insects and rats.
- * When you empty the silo, make sure all the grain is out. Grain left in an empty silo will attract insects and rodents.
- * Clean the silo well before you fill it again. You can burn a small fire made of grass inside the silo. This kind of fire makes a lot of smoke. The smoke and heat from the fire kill insects and insect eggs.
- * Sweep out the ashes, dust, and old grain.
- * When your silo is clean and repaired, you are ready to put the next crop of grain into the silo.

FERROCEMENT FOR GRAIN STORAGE

Materials in this section have been adapted from articles in *Ferrocement: Applications in Developing Countries*, National Academy of Sciences, Washington, D. C., Feb., 1973; and from "Hermetic Storage of Rice for Thai Farmers by Smith, Boon-Long, Loo, Nutalaya and Pataragetvit, Thai Journal of Agricultural Science, July, 1971.

Ferrocement is a kind of reinforced concrete. Ferrocement is made of wire mesh, sand, water, and cement. It is strong and durable. Generally, ferrocement structures are from 1 cm to 5 cm in thickness. The reinforcement is layers of steel mesh with thin steel reinforcing bars placed between the layers. Ferrocement has been used as a material for building boats for many years. Now ferrocement is being used with increasing success for grain storage in a number of countries.

Ferrocement is appropriate for building structures in many areas of the world:

- * The materials to make it are usually available all over the world.
- * It can be made into almost any shape. Therefore, an improved structure can be made which looks very much like the old one.
- * It is cheaper than a metal bin, in some places.
- * Building with ferrocement does not require a lot of equipment or machinery.
- * It can be built almost anywhere, even in isolated locations.
- * It does not take very long for workers to learn to use ferrocement.
- * It needs little maintenance after completion. Repairs, if necessary, are easy to make.

MATERIALS FOR FERROCEMENT

Reinforcing Mesh

Many kinds of mesh will work as long as the mesh can be shaped easily (is flexible). The mesh will have to be more or less flexible depending upon the shape of the final ferrocement product. If the ferrocement is to be a rounded structure, the mesh has to be more flexible than it would have to be for a straight-sided container.

For grain storage uses, chicken wire can be used as reinforcing mesh. Chicken wire is usually available, though in some areas it can be expensive.

In cases where chicken wire or wire mesh is not available, the mesh can be made by using straight wire. This allows the user to make the size mesh he wants, and it is cheaper to buy coils of straight wire than it is to buy mesh. The mesh does not need welding; either galvanized or non-galvanized wire can be used.

Cement, Sand, and Water

Almost any ordinary cement can be used. The sand should not be too fine (have too many tiny pieces). If there are pieces of dirt, leaves, or other organic matter in the sand, wash the sand before using it. The water also must be free from silt and other dirt. These materials weaken the ferrocement if they are left in the sand and water.

BUILDING WITH FERROCEMENT

There are three areas in ferrocement construction which are particularly important:

Mixing the Mortar

A general mix is 1 part cement to 2 parts sand. Only enough water is added to make a pastelike mixture. Experience will be the best way to find out the best consistency for the mortar. Machines can be used for mixing, but hand mixing the mortar works very well and may cost less.

Putting the mortar on the wire mesh

Before mixing the mortar, the mesh structure should have been formed in the shape desired. Then, using fingers and trowels, push the mortar into the mesh structure. Some kind of vibrating movement helps push the mortar into the mesh and packs it in better. For grain storage purposes, just put a handle on a piece of wood and create a vibrating movement.

When placing the mortar, there are two important points to keep in mind: you must completely cover the steel wire mesh with mortar so that the steel cannot rust and lose its strength; at the same time, the wire mesh should be as near the surface as possible. This means that the covering over the wire mesh must be thin but complete.

Curing the Mortar

Ferrocement must not dry too quickly. It should be kept moist for at least seven days. It also must be protected from sun and wind. Both too much sun and too much wind will dry the ferrocement too quickly: ferrocement must dry slowly to be strong.

FERROCEMENT FOR GRAIN STORAGE

There are many things about ferrocement which make it good for grain storage; it is particularly good in areas of the world where high temperatures and damp air cause grain to rot and mold easily. (However, if wire is very costly, and cement powder relatively inexpensive, the farmer may want to build a cement stave silo.)

Ferrocement:

- * can provide watertight storage, if treated.
- * can be made to provide airtight storage, and, therefore, insecticides are not needed.
- * does not heat the stored grain as much as metal bins do.

Disadvantages

One major disadvantage to ferrocement at the moment seems to be that the use of ferrocement for grain storage is still new, and knowledge of the technique is not widely available. Also, for the small farmer, ferrocement is relatively expensive.

AN OVERVIEW OF GRAIN STORAGE USES FOR FERROCEMENT

This section on ferrocement provides an introduction to ferrocement as a building material for grain storage uses. It includes descriptions of ferrocement bins and a ferrocement lining for underground storage pits. The Thai Ferrocement Silo (Thailo), which can hold 3.5 tons of paddy rice, is presented in some detail.

Ferrocement has been used to make water tanks for a number of years. But ferrocement is still being tested for its grain storage value and much of this knowledge is still in the hands of designers and testers. Hopefully, by reading the above general material on ferrocement, and, then, by reading the following descriptions of possible grain storage uses, you will be able to form some ideas as to whether or not ferrocement is worthy of more investigation for use in your area.

THAI FERROCEMENT SILO (THAILO)

Tools and Materials

- * Cement 1,000kg
- * Sand 1,725kg * Aggregate 965kg (used in the base)
- * Mortar plasticizer 2kg
- * Sealant for base 5kg
- * Paint 0.75kg
- * Chicken wire 2 Rolls
- * No. 2 rod 80m
- * Water pipe (19mm dia.) 32m

These are materials available in Thailand; they may not be easy to find in other places. But other materials may be substituted. For example, the silo has been built using bamboo poles instead of water pipe. The pipe was substituted to prevent termite infestation. If it is not clear that termites will be a problem, experimenting with other available materials will be needed. Using bamboo, means the walls will be much thicker -- 5 to 7.5cm --, requiring more cement. Walls using water pipe are only 4cm thick.

The sealant is to help protect the silo in areas where flooding is a problem. Any kind of asphalt seal should provide protection.

1. Build the Base

- * The base is saucer shaped and can be built on a pile of hard earth. This should be done if the area has seasonal flooding or very heavy rains. The base can be changed easily to fit different ground conditions.

- * Put a sealing mortar on the earthen base and apron. Make the mortar using, by weight: 1 part cement 3 parts sand 0.6 parts water

- * Lay one layer of concrete over the apron and base. Make it 5cm thick.

- * Reinforce this concrete layer with 19mm wire mesh. (Chicken wire can be used) after you have laid down half the thickness of concrete. Use this concrete mix, by weight: 1 part cement 1.5 parts sand 2 parts aggregate 0.33 parts water.

- * Let this layer of concrete harden and water it 3 times a day. Keep the concrete damp for 7 days. This lets the concrete harden slowly, and the concrete will, therefore, be stronger. Treat the concrete with an asphalt seal. In Thailand, a brand called Flintkote is used in 2 coats. (Flintkote is simply a bitumen emulsion). The first coat is mixed with water -- 1 part Flintkote, 3 parts water. The second layer contains no water.

- * Put down another layer of 5cm thick concrete with mesh reinforcement (about midway in its thickness). This time put the concrete over the base, but not over the apron. The mesh should stick out of the concrete to the end of the apron. It will be used later as more reinforcement for the walls.

<FIGURE 66>

1. Build the Wall Support Structure

- * The walls slope inward towards the top in a cone shape. The opening at the top of the cone is the entrance, or manhole.

- * Build a wooden "tree" to support the wall structure until it is finished. The tree should stand about 2m high with a circular platform at the top.

<FIGURE 67>

* Extend steel water pipes or whatever reinforcing materials are used from the base to the tree platform at regular intervals. These pipes, called struts, form the support for the wire mesh.

<FIGURE 68>

* Bring mesh up from the base and fasten to struts with wire.

* Wire horizontal hoops of reinforcing rod to the struts.

* Put one layer of wire mesh on the outside surface and one layer of wire mesh on the inside.

* Fasten mesh, reinforcing rod, and struts together with short pieces of wire threaded through the wall and back. Tie by twisting the ends with pliers.

<FIGURE 69>

1. Apply Mortar

* Hand mix the mortar in the following proportions, by weight:

1 part cement 1.75 parts sand

Enough water to make a thick paste. * Work the mortar into the mesh structure using trowels and hands. * The wall thickness inside and out should be about 4cm (if using steel pipes) and 5-7.5cm (if using bamboo).

1. Make the cover or Top

Here are 2 choices for the top.

1. Ferrocement outer cover with gaskets of rubber which act as airtight seals. This can be made on site or erected before cementing the walls.

An inner lid can be used. This lid can be an aluminum trash can lid. If this inner lid is used, place a polystyrene (plastic) lining between the grain and the trash can lid to insulate against heat and prevent moisture condensation.

2. Build a small piece of formwork supported by wires attached to the tops of the steel pipes which form the struts for the wire mesh. Or long nails can be driven into the wooden platform which supports the struts. These nails are bent up to shape a form.

The topseal consists of 2 parts:

* Aluminum lid with polystyrene insert and a tubular ring of plastic placed between the lid and the wall.

* A piece of sheet metal screwed to the top with a sealing gasket.

Some General Notes on Ferrocement Silos

IMPORTANT: Do not mix too much water into the mortar and concrete mixtures.

IMPORTANT: Wet the finished ferrocement 3 times per day for 7 days. Cover the silo with moist sacks and make sure the cover is kept wet. It is very important not to let the sun and wind dry the silo too quickly. Slow drying, called curing, gives cement its durability and strength.

- * Painting the silo with chlorinated rubber-base paint, coal tar or bitumen should be done to make sure it is completely airtight and watertight.

- * Fill the finished silo with water for one week if you wish to test it. Water is heavier than the stored grain. If there are cracks or weak places they will leak. Make repairs as needed. The silo must be dried for 4-6 weeks particularly if it has been filled with water. Remember that the shape and size of the ferrocement silo can be changed to fit your own needs.

FERROCEMENT-LINED UNDERGROUND PITS

This material is adapted from Ferrocement: Applications in Developing Countries, National Academy of Sciences, Washington, D. C., Feb., 1973. The illustration is from a report prepared by R. A. Boxall for the United Kingdom Committee of the Freedom from Hunger Campaign and Christian Aid, 1971-72.

A traditional pit can be made into an air and watertight grain storage container by using ferrocement to line the pit. Ferrocement linings work even in pits built in very wet ground. The cost of this pit was \$20.00 (U. S. currency) in 1972.

<FIGURE 70>

Here is an outline of the construction process.

1. Clean the pit

- * Remove trash
- * Make sure walls are smooth and free of termites.
- * Apply poison to kill termites if necessary.

1. Prepare the floor of the pit

- * Lay down a 10mm layer of hardcore.
- * Lay a layer of concrete on top of the hardcore. Use a concrete mix like the one given for the base of the Thailo grain store pits.

1. Make the mortar

- * Mix well one part cement and 3 parts sand.
- * Add as little water as possible to make a paste.

1. Line the walls

- * Use hands and trowels to put a 2.5-3cm layer of mortar to the walls.
- * Place wire mesh reinforcement, or chicken wire on the surface of the mortar where it is wet.

* See waterproofing material before placing the second layer of mortar. The other method of waterproofing is cheaper, requires less labor and may work well depending on the ground water level. This method uses a single layer of bitumen between the two cement layers. If you choose this method, Step 6 is not necessary. * Put another layer of mortar on top of the chicken wire.

1. Cure the lining

* Keep the walls and inside of the pit damp for at least 5 days. Seven days is better. * Do not let the pit dry out quickly!

1. Waterproof the lining There are 2 methods. Here is the most expensive. *

Brush off any loose concrete with a wire brush. * Use a stiff brush to put on a first coat of Bitumen Emulsion. This first coat is diluted -- 1 volume of emulsion to 1 volume of water.

* Make sure the emulsion gets worked deeply into the lining.

* Let this first, or priming coat, dry.

* Apply a layer of undiluted Bitumen Emulsion and let dry.

* Mix 1 volume of water to 1 volume of cement to 10 volumes Bitumen Emulsion and brush this over the entire inside of the pit.

1. Make the-lip

* Build up the mouth of the pit using stones.

* Mix concrete of the type used at the bottom of the pit and lay a sloping lip at the mouth of the pit as shown in the drawing. Drain pipes can be used to carry water even further away.

* Let dry well.

1. Seal the pit

* A traditional lid can be used.

* A metal or concrete lid which is sealed with bitumen makes a very airtight storage container.

* If you choose to use a metal lid place old cloths or sacks between the top of the grain and the cover. This cloth will absorb any moisture which forms on the metal lid.

OTHER FERROCEMENT GRAIN STRUCTURES

From a VITA Volunteer in India come the following ferrocement specifications and drawings. Since these grain bins are presented in sizes suitable for use by small farmers, they are included here to illustrate further the ranges of ferrocement shapes and applications. These plans were proposed by the Keetaram Agricultural Services, Pvt., Ltd., of New Delhi, India.

Ferrocement Grain Bin #1 (CB-1)

Useful for seed storage or where smaller batches of various types or qualities of grain have to be preserved. For indoor use, although the design will permit long exposure to sunshine and rain without deterioration of the contents.

The bin has an internal diameter of 750mm and is 1 metre tall. A large manhole, 600mm in diameter, is used for loading and unloading of grain. This manhole is closed by means of a loose fitting over which is equipped with a facility for padlocking. The bin can be easily sealed by caulking wet clay all around the cover. Since the bin will be placed directly on the floor no opening is considered necessary at the bottom, since this will make the extraction of grain at ground level a very tedious operation. The height of 1 metre makes it easy for the grain to be removed from the top manhole.

The walls of the bin are 12mm thick and have a smooth internal finish preventing lodging of any bacterial infestation. All corners and edges are rounded off for the same reason and to facilitate cleaning of the bin before loading.

This bin holds 0.4 cubic meters. It will store 350kgs of wheat. The bin weighs about 230kg when empty and 580kg when full.

<FIGURE 71>

Ferrocement Grain Bin #2 (CB-2)

This has an internal diameter of 1,000mm and a height of 1,500mm. A manhole diameter is provided at the top for loading of grain. The manhole can be closed by means of a loosely fitting manhole cover with a padlocking arrangement. At the bottom of the bin a square opening is provided and this is fitted on with nuts and bolts on to the recessed enclosure of the opening. This cover will be normally opened once a year, when the bin has been emptied and is to be thoroughly cleaned before fumigation. For unloading grain, there is a 8cm diameter sheet metal screw conveyor fitted over the cover. This is manually operated and is estimated to discharge at the rate of about 15kg per minute by manually turning the conveyor at 60 RPM.

The capacity of this bin is 1.4 cubic meters. It will store 1,000kg of wheat. The bin weighs 340kg when empty and, therefore, about 1,350kg when full.

Ferrocement Grain Bin #3 (CS-1)

This is the first of the new series of medium-size bins. It is also a vertical cylinder, having an inside diameter of 1.5 meters and an overall height of 1.5 meters. Because of their large size, these bins will usually be kept outdoors or under open verandahs or corridors. The roof of this bin is dome-shaped so that rain water will run off.

Loading is done by a man standing on a stool. A manhole of 450 mm diameter with a detachable cover is provided in the roof, along with a padlocking arrangement.

Unloading is done at the base through a screw conveyor identical to that described under type CB-2.

The capacity of the bin is 3 cubic meters, and it will store 2-3 tons. The bin weighs 700kg when empty and 3,000kg when full.

Ferrocement Grain Bin #4 (CS-2)

The second bin in this series has the same inside diameter as type CS-1 viz 1.5 meters, but the overall height is increased to 2.9 metres. The construction of this bin is generally identical with type CS-1. However, because of the height the loading arrangement is different. Provision has been made for installing a pulley at the top manhole. One man standing on the roof of the bin will lift the sack by the pulley and empty that sack into the bin. A detachable ladder is provided for climbing up to the roof.

Unloading arrangements provided at the bottom of the bin are identical with Type CB-2.

The capacity of this bin is 5.4 cubic meters. It will store 4.5 tons of wheat. The bin weighs about 1,100kg when empty and 5,600 when full.

<FIGURE 72> STORING GRAIN IN CEMENT/CONCRETE STRUCTURES

This manual has already discussed a number of materials used for storage -- mudblocks, plastic, metal, ferrocement. The final construction material discussed here is cement/concrete.

Three plans for storage structures which use cement are offered here.

The first, and simplest, was designed by Peace Corps Volunteers in Senegal and built by local farmers.

<FIGURE 73>

<FIGURE 74>

The second plan includes detailed drawings for a 4.5 ton Cement Stave Silo. This silo has been built and tested by Peace Corps Volunteers in Benin. The testing process has led to some design improvements and these have been incorporated into the plan included here.

The third plan is for building and establishing Concrete Block Square Silos for cooperative storage. Since small farmers often cannot afford to make improvements by themselves, they enter into cooperative agreements and store their grain all together in large bins. This plan offers a low-cost alternative to the traditional large round silo, and the problems of keeping strict measurements of each farmer's input to the silo, by giving information on how to construct square, multi-celled (each cell is relatively small) silos.

<FIGURE 75>

BRICK GRAIN STORAGE SILO

<FIGURE 76>

Description

Traditional family granaries in West Africa are constructed of clay, bamboo, or millet stalks with a thatch roof. They are easy prey for insects, rodents, fire, and thieves. The silo described here was designed by Peace Corps Volunteers to protect grain against these dangers and, equally as important, to be of low cost and easy to build.

The silo is made of mortared concrete bricks placed on a reinforced foundation. A reinforced cover with a manhole is cast to place over the bricks. The manhole cover can be made of sheet metal for ease in handling, but if welding is a problem, a cover can be cast in concrete.

All labor was done by Senegalese villagers with the help of a Peace Corps Volunteer. With the assistance of an experienced village mason, a farmer can do the work necessary to build this silo.

Advantages:

- * Protects against insects and rodents.
- * Easy to build.
- * Does not cost a lot of money.
- * Holds 3-cubic meters of grain.
- * Easy to reach to take grain in and out.

Disadvantages:

- * Making the manhole cover may be difficult.
- * Moisture may be a problem unless the silo is water-proofed.

Materials and Tools

- * Cement (for bricks, foundation, cover, mortar, plaster) 7 bags
- * Reinforcing rod (6mm) 36 meters
- * Sheet metal for manhole cover as needed.

1. Make Forms for Silo Base and Cover

- * Dig a hole 1.75m x 1.75m and 6cm deep. This is for the silo base.
- * Dig a hole 1.6m x 1.6m and 8cm deep. This hole is for casting the silo cover.
- * Make, and place in the hole, a wooden mold 60cm square by outside measurement.

<FIGURE 77>

1. Make the Base and Cover

* Cut reinforcing rod for both the silo and base. * Mix concrete and pour each form half full. * Set reinforcing rods into concrete. * Finish pouring concrete. * Pour concrete for the cover up to a level of 8cm. When concrete is somewhat set, make and place a form which is 62cm square by 2cm high around the smaller form on top of the already poured concrete. Then pour concrete into the space between the two frames. This forms the lip around the manhole cover. The manhole cover should be designed to fit around this lip. This gives increased protection from insects and rodents.

<FIGURE 78>

* Remember to set the staples for the locking arrangement in the wet concrete of the silo cover.

<FIGURE 79>



* Make a manhole cover now if a concrete manhole cover is to be used.

* Keep the concrete damp. Wet it 3 times a day and keep it shaded.

1. Make Bricks

* Make 100 sandcrete bricks with a mixture of 1 to 5. The exact number of bricks needed depends upon the size of the brick.

* Dry and cure the bricks for 3 days. Keep them damp so they dry slowly.

1. Build the Walls

<FIGURE 80>

* Mortar the bricks into place with the corners overlapping alternately for strength.

* Let the bricks and mortar set for 5 days.

* Plaster the inside.

1. Put on the Silo Cover

* Put a layer of mortar on the top edge.

* Put the cover in place.

1. Put on Manhole Cover

* Make a steel manhole lid and set it in place. Or put in place an already prepared concrete cover.

* Lock the cover in place.

<FIGURE 81>

THE 4.5 TON CEMENT STAVE SILO

This silo was developed in Benin, West Africa, by local agricultural extension agents and U.S. Peace Corps Volunteers. Over 250 of these silos have been built. The plan in the following pages is adapted from one prepared by Peace Corps Volunteers. The drawings were done for this manual by Nicolas Reinhardt, a VITA Volunteer.

The cement stave silo, if protected from rain by a shelter, will keep unwanted moisture away from the stored grain better than earthen-walled silos which have not been specially treated.

In drier areas, the higher cost of the cement stave silo means that farmers should check out other, cheaper types of silos. However, the cement stave silo will work in drier areas as well as more humid ones.

<FIGURE 82>

Advantages

- * Stores large amounts of grain.
- * Gives good insect control when insecticide is added to the grain to kill insects already in the grain.
- * Offers good protection for the grain from rodents.
- * Is less expensive than a metal silo of similar capacity and is more durable.

Disadvantages

- * Has to be protected from rain or it does not provide good moisture control.
- * Uses materials and equipment which make it more expensive to build than the mudblock silo.

THE SITE

- * Build the silo on high, well-drained ground. Do not build the silo where it will be in the path of water from flooding or heavy rains.
- * Test the ground to see if it will support the silo. You should build this silo on hard-pan, rock, or stable soil.
- * Dig a small hole, about 65cm deep. If you do not reach hard-packed earth or rock, try another location, if possible. If there is no other location available, and you are in doubt about whether the earth is hard enough, special precautions should be taken.
- * Locate the silo so that it is level. If a dryer such as the Pit Oil Barrel Dryer, is being built on the same site, the location must be chosen so that the front of the dryer is facing the oncoming winds during the time of year you will be drying.

THE SHELTER

A straw or tin-roofed shelter can be built before building the cement stave silo.

- * The shelter protects the silo from rain and sunlight. Also, it provides a good working place for the builders of the silo.
- * It is important to build the shelter so that there is at least 50cm on all sides of the silo (and dryer). This will ensure protection from rain.

<FIGURE 83>

- * The type of roof will depend on what the farmer can afford. A thatch roof can always be replaced by a tin roof after the silo and shelter have had several years to pay for themselves.
- * Many farmers build a larger shelter so that both the silo and a dryer, like an oil barrel dryer, can be put underneath it.

Tools and Materials

- * Digging tools
- * Tools for working cement and mortar
- * Cement, 16 sacks (50kg each) * Re-rod (6mm diameter), 10 - 12 bars (each 6m long)
- * Galvanized wire (3mm diameter), 1 roll (4kg)
- * Wire tighteners, 10
- * Coal Tar, 15 litres
- * Plastic or other suitable moisture barrier material

Some General Comments

- * Cement should be stored on log supports or plastic: it will harden if stored directly on the ground. If there are lumps in the cement and they cannot be broken easily, they should be removed and the amount of cement should be increased by 1/4 to 1/3.

<FIGURE 84>

- * Road sand can be used if it is clean and does not have too much clay content.
- * Gravel should be smaller than 1/3 the thickness of the slab in which it will be used. The gravel should be washed if there is dirt or other impurities in it.
- * Water should be free of dirt, oil, and chemicals. These weaken cement. If water will be stored in barrels, these should be washed thoroughly before use.
- * Mixing should be done on cement or on swept, packed earth. Be careful not to scrape dirt into the mixture. When mixing on dirt, all mixtures should be made on the same spot since that spot will harden after the first mixing.

* Too much water causes cement to separate from the mixture when it is tamped. Losing this cement weakens the mixture. 20-25 liters of water for each 50kg sack of cement is about right for all mixes.

READ THE INSTRUCTIONS THROUGH BEFORE YOU BEGIN

1. Make the Forms for the Staves

- * Make at least one wooden form (mold) for each of the two sizes of stave.
- * Check the forms carefully to make sure they have very flat and regular inside surfaces.

<FIGURE 85>

* IT IS IMPORTANT THAT THESE SURFACES BE SMOOTH AND AT THE CORRECT ANGLE. SINCE MORTAR IS NOT USED TO PUT THE STAVES TOGETHER, ITS AIR- AND WATER-TIGHTNESS WILL DEPEND ON THE TIGHTLY FITTING EDGES OF THE STAVES.

1. Make the Staves

- * Mix the mortar with a mixture of 1 part cement to 4 parts sand.
- * Tamp the staves down firmly, with a bottle, for example. Be careful the cement is not so wet that water runs out of the form or the staves slump.
- * Make 91 large staves and 26 small ones for the walls.
- * Make 5 more large staves as extras in case of breakage.

<FIGURE 86>

- * Make one large stave with a hole in it (12cm in diameter) for inserting the emptying plug.
- * Place a ring of 6mm re-rod (50cm long) around the hole for added strength.
- * Cure the staves. <FIGURE 87>

1. Make Bricks for the Foundation

- * Make a form of 14x20x30cm for making bricks. This form will give the size blocks used in this particular plan.
- * Use a mixture of 1 part cement to 4-7 parts of sand, depending upon the quality of the sand and cement.

* Make about 80 bricks for a foundation like the four-brick layer foundation pictured below. (The actual number of layers depends upon how far down you must dig to find hard-packed earth or rock upon which to build the foundation.)

* Make 8 more bricks, if you feel the earth is soft under the silo, or if you are not sure the floor slab is going to be made of very good quality cement. These 8 bricks will make a pillar in the center of the foundation.

* Be sure to water and dry the bricks the same way as you did the staves.

* Substitute regular, already made concrete blocks of the type used in houses, if they are a good size to use and if they are strong.

1. Build a Foundation

* Dig a hole with an outside diameter of 2.2m. The foundation should rest on hard-packed earth or rock.

<FIGURE 88>

* Lay the bricks using a mortar consisting of 1 part cement to 6-8 parts sand.

* Lay the bricks so that each one crosses over a joint between bricks in the layer below. This will make the wall stronger.

* Be sure the foundation extends 15-20cm above ground level.

* Build the pillar, if required, by placing two bricks, joined with mortar, in the center of the foundation hole. Lay the second layer of bricks with mortar crosswise over the first layer. Continue laying bricks and mortar until the pillar is even with the top of the foundation.

* Fill the foundation with sand and hard-pack (tamp) the sand to the level of the top layer of the foundation.

1. Waterproof the base

* Use plastic sheets, coal tar, or tar felt.

* Lay a 3cm layer of mortar on top of the hard-packed sand if using coal tar or tar felt. This is not required when plastic is used.

* Overlap joints of tar felt 20cm and spread coal tar on the seams.

* Use 4 layers of coal tar if that material is chosen to paint over the 3 cm layer of mortar.

1. Make a Form for the Floor Slab

- * Use 29 large staves (temporarily) to make the form for the floor slab.
- * Place the staves around the outside of the foundation wall in a 2.2m diameter circle. In other words, the circle of staves will be flush with the outer perimeter of the foundation wall.
- * Hold the staves in place using two wires and wire tighteners.
- * Line the inner face of the staves with paper, plastic, or masonite to prevent sticking when the staves are later removed.

<FIGURE 89>

- * Mark the form to show a point 4cm above the base and another point 10cm above the base. These marks will guide you when you pour the concrete into the form.

1. Form the Re-rod Pattern for the Base

- * Form a 6.6m re-rod perimeter for the slab.
- * Use one 6m piece of 6mm re-rod and one 1m piece.
- * Bend the ends of each re-rod piece to form 10cm hooks.
- * Join these hooks together to make a longer bar for the perimeter.
- * Leave an extra 10cm at each end when cutting re-rods. These extra lengths will be bent to form hooks for attaching the straight bars to the perimeter re-rod. The two longest straight re-rods are each 2.3m long. A total of 18 straight re-rod pieces will be needed.
- * Put the re-rods into position.
- * Attach all hooks and intersecting points with fine wire.
- * Place the finished re-rod pattern into the form to be sure it fits -- before you pour the cement.

<FIGURE 90>

1. Mix and Pour Concrete for the Floor Slab

- * Use a mixture of one part cement, two parts sand, and three parts gravel (1:2:3).
- * Mix the concrete so that it can be worked easily but does not flow.
- * Wet the inside of the form completely before pouring the concrete.
- * Pour 4cm of concrete before placing the re-rod pattern in.
- * Tamp the concrete down well.
- * Put the re-rod in and finish pouring concrete to the 10cm level marked previously.
- * Tamp very well. THIS IS IMPORTANT.

- * Smooth and level the surface carefully.
- * Water the slab 3 times per day for 7 days. Keep the slab shaded.

1. Mount the Wall

<FIGURE 91>

- * Mark a circle of 100cm radius from the center of the slab.
- * Place 13 large and 13 small staves around the circle, alternating the large and small staves, with their smaller faces inside.
- * Place a thin layer of 1:6 mortar under the bottom row of staves for proper seating.
- * Place the large stave with the emptying hole in the first layer, with the hole toward the bottom slab.
- * Place no mortar between the staves.
- * Place and tighten a retaining wire at each 25cm of height.
- * Place 2 wires in the bottom 25cm, 8cm from the top and the bottom of the small staves (one above and one below the emptying hole).
- * Place the tighteners for these 2 wires only on the large staves. When tightened, the tighteners should be centered on the large staves.
- * Form each following layer by placing 13 large staves in the gaps until reaching a height of 2.0m (4 large staves vertically).
- * Complete the final layer by placing 13 small staves in the remaining gaps.
- * Hold these staves in place with 2 wires, 8cm from the top and 8cm from the bottom of the small staves.

1. Make a Form for the Cover Slab

The cover slab is like the floor slab except that it must have a filling hole and is only 8cm thick.

- * Cover the top of the wall completely with solid boards. These must extend beyond the edge of the wall.
- * Place an upright collar of masonite on the boards 5cm outside the edge of the wall.
- * Hold the collar in place with nails.
- * Support the boards from within the silo if they are not strong enough to support a man without sagging.
- * Cover the boards completely with paper or plastic inside the masonite circle to prevent the concrete from sticking to the boards or from leaking through any large cracks.
- * Place the manhole (for entry and filling) form 20cm inside the masonite circle. The form should be about a 50cm diameter circle made with an inverted basket, or masonite held in place with nails.

1. Form the Re-rod Pattern for the Cover

- * Form the re-rod pattern in the same way as you did the floor slab except that space must be left for the manhole.

<FIGURE 92>

- * Test the pattern in the form for fit before pouring concrete.

1. Make the Cover

- * Mix another batch of 1:2:3 concrete for the cover.
- * Pour and tamp a 4cm layer of concrete before placing the re-rod pattern.
- * Place the re-rod pattern.
- * Pour the remaining 4cm layer of concrete.
- * Tamp and smooth out the slab with a slight slope away from the entry hole.
- * Make a manhole cover 6cm thick and 60cm in diameter with the remaining concrete.
- * Use a masonite strip or a hole dug in the ground and lined with paper as a form.
- * Place a re-rod, bent into the correct shape for a handle, into the concrete. This re-rod also gives added strength to the cover.

<FIGURE 93>

- * Cure and dry the cover slab and the manhole cover in the same way as the bottom slab. (Wet the concrete 3 times a day for 7 days and keep the concrete shaded.)
- * Be sure the slab is dry before removing the form (wait at least 10 days). It is easiest to remove the boards by gently levering the edges of the slab, sliding out boards as you go.
- * Be careful not to apply pressure to the strip between the manhole and the outer wall. This strip is the weakest part of the slab.
- * Close the space between the cover slab and the upper walls with mortar after taking out the boards of the form.
- * Place a sealing ring cut from a rubber inner tube, for example, around the manhole. Or make a sealing ring of mortar. If you use a piece of rubber, cover the rubber with mortar. Cover the mortar with paper, and place the manhole cover on it. This will provide a raised horizontal joint to prevent water from getting into the manhole.

<FIGURE 94>

1. Make a Security Plate (Anti-Theft System)

- * Use the bottom of an oil barrel or a piece of heavy sheet metal.
- * Cut a piece 20cm x 25cm.
- * Pierce two holes on one of the 20cm sides, 2cm in from the side and 4cm from each end. A hinge will pass through each of these holes.
- * Cut a slot 5cm long and 1.5cm wide, centered on the other 20cm side of the metal piece, 3cm from the edge.

<FIGURE 95>

- * Use the remaining re-rod material to make a staple and two hinges.

<FIGURE 96>

1. Plaster the Silo

- * Make a 1:6-8 mortar mixture. * Install the security plate before plastering the outside. Apply the mortar 2cm thick.

<FIGURE 97>

- * Plaster the outside walls to a thickness of 2cm.
- * Close the inside joints with a cement wash or plaster to keep grain from getting stuck in the joints and to increase moisture resistance.
- * Put the plastic plug into place and use mortar to form a tight fit between the plug and emptying hole. BE CAREFUL NOT TO SEAL THE PLUG SO FAR INTO THE HOLE THAT YOU CANNOT PULL IT OUT.

<FIGURE 98>

1. Paint the Silo

- * Let the silo dry after plastering for at least one month before using it.
- * Do not apply coal tar to any plastered surfaces until after the plaster has been allowed to dry for at least two weeks. * Apply coal tar to the outside surfaces of the silo wall and to the cover slab to increase the silo's moisture resistance further.
- * Paint the inside floor with coal tar. If the floor is painted, let it dry for at least two weeks before storing grain so that the grain does not stick to the tar.

<FIGURE 99>

INSTRUCTIONS FOR USE OF THE CEMENT STAVE SILO

To be sure of good quality storage for your grain, it is important to understand the proper way to use the Cement Stave Silo. This can be done easily by a few steps taken at the right times.

The Shelter

The silo must have a good roof over it for protection from rain.

- * Check the roof often to be sure there are no holes in it which will let rainwater fall on the silo.

- * Repair holes immediately.

The Silo

- * Make sure the filling and emptying holes are well sealed during storage times. Each time you add grain to the silo, carefully re-seal the filling hole. Use cement mortar or banco (hand-packed, wetted earth). Banco is, of course, less expensive and is easier to use. If the emptying hole does not seal tightly with mortar, it can be sealed with melted candle wax or banco.

<FIGURE 100>

- * Clean the inside of the silo and check for cracks in the walls shortly before the beginning of storage each year. Light will pass through even the smallest cracks. If cracks are found, cover them carefully with a mixture of cement and water.

- * Use insecticides when storing grain in this silo. Even though the silo is completely closed and insects cannot enter to attack the stored grain, there will always be some insects in the grain at the time of filling. These insects not only destroy the grain by eating it, they can cause conditions which lead to rotting.

- * Open the emptying hole each month to make sure the grain is storing well and that no insects are alive inside. When you open the silo, if it seems very warm inside, or if there is a smell of rotting grain, empty the silo immediately. Re-dry the grain.

CONCRETE BLOCK SQUARE SILOS FOR COOPERATIVE STORAGE

Many farmers form cooperatives and store their grain collectively in large bins. This allows the farmer to get better quality storage (and drying) than he could afford as an individual.

The formation of farmers' cooperatives is an important subject, but this manual edition will not deal with coop formation and processes. However, the following plan is presented as an illustration of how newer ideas and methods of storage can

be applied to cooperative storage situations. It is presented as an alternative to the larger, round silos so often used for cooperative storage.

<FIGURE 101>

Some of the Advantages of the Square Silos

- * Less expensive to build than groups of round silos because the walls are shared. Also, building a group of round silos of the same capacity would take a greater area and would mean greater roofing costs.
- * Easy to expand by adding more storage cells on to the ends and/or sides.

<FIGURE 102>

- * Stress and pressure of the grain on the walls is not as great as in the round silo because each storage cell is relatively small.
- * Only one cell has to be opened at a time to get out a farmer's grain. This means that opening the bin is not going to mean that the grain in all the other bins must be re-fumigated, as would be needed if a large round silo had to be opened.

DESCRIPTION

This multiple celled storage bin has a capacity of 30 tons. It is constructed of brick and re-inforced concrete with outside dimensions of 9m x 4.6m. It has 8 storage cells with inside dimensions of 2m x 2m x 2m. A 4m x 4m open space for weighing and grain drying is sheltered by the roof at one end. Each storage cell will have an opening on the top to fill the silo and a chute at the bottom to remove grain.

<FIGURE 103>

1. Build the Walls

- * Dig down to solid sub-soil.
- * Pour a pad of re-inforced concrete 25cm thick x 25cm wide. This will extend under the inside and outside walls of the storage cells.
- * Make wall bricks of fired clay brick or use concrete blocks.
- * Make two layers of re-inforced concrete: one, halfway up the walls and the other at the top of the walls. These layers of concrete will support the stress of the stored grain and prevent bursting of the bin walls.

<FIGURE 104>

1. Make the Floor

- * Fill and pack sand or coarse gravel in the bins to a height 20cm above ground level. This layer of sand or gravel will reduce the amount of ground moisture which will be in contact with the floor slab.
- * Lay a 7cm thick floor slab of re-inforced concrete on the hard-packed sand
- * Put a layer of tar paper (or other waterproofing material) on the concrete floor slab.
- * Coat all edges and seams of the tar paper with a heavy layer of roofing tar.
- * Pour a final 3cm thick layer of concrete on top of the tar paper. This will protect the tar paper moisture barrier from being damaged later during storage. The final floor level is approximately 30cm above ground level.

1. Finish the Walls

- * Cover the walls with a rough cement plaster on both the inside and outside.
- * Paint the outside walls with coal tar or other water-repellant material.

1. Cover the Bins

- * Make 8 individual slabs of reinforced concrete.
- * Make the slabs on the ground using reusable wooden frames.
- * Make a form which leaves a 60cm x 60cm opening for filling the bins.
- * Place the re-inforced slabs side by side to cover the silo cells.
- * Join all edges and seams with a heavy layer of roofing tar.
- * Fill with grain, put concrete cover over the filling hole and seal with roofing.

1. Make a Roof

- * Cover the entire building with a roof, for example, of corrugated sheet metal or local thatch.

1. Dig a Drainage Ditch

- * Dig a gutter along the sides of the building where the roof is pitched.
- * Slope the ground away from the foundation.

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 tropical 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 benefits from their renewable resources.

Reproduction of this bibliography, in whole or in part, is gladly permitted provided that full acknowledgement is given to the Tropical Products Institute, Foreign and Commonwealth Office, (Overseas Development Administration), and to the authors.

Requests for further information on this subject should be addressed to:

Tropical Stored Products Centre (Tropical Products Institute) London Road Slough
SL3 7HL Bucks.

Contents

TEXTBOOKS

JOURNALS

ANNUAL REPORTS

HANDBOOKS, BULLETINS, SPECIAL REPORTS

ADVISORY LEAFLETS

SCIENTIFIC PAPERS

NOTES

This bibliography attempts to bring together a selection of the more important publications dealing with tropical crop storage; it clearly cannot be exhaustive.

Where possible, the prices (at time of publication) and addresses are given for obtaining publications listed here, excluding scientific papers. A list of the most common addresses appears below.

BRITISH STANDARDS INSTITUTION: Sales Branch, 101-113, Pentonville Road,
London, N.1.

MINISTRY OF AGRICULTURE, FISHERIES and FOOD: Tolcarne Drive, Pinner,
Middlesex.

UNITED NATIONS: FOOD & AGRICULTURE ORGANIZATION: Distribution & Sales
Section, Via delle Terme di Caracalla, 00100 Rome, Italy.

UNITED STATES: DEPARTMENT OF AGRICULTURE: Superintendent of Documents, U.S. Government Printing Office, Washington D.C. 20402, U.S.A Textbooks

ANDERSON, J.A. and ALCOCK, A. W. (Eds). 1954 Storage of cereal grains and their products. St. Paul, Minn: Amer. Ass. Cereal Chem., 1954, ix + 515 pp. (Out of print: obtainable from Univ. Microfilms, Ann Arbor, Mich., price 10.00 [pound]. Currently under revision).

BUSVINE, J. R. Insects and hygiene. The biology and control of insect pests of medical 1966 and domestic importance. London: Methuen and Co., 1966, 2nd rev. edn, xi + 467 pp. Price 5.00 [pound].

CHRISTENSEN, C.M. and KAUFMANN, H.H. 1969 Grain storage. The role of fungi in quality loss. Minneapolis, Minn.: Univ. Minnesota Press, 1969, vii + 153 pp. Price 6.50.

COTTON, R. T. Pests of stored grain and grain products. Minneapolis, Minn: Burgess 1963 Publ Co., 1963, rev. edn, 2 + i + 318 pp. (Out of print).

MUNRO, J. W. Pests of stored products. London: Hutchinson (The Rentokil Library), 1966 1966, 234 pp. Price 2.10 [pound].

TRISVYATSKII, L.A. 1966 Storage of grain. Moscow: Izdatel'stva 'Kolos', 1966, 3rd edn, 406 pp. (Translated into English by Keane, D.M. and edited by Kent, N.L. & Freeman, J.A. Boston Spa: natn. Lending Libr., 1969, 3 volumes, 244, 287 & 307 pp. Price 1.25 [pound] per vol., 3.75 [pound] the set).

Journals

BULLETIN OF GRAIN TECHNOLOGY. Quarterly. Hapur: Foodgrain Technologists' Research Association of India. Price \$3.00 per annum.

JOURNAL OF STORED PRODUCTS RESEARCH. Quarterly. Oxford: Pergamon Press. Price 12.00 [pound] per annum.

TROPICAL STORED PRODUCTS INFORMATION. Biannual. Bulletin of the Tropical Stored Products Centre (Tropical Products Institute). Free. (Enquiries to the Tropical Stored Products Centre, (TPI), London Road, Slough SL3 7HL, Bucks).

Annual Reports

CENTRAL FOOD TECHNOLOGICAL RESEARCH INSTITUTE. Annual reports of the C.F.T.R.I., Mysore - 2, India. Priced.

INFESTATION CONTROL. Reports of the infestation Control Laboratory (Ministry of Agriculture, Fisheries & Food). London: HMSO. Priced.

NIGERIAN STORED PRODUCTS RESEARCH INSTITUTE. Annual reports of the Nigerian Stored Products Research Institute, Federal Ministry of Trade. Lagos: Fed. Minist. Inform., Printing Div. Priced.

PEST INFESTATION RESEARCH. Annual reports of the Pest infestation Laboratory (Agricultural Research Council). London: HMSO. Priced.

TROPICAL PRODUCTS INSTITUTE. Annual reports (up to and including 1967) and then Biennial reports of the Tropical Products Institute, (Overseas Development Administration). May be priced. (Enquiries to the Scientific Secretariat, Tropical

Products Institute, 56-62 Gray's Inn Road, London WC1X 8LU).

TROPICAL STORED PRODUCTS CENTRE: MINISTRY OF OVERSEAS DEVELOPMENT. 1970. Tropical Stored Products Centre. A Report on the work 1965 - 1966. (The work of the Centre prior to 1965 was reported as part of the Annual Report 'Pest Infestation Research'; from July 1967 it forms a part of the Annual and Biennial Reports of the Tropical Products Institute. Enquiries to the Tropical Stored Products Centre, (TPI), London Road, Slough SL3 7HL, Bucks).

Handbooks, Bulletins, Special Reports

BROWN, W.B. Fumigation with methyl bromide under gas-proof sheets. Dep. Sci Ind. 1959 Res., Pest infest. Res. Bull. No. 1. London: HMSO, 1959, 2nd edn, ii + 44 pp. Price 22 1/2p.

COTTERELL, G.S. and HOWE, R. W. 1952 Insect infestation of stored food products in Nigeria. (Report of a survey, 1948 - 50, and of control measures adopted). Colonial Res. Publ. No. 12. London: HMSO, 1952, 40 pp. Price 25p.

EASTER, S.S. (Ed). Preservation of grains in storage. Papers presented at the international 1947 meeting on infestation of foodstuffs, London, 5 - 12 Aug., 1947. Wash., D.C.: Fd. Agric. Org. agric. Stud. No. 2, 1948, 174 pp. Price \$1.50.

FREEMAN, J.A. Control of pests in stored agricultural products with special reference to 1958 grain. Report of a survey in North and South America and certain Mediterranean countries in 1954 and 1955. Org. eur. econ. Coop., eur. Productivity Agency Project No. 212, Feb. 1958. Paris: OEEC, 1958, 169 pp. Price 57 1/2p. (OEEC Dist. & Sales Serv., 33 Rue de Franqueville, Paris 16e and overseas agents).

FURMAN, D.L. Suggested guide for the use of insecticides to control insects affecting crops, 1968 livestock, households, stored products, forests and forest products. U.S. Dep. Agric., agric. Res. Serv., agric. Handbk No. 331, 1968, rev. edn, xvi + 273 pp + 2 app. Price \$1.50.

HALL, D.W. Handling and storage of food grains in tropical and sub-tropical areas. FAO 1970 agric. Dev. Paper No. 90. Rome: UNFAO, 1970, xiv + 350 pp. Price US \$6 (2.40 [pound]).

HINTON, H.E. and CORBET, A.S. 1963 Common insect pests of stored food products. A guide to their identification. Econ. Ser. Brit. Museum (nat. Hist.), No. 15. London: British Museum, 1963, 4th edn,, vi + 61 pp. Price 17 1/2p.

HOLMAN, L.E. (Compiler). Aeration of grain in commercial storages. U.S. Dep. Agric., 1960 Mktg Res. Rep. No. 170, 1960 (revised and reprinted Sept. 1966), 46 pp. Price 35 cts.

HUGHES, A.M. The mites of stored food. Tech. Bull. Minist. Agric. Fish, Fd, No. 9, 1961, 1961 vi + 287 pp. London: HMSO. Price 87 1/2p.

INTERNATIONAL: EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANISATION. Report of the international conference on the protection of stored products, 1968 Lisbon 27 - 30 Nov. 1967. EPPO Publications, Ser. A, No. 46-E. Paris: EPPO, 1968, 171 pp. Price 1.65 [pound]. (EPPO, 1 rue le Notre, Paris).

INTERNATIONAL: EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION. Report of the working party on Stored Products of Tropical Origin (Hamburg, 1969 5 - 6 Nov. 1968). EPPO Publications, Ser. A, No. 51-E. Paris: EPPO, 1969, 38 pp + 7 tables. Price 50p. (EPPO, 1 rue le Notre, Paris).

INTERNATIONAL: EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANISATION. Report of the Working Party on Stored Products of Mediterranean Origin 1970 (Lisbon, 13 - 14 March, 1969). EPPO Publications, Ser. A, No. 56. Paris: EPPO, 1970, 85 + xxx pp. Price unknown. (EPPO, 1 rue le Notre, Paris).

JOUBERT, P.C. and DE BEER, P.R. 1968 The toxicity of contact insecticides to seed-infesting insects. Series No. 6. Tests with bromophos on maize. S. Afr. Dep. Agric., tech. Serv., tech. Commun. No. 84. Pretoria: Government Printer, 1968, 9 pp.

KAMEL, A.H. and SHAHBA, B.A. 1958 Protection of stored seeds in Egypt. Bull. Minist. Agric. Egypt, Ext. Dep., No. 295. Cairo: General Organization for Government Printing Offices, 1958, 16 pp.

LAHUE, D.W. Evaluation of several formulations of malathion as a protectant of grain 1969 sorghum against insects - in small bins. U.S. Dep. Agric., agric. Res. Serv., Mktg Res. Rep. No. 828, 1969, iv + 19 pp. Price 20 cts.

LAHUE, D.W. Evaluation of malathion, diazinon, a silica aerogel and a diatomaceous 1970 earth as protectants on wheat against lesser grain borer attack ... in small bins. U.S. Dep. Agric., agric. Res. Serv., Mktg Res. Rep. No. 860, 1970, iv + 12 pp.

LOCHNER, E.H.W. Safe storage of food grains in the Republic of South Africa. S. Afr. Dep 1963 Agric., tech. Serv., tech. Commun. No. 13. Pretoria: Government Printer, 1963, ii + 45 pp.

LOCHNER, E.H.W. Fumigation of maize in railway trucks in transit to the ports. (In Africaans 1964 with English Summary). S. Afr. Dep. Agric., tech. Serv., tech. Commun. No. 25. Pretoria: Government Printer, 1964, ii + 62 pp.

McFARLANE, J.A., MARTIN, H.G., DIXON, W.B. and MOLLISON, D.W. 1961 Prevention and control of infestation of stored grain by insect pests and rodents. Prepared jointly by the Storage and Infestation, Division (Mktg Dept, Minist. Trade and Ind.) and Plant Protection Division (Minist. Agric. and Lands). Kingston, Jamaica: Govt Printer, 1961, iii + 57 pp.

MONRO, H.A.U. Manual of fumigation for insect control. F.A.O. agric. Studies, No. 79. 1971 Rome: FAO, 1971, xii + 381 pp. Second edn, revised. Price 2.80 [pound].

ORDISH, G. (Gen. Ed). Pest control in groundnuts. PANS Manual No. 2. London: 1967 Minist. Overseas Dev, trop. Pestic. Res. H.Q. & Inf. Unit, 1967, iv + 138 pp. Price 45p. (56-62 Gray's Inn Rd, London, WC1 X 8 LU).

PREVETT, P.F. An investigation into storage problems of rice in Sierra Leone. Colonial 1959 Res. Studies, No.28. London: HMSO, 1959, 52 pp.

RANSOM, W.H. Buildings for the storage of crops in warm climates. Dep. sci. ind. Res. 1960 Trop. Building Studies, No. 2. London: HMSO, 1960, 24 pp. Price 22 1/2p.

SALMOND, K.F. Investigations into grain storage problems in Nyasaland with special 1957 reference to maize (*Zea mays* L.). Colonial Res. Publ. No. 21. London: HMSO, 1957, 49 pp. Price 22 1/2p.

SMITH, C.V. Meteorology and grain storage. Tech. Note U.N. Wld met. Org., No. 101 1969 (WMO No. 243 TP 133). Geneva: Secretariat of World Meteorological Organisation, 1969, xvi + 47 pp. Price 1.00 [pound].

STEELE, B. (Gen. Ed.). Pest control in rice. PANS Manual No. 3. London: Minist. 1970 Overseas Dev. trop. Pestic. Res. H.Q. & Inf. Unit, 1970, ii + 270 pp. Price 62 1/2p. (56-62 Gray's Inn Rd, London WC1X 8LU).

UNITED NATIONS: FOOD AND AGRICULTURE ORGANIZATION. 1968 Improved storage and its contribution to world food supplies. Chapter 4 in 'State of Food and agriculture, 1968', pp 115 - 143. Rome: FAO, 1968, 205 pp. Price \$5.75 or 2.30 [pound].

UNITED NATIONS: FOOD AND AGRICULTURE ORGANIZATION. 1969 Crop Storage. Technical Report No. 1 of the Food Research and Development Unit, Accra, Ghana. Prepared for the Government of Ghana by FAO acting as executing agency for the United Nations Development Programme, based on the work of J. Rawnsley. PL:SF/GHA 7. Rome: FAO, 1969, ix + 89 pp + 7 app.

[UNITED STATES: DEPARTMENT OF AGRICULTURE: AGRICULTURAL MARKETING SERVICE, BIOLOGICAL SCIENCES BRANCH, STORED PRODUCTS INSECTS SECTION. 1958 Stored grain pests. U.S. Dep. Agric. Fmrs Bull. No. 1260, 1958, rev., 46 pp. Price 25 cts.

WOGAN, G.N. (Ed.). Mycotoxins in foodstuffs. Proceedings of a symposium at Massachusetts 1965 Inst. Technol., March 1964. Cambridge, Mass: Mass. Inst. Technol. Press, 1965, xii + 291 pp. Price 3.75 [pound].

WORLD FOOD PROGRAMME. 1970 Food storage manual. (Prepared by the Tropical Stored Products Centre, Ministry of Overseas Development). Rome: FAO, 1970, 3 vols, 820 pp. Price \$18.

Advisory Leaflets

BOOTH, C, HOLLIDAY, P. and SUBRAMANIAN, C.V. 1969 C.M.I. descriptions of pathogenic fungi and bacteria. Set 22, sheets 211 - 220. Kew: Commonw. Mycol. Inst., 1969. Price 25p. (Commonw. Mycol. Inst., Ferry Lane, Kew, Surrey).

BRITISH STANDARDS INSTITUTION. 1967 Methods for sampling oilseeds. Br. Stand. No. 4146, 1967, 16 pp. Price 30p.

BRITISH STANDARDS INSTITUTION. 1968 Methods of test for cereals and pulses. Part 2. Determination of moisture content of cereals and cereal products (basic reference method). Br. Stand. No. 4317, Part 2, 1968, 12 pp. Price 25p.

BRITISH STANDARDS INSTITUTION. 1968 Methods of test for cereals and pulses. Part 4. Determination of impurities in pulses. Br. Stand. No. 4317, Part 4, 1968, 7 pp. Price 20p.

BRITISH STANDARDS INSTITUTION. 1969 Methods for sampling cereals (as grain). Br. Stand. No. 4510, 1969, 19 pp. Price 50p.

BRITISH STANDARDS INSTITUTION. 1969 Methods for sampling pulses. Br. Stand. No. 4511, 1969, 16 pp. Price 40p.

BRITISH STANDARDS INSTITUTION. 1969 Recommended common names for pesticides. Br. Stand. No. 1831, 1969, 4th rev., 107 pp. Price 2.00 [pound].

HARMOND, J.E., BRANDENBURG, N.R. and KLEIN, L.M. 1968 Mechanical seed cleaning and handling. U.S. Dep. Agric., agric. Res. Serv. (in conj. w. Oregon agric. Exp. Stn), agric. Handbk No. 354, 1968, 56 pp. Price 55 cts.

MINISTRY OF AGRICULTURE, FISHERIES and FOOD. 1966 Fumigation with the liquid fumigants carbon tetrachloride, ethylene dichloride and ethylene dibromide. Precautionary measures. London: HMSO, 1966, rev. edn, i + 8 pp. Price 7 1/2p.

MINISTRY OF AGRICULTURE, FISHERIES and FOOD. 1968 Heating of grain in store. Minist. Agric. Fish. Fd, Adv. Leaflet. No. 404, 1968, rev., 6 pp. Single copies free.

MINISTRY OF AGRICULTURE, FISHERIES and FOOD. 1968 Insect pests in food stores. Minist. Agric. Fish. Fd, Adv. Leaflet. No. 483, 1968, rev., 8 pp. Single copies free.

MINISTRY OF AGRICULTURE, FISHERIES and FOOD. 1969 Fumigation with ethylene oxide. Precautionary measures, 1969. London: HMSO, 1969, 8 pp. Price 9p.

UNITED STATES: DEPARTMENT OF AGRICULTURE: AGRICULTURAL RESEARCH SERVICE, AGRICULTURAL ENGINEERING RESEARCH DIVISION. 1969 Guide lines for mold control in high-moisture corn. U.S. Dep. Agric., Fmrs Bull. No. 2238, 1969, rev., 16 pp. Price 10 cts.

UNITED STATES: DEPARTMENT OF AGRICULTURE: AGRICULTURAL RESEARCH SERVICE, MARKET QUALITY RESEARCH DIVISION. 1969 Controlling insects in farm-stored grain. U.S. Dep. Agric., Leaflet. No. 553, 1969, 8 pp. Price 10 cts.

Scientific Papers

A full list of papers published by staff of the Tropical Stored Products Centre is available on request from the TSPC, (TPI), London Road, Slough SL3 7HL, Bucks).

AMARO, J.P. and CANCELA DA FONSECA, J.P. 1957 Panorama actual dos problemas fitossanitarios dos produtos armazenados em Africa. (Comprehensive survey of phytosanitary problems of stored products in Africa). Garcia de Orta, 5 (4), 675 - 699.

ASHMAN, F. The chemical control of stored food insect pests in Kenya. J. agric. vet. 1963 Chem., 4 (2), 44-48.

ASHMAN, F. An assessment of the value of dilute dust insecticides for the protection of 1966 stored maize in Kenya. J. appl. Ecol., 3(1), 169 - 179.

ASHMAN, F. Inspection methods for detecting insects in stored produce. Trop. stored 1966 Prod. inf., (12), 481 - 494.

ASHMAN, F., ELIAS, D.G., ELLISON, J.F. and SPRATLEY, R. 1969 An instrument for detecting insects within food grains. Milling, 151 (3), 32, 34 & 36.

ATTIA, R. and KAMEL, A. H. 1965 The fauna of stored products in U.A.R. Bull. Soc. ent. Egypte, 49, 221 - 232.

BAILEY, S.W. Airtight storage of grain, its effects on insect pests. II. *Calandra oryzae* 1956 (small strain). Aust. J. agric. Res., 7 (1), 7 - 19.

BAILEY, S.W. Airtight storage of grain, its effects on insect pests. II. *Calandra oryzae* 1957 (large strain). Aust. J. agric. Res., 8 (6), 595 - 603.

BAILEY, S. W. The effects of percussion on insect pests of grain. J. econ. Ent., 55 (3), 1962 301 - 305.

BAILEY, S. W. Airtight storage of grain - its effect on insect pests. IV. *Rhyzopertha* 1965 *dominica* (F.) and some other Coleoptera that infest stored grain. J. stored Prod. Res., 1 (1), 25 - 33.

BARNES, J. M. Pesticide residues as hazards. PANS, 15 (1), 2 - 8. 1969

BREESE, M.H. The infestibility of stored paddy by *Sitophilus sasakii* (Tak.) and 1960 *Rhyzopertha dominica* (F.). Bull. ent. Res., 51 (3), 599 - 630.

BREESE, M.H. Studies on the oviposition of *Rhyzopertha dominica* (F.) in rice and paddy. 1963 Bull. ent. Res., 53 (4), 621 - 637.

BURRELL, N.J. The chilled storage of grain. Ceres, (5), 15-20. 1969

CABRAL, A.L. and MOREIRA, I.S. 1960 Da ocorrência de algumas pragas de produtos ultramarinos en poroes de navios mercantes (Carreira da Guini). (Occurrence and distribution of some pests of stored products in ships' holds of cargo ships of the Guinea Line). Garcia de Orta, 8 (1), 47-57.

CASWELL, G.H. The infestation of cowpeas in the Western Region of Nigeria. Trop. Sci., 3 1961 (4), 154 - 158.

CASWELL, G.H. and CLIFFORD, H. T. 1960 Effect of moisture content on germination and growth of fumigated maize grain. Emp. J. exp. Agric., 28, 139 - 149.

CHRISTENSEN, C.M. and KAUFMANN, H.H. 1965 Deterioration of stored grains by fungi. A. Rev. Phytopath., 3, 69 - 84.

CHRISTENSEN, C.M. and LOPEZ, L.C. 1963 Pathology of stored seeds. Proc. int. Seed Test. Ass., 28, 701 - 711.

CLARKE, J.H. Fungi in stored products. Trop. stored Prod. Inf., (15), 3 - 14. 1968

COAKER, T.H. 'Insack' treatment of maize with insecticide for protection against storage 1959 pests in Uganda. E. Afr. agric. J., 24 (4), 244 - 250.

COLLINGS, H. Hermetic sealing of a stack of maize with bituminous roofing felt. 1960 Trop. Agric., Trin., 37 (1), 53 - 60.

COURSEY, D.G. Yam storage. I : a review of yam storage practices and of information on 1967 storage losses. J. stored Prod. Res., 2 (3), 229 - 244.

COVENEY, R.D. Sacks for the storage of food grains. Trop. stored Prod Inf., (17), 3-22. 1969

CRANHAM, J.E. Insect infestation of stored raw cocoa in Ghana. Bull. ent. Res., 51 (1), 1960 203 - 222.

DAVEY, P.M. and ELCOATE, S. 1967 Moisture content/relative humidity equilibria of tropical stored produce. Part 3. Legumes, spices and beverages. *Trop. stored Prod. Inf.*, (13), 15 - 34.

DAVIES, J.C. Aluminium phosphide for bulk grain fumigation in Uganda. *E. Afr. agric. J.*, 24 (2), 103 - 105.

DAVIES, J.C. A note on the control of bean pests in Uganda. *E. Afr. agric. J.*, 24 (3), 1959 174 - 178.

DAVIES, J.C. Coleoptera associated with stored products in Uganda. *E. Afr. agric. J.*, 25 1960 (3), 199 - 201.

DAVIES, J.C. Storage of maize in a prefabricated aluminium silo in tropical conditions. 1960 *E. Afr. agric. J.*, 25 (4), 225 - 228.

DAVIES, J.C. Experiments on the crib storage of maize in Uganda. *E. Afr. agric. J.*, 26 1960 (1), 71 - 75.

DEXTER, S.T., CHAVES, A.M. and EDJE, O.T. 1969 Drying or anaerobically preserving small lots of grain for seed or food. *Agron. J.*, 61 (6), 913 - 919.

ELDER, W.B. CSIRO develops aeration system for farm-stored grain. *Pwr Fmg Bett. Fmg* 1969 *Dig.*, 78 (10), 10 - 13.

FULLERTON, R.L. Low-cost farm buildings for storage and equipment housing in Ghana. 1968 *Ghana J. agric. Sci.*, 1 (2), 165 - 170.

GILES, P.H. The storage of cereals by farmers in Northern Nigeria. *Trop. Agric., Trin.*, 1964 41 (3), 197 - 212.

GILES, P.H. Control of insects infesting stored sorghum in Northern Nigeria. *J. stored* 1965 *Prod. Res.*, 1 (2), 145 - 158.

GILES, P.H. Maize storage: the problem of today. *Trop. stored Prod. Inf.*, (14), 9 - 19. 1967

GILES, P.H. Observations in Kenya on the flight activity of stored products insects, 1969 particularly *Sitophilus zeamais* Motsch. *J. stored Prod. Res.*, 4 (2); 317 - 329.

GOLUMBIC, C. and DAVIS, D.F. 1966 Radiation disinfestation of grain and seeds. *Proc. Symp. Food Irradiation*, Karlsruhe, 1966, pp 473 - 488. Vienna : Int. Atomic Energy Agency.

GONEN, M. and CALDERON, M. 1968 Changes in the microfloral composition of moist sorghum stored under hermetic conditions. *Trop. Sci.*, 10 (2), 107 - 114.

GRAHAM, W.M. Warehouse ecology studies of bagged maize in Kenya. I. The distribution 1970 of adult *Ephestia* (*Cadra*) *cautella* (Walker) (Lepidoptera, Phycitidae). II. Ecological observations of an infestation by *E. cautella*. III. Distribution of the immature stages of *E. cautella*. IV. Reinfestation following fumigation with methyl bromide gas. *J. stored Prod. Res.*, 6 (2): I, 147 - 155; II, 157 - 167; III, 169 - 175; IV, 177 - 180.

GREEN, A.A. The protection of dried sea-fish in South Arabia from infestation by 1967 *Dermestes frischii* Kug. (Coleoptera, Dermestidae). *J. stored Prod. Res.*, 2 (4), 331 - 350.

HALL, D.W. Prevention of waste of agricultural produce during handling, storage and 1968 transportation. *Trop. stored Prod. Inf.*, (1 5), 15 - 23.

HALL, D.W. Food storage in the developing countries. *J. R. Soc. Arts*, 117 (5156), 1969 562 - 579.

HALLIDAY, D. Build-up of free fatty acid in Northern Nigerian groundnuts. *Trop. Sci.*, 9 1967 (4), 211 - 237.

HAYWARD, L.A.W. Infestation control in stored groundnuts in Northern Nigeria. *Wld Crops*, 1963 15 (2), 63 - 67.

HOWE, R.W. Entomological problems of food storage in Northern Nigeria. *Bull. ent. 1952 Res.*, 43 (1), 111 - 144.

HOWE, R.W. A summary of estimates of optimal and minimal conditions for population 1965 increase of some stored products insects. *J. stored Prod. Res.*, 1 (2), 177 - 184.

HOWE, R.W. Losses caused by insects and mites in stored foods and feeding stuffs. *Nutr. 1965 Abstr. Rev.*, 35, 285 - 293.

HOWE, R.W. and CURRIE, J.E. 1964 Some laboratory observations on the rates of development, mortality and oviposition of several Bruchidae breeding in stored pulses. *Bull. ent. Res.*, 55 (3), 437 - 477.

HYDE, M.B. Hazards of storing high-moisture grain in airtight silos in tropical countries. 1969 *Trop. stored Prod. Inf.*, (18), 9 - 12.

JOFFE, A. Moisture migration in horizontally stored bulk maize: influence of grain-infesting 1958 insects under South African conditions. *S. Afr. J. agric. Sci.*, 1 (2), 175 - 193.

JOFFE, A. The effect of physical disturbance or 'turning' of stored maize on the 1963 development of insect infestation. I. Grain elevator studies. *S. Afr. J. agric. Sci.*, 6, 55 - 64.

KAPUR, N.S. and SRIVASTAVA, H.C. 1959 Storage and preservation of fatty foods. *Food Sci., Mysore*, 8, 257 - 262.

KHALIFA, A. On open-air and underground storage in the Sudan. *Bull. Soc. ent. Egypte*, 1960 53 (44), 129 - 142.

KHALIFA, A. The relative susceptibility of some varieties of sorghum to *Trogoderma* 1962 attack. *Emp. J. exp. Agric.*, 30 (118), 133 - 136.

KOCKUM, S. Protection of cob maize stored in cribs. *E. Afr. agric. J.*, 19 (2), 69 - 173. 1953

KOCKUM, S. Control of insects attacking maize on the cob in crib stores. *E. Afr. agric. 1958 J.*, 23 (4), 275 - 279.

LE PELLE, R.H. and KOCKUM, S. 1954 Experiments in the use of insecticides for the protection of grains in storage. *Bull. ent. Res.*, 45 (2), 295 - 311.

McFARLANE, J.A. An annotated record of Coleoptera, Lepidoptera, Hemiptera and Hymenoptera 1963 associated with stored produce in Jamaica. *Trop. Agric., Trin.*, 40 (3), 211-216

McFARLANE, J.A. The productivity and rate of development of *Sitophilus oryzae* (L.) (Coleoptera, 1968 Curculionidae) in various parts of Kenya. *J. stored Prod. Res.*, 4 (1), 31 - 51.

McFARLANE, J.A. Stored products insect control in Kenya. *Trop. stored Prod. Inf.*, (18), 13 - 23 1969

McFARLANE, J.A. Treatment of large grain stores in Kenya with dichlorvos slow-release strips 1970 for the control of *Cadra cautella*. *J. econ. Ent.*, 63 (1), 288 - 292.

MACKAY, P.J. Theory of moisture in stored produce. *Trop. stored Prod. Inf.*, (13), 9 - 14. 1967

MAJUMDER, S.K. and BANO, A. 1964 Toxicity of calcium phosphate to some pests of stored grain. *Nature, Lond.*, 202 (4939), 1359 - 1360.

MAJUMDER, S. K., KRISHNAMURTHY, K. and GODAVARIBA, S. 1961 Pre-harvest prophylaxis for infestation control in stored food grains. *Nature, Lond.*, 192 (4800), 375 - 376.

MAJUMDER, S. K., NARASIMHAN, K.S. and SUBRAHMANYAN, V. 1959 Insecticidal effects of activated charcoal and clays. *Nature, Lond.*, 184 (4693), 1165 - 1166.

MAJUMDER, S.K. and NATARAJAN, C.P. 1963 Some aspects of the problem of bulk storage of foodgrains in India. *Wld Rev. Pest Control*, 2 (2), 25 - 35.

MISHRA, A. B., SHARMA, S.M. and SINGH, S.P. 1969 Fungi associated with *Sorghum vulgare* under different storage conditions in India. *PANS*, 15 (3), 365 - 367.

PAGE, A.B.P. and LUBATTI, O.F. 1963 Fumigation of insects. *A. Rev. Ent.*, 8, 239 - 264.

PARKIN, E.A. The protection of stored seeds from insects and rodents. *Proc. Int. Seed 1963 Test. Ass.*, 28 (4), 893 - 909.

PARKIN, E.A. The onset of insecticide resistance among field populations of stored product 1965 insects. *J. stored Prod. Res.*, 1 (1) 3 - 8.

PINGALE, S.V., KADKOL, S.B., RAO, M.N., SWAMINATHAN, M. and SUBRAHMANYAN, V. 1957 Effect of insect infestation on stored grain: II. Studies on husked, hand-pounded, milled raw rice and parboiled milled rice. *J. Sci. Fd Agric.*, 8 (9), 512 - 516.

PINGALE, S.V., RAO, M.N. and SWAMINATHAN, M. 1954 Effect of insect infestation on stored wheat. I. Studies on soft wheat. *J. Sci. Fd Agric.*, 5 (1), 51 - 54.

PIXTON, S.W. Moisture content - its significance and measurement in stored products. 1967 *J. stored Prod. Res.*, 3 (1), 35 - 47.

PIXTON, S.W. A possible rapid method of determining the moisture content of high-moisture 1970 grain. *J. Sci. Fd Agric.*, 21 (9), 465 - 467.

POINTEL, J-G. Contribution a la conservation du niebi, du vouandzou, du mais, des 1968 arachides et du sorgho. (Contribution to the preservation of cowpeas, *Voandzeia subterranea* (Bambarra groundnut), maize, groundnuts and sorghum). *Agron. trop.*, Nogent, 23 (9), 982 - 986. POINTEL, J-G. Essai et enquete sur greniers a mais togolais. (A trial and survey on 1969 Togolese maize granaries). *Agron. trop.*, Nogent, 24 (8), 709 - 718.

- PRADHAN, S., MOOKHERJEE, P.B. and SHARMA, G.C. 1965 Pusa bin for grain storage. *Indian Fmg*, 15 (1), 14 - 16.
- PREVETT, P.F. A study of rice storage under tropical conditions. *J. agric. Engng Res.*, 4 1959 (3), 243 - 254.
- PREVETT, P.F. The distribution of insects in stacks of bagged groundnuts in Northern 1964 Nigeria. *Bull. ent. Res.*, 54 (4), 689 - 713.
- QURESHI, Z.A., WILBUR, D.A. and MILLS, R.B. 1970 Irradiation of early instars of the Angoumois Grain Moth. *J. econ. Ent.*, 63 (4), 1241 - 1247.
- RHYNEHART, T. The control of insects infesting groundnuts after harvest in the Gambia: 1960 IV. The practical application of control measures. *Trop. Sci.*, 2 (3), 134 - 139.
- ROBERTSON, J. V. Trials with small capacity grain silos in Dar es Salaam, Tanzania. *E. Afr. 1968 agric. for J.*, 34 (2), 263 - 276.
- ROWLANDS, D.G. The metabolism of contact insecticides in stored grains. *Residue Rev.*, 17, 1967 105 - 177.
- SARID, J.N. and KRISHNAMURTHY, K. 1965 Storage structures for large scale handling and preservation of food grain. *Bull. Grain Tech.*, 3 (2), 62 - 69.
- SARID, J.N. and KRISHNAMURTHY, K. 1968 Protection of marketable grain. *Bull. Grain Tech.*, 6 (1), 16 - 20.
- SARID, J.N., RAI, L., KRISHNAMURTHY, K. and PINGALE, S.V. 1965 Studies on the large scale storage of food grains in India. Part II. Studies on the relative suitability of cement concrete and aluminium bins for storing wheat. *Bull. Grain Tech.*, 3 (4), 135 - 141.
- SARID, J.N., RAI, L. and PINGALE, S.V. 1967 Studies on the large scale storage of food grains in India. Part III. Studies on the insect and temperature fluctuations in bag storage of wheat. *Bull. Grain Tech.*, 5 (1), 3 - 11.
- SODERSTROM, E.L. Effectiveness of green electroluminescent lamps for attracting stored-product 1970 insects. *J. econ. Ent.*, 63 (3), 726 - 731.
- SOUTHGATE, B.J. Plastics films for the bulk storage of food. *Plast. Inst. Trans. & J.*, 33 1965 (103), 11 - 15.
- STRONG, R.G. and LINDGREN, D.L. 1960 Germination of cereal, sorghum and small legume seeds after fumigation with hydrogen phosphide. *J. econ. Ent.*, 53 (1), 1 - 4.
- STRONG, R.G. and LINDGREN, D.L. 1961 Effect of methyl bromide and hydrocyanic acid fumigation on the germination of corn seed. *J. econ. Ent.*, 54 (8), 764 - 770.
- SWAINE, G. Trials on the underground storage of maize of high moisture content in 1957 Tanganyika. *Bull. ent. Res.*, 48 (2), 397 - 406.
- VENKAT RAO, S., NUGGEHALI, R.N., PINGALE, S.V., SWAMINATHAN, M. and SUBRAHMANYAN, V. 1960 Effect of insect infestation on stored field bean (*Dolichos lablab*) and black gram (*Phaseolus mungo*). *Fd Sci., Mysore*, 9, 79 - 82.

VENKAT RAO, S., NUGGEHALLI, R.N., SWAMINATHAN, M., PINGALE, S.V. and SUBRAHMANYAN, V. 1958 Effect of insect infestation on stored grain: III. Studies on Kaffir corn (*Sorghum vulgare*). J. Sci. Fd Agric., 9 (12), 837 - 839.

WATTERS, F.L. Effects of grain moisture content on residual toxicity and repellency of 1959 malathion. J. econ. Ent., 52 (1), 131 - 134.

WATTERS, F.L. Physical methods of insect control. Proc. Ent. Soc. Manitoba, 21, 1965 18 - 27.

WATTERS, F.L. An appraisal of gamma irradiation for insect control in cereal foods. 1968 Manitoba Ent., 2, 37-45.

WILKIN, D.R. and GREEN, A.A. 1970 Polythene sacks for the control of insects in grain. J. stored Prod. Res., 6 (1), 97 - 101.

WRIGHT, F.N. New storage, transportation and handling techniques for tropical agricultural 1965 produce. Congr. Prot. Cult. trop., Marseilles, 1965, pp 93 - 98. Marseilles: Chambre de Commerce et d'Industrie.

WRIGHT, F.N. and SOUTHGATE, B.J. 1962 The potential uses of plastics for storage with particular reference to rural Africa. Trop. Sci., 4 (2), 74 - 81.

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, use either the tables in Figure 2 or the equations.

The chart in Figure 3 has metric divisions of one centimeter to three meters, and English units in inches and feet to ten feet. It is accurate to about plus or minus one centimeter.

Example:

An example will explain how to use the tables. Suppose you wish to find 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.

Equations:

1 inch = 2.54cm 1 foot = 30.48cm = 0.3048m 1 yard = 91.44cm = 0.9144m 1 mile = 1.607km = 5280 feet 1cm = 0.3937 inches 1m = 39.37 inches = 3.28 feet 1km = 0.62137 miles = 1000 meters

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 93.82 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 105>

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
 106.82 108.03 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 80 176.37 178.58 180.78 182.98 185.19 197.39 189.60 191.80
 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 21.319 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 = $5/9 \times \text{Degrees Fahrenheit} - 32$

Degrees Fahrenheit = $1.8 \times (\text{Degrees Celsius}) + 32$

Example:

This example may help to clarify the use of the equations; 72F equals how many degrees Celsius?

$72F = 5/9 (\text{Degrees F} - 32)$

$72F = 5/9 (72 - 32)$

$72F = 5/9 (40)$

$72F = 22.2C$

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