PB-219 721

DEVELOPMENT OF A SIMPLE STORAGE UNIT AND STORAGE METHOD APPLICABLE FOR HUMID AREAS IN DEVELOPING COUNTRIES

Do Sup Chung

Kansas State University

Prepared for:

Agency for International Development

30 June 1972

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

PB 219 721

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

BIBLIOGRAPHIC DATA SHEET	1. Report No. 631.23-C559	2.	3. Recipient's Accession No. PB-219 721

4. Title and Subtitle
"Progress Report on Development of a Simple Storage Unit and Storage Method Applicable for Humid Areas in Developing Countries"

5. Report Date
June 1972

6.

7. Author(s)
Do Sup Chung

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Food and Feed Grain Institute
Kansas State Univ~~ersity~~
~~Manhattan, Kansas 66506~~

10. Project/Task/Work Unit No.
Proj. 931-11-150-786

11. Contract/Grant No.
AID-csd-1588

12. Sponsoring Organization Name and Address
Department of State
Agency for International Development
Washington, D.C. 20523

13. Type of Report & Period Covered
Progress Report

14.

15. Supplementary Notes

16. Abstracts
The development of a simple, inexpensive grain storage unit and storage method which can be used at farm and local levels in humid areas in order to preserve the quality of grain is discussed. Grain marketing problems in developing countries is dependent primarily upon their harvesting, storage, and handling methods. Losses ~~are~~ the result of inadequate facilities and improper handling of food grains. Efforts are devoted to the development of a unit and method of storage that would not require electricity, and ~~also~~ could be easily maintained and operated by unskilled labor. It is proposed that an adsorbant be placed into a grain storage mass to create a drier condition, thus maintaining grain quality. Materials, methods, time and partial results are discussed. The grain used in this preliminary report was corn. Results indicated that corn can be stored, without noticeable deterioration, at fifteen and twelve percent moisture at extremely adverse storage conditions by using a silica-gel adsorbant. A tentative plan for further research in this area is given, including a discussion of cheaper drying agents to substitute for the alumina-gel adsorbant, possibly salt and $CaSO_4$.

17. Key Words and Document Analysis

17b. Identifiers/Open-Ended Terms
(*Grain, Storage), *Silos, * Crops and climate

17c. COSATI Field/Group 631

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages ~~19~~ 24
	20. Security Class (This Page) UNCLASSIFIED	22. Price $3.25

FORM NTIS-35 (REV. 3-72) USCOMM-DC 14952-P72

THE PROGRESS REPORT

on

"Development of a Simple Storage Unit and Storage Method applicable for Humid Areas in Development Countries"

by Do Sup Chung
Food and Feed Grain Institute
Kansas State University
June 30, 1972

Prepared for the

AGENCY FOR INTERNATIONAL DEVELOPMENT

AID/csd-1588
Technical Assistance in
Food Grain Drying, Storage, Handling and Transportation

at the
FOOD AND FEED GRAIN INSTITUTE
Kansas State University
Manhattan, Kansas 66506

Dr. William J. Hoover, Director
Dr. Leonard W. Schruben, Associate Director
Dr. Richard Phillips, Agricultural Economist
Dr. Harry B. Pfost, Agricultural Engineer
Do Sup Chung, Agricultural Engineer
John R. Pedersen, Entomologist

TABLE OF CONTENTS

Page

Introduction..... 1
Materials and Methods..... 3
Results and Discussion..... 6

Figures
Figure 1. Schematic diagram of climatic control apparatus.... 4
Figure 2. Moisture Content vs. Days in Storage for 20% Corn Samples at Various Conditions..... 7
Figure 3. Moisture Content vs. Days in Storage for 15.5% Corn Samples at Various Conditions.....10
Figure 4. Moisture Content vs. Days in Storage for 12.0% Corn Samples at Various Conditions.....12
Figure 5. Temperature of Corn vs. Days in Storage.....13

Appendix
Tentative Plan of Research Project

Plan of Work.....15
Facility, Equipment and Personnel.....17
Anticipated Schedule for Conducting the Project.....17
Table 1. Experimental Factors and Conditions to be Tested....18
Figure 1. Internal Structures of Grain Storage Unit.....19

THE PROGRESS REPORT

on

"Development of a Simple Storage Unit and Storage Method Applicable for Humid Areas in Developing Countries"

by Do Sup Chung
The Food and Feed Grain Institute
Kansas State University

Introduction

The broad objective of the project is to develop a simple and inexpensive grain storage unit and storage method which can effectively be used at farm and local levels in humid areas of developing countries in order to preserve the quality of grain.

The grain losses associated with harvesting, handling, and storing of food grains in developing countries are very serious problems. It is estimated that more than 40 percent of all food grains harvested is lost before consumption in some parts of the world, especially in warm, humid areas. These losses are due primarily to the lack of adequate facilities and improper ways of handling, drying and storing food grains.

Although it is recognized that the solution of over-all grain marketing problems in developing countries is largely dependent upon how well the storage, handling, and drying problems at farm and local levels are treated, very little attention was given to these problems. In developed countries such as the United States, Canada, and England, grain storage, handling, and drying problems have been well studied. But a certain technology developed cannot readily be adopted in developing countries, especially at farm and local levels, because of climatic and economic reasons. In addition, due to the lack of competent personnel and availability of utilities around farm and local levels for operating advanced grain storage, handling, and drying systems, it is impractical to introduce such systems at these levels.

The grain dried to a safe storage condition very often regains the moisture in humid areas, so the grain must be recycled through a dryer or other drying facility for further storage. Besides the added costs due to such a grain recycling process, some loss in grain quantity and quality are also expected at each recycling process. At the present time, no effective and economical means of maintaining the grain quality during storage that can be applicable to farm and local levels at humid conditions are available.

Therefore, our effort will be devoted to developing a simple and inexpensive storage unit and method that would not require electricity and fuel. Also, the storage unit and method to be developed should be easily maintained and operated by unskilled persons. The approach proposed in this project is to place an adsorbent (drying agent) into a grain mass for the purpose of creating a drier air condition within a storage unit such that the grain quality can be maintained.

In this report, an overview concerning the time spent on the project to date is given; and also given are materials, methods, and partial results of experiments. In addition, as a reference, the tentative plan of research prepared at the begining of this project is appended.

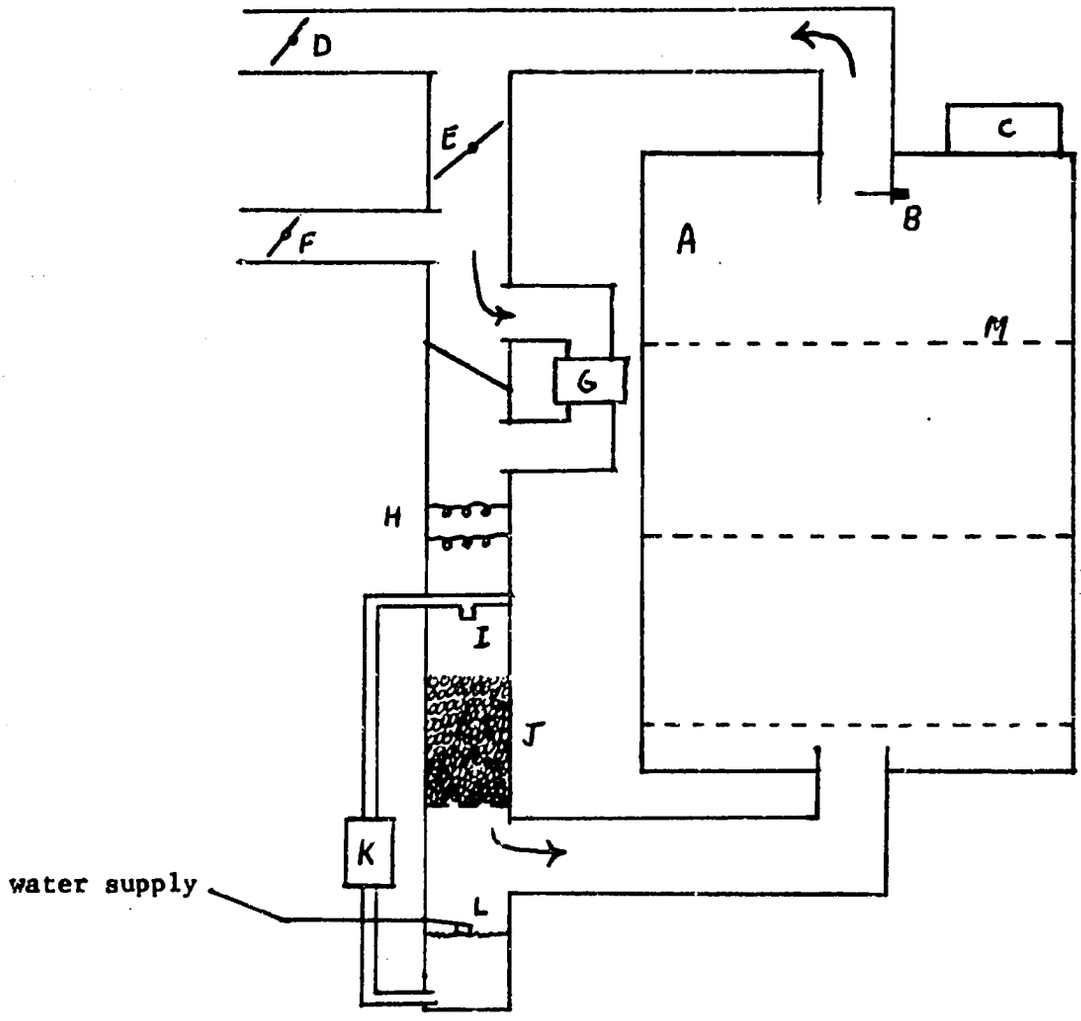
The initial planning stage of the project began at the beginning of January, 1972. Prior to that time, reviews of literature were made; and also during the months of January and February, much of our time went into a review of the literature dealing with grain storage. A considerable amount of time was devoted to actually thinking about the research and deciding how things should be done and exactly what needed to be done. During that time, the tentative plan of research was prepared.

From the first of March till our first test sample was placed in storage on June 20, 1972, we devoted most of our effort to setting up the experiment. The research equipment had to be cleaned, and some parts had to be repaired or replaced. Some materials needed for experiments were ordered. Several weeks were needed to just familiarize ourselves with the research equipment and controls. Much of this time was devoted to stabilizing the environmental conditions within test chambers to those we desired for the experiments.

Materials and Methods

Grain tested in this project was shelled yellow corn at about 20%, 15%, and 12% moisture contents (wet basis). Adsorbents (dessicants or drying agents) being tested were lime, silica-gel, and salt. Small metal cans 7½ inches in diameter and 7½ inches deep, which hold about 10 lbs. of corn, are being used as storage containers. For positioning and placing a dessicant in a storage container, a small screen cylinder, approximately 5/8 inch in diamter was placed at the center of a container, welded on the bottom of a container. Also, some containers had three screen cylinders which were uniformly positioned in the containers. Before a corn sample was poured into a container, the dessicant was placed in a small nylon cloth sack which was put into a screen cylinder; thus a small nylon cloth sack which contained a dessicant could readily be removed for weighing and re-drying.

The containers with corn and adsorbent were placed in the climatic control chamber which was set to a desired environmental condition for storage test. Figure 1 shows a schematic diagram of the climate control appartus used for simulating various environmental conditions.



A. Controlled Chamber
B. L7038A Honeywell Thermistor
C. R7187D1019 Honeywell Controller
D. Outlet Control Valve
E. Return Control Valve
F. Inlet Control Valve
G. Air Fan
H. 1000 Watt Resistance Heater
I. Sprinkler Nozzle
J. Rock Column
K. Water Pump
L. Float to Control Water Level
M. Shelves for Cans

Figure 1. Schematic diagram of climatic control apparatus.

The controlled chamber, A, in Figure 1 is made from an old refrigerator. The outlet valve, D, controls the flow of air to the atmosphere, while the inlet valve, F, controls the flow of air into the system from a refrigerated chamber. This control is mainly for controlling temperature below atmospheric conditions. For this experiment, both D and F were closed while E was completely open to permit free air flow through the system. We felt this would give us better humidity control (i.e. circulating the same air). The air fan, G, forces the air through the system. The air is heated by the use of a 1000-watt resistance heater controlled by the R7187D1019 Honeywell Controller, C, and the L703BA Honeywell Thermistor, B. This maintains the air temperature at the desired level.

After passing the heater, the air is forced through a rock column being sprayed with an antifreeze-water solution. This is the method used to control the relative humidity. The more antifreeze added, the lower the relative humidity. Once the ratio of anti-freeze and water for a desired relative humidity is set, it is kept constant by the float mechanism in the bottom of the duct. After passing through the rocks, the moist air is circulated up through the controlled chamber and then back through the cycle. The Honeywell units continuously control the air temperature.

Environmental conditions set up for storage tests were 80-90% R.H. (relative humidity) at 90-95°F. air temperature and 90-100% R.H. at 90-95°F. The conditions of storage containers with respect to environmental conditions examined were: a) lid tightly closed (no air in and out), b) the lid loosely placed (considerable air in), and c) the lid tightly closed but few small holes in the side of container (some air in).

The data which were recorded for each sample included the weight of the storage unit (corn included) with the adsorbent sack removed, the

weight of the adsorbent, and the temperature of corn. The data were recorded twice daily for each sample (12 hour intervals).

When the dessicant was almost to the point of saturation, it was dried for approximately an hour at 95-100°C by a laboratory oven. After drying, the dessicant was cooled and then placed back in the storage container. During the time of dessicant drying, the container was placed in the climate control chamber.

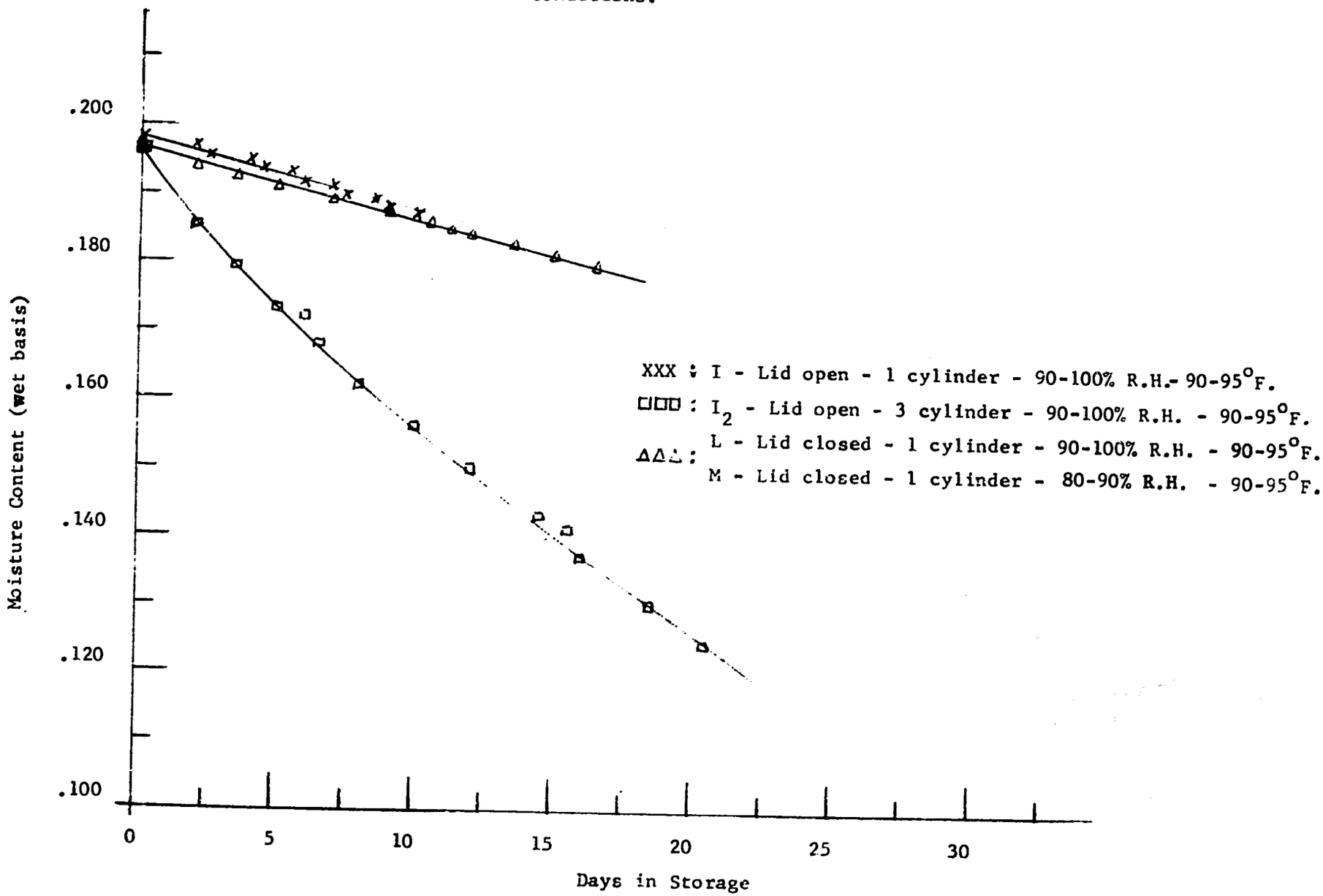
Results and Discussion

The first series of experiments was conducted with corn samples at about 20%, 15% and 12% moisture (wet basis) using regular feeding lime as the dessicant, placed in 80-90% R.H. and 90-100% R.H. at 90-95°F in the chamber. After several weeks of storage, it was determined that the lime used just did not have enough adsorptive capacity to be effective for our expressed purpose of grain storage in very humid conditions.

The second series of experiments was also studied with corn at 20%, 15%, and 12% moisture (wet basis) using silica-gel (6-16 mesh) as the dessicant. We are testing two different climatic conditions with several conditions as stated in the previous section. The climatic conditions tested were 80-90% R.H. and 90-100% R.H. at 90-95°F. Some experimental results are shown in Figures 2 to 4. The changes in moisture contents of corn with respect to storage time are shown in Figure 2, for 20% initial moisture corn, in Figure 3 for 15% initial moisture corn, and in Figure 4 for 12% initial moisture corn at 80-90% R.H. and 90-100% R.H. at 90-95°F. with several conditions of containers.

Sample I in Figure 2 was the case for silica-gel placed in a single cylinder down the center of the corn with the lid loosely open to the

Figure 2. Moisture Content vs. Days in Storage for 20% Corn Samples at Various Conditions.



90-100% R.H. and 90-95°F of air in the chamber. The initial weight ratio of grain to dessicant was 153 to 1. The first sign of mold on corn was detected on three days after storage. Since the mold increased rapidly, the corn sample was removed from storage ten days after introducing it to the system. As the container was emptied, it was discovered that the corn sample was moldy throughout.

Sample L (20% moisture) had one cylinder with the lid closed. It was placed in a 90-100% R.H. chamber. The grain to dessicant ratio was 173 to 1. In this sample the mold was noticed after 3½ days in storage. When we took it out after 17 days in storage, it also was moldy throughout. The saturation moisture of the dessicant in Sample L was 23.7% (wet basis), and the drying of dessicant was required every day and a half. Sample M, which was 20% initial moisture, was placed in 80-90% R.H. chamber (a single cylinder). It also showed mold formation on the third day. The result of Sample M with the ratio being 177 to 1 and the saturation 23.6% was almost the same as Sample L.

Sample I_2 with 20% initial moisture had three cylinders with the lid loosely open. The grain to dessicant ratio was 52 to 1. The dessicant was dried every day and a half for the first ten days; but after that, the drying of dessicant took place every two days. It was observed that the dessicant reached about 90% of its adsorptive capacity in the first half day. Its saturation point was about 23%. The visible mold spots were noticed after 4½ days in storage, but the mold did not seem to increase appreciably.

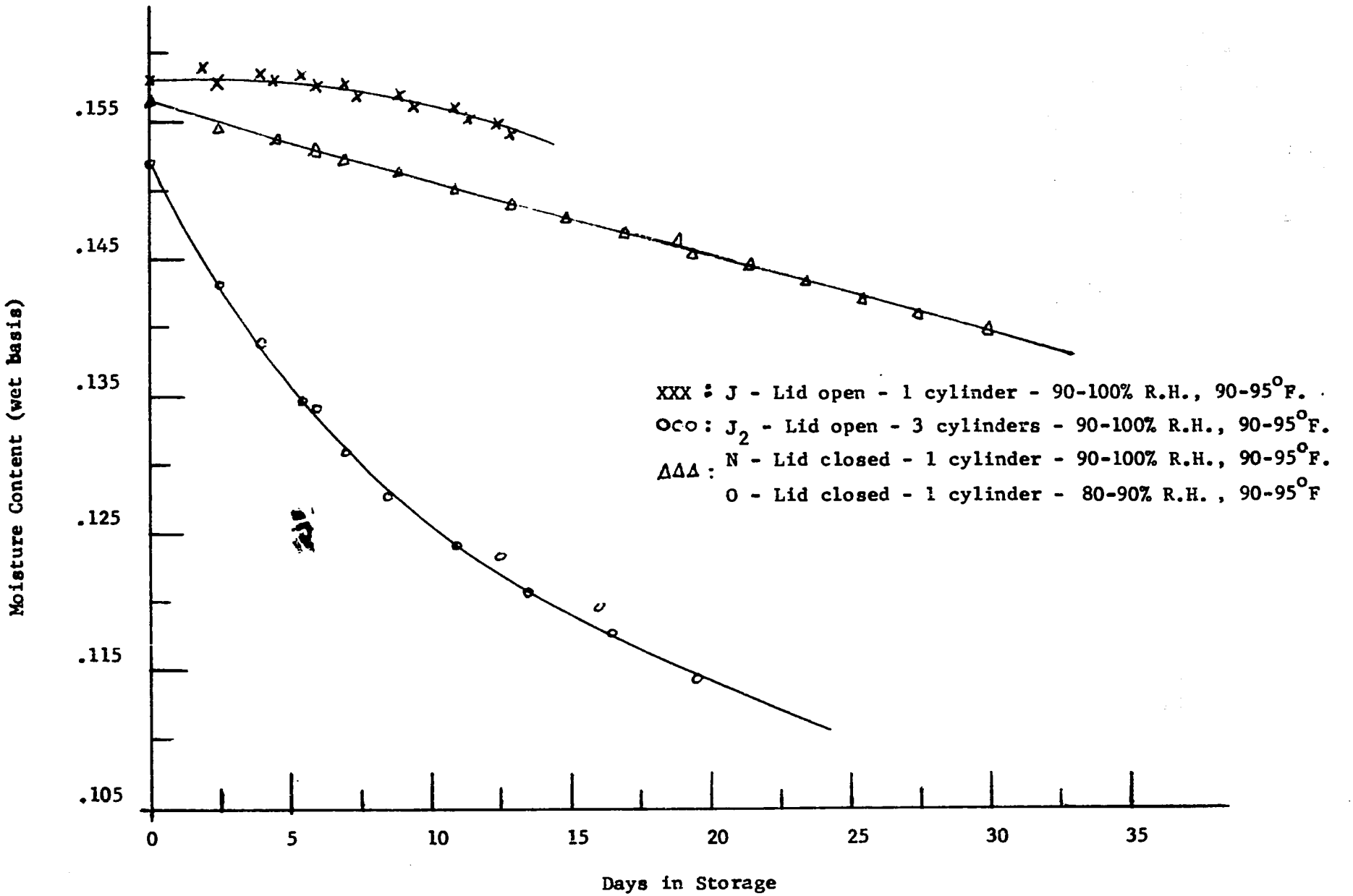
The rate of desorption of water from corn was considerably increased by increasing the amount of dessicant. Within 20 days storage, corn at initially 20% moisture reached about 12.5% moisture.

The corn samples initially at 15% moisture were stored at the same conditions as those at 20% moisture (Figure 3). Sample J was a single cylinder sample with the lid open. The grain to dessicant ratio was 160 to 1 by weight and the saturation point for the dessicant was 22.7%. The dessicant in this case acquired almost 80% of its adsorptive capacity the first half day after storage and required drying after a day and a half or two days. Mold was noticeable after 6 days in storage. When the sample was emptied after 13 days in storage, mold was present, but not really in large quantities. The corn seemed to be of good quality at the bottom of the can.

The second in this series was J_2 with 3 cylinders and the lid open. Its grain to adsorbent ratio was 53 to 1 and the saturation point for the dessicant was 23.4%. In this sample, the dessicant accumulated 70-80% of its adsorptive capacity the first half day. Mold was never visible in this sample. Drying the dessicant was needed every 2 to 3 days. A considerable decrease of moisture in Sample J_2 was observed (15% moisture to 12.5% moisture within 10 days storage).

Samples N and O are the two samples with lids closed and one cylinder. They have ratios of 179 and 212 respectively. Sample N (stored in 90-100% R.H. showed some mold formation after 14 days in storage, but the growth was very slow. After 30 days in storage, the corn still appears to be in good condition. Sample O has never really showed any mold formation after storing the same amount of time as Sample N. Generally, the drying of the dessicant was needed every 2 to 3 days and the dessicant acquired 65-75% of its adsorptive capacity the first half day for these two samples.

Figure 3. Moisture Content vs. Days in Storage for 15.5% Corn Samples at Various Conditions.



In the experiments with 12% initial moisture corn (Figure 4), Samples P and Q had the grain to dessicant ratios of 182 to 1 and 183 to 1 respectively. Both of these samples had a single cylinder and the lid closed. Sample P was stored in 90-100% R.H. chamber while Q was in 80-90% R.H. Saturation points for Samples P and Q appeared to be 24.2% and 20.9% respectively. Drying of the dessicant as needed for these samples every 2½ to 3 days. Neither sample showed mold at any time during the storage period (30 days).

Sample R with 12% moisture placed in 90-100% R.H. chamber had a single cylinder with the lid loosely open and holes in the side. Its grain to dessicant ratio was 186 to 1, and saturation occurred at 21.4% moisture (wet basis). Drying of dessicant was required every 2½ to 3 days. After 31 days in storage, no mold was visible. About 60-70% of the dessicant adsorptive capacity was used up during the first day and a half for Sample R

Sample S with 12% moisture placed in 90-100% R.H. chamber had a single cylinder with the container having holes in side but the lid closed. Its grain to dessicant ratio was 196 to 1, and the dessicant saturation was about 21% mositure. The dessicant in this sample needed drying every 2½ to 3 days also. About 50-60% of its adsorptive capacity was acquired the first day and a half of storage. No mold was ever visible in this sample.

In general, the temperature of corn at 2 inches from the wall of the container reached the air temperature in a chamber within 24 hours storage and stayed fairly constant throughout storage period except samples that developed mold (see Figure 5).

Figure 4. Moisture Content vs. Days in Storage for 12.0% Corn Samples at Various Conditions.

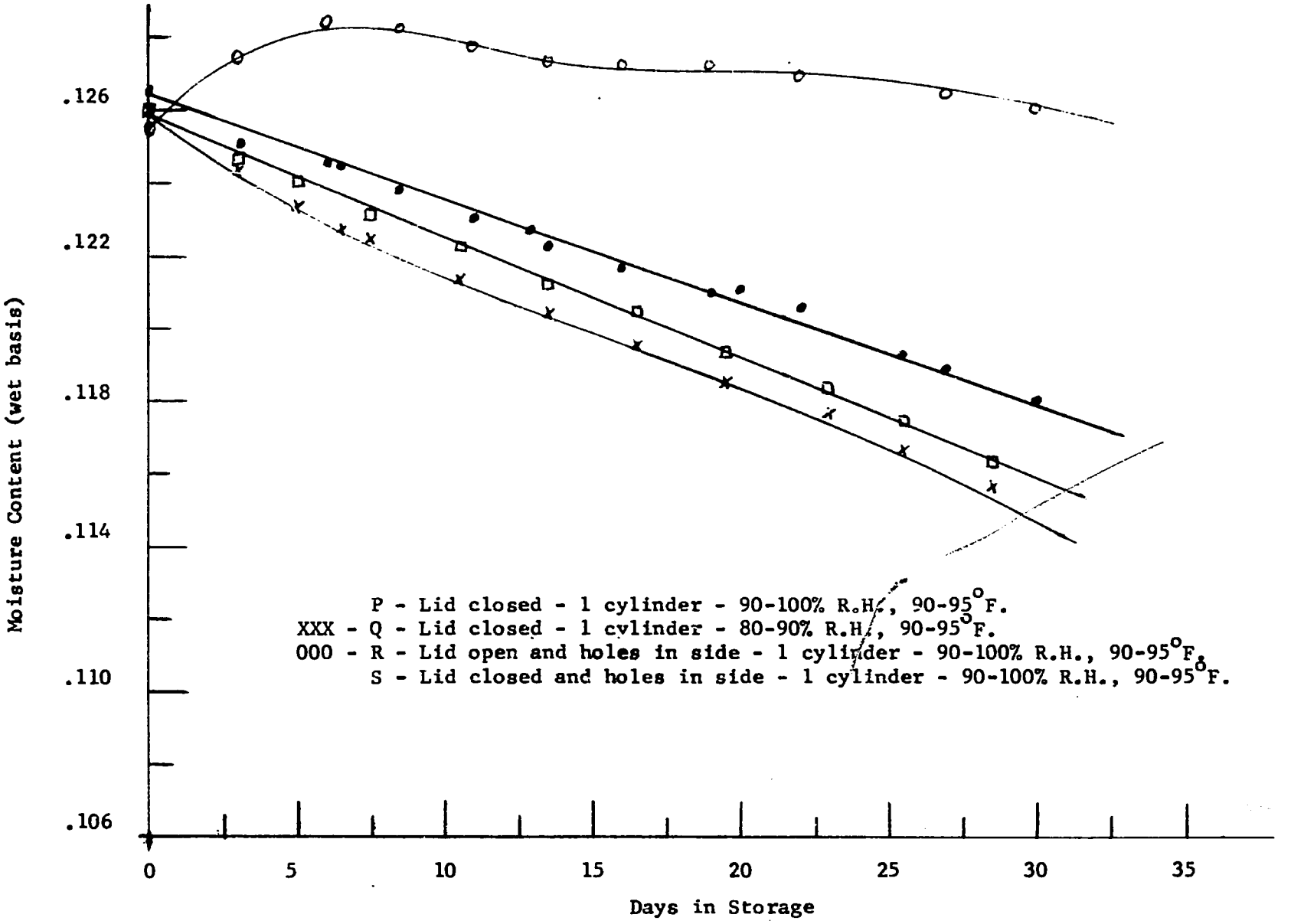
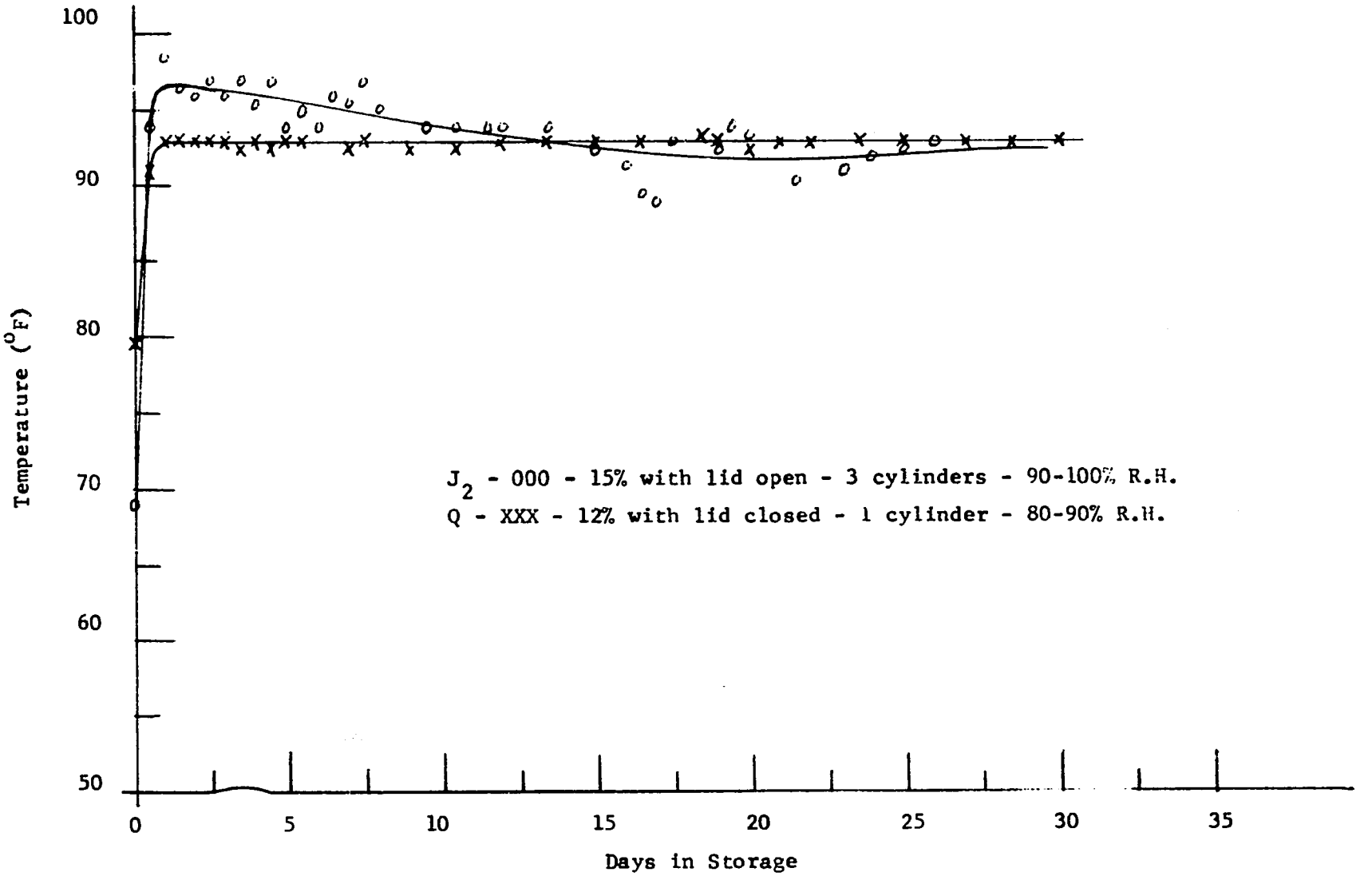


Figure 5. Temperature of Corn vs. Days in Storage



Our preliminary study showed a definite feasibility of storing corn without deterioration at 15% and 12% moisture even at extremely adverse storage conditions (very high temperature and humidity, and poor conditions of the storage container) by using silica-gel as drying agent. However, we have failed to show the feasibility of storing corn without deterioration at 20% moisture content by using only about 50 to 1 ratio of grain to dessicant. We are hopeful that the workable solution for 20% moisture corn may be developed by revising our approach (i.e. either by increasing the grain to dessicant ratio or by taking out and drying the dessicant before complete saturation of dessicant). Also we are hopeful that we may be able to find a cheaper drying agent for the storage purpose (i.e. salt and $CaSO_4$).

APPENDIX

Tentative Plan of Research Project

Plan of Work.....15

Facility, Equipment and Personnel.....17

Anticipated Schedule for Conducting the Project.....17

Table 1. Experimental Factors and Conditions to be Tested...18

Figure 1. Internal Structures of Grain Storage Unit.....19

THE TENTATIVE PLAN OF RESEARCH PROJECT

on

"Development of a Simple Storage Unit and Storage Method Applicable for Humid Areas in Developing Countries"

by Do Sup Chung
The Food and Feed Grain Institute
Kansas State University

Plan of Work:

1. The first phase of the project is to examine the effectiveness of several types of adsorbents placed in small containers in which corn is stored (bulk storage), at various initial moisture contents for the means of preserving the corn quality under simulated humid conditions.

The grain to be tested is shelled yellow corn stored initially at 20%, 15%, and 12% moisture content. The adsorbents to be tested are silica gel, lime, $CaSO_4$, and salt. The adsorbents will act as a drying agent for dehumidifying air in a container. Hopefully it will create a relatively dry air condition in the container such that the adsorption of water vapor on grain will not take place; rather, some desorption of water vapor from corn at above 12% moisture content would take place.

The adsorbent is placed in a grain storage container surrounded by humid air. Humid environmental conditions for experimental tests will be simulated by environmental chambers located in the Agricultural Engineering Department. These are 80-90 percent R.H. and 90-100 percent R.H. at 75°F., 85°F., and 95°F. air temperatures.

First of all, we have to establish the most effective adsorbent and the right ratio of the amount of adsorbent to that of corn needed for preserving the grain quality at various environmental conditions. Secondly, we have to find an efficient and effective way of distributing or positioning the adsorbent in a grain mass, with respect to grain and adsorbent handling as well as to maintain the grain quality.

Reproduced from best available copy.

Circular metal containers with different internal structures for placing adsorbent will be constructed capable of holding 10 lbs. of corn. A few geometric configurations of internal structures for containers in which the adsorbent and corn will be placed and tested are shown in Figure 1.

Experiments will be conducted with several containers shown in Figure 1 under various environmental conditions. Three conditions of a storage unit or container with respect to environments will be simulated and tested: 1) the lid tightly closed (no air in or air out); 2) the lid loosely placed (allow some air in or air out); and 3) the container with a few small holes and the lid loosely placed.

During the experiments, the changes in temperatures and moisture contents of grain and the grain quality (molds or insect development) at various locations in a container will be measured periodically until grain deterioration occurs. Also, the saturation rate of adsorbent at a specified environmental condition will be examined and the saturated adsorbent will be reactivated for further use. Experimental factors and conditions to be tested are tabulated in Table 1.

2. The second phase of the project is essentially an extension of the first phase with larger grain quantities in order to study the scale-up factors for full-scale grain storage unit. Based on the results from the first phase, a type of adsorbent, the ratio of the amount of adsorbent to that of grain, and a type of internal structure for a container that are technically and economically feasible for preserving the grain quality will be selected to examine whether such results can be extended to large grain samples or not.

Corn samples to be tested will be 100 lbs. and 1,000 lbs. The storage units or containers capable of holding 100 lbs. and 1,000 lbs. with the most

promising internal structure (based on the study from the first phase) for placing the adsorbent in a grain mass will be constructed. Experiments will be performed with the storage unit constructed under various environmental conditions as mentioned in the first phase.

3. The third phase of the project is to analyze the results to be obtained in the first and second phases in order to provide the detailed for a storage unit and procedures for maintaining the grain quality in humid areas, and to conduct the economic analysis of the grain storage practice to be proposed in this study.

4. The fourth phase of the project should be designed to test the recommended storage unit and method at a selected humid area in a developing country.

Facility, Equipment, and Personnel:

Major facility, equipment, and instruments needed to perform the proposed project are available in Agricultural Engineering Department, Kansas State University. However, some technician's help (one month service) is needed in the fiscal year, 1973, for servicing and calibrating control units at environmental chambers, temperature and humidity sensing and recording units, and for constructing small storage units for tests. In addition, some funds are needed for purchasing supply and materials (adsorbents, corn, materials for constructing storage units, etc.).

Anticipated Schedule for Conducting the Project:

For the first phase:	8 months (by November, 1972)
For the second phase:	8 months (by July, 1973)
For the third phase: (including the report writing)	4 months (by November, 1973)
For the fourth phase:	12 months

Table 1. Expermental Factors and Conditions to be Tested.

Grain:	Shelled Yellow Corn
Grain Sample Size:	10 lbs., 100 lbs., 1,000 lbs.
Initial Moisture Content of Corn:	20%, 15%, 12%
Adsorbent:	Lime, Silica-Gel, Salt, $CaSO_4$
Amount of Adsorbent to Amount of Grain:	To be determined by trial and error (Min. ratio, 1:200)
Air Relative Humidity:	80-90%, 90-100%
Air Temperature:	75°F., 85°F., 95°F.
Internal Structures of Storage Unit:	See Figure 1.
Conditions of Storage Unit:	a) Lid tightly closed b) Lid loosely placed c) b) and storage unit with few small holes

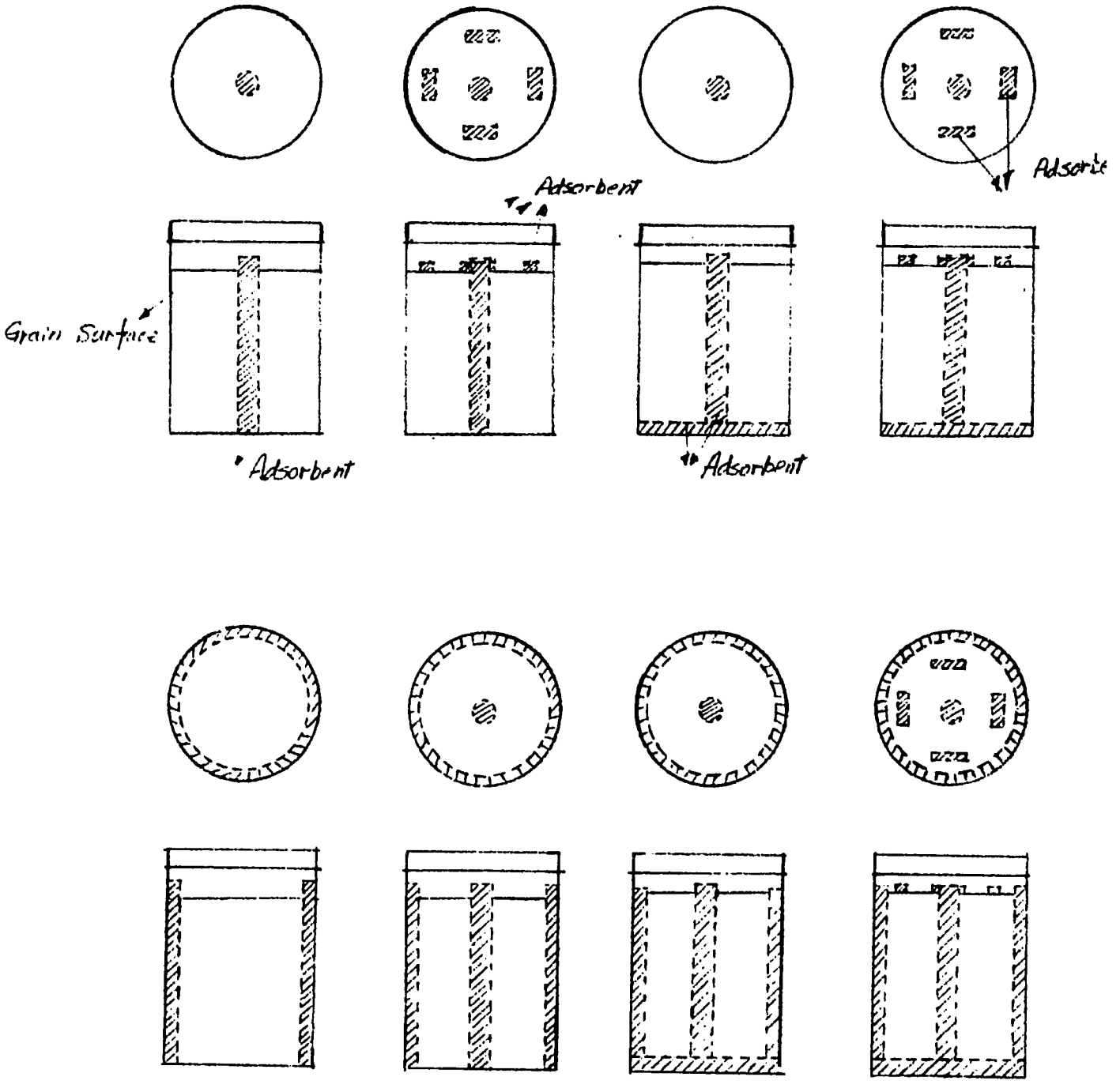



Figure 1. Internal Structures of Grain Storage Unit For Placing the Adsorbent.