China: Grain Storage Structures

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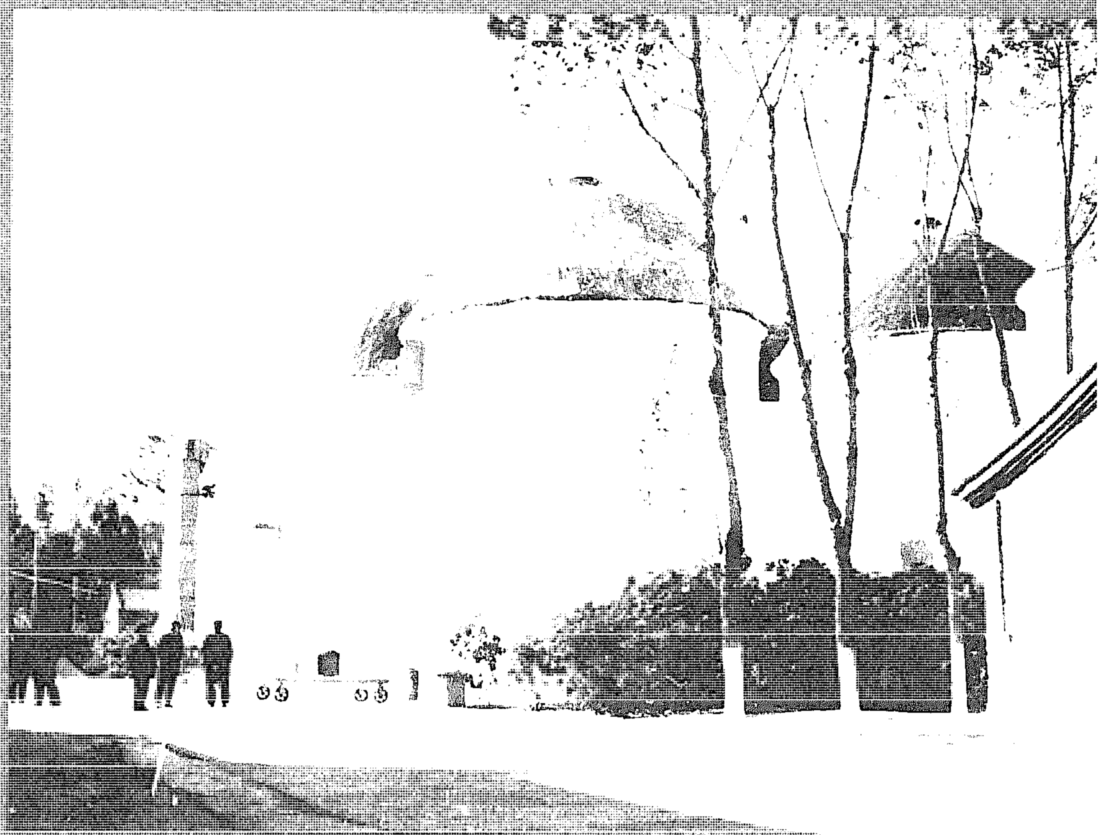

FOOD AND AGRICULTURE ORGANIZATION
OF THE UNITED NATIONS ROME

china:
grain storage structures

report on a

fao/undp workshop study tour
in the people's republic of china

18 october to 16 november 1979

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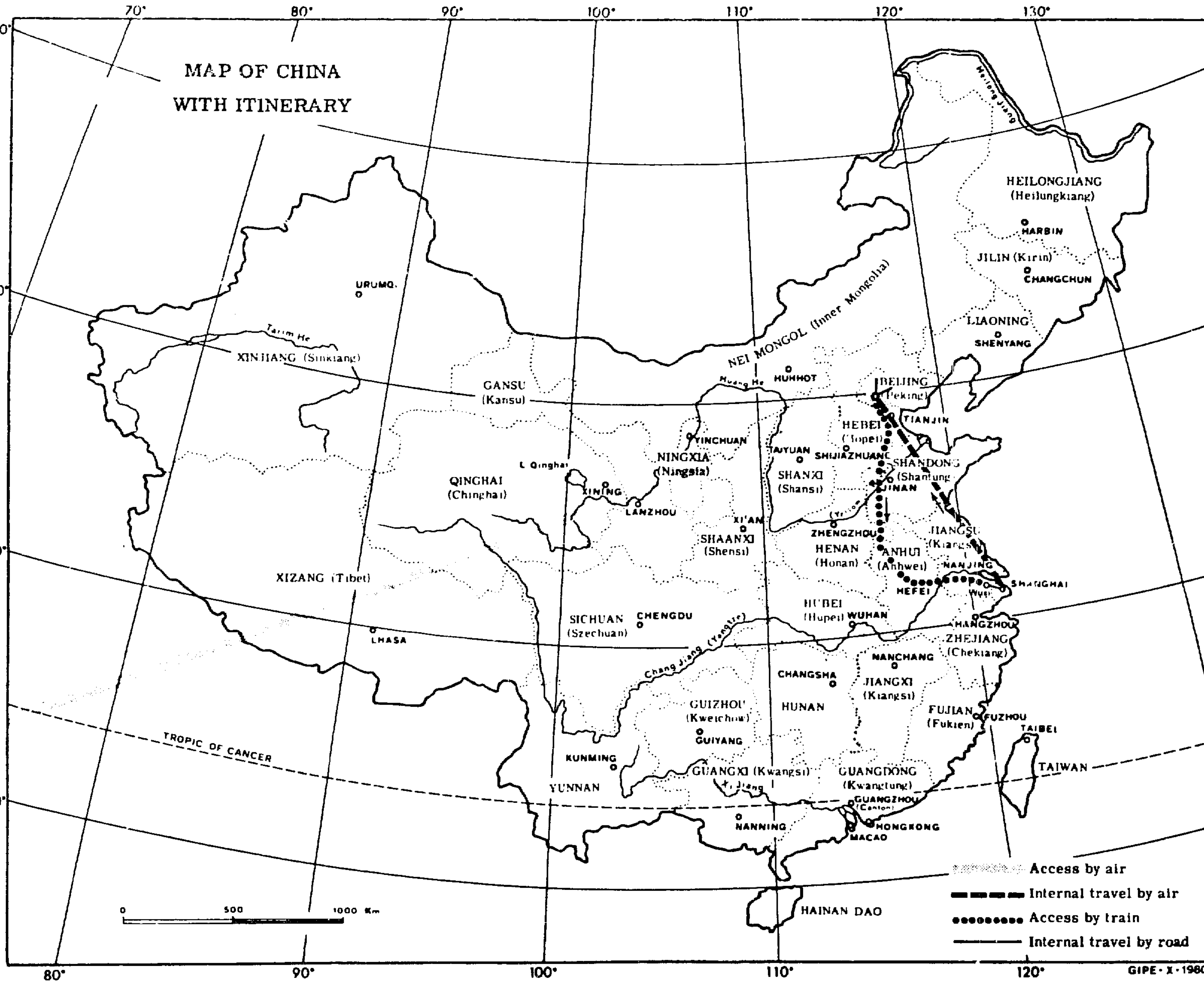
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CHANGCHUN
LIAONING
SHENYANG
NEI MONGOL (Inner Mongolia)
HUHHOT
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TIANJIN
HEBEI (Hopei)
SHIJIAZHUANG
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SHANXI (Shansi)
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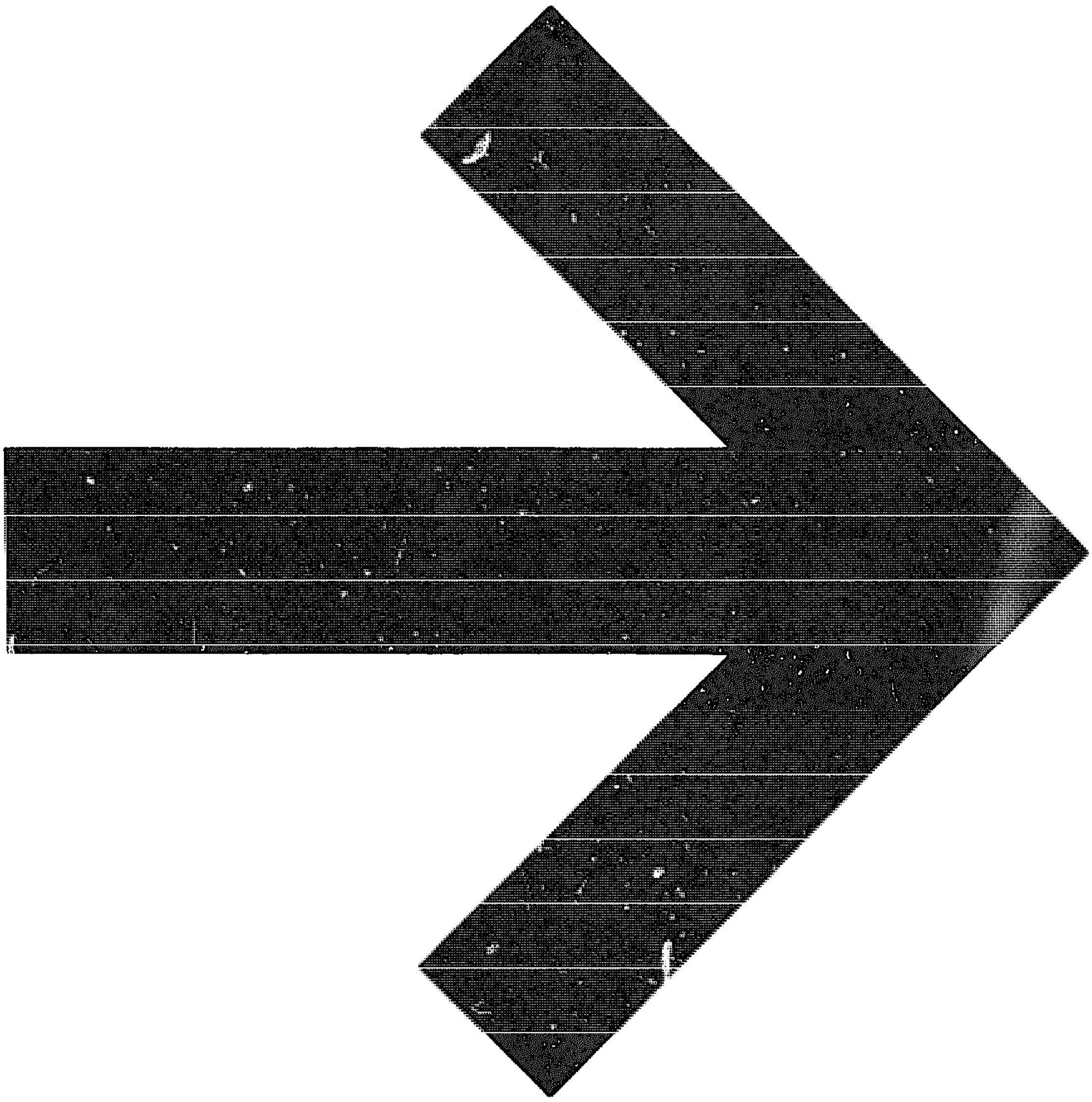

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ACKNOWLEDGEMENTS

All of us who participated in the workshop/study tour on grain storage structures in the People's Republic of China, from 18 October to 16 November 1979, appreciated greatly the opportunity to learn about building techniques and storage methods widely used in China today.

Our appreciation goes in the first place to the Government of the People's Republic of China, who organized the workshop/study tour and paid the local expenses, and to the United Nations Development Programme (UNDP) and the Food and Agriculture Organization of the United Nations (FAO) who made the international arrangements and paid non-local costs.

In China the programme was arranged and conducted by the Ministry of Food. Special thanks are due to Mr. Yang Deshu, Acting Director of the Foreign Affairs Department, and Mr. Wang Wenqing, Head of the Foreign Affairs Division, and their staff for their unsparing efforts to provide us with all possible technical information and for taking care of accommodation and travel arrangements as well as cultural events in an excellent manner.

The directors and staff of the Provincial Grain Bureau, Wuxi, Jiangsu Province and the Grain Bureau, Shanghai, who were in charge of the arrangements in their respective areas, prepared very good and comprehensive programmes with excellent travel arrangements. The Grain Bureaux at county level and the Grain Storage Corporation, Shanghai, assisted greatly with the local programmes.

At all the depots we visited we appreciated the readiness to share technical information and also the warm hospitality and the great feeling of friendship. To the directors and their entire staff our warmest gratitude. Special thanks are due to director Huan Shiu and engineer Wang Shoude of Niou Pao Tun Depot, for the arrangements they and their staff made to let us practise the construction of clay/straw silos.

We felt greatly honoured that representatives of the municipalities in the areas visited came to meet us and also accompanied us during part of our travel.

In view of the problem of communication, we are greatly indebted to our two main interpreters, Mr. Mao Yingfa and Mrs. Chen Fei, who were with us during our whole stay, and who patiently and tactfully interpreted during technical visits and discussions, at social events and during leisure time. This was an onerous task which was always carried out with great willingness.

Greatly impressed as we were by the well-organized programme and wealth of technical information provided, we will, however, remember for longer than anything else the feeling of warmth and friendship we encountered everywhere during our visits.

INTRODUCTION

The workshop/study tour "Post-Harvest Grain Technology - (Storage Structure Design)" (RAS/79/006) was organized under the FAO/UNDP programme in cooperation with the People's Republic of China.

The aim of the workshop/study tour was to impart a knowledge of practical techniques used in Chinese post-harvest grain systems for construction of grain storage bins and grain warehouses. The equipment used for handling and transport, as well as systems for management and control of stored grain were also included in the workshop to the extent required for the specification of design criteria.

Twenty participants and two FAO staff members took part in the workshop/study tour which was conducted during the period 18 October - 16 November 1979.

Travel and studies in China were mainly in the areas around Beijing (Peking), Wuxi and Shanghai.

Participants were from ten different Asian countries and one participant came from Africa (Appendix 1 - List of Participants; Appendix 2 - Some Background Data on Countries Represented at the Workshop/Study Tour).

The programme (Appendix 3) was concentrated entirely on grain storage structures and therefore this publication has been called Grain Storage Structures - China. It contains mainly a description of structures used for grain storage, their designs, construction techniques, etc. Some information about climatic conditions, organization of the grain-handling system and the management of stored grain, etc., has been included as required for a full understanding of the buildings and their function.

As the clay/straw-walled silo is a unique indigenous storage structure for grain found in the People's Republic of China today, an attempt has been made to illustrate fully how these silos are built.

Warehouses, and in particular their extensive use for storage of bulk grain, are described. In particular the simplicity of design of warehouses and the conversion of old warehouses for bulk storage are of great interest.

Other interesting stores, such as open-air stores and underground stores, are included, as well as some information on modified atmosphere stores.

Many of the things which seem obvious and work well in China may not, for several reasons, be directly applicable in other countries. Climatic conditions, building materials, skills and traditions, etc. require a careful adaptation. It is up to us, the participants in this workshop/study tour, and to you, the readers interested in the development of appropriate, functional, low-cost grain storage structures, to carry on with this adaptation. Some project ideas suggested by participants have been listed in Appendix 5.

All participants in the workshop/study tour have helped with the collection of information and data for this publication and in the preparation of first drafts of various chapters. Without their collaboration it would not have been possible to collect so much technical information. My thanks go to them, to my FAO colleague Ove Sode, who assisted greatly in the preparation of the written material, and to Sergio Bernardini, whose studio in Rome assisted in the preparation of the drawings.

Carl Rånnfelt

Team Leader

For the purpose of this report, an exchange rate of 1 US$=1.5213 RMB Yuan has been used throughout.

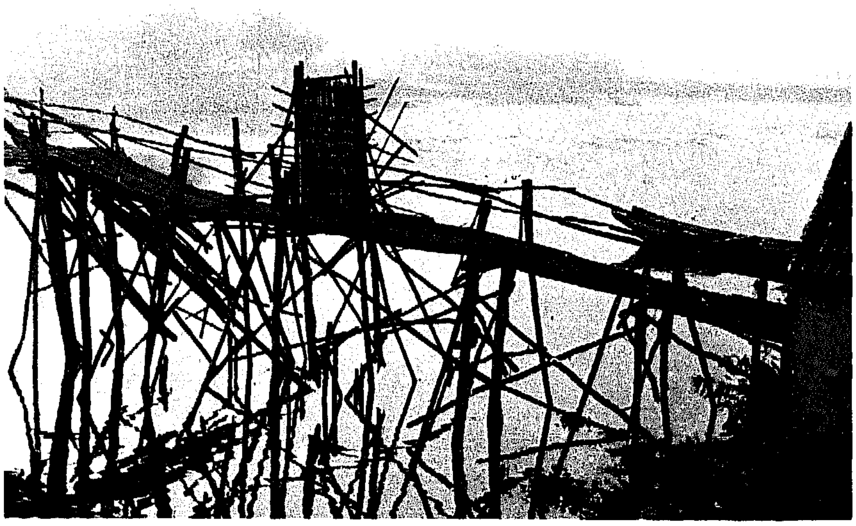


Photo 1 - Walk bridge near Wuxi. Chinese structural designs are often functional, empirically developed and make maximum use of locally available materials and labour

CHINESE PROVERB

you hear ...

and you forget

you see ...

and you remember

you do ...

and you learn

Only those of us
who had the privilege of participating in this study tour
had the opportunity to build and thus to learn

But it is hoped that you (the readers)
will understand (remember) from pictures, illustrations and descriptions
the ingenuity of Chinese construction techniques
which are based on old traditions
with designs empirically developed
using locally available building materials and labour

To produce buildings
which are well suited
to give maximum protection to stored grain

If you become interested
and do start learning
through construction of such buildings
adapted to your local conditions
it will have been worthwhile
producing this publication.

CHAPTER 1

ORGANIZATION OF GRAIN STORAGE IN CHINA

1.1 GRAIN PRODUCTION

China's total grain production (1) has been estimated at 261 million tons for 1978 with a distribution of the most important crops as follows:

Rice (paddy)	131 million tons
Wheat	44 million tons
Maize	33 million tons
Millet and sorghum	24 million tons
Barley	20 million tons

Higher total grain production figures are sometimes quoted, e.g. 332 million tons for 1979 (2). These higher estimates probably include also feed grain and root crops converted into grain equivalents.

1.2 GRAIN CONSUMPTION

With a population stated to be 970 million at the end of 1979, the grain availability is of the order of 250 kg per inhabitant per year, but no information is available on how much of this grain is used for feeding animals. The high level of grain intake is illustrated by the fact that the normal grain ration is 15 kg per person per month.

It has been stated that 78 percent of the average daily diet in China is composed of cereals, potatoes and root crops, while in the United States the same foodstuffs constitute only 23 percent of the average daily diet (3). The quality and availability of grain are therefore of vital importance to the whole nation.

1.3 RURAL AND URBAN CONSUMPTION

The rural population is about 60 percent of the total. On this basis it could be estimated that the urban consumption is:

$$0.40 \times 970\ 000\ 000 \times 0.180 = 69\ 840\ 000 \text{ tons},$$

based on a ration of 15 kg/month = 180 kg/year. This may be an indication of the amount of grain passing through the grain handling system to reach urban consumers. The rest of the grain remains in rural areas, and usually never reaches levels above the production team. Overall central grain stocks in China were estimated to be 40 to 60 million tons in 1975 (4).

1.4 IMPORT AND PRODUCTION TRENDS

During the last three years grain imports have been about 10 million tons per year, of which about 80 percent is wheat. The present growth rate in food grain production is about 3 percent per year.

1.5 DECENTRALIZATION OF STORAGE

"Store Grain Everywhere" is a policy directive which seems to have been followed and which has led to a very decentralized storage system. The various levels of the commune system and the average number and size of the units are given below to provide a background to the discussion about grain storage at various levels which follows:

Table 1 - The Commune System

	Commune	Production brigade	Production team
No. of units in the country	50 000	750 000	5 000 000
No. of households per unit	3 346	220	33
No. of persons per unit	14 720	980	145
Arable land, ha per unit	2 033	136	20
No. of production brigades per commune	15	-	-
No. of production teams per commune or brigade	100	7	-

Local variations are great but the table may still be useful in establishing orders of magnitude.

At farm household level the grain ration is kept for the family. From the information that the average ration is 180 kg/person per year and with a 60-percent rural population, it may be assumed that over 100 million tons are stored at farm household level in China. Households normally have a plot (on average about 300 m^2) (5), but on these plots state-controlled produce such as grain is not normally cultivated.

At production team level it is common to store seed grain. The grain produced is transferred to depots at higher levels in the system, while the ration for the households is retained. The team is the basic production unit and manages most of the labour and arable land.

At production brigade level the grain quotas are received from the commune and the fulfilment of these quotas is agreed with the production teams. Brigades could be engaged in specialized agricultural production such as raising of piglets for production teams, operation of orchards, fishponds, etc. Brigades usually also provide the machinery which is used at production team level. Involvement in grain storage and/or processing does not seem to be a normal function at brigade level, although there is some indication that reserve stocks are kept at this level (4).

At commune level most of the grain from the production teams, and sometimes from other communes without adequate storage facilities, is collected, cleaned, weighed and dried if required. For production exceeding the stipulated quota a premium is paid which could be up to 50 percent higher than the base price, thus giving a strong incentive for higher production.

1.6 FOOD SECURITY

The described decentralization of grain storage results in a substantial level of reserve stock maintained below State level. Kept at household level or at other levels in the commune system, in low-cost storage facilities built from local building material, grain reserves can be kept at very low cost. Also, the requirements and investments needed at State level are thus considerably reduced.

1.7 STATE GRAIN TRADE

Food grain is a State-controlled commodity and purchase and sales are handled only through the commune and the State. The State thus takes the responsibility for supplying food grain to all urban as well as non-agricultural rural populations.

1.7.1 Organization

The organizational structure (see Fig. 1) for the State grain trade is centrally headed by the Ministry of Food (sometimes referred to as Ministry of Food and Grains). At provincial levels the Ministry of Food is represented by 30 Grain Bureaux which in turn are prepresented at county level by about 300 local Grain Bureaux.

The provincial Grain Bureaux have Grain Storage Corporations which are in charge of depots and purchase and supply stations and the local Grain Bureaux at county level also have special sub-sections for grain storage which are in charge of depots and storage.

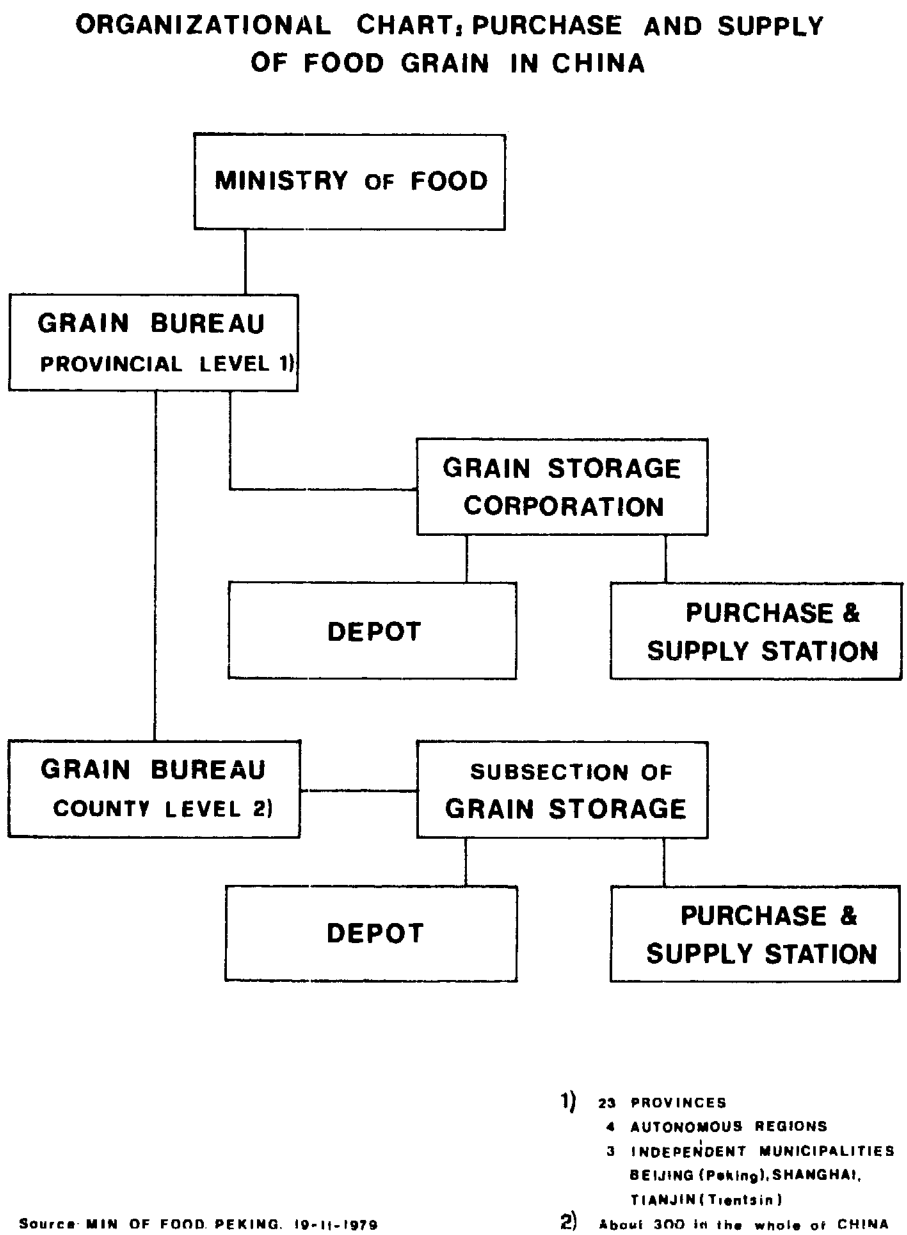


Figure 1 - Organizational chart - purchase and supply of food grain in China

1.7.2 Depots

These depots exist at county, town or city level and are designed primarily for storage and receive their grain from communes and nearby production teams. The depots are equipped to receive and store grain in bulk and storage is mainly in warehouses and clay/straw silos, but also, when needed, in open-air stores.

1.7.3 Purchase and Supply Stations

The purchase and supply stations receive their grain from depots or from communes. The stations normally undertake processing and deliver milled rice or wheat flour, which is usually stored and distributed in bags.

No figures could be obtained for the total amount of grain stored and handled by the State. In view of the previous estimate of about 70 million tons required for the urban population, and in addition the requirements for the non-agricultural rural population, as well as the need in deficit areas, amounts handled by the State may approach 100 million tons.

1.8 INSTALLATIONS VISITED

The participants in the workshop/study tour during their stay in China had the opportunity to study storage mainly at State depots and purchase and supply stations. Little information was collected about storage at commune level and household level. Some data for the depots and stations visited are shown in Table 2. Most installations are large-scale depots or stations with storage capacities of 7 800 to 75 000 tons, and annual turnover of stock normally two to three times. It should be noted that some of these depots and stations keep a considerable amount of grain in open-air stores.

1.9 CONSTRUCTION PROCEDURES

1.9.1 Planning and Design

Construction procedures at commune level and below are not strictly formalized. For small-scale construction of warehouses and clay/straw silos, no authorization is required and the communes are free to build according to their own wishes within the limits of their budget.

The same applies to State level depots (county, town and city depots) for small-scale contruction, i.e. below 50 000 tons of stored grain.

For construction of units with over 50 000 tons of stored grain, an authorization is required and can be obtained at provincial level. Designs are usually made by the design engineers of the depot but have also to be approved at provincial level. The financing of major construction programmes, which are not financed by the depot itself, has to be included in the planning carried out by the Ministry.

1.9.2 Construction

Most depots have a construction unit which could be composed as follows (First Depot, Wuxi):

1 building engineer
2 building designers
6 masons
4 carpenters
1 blacksmith
2 painters

Table 2 - Some Data for Depots and Stations Visited

Name	Type of depot	Annual turnover tons	Total No. of people employed	Total[1] storage capacity tons	Types of stores and their capacity: Warehouses No. of units	Warehouses Total tons	Clay/straw silos No. of units	Clay/straw silos Total tons	Open-air stores tons	Brick silos tons	Other installations
Zhang Xi Zhuang (Shunye county)	county depot	... ...	30 30	8 000 8 000	1 1	1 500 1 500	59 59	6 560 6 560		-	-
Niou Pao Tun	county depot	25 000	56	21 500	20	14 400	48	7 100		-	Flour and feed mill
First Depot (Wuxi)	town depot	200 000	220	75 000	...	...	...	...		-	Rice mill
Bao An Depot (Wushen county)	county depot	50 000	73	15 000	5	8 500	10	1 250		-	-
First Purchase & Supply Station (Shanghai)	city purchase & supply station	350 000	600	30 000	...	30 000	-	-	15 000±	-	Rice mill, 150 tons/day
South Gate Depot (Sunjiang county)	county depot	100 000	105	37 000	18	25 000	126	12 000	20 000±	-	-
Seventh Depot (Shanghai)	city depot	200 000	255	28 400	18	26 000	...	...	30 000±	2 400	-

1/ excluding open-air stores
... figures not available

The construction unit is normally intended for repair and maintenance of existing buildings but could also be extended and equipped for construction of clay/straw silos.

For more important construction, beyond the capacity of a depot's construction unit, the Ministry of Construction carries out the work. A partial bill of quantities, specifying cement, iron and timber, is drawn up. Other material required for the construction is usually provided by the ministry in question, i.e. the Ministry of Food in the case of grain storage depots.

CHAPTER 2

CLIMATOLOGICAL CONDITIONS AND GRAIN PROPERTIES

2.1 GEOGRAPHICAL LOCATION

China extends from the Tropic of Cancer in the south to 50° N latitude, with considerable variation in grain production conditions. From a humid continental climate in the north, with one crop of wheat per year, China reaches areas between 20°-30° N latitude with humid subtropical conditions and two to three rice crops per year (see frontispiece).

2.2 TEMPERATURE AND RELATIVE HUMIDITY

Temperature and relative humidity data are given in Table 3 for Beijing, Shanghai and Guangzhou.

Table 3 - Climatological Data, China

Month	BEIJING Temperature Max. °C	Av. °C	Min. °C	Rel. humid. %	SHANGHAI Temperature Max. °C	Av. °C	Min. °C	Rel. humid. %	GUANGZHOU Temperature Max. °C	Av. °C	Min. °C	Rel. humid. %
January	10.7	-4.8	-22.8	51	19.8	3.5	-9.4	78	27.9	13.7	0.6	78
February	15.5	-2.0	-17.6	42	22.9	4.9	-7.9	79	28.6	14.6	0	80
March	22.6	4.3	-12.5	46	27.6	8.2	-5.4	79	31.0	17.9	3.9	82
April	31.1	13.3	-2.4	49	31.7	13.7	1.1	79	33.0	21.8	10.8	84
May	36.6	19.9	3.7	56	33.1	18.6	7.0	80	35.7	25.6	15.4	83
June	38.9	24.1	11.2	67	36.9	23.4	12.5	84	35.2	27.3	20.2	83
July	39.6	25.8	16.1	74	38.3	28.0	19.4	84	37.1	28.3	21.9	80
August	38.3	24.5	12.3	80	38.9	27.6	19.6	84	38.7	28.2	22.0	81
September	32.3	19.5	4.9	73	37.3	23.5	12.5	83	36.3	27.0	18.3	77
October	29.3	12.6	1.4	66	29.3	17.8	1.7	79	33.1	23.7	11.3	77
November	23.3	4.0	-11.6	65	28.6	12.5	-3.8	78	31.7	19.5	5.3	76
December	13.5	-2.6	-18.0	42	23.3	6.5	-6.2	77	28.3	15.2	2.2	71
Year average		11.6		59		15.7		80		21.9		78

In the Beijing area conditions at harvest are comparatively favourable and grain can usually be brought down to a moisture content of 12.5-13 percent through drying in the field after harvesting by hand.

Shanghai and Guangzhou have a less favourable combination of temperatures and average relative humidities, the latter being about 80 percent at harvest time. Equilibrium moisture contents at harvest can be 14-16 percent and it is difficult to arrive at a sufficiently low moisture content for safe storage through field drying.

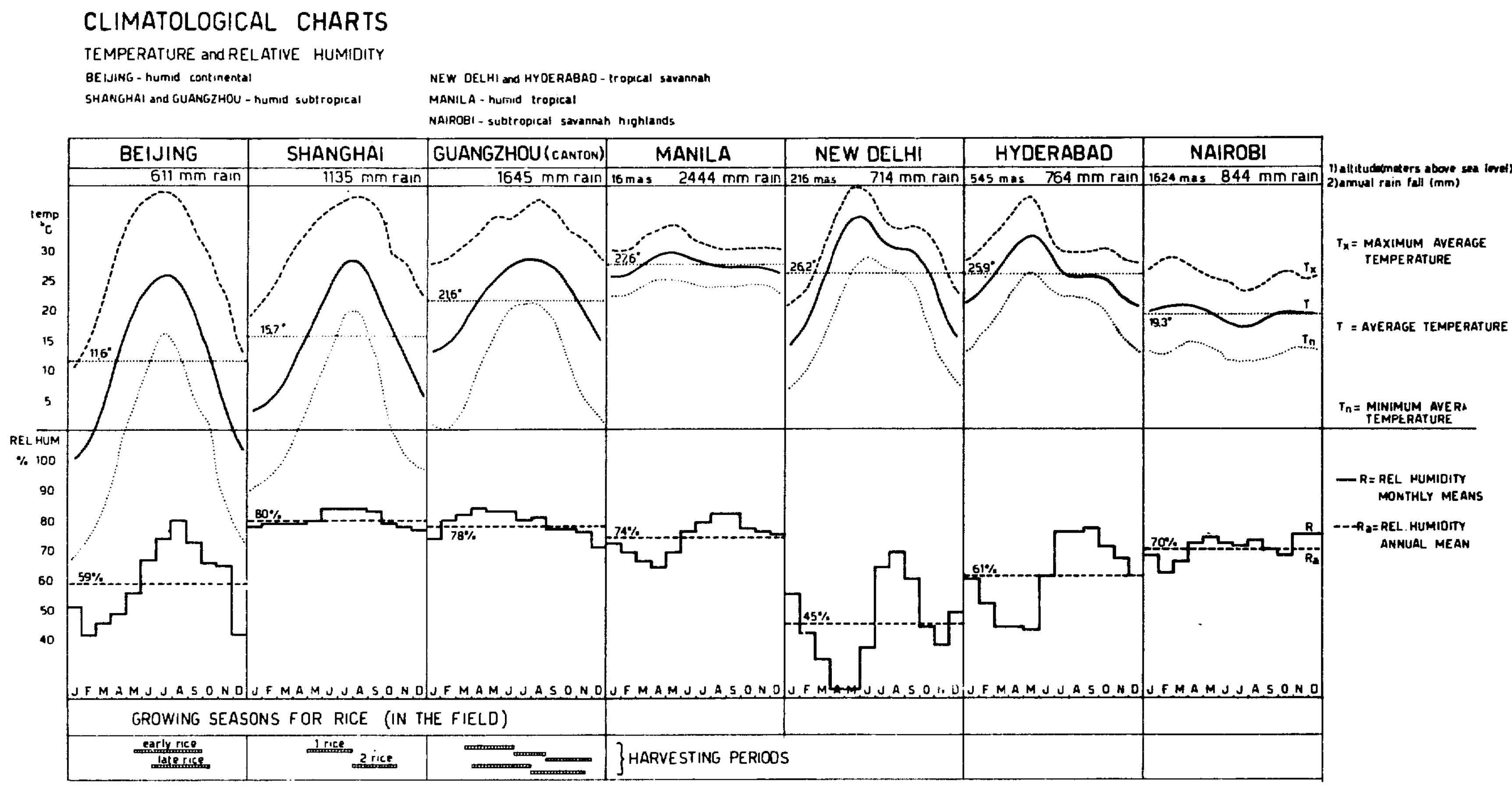


Figure 2 - Climatological charts

The data from Table 3 have been plotted in the graph in Fig. 2 where comparable graphs have also been plotted for Manila, New Delhi, Hyderabad and Nairobi. Considering annual average values for temperatures and relative humidities and corresponding values for equilibrium moisture content (6), it can be concluded that New Delhi, because of the very low relative humidity, should offer the best storage conditions with average equilibrium moisture contents of 10-11 percent, Hyderabad, Nairobi and Beijing should be comparable with average equilibrium moisture contents around 13 percent, while Shanghai, Guangzhou and Manila have average equilibrium moisture contents of about 15 percent, making it difficult to obtain grain safe for long-term bulk storage without artificial drying.

Conditions at the time of harvest, wind force and frequency are among the many deciding factors in obtaining grain which can be stored safely. The discussion above, using equilibrium moisture content as a criterion, shows, however, that conditions in China are not so different from the other places which have been used for comparison.

The main and most favourable advantage of the Beijing type of climate is of course the very low temperature during winter. Natural cooling is also used to a large extent in the north of China to protect stored grain.

2.3 HARVESTING

Most of the grain is harvested by hand (photo 2) and left in the field to dry in sheaves. In the drier areas this seems to be sufficient to ensure a safe moisture content before threshing. In some conditions a further drying on straw mats takes place after the grain has been threshed on drum threshers. Some depots are equipped with coal-fired artificial dryers.

Combine harvesting (photo 3) of rice has been tried in some areas for paddy but this method at the present stage of development has led to considerably higher field losses than hand harvesting and also often requires artificial drying to arrive at clean grain which is safe to store. A mower-bundler is also locally manufactured (7) and may be a more feasible harvesting method, as the required drying can take place in the field.

2.4 PROCUREMENT AND GRADING

After threshing and winnowing (photos 4, 5 and 6) at the production team level, the grain is delivered to a commune, county or town depot. Some quantities of grain intended for seed are also stored at production team level (photo 7).

The grading system is illustrated in the following tables:

Table 4 - Grading of Paddy (Indica Type)

Grade	Brown rice %	Immature grain & impurities max. %	Moisture content		Live insects
			Early crop	Late crop	
1	79				
2	77				
3	75	1	13.5	14	None
4	73				
5	71				

Table 5 - Grading of Paddy (Japonica Type)

Grade	Brown rice %		Immature grain & impurities max. %	Moisture content max. %		Live insects
	Early crop	Late crop		Early crop	Late crop	
1	81	82				
2	79	80				
3	77	78	1	15	15.5	None
4	75	76				
5	73	74				

Table 6 - Grading of Wheat

Grade	Density of grain gram/litres	Immature grain max. %	Impurities max. %		Moisture content max. %	Live insects
			Total	Organic matter		
1	770					
2	750					
3	730	6.0	1.0	0.5	13.5	None
4	710					
5	890					

Further efforts are required at the depot to bring down the comparatively high moisture content which is accepted at procurement, i.e. 13.5-15.5 percent for paddy and 13.5 percent for wheat, through careful ventilation and, in some cases, drying. Further cleaning is also done at the depots and grain is sorted and stored according to quality class.

Photo 2 - Rice harvested by hand. Rice is normally harvested by hand with sickles and the bundles are left in piles at the borders of the field to dry (near Wuxi)

Photo 3 - Rice combine harvester. Used to some extent but will require considerably expanded drying facilities (Malu Commune, Jiading County, Shanghai)

Photo 4 - Electrically-driven drum thresher (working team, Malu Commune, Jiading County, Shanghai)

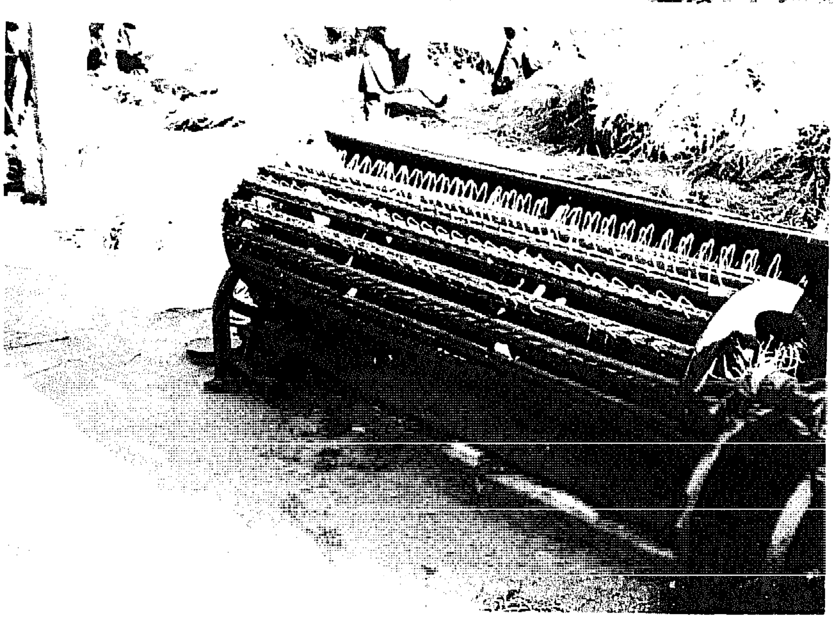
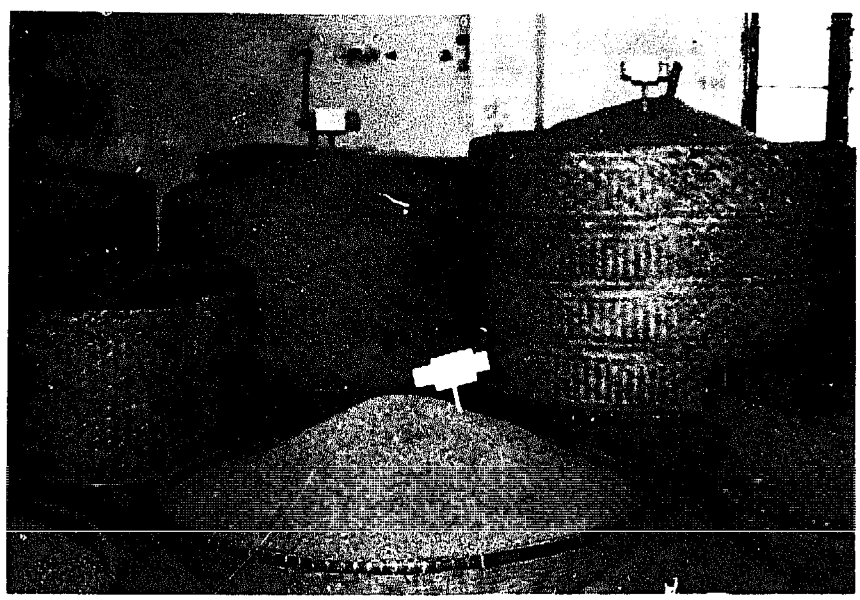


Photo 5 - Drum thresher. Detail of threshing drum (working team Malu Commune, Jiading County, Shanghai)

Photo 6 - Winnowing of paddy. An electric fan is used to separate the chaff from the paddy (production team, Malu Commune, Jiading County, Shanghai)

Photo 7 - Seed storage at production team level (Malu Commune, Jiading County, Shanghai)



CHAPTER 3

STORAGE MANAGEMENT AND PROTECTION OF STORED GRAIN

3.1 THE FOUR "WITHOUTS"

The main emphasis in the management of stored grain is given to preventive treatment and very careful monitoring and control of the grain in stock. The four "withouts", i.e.,

without insects
without fungi (mould and others)
without birds and rodents
without accidents (fire, water damage, etc.)

are basic aims of every depot and every worker in a depot seems to be aware of his responsibility to achieve these aims. The main activities, carried out on a routine basis, to achieve the four "withouts" are described under 3.2 to 3.7 below. See also photos 8 to 15, which illustrate some of the protection and control measures.

3.2 SANITATION AND HYGIENE

Before a store is filled with grain a thorough mechanical cleaning is carried out by sweeping and brushing. If the store has been infested by insects it is sprayed with an insecticide, usually DDVP (Dichlorvos, see 3.6 below). When the store has been cleaned and disinfected, the inside of the building is usually whitewashed with lime.

Tools and equipment are also cleaned and fumigated, if necessary. Tools which have been used for infested grain are not allowed to touch non-infested grain.

3.3 QUALITY CONTROL AND GRADING BEFORE STORAGE

In order to be accepted at a depot the grain has to meet the basic standard requirements (see Tables 4, 5 and 6, Section 2.4). Before grain goes into storage, lots are separated according to quality and moisture content. Cleaning and disinfestation are carried out as and when required.

3.4 REGULAR INSPECTION OF STORED GRAIN

Regular inspection of stored grain is carried out in order to register temperature, moisture content and the possible presence of insects, birds or rodents.

Temperature control in stores with an area of less than 100 m^2 is usually carried out at five points (four along the sides and one at the centre), and for larger stores five points are taken for every 100 m^2. For each point the temperature is registered at three levels: upper level (30 cm below the grain surface), middle level and lower level of the grain pile. At the same time, the temperature inside and outside the store is recorded. It is recommended that the temperature be registered once every three days, and for grain in a critical condition, once every day.

Grain moisture inspection is made at least once in the first and fourth quarters of the storage period and during the second and third quarters, at least once a month.

Inspection for insects is carried out once a quarter for grain with a temperature below 15°C, once every two weeks for grain with a temperature between 15° and 20°C, and once a week when the grain temperature is above 20°C. Samples are taken from 5 to 10 places in stores below 100 m^2 and from more than 15 places in stores with floor areas of 100 to 500 m^2. Each sample has to be at least 500 g. From stores with bagged grain, samples are drawn from at least 10 bags out of stacks containing up to 500 bags and for bigger stacks at least two bags are sampled for each 100 bags in the stack. The samples are analysed for live insects through sieving and by cutting kernels or dyeing for immature insects. Alongside the other inspections, observations are also made for possible footprints, excreta, damaged kernels, etc., which might indicate the presence of rodents or birds.

3.5 VENTILATION AND AERATION

Full use is made of natural ventilation through windows and doors to reduce the temperature inside the stores during dry and cool weather. Usually the window area of the stores is about 4 to 6 percent of the floor area and the windows can all be opened. Doors are also fully utilized for ventilation during suitable weather with the openings protected by screens against birds and rodents and against insects by means of an insect barrier. Doors and windows together usually provide 5 to 9 percent of the floor area as openings. Before the temperature goes up in the spring, doors and other openings are sealed, and sometimes also the grain pile sealed with plastic sheeting to preserve the low temperature as long as possible (see also Chapter 7).

Where high temperatures are observed, they are reduced either through turning the grain or by means of portable suction fans with a spear lowered into the grain pile. The aeration rate is about 30 m^3 of air per ton of grain per hour.

3.6 CHEMICALS FOR INSECT CONTROL

DDVP (Dichlorvos, an organo-phosphate compound) and ALP (Aluminium phosphide, a phosphine (PH_3)-generating fumigant) are locally manufactured chemicals which are the main ones in use in China today. The DDVP available has a purity of 80 percent while ALP is available as tablets with 58 percent purity or as a powder with 90 to 95 percent purity.

Total use of chemicals is low. For example, the First Depot, Wuxi, with an annual turnover of 150 000 to 200 000 tons of grain, had an annual consumption of chemicals as follows:

	Paddy	Wheat	Total
DDVP (kg)	240	60	300
ALP (kg)	1 100	200	1 300

which corresponds to less than 1 kg of chemicals per 100 tons of grain.

For disinfection of empty stores, 100 to 200 mg of DDVP emulsified oil with 80 percent purity is applied per cubic metre of space by means of spraying or by hanging cloth strips soaked in the liquid. For spraying, the 80-percent DDVP emulsified oil is diluted with water 100 to 200 times. The depot is then sealed for three days and access is allowed only after doors and windows have been open for 24 hours. For hanging cloth strips the 80-percent DDVP emulsified oil is diluted 2 to 5 times with water. The cloth strips are soaked in the liquid and hung on wires which are fixed 2 metres apart, and the store is sealed for three days. A chemical which has been tried recently for disinfection of stores is Phoxim (an organo-phosphate insecticide like DDVP) which is applied by spraying. It is reported to have very low residual effects and its cost is comparatively low.

DDVP is also used for treatment against insects on the surface of the grain through the method of hanging cloth strips. One gram of emulsified 80-percent DDVP is used per m^3 volume of the whole depot. Straw mats are laid on top of the grain pile to prevent liquid from dripping on the grain. At the same time, DDVP powder may be mixed with bran applied around the grain pile or dusted on fibre mats to prevent crawling insects from entering the grain pile.

ALP is used for fumigation of stored grain. The dosage recommended is as follows:

	Purity %	Dosage, g/m^3 store volume: Empty store	Food grain	Seed grain	Period of sealing days
Tablet	58	3-6	6-9	6	5-7
Powder	90-95	2-4	4-6	4	5-7

For surface treatment of stored grain the distance between points of application is usually not more than 1.2 m. For internal treatment of the grain pile small cloth bags with chemicals are buried in the grain pile. The bags are attached to coloured string, which is left on the grain surface, for easy removal of the bag with remaining chemicals after the fumigation has been completed.

3.7 BIRD AND RODENT CONTROL

The main weapons against rats and birds are cleanliness in the first place and also very careful attention to all openings, which are normally covered by wire mesh when kept open for ventilation purposes. Rodents have been almost completely eradicated through regular campaigns involving whole towns or communities.

For example, in the city of Shanghai there are two rat campaigns every year, one in the spring and one in the autumn, each of a week's duration. Through practically complete eradication of rats during these two campaigns each year, the depots have no rat problem. It was also pointed out by the depot management that without such total campaigns, rat control within a depot only would be nearly impossible.

It must be noted as rather remarkable that during the whole time we spent in China visiting so many depots, even many with a high proportion of grain stored in open-air stacks, we did not see one rat or even any traces of rats.

Photo 8 - Fibre mats on the floor of a clay/straw silo (South Gate Depot, Songjiang County, Shanghai)

Photo 9 - Plastic sheets on the floor to protect milled rice in bags (First Purchase and Supply Station, Shanghai)

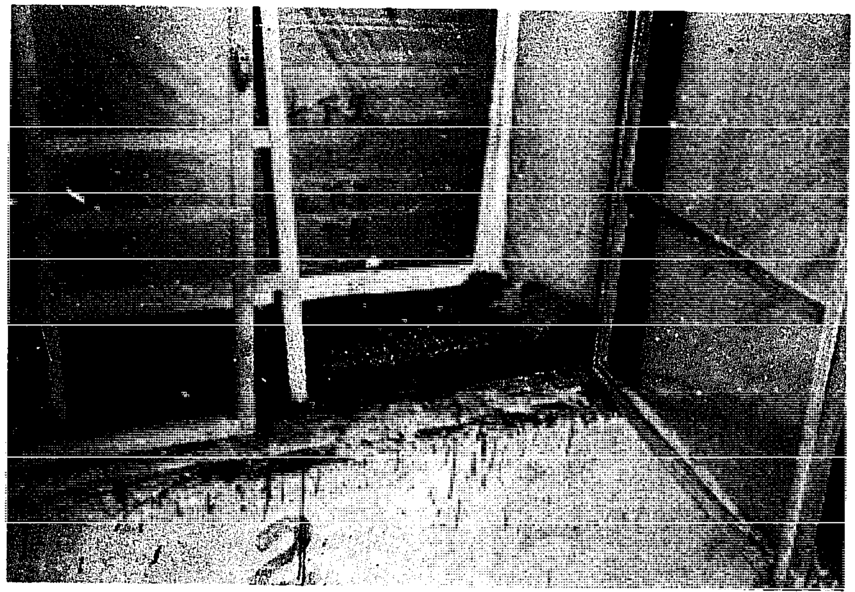


Photo 10 - Fibre mats dusted with chemical to prevent insects from entering when doors are open for ventilation (First Depot, Wuxi)

Photo 11 - Temperature registering device (thermistor) in a bulk grain store (Baoan Depot, Wuxi)

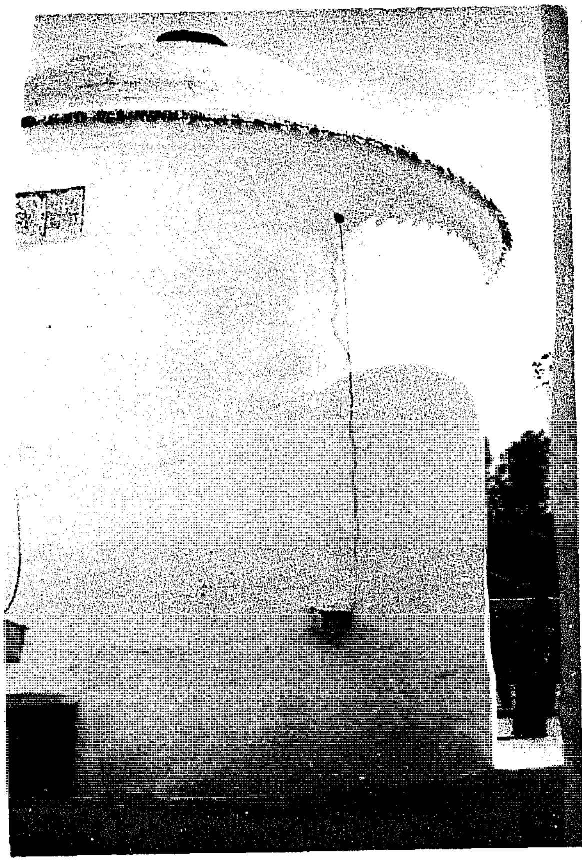


Photo 12 - Temperature registering device with check point on silo wall (Zhuang Xi Depot)

Photo 13 - Registering temperature in a clay/straw silo (South Gate Depot, Songjiang County, Shanghai)

Photo 14 - Central temperature registering panel (Baoan Depot)

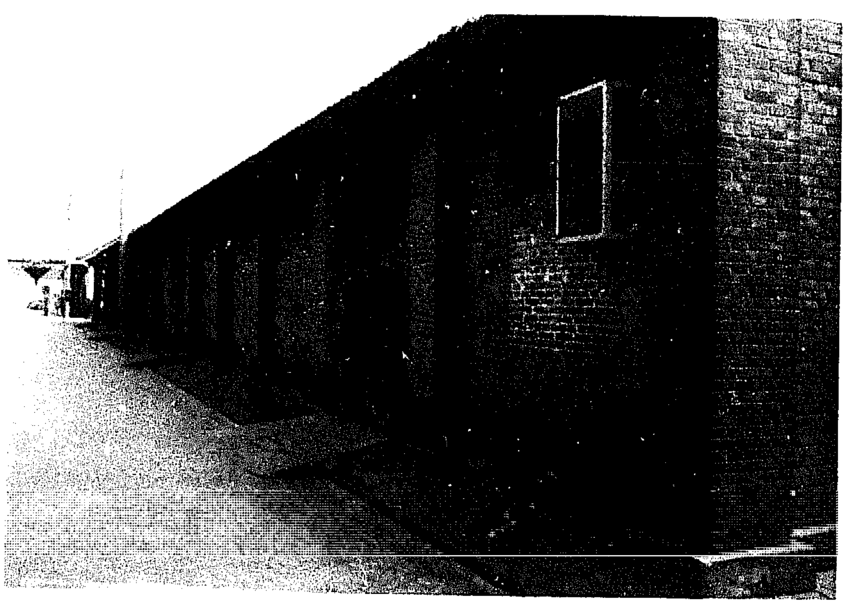


Photo 15 - Ventilation openings controlled by electric motor (Baoan Depot)

CHAPTER 4

LOCAL BUILDING MATERIALS

Some background information on the most common building materials now in use in China is given below. Particular emphasis will be given to the main material components used in clay/straw silos and warehouses.

4.1 CLAY

A very good-quality clay is available in the eastern part of China and has traditionally been used as building material, originally untreated, laid "in situ" and sun-dried, later as burnt brick or tiles. Here the guidelines given will be mainly for the use of clay in the construction of clay/straw silos.

Clay used for construction of clay/straw silos must be cohesive and have high plasticity. Distribution of particles in the fractions is as follows:

Fraction	Particle size, mm	Desirable content
Clay/loam	< 0.005	High
Loam/silt	0.005-0.15	
Sand	0.15-5.0	Low $< 5\%$

The clay has to be fine, smooth and uniform, and free from impurities such as broken tiles, roots, twigs, etc. It should be possible to roll it in the hands into very thin cylinders which do not break when bent into rings. Tests to determine the suitability of the clay for construction purposes can be carried out for consistency according to Figure 3 and for water resistance according to Figure 4. The consistency can be adjusted through the amount of water added to the clay. The water resistance, if found unsatisfactory, can be adjusted through the addition of a certain proportion of clay with high water resistance. The water resistance is of particular importance when using the clay for roof construction.

4.2 STONE

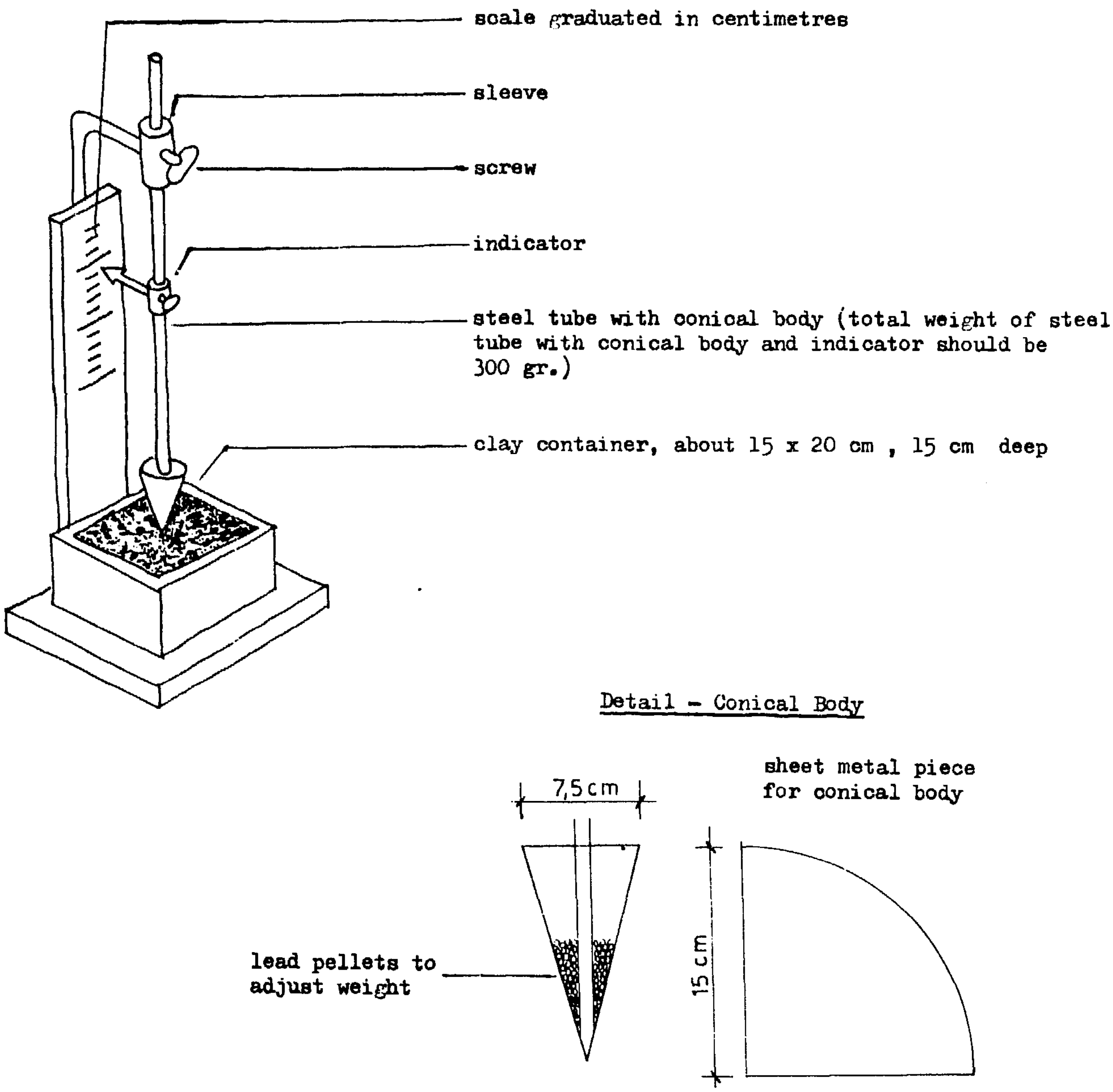
Good-quality hard stones are found in most parts of China and used for construction of foundations for clay/straw silos and for other structures as well. If not available close to the building site, transport cost may be prohibitive and other materials such as brick could be more economical for foundations.

4.3 SAND

Sand suitable for construction is usually available and collected from river beds or lakes.

4.4 BRICK

Good-quality bricks are manufactured locally in most parts of China in coal-fired ovens. The standard size of brick is 240 x 115 x 53 mm and 550 bricks are used per m^3 of masonry. The quality standards of common clay bricks are as follows:



Sinking depth in 10 seconds should be:

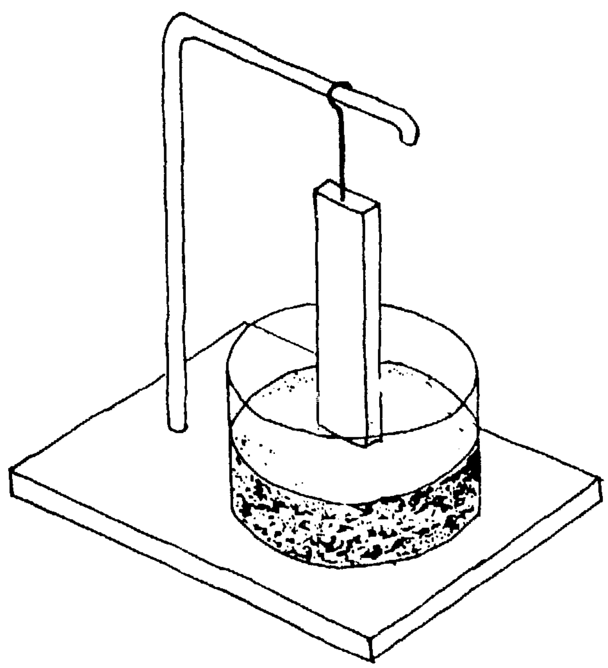
- for wall construction: 5.5 cm
- for roof construction: 4.5 cm

Figure 3 - Testing the consistency of clay

Table 7 - Quality Standards of Clay Bricks

Quality	Compressive Strength kg/cm^2		Breaking Strength kg/cm^2	
	Average 5 bricks not less than	Single brick not less than	Average 5 bricks not less than	Single brick not less than
200	200	140	40	26
150	150	100	31	20
100	100	60	23	13
75	75	45	18	11
50	50	35	16	8

Normally bricks with 75-100 kg/cm^2 compressive strength are used for warehouse construction.



A clay slab, 4 x 2.5 x 22 cm to be made in a wooden mould. After three days drying in air (20°C) or, alternatively, oven drying, the slab is suspended in a dish filled with water to a depth of 5 cm. If the submerged portion of the slab dissolves within 30 minutes, the water resistance is considered insufficient for construction purposes.

Figure 4 - Testing the water resistance of clay

4.5 TIMBER

Timber is widely used as a construction material and in nearly all warehouse construction, until recently, trusses, internal pillars, doors and windows were all wood. Bamboo poles in combination with wooden beams are used as a supporting structure for roof thatching on clay/straw silos.

4.6 STEEL

Steel is used for reinforcement of concrete and is available as plain mild steel bars or twisted bars. Steel is sometimes integrated with wood in trusses (see photograph 39). For modern large-span warehouses, portal concrete frames and prestressed concrete rafters seem to be preferred to steel trusses.

4.7 CEMENT

Cement is readily available all over China. Fifty percent of the cement used in China is produced by small local factories at commune and county level, producing from about 200 tons to 30 000 tons each per year. Although the small plants require higher investment per ton produced and have considerably smaller production per worker, the reduction in transport costs, the rural employment created and the good availability of cement all over the country speak in favour of the small plants (8).

4.8 LIME

Lime is used extensively and seems much more common as a binding agent than cement. It is used as mortar for most stone and brick work, as lime plaster on brick walls and on reed or other fibre mats and for the whitewashing of the interior of grain stores.

4.9 ASPHALT

Asphalt is commonly used for flooring in warehouses, to provide damp-proof layers and to ensure water-proofing of clay dome-roofed silos. Asphalt mortar (asphalt with an admixture of sand) and asphalt concrete (asphalt, gravel and sand) has to be prepared at a temperature of 150°-170°C and the laying of the floor takes place at about 130°C.

4.10 STRAW AND FIBRE

Straw is an important ingredient in the construction of clay/straw silos where straw is mixed with clay in weight proportions 1:7. Normally, rice straw is used for silo construction and in spite of its comparatively low tensile strength it is sufficient for the purpose. Comparative tests have given the following strengths for various types of straw.

Table 8 - Comparative Tensile Strength of Various Types of Straw

Type of straw	No. of straws	Mean breaking strength (kg)
Rice	1	7.6
	20	138.0
Millet	1	66.5
	10	245.0
Wheat	1	17.0
	20	152.0
Reed	1	55-173
	4	400-700

4.11 INSULATION MATERIAL

In low-temperature stores, polystyrene is used for roof insulation. For walls, insulation consists of a mortar with lime, perlite (volcanic material, expanded at 1 000°C) and water in proportions 1:4:0.37.

4.12 COST OF BUILDING MATERIALS

Although cost comparisons with other countries are very difficult, prices quoted are given for some of the more common building materials. In order to facilitate comparison, prices have been converted into US dollars using a conversion rate of US$100=RMB Yuan 152.13 (Bank rate, Beijing, 15 November 1979).

Table 9 - Prices of Some Common Building Materials
(usually including transport to site)

Material	Unit	RMB Yuan/Unit	Converted to US$/Unit
Stone	m^3	5-50[1]	3-33
Brick	100 pieces	5-10	3-6
Sand	m^3	12-25	8-16
Cement	ton	70-100	46-66
Lime	ton	23-25	15-17
Wood	m^3	200	131
Steel (reinforcement)	ton	500-700	328-460
Asphalt	ton	176	116
Asphalt felt	m^2	0.74	0.50
Straw	ton	50-100	33-66

[1] great variation due to transport costs.

CHAPTER 5

CLAY/STRAW SILOS

5.1 ORIGIN

Clay/straw silos are often referred to as clay dome roof silos. In recent construction, silos with a thatched roof seem to be predominant and therefore all clay/straw-walled silos, whether with a clay dome or a thatched roof, are referred to as clay/straw silos.

The method of construction used in these silos is based on an old Chinese building tradition. The first clay/straw silos were developed by farmers in Mingshui County of Heilongjiang Province in the north-eastern corner of China. Originally, these silos were used only at production team level and were built in small sizes. The original sizes were as follows:

Table 10 - Original Sizes of Clay/Straw Silos

Diameter m	Storage height m	Storage volume m^3	Holding capacity (tons) (paddy, 550 kg/m^3)
4	2	25	14
6	3	84	46
8	4	201	110

5.2 RECENT DEVELOPMENT OF CLAY/STRAW SILOS

Since 1969 a massive construction programme has been carried out and today there are about 11 million tons of grain stored in clay/straw silos. Though built in all provinces, there is a significant concentration of clay/straw silos toward the north-east, the area of origin of this construction method, as indicated on the map, Fig. 5.

The clay/straw silo today is used by depots at all levels, including large State depots. The size of each silo has therefore been developed considerably and, for example, in the Beijing area the most commonly reported sizes are:

Table 11 - Common Sizes of Clay/Straw Silos Built Today

Diameter m	Storage height m	Storage volume m^3	Holding capacity (tons) paddy 1/	wheat 2/
6	4	113	62	85
8	6	307	169	230
10	7	550	302	412

1/ volume weight 550 kg/m^3
2/ volume weight 750 kg/m^3

Figure 5 - Geographical distribution of clay/straw silos in China

Over the last 20 years, about 70 000 units of clay/straw silos have been built in China which, with a quoted total holding capacity of 11 million tons, gives an average holding capacity per silo of 157 tons. The biggest clay/straw silo built is reported to have a diameter of 15 m and a storage height of 15 m, thus having a total storage volume of 2 300 m^3, enough to hold 1 260 tons of paddy or 1 720 tons of wheat.

The silos we visited during the workshop/study tour are very representative of the range of the most common sizes built today, as illustrated in the following table (see also photos 16 to 19):

Table 12 - Clay/Straw Silos Visited

Depot	Diameter m	Storage height1/ m	Stored volume of grain m^3	Holding capacity2/ paddy tons
Zhang Xi Zhuang	6	3.25	92	50
" " "	6	4	113	60
Niou Pao Tun	7	4	154	85
South Gate	8	3.5	175	96
Baoan	8.1	5	258	140
South Gate	9	5.7	363	200
Niou Pao Tun	8.5	6.5	368	200
Zhang Xi Zhuang	8	8.5	427	230

1/is here understood as the height of the grain pile at the silo wall. External wall height at eaves is usually 3 m higher (1 m plinth + 1.5-2 m internal free height above the grain pile).
2/is normally holding capacity in terms of tons of paddy with a volume weight of 550 kg/m^3.

Other types of silos than the clay/straw type were not seen in any of the depots visited except at the Seventh Depot, Shanghai, which has a 2 400-ton silo built in brick which consists of 12 bins, each with a diameter of 6 m and a height of 12 m (see photo 62).

5.3 MAIN FEATURES

The clay/straw silo is widely accepted and distributed in China because of the following characteristics:

- low cost per ton stored grain (usually half the cost of warehouses);
- locally available material (no steel, cement, etc.);
- no specialized labour required (regular labour of a grain depot can build);
- earthquake resistance (claimed, to some extent);
- lot sizes convenient (50-250 tons/silo normally);
- protection of stored grain is good.

Originally, silos were designed only for manual handling and they were all flat-bottomed. More recently, with the introduction of larger bins at State depots, mechanical handling of grain was introduced and conical and V-shaped bottoms have been used to achieve a certain degree of self-emptying. In the silos seen, slopes were usually very moderate, about 10-15^{o} only. At railheads and other places with a very high turnover, bins are built with bottom slopes of about 40^{o}, for complete self-emptying.

For general reference, Drawings 1 and 2 are used. Drawing No. 1 shows the original type of clay/straw silo with clay dome roof. This type of silo is usually not built with a diameter larger than 6 m.

Drawing No. 2 illustrates the now commonly built clay/straw silo with thatched roof. Silos with short storage periods and those in the north are usually built without ceiling, while for long-term storage in the south a ceiling of fibre mats with lime fibre plaster is common.

5.4 FOUNDATIONS

Foundations for clay/straw silos are usually built of brick or stone, as shown in Fig. 6. (See also photos 21 and 22). Depth of the foundations and width of the footing vary with respect to soil conditions.

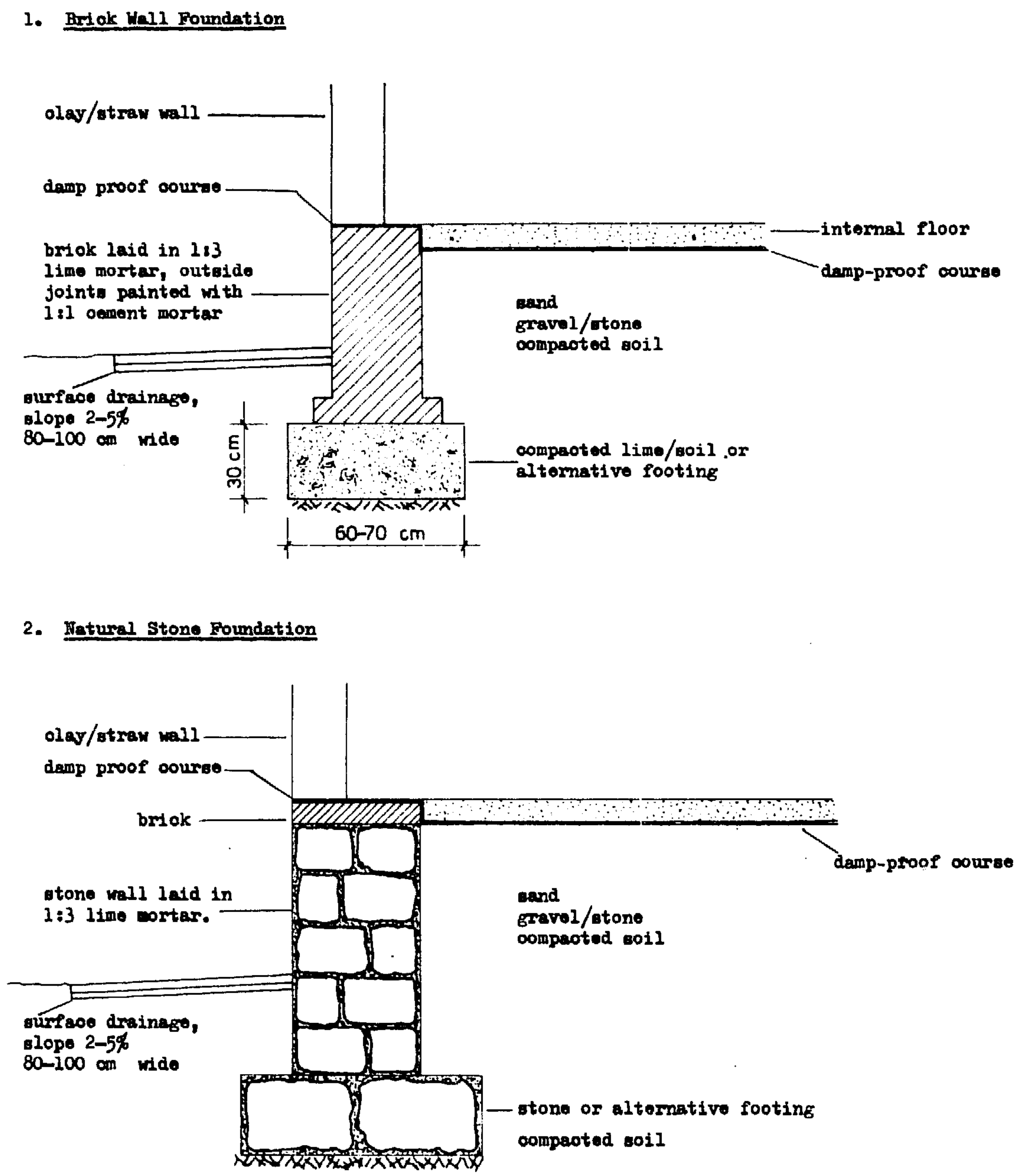


Figure 6 - Foundations for clay/straw walled silos, 1:20

Surface drains around the silo are 80-100 cm wide and serve mainly to take rainwater away from the foundations but are also important for facilitating cleaning around the silo. They could be built of brick in lime mortar on compacted soil or of a 2.5-cm thick cement mortar on a 10-cm thick bed of crushed stone or brick.

The damp-proof course, which should be continuous under wall and floor, usually consists of a layer of asphalt felt covered with one or two coats of asphalt emulsion, but could also be made of a 2-3-cm thick layer of 1:2.5 cement mortar with the addition of a 3 percent waterproofing agent (ferric chloride powder).

5.5 FLOOR

Great emphasis is placed on the construction of the floor of the silo and in particular on the damp-proofing. Although some silos still exist with only rice husk and fibre mats as damp-proofing and flooring (South Gate Depot, Shanghai, photo 20), most now have a hard floor on well compacted soil with a damp-proof course or a capillary-breaking layer. Seven alternative floors for clay/straw silos are shown in Fig. 7. It is particularly noteworthy that brick is a very popular material for flooring. This is partly due to availability but also because of its ability to absorb small amounts of moisture, and its heat-insulating properties, which prevent condensation on the surface in cases where this may occur on a concrete floor.

The roof of the channel for mechanical transport is normally made of prefabricated reinforced concrete slabs (photo 21), but can also be made as a brick arch.

5.6 WALLS

5.6.1 Wall Thickness

The wall is built from clay/straw bundles, this being the most essential and unique feature in the construction of this type of silo. The thickness of the wall is decided empirically and the following formula is used to decide the wall thickness:

Wall thickness (cm) = internal diameter of silo (m) + 12

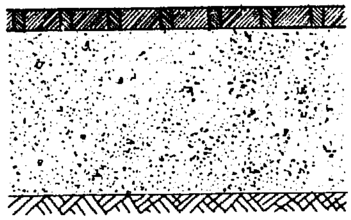
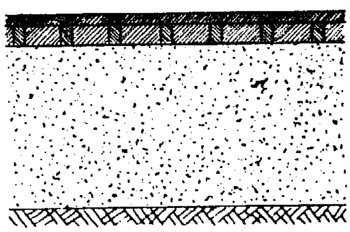
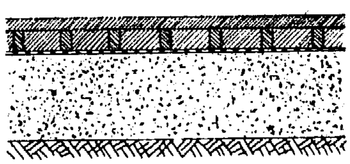
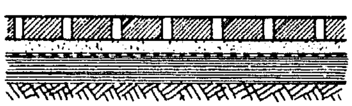
which means that for an 8-m diameter silo, wall thickness should be 8 + 12 = 20 cm.

5.6.2 Clay Mud

The clay to be used for construction should be sun-dried, then crushed and pulverized and soaked in water for one or two days. For builders without experience, it is wise to check the water resistance of the clay before selection and to check the consistency before construction, as described in paragraph 4.1. It should also be noted that the clay has to be somewhat thinner under hot and dry conditions. (See photo 23)

5.6.3 Clay/Straw Bundles

Any type of dry straw can be used, and rice straw, even in spite of its limited strength, seems to be the most commonly used in China. First, straw bundles are produced, levelled at the root ends against a level surface, and then divided into two halves. The root parts are turned in opposite directions and the two straw bundles placed together so that they overlap by about two thirds of the length of the straw. The straw bundle is then spread out flat and soaked in the clay mud, twisted and turned until every straw is covered with clay mud. A thorough covering of each straw is essential for the final strength of the wall. The straw is then twisted together and excess mud removed. The final clay/straw bundle should be thick in the middle and tapered at both ends, have a length of 80-100 cm and a diameter at the middle of about 5 cm. The ideal proportion of straw and clay on a dry weight basis is 1:7. (See photos 24 and 25)

Type	Detail	Description (layers from top)
1. Brick/sand		- Brick in lime mortar or lime/cement mortar - 300–400 mm dry sand (coarse; particle size, > 0.5 mm) - compacted soil
2. Sun dried brick with lime mortar finish		- 25 mm lime mortar finish - sun dried brick (1 course) - 150 mm dry sand bedding - kraft paper or cement bag paper with asphalt applied on top - compacted soil
3. Burnt brick with cement mortar finish		- 25 mm 1:3 cement mortar finish - brick layer (1 course) in lime mortar - 200–400 mm dry sand (coarse; particle size > 0.5 mm) - compacted soil
4. Burnt brick with cement mortar finish and damp proof course		- 25 mm 1:3 cement mortar finish - brick layer (1 course) - asphalt felt (joints sealed with asphalt - 200+ mm dry sand - compacted soil
5. "Checker"[1/] brick in asphalt mortar		- "checker" brick in asphalt mortar - 30 mm dry sand - 2–3 mm No. 4 asphalt - 60 mm 1:1:6 lime/clay/sand - compacted soil
6. Lime/slag		- 30 mm 1:2 lime/slag, well compacted - asphalt felt - 100 mm 3:7 lime/soil - compacted soil
7. Lime/soil with cement mortar finish		- 25 mm 1:3 cement/sand screed with 3% water proofing agent (ferric chloride) - 100 mm 3:7 lime/soil - compacted soil

1/ a special quality of brick

Figure 7 - Floors for clay/straw silos

5.6.4 Construction

The clay/straw bundles are placed on the wall usually according to one of the patterns shown in Fig. 8. The "straight laying" method seems to be preferred as being the easiest.

The wall must be built in separate layers, usually about 20 cm high, and then left to dry out to about 50 percent moisture content before the next layer can be built. In general, during dry weather, about 20 cm wall height can be built each day, but work must be halted on wet days. If too much is built every day or if a consecutive layer is placed before the previous layer has dried out sufficiently, the result will be a distorted wall. (See photos 26-30)

5.6.5 Roundness of the Silo

The roundness of the silo has to be checked continually during the whole time of construction. Usually, this is done by fixing a round pole at the centre of the silo and fixing on it a distance rod with a sleeve. The roundness can then be checked by turning the distance rod.

5.6.6 Vertical Walls

Both sides of the wall must also be absolutely vertical and this should be checked continually during the whole construction with a plumb line.

5.6.7 Levelling Off Each Layer

Each layer of the wall must be finished completely level. If a layer is left with a round top surface the result will be a bulging wall.

"straight laying"

"cross laying"

Figure 9 - Methods of placing the clay/straw bundles when constructing the wall

5.6.8 Compaction for High Density

The compaction of the wall continuously during construction to ensure a solid wall is absolutely necessary in order to arrive at a strong, durable silo wall. Compaction is done firstly by pressing by hand and then with a wooden hammer and by some kind of pressing die, which also controls the thickness of the wall. The density of the wall should be 966 g/cm^3 and settlement should not exceed 1 percent if the wall has been well compacted. As an example of the good quality of the clay/straw wall, it is quoted that in Jiangsu Province a clay/straw silo, after two weeks of flooding with water 1.4 m deep, was undamaged and the interior still dry. This quality of wall can only be achieved if the compaction during the whole construction time is carried out with the utmost care.

5.6.9 Alternative for Greater Strength

An interesting alternative method for wall construction is being tried in the Guangding region. The straw:mud dry weight ratio is 1:12 and 20 percent sand and 2 percent lime are added to the dry mud. This method is claimed to increase considerably the density and strength of the wall.

5.6.10 Plastering Inside

After proper settlement and drying, the inside of the wall is smoothed off with clay and covered with lime plaster to seal crevices and porous spots.

5.7. ROOF

Although the thatched roof seems to have become the most common in later construction and is the easiest to build, a short description will also be given of the construction of the original clay dome roof as this could be of particular interest for small farm-size units of clay/straw silos. As this method of construction was not practised during the workshop and no clear specifications are available, the description is not satisfactory to serve as guidance for construction of large domes for builders without previous experience of this type of structure. For small-scale construction and as a basis for its development, the description might be useful. It must be stressed that construction of the clay dome requires a lot of skill and experience and is not likely to be successful when tried for the first time.

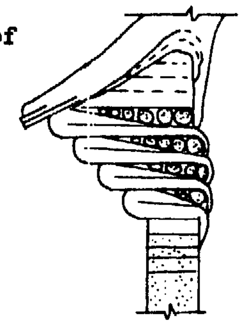
5.7.1 Construction of the Eaves

The eaves form the base and support for the rather heavy clay dome and also create the roof overhang to protect the walls from water. The construction of the eaves is illustrated in Fig. 9, showing in section how the clay/straw bundles are placed and in plan the method of interweaving perpendicular clay/straw bundles with those running parallel to the wall. This method of construction allows a level top surface to be maintained on each layer during the construction of the eaves. (See photos 32 and 33)

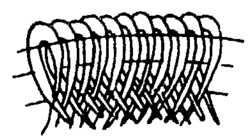
5.7.2 Shape of Clay Dome Roofs

A clay dome roof is a shell structure and various shapes have been tried to reduce internal forces and forces acting on the eaves. The height of the dome is usually about equal to the radius of the silo (50 percent of the diameter) but higher domes are easier to construct and give a better run-off for water. In areas where a high-quality roofing material, such as tiles, is used and where the necessary skill and experience in dome construction are present, domes with a height of 35 to 45 percent of the diameter have been built.

The two most common and recommended shapes of the clay dome are a "corrected parabola" shape and a "pointed arc" shape, but also semi-circular domes are used.



Section



Plan

Figure 9 - Construction of the eaves

Each layer gives an overhang of 6-8 cm, thus with 5 layers a total of about 30 cm. Clay/straw bundles parallel to the silo wall fix the folded bundles.

5.7.3 Clay Dome Construction

The method of construction of the dome is illustrated in Fig. 10. The thickness of the roof at the base is about wall thickness and is then tapered off to about half this thickness at the top of the dome. The placement of the clay/straw bundles is shown in the cross section and the side elevation is shown in the same figure.

The mud used for roof dome construction should be somewhat thinner than that used for wall construction and the clay/straw bundles somewhat finer, 3 to 4 cm in diameter at the centre when starting from the base and then progressively reduced as the roof thickness is reduced.

A foot for the arch is built up on the level surface of the eaves and then the bundles are placed as shown in Fig. 10, in an inclined straddling position, each course changing direction.

For the roof dome, the construction must also be limited to about 20 cm per day to allow each layer to dry and consolidate properly.

Clay dome roofs must be waterproofed after they have been properly dried and settled. Methods of waterproofing in use are:

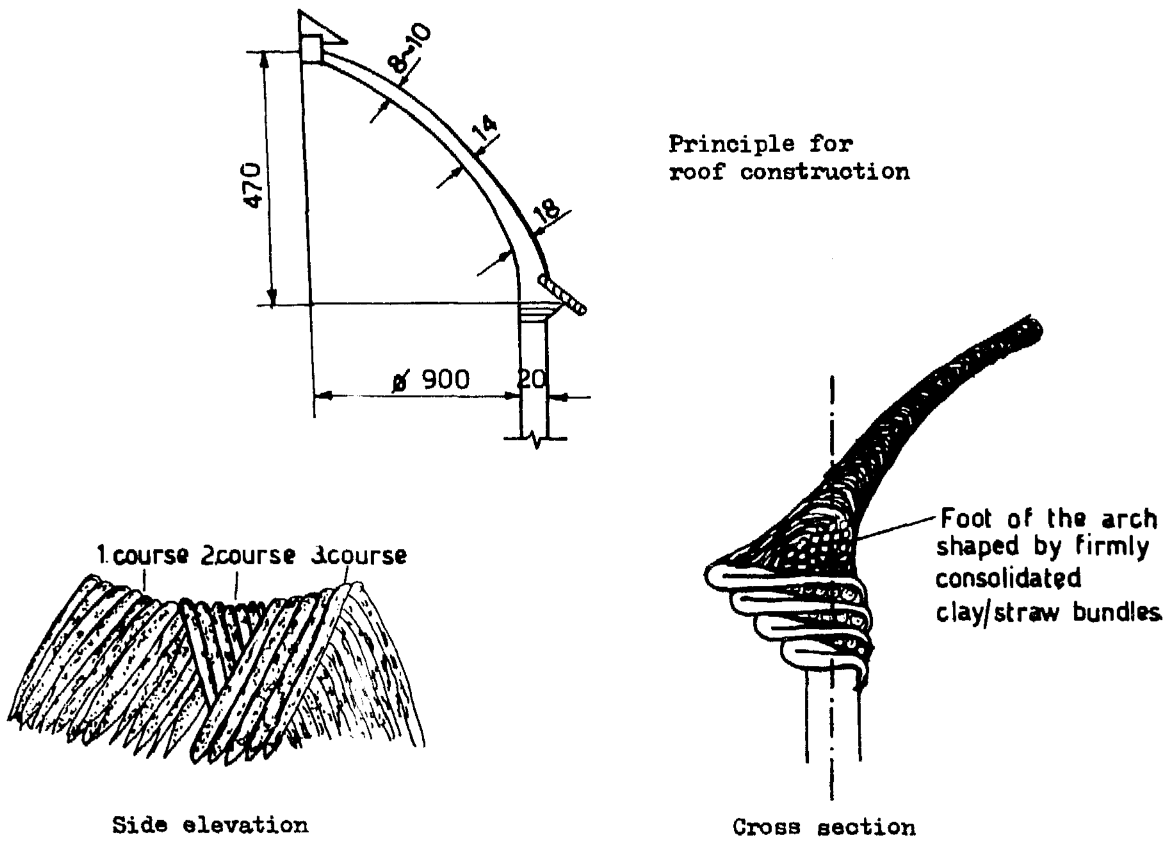


Figure 10 - Clay/straw dome roof

Thickness at the base is the same as that of the wall, tapering off to half this thickness at the roof top. Detail showing placement of clay/straw bundles to build up the roof.

- Thatching with straw;
- Tiles placed in straw-reinforced lime mortar;
- Roofing felt fixed with asphalt and coated with a layer of asphalt mastic and fine gravel (the most common method).

A sophisticated waterproofing method for clay domes has been developed at the South Gate Depot, Shanghai. The layers of coating, in order from the clay surface outward, are as follows:

- Asphalt
- Asphalt felt
- Asphalt
- Fibre cloth (hemp or jute)
- Asphalt,
- Gravel
- Whitewash (300 kg lime with 5 kg alum and 2.5 kg bone glue).

5.7.4 Thatched Roofs

Thatched roofs are light and the necessary roof overhang is created by the roof itself, which makes eaves unnecessary. Usually, the roof supporting structure is built of timber braces fixed with wooden dowels in the clay/straw wall (see Drawing No. 2). Between the wooden braces are fixed braces of bamboo or other light material. After a supporting roof structure has been completed the roof is covered first with reed mats and then finally thatched with locally available thatching material. (See photo 34)

In some areas the thatch, usually reed, is plastered with a layer of mud which in turn is covered with lime mortar. On top of the lime mortar another layer of thatch is placed for waterproofing.

5.7.5 Ceilings

Silos with thatched roofs should usually have a ceiling to create a clean and smooth internal surface which is easy to clean and disinfect when required. In the north, where the insect problem is not so serious, and for silos with high turnover and short storage periods, many silos do not have ceilings.

Ceilings are made of reed mats or other fibre mats plastered with lime/jute plaster or other lime/fibre plaster.

5.8 OPENINGS

Openings are kept to a minimum but every silo usually has some of the following:

1. Ventilation openings
2. Inspection and entrance doors
3. Opening for mechanical conveyors
4. Opening for manual grain removal
5. Temperature control openings
6. Ventilation cowl.

Usually, openings 1 to 4 above are made with wooden frames and wooden doors. In order to fix frames firmly and not to weaken the silo wall the fixing of the frames is very important and is illustrated in Fig. 11. "Pull rods" of metal or wood are fixed on the sides of the frames and the clay/straw bundles are twisted around these "pull rods" to ensure full strength of the wall.

The silo wall will settle when drying, while the frames for openings maintain their original dimensions. This must be provided for as otherwise separation will occur in the wall at the sides of the openings or the frame may tilt when the wall has settled. Therefore, a "cushion" 3-5 cm thick should be placed below the lower horizontal member of the wooden frame. This cushion can be removed when construction has reached the upper horizontal member of the frame and the frame then has the required space for settlement in the wall.

5.8.1 Size of Ventilation Openings and Doors

Ventilation doors are placed in the wall, well above the level of the grain pile. They should be located for maximum efficiency with respect to prevailing winds. If the silo is filled by mechanical conveyor the same opening could serve both for ventilation and for filling the silo. A 58 x 68 cm opening is sufficient for this purpose.

If the silo is also filled manually, a larger opening, 120 x 80 cm, is required. Two or three ventilation openings are usually provided for each silo.

When grain is removed manually from the silo, a door with an opening 90 x 190 cm is provided. If the grain removal is mechanical and workers have to enter only to clean out the remainder at the bottom of the silo, an opening 60 x 60 cm is usually provided about 1 m above the internal floor level.

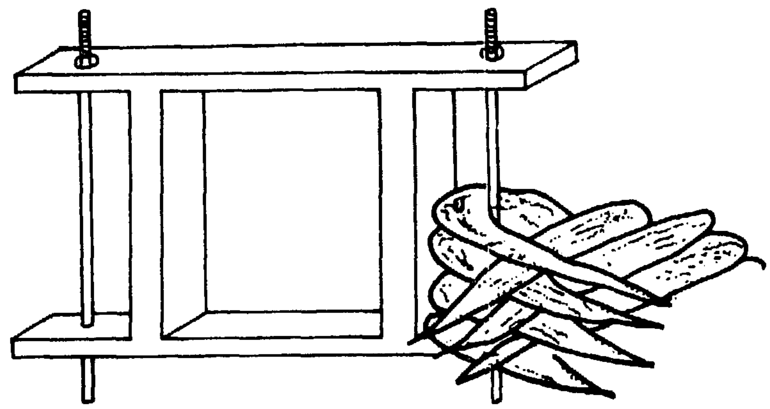


Figure 11 - Fixing of door and window frames in fixing rods of wood or metal, around which the clay/straw bundles are twisted

5.8.2 Other Openings

For manual grain removal the silo usually has bagging spouts which are located in the silo wall or in the door.

For sampling of grain and for temperature measurements, openings are sometimes provided as shown in Fig. 12.

On clay dome roof silos a ventilation cowl is usually provided as shown in Fig. 13. The ventilation cowl is installed to remove small amounts of moisture which may form through the respiratory activity in the grain. The "inverted plate" type of cowl as shown in Fig. 13 can be closed, is bird and rain proof and has a "ceiling" to avoid condensation dripping down on the grain in the silo.

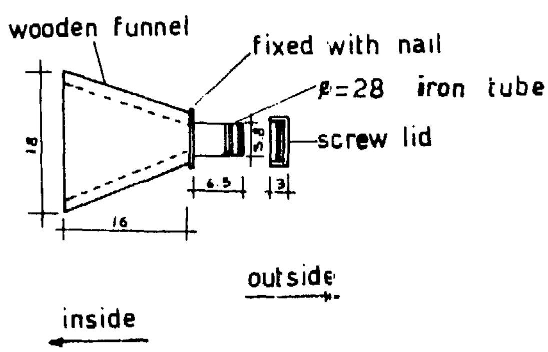
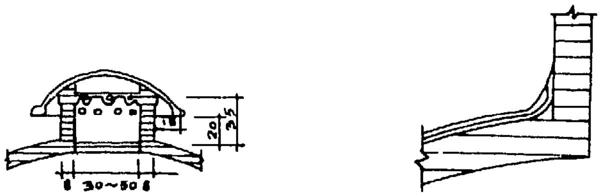


Figure 12 - Opening for temperature measurement and grain sampling



Ø 30 cm for 3–5 m diameter silos and
Ø 50 cm for 6–8 m diameter silos.
Note careful sealing between roof and chimney.

Figure 13 - Ventilation cowl

5.9 WATERPROOFING OF SILO WALLS

Waterproofing of silo walls is usually carried out during the season after construction of the silo. It is necessary to first let the clay/straw wall dry out and reach a water content of 4 percent or less and to allow all possible settlement. One method of waterproofing is by nailing rice straw "fringes" to the silo wall (see photo 37). Another method is shown in Fig. 14 and in photos 35 and 36. Wooden laths are mailed to the silo wall and reed mats are wrapped around the silo and nailed to the wooden laths. On top of the reed mats two layers of lime/fibre (usually jute fibre) plaster is applied. Various methods of direct plastering of the outside wall have been tried but have not been found satisfactory, while the two above-mentioned methods seem to be preferred.

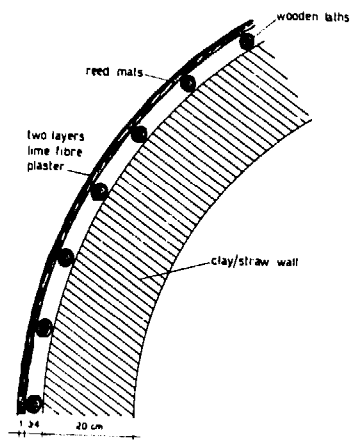


Figure 14 - Waterproofing of clay/straw silo wall

5.10 COST OF CLAY/STRAW SILOS

5.10.1 Labour

Labour requirements for a clay/straw silo of 7 m diameter and storage height of 4 m, as shown in Drawing 2, are about 400 working days (i.e., 400 working days x 8 h = 3 200 man hrs). Usually, construction requires about one month for a team of about 15 men. It is not possible to speed up construction as each consecutive layer of the wall has to be allowed time to dry out before the next layer can be built. The working capacity of a team is usually sufficient to build two or three silos at the same time.

The cost of labour in the Beijing area was quoted as follows:

Worker (country)	1-1.5 Yuan/day (US$0.66-0.99/day)
Worker (city)	1.7 Yuan/day (US$1.12/day)
Foreman	2.0 Yuan/day (US$1.31/day)

Comparative prices in US dollars have been indicated using a conversion rate of US$1 = RMB Yuan 1.5213.

5.10.2 Cost per Ton Storage Capacity

Cost of clay/straw silos with about 100 tons holding capacity in the Beijing area is quoted at about 30-40 Yuan per ton (US$20-26 per ton). A 100-ton silo thus costs about 3 000-4 000 Yuan to build, about 25 percent of the cost being labour and 75 percent building materials. The conversion into US dollars may not be very meaningful but an indication of the cost advantage is useful for a comparison with warehouse construction; the building cost per ton of stored grain in the clay/straw silo is about half that for warehouse construction.

5.10.3 Material and Labour Costs for a 75-ton Clay/Straw Silo

The cost of material and labour for a clay/straw silo as shown in Drawing No. 2 was given as follows:

Table 13 - Material and Labour Costs for a Clay/Straw Silo of 7 m Diameter (Storage Capacity 75 tons of paddy or 100 tons of Wheat)

Item	Unit	Quantity	Unit Price Yuan	Total Yuan
Stone	m^3	31.5	25	790
Lime	ton	3.5	23	80
Cement	ton	1.8	70	126
Sand	m^3	18	12	216
Bricks	ea.	2 100	0.10	210
Asphalt	ton	0.1	196	20
Asphalt felt	m^2	50	0.74	37
Straw	ton	2.5	100	250
Reed mats	ea. [1]	24	6	144
Reeds	bundle	110	3	330
Wooden rods	ea.	120	1	120
Labour	day	400	1.80	750
				3 073

[1] 3.30 x 1.70 m each.

This silo for 100 tons of wheat or 75 tons of paddy has, according to the above estimate, a unit cost per ton of storage capacity of 30 Yuan for wheat and 40 Yuan for paddy.

The prices quoted include cost of transport to the building site but variations can be considerable here, particularly for stone, sand and brick.

The labour cost in this example is exactly 25 percent of the total cost. It should be noted that under circumstances where labour rates are $6/day (9 Yuan), the cost of the silo doubles and labour cost is 60 percent of total cost.

5.11 POTENTIAL OF THE CLAY/STRAW SILO

5.11.1 In China

The clay/straw silo has undoubtedly played a very important role in the Chinese grain-handling system and offers an alternative which is technically sound and economically feasible.

The main technical problems have been the construction of the clay dome roof, especially for large-diameter silos, and the maintenance required to avoid moisture damage on roof and walls. Since the clay dome roof has mainly been replaced by thatched roofs and waterproofing as described under para. 5.9 seems to offer a satisfactory solution, these two main technical problems appear to have been resolved or at least avoided.

With the experience and the highly developed skills in clay/straw construction, it seems that the clay/straw silo will play an important role in further extending grain storage capacity in China, particularly at commune level and lower levels in the grain-handling system. If the fixed labour of the depot can be used, the very high labour requirements in the construction of clay/straw silos may be acceptable. For the large city depots and purchase and supply stations with a high turnover and comparatively high labour rates the economic feasibility of the clay/straw silo already seems questionable (see para 6.6). Where large lots are to be stored and handled, modern warehouses seem to offer a competitive alternative.

The very large clay/straw silos which have been tried may be feasible for the large depots, provided that the roof construction and other technical problems can be solved. With the presently common sizes of clay/straw silos ranging from 100 to 200 tons per unit, the transport and handling as well as control of the grain are elaborate for a large depot, and the utilization of the site area is very low with a high requirement for additional investments in internal roads, drainage, fencing, etc.

5.11.2 The Pakistan Experience

To promote low-cost, appropriate construction, the Government of Pakistan invited a team of Chinese experts in April 1977 and three clay/straw silos were built at Manga, 25 km from Lahore along the Lahore-Multan road. The results of this construction experiment were published and were presented at an International Seminar on Low-Cost Farm Structures held at Peshawar University, 27 February to 4 March 1978 (9). The three silos built were the following:

1 and 2: 3.3 m diameter, 3.45 m high, 22-ton storage capacity (wheat)
3: 6.6 m diameter, 4.50 m high, 100-ton storage capacity (wheat).

All three silos were built with dome roofs plastered with a cement-lime-sand-mud mortar 1:2:2:4, and further covered with bitumen felt and bitumen emulsion.

Walls are 20 cm thick for the 3.3-m diameter silo and 25 cm for the 6.6-m diameter silo, and are waterproofed by a cover of reed sheets plastered with a mud-lime-straw plaster 4:1:1.

It appears that the silos were built using building contractors and the final prices were accordingly high. Originally anticipated to be about Rs. 100 per ton (about US$10 per ton), the final cost of the three silos proved to be Rs. 550 per ton (about $55) which is higher than the cost of a conventional brick building with GCI roof in Pakistan for the same amount of grain. It has been anticipated that if clay/straw silos were built by farmers in rural areas of Pakistan the cost would be about Rs. 225 per ton (US$22.50 per ton) which would be feasible. From the bills of quantities presented it appears that the Pakistani design of clay/straw silos is more sophisticated than the normal Chinese design with considerably larger amounts of brick and cement in the structure than are used in China.

Some indication has recently been obtained that the three clay/straw silos at Manga have now been abandoned because of moisture problems. Unfortunately no official report is at present available to say if and why the use of the clay/straw silos has been discontinued.

5.11.3 In Developing Countries

The clay/straw silo has no doubt a great potential to serve as a low-cost functional storage container for grain in many developing countries, particularly in areas where there already exists a tradition of building with mud and some type of fibre reinforcement.

The Pakistani experience seems discouraging but should be followed up to analyse what went wrong. The obvious lessons to be learned from it seem to be:

(i) The clay/straw silo is feasible only when built without involvement of the commercial building industry. Farm and village construction and country depots, where local labour and the required stone, clay and straw are available, seem priority areas for further pilot projects.

(ii) Local adaptation will be necessary in most places and the techniques used should relate as closely as possible to already existing tradition.

(iii) Already existing local structures should always be considered first and the performance and cost of the clay/straw silo, or a modification thereof, should be compared with existing local structures.

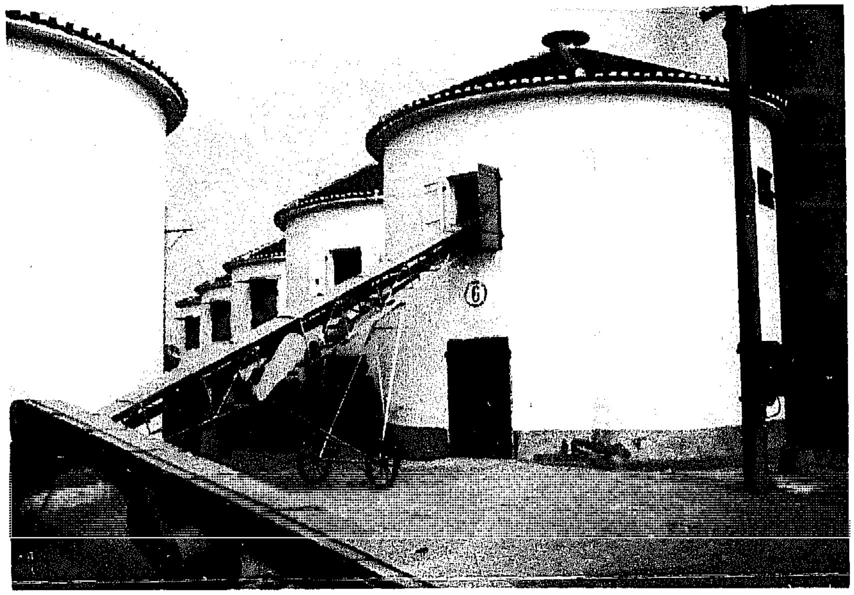


Photo 18 - *Clay/straw silo with tile-covered clay dome, 8 m diameter. Holding capacity 125 tons paddy. Door at ground level for manual removal of grain. (Baoan Depot)*

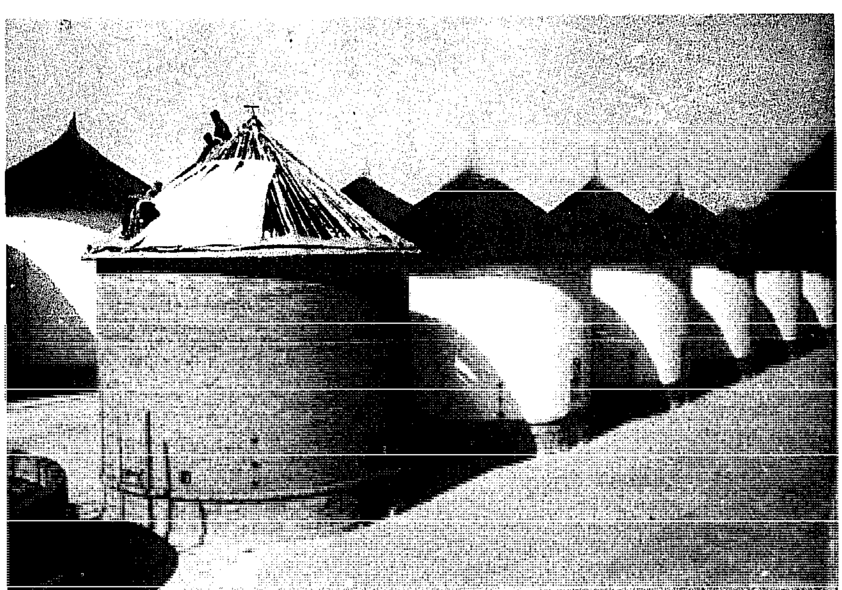


Photo 19 - *Clay/straw silo with thatched roof (see Drawing No. 2). Diameter 7 m, holding capacity 75 tons paddy or 100 tons wheat. Central channel for mechanical removal of grain. (Niou Pao Tun Depot)*

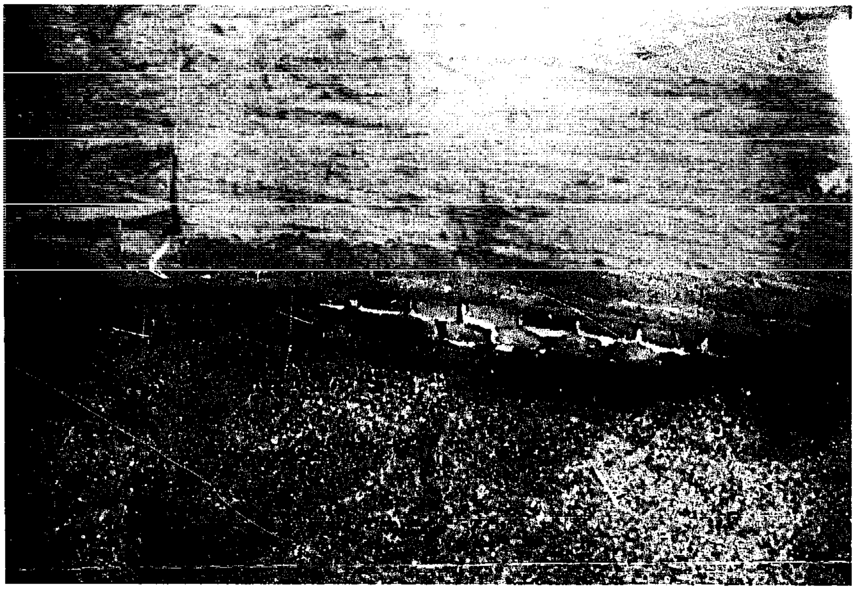


Photo 20 - Rice husk as damp-proof course in clay/straw silo. A 10-15 cm layer of rice husk on a one-layer red sheet (South Gate Depot, Shanghai)

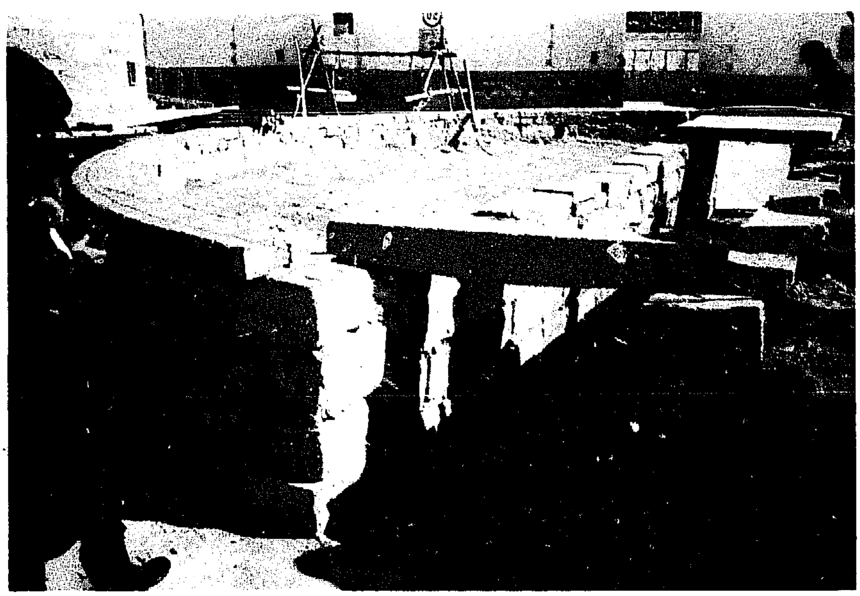


Photo 21 - Stone foundation with two layers of brick. Central channel for mechanical removal of grain. Covered by prefabricated concrete slabs. (Niou Pao Tun Depot)

Photo 22 - Placing a brick layer on top of stone foundation wall (Niou Pao Tun Depot)

Photo 23 - Dry clay before soaking and working into a plastic mud (Niou Pao Tun Depot)

Photo 24 - Mud in half oil drum. Water being added to adjust consistency. Clay/straw bundles hanging above drum. (Niou Pao Tun Depot)

Photo 25 - When straw bundles are thoroughly covered with clay mud, excess mud is removed. (Niou Pao Tun Depot)

Photo 26 - Clay/straw bundles being placed according to "straight-laying" method. (Niou Pao Tun Depot)

Photo 27 - Tools required for construction of the silo wall: wooden hammer, wooden trowel and pressing dye, here made from tubes, which also controls thickness of the wall. (Niou Pao Tun Depot)

Photo 28 - Compaction and levelling of the wall are absolutely essential to arrive at high-quality wall. (Niou Pao Tun Depot)

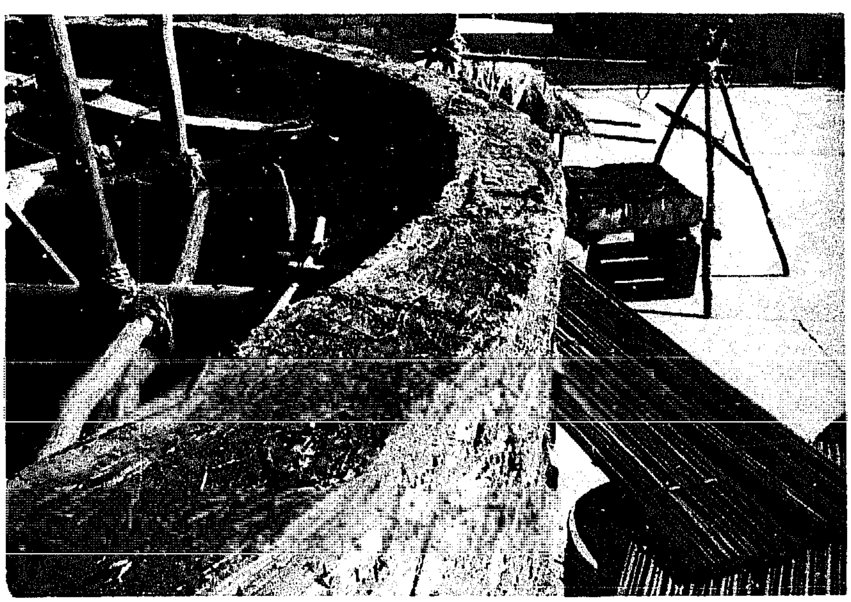


Photo 29 - 20 cm thick silo wall. Density of the clay/straw wall must be 966 g/cm^3 or more.

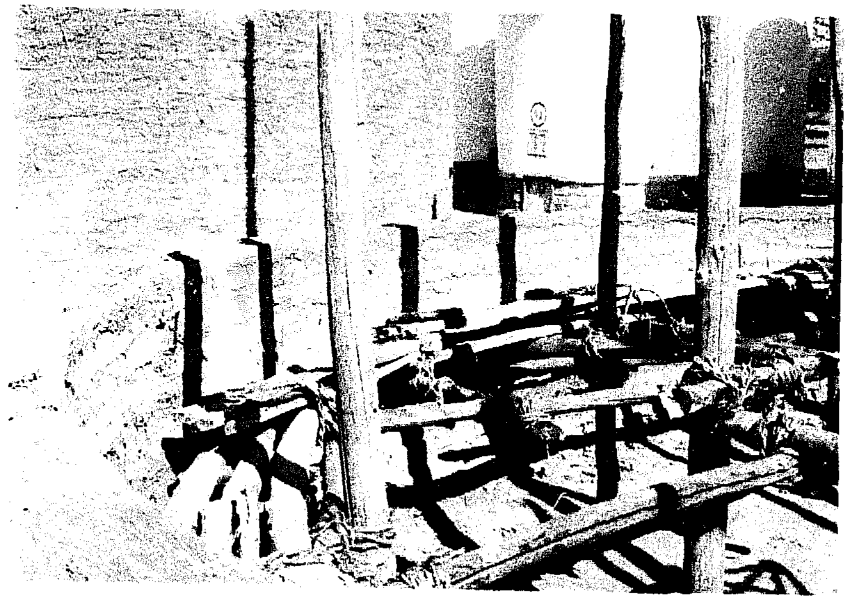


Photo 30 - Working platforms inside silo (Niou Pao Tun Depot)

Photo 31 - Fixing door frame in silo wall. Note the space left below window frame (3-5 cm) to allow for the clay/straw wall to settle. (Niou Pao Tun Depot)

Photo 32 - Construction of eaves. The first layer has been placed and second layer is being started, with the clay/straw bundles turning in the opposite direction. (Niou Pao Tun Depot)

Photo 33 - Third layer of eaves. The top surface must be kept level by placing clay/straw bundles along the wall. (Niou Pao Tun Depot)

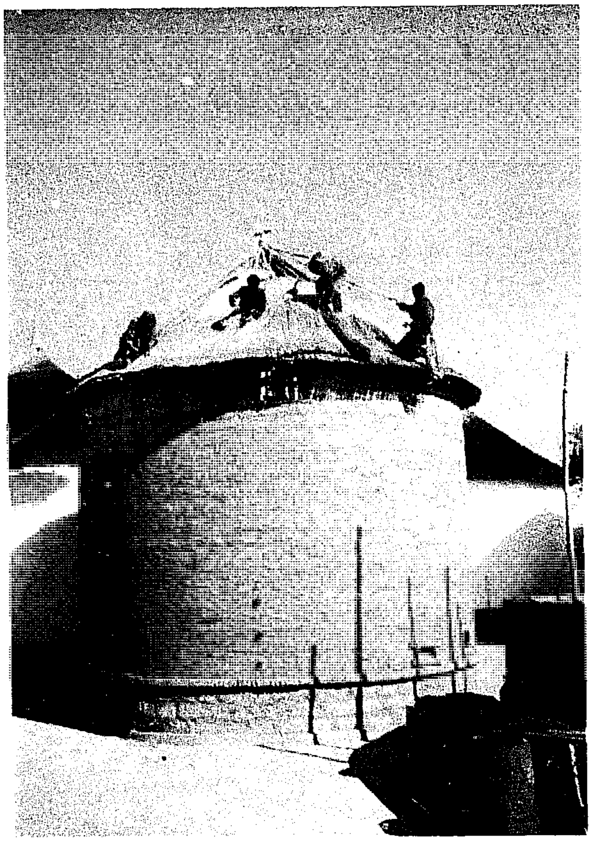


Photo 34 - Thatching of clay/straw silo. Reed bundles are placed on top of fibre mats. (Niou Pao Tun Depot)

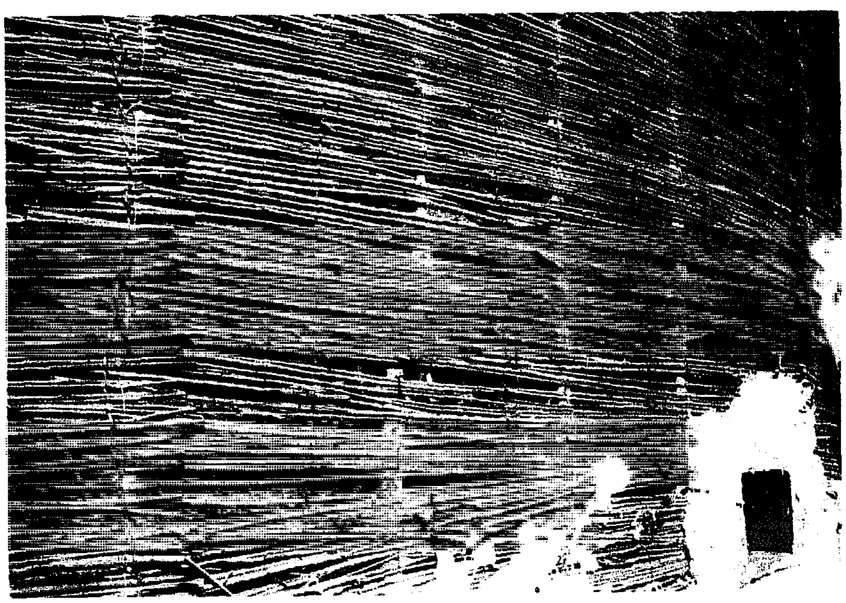


Photo 35 - Waterproofing of silo wall. Reed mats fixed on wooden laths. (Niou Pao Tun Depot)

Photo 36 - Reed mats are plastered with two layers of lime/fibre plaster. (Niou Pao Tun Depot)

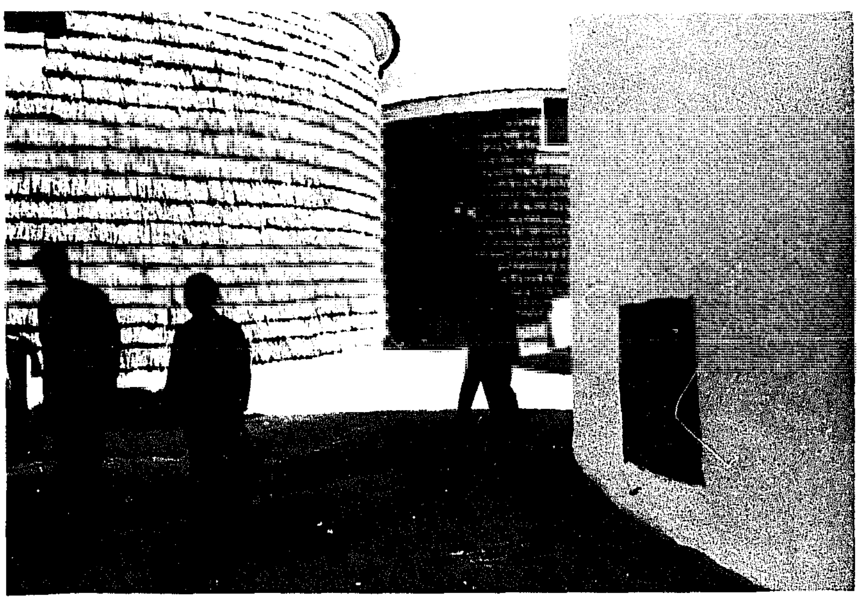


Photo 37 - Alternative method of waterproofing silo walls. "Fringes" of rice straw are fixed on the clay/straw wall. (South Gate Depot)

CHAPTER 6

WAREHOUSES

The warehouse is the most common structure for grain storage in China at all levels of depots. The production team has a small warehouse for storage of seed. Commune and county-level stores, as well as the large State depots, all have the warehouse as the basic structure.

6.1 MAIN FEATURES OF CHINESE GRAIN WAREHOUSES

The main types of warehouses studied are summarized in Table 14, which gives the structural features, and in Table 15, which gives dimensions and data concerning utilization.

6.1.1 Building materials

Brick, wood and lime are the main building materials. Asphalt and asphalt felt are used for moisture proofing which is carried out with great care. Floors are always raised 30 cm or more above ground level. Roof cladding is tiles laid in mortar on reed mats. (Photo 38)

6.1.2 Design

The designs are based on a simple brick structure without a concrete frame (pillars and beams). Pillars and buttresses are built of brick and reinforce the wall enough to take the lateral pressure from the grain pile. Reinforced concrete has been used sparingly and only to reinforce the lower part of the brick wall (Reformed "54"). Clear-span buildings have been used for building widths up to 12 m, while for wider buildings internal pillars are required. Only in later designs (Drawings Nos. 9, 10 and 11) (photos 47 and 50) have wider clear-span buildings been developed, with widths of 18-20 m.

All types of warehouses have a ceiling (photos 39 and 41), usually built of lime-plastered reed mats, or some kind of roof insulation or a double-skin roof.

6.1.3 Doors and Windows

The number of doors is high, to allow easy access with mobile mechanical equipment. In the large-span warehouses there are normally doors on both sides. Doors are also used extensively as ventilation openings. Dimensions of doors are small, 1.2-2.6 m wide and 2.2-3 m high. Windows are divided into many small units, 1-1.2 m wide and 0.6-0.8 m high. All windows can be opened and, together with the doors, serve to ventilate the building. Sometimes the windows can be controlled manually from ground level (photos 42 and 48), or by an electric motor (photo 15). The window area is recommended to be at least 5 percent of the wall area but, as is shown in Table 14, there is great difference between the various types of warehouses

Table 14 - WAREHOUSES: Description

AREA	BEIJING		
COUNTY	SHUNYI		
DEPOT	ZHUANG XI		
TYPE	Bulk	"50" Bulk	Reformed "51" Bulk
Foundation	50-cm brick wall on 30 x 100 cm lime/clay footing. Damp-proof course at floor level	According to local conditions	According to local conditions
Building Frame			
1. Columns			
- Wall	-	Buttresses (2) at gable walls	Buttresses 100 x 50 cm outside the brick wall at cc 290 cm
- Internal	-	Four for each truss. Wood	-
2. Trusses	cc 150 cm. Wood and steel	cc 420 cm. Round wood	cc 420 cm. Wood and steel
Floor	Brick (or 8 cm concrete 100 kg cement/m^3) 2 layers asphalt felt, 15 cm 3:7 lime/clay mortar on compacted soil	Wood	Bricks + 2 layers of asphalt felt + 10 cm concrete on compacted soil
Wall	37-cm brick wall (1½ stone) joints 1:3 lime/sand mortar	37-cm brick wall; internal wall wooden plank	37-cm brick wall, normally plastered and whitewashed
Roof	Tiles on two layers of reed mats with clay/fibre plaster; purlins round wood, ∅ 5-6 cm, cc 20 cm	Tiles on clay/reed; purlins wood	Tiles on clay/reed; purlins wood
Ceiling	Plastered reed mats	Wood	Wood

WUXI			
WUXI			
FIRST DEPOT			
"51" Bulk	"53" Bulk	"54" Bulk	Reformed "54" Bulk
According to local conditions	According to local conditions	According to local conditions	According to local conditions, normally reinforced
Brick columns 37x49 cm outside brick wall, cc 350 cm. Buttresses between columns and at gables	-	-	Buttresses 49 x 49 cm outside the wall, cc 350 cm
-	Two for each truss. Wood	Two for each truss. Wood	-
cc 350 cm. Round wood	cc 410 cm. Round wood	cc 350 cm. Round wood	cc 350 cm. Steel
1.5 cm asphalt mortar. 3.5 cm asphalt concrete 15-20 cm coarse concrete	1.5 cm asphalt mortar. 3.5 cm asphalt concrete. 15-20 cm coarse concrete	1.5 cm asphalt mortar. 3.5 cm asphalt concrete. 15-20 cm coarse concrete	1.5 cm asphalt mortar. 3.5 cm asphalt concrete. 15-20 cm coarse concrete
49-cm brick wall	37 cm ($1\frac{1}{2}$ stone brick wall widened to 49 cm at the lower part)	49-cm (2-stone) brick wall	37 cm brick wall; lower part supported by 15-45 cm reinf. concr.
Tiles on clay/reed; purlins wood	Tiles on asphalt felt, and mortar on reed matting with wooden rafters and purlins	Double skinned, outside tiles on asphalt felt. Wooden rafters and purlins, wooden boards	Tiles, reed, asphalt
Plaster on reed	-	-	Horizontal ceiling of fibreboard

		SHANGHAI	
		SONGJIANG	
		SEVENTH DEPOT	
"54" Bulk	Reformed "54" Bulk	Prefab Prestressed Truss Bags	Prefab Portal Frame Bags
According to local conditions	According to local conditions, normally reinforced	According to local conditions	According to local conditions
-	Buttresses 49 x 49 cm outside the wall, cc 350 cm	Brick columns. Buttresses 49 x 49 cm laid with cement mortar, cc 400 cm	Prefab. reinforced concrete portal frames, cc 400 cm. Buttresses up to 3 m height between frames and at gables
Two for each truss. Wood	-	-	-
cc 350 cm. Round wood	cc 350 cm. Steel	cc 400 cm. Triangular in prestressed concrete, with steel tie rod.	cc 400 cm. Portal frame, prefabricated reinforced concrete
1.5 cm asphalt mortar. 3.5 cm asphalt concrete. 15-20 cm coarse concrete	1.5 cm asphalt mortar. 3.5 cm asphalt concrete. 15-20 cm coarse concrete	1.5 cm asphalt mortar. 10 cm. concrete (150 kg/m^2). 10 cm broken bricks	1.5 cm asphalt mortar. 10 cm concrete (150 kg/m^2). 10 cm broken bricks
49-cm (2-stone) brick wall	37 cm brick wall; lower part supported by 15-45 cm reinf. concr.	37 cm brick wall laid with cement mortar. Inside plastered	37 cm brick wall laid with cement mortar. Inside plastered
Double skinned, outside tiles on asphalt felt. Wooden rafters and purlins, wooden boards	Tiles, reed, asphalt	Tiles on asphalt felt, and reed screen with plaster. Wooden laths on prestressed concrete purlins	Tiles on asphalt felt on 15 mm wooden board supported by U-shaped reinf. concrete slabs 12 x 74 cm between trusses
-	Horizontal ceiling of fibreboard	-	-

Table 15 - WAREHOUSES: Dimensions and Utilization

AREA	BEIJING	WUXI						SHANGHAI	
COUNTY	SHUNYI	WUXI						SONGJIANG	
DEPOT	ZHUANG XI	FIRST DEPOT						SEVENTH DEPOT	
TYPE	Bulk	"50" Bulk	Reformed "51" Bulk	"51" Bulk	"53" Bulk	"54" Bulk	Reformed "54" Bulk	Prefab Prestressed Truss Bags	Prefab Portal Frame Bags
REF. DRAWING	3	4	5	6	7	8	9	10	11
STRUCTURE									
Width (span) m	8.00	13.00	12.34	20.60	15.00	20.00	20.00	18.00	18.00
Length, m	30.00	33.60	37.80	49.00	73.80	52.50	52.50	60.00	60.00
Heights, m 1/									
Eaves	3.80	4.00	4.30	5.00	4.50	3.20	6.20	6.30	4.80
Ceiling	-	4.00–5.50	4.30	4.20–7.20	-	-	6.15	-	-
Apex	6.50	8.20	8.30	11.50	9.30	8.30	12.20	10.60	9.80
Roof pitch	30°	30°	30°	30°	30°	26°	30°	22°	26.5°
Floor level	+0.30	+0.60	+0.30	+0.60	+0.30	+0.48	+0.60	+0.30	+0.30
Doors									
Nos.	2	8	2	12	12	8	8	6	8
Dimensions, WxH, m	1.8 x 2.8	1.2 x 3.0	1.2 x 3.0	1.7 x 3.2	1.5 x 3.0	2.6 x 2.2	2.6 x 2.4	2.6 x 3.0	2.0 x 3.0
Windows									
Nos.	18	24	28	32	48	22	22	32	24
Dimensions, WxH, m	1.2 x 0.6	1.2 x 0.6	1.2 x 0.8	1.2 x 0.8	1.2 x 0.8	1.1 x 0.6	1.0 x 0.8	1.2x 0.8	1.6 x 0.9
Total area	12.96	17.24	26.88	30.72	46.08	14.52	19.36	30.72	34.56
Window area as % of floor area	5.9	4.1	6.1	3.2	4.6	1.4	1.9	3.0	3.4
UTILIZATION									
No. of compartments	2	4	1	2	6	1	1	1	1
Net floor area 2/ m^2	225	413	434	960	994	1 009	984	1 050	1 023
Area in pile or stacks, m^2	-	385	434	-	-	-	-	685	680
Piling (stacking) height, m. 3/									
Wall	2.00	3.00 (2.30)	2.00	3.00 (3.00)	3.00 (2.30)	2.00	4.50	5.7	4.0
Centre	3.00	3.00 (2.30)	3.00 (2.00)	5.00 (3.00)	4.50 (2.30)	4.00 (2.00)	4.50	5.7	7.0
Holding capacity, tons 4/									
Paddy total	-	635	664	1 500	1 856	1 428	2 436	1 867	1 653
Paddy, t/m^2, net floor area	-	1.53	1.53	1.56	1.87	1.41	2.48	1.78	1.61
Wheat total	470	664	650	1 536	1 716	1 513		2 542	2 254
Wheat, t/m^2, net floor area	2.1	1.61	1.50	1.59	1.73	1.50		2.42	2.20

1/ above floor level
2/ total internal usable floor area
3/ for paddy; when for wheat, figures are given in brackets
4/ refers to utilization as indicated in the drawings and calculated on the following volume weights (tons/m^3):

	Bulk	In stack bagged
Wheat	0.75	0.64
Paddy	0.55	0.47

6.1.4 Dimensions and Utilization

Unit sizes of warehouses range from 500 to 2 500 tons in one building. Through sub-divisions lot sizes are usually of the order of 150 to 750 tons per lot. The large city depots, however, have lot sizes of up to 2 500 tons.

Piles of bulk grain are low, in the old warehouses 2 to 3 m, and in the newer warehouses 4 to 5 m. Stacking height in bag warehouses is 5 to 6 m, sometimes higher at the centre to utilize the space in a portal frame building.

Storage capacity per area unit is low; for bulk stores normally 1.5 to 2 tons per m^2 and only in some later designs up to 2.5 tons per m^2. For bagged grain warehouses, considering the allowance necessary for alleys and free space between bag stacks and the wall, the total floor area has a capacity of 2 to 2.5 tons per m^2.

6.2 BULK GRAIN WAREHOUSE IN THE BEIJING AREA

The bulk grain warehouse shown in Drawing No. 3 and photos 38 and 39 is a very basic design but functional and appropriate for its purpose.

6.2.1 Foundation

The foundation is built of brick on a concrete footing, usually concrete with 100 kg cement per m^3. A damp-proof course is laid on top of the foundation wall and consists of asphalt felt and one or two layers of asphalt emulsion. This damp-proof course should be joined to the damp-proof course under the floor.

Surface drainage around the building is provided through a 60-80 cm wide strip with an outward slope of 2 to 5 percent. The top layer consists of 1-2 cm thick 3:7 lime/clay mortar, placed on a base of crushed stone or brick.

6.2.2 Floor

The floor is raised at least 30 cm above ground level and consists of brick laid in lime/cement mortar on a damp-proof course of two layers of asphalt felt. The floor is laid on a 15 cm thick 3:7 lime/clay mortar base, which is levelled off with a 1:3 lime mortar poured on a base of well-compacted soil. Fig. 15 refers.

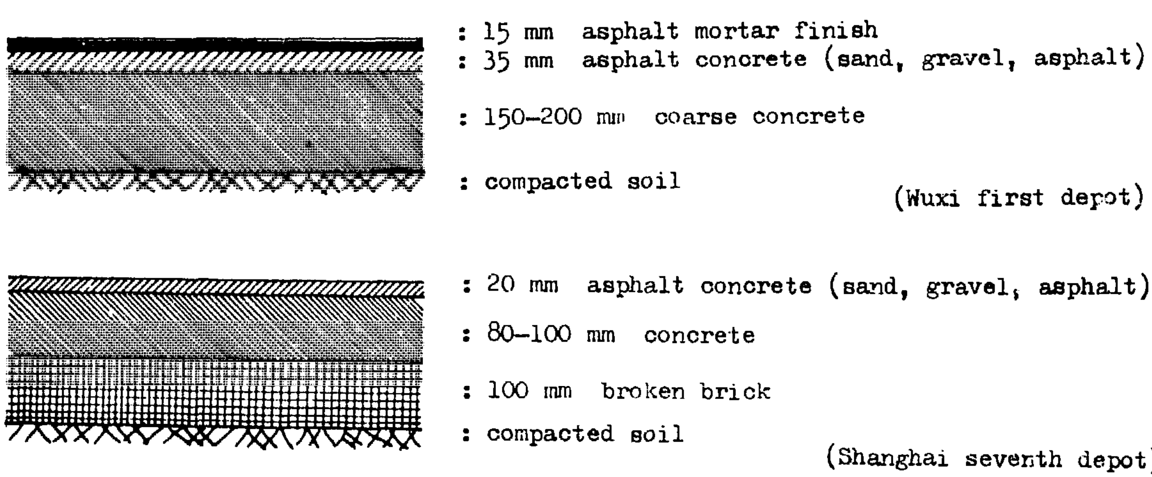


Figure 15 - Floors for warehouses (1:10)

6.2.3 Walls

Walls are 37 cm brick walls which are laid in a 1:3 lime mortar up to a height of 2.50 m and above that level in a lime/cement mortar.

Outside the walls are plastered to a height of 1 m with 1:4 cement plaster, and inside to full height with a 1:3 lime plaster.

6.2.4 Roof Structure and Roofing

The roof structure consists of metal/wood roof trusses spaced at approx. 1.5 m. (see photo 39). The top chord of the truss is 8x12 cm wood and the bottom chord a 16 mm diameter round iron. Round wood, 5-6 cm diameter, is used for purlins, placed at a distance of approx. 20 cm. The roof cover consists of two layers of reed mats fixed on the purlins and covered with clay/fibre plaster in which roof tiles are laid.

6.2.5 Ceiling

Below the roof is a ceiling consisting of reed mats fixed on wooden laths and plastered with lime/fibre plaster (see photo 39).

6.3 BULK GRAIN WAREHOUSES IN THE WUXI AREA

The bulk grain warehouses shown in Drawings Nos. 4-9 and photos 40-44 illustrate the interesting development of traditional warehouses being adapted for bulk storage. These warehouses were built during the early 1950s and represent very basic, simple designs, but are still fully utilized and maintained in good state.

6.3.1 Type "50"

See Drawing No. 4. This is an original design where wooden bins were built inside the warehouse to protect the grain against the moisture from floor and walls. Horizontal thrust is taken by the internal wooden wall and no pressure is exerted against the brick wall, which in this case has not been supported by buttresses. A trapezoidal-shaped ceiling is provided for heat insulation.

This type of store provides good insulation against heat and humidity. Insect control is difficult because the insects hide in the joints between wooden boards and cannot be removed by mechanical cleaning and not even completely by chemicals. Internal pillars are numerous and mechanical handling of grain is inconvenient. Consumption of steel and cement is low but timber consumption is very high.

6.3.2 Type "51-1"

See Drawing No. 5 and photos 40 and 41. Based on the experience with the Type "50" warehouse, Type "51" was created. Wooden bins have been eliminated, the outside wall has been designed as a "thrust" wall with brick buttresses. The floor has been moistureproofed with an asphalt/concrete layer.

6.3.3 Type "51-2"

Another type of modification resulted in a large-span warehouse, first built with wooden bins, but later modified as shown in Drawing No. 6, with "thrust" walls supported by buttresses and moisture-proof floor. Both types of warehouses "51" require large lots of 650-700 tons each, which was found sometimes to be a limitation for efficient use.

6.3.4 Type "53"

See Drawing No. 7. This type of warehouse has been subdivided to accommodate lots of about 300 tons of bulk grain each. Mechanical handling is facilitated by a door on each side of the building for each compartment. Moisture-proofing of floors and walls has been further improved. No ceiling but a reed layer provides some roof insulation and a kind of "double-skin" roof.

In this design the walls are tapered, starting with a base of a 49-cm brick wall with a slab of reinforced concrete incorporated, and then a 37-cm brick wall. The many columns inside the grain pile are considered to be the main disadvantage of this type of store.

6.3.5 Type "54"

See Drawing No. 8. This warehouse represents another attempt to design a low-cost bulk warehouse. Walls are low to reduce horizontal thrust and consequently doors are also low, only 2.2 m. Several disadvantages have been found with this type of store. One large uniform lot of 1 400 to 1 500 tons is often not available. The low walls and the location of the openings make proper ventilation difficult and in hot summers heat accumulates above the grain pile. Mechanical handling is difficult owing to the low doors and the large number of pillars in the grain pile.

6.3.6 Type "54" Reformed

See Drawing No. 9, and photo 44. Based on the experience gained from all the various models, a so-called Type "54" Reformed has been designed. This is a clear-span building with metal trusses. The wall height has been increased with the height at eaves being 6.8 m and the piling height 4.5 m. The wall is designed as a "thrust" wall. The upper part is a 37-cm brick wall and the lower part is tapered up to a width of 45 cm. A reinforced concrete slab is integrated in the lower part of the wall. A horizontal fibreboard ceiling is built.

Only with this design has an efficient large-scale bulk store been achieved. The lot size of 2 400 tons of paddy seems to be acceptable at least for some warehouses at large depots. Mechanical handling is easy and the ceiling and the location of the windows allow for efficient ventilation.

6.3.7 Concrete Dome-Roofed Warehouse, Baoan

This warehouse consists of three units, each 16 x 20 m, and has an interesting design based on arch construction. Each section of the building is 20 m long and has a roof structure consisting of ten 2 m concrete vaults arched across from wall to wall providing a very attractive clear-span warehouse. Unfortunately the roof has been leaking and heat insulation has proved unsatisfactory. A tiled roof was put on top of the concrete dome which now serves only as a ceiling. Because of the difficulty of construction, this type of warehouse is no longer built. (See photos 45 and 46.)

6.4 PREFABRICATED WAREHOUSES IN THE SHANGHAI AREA

In the 1970s prefabricated buildings were set up as warehouses and two examples of these designs were seen at the Seventh Depot, Shanghai. Both were used for storage of bagged milled rice.

6.4.1 Prestressed Concrete Design

Drawing No. 10, and photos 47 and 48. Different versions of this type of building exist, with 12-, 14- and 18-m spans.

The warehouse has a 37-cm brick wall, 6.3 m high at eaves, and is supported by 49 x 49 cm brick columns at cc 6 m. It is claimed that the wall has been designed to withstand the pressure of a 4 m high grain pile, if used for bulk storage.

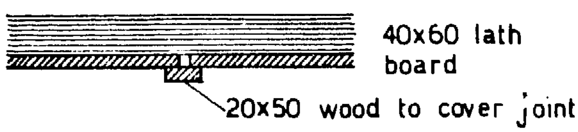
The roof structure consists of prestressed concrete rafters and steel tie rods. Purlins are also of prestressed concrete and support a roof cladding consisting of tiles laid in plaster on reed mats and with an asphalt felt layer for moisture-proofing (Fig. 16-3). The roof surface layer is supported by wooden rafters placed over the purlins at cc 40 cm. Two warehouses of this type with a total area of 2·000 m^2 can be built in about five months. The relatively short construction time and low construction cost are considered the main advantages of this type of prefabricated store.

1.

Ceiling (First Depot, Wuxi)

: wooden battens, 6 x 40 mm, spaced 12 mm
: lime/cement plaster with admixture of fibre

2.



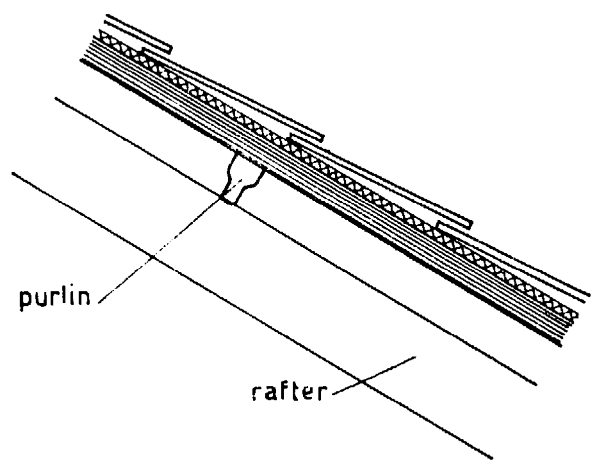
Ceiling (First Depot, Wuxi) fixed on wooden laths

: fibre board with wood to cover joints

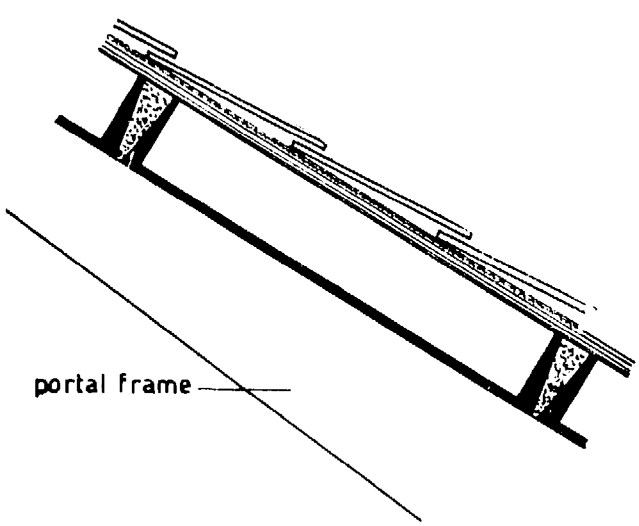
Insulated roof on prestressed concrete frame (Seventh Depot, Shanghai)

: roof tiles
: reed mats (2 layers) with plaster on wooden laths

3.



4.



Insulated roof on prestressed concrete roof elements (Seventh Depot, Shanghai)

: roof tiles
: asphalt felt
: wooden board

Figure 16 - Ceiling and roof insulation for warehouses

6.4.2 Portal Frame Design

Drawing No. 11, photos 49 and 50. Another type of prefabricated warehouse is represented by the 18 x 60 m portal frame building. The portal frames are spaced at cc 4 m with a 37-cm brick wall supported also by 3 m high brick buttresses. Height at eaves is 4.5 m and the design allows for a 3 m high grain pile against the wall.

The roof consists of trough-shaped prefabricated elements (Fig. 16-4), 70 cm wide, which stretch between the portal frames. Wooden rafters on top of the roof concrete elements support the cladding which consists of roof tiles laid in plaster on reed mats and with an asphalt felt layer for moisture-proofing. This warehouse does not seem so well adapted to bag storage as the stacks have to be pitched to utilize space.

6.5 UTILIZATION OF BAG WAREHOUSES FOR BULK STORAGE

To protect stored grain against moisture in the walls and to take the lateral pressure from the grain pile, warehouses were first built with internal wooden bins as described under 6.3.1 for the Type "50" warehouse at Wuxi. In many warehouses where the floor has been properly moisture-proofed, usually with asphalt/concrete, walls of grain bags have been built up around the warehouse to take the lateral pressure and to keep the grain away from the wall which is not always moisture-proof. Grain bags are also used to create "stairs" for access to the grain pile and to protect the doors (photo 51).

Bags are often made from rice-straw fibre and normally contain 100 kg, but 50-kg and 90-kg bags were also seen. Bags are stacked in one row and placed perpendicular to the wall, leaving a 1 m wide alley between the warehouse wall and the bags. Each row is 12 to 16 bags high (2.5-3 m). If necessary, double rows are placed at the lower part of the bag stack. Often the bag stack is covered with polyethylene sheets to prevent the grain in the inside pile from penetrating among the bags and to protect the stored grain (see photo 52).

6.6 MATERIAL REQUIREMENTS AND BUILDING COSTS

A summary of basic materials used and of building costs, as given by the Chinese authorities, is presented in Table 16. As the figures were obtained from different sources and it has not been possible to check them against actual bills of quantities, they may not be comparable and may not always include all materials used. It is clear, however, that the trend is toward warehouses with less timber and bricks per area unit, requiring more cement and steel.

The building cost figures refer to the year of construction and it is interesting to note that cost per area unit is lower for the warehouses built later. Unit cost for construction ranges from RMB Yuan 65-125 per m^2 which corresponds to US\$43-82 per m^2, at an exchange rate of US\$100 = RMB Yuan 152.13. With a storage capacity of 1.5-2 tons per m^2 the building cost per ton stored is RMB Yuan 35-80 per ton. Earlier the building cost for a 100-ton clay/straw silo was given as RMB Yuan 30-40 per ton. It appears that for small lot sizes (100-150 tons) the clay/straw silo is considerably cheaper while warehouses with large lots can well compete with the clay/straw silo.

It is noteworthy that the two latest designs with prefabricated buildings have a very low unit cost and the building cost is of the order of RMB Yuan 25 per ton stored. If these same stores were used for bulk storage, for which they were designed, with piling heights of 3-4 m, they would accommodate 2-2.5 tons of wheat per m^2 and the cost per ton stored would be RMB Yuan 30-35.

From the prices quoted it appears that modern large-scale warehouses do not cost more per ton stored than clay/straw silos, at least not where large lots are to be stored. They do, however, require large amounts of commercial building materials - cement, steel- while the clay/straw silos are made nearly exclusively from non-commercial building materials.

Table 16 - Material Consumption and Building Cost for Warehouses .

Type of Warehouse	Material: Steel kg/m^2	Timber m^3/m^2	Cement kg/m^2	Brick pieces/m^2	Building Cost Yuan/m^2
Type "50" Wuxi, 815 m^2	7	0.17	17	292	125
Type "51" Wuxi 12.34x37.8=466 m^2	7	0.145	15	388	104
Type "53" Wuxi 15x73.8= 1 107 m^2	9	0.08	25	314	70
Type "54" Wuxi 20.6x49.0=1 009 m^2	9	0.068	20	78	65
Type "54" Ref. Wuxi 20.0x52.5=1 050 m^2	18	0.050	80	150	115
Prestressed concrete, Shanghai 18.0x60.0=1 080 m^2	8	0.04	89	-	73.30
Portal frame, Shanghai 18.0x60.0=1 080 m^2	17.6	0.04	85	-	71

Photo 38 - Bulk grain warehouse, three sections, 8 x 30 m. (Zhuang Xi Depot)

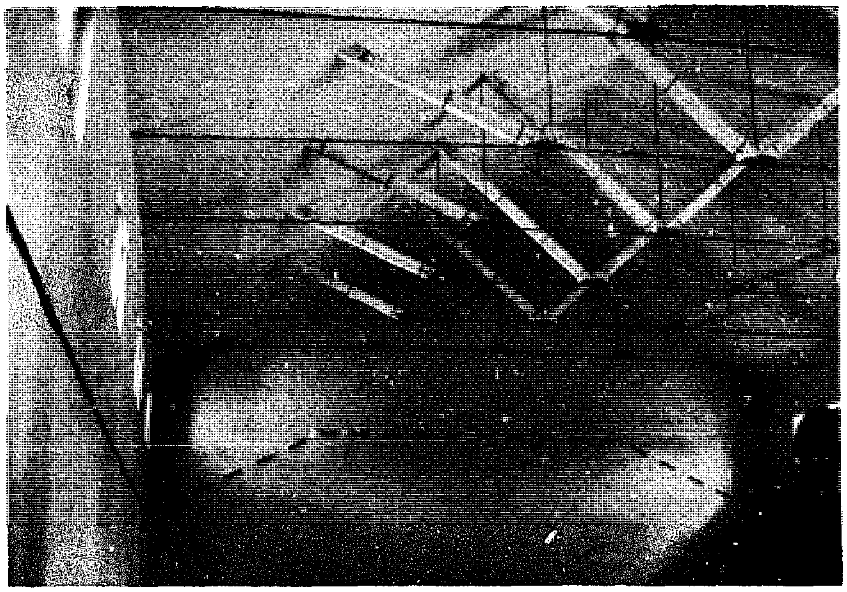


Photo 39 - Bulk grain warehouse. Trusses wood/steel ca 150 cm. Ceiling of plastered reed mats. Note line on walls indicating pile height. (Zhuang Xi Depot)

Photo 40 - Bulk grain warehouse, two sections, 20 x 24.5 m each. Type "51". (First Depot, Wuxi)

Photo 41 - Type "51" bulk grain warehouse. Wooden building frame and ceiling. Pile height 3 m at wall and 5 m at centre for paddy. (First Depot, Wuxi)

Photo 42 - Type "51" bulk grain warehouse. Windows for ventilation adjustable from ground level with a rope. (First Depot, Wuxi)

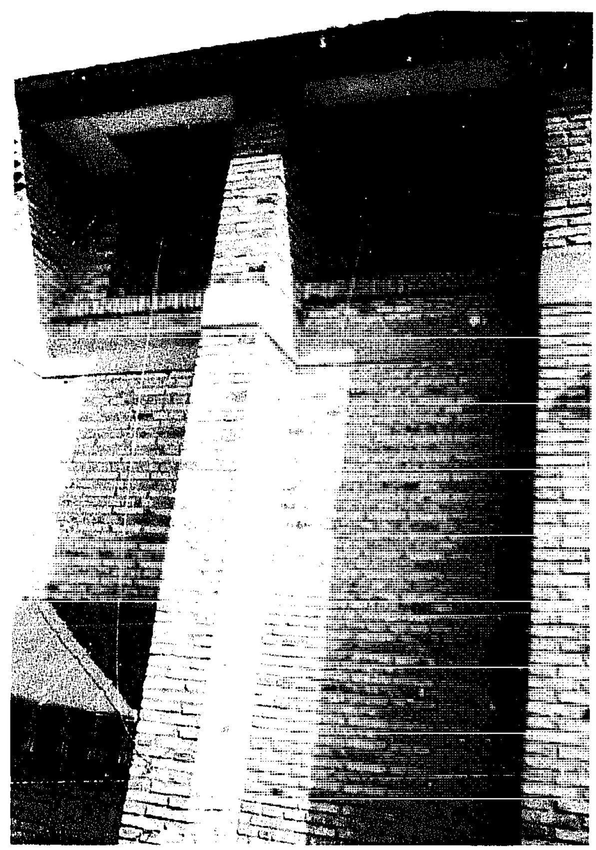


Photo 43 - Type "51" bulk grain warehouse. Floor level 0.60 m. Slot in pillar to fix plank wall to support grain pile. Fibre mat across the opening dusted with insecticide. (First Depot, Wuxi)

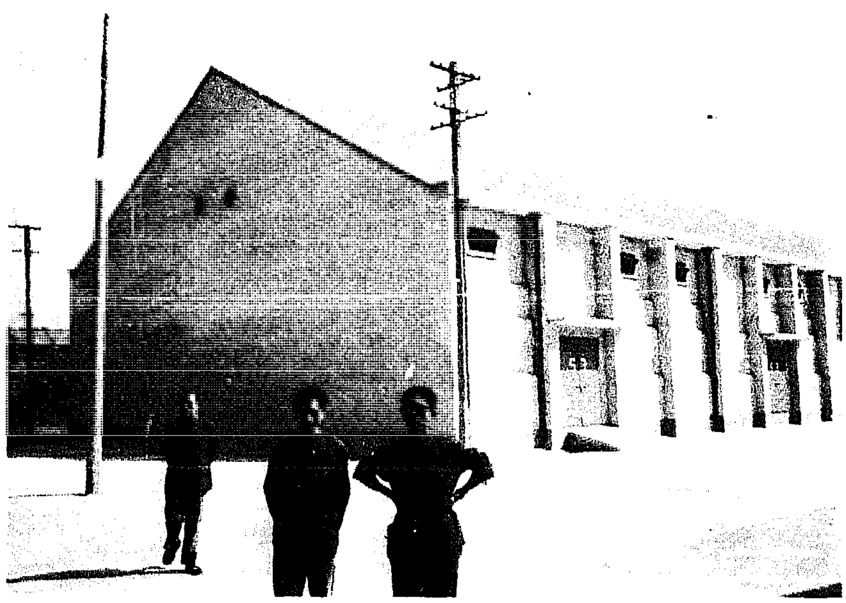


Photo 44 - Type "54" bulk grain warehouse, 20 x 52 m. (First Depot, Wuxi)

Photo 45 - Concrete dome-roofed warehouse with tile roof. Three bays, each 16 x 20 m. Built 1959. Total holding capacity 1 500 tons paddy. (Baoan Depot)

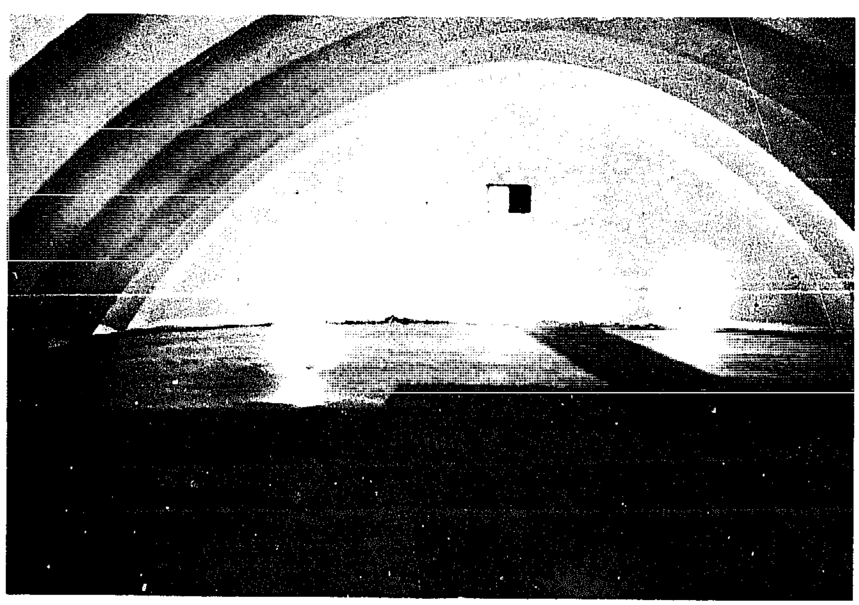


Photo 46 - Concrete dome-roofed warehouse. Ten 2-m vaults in concrete arched across a 16-m span. (Baoan Depot)

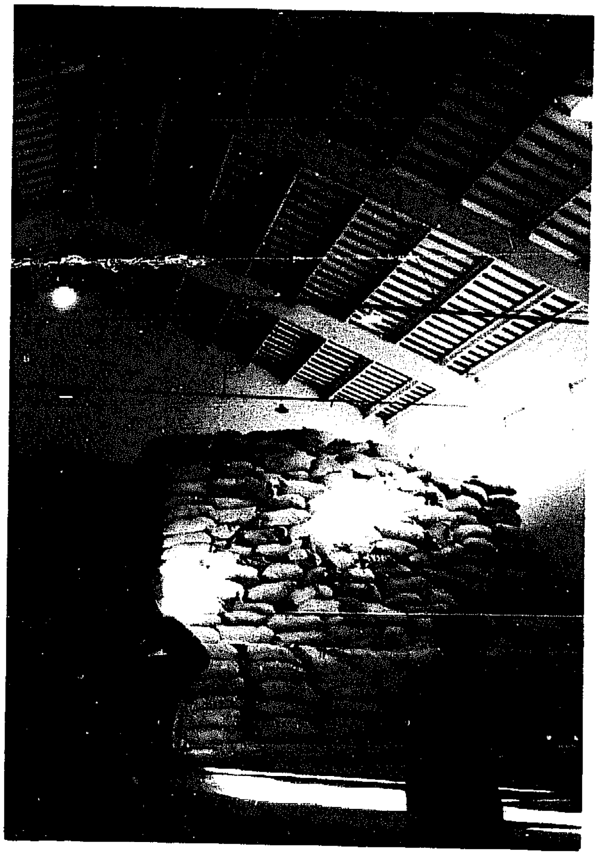


Photo 47 - Warehouse for bagged grain, 18 x 60 m. Rafters and purlins in prefabricated prestressed concrete; steel tie rods; trusses cc 6 m. (Seventh Depot, Shanghai)

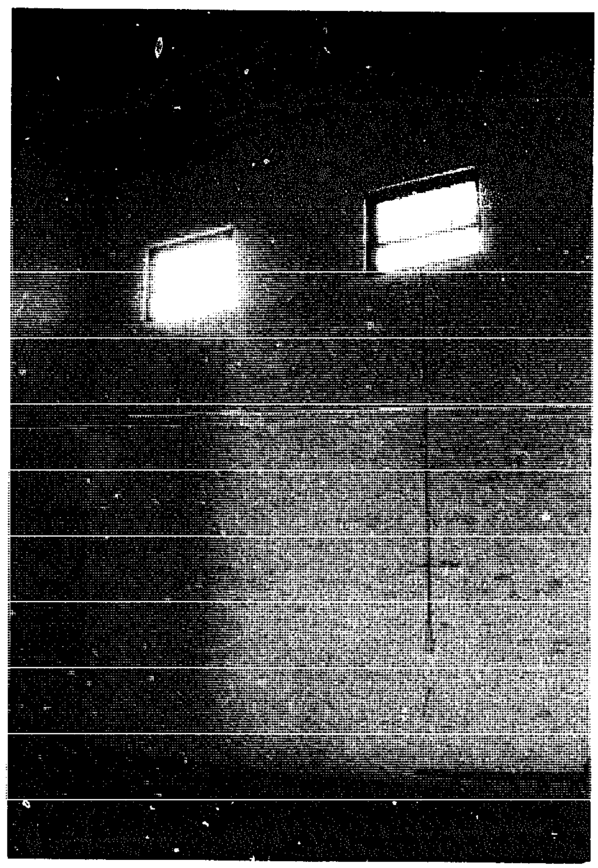


Photo 48 - Same warehouse for bagged grain. Windows opened from the ground with ropes. (Seventh Depot, Shanghai)

Photo 49 - Warehouse for bagged grain. Portal frames at cc 4 m. Buttresses between portal frames. (Seventh Depot, Shanghai)

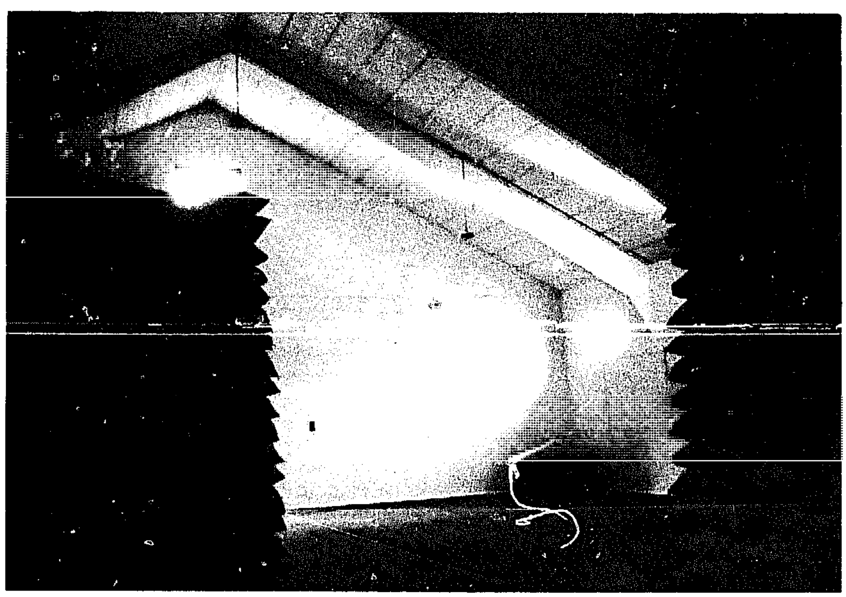


Photo 50 - Same warehouse for bagged grain. Prefabricated concrete elements span between portal frames at cc 4 m. (Seventh Depot, Shanghai)

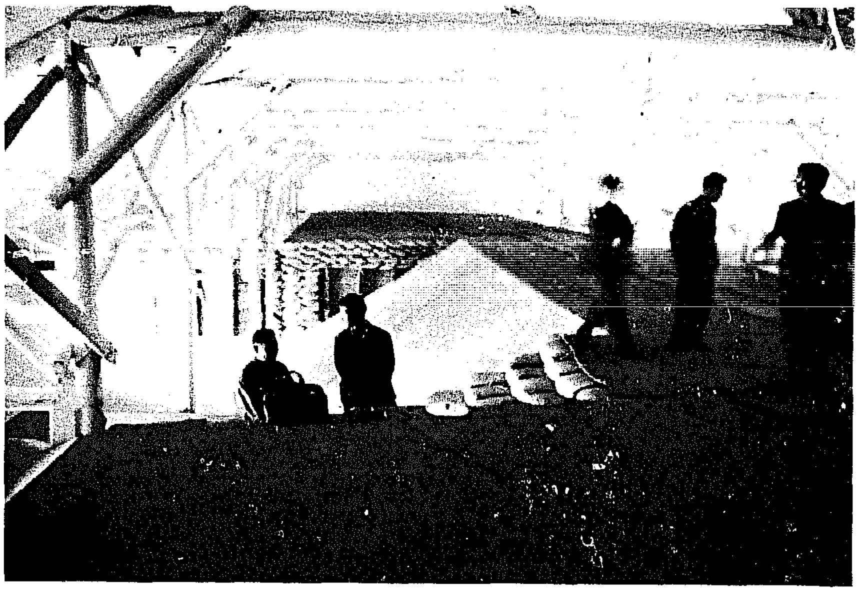


Photo 51 - Interior of bulk warehouse. Walls and stairs built from grain bags. Walking area covered with fibre mats. (First Depot, Wuxi)

Photo 52 - "Thrust" wall built from grain bags. Bags are stacked thirteen high, with 1-m alley between bags and warehouse wall. Bag wall is 2.5 m high and normally made of one row of bags, covered with polyethylene sheet. (Baoan Depot)

CHAPTER 7

ENVIRONMENTAL CONTROL IN GRAIN STORES

7.1 LOW-TEMPERATURE STORAGE

7.1.1 Prevention of Temperature Increase

As already discussed in para. 3.5, careful use is made of low ambient temperatures. In some cases, bulk grain is even taken out of stores during the cold period to cool down to near ambient temperature. After the store has been refilled, openings are sealed and ventilation is blocked to preserve the low temperature of the grain as long as possible.

In the Beijing area, with the benefit of very low ambient temperatures during the period November to March, and with well-insulated stores, like the clay/straw silo, it is possible to maintain a favourably low temperature in the grain pile throughout the year, as illustrated in Fig. 17. Covering the grain piles with plastic was also used as a means of preserving a low temperature. After fumigation the plastic is often left on grain stacks or grain piles in order to prevent reinfestation and to preserve the temperature inside the pile or stack. A well-sealed bulk storage warehouse is shown in photo 53.

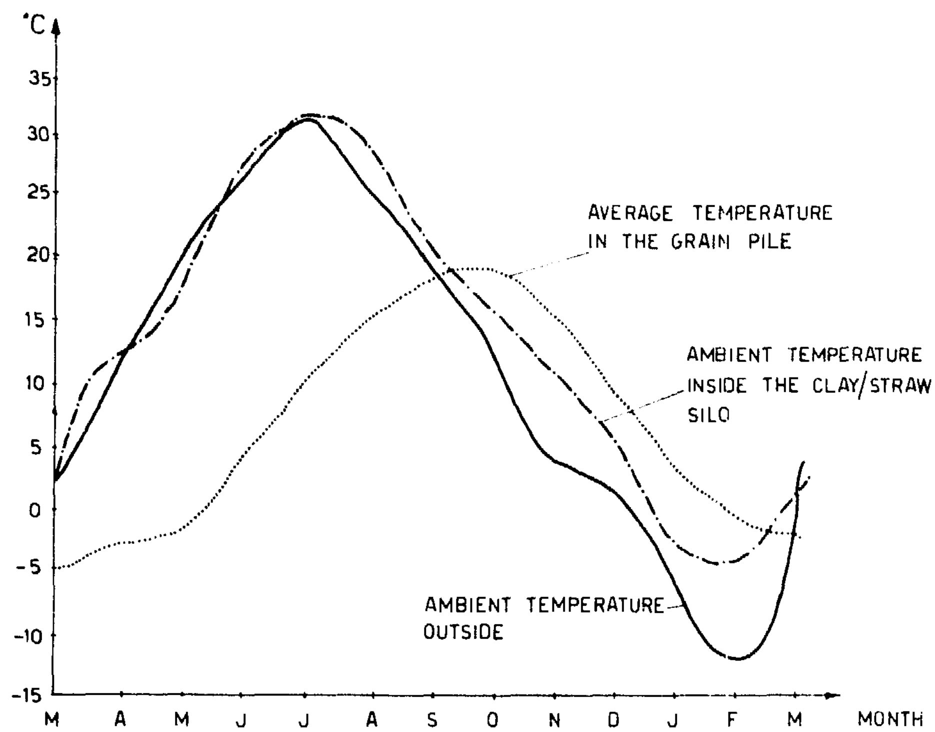


Figure 17 - Grain temperature in relation to ambient temperature in a clay/straw walled silo (Zhuang Xi Depot, Beijing)

7.1.2 Aeration

Many depots are equipped for aeration of bulk grain when warm spots have been discovered through the temperature control system or to cool the grain when ambient temperatures are favourable.

Usually a single-tube suction fan system is used. The tube has a diameter of 50 mm, is 2 or 3 m long and is perforated for about 500 mm from the bottom end (see photo 54). The system is simple but labour-consuming as 33 fan units have to be installed for a 1 000-ton store. The suction system prevents condensation. A risk is that wet air may be recirculated. To avoid this the warehouse has to be very well ventilated during the period when the fans are working. A multi-tube suction fan system is also used with one control fan located outside the building serving several tubes. The main disadvantage with this sytem is the power loss occurring in the long ducts.

In the Wuxi area it was stated that the power requirement for aeration with a single-tube suction fan system is about 3/4 kWh per ton of grain to reduce the temperature by 1°C during the cold season.

7.1.3 Ventilation with Chilled Air

7.1.3.1 The system

Chilled-air ventilation is used mainly for the storage of milled rice of the Japonica type (because of its higher moisture content; for Indica type rice, cooling is not normally required) with a moisture content of 15 to 15.5 percent. At this moisture content the temperature in the store is kept at 13-15°C. The following guidelines were given for the adjustment of the temperature in the store with respect to the moisture content of the grain:

Grain moisture content percent	Temperature required for safe storage (°C)
14	18
15.5	13-15
16	8-10

With low-temperature stores, no fumigation against insects is required and mould growth does not occur. As the respiration rate is reduced, dry matter losses are small. Also the quality of the rice is maintained well. Over a six-month period, it was observed that the fatty acid content of rice stored in conventional stores had increased by 350 percent compared with 50 percent for rice stored in low-temperature stores.

Construction of low-temperature stores started in the Shanghai area in 1975 and is still considered to be in the development stage. Experience so far indicates that low-temperature storage is the best method for preservation of milled rice.

7.1.3.2 The buildings

Remodelling of existing warehouses to make them suitable for low-temperature storage has been carried out successfully at the First Purchase and Supply Station in Shanghai. Drawing No. 13 and photo 55 show the exterior of a 1 000-m² conventional store which was remodelled as a low-temperature store in 1975.

Photo 56 shows the interior of the same store with the distribution unit for the chilled air. The main features of the remodelling are the following :

i) the windows and doors were sealed up and insulated, except for one main sliding door;

ii) the brick walls (37 cm) were insulated with a layer of perlite (see para. 4.11) 10 cm thick; the floor normally being concrete without insulation;

iii) a polystyrene ceiling, 7 cm thick, was suspended by galvanized wires at 5.2 m above floor level.

The remodelling of this warehouse, excluding installations for cooling and air distribution, required an investment of 32 RMB Yuan per m^2 compared to a quoted cost for non-insulated warehouses in the Shanghai area of 78 RMB Yuan per m^2. The material consumption for the remodelling was specified as follows:

Steel	2 kg per m^2
Perlite	0.13 m^3 per m^2
Polystyrene	0.075 m^3 per m^2

Bags are stacked 17 to 18 high in this store with pile heights of 3.60 m or more (photo 54), allowing storage of about 2 tons per m^2.

Another warehouse at the same depot is shown in photo 57. This warehouse is built in three bays, 17.5 m, 9.5 m and 17.5 m wide respectively, with a total floor area of 1 800 m^2.

This store has a multi-layer wall consisting of (from the outside): 12 cm brick, 14 cm perlite, 22 cm brick and 5 cm perlite. A horizontal ceiling is located at 7.5 m above floor level and has a 15 cm polystyrene insulation.

The cost of this warehouse is quoted at 93 RMB Yuan per m^2, including insulation but excluding the cooling and air distribution system.

7.1.3.3 The installations

The mechanical installation for cooling is shown in the diagram, Drawing No. 13, and consists of a traditional compressor cooling system with a heat exchanger and an air distribution unit. The cooling agent is freon and a 22-kW compressor is sufficient for the 1 000-m^2 store (2 000 tons of bagged rice). The total running time for the cooling machinery in Shanghai is about 800 hours in one year, distributed as follows: June to September, 5-6 h/day; October to May, 2-3 h/day.

7.2 MODIFIED ATMOSPHERE STORAGE

7.2.1 Nitrogen Atmosphere Storage

Storage in a nitrogen atmosphere is commonly used in the Shanghai area and it is believed that one third of the grain stored for more than six months is kept in a nitrogen atmosphere. Nitrogen storage is used mainly for milled rice but sometimes also for paddy. Usually it is applied for bagged grain but it is claimed that the technique also works well for bulk grain. Good control of insects and moulds is achieved and the cost is estimated at about 50 percent of the cost of conventional storage with two to three fumigations. This method is not considered suitable except in the temperature range +5° to +30°C and the moisture content of the stored grain should not be above 15 percent.

Normally the treatment is carried out for stacks containing about 1 000 bags, i.e. 100 tons. The floor is covered with 0.3 mm polyethylene film and on top of this a layer of jute cloth on which the bags are placed (photo 58). The sides and top are covered with 0.23 mm polyethylene film and the cover is sealed. From an upper connection, air is evacuated from inside the cover and the lower connection is attached to a nitrogen cylinder. When a nitrogen concentration of 95-98 percent is achieved, the connections are closed and sealed. A stack of 100 tons of grain requires 50-60 m^3 of nitrogen at 760 mm Hg and at 36.5°C.

As a rule the grain is stacked during relatively low outside temperatures and the nitrogen atmosphere is maintained during the summer.

For the large depots around Shanghai, low-temperature stores are today the preferred storage system as it is fairly independent of ambient conditions. A slight problem has been condensation which occurs when cold grain is taken out from the low-temperature store under hot and humid conditions.

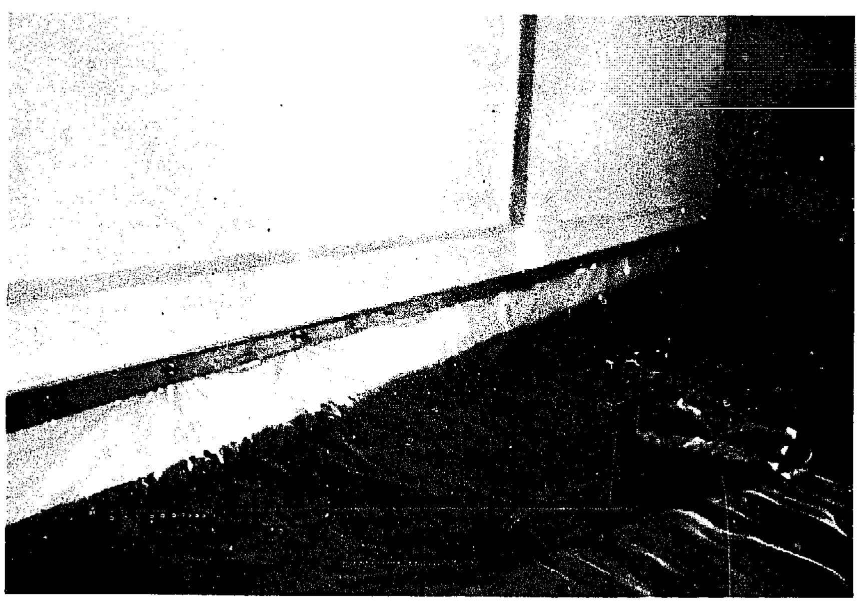


Photo 53 - Bulk grain covered with plastic sheet. Note sealing along the wall and openings for sampling and inspection. (South Gate Depot)

Photo 54 - Single-tube suction fan. One unit for about 30 tons of grain. Used in bulk stores with piles 2-3 m high. (Baoan Depot)

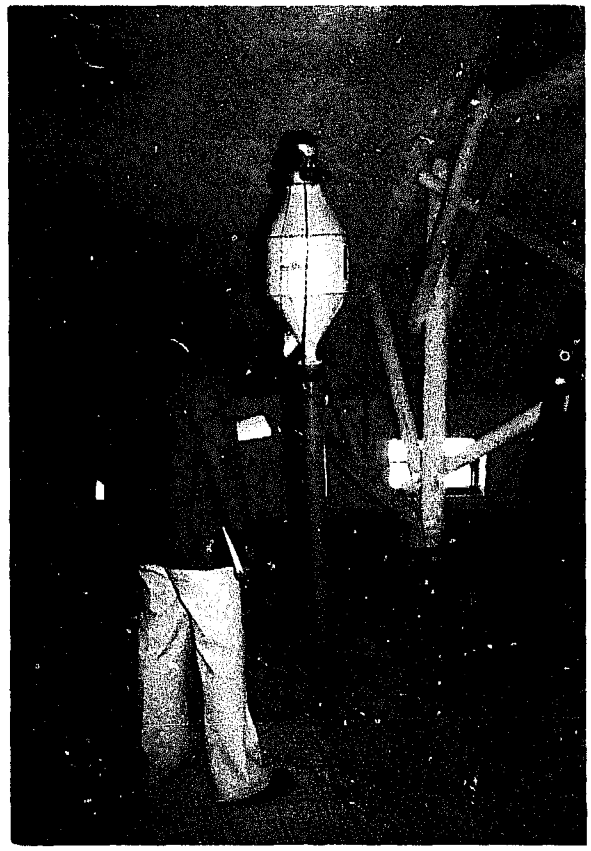


Photo 55 - Low-temperature store remodelled from a traditional warehouse in 1975. Storage capacity about 2 000 tons bagged rice. (First Purchase and Supply Station, Shanghai)

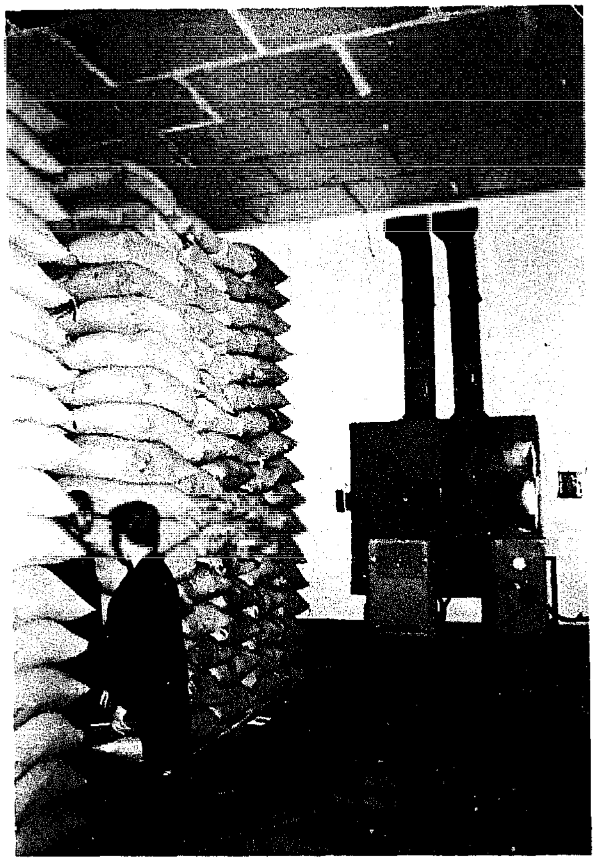
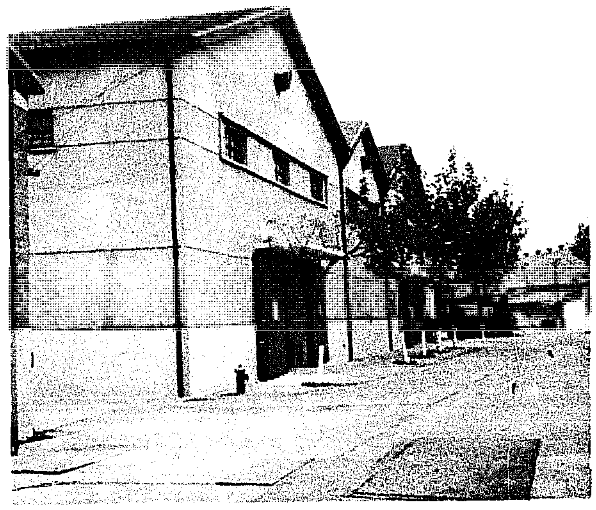


Photo 56 - *Interior of low-temperature store. Polystyrene ceiling suspended at 5.2 m above floor. Stacking 17 bags high (3.60 m)*

Photo 57 - *Low-temperature store. Three-bay warehouse with 1 800-m² floor area and storage capacity of 3 600 tons of milled rice (First Purchase and Supply Station, Shanghai)*



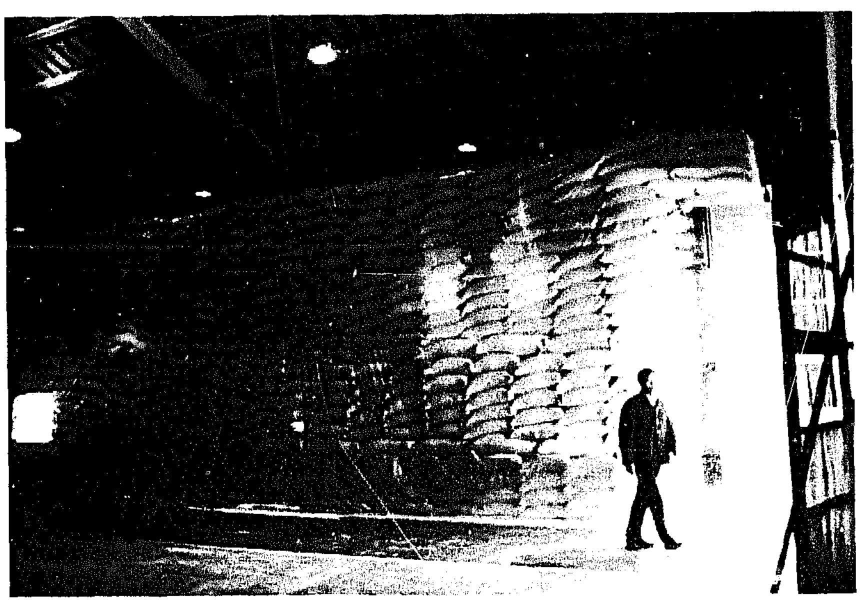


Photo 58 - *Nitrogen-atmosphere storage in 100-ton bag stacks, covered with polyethylene and sealed. (Seventh Depot, Shanghai)*

CHAPTER 8

OTHER TYPES OF STORAGE

8.1 UNDERGROUND STORES

Storage of grains in tunnels (air shelters) has been reported from China and quite considerable experience has been gained in underground construction in Henan Province which is located between latitudes 30° and 35°N. This inland province has a fairly continental climate and is hilly, with good natural conditions for underground construction, such as good-quality soil and a low groundwater table. Unfortunately it was not possible for the workshop/study tour to visit this area and the information given here is based on a lecture given to the group by Mr. Shi Youli, Civil Engineer, Grain Bureau, Henan Province, and also draws on some translations from the book "Underground Storage" by Yun Shi Mi.

8.1.1 The Structure

8.1.1.1 Shape and size

There are several different shapes for the cross-section of the stores, such as oval, tubular, arch, etc. The most advantageous is considered to be the bell-shaped structure as illustrated in Drawing No. 13. These stores are usually built with diameters of 8-18 m and with depths of 8-12 m, thus attaining storage capacities ranging from 200 to 2 000 tons per unit.

8.1.1.2 Building material and construction techniques

The construction is carried out using exclusively local material, mainly bricks and some cement for the roof, the foundation of the roof, and for mortar. Moisture-proofing is achieved with asphalt felt and asphalt emulsion.

The construction is made without scaffolding, the roof vault being built on the soil layer which has to be shaped according to the design of the roof.

The roof layers from the bottom consist of the following:

1. brick laid in asphalt mortar;
2. asphalt felt and two layers of asphalt emulsion;
3. brick laid in cement mortar;
4. 9 cm thick cement mortar;
5. asphalt felt and two layers of asphalt emulsion;
6. 10 cm thick layer of coarse sand.

When the roof is finished the space above it is refilled with consolidated clay and an access road for filling the store from the centre top is sometimes also built. When the roof structure is finished, a tunnel is opened and the interior is excavated and all material transported through the tunnel.

When the excavation is completed, the walls are built as follows (from outside to inside):

1. 5 cm coarse sand (only for the lower part);
2. brick laid in cement mortar;
3. asphalt felt and asphalt emulsion;
4. brick laid in asphalt mortar.

Labour consumption for construction is high, quoted to be about 3 000 man/days for a silo as described above (2 000 m^3 or 1 500 tons of wheat), but material cost is low and the total cost is therefore about 40 percent less than for warehouse construction.

8.1.2 Experience and Utilization

Underground stores as described above have been built for a long time but are still considered to be in the development stage. Wheat kept for 12 years in an underground store has been sown and the germination rate was still satisfactory.

Mechanical handling with a conveyor in the tunnel can easily be installed but many underground stores are reported to be emptied manually.

Ambient temperature in Henan Province ranges from -10°C-+40°C. Grain put into underground stores should have a temperature not exceeding +10°C, and the moisture content of the grain should be 13 percent or less. If these conditions can be met the grain in the underground store maintains its temperature at 10-15°C and grain quality can be maintained for many years without fumigation or other treatment.

8.2 OPEN-AIR STORAGE

As illustrated by the data given in Table 2, for some depots substantial amounts of grain are kept in outside stacks or piles. Considered originally as a temporary measure, the open-air stacks have developed into permanent features for many depots due to lack of buildings. Storage duration in open-air stacks is normally 3 to 12 months but in some cases this has been extended to two years.

In this type of store it would seem that rat control is a major problem, but owing to the campaigns referred to under para. 3.7, the depots have encountered no problem with rats. It can be assumed that without such general rat campaigns the open-air type of store would not be possible.

8.2.1 Outdoor Bag Stacks

Outdoor bag stacks are usually built in sizes from 2 000 bags up to 4 000 bags (see photos 59-62). A stable, well-raised platform of wooden frames, careful stacking and a well-mounted cover of reed mats are the main important features of these outdoor stacks. Details of the construction of a 250-ton outdoor stack are shown in Drawing No. 14.

The main steps of the construction are the following:

1. clean, level and remove the soil and provide for appropriate surface drainage;
2. place the foundation stones 40 cm high in a grid 0.90x0.90 m;
3. place wooden frames 0.90x1.80 m each;
4. cover the platform with polyethylene sheets and reed mats;
5. stack grain bags; usually eaves height about 4 m; central passage for ventilation 0.5x1.8 m; the roof is formed by stepping in each consecutive layer about 15 cm, giving a roof pitch of about 55°; maximum 24 bags high at centre;

6. cover with reed mats which are fixed with bamboo spikes to the grain bags; the cover is made of several layers with ample overlap.

Consumption of material for a 200-ton stack is as follows:

Stones	360	
Wooden frames, 0.90x1.80 m	54	(about 7 m^3 wood)
Bamboo spikes	1 600	
Reed mats, 1.28x1.68 m	1 600	(about 3 400 m^2)

8.2.2 Outdoor Bulk Storage

Round bulk stores were built in some depots using bags filled with grain to build the walls (photo 63). A kind of plinth is built covered with polyethylene sheets and reed mats. After the wall has been built the interior is filled with grain (paddy in this case) and then topped up with straw. Walls are covered with reed mats and the roof usually with some kind of thatch. Unit sizes of such bulk storage facilities are usually 100-150 tons (of paddy).

In some areas rectangular bulk stores are built on the same principle.

Photo 59 - Outdoor bag stacks of about 250 tons paddy. Dimensions 7 x 17 m, 6.50 m high. (First Purchase and Supply Station, Shanghai)

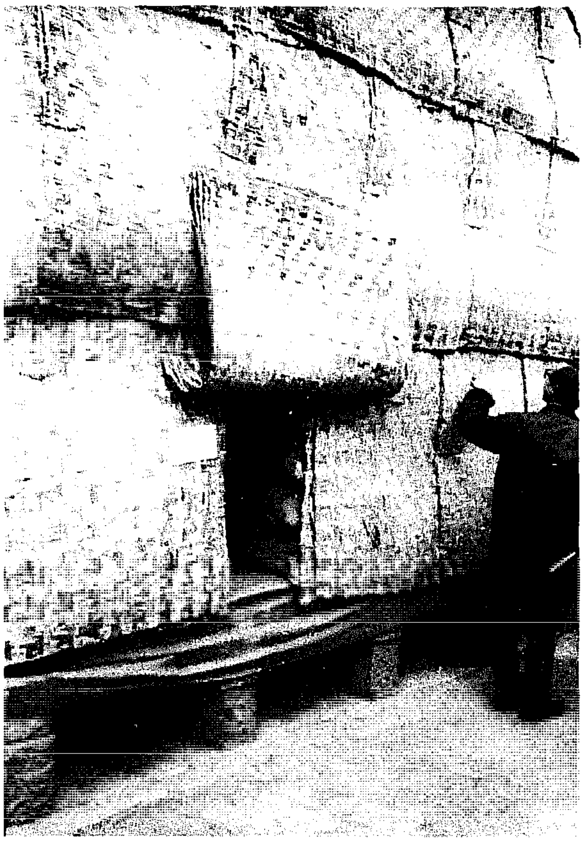


Photo 60 - Outdoor bag stack with ventilation opening 50 x 180 cm. Wall cover is double layer of reed sheets, 128 x 164 cm each. Under the stack, polyethylene sheets and reed mats on wooden platform.

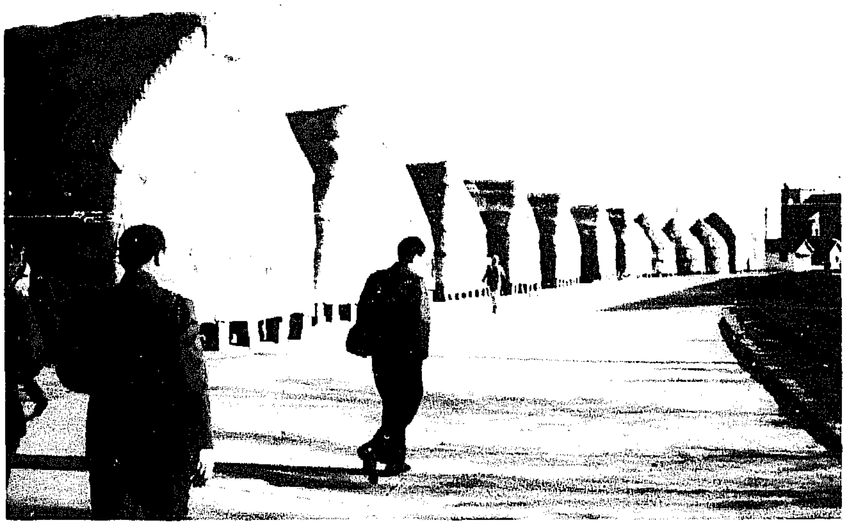


Photo 61 - Outdoor bag stacks. In some large depots, a large proportion of grain is kept in outdoor stacks. (Seventh Depot, Shanghai)

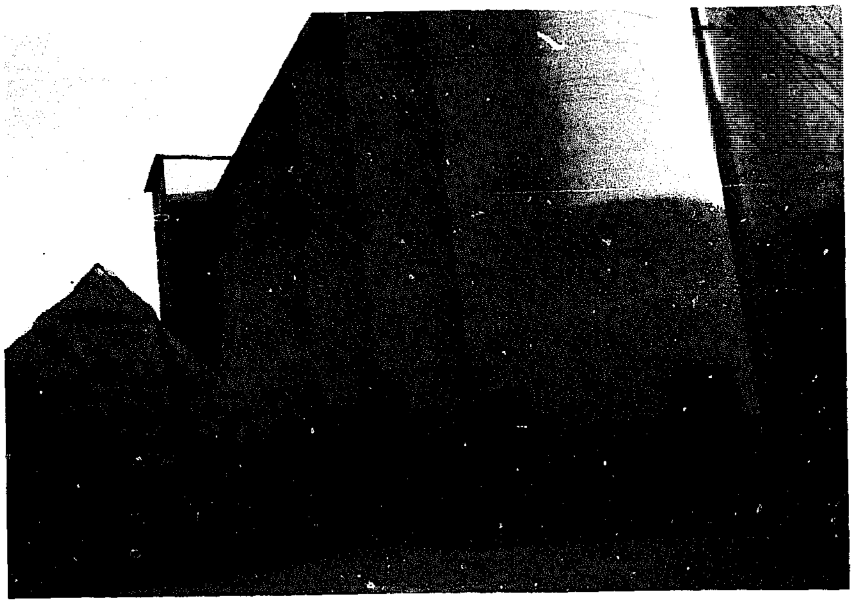


Photo 62 - Outdoor bag stack next to a 12-bin brick silo, 6 m diameter. (Seventh Depot, Shanghai)

Photo 63 - Outdoor bulk storage for 150 tons of paddy. Walls built from bags filled with paddy, interior space filled with bulk paddy. The top cone is shaped by straw piled on top of the rice, then thatched and fixed with a rope net. (Xinqiao Grain Purchasing and Supply Station, Songjiang County)

CHAPTER 9

EQUIPMENT FOR GRAIN DEPOTS

9.1 MECHANIZATION AND MANUFACTURE OF EQUIPMENT

Mechanization of grain handling started in China in the late 1950s. Through mechanization it has been possible to introduce bulk handling and storage of grain and to reduce considerably the amount of manual labour. For example, at the First Depot, Wuxi, the labour force has been reduced from 986 workers in 1950 to 220 workers today.

The equipment installed today is as follows:

Ship unloading	30-50 kW	30 tons/hour
Processing (cleaning, drying, etc.)	51 kW	20 tons/hour
Receiving transport line	43 kW	30 tons/hour
Delivery transport line	26 kW	30 tons/hour

However, it was emphasized at several depots that the main objective of mechanization of grain handling was to avoid drudgery and hand labour in handling 90-100 kg grain bags.

Designs of warehouses have been modified to facilitate mechanical handling. Internal heights are increased, doors are made higher and located in such a way that mobile transport equipment can cover most of the floor area.

Of particular interest is the fact that most of the equipment has been designed at the depots and manufactured by their own workshops. Therefore, a great variety of designs is available. Most designs are uncomplicated, the equipment is built from locally available material and the manufacturing methods do not usually require sophisticated tools or other equipment not normally available to a grain depot workshop. Most equipment is of low to medium capacity. Mobile units are predominant.

9.2 SHIP UNLOADING

Waterways are used for grain transport whenever possible. To facilitate ship unloading, small pneumatic grain unloaders have been developed. A high-pressure type with compressor and a static pressure of 3 500 mm water column (photos 64 and 65), and a low-pressure type with centrifugal fan and a static pressure of 800 mm water column (photo 67) were seen, both with a capacity of about 30 tons per hour.

After unloading from ships the grain is taken to a central building (photo 67) for processing as required. The sequence of the processing is usually as follows:

1. (Weighing)
2. Precleaning
3. Cleaning
4. Drying and cooling
5. Weighing
6. Transport to bulk store

9.3 WEIGHERS AND CLEANERS

The weighers for bulk grain are of traditional design with beam and automatic tipping. The one seen at the First Depot, Wuxi, had a box for 300 kg per batch and an accuracy of 0.001. Each batch of 300 kg requires 20 seconds to weigh, thus giving an hourly maximum capacity of 54 tons. The rest weighing is manual.

The amount of impurities in incoming grain is usually around 2 percent, and cleaning is done before drying and storage. A rotary sieve precleaner (photo 68) with a capacity of 20 tons per hour does the first cleaning and the grain then passes over two vibrating sieve-type cleaners, each with a capacity of 10 tons per hour (photo 69).

9.4 GRAIN DRYERS

In the Wuxi area, incoming wheat usually has a moisture content of around 13 percent and does not require drying. Paddy, on the other hand, can arrive with moisture contents of up to 17-18 percent and is dried down to 13.5 percent for the first crop and 15.5 percent for the second crop.

Drying equipment is not commonly available as field drying and drying on special drying floors could handle this problem. An example of how a depot has solved the drying problem is shown in photo 70, using a coal-fired single-pass drum dryer. After drying the grain passes through a cooling tower.

9.5 CONVEYORS AND ELEVATORS

As has already been shown in photos 16 and 18, in connection with clay/straw silos, mobile conveyors are used extensively for grain transport. In the warehouses, too, mobile equipment is combined to form transport chains (photos 71 and 72). Fixed conveyors are often installed alongside the building and then connected to the interior of the warehouses through small mobile conveyors. Joints in the fixed conveyor system may allow for "four-way traffic" as illustrated in photo 73. Fixed installations inside a warehouse are rare but one example is shown in photo 74.

Most conveyors have rubber belts and are of a very light design (photo 75). There are interesting design variations due to the decentralized manufacture. Photo 76 shows a so-called "electric roll" type belt conveyor with an electric motor integrated with the pulley. Photo 77 shows a flat belt conveyor with sides made of sheet metal. Some of the more common types of belt conveyor are specified in Table 17. Augers for grain transport are not common but in Wuxi a 4-m auger, 300 mm diameter, with a 1.7-kW motor and a capacity of 20 tons per hour, was seen. It is also reported that sweeping augers have been tried for emptying clay/straw silos.

Mobile bucket elevators are sometimes used to fill clay/straw silos. For example, a 50-ton/hour unit, 5.8 m high, has a 3-kW motor and a linear belt speed of 1.8 m/sec. The buckets are spaced 20 cm apart and only every fourth bucket has a bottom. The others are bottomless and the grain column more or less fills the space between the buckets with bottoms, thus allowing for a better utilization of the space in the elevator tube.

To take the grain out from bulk warehouses, various types of self-loading grain conveyors are used. Photo 78 shows one model with a rated capacity of 60 tons/hour.

9.6 EQUIPMENT FOR FILLING AND STACKING OF BAGS

For the big city depots in particular, the handling of bagged rice is very important and considerable design effort has been made to produce equipment for easy bag handling. At the First Purchase and Supply Station, Shanghai, a semi-automatic bag-filling machine and automatic bag stackers have been developed.

The semi-automatic bag filler has an automatic weigher for bags of 50 to 100 kg each, sack holders which are controlled by a hydraulic system and automatic sewing. The power required for the bag filler is 4 kW and the capacity is 180 bags per hour. One worker is required to operate this machine.

The automatic bag stacker (photo 79) consists of one main bag conveyor and two side conveyors which place the bag directly in the shed. It is claimed that the bag stacker can handle 400 to 550 bags per hour with one operator. At the same depot, 20 workers can handle and stack about 2 000 bags in 8 hours, stacking the bags by hand. A serious limitation of this stacker is that it can only stack up to a height of 3 m. Modifications are under study to allow for higher stacks.

9.7 AERATION EQUIPMENT

As earlier mentioned, aeration is widely used to cool grain and to remove "hot spots" within the grain pile. The two prevailing systems for aeration are single-tube suction fans and multi-tube suction fans.

The single-tube system consists of small fan units (photo 80) with an output of about 1 000 m^3/hr per fan unit. In a 1 000-ton bulk warehouse, 33 such fans are installed or one unit for 30 tons of grain. During the areation, the warehouse must be very well ventilated to avoid recirculation of the warm, humid air drawn from the grain pile. Each fan has a 0.75-kW motor and its working range is a 90-120-mm water column.

The multi-tube suction fans have a central fan unit located outside the warehouse. The fan has a 7-kW motor and produces 3 500-4 000 m^3 per hour. It is designed for a working range of 170-230-mm water column. Each unit serves six suction pipes.

9.8 FUMIGATION EQUIPMENT

Although fumigation is used sparingly, some interesting developments of equipment for fumigation have taken place.

The fumatorium (photo 81) consists of a reaction barrel in which hydrogen phosphide (PH_3) is produced through reaction between aluminium phosphide and zinc phosphide. The 1.1-kW motor blower has its intake connected to the reaction barrel and the outlet to the 100-mm diameter duct connected to the bottom/central part of the grain pile to be fumigated. The grain, whether in a silo or warehouse, has to be covered by polyethylene sheets and the pile must be well sealed before fumigation can start. The air inlet of the reaction barrel is connected with the grain pile through the other duct seen in photo 81. Normally, after 30 minutes the PH_3 concentration within the grain pile has reached a level of 0.4 g PH_3/m^3, and after 4 hours a level of 1.0 g PH_3/m^3.

Table 17 - Some Different Types of Belt Conveyors

Type	Length m	Capacity tons/h	Belt speed m/sec	Belt width mm	Motor kW	Tilt angle	Remarks
Sliding belt conveyor	13	60	2.5	400	3	58°	Sliding over fixed rail.
Fixed belt conveyor	18-30	60	2.5	400	3	58°	For loading and unloading.
Horizontal extendible belt conveyor	2.3-6.6	30	2.4	400	2.2	-	Extendible by 4.2 m.
Adjustable (height) belt conveyor	6.9	25	2.4	400	3.3	-	Unloading grain from clay dome roof silo.
Adjustable (height) portable belt conv	7.5	40	2.4	-	2.2	-	Lifting range 1.8-3.2 m.

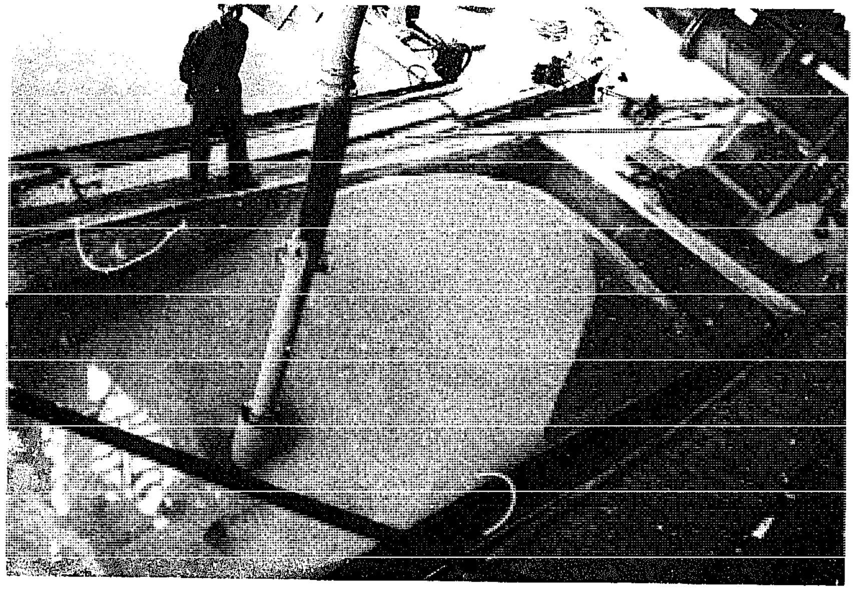


Photo 64 - Pneumatic ship unloader. Suction pipe 150 mm diameter. Length 7.2 m. Connected to compressor unit shown in photo 65. (First Depot, Wuxi)

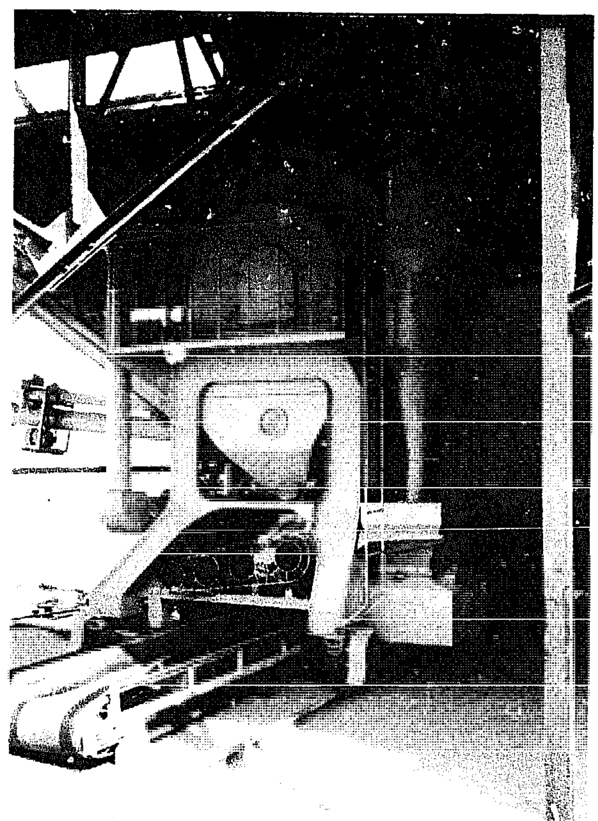


Photo 65 - Receiving unit with 30-kW, 550 rpm (LGA 90-3600-1) compressor, 30 m^3/min air output at a pressure of 3 500 mm water column. Transport capacity 30 t/h for paddy. (First Depot, Wuxi)

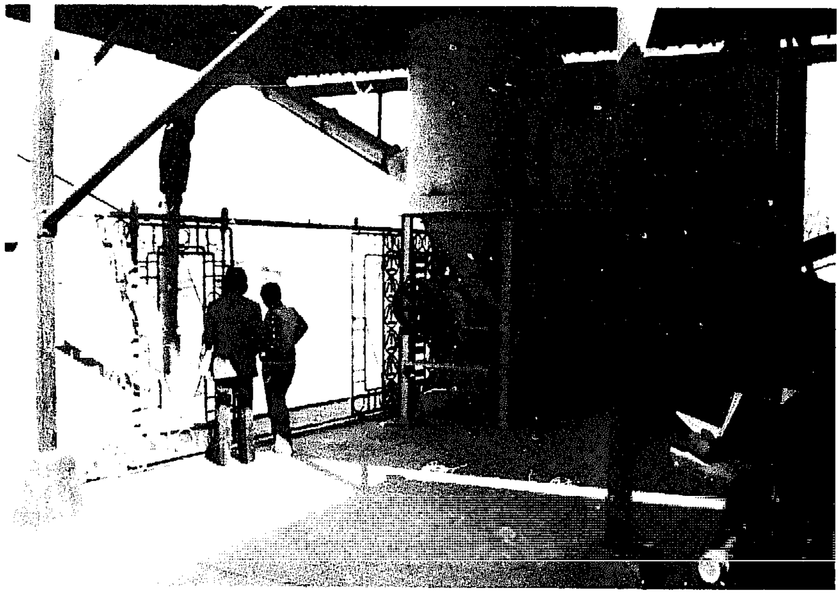


Photo 66 - Pneumatic ship unloader. Receiving unit with 22-kW, 2 800 rpm high-pressure centrifugal fan. 100 m^3/min air output at a pressure of 800 mm water column. Transport capacity 30 t/h for paddy. (First Depot, Wuxi)

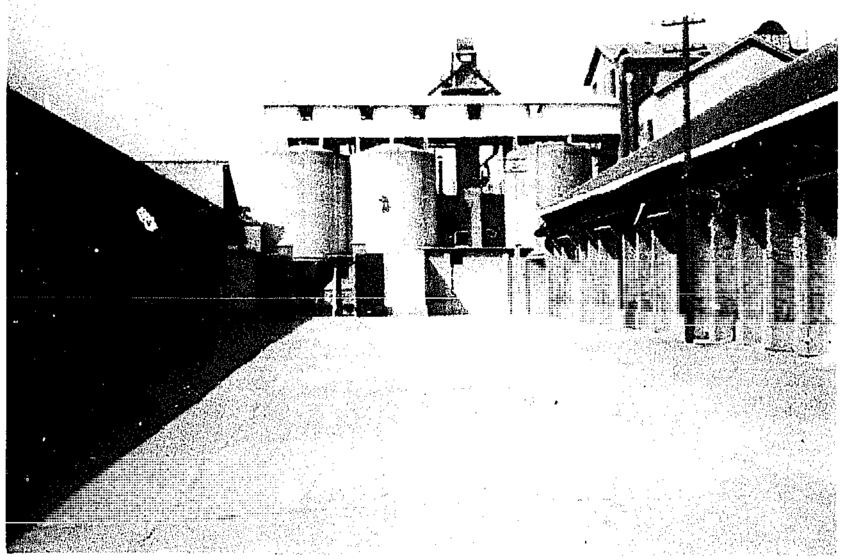


Photo 67 - Central building for reception, cleaning, weighing, and for distribution to warehouses. (First Depot, Wuxi)

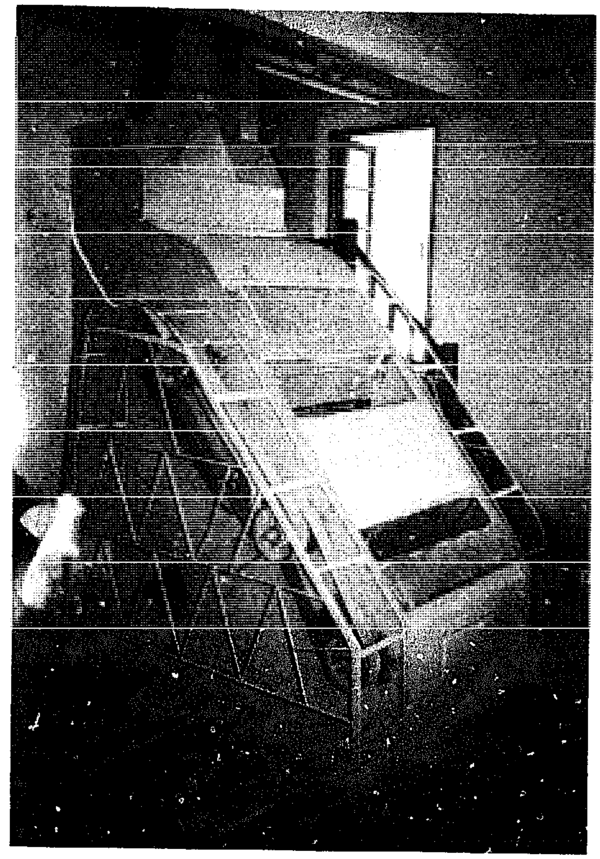


Photo 68 - Precleaner. Three rotating sieves and aspiration. 2.2-kW motor, sieves rotating with 20-40 rpm. Built in depot workshop in 1973. Capacity 20 t/h paddy or wheat. (First Depot, Wuxi)

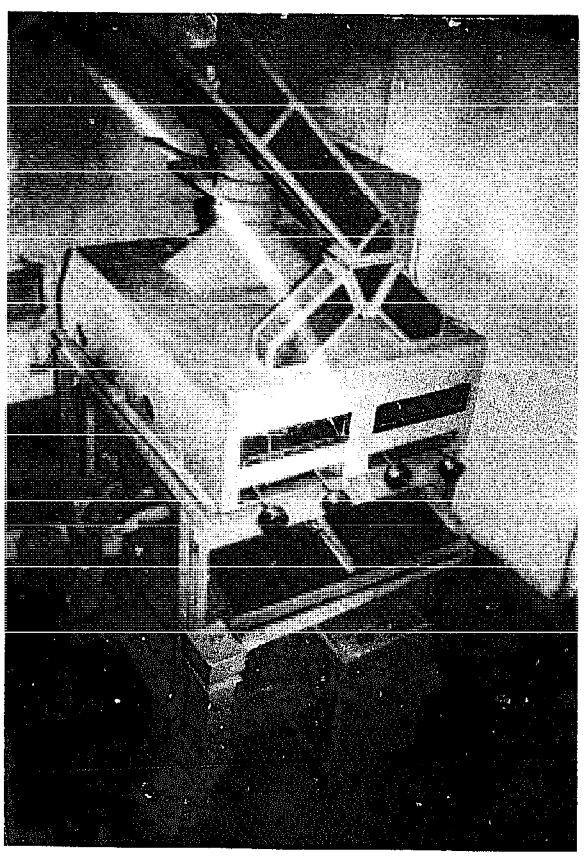


Photo 69 - Cleaner. Two vibrating sieves, 1.5-kW motor (excl. air exhaust). Capacity 10 t/h paddy or wheat. (First Depot, Wuxi)

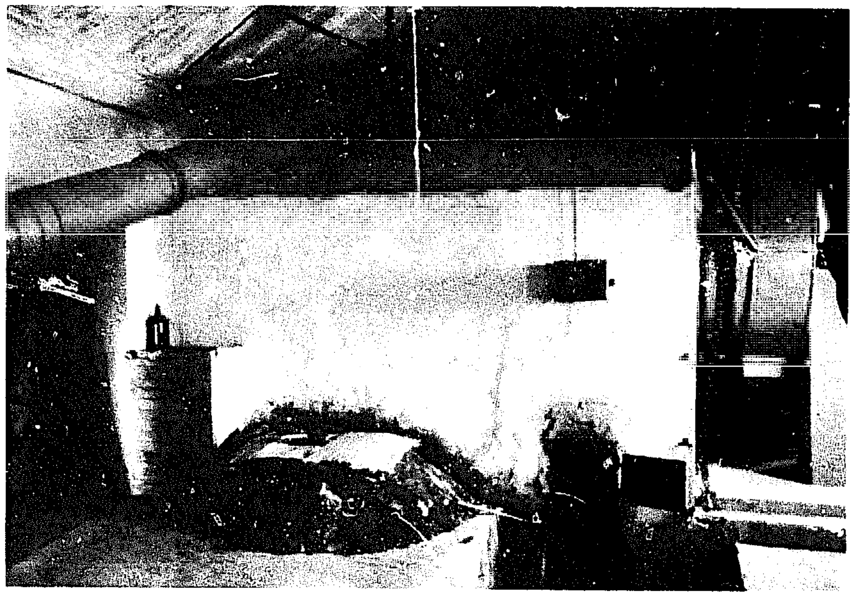


Photo 70 - Grain dryer. Rotating drum diameter 130 cm, length 6.5 m. Blower capacity 6 500 m^3/h. Air temperature at entrance 180-200°C. Max. grain temperature 50-55°C. One pass removes 2-2.5% moisture after cooling. Capacity 15 t/h. Heating by coal fire, consumption of coal 2 kg/ton for 1% moisture content reduction. (First Depot, Wuxi)

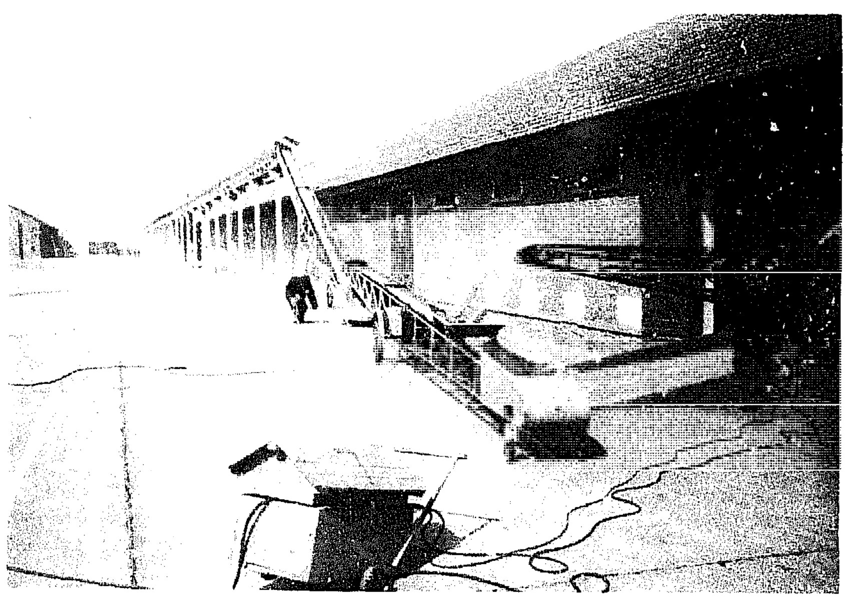


Photo 71 - Transport system. Combination of fixed conveyors along sides of warehouse and mobile conveyors for filling and emptying. Capacity 30 t/h. (First Depot, Wuxi)

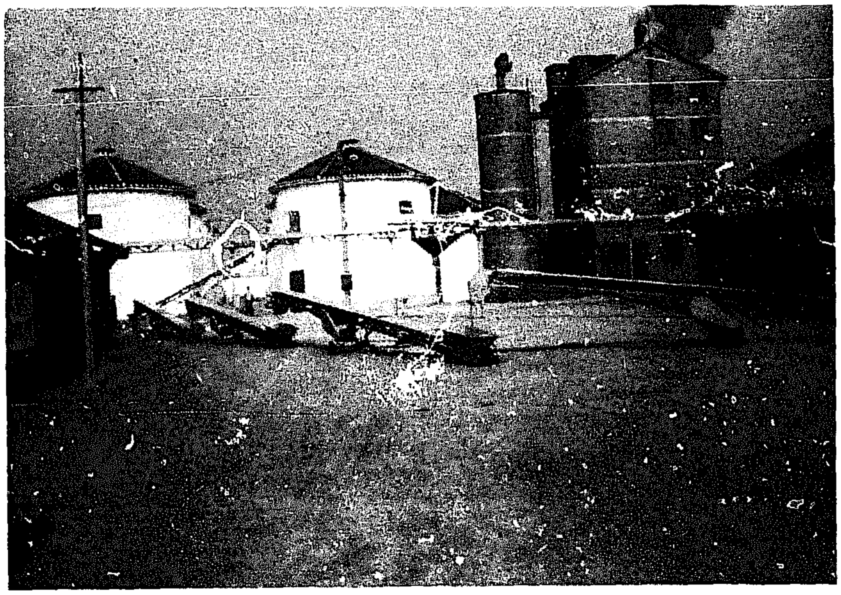


Photo 72 - Transport system - mobile belt conveyors and a fixed conveyor. Mobile conveyors are 12 m long, have a 350 mm wide belt and a belt speed of 3.5 m/sec. Maximum capacity 50 t/h. (Baoan Depot)

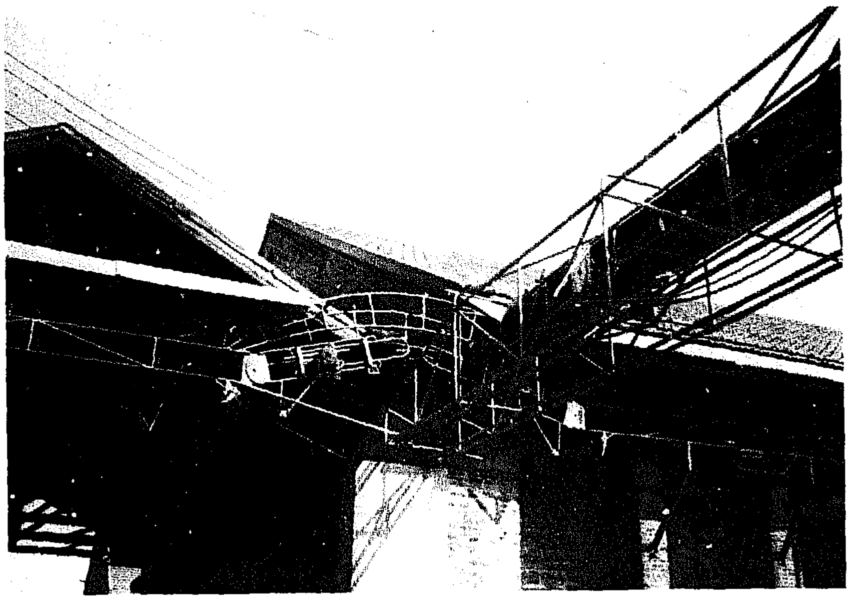


Photo 73 - Transport system. Joint between fixed belt conveyors. Two short adjustable conveyors and two sliding conveyors allow for "four-way traffic". (First Depot, Wuxi)

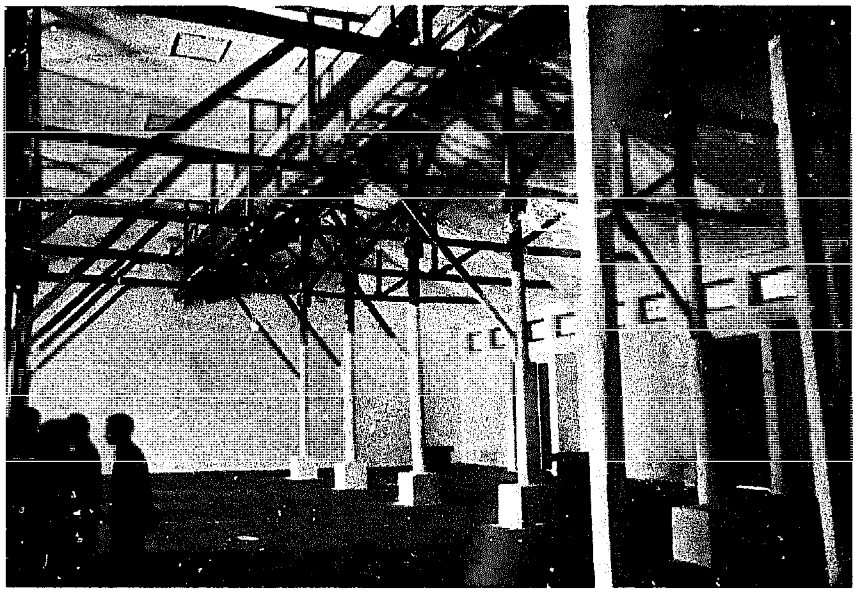


Photo 74 - Transport system. Centrally installed conveyor for distribution of grain in a bulk warehouse. (First Depot, Wuxi)

Photo 75 - Belt conveyor. Mobile with 400-mm rubber belt. Belt speed 2.5 m/sec. Capacity 30 t/h. (First Depot, Wuxi)

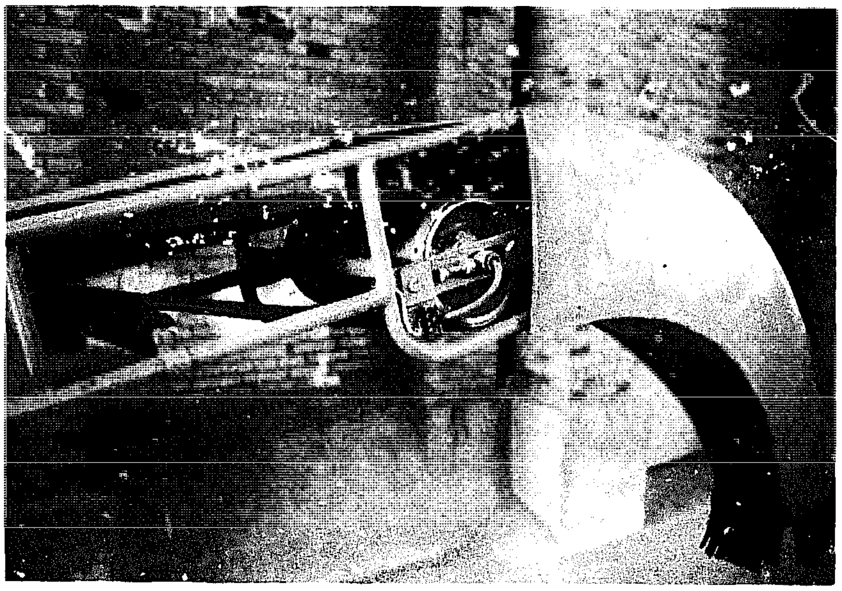


Photo 76 - Belt conveyor, "Electric roll" type with combined motor and pulley. The 1.5-kW motor has 16 poles. Conveyor is 6 m long, belt is 400 mm wide with a linear speed of 3.5 m/sec. Total weight 260 kg. Maximum capacity 60 t/h. (First Depot, Wuxi)

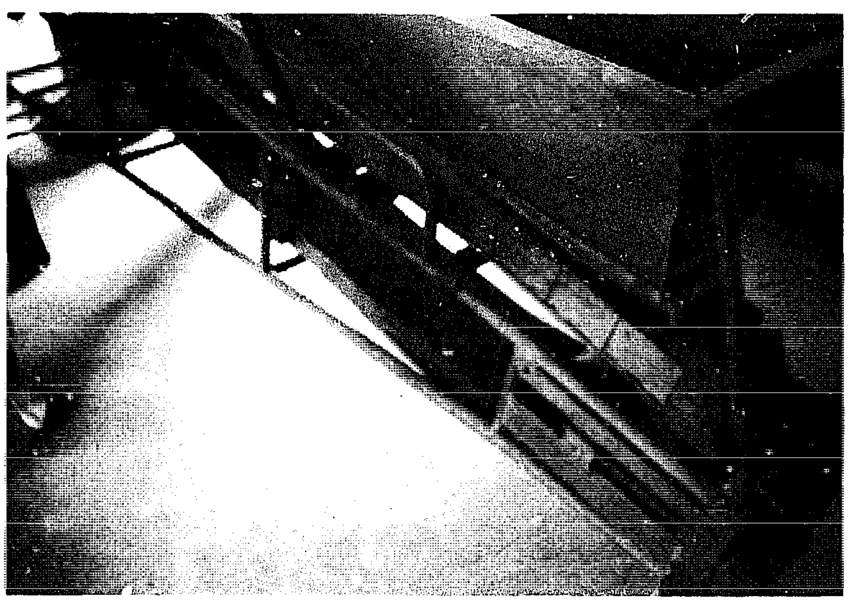


Photo 77 - Belt conveyor. 230-mm wide flat belt with sides made from sheet metal plates 150 mm long and 80-100 mm high. Pulley 250 mm diameter. Capacity 35 t/h.

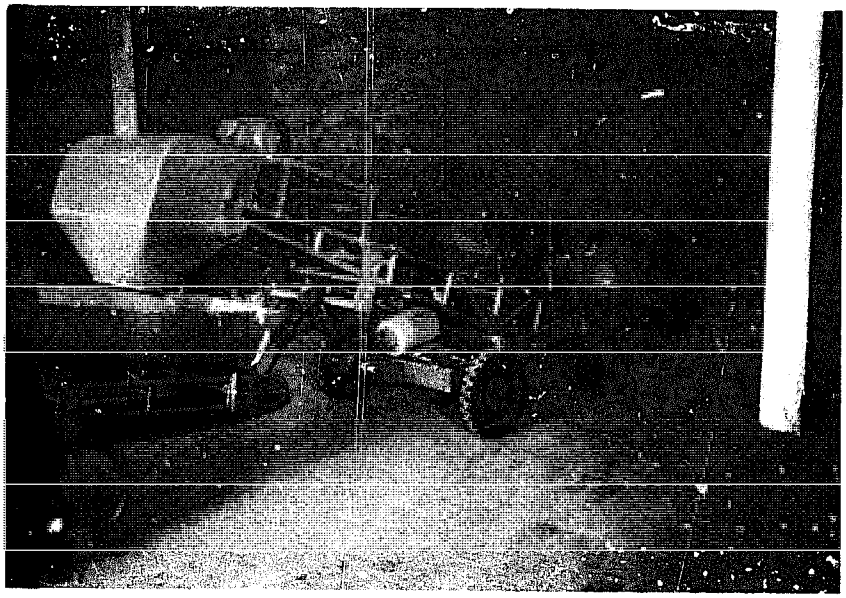


Photo 78 - Self-loading bulk grain conveyor for loading grain from bulk warehouses. It is remote-controlled and can be moved in all directions. It has 7 electric motors with a total of 6.6 kW. Capacity 60 t/h. (First Depot, Wuxi)

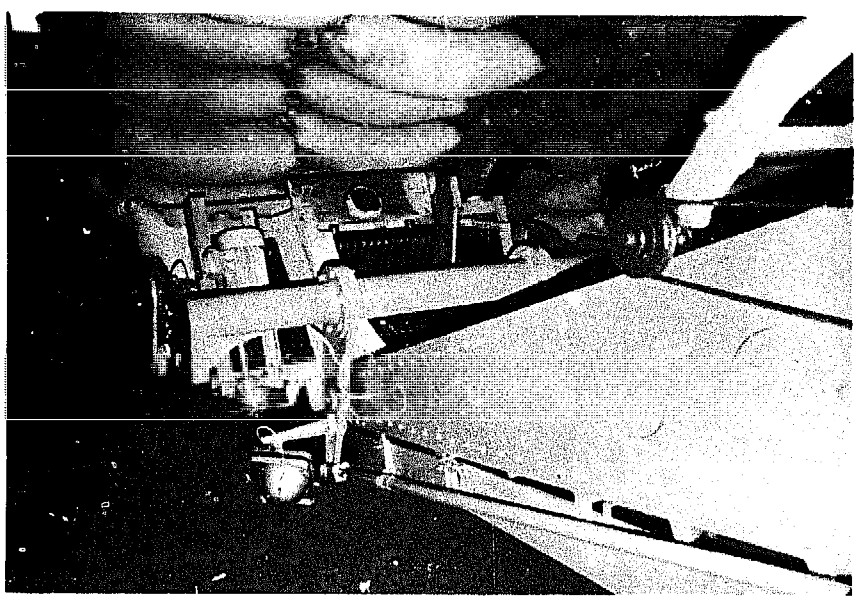


Photo 79 - Bag stacker, 400-550 bags/h up to a height of 3 m. (First Purchase and Supply Station, Shanghai)

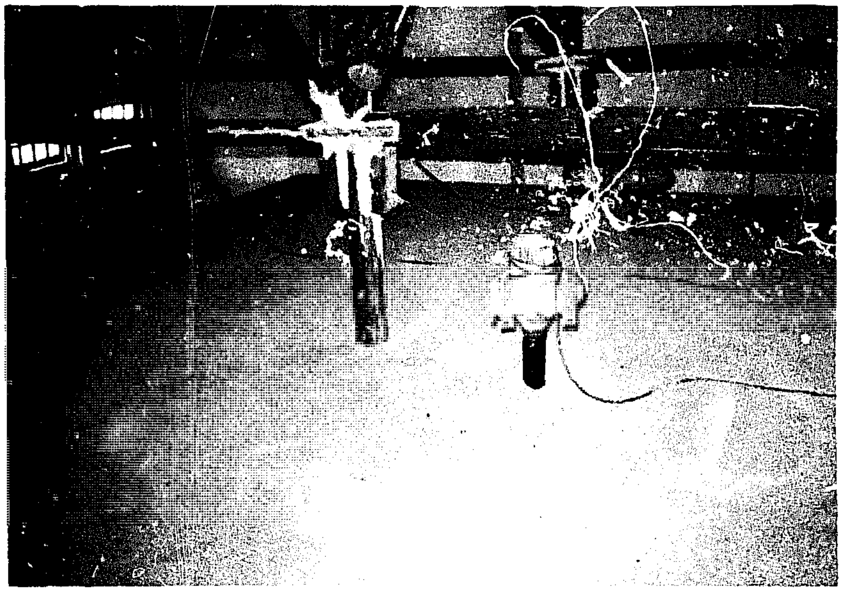
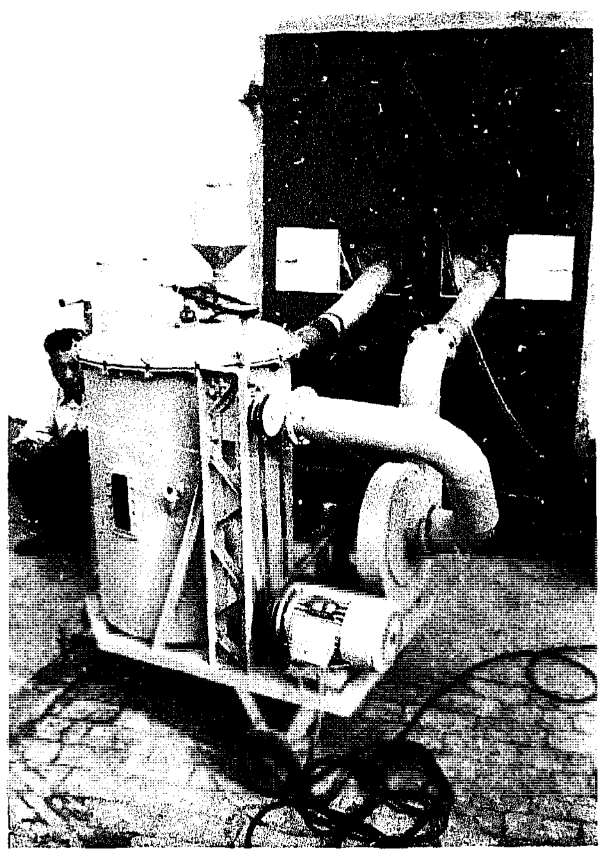


Photo 80 - Single-tube suction fan. 0.75-kW motor per unit, 1 000 m^3 at 90-120 mm water column. Suction pipe 80 mm diameter, length 3 m. 33 fan units/1 000 tons or one fan/30 tons. (First Depot, Wuxi)

Photo 81 - Fumatorium. Reaction tank with water and aluminium phosphide to produce PH_3. Blower 600 m^3/h. Two hours required to fumigate 125 tons. (Zaoan Depot)



APPENDIX 1

LIST OF PARTICIPANTS

Bangladesh

HAQUE, Entazul	Silo Superintendent Ministry of Food Santahar Silo, Santahar, Bogra
KASHEM, Abul	Deputy Director Directorate of Silos Ministry of Food 16 Abdul Gani Road, Dacca-2 Tel: 250551

Burma

U HTWE	Divisional Manager Agriculture and Farm Produce Trade Corp. Ministry of Trade Sagaing Division, Sagaing Tel: Sagaing (57) and (80)
U WIN MYINT THEIN	Consolidated Township Engineer Agriculture and Farm Produce Trade Corp. Let Padan

India

MATHUR, Avadhesh Prasad	Manager, Engineering Central Warehousing Corporation Ministry of Agriculture and Irrigation 92 Nehru Place New Delhi 110024 Tel: 681597 (Office) - 6644088 (Residence)
GARG, Narend Kumar	Indian Grain Storage Institute Punjab Agricultural University Campus Ludhiana (PB) - 141004

Iran

KESHAVARZ, Abbas	Agricultural Engineering Expert Department of Research and Planning Ministry of Agriculture and Rural Development Tehran, Karaj Zobahan Ave., Sarasyab Cross, Latifpour Alley 27 Tel: 6781

Iran (cont.)

KIAEE, Javad Yousef	Director-General Technical Services Training Ministry of Agriculture and Rural Development Tehran Television Ave., Ave. No. 20, Plack 12+1 Tel: 629785

Kenya

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Malaysia

LOO KAU FA	Director of Engineering National Paddy and Rice Authority 18-21 Floor, UMBC Building 4 Sulaiman Road P.O.Box 108, Kuala Lumpur Tel: 206133
SINGH, Ajit	Deputy Director Crop Production Branch Department of Agriculture Swettenham Road Kuala Lumpur 10-02

Nepal

REGMI, S.N.	Chief Agricultural Engineer Agricultural Engineering Section Department of Agriculture Shree Mahal Pulchowk Patan Tel: 21307

Pakistan

ANDRABI, Sharifuddin	Director, Agriculture Department Azad Jammu and Kashmir Government Muzaffarabad Tel: 3392 (Office) - 3309 (Residence)

Philippines

ANDALES, Silvestre C.	Assistant Professor and Head, Grain Processing Division Institute of Agricultural Engineering University of the Philippines Los Baños College, Laguna
CLASARA, Ernesto Cruz	Supervising Civil Engineer, Division Chief National Grains Authority 9th floor, Matimyas Building E. Rodriguez Sr. Ave. Quezon City
VIROLA, Ronald T.	Supervising Civil Engineer National Grains Authority 101 E. Rodriguez Sr. Ave. Quezon City

Sri Lanka

PITAWELA, R. Neville	Superintendent Paddy Marketing Board Badulla

Thailand

JARIT-NGARM, Chaiya	Civil Engineering Division Cooperatives Promotion Department Ministry of Agriculture and Cooperatives Bangkok 2
PIRIYAPAN, Veera	Extension Engineer Head, Agri-Mechanization Section Department of Agriculture Extension Ministry of Agriculture and Cooperatives Bangkhen, Bangkok
THONGSWANG, Maitrie	Agricultural Engineer Department of Agriculture Ministry of Agriculture and Cooperatives Bangkok 2

FAO

RANNFELT, Carl (Team Leader)	Senior Agricultural Engineer Agricultural Services Division FAO, Via delle Terme di Caracalla 00100 Rome, Italy Cables: FOODAGRI ROME Telex: 61181 FOODAGRI Tel: 57974614
SODE, Ove	Regional Coordinator FAO/SIDA Cooperative Programme Rural Structures, East and Southeast Africa P.O.Box 30470, Nairobi, Kenya Tel: 337956, 337957 Nairobi

APPENDIX 2

<u>Some Data from Countries Represented at the</u>
<u>FAO Workshop/Study Tour on Post-harvest Technology (Storage Structure Design)</u>

<u>China, 18 October – 15 November 1979</u>

		Bangladesh	Burma	India	Iran	Kenya	Malaysia	Nepal	Pakistan	Philippines	Sri Lanka	Thailand	China North	China South
Total land area, (million km^2)		0.14	0.65	3.0	1.6	0.58	0.33	0.14	0.78	0.3	0.06	0.51	9.6	
Population (millions)		80	33	660	34	15	13	13	78	46	15	46	975	
Cultivated area (million ha.)		9.0	10.0	16.5	15.0	1.8	3	2.3	20.0	5.25	1.0	15.7	100	
Rainfall, mm/year		1,500	3,000	–	150–1,400	50–1,500	2,000	1,700	800	2,300	–	–	600	1,500
Grain prod yr (mil.t.)	Total Cereals	19.3	10.7	141.0	8.0	2.9	1.6	3.7	14.5	10.2	2.0	20.0	304	
	Paddy	19.0	10.0	79.0	1.6	0.04	1.6	2.4	4.7	6.9	2.0	17.0	132	
	Wheat	0.34	0.09	31.0	5.7	0.14	0	0.4	8.0	–	–	–	44	
Net imports or exports of foodgrains (mill. t.)		Imp. 1.2	Exp. 0.7	–	Imp. 1.2	–	–	Exp. 0.7	–	Exp. 0.5	–	Exp. 8.0	–	
Marketed grain handled by (%)	Government	–	40	30	22	10	15	–	30	18	35	10	20	
	Private	–	–	–	4	–	55	25	–	2.1	15	30	–	
	Cooperatives	14	–	–	4	–	–	–	–	13	–	–	–	
	Others	–	–	–	–	–	–	5	–	–	–	–	–	
Grain kept on farms (% of total crop)		84	60	70	70	90	30	70	70	48	50	40	80	

(cont.)

		Bangla-desh	Burma	India	Iran	Kenya	Malay-sia	Nepal	Paki-stan	Philip-pines	Sri Lanka	Thai-land	China North	China South
No. of crops/yr., paddy		2	1	2	1	–	1.2	1.2	1	2	2	2	1	2
Yield: tons/ha. Average	All cereals	1.9	1.9	1.35	1.1	1.5	2.5	1.6	1.4	1.4	2.1	2.1	2.1	
	Paddy	1.9	2.0	2.0	3.6	6.0	2.5	1.8	2.6	1.8	2.1	2.1	3.5	
	Wheat	1.7	1.0	1.5	1.0	1.2	–	1.1	1.3	–	–	–	1.4	
Mechanization of Harvest	Paddy	Low	–	Med.	Low	Low	Low	Low	Low	Med.	–	Med.	Low	Med.
	Wheat	–	–	High	High	High	–	Low	Low	–	–	–	High	Med.
	Others	–	–	Low	Med.	Low	Low	Low	Low	Low	–	–	Low	Low
Climatic Conditions at Harvest	Temperature °C	28	26	28	30	30–35	30	20–30	20–25	20–30	20–28	27	P. 12 W. 24	P. 18 WP 33
	Relative humidity	80–90	80	70	P. 90 W. 30–40	80–90	90	80–90	80	85	80–90	27	P. 69 W. 59	P. 77 WP 84
	Moisture content	20–28	20–22	20	P. 25 W. 15	18–30	20–30	20–30	20–25	20–28	20–24	18–22	–	–

P. = Paddy; W. = Wheat

Note: The figures in the table are based on information obtained from participants. Where available, statistics on areas, production, yields, etc. have been taken from the 1978 edition of the FAO Production Yearbook. For China, figures have been obtained from the Ministry of Food.

APPENDIX 3

PROGRAMME

18 October 1979	Arrival of participants in Beijing.
19 October	Introduction and discussion of the programme with Mr. Wang Wenqing, Head of Foreign Affairs Division, Ministry of Grain and Food.
20 October	Visit to Zhang Xi Zhuang Depot in Shunye County, Beijing. Clay/straw walled dome-roofed silos and small flat stores for bulk handling.
21-22 Oct.	Visit to Niou Pao Tun Depot in Tungxian County, Beijing. Technical explanation and practice by participants in construction of clay/straw walled silos.
23 October	Discussions with the Chinese counterparts.
25 October	Discussions with the Chinese counterparts.
26 October	Group discussions.
27-29 Oct.	Visit to the First Depot, Wuxi. Briefing on storage methods and types of stores in the area.
	Further briefing on mechanical handling equipment and control of pests and grain quality.
31 October	Visit to Baoan Depot, Wuxi. Stores for bagged grain.
1 November	Discussions with the Chinese counterparts. Participants giving lectures on grain storage in their own countries.
2 November	Group discussions.
3 November	Visit to the First Purchase and Supply Station, Shanghai. Stores for bagged grain, low-temperature storage, mechanical equipment for bagged grain.
4 November	Visit to the South Gate Depot, Sunjiang County. Bulk storage in clay dome-roofed silos.
5 November	Visit to Shanghai Grain Food Science Research Institute.
	Visit to 7th Depot, Shanghai. Large stores with prefabricated roof structures.
6 November	Discussions with the Chinese counterparts. Participants giving lectures on grain storage in their own countries to the Chinese counterparts.
7 November	Visit to National Exhibition Centre, Shanghai.
	Visit to Malu Commune, Jiading County.

8 November	Harvesting, threshing and storing of paddy at production team level.
9 November	Beijing. Group discussions and preparation of group work.
10 November	Group work. Participants giving lectures on grain storage in their own countries to the Chinese counterparts.
11 November	Preparation of group work.
12 November	Group discussions. Final examination for the participants.
13 November	Preparation of group work. Lecture on underground storage.
14 November	Group discussions.
15 November	Departure of 12 participants.
16 November	Departure of 1 participant. The Team Leader, 1 FAO staff member and 2 participants remain to prepare the final report.
17-21 Nov.	Preparation of final report. Final discussions with Chinese officials.
18 November	Departure of 2 remaining participants.
22 November	Departure of Team Leader and FAO staff member.

ᴾPENDIX 4

PERSONS MET

l. BEIJING

Ministry of Grain and Food

杨德树	Yang Deshu	Acting Director of Foreign Affairs Department
王文钦	Wang Wenqing	Head of Foreign Affairs Division
隋继祥	Suei Jixiang	Head of Grain Storage Division
关延生	Guan Yansheng	Staff Member
王立翔	Wang Lixiang	" "
陈 菲	Mrs. Chen Fei	" " (interpreter)
谢小英	Miss Xie Xiaoying	" " (")
毛英发	Mao Yingfa	" " (")

Zhang Xi Zhuang Grain Depot, Shunyi County

	Li Motin	Director of Depot

Niou Pao Tun Depot, Tungxian County

	Huan Shiu	Director of Depot
王守德	Wang Shoude	Instructor in practical work from the Municipal Corporation of Food and Grain, Beijing

Lecturers

Grain Storage Systems in China

隋继祥	Suei Jixiang	Head of Grain Storage Division, Ministry of Grain and Food

Clay-Straw Silos

王守德	Wang Shoude	Engineer, Municipal Corporation of Food and Grain, Beijing
叶钟英	Ye Zhongying	

Underground Stores

师有礼	Shi Youli	Civil Engineer of the Grain Bureau, Henan Province

2. WUXI

The Provincial Grain Bureau, Jiangsu Province

汤西谷	Tang Xigu	Director
徐惠迺	Xu Huinai	Deputy Director, Grain Storage Department
陈志顺	Chen Zhishun	Staff member, Foreign Affairs Department (French and English speaking)

The Municipal Grain Bureau

石 峰	Shi Feng	Director
杨俊甫	Yang Junpu	Head of Administration Office
朱效鸣	Zhu Xiaoming	Head of Grain Storage Section

Wuxi Municipality

郑苏苏	Zheng Susu	Staff Member of the Foreign Affairs Office (interpreter)

First Depot, Wuxi

Wang Liching	Director
Chin Haosing	Architect
Yoe Yonlong	Assistant Architect
Lu Futing	Assistant Architect
Lu Xiting	Technician, Storage
Shen Thenguo	Technician, Storage
Shao Ginshar	Mechanical Engineer
Zu Thugong	Technician, Mechanical
Yang Houji	Technician, Laboratory

Baoan Depot, Wuxian County

杜 钰	Du Yu	Director
沈顺喜	Shen Shunxi	Assistant Director

Baoan Depot, Wuxian County (cont.)

国中伟	Guo Zhongwei	Storage Department
季　兴	Ji Xing	Mechanical Engineer

The Grain Bureau, Wuxian County

吴　杰	Wu Jie	Director
惠金木	Huei Jinmu	Head of the Grain Storage Department
赵俭成	Zhao Jiancheng	Technician

Baoan Commune

	Chen Tinghua	Director of the Commune

3. SHANGHAI

The Grain Bureau

浦　清	Pu Qing	Deputy Director
朱仲麟	Zhu Zhonglin	Deputy Director, Foreign Affairs Division
金问树	Jin Wenshu	Staff member, Foreign Affairs Division
	Sung	" " " " "

The Grain Storage Corporation

宋亚祥	Song Yaxiang	Director
邱福亭	Qiou Futing	Head, Grain Storage Section
宋加康	Song Jakang	Head, Grain Storage Section

Shanghai Municipality

谢文英	Mrs. Xie Wenying	Office of Foreign Affairs

The First Purchase and Supply Station

腾学礼	Teng Xueli	Director
李长林	Li Changlin	Deputy Director
徐 樑	Xu Liang	Deputy Director
赖仁泉	Lai Renqun	Head, Grain Storage
杨金华	Yang Jinhua	Civil Engineer
	Liu	Storage Technician (open-air storage)

The Grain Bureau, Songjiang County

陈 雄	Chen Xiong	Director

South Gate Depot

何秉衡	He Bingheng	Director

Xinqiao Grain Purchasing and Supply Station

	Li Tuxiang	Director

Shanghai Grain Food Science Research Institute

	Wang Chenyer	Director
	Chao Tungfang	(English speaking)

Seventh Depot

吴志达	Wu Zhida	Director
孙公伟	Sun Gongwei	Civil Engineer

APPENDIX 5

PROJECT IDEAS

These ideas are proposed by participants from the various countries.

1. BURMA

Testing of clay/straw silos for storage of paddy under Burmese conditions

To build and test clay/straw silos in Upper Burma (Sagaing Division) to serve the Agricultural and Farm Produce Trade Corporation (AFPTC) for procurement of paddy. Three sizes of silo are proposed:

- Diameter 4 m, height 2 m;
- Diameter 6 m, height 4 m;
- Diameter 8 m, height 6 m.

2. IRAN

Open-air storage

Temporary stores for buying centres to reduce losses during grain procurement. It is anticipated that such stores may be needed in 1 200 locations and storage units should hold 100 to 200 tons each.

Low-temperature stores

For the hottest parts of the country where substantial losses occur in ambient air temperature stores.

3. KENYA

Small clay/straw silos for farm use

Development and testing of small-scale clay/straw silos for low income farmers who cannot afford to buy building materials or insecticides. Silos will have to be adapted to conditions in Kenya and should serve mainly for storage of grain to be consumed on the farm. This type of silo could be suitable for maize which has been dried in cribs.

Conversion of bagged grain warehouses to bulk grain warehouses

Applying the method used in China (bag walls/plastic sheets), bulk storage of grain should be tried.

4. MALAYSIA

Nitrogen stores for milled rice

Temperatures below 27°C and relative humidities below 65 percent cannot be obtained in Malaysia, and there is considerable deterioration of quality in milled rice during storage. A conventional flat store could be used for this trial. Stacks of rice bags will be covered with polyethylene and the "tent" filled with nitrogen gas. The experiment should be monitored and quality changes recorded every time.

5. PAKISTAN

Constrvction of clay/straw silos

.n collaboration with a rural development programme, build and test small clay/ straw silos with a holding capacity of 5-10 tons each.

6. PHILIPPINES

Testing of clay/straw silos

To design and build clay/straw silos adapted to Philippine conditions and test their suitability for climatic conditions.

Conversion of a bagged grain warehouse to bulk storage

Using methods studied in China, convert one warehouse belonging to the National Grains Authority to bulk storage and carry out a technical and economic comparison with conventional bag storage in the same type of warehouse.

Storage of grain under a polyethylene cover

To study the effect and possible advantage of protecting bag stacks with polyethylene sheeting to create "modified atmosphere" storage.

7. SRI LANKA

Storage of grain under a polyethylene cover

To prevent grain stored in bulk from absorbing moisture during the wet season, grain piles to be covered with polyethylene sheeting which should be sealed.

8. THAILAND

Construction and testing of clay/straw silos

To build and test in Lumpang and Chainat provinces three different sizes of clay/ straw silo:

- Diameter 4 m, 15 tons paddy (for farm warehouse);
- Diameter 6 m, 50 tons paddy (for small production team);
- Diameter 7 m, 130 tons paddy (for seed multiplication collecting centre).

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A. MAIN REFERENCES (HANDOUTS PROVIDED TO PARTICIPANTS)

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12. The Barn Construction. Grain Storage and Transportation Corporation, Shanghai. 7 p. and drawings. Stencil.

B. OTHER REFERENCES

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2. FAO. 1980 Economic Information on Centrally Planned Economies, No. 28. ESS/DBU. Rome.

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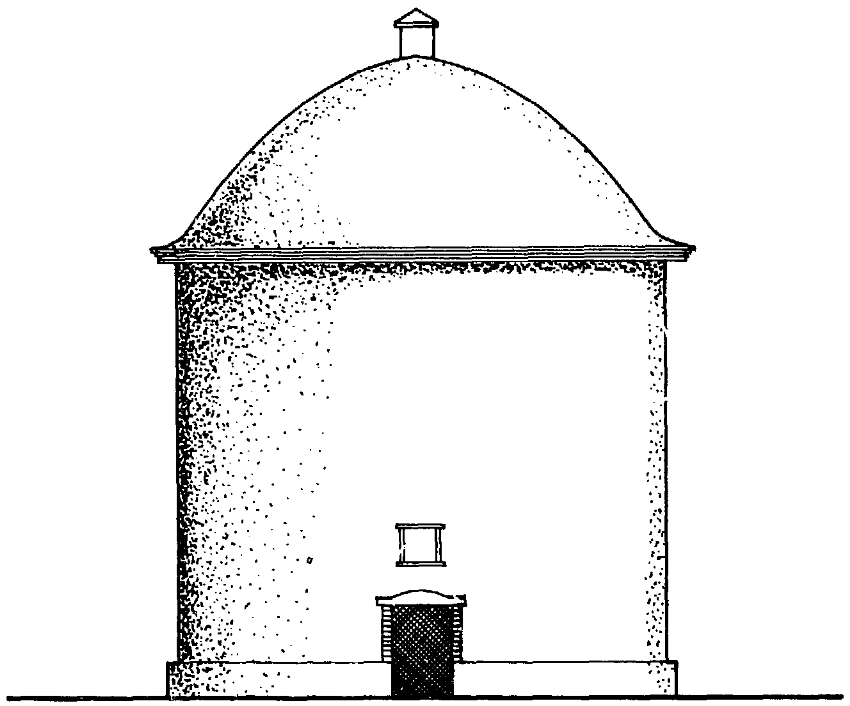
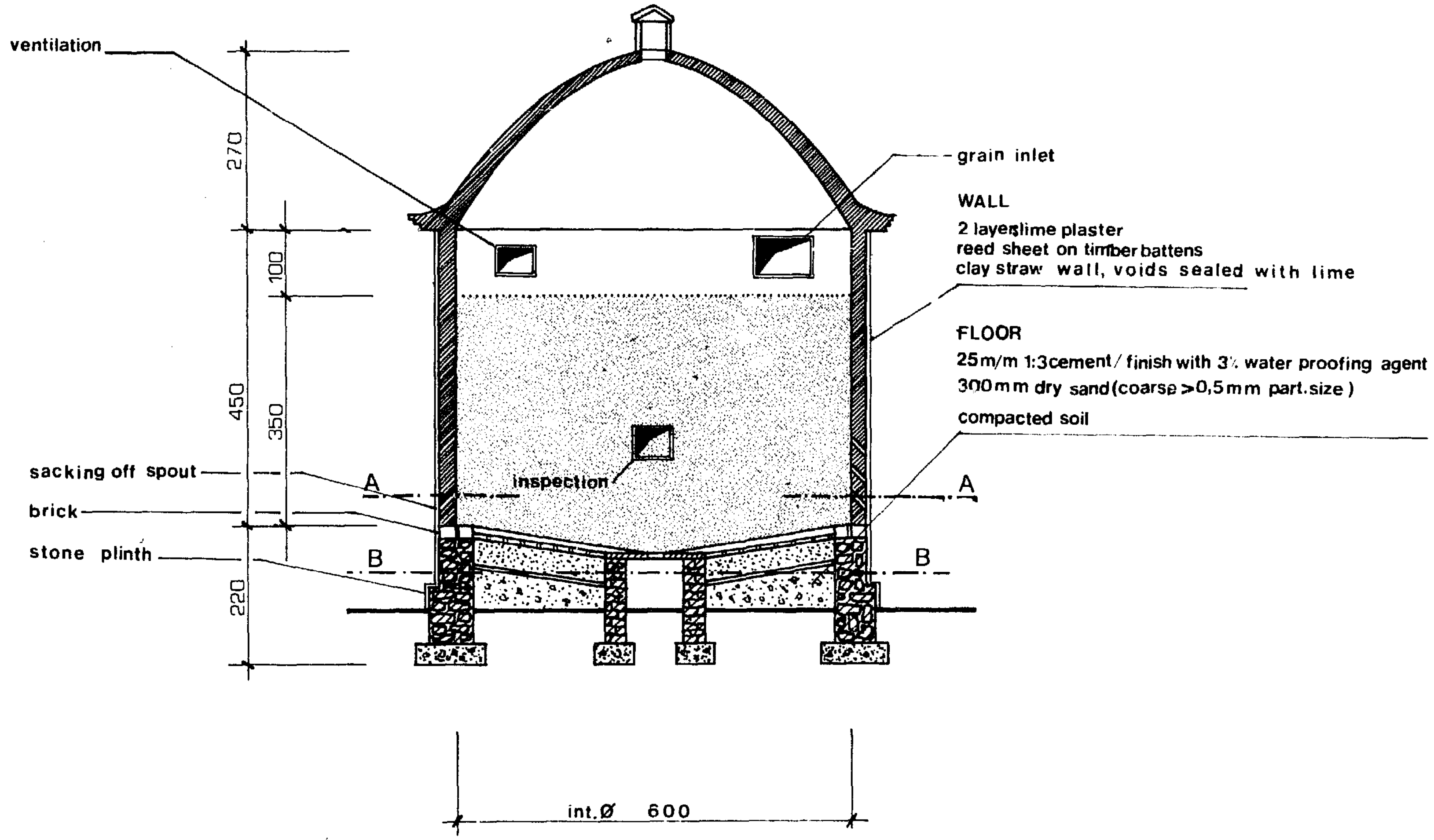
8. Jigurdson, J. Rural Industrialization in China. Paper submitted to 94th Congress, 1975 1st Session, Joint Committee. US Government Printing Office.

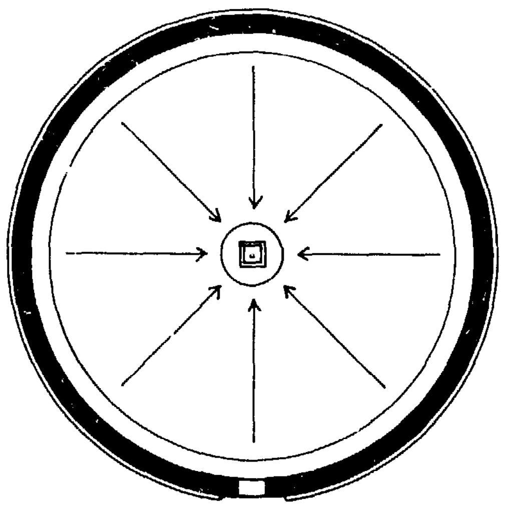
9. Ahmad, M.G. Chinese Pattern Mud Silos. Paper presented at the International Seminar 1978 on Low-Cost Farm Structures, Peshawar University, 27 Feb. - 4 March 1978. Lahore, Pakistan Agricultural Storage and Services Corporation.



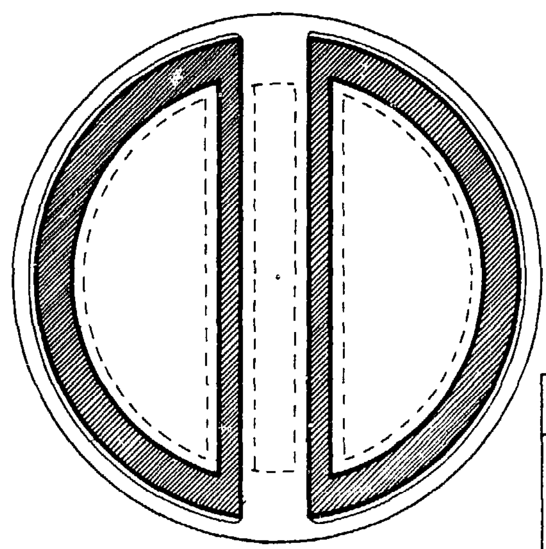
ELEVATION



SECTION



PLAN A–A



FOUNDATION PLAN B–B

RAS 79/006 - GRAIN STORAGE STRUCTURES-CHINA

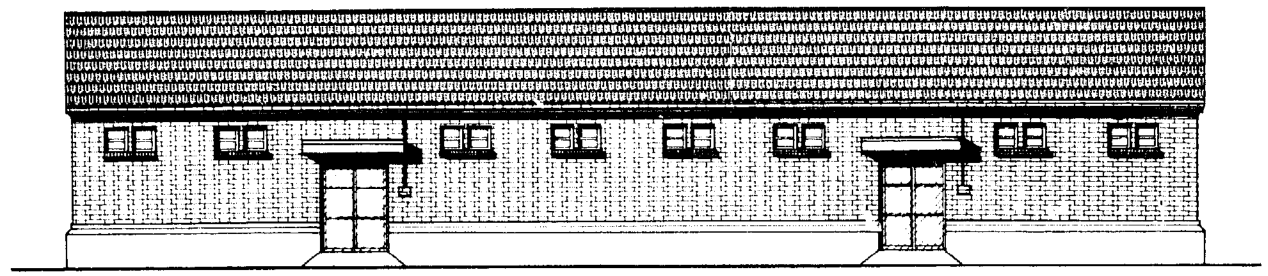
CLAY STRAW SILO WITH CLAY DOME ROOF

Ø 6 m.

60 tons of paddy
85 tons of wheat

DRWG N° 1

Scale 1:100



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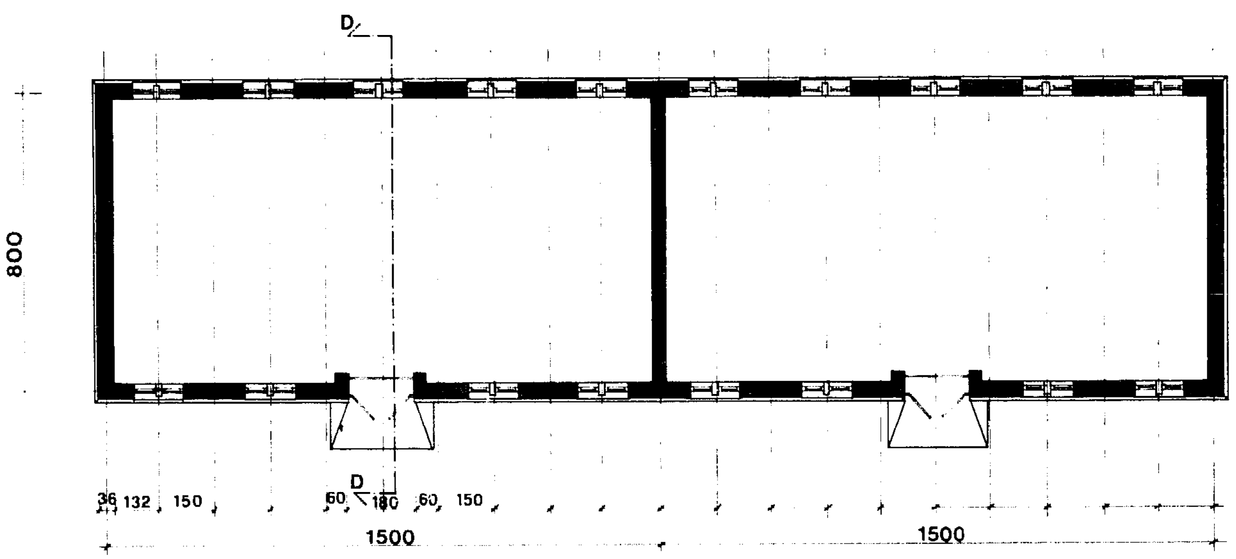
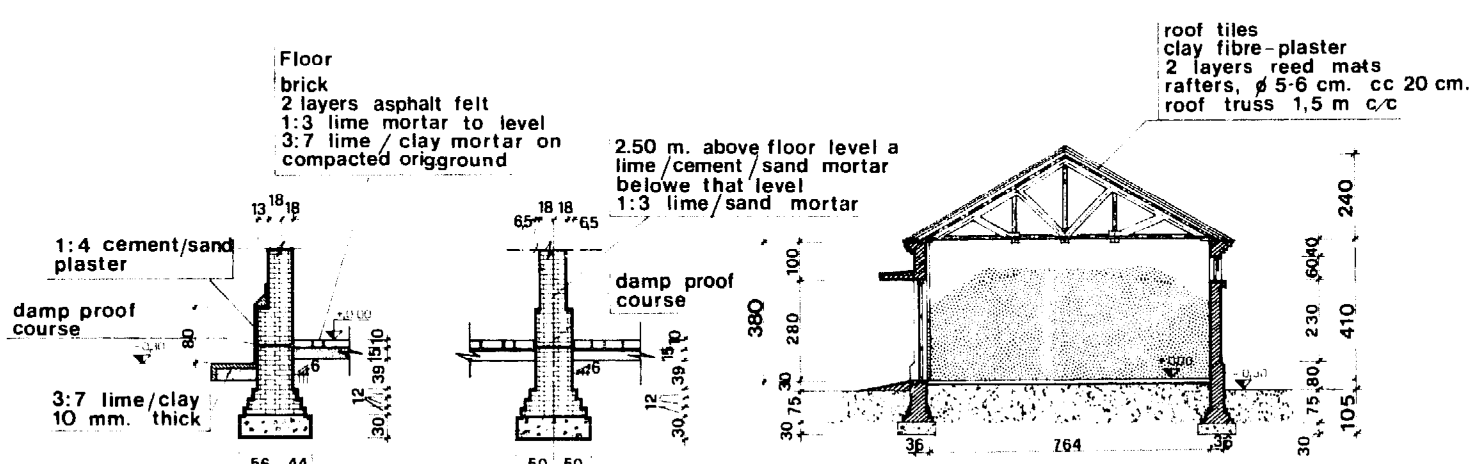


PLAN

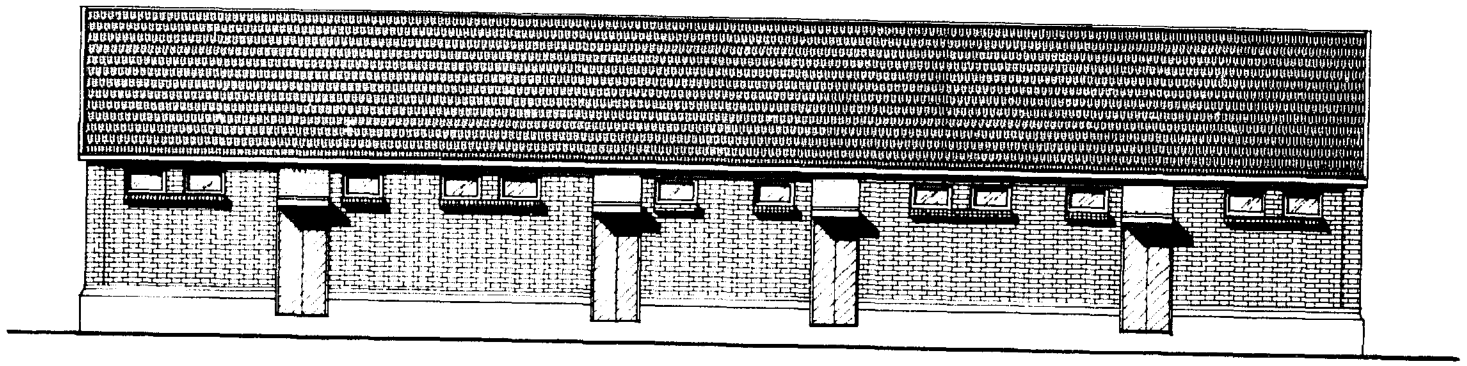


FOUNDATION

EXTERNAL WALL INTERNAL WALL

Scale 1:100

RAS 79/006-GRAIN STORAGE STRUCTURES-CHINA	
BULK GRAIN WAREHOUSE	DRWG N° 3
8.00×15.00 m 470 TONS OF WHEAT	
(CHANG-XI DEPOT)	Scale 1:200



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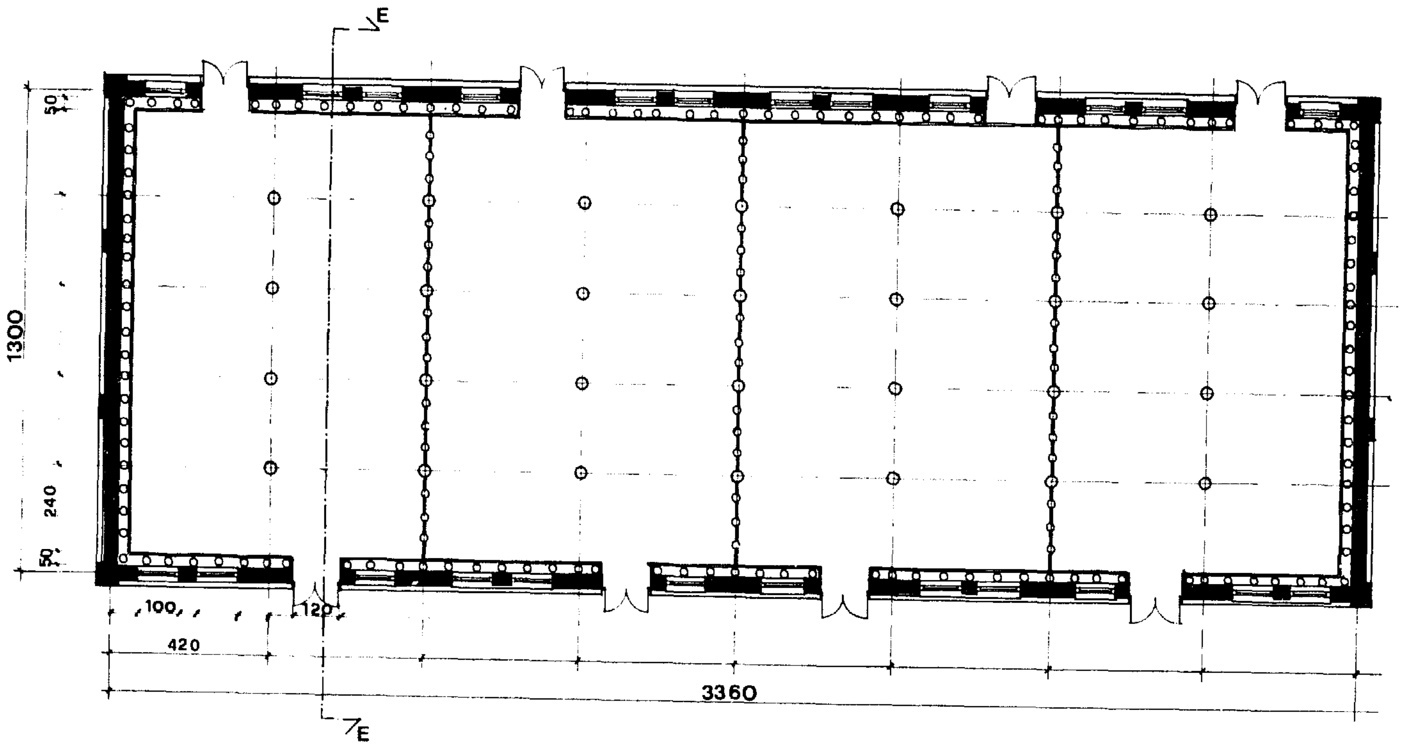

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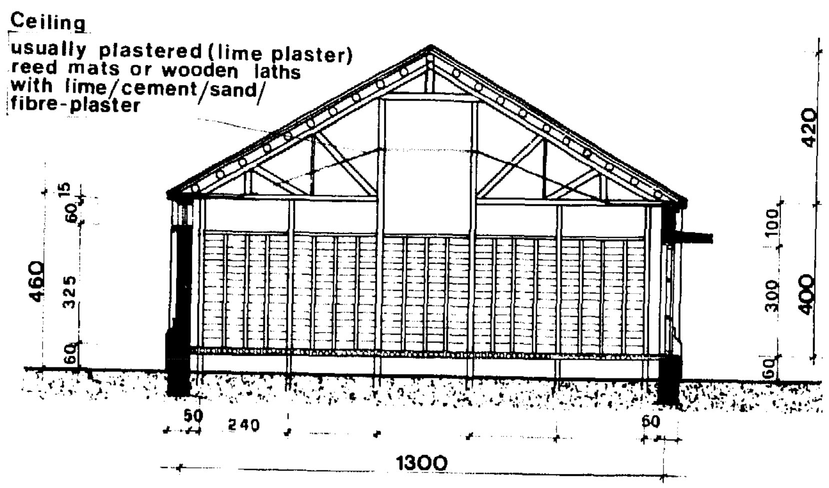
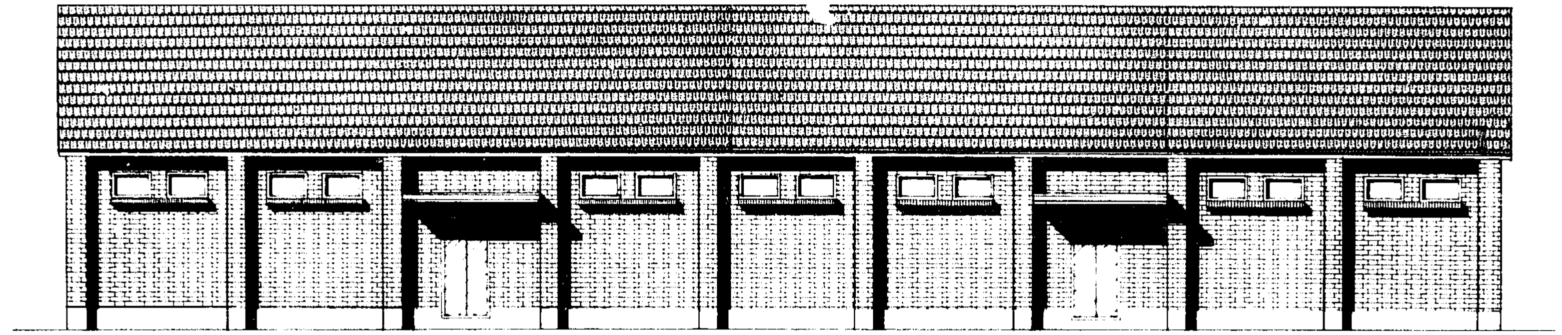


SECTION E-E

RAS 79/006 - GRAIN STORAGE STRUCTURES - CHINA

BULK GRAIN WAREHOUSE 13.00×33.60 m — 635 TONS OF PADDY, 664 TONS OF WHEAT (TYPE "50" WUXI)	DRWG N° 4
	Scale 1:200



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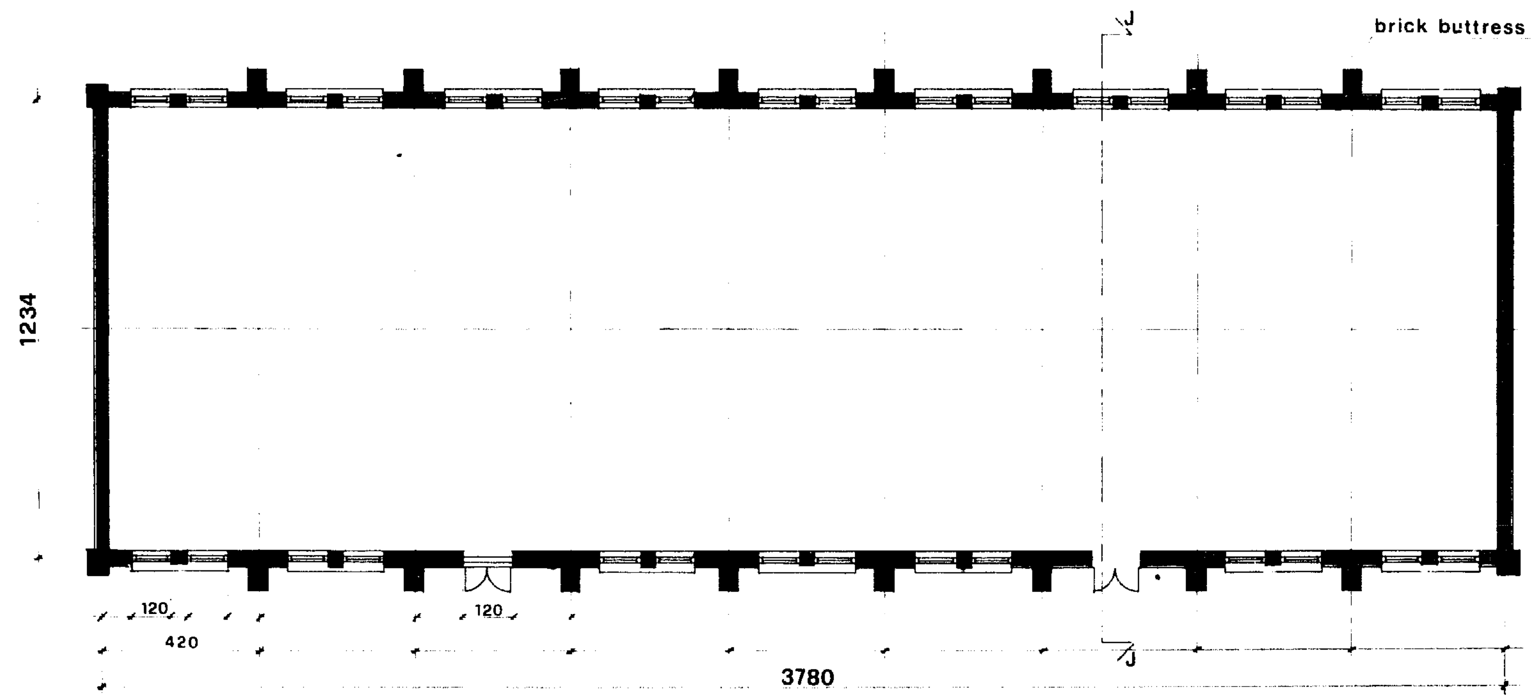
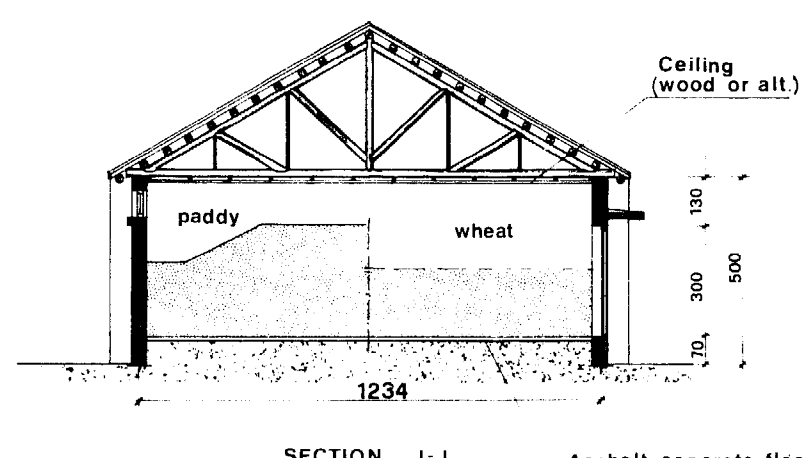


PLAN



SECTION J-J

RAS 79/006-GRAIN STORAGE STRUCTURES-CHINA

BULK GRAIN WAREHOUSE

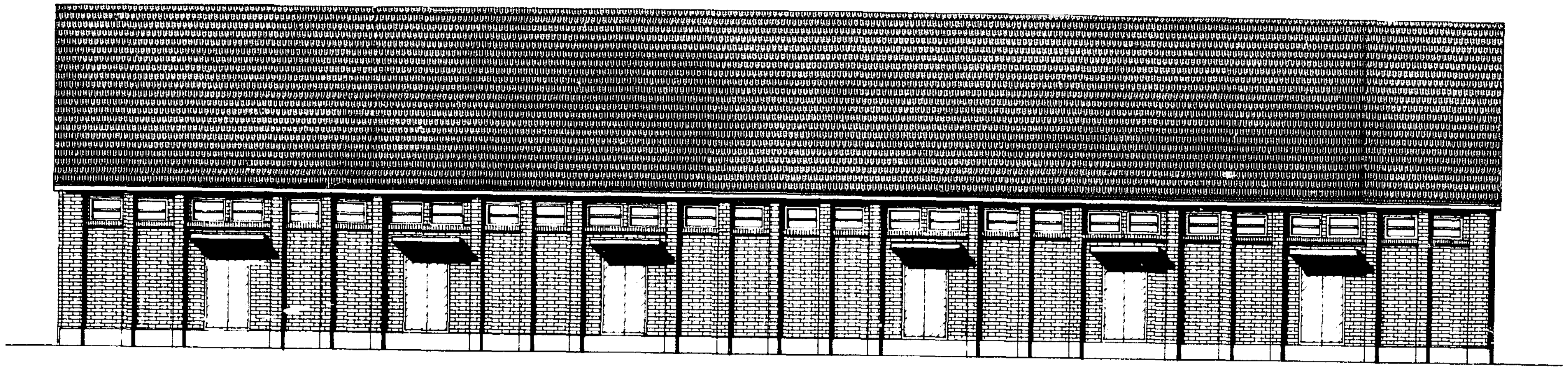
12.34x37.80 m

664 TONS OF PADDY
905 TONS OF WHEAT

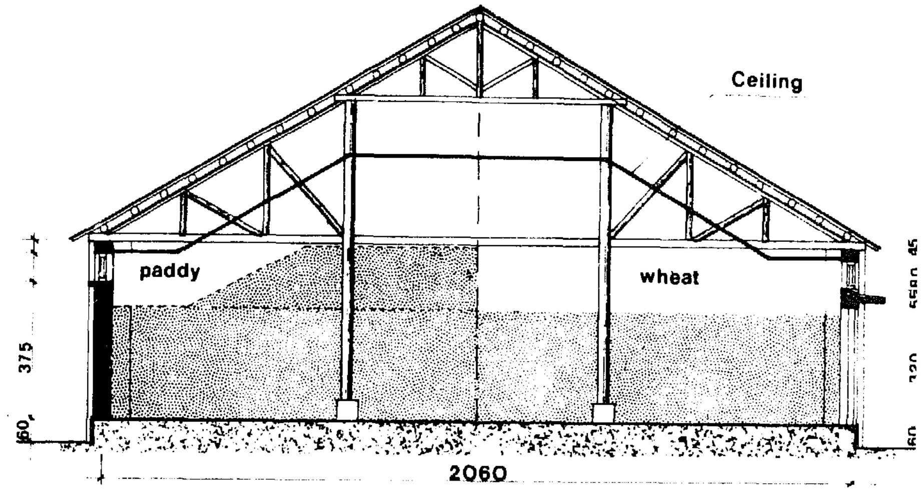
(REFORMED TYPE "51" WUXI)

DRWG N° 5

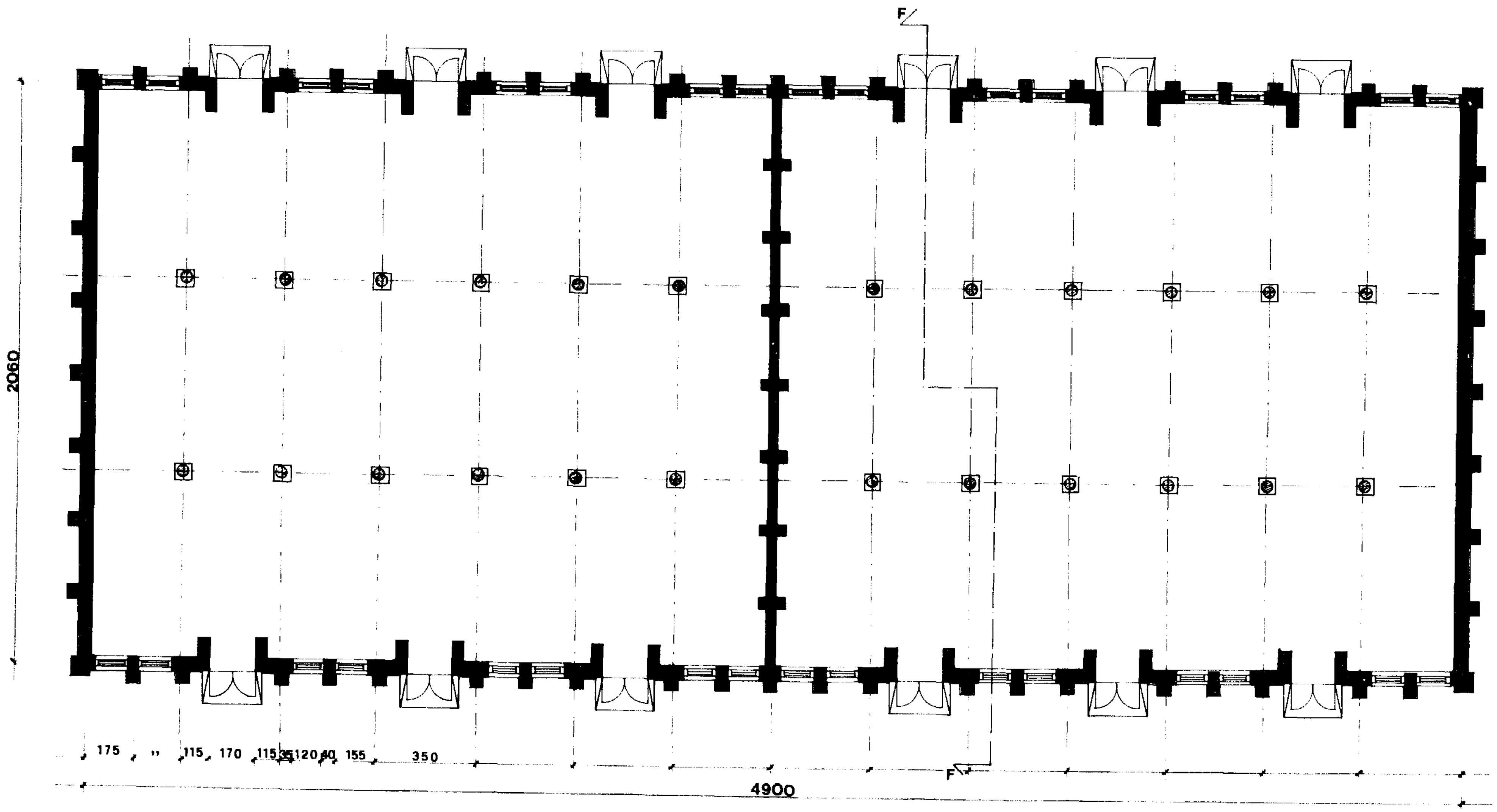
Scale 1:200



ELEVATION



SECTION F-F



PLAN

RAS 79/006 - GRAIN STORAGE STRUCTURE

BULK GRAIN WAREHOUSE

20.60x49.00 m

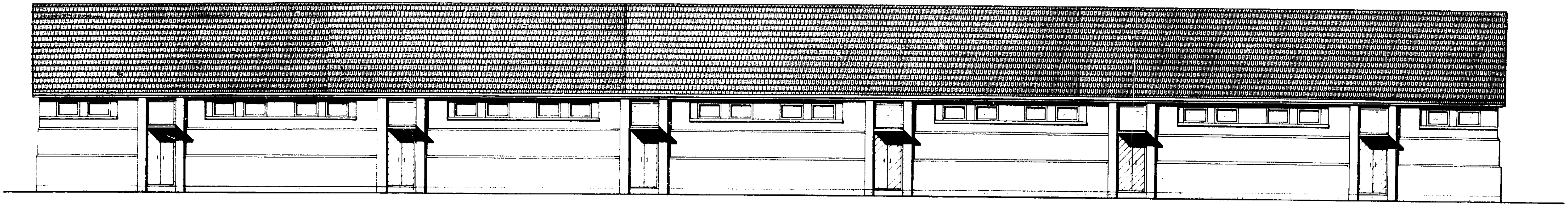
1500 TONS OF PADDY
1530 TONS OF WHEAT

(REFORMED TYPE "51" WUXI)

DF

Sc

1:



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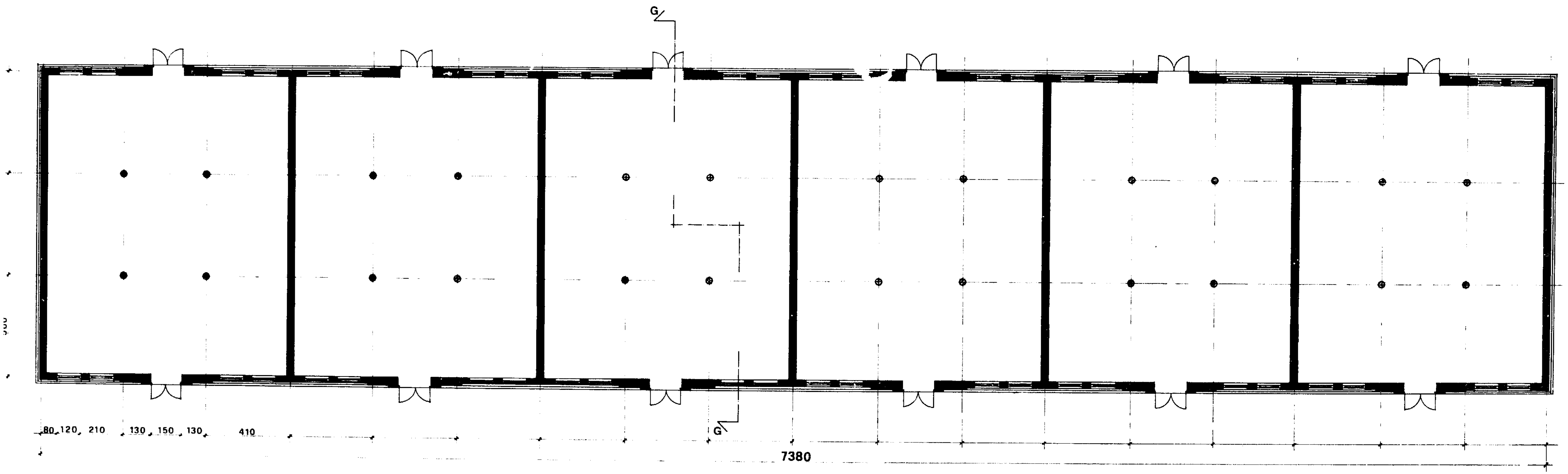
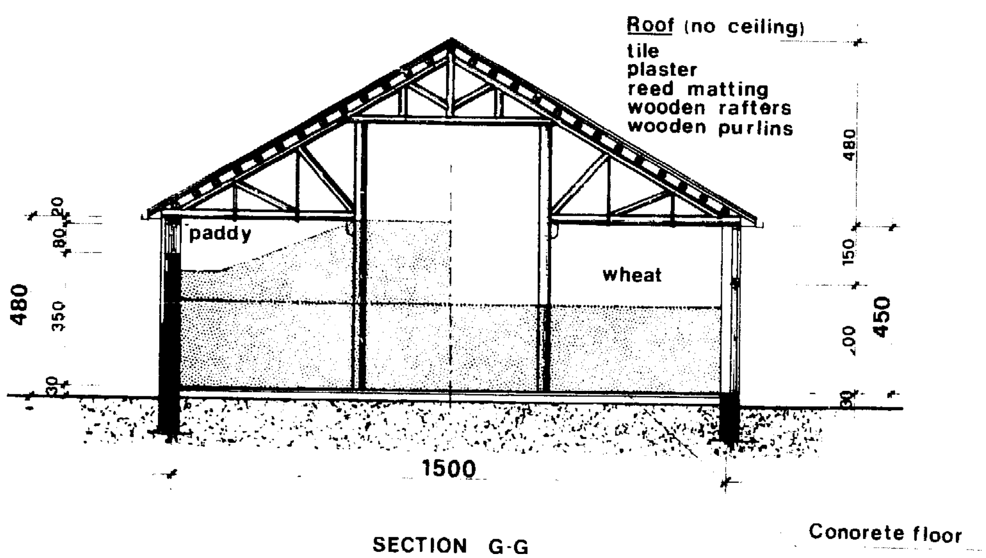
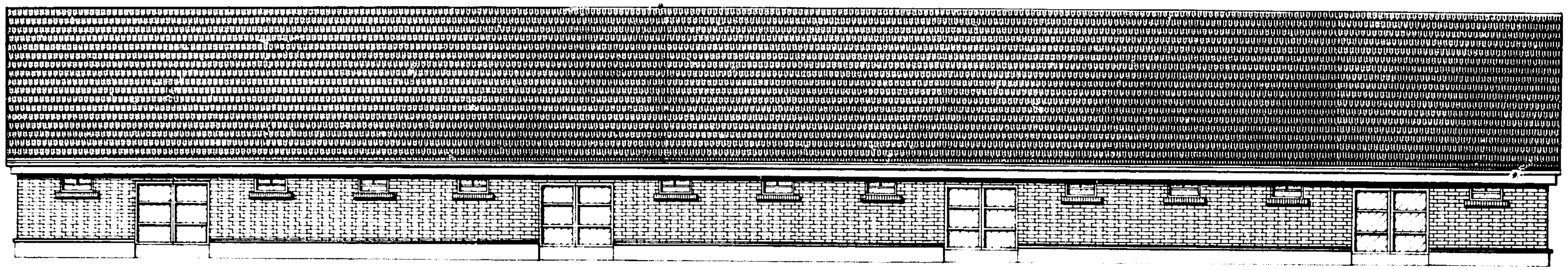


PLAN

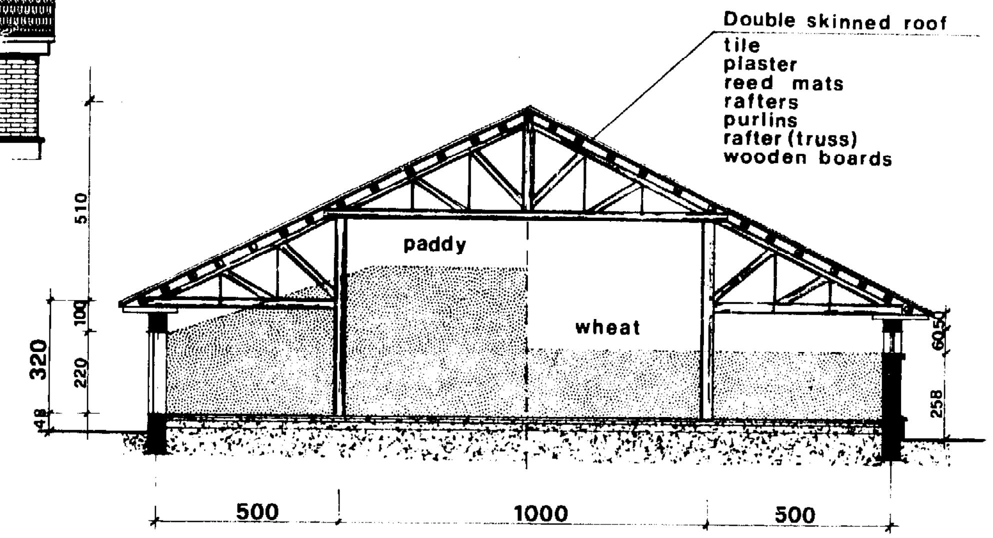


SECTION G-G

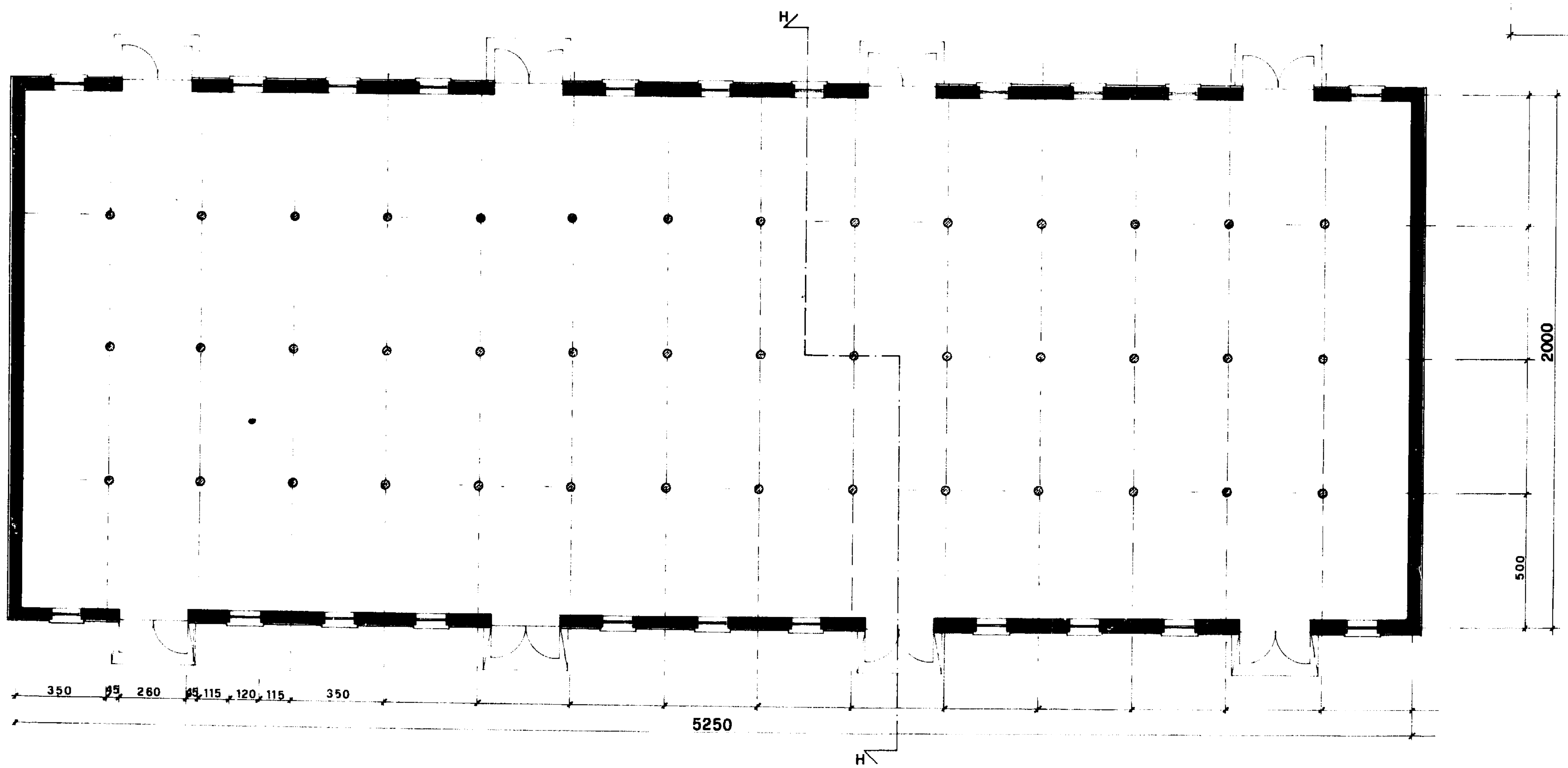
RAS 79/006-GRAIN STORAGE STRUCTURES-CHINA	
BULK GRAIN WAREHOUSE	DRWG N° 7
15.00 x 73.80 m — 1856 TONS OF PADDY, 1716 TONS OF WHEAT	Scale 1:200
(TYPE "53" WUXI)	



ELEVATION



SECTION H-H



PLAN

RAS 79/006 - GRAIN STORAGE STRUCTURES - CHINA

BULK GRAIN WAREHOUSE

20.00 x 52.50 m

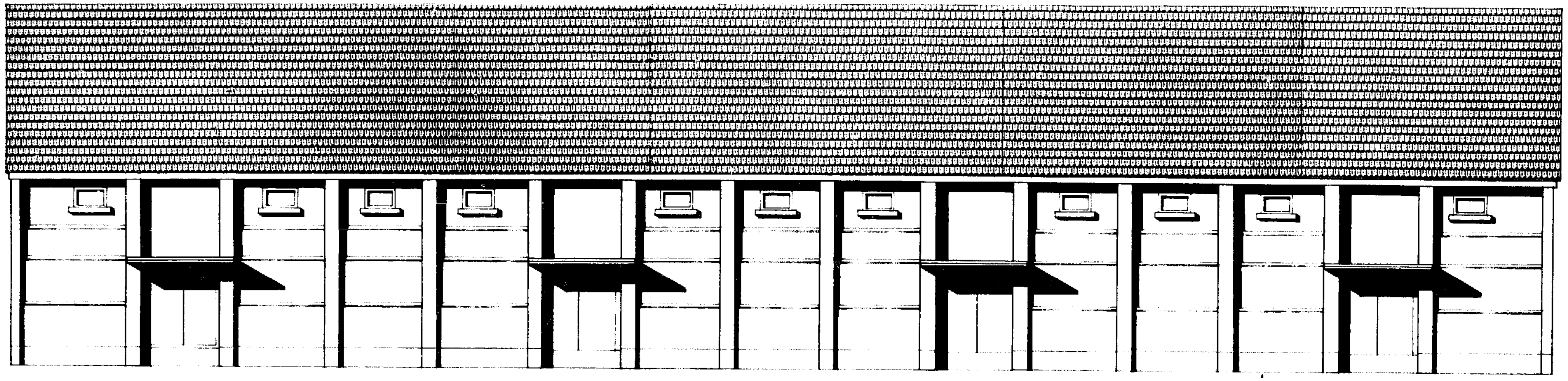
(TYPE "54" WUXI)

1428 TONS OF PADDY

1513 TONS OF WHEAT

DRWG N° 8

Scale 1:200



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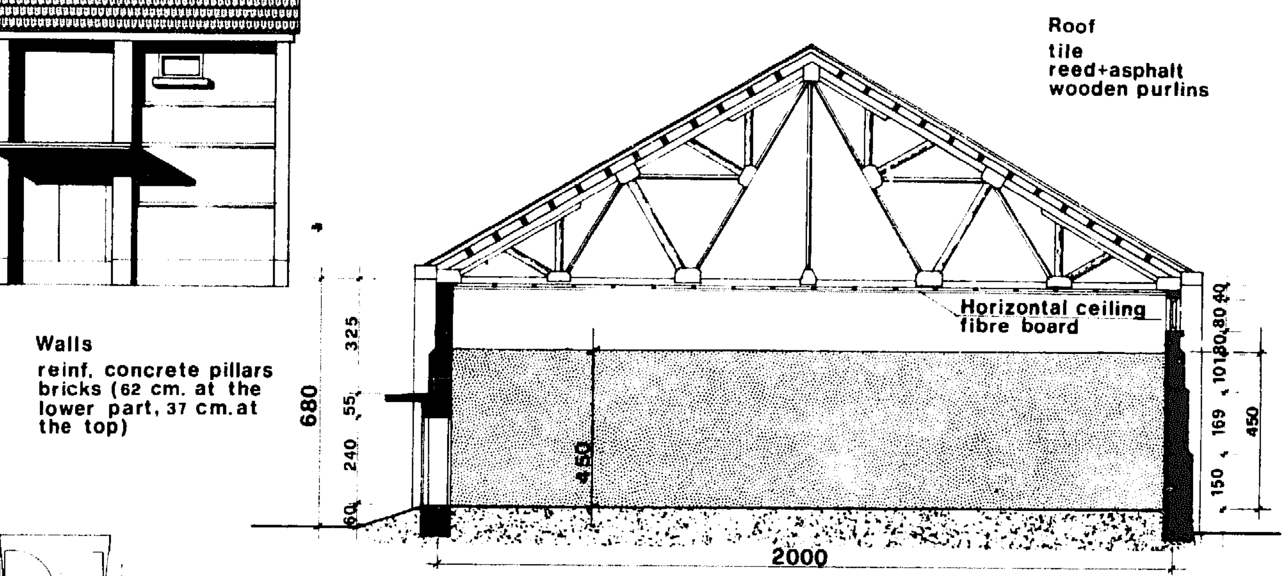
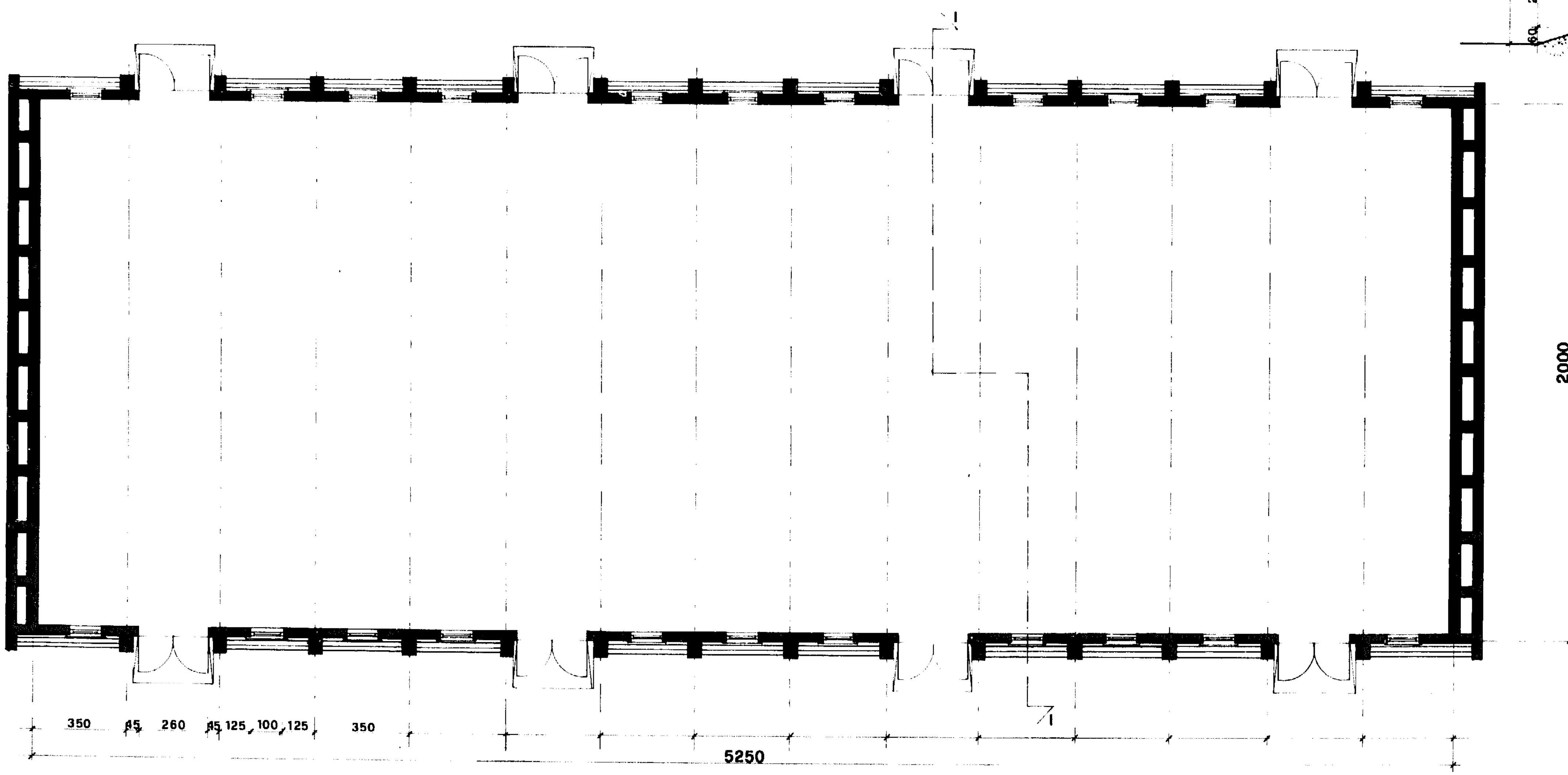
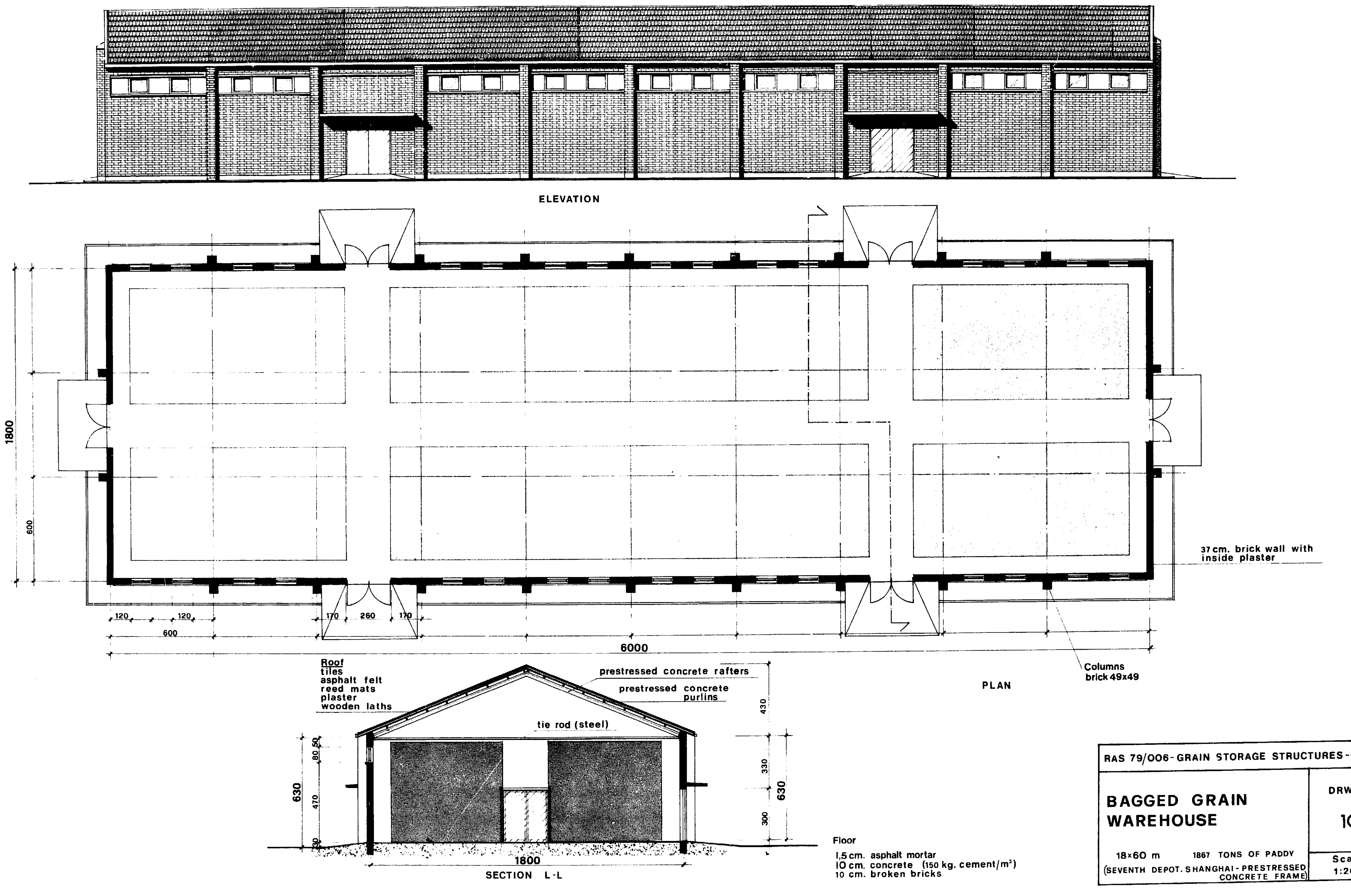


SECTION I-I



PLAN

RAS 79/OO6-GRAIN STORAGE STRUCTURES-CHINA	
BULK GRAIN WAREHOUSE	DRWG N° 9
20.00x52.50 m — 2436 TONS OF PADDY, 3322 TONS OF WHEAT	Scale 1:200
(REFORMED) TYPE "54" WUXI	



RAS 79/006-GRAIN STORAGE STRUCTURES-CHINA

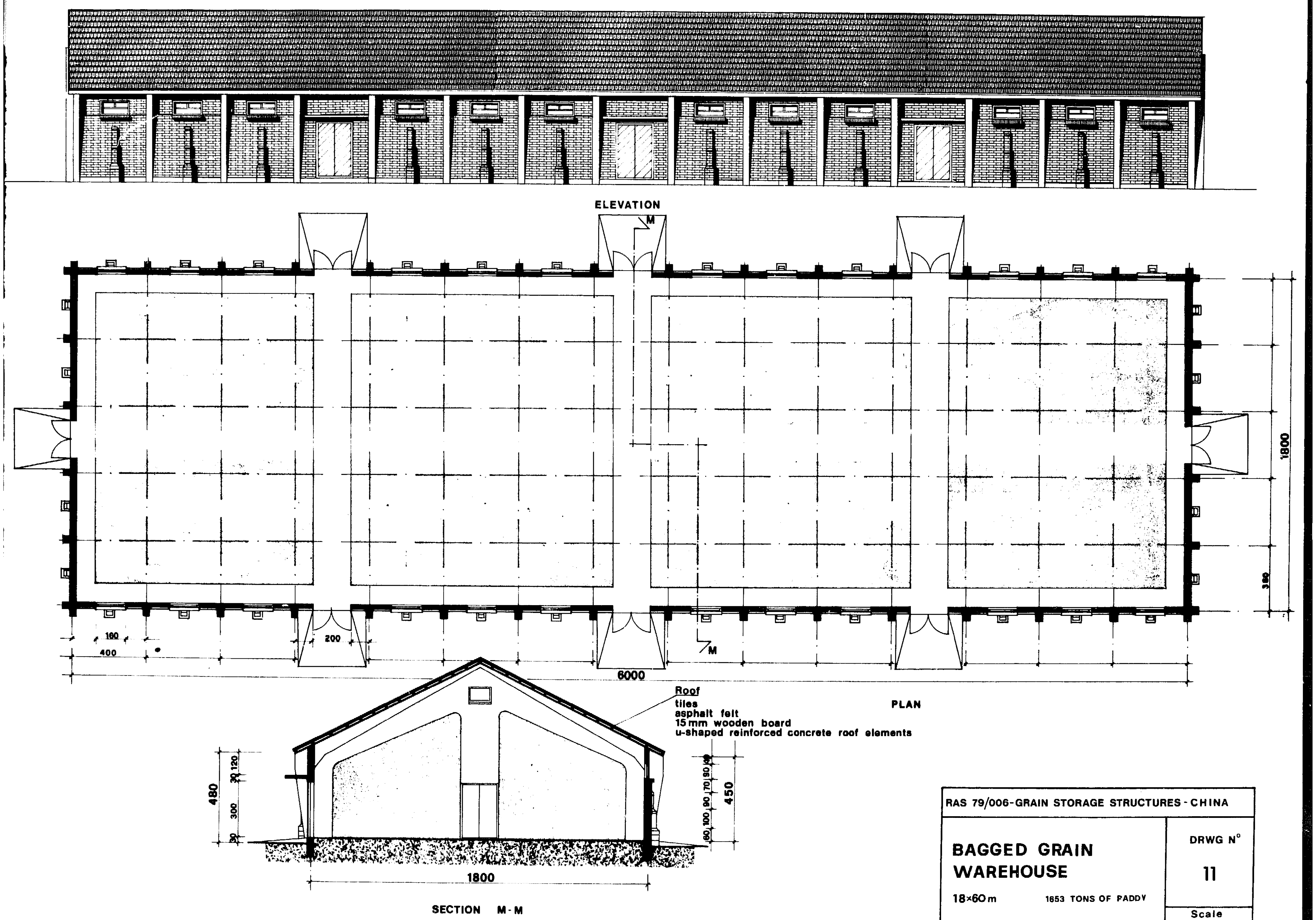
BAGGED GRAIN WAREHOUSE

18x60 m 1867 TONS OF PADDY

(SEVENTH DEPOT. SHANGHAI - PRESTRESSED CONCRETE FRAME)

DRWG N° 10

Scale 1:200



RAS 79/006-GRAIN STORAGE STRUCTURES - CHINA

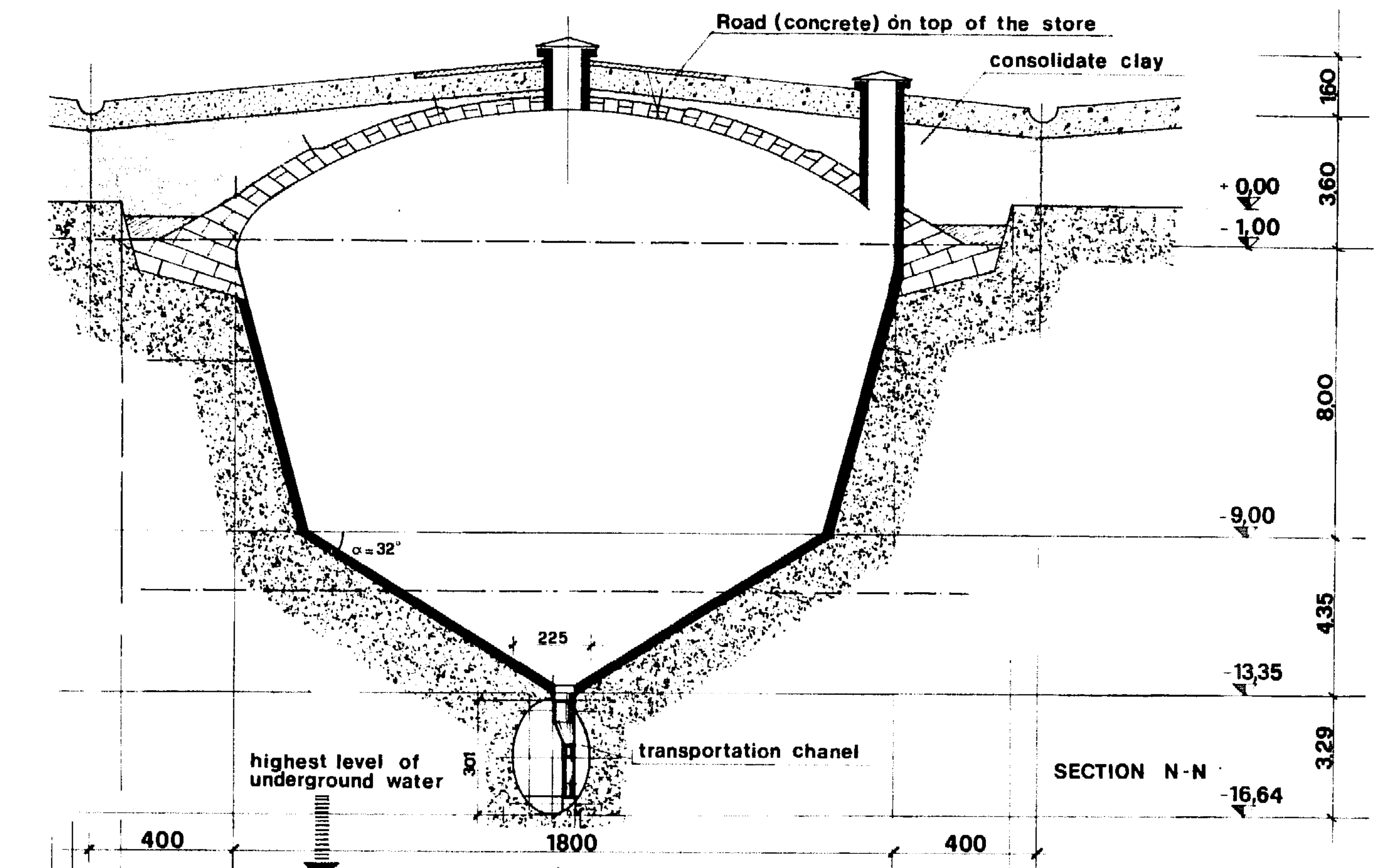
BAGGED GRAIN WAREHOUSE

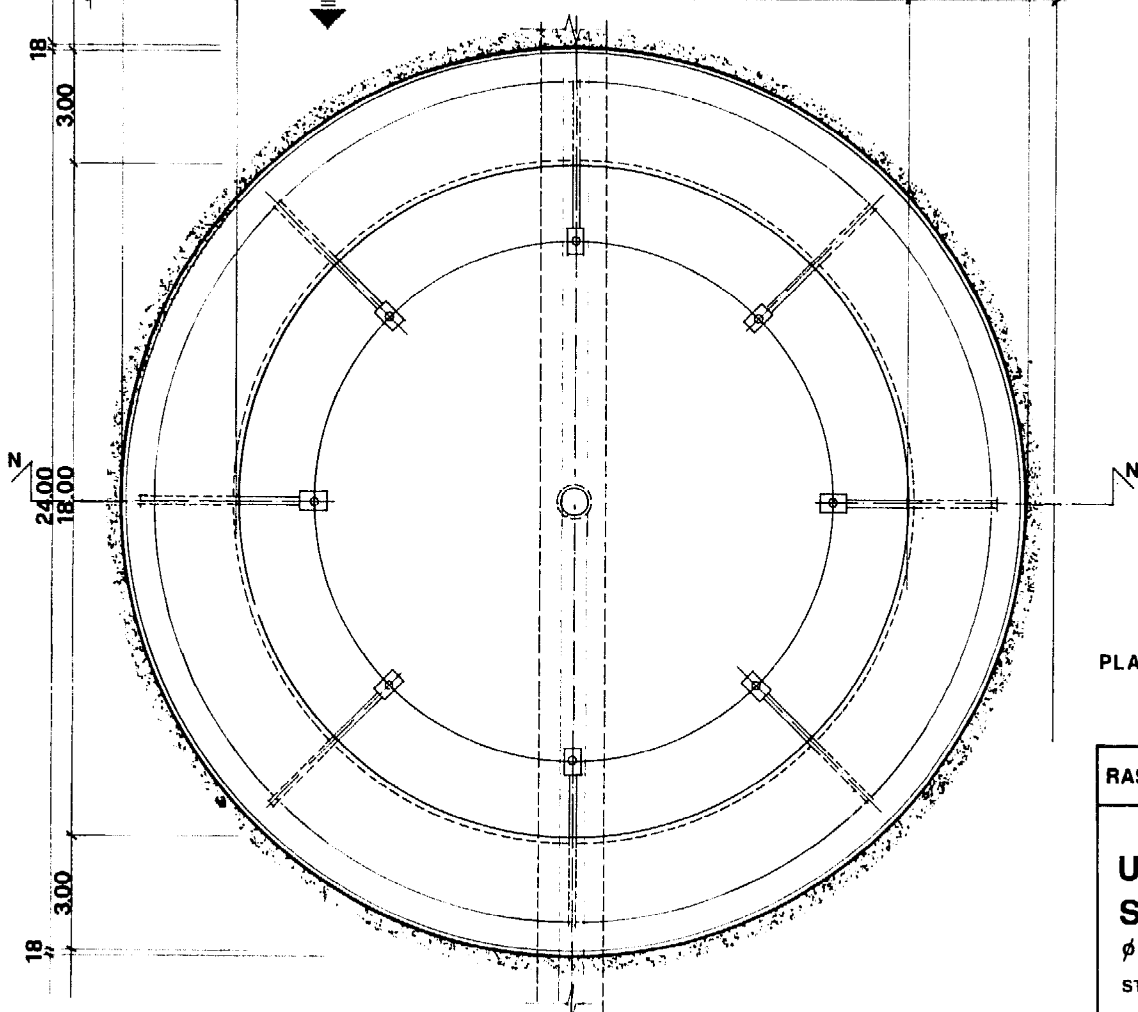
18×60 m 1653 TONS OF PADDY

(SEVENTH DEPOT SHANGHAI-PORTAL FRAME)

DRWG N° 11

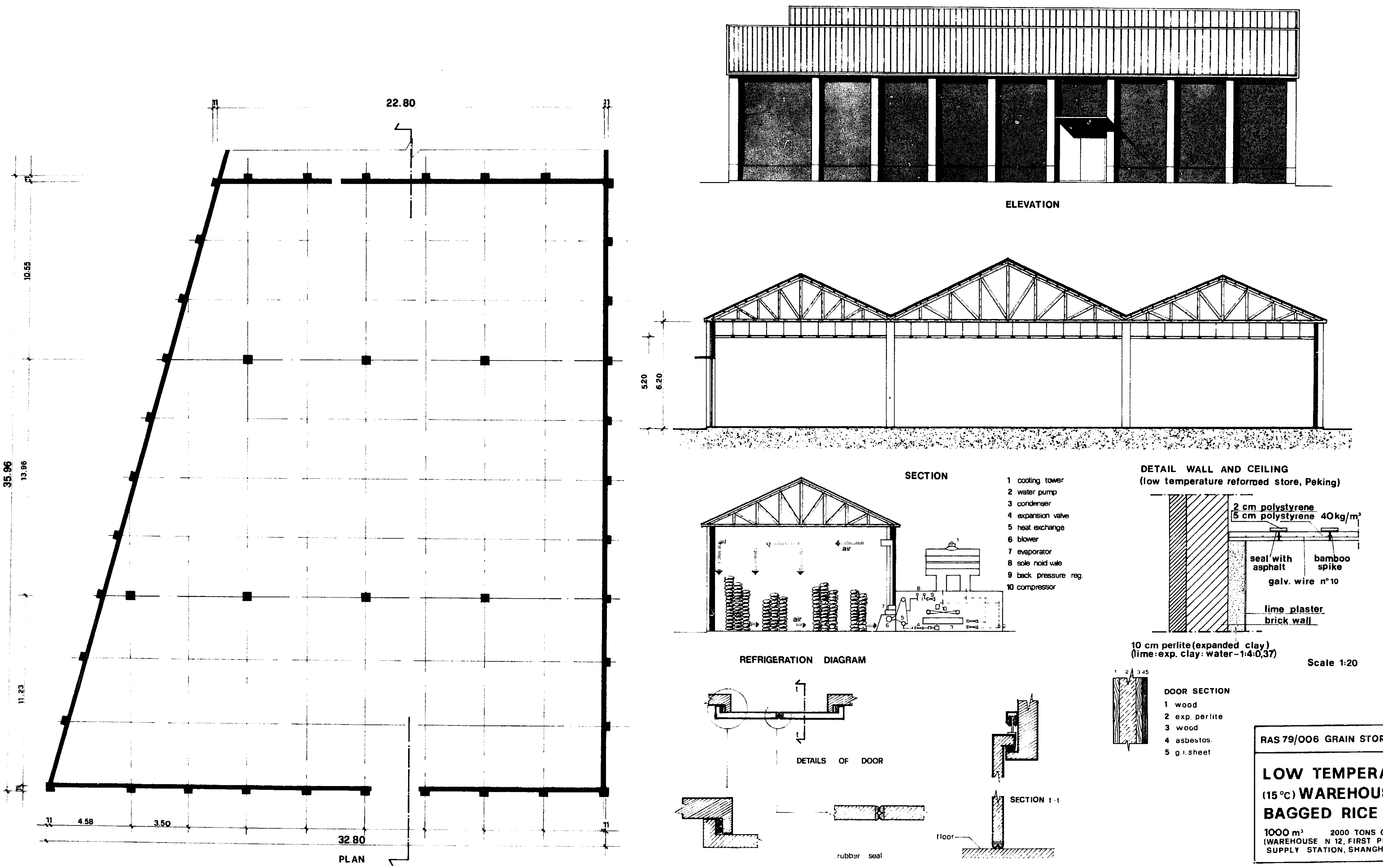
Scale 1:200





PLAN LEVEL -1.00

RAS 79/006-GRAIN STORAGE STRUCTURES-CHINA	
UNDERGROUND STORE ϕ 18 m DEPTH ABOUT 15 m STORAGE VOLUME ABOUT 2000 m³ FROM YUN SHI MI UNDERGROUND STORAGE	DRWG N° 12 Scale 1:200



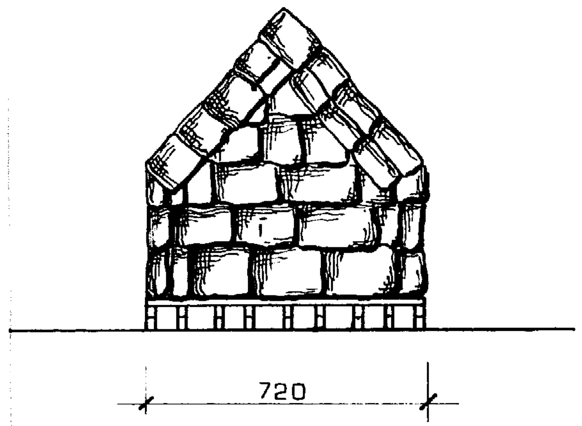
RAS 79/006 GRAIN STORAGE STRUCTURES-CHIN

LOW TEMPERATURE (15 °C) WAREHOUSE FOR BAGGED RICE

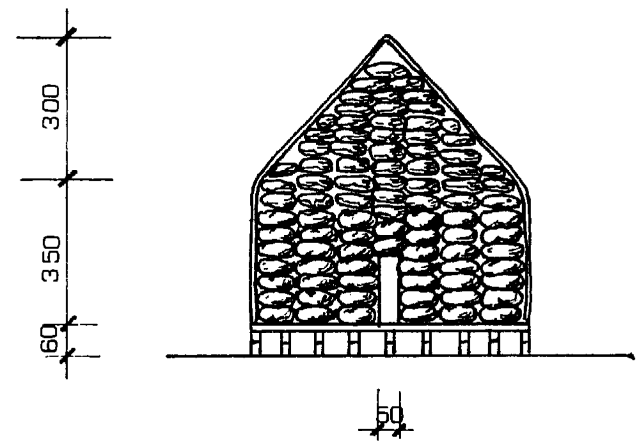
1000 m³ 2000 TONS OF BAGGED RICE
(WAREHOUSE N 12, FIRST PURCHASE & SUPPLY STATION, SHANGHAI)

DRWG 13

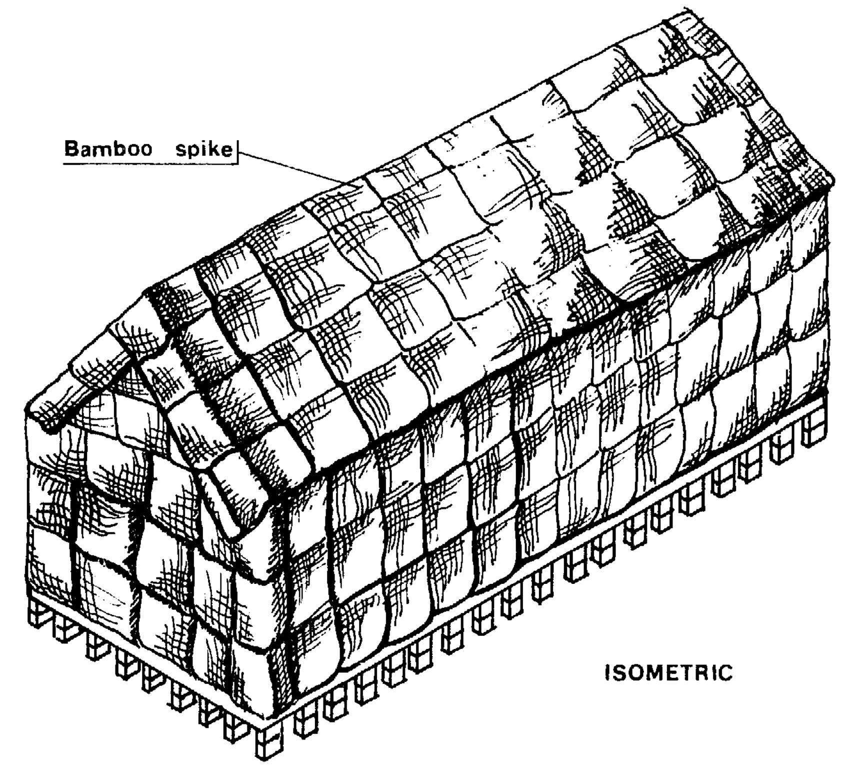
Scal 1:20



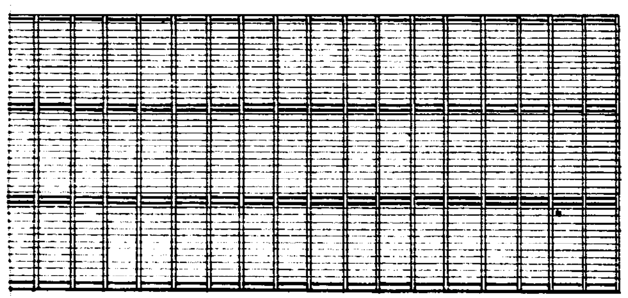
FRONT ELEVATION



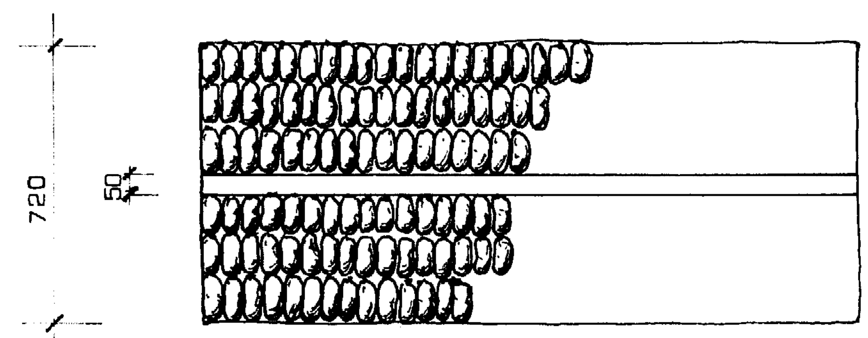
SECTION



ISOMETRIC



FLOOR FRAMING PLAN

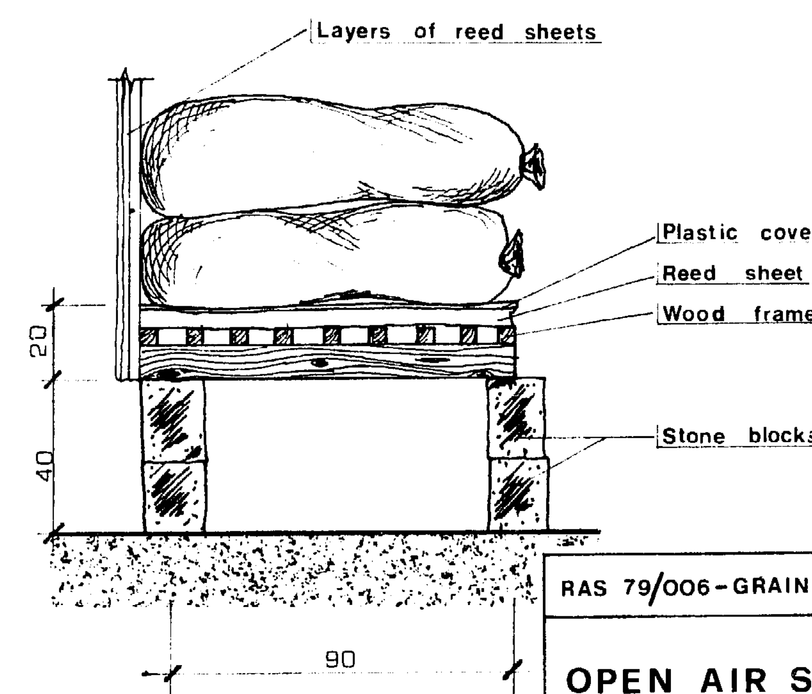


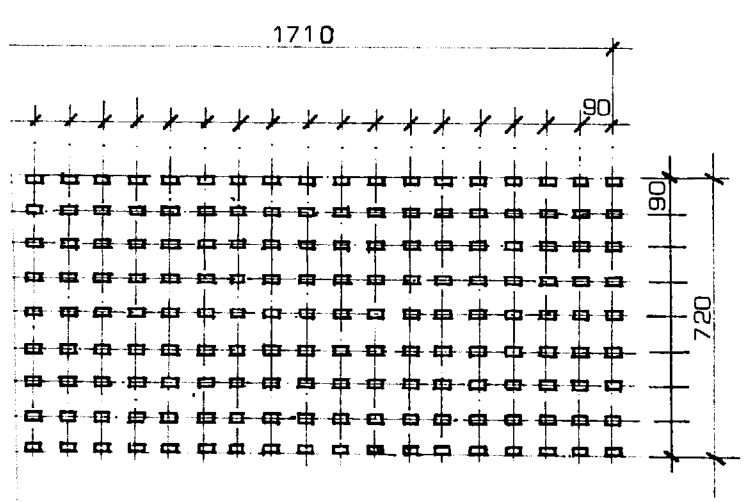
2 4

PILING PLAN

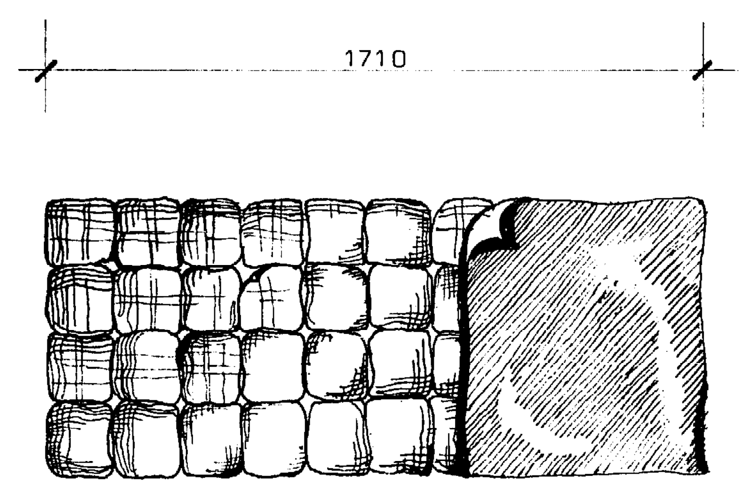
DETAIL

scale 1:20





FOUNDATION



1 3

FLOORING SHEET COVER

RAS 79/006-GRAIN STORAGE STRUCTURES-CHINA	
OPEN AIR STACK FOR BAGGED GRAIN 300-350 TONS	DRWG Nº 14
	Scale 1:200

consideration. For example, determine what the effect of flash flooding or termites might be and take the appropriate preventive action.

(iii) use of plastic sheet. For many solar dryers, the clear plastic sheet used is the major capital cost to the farmer; therefore, the type of plastic chosen is important. A choice must be made between a relatively cheap plastic such as ordinary polyethylene which will last, at best, for one season due to photo-degradation and wear and tear; and a more expensive, better quality plastic less prone to photo-degradation; or even glass or a rigid plastic.

Attaching plastic sheet to the framework structure, so as to minimise the likelihood of the plastic being torn is, perhaps, the most difficult part of building a dryer. Listed below are some general points which should be followed to prolong the useful lifetime of plastic sheet on a solar dryer:

(i) when attaching plastic sheet to the framework, care should be taken not to stretch the plastic at the points of attachment, but the plastic should not be so loose that it will flap about in the wind.

(ii) rather than merely stapling or nailing the plastic directly to the framework, it is preferable to sandwich the plastic between the framework and a batten. This may not be practical when unprepared wood or other materials are being used;

(iii) no sharp edges should come in contact with the plastic sheet since these will initiate tears;

(iv) fold over the plastic at the point of attachment to the frame, so that there are two or more layers of plastic. This will help prevent tears;

(v) when fixing the sheet over the framework, sags and hollows in which water can collect should be avoided wherever possible;

(vi) the dryer should be handled as carefully and as seldom as possible during operation and when not in use.

The comparative merits of natural convection and forced convection systems have already been described. It has been indicated that simple natural convection dryers will probably have the more widespread application in the rural sectors of developing countries. The information contained in the manual should be sufficient to enable simple dryers to be constructed and operated for a range of commodities. Where the reader feels that a forced convection dryer would be appropriate, he/she is advised to obtain more detailed information before attempting the construction. The reader will need to know about fan delivery mechanisms to ensure the correct air flow rates through the dryer. Efficiencies at various stages of the drying process will have to be measured, including collector efficiency and overall drying efficiency. Furthermore, the performance of the dryer in its working location will have to be routinely monitored to ensure continuous performance at maximum efficiency. This implies that a continuing input to such a development would be necessary by an individual well versed in solar drying theory and practice. The reader may find that such skills are available to him/her locally at national institutes. There are, to the author's knowledge, solar research and development projects where the required specialist knowledge is available in many countries in South and South East Asia and in most of the African Commonwealth nations. The reader is also referred to the list of references at the back of this manual for further information.

To summarise, the technologist will need to obtain a range of technical and socio-economic information to allow the selection of the most appropriate dryer. The technologist should then present a complete package to the extension worker. This should include a working dryer with information in a suitable form on its construction and use. Details of drying techniques can be found in the individual commodity chapters together with suggestions on how to put the information across.

1. Technical crite ia

The following d sign factors must be established:

- the throughput f the dryer over the productive season;
- the size of bat h to be dried;
- the drying per d(s) under stated conditions;
- the initial a desired final moisture content of the commodity (if known);

- the drying characteristics of the commodity, such as maximum drying temperature, effect of sunlight upon the product quality, etc.;
- climatic conditions during the drying season, i.e. insolation intensity and duration; air temperature and humidity; windspeed; (such data may be available from local meteorological stations);
- availability and reliability of electrical power;
- the availability, quality, durability and price of potential construction materials such as:

  glazing materials: glass, plastic sheet or film;
  wood (prepared or unprepared),
  nails, screws, bolts etc.;
  metal sheet, flat or corrugated angle iron;
  bricks (burnt or mud), concrete blocks, stones, cement, sand etc.;
  roofing thatch;
  metal mesh, wire netting etc.;
  mosquito netting, muslin etc.;
  bamboo or fibre weave;
  black paint, other blackening materials;
  insulation material; sawdust etc.;
  fossil fuels (to power engines to drive fans if electricity is not available);
- the type of labour available to build and operate the dryer;
- the availability of clean water at the site for preparation of the commodity prior to drying.

In any one situation there may well be other technical factors that need to be considered.

2. Socio-economic criteria

From the initial considerations, estimates of the capital costs of the dryer, the price of the commodity to be dried, and the likely selling price of the dried product will have been made. Other questions that need to be considered are the following:

- who will own the dryer?
- is the dryer to be constructed by the end-user (with or without advice from extension agencies), local contractors, or other organisations?
- who will operate and maintain it?

inter-related. A technology which has been tried and tested and found to be good is the one which is most likely to be widely adopted irrespective of whether there is large extension effort. It can be argued that the greater the effort which is spent ensuring that the correct technology and level of application have been identified, the easier will be the job of the extension worker. The converse is also the case in that no amount of well-implemented extension work will result in the successful introduction of an inappropriate or ill-conceived technology. Extension cannot therefore be discussed in isolation from research and development.

In this section some of the problems likely to be encountered in efforts to promote the solar drying technology to the rural population will be considered. Suggestions will also be made on methods of overcoming these problems. A note of caution needs to be added here: the examples cited may be pertinent only to dissemination of engineering technology to agriculture, and are not necessarily typical of general extension practices.

II.1 Prerequisites to successful dissemination of engineering technologies in agriculture

Many extension experts agree that engineering technologies are among the most difficult technologies to disseminate to farmers, particularly to smallholder farmers. Engineering technologies include improved and modern cultivation implements and machines, as well as post-harvest processing techniques such as solar drying. By comparison, the extension of agricultural improvements may be relatively simple. An example often quoted is the successful adoption of hybrid maize seeds by small-scale farmers in East Africa. By contrast, modern farming tools such as oxen-powered cultivators and tractors have not been adopted to any great extent by the same sector, where about 80 per cent of the cultivated land is still being worked with hand tools.

In many cases engineering technologies have the objective of optimising the use of labour as well as eliminating drudgery. Several reasons have been given for the limited adoption of engineering technologies in agriculture:

(i) engineers have tended to design expensive and complicated equipment or implements which are beyond the financial and technological capabilities of the farmers and even of the extension workers;

(ii) these technologies have often aimed at optimising labour use and hence they are perceived as leading to increased unemployment, especially in rural areas;

(iii) these technologies have relied on imported inputs which are difficult to obtain locally;

(iv) research and development by engineers have often been done in laboratories without any regard to the situation in the field.

It is often forgotten that engineering technologies demand that the user have a level of technical knowledge higher than that required for the adoption of agricultural improvements. The introduction of a new hybrid maize may result from years of sophisticated intense research, but what is eventually offered to the farmer is seeds which he/she has to plant in a particular way. It is not necessary that the farmer be aware of the genetic changes in the hybrid stock. However, in order to appreciate the advantages of a new implement such as a solar dryer, a higher level of technical appreciation is required. It is therefore of great importance that the front-line extension worker be technically well-informed.

For successful extension of solar drying technologies there is therefore a need for:

(i) proper evaluation and experimentation before extension. The whole system in which the farmer and extension agent are working should be understood, and the technology should be developed to suit the local scene rather than expecting that the local scene will adapt to the technology;

(ii) the front-line extension worker should be well trained and conversant with the new technology. If the extension agent does not understand the new technology it is unlikely that he/she will extend it effectively, and likewise, it is unlikely that the farmer will understand and adopt it;

(iii) the technology must aim at solving an issue which both the farmer and extension agent see as a problem and which the farmer regards as a priority problem among his many others. There is no point, for example, of concentrating on a solar maize dryer when the farmer's principal problem is organising land preparation, planting and weeding to exploit the short rainy season common in his locality. He will certainly not invest in a dryer if he is not even sure of harvesting the maize to be dried;

(iv) the technology must aim at solving the problem by optimising the use of labour at a reduced level of human energy expenditure, i.e. the technology must not increase drudgery;

(v) the technology will have most chance of success if the need has been recognised by the main decision maker of the farm or cooperative organisation. The decision maker will be more enthusiastic if the advantages of the improved technique benefit him directly;

(vi) there must be a financial or other obvious incentive to adopt the new technology;

(vii) the technology must be within the financial resources of the farmer and must be easily and inexpensively repaired if there is any breakdown.

The important thing to note is that the solar drying will not be operated in isolation from the environment; all the external and internal factors which affect the system need to be considered.

II.2 Extension work outlets

The solar drying technologist must decide which extension service, if there is more than one, will be the most suitable to be responsible for carrying out extension work in improving sun and solar drying technologies. There may be several different extension networks in the country each having its own priorities and areas of operation.

Examples of the possibilities, which are by no means representative of any one country, are discussed below.

1. front-line extension workers; These are normally government employees working for the various ministries responsible for agriculture,

fisheries, livestock etc. It is likely that these employees will be trained to certificate or diploma level at a national college. In some cases the extension staff will have received all their training on the job and will hold their current positions due to long working experience in the sector. Extension workers at this level have the advantage of local knowledge and close working relations with the rural population. However, the front-line extension worker's knowledge of engineering principles is usually quite low. At a management level above this, the extension coordinator for a region or district, while not actively involved in the field, may have some specialist knowledge or have other specialists reporting to him who would be capable of implementing the proposed programme. The responsibility for translating the operating requirements accurately into locally comprehensible terms may however remain with the reader.

2. crop authority extension agents; In some countries extension networks may be developed for a specific commodity, particularly where the national importance of a crop has been recognised. Foodstuffs covered in this way may include coffee and fish where production may be controlled by a quasi-autonomous produce board within the appropriate ministry. These specialised agencies can be effectively used to extend new technologies such as solar drying since they will be aware of the problems specific to the crop and may also be aware of the techniques required to overcome these problems.

3. extension departments in academic institutes; Many research institutes and university faculties have their own extension departments which carry out some extension work. They are normally staffed by highly trained extension experts, usually educated to at least first degree level. One limitation is that, in some instances, the department's primary consideration is the theory of different extension techniques and socio-economic studies of extension impact rather than practical extension work.

4. rural development agencies; These bodies are often set up by ministries responsible for education or social welfare. They often have the brief of improving the lives of the rural people by introducing elementary health care, nutritional education, etc. Project areas include small-scale cultivation and simple preservation techniques. Extension

workers in these agencies might prove suitable contacts to promote the use of simple drying techniques. Again it should be emphasised that the information should be presented in a suitable form.

5. appropriate technology or rural technology centres; In recent years many appropriate technology centres have been established with differing mandates but essentially for the development and adaptation of technologies to local conditions. These centres may prove to be suitable vehicles for the transfer of solar drying technology.

6. commercial companies; Where there is an obvious need for a particular item of equipment, commercial companies can purchase the patent of a particular technology or else manufacture it under licence. The marketing departments of these companies then carry out the extension work. Since the companies are profit motivated, the initial evaluation of the process tends to be thorough. Once a commercial organisation enters into such an enterprise it can be assumed that the technology stands a good chance of being extensively adopted.

In addition to the above, there are other organisations such as religious organisations, women's groups, local cultural groups and schools which may be used to popularise the technology and lead to its wider adoption. The route which is most effective in propagation and hence widespread adoption of the technology is best determined by careful examination of the local situation.

II.3 Extension techniques

In addition to the route through which the technology reaches the farmer or target group, there are also different methods through which the technology can be demonstrated to farmers. Many of these techniques have been developed for agricultural technology - e.g. crop husbandry, livestock husbandry etc. and how effective they may be for engineering technologies is difficult to ascertain. The main techniques are:

(i) demonstration at market places/meeting places; In this case the extension officer takes the technology to a place where the people in that particular area gather in large numbers. This may be at a market place. He/she then exhibits the solar dryer (or any other technology) to the people providing as much information as possible;

This technique is more appropriate to the introduction of simple improvements such as a hybrid seed variety or small portable implements, where either the risk to the farmer is low or the improvement is obvious. It is preferable to have a permanent demonstration site for solar dryers where continuing drying practices can be demonstrated. Since drying takes several days to complete, it is not practical to demonstrate it in the market place. However, poster-displays in the local language and samples of the dried foods could be exhibited. Interested farmers could then be taken to the pilot-plant demonstration unit at the local extension office or rural technology centre;

(ii) progressive farmer technique; In this case a progressive farmer in a particular locality is selected and encouraged to use the new technology (either on loan or at a subsidised price) and if he/she is satisfied with its performance he/she can, through the demonstration effect, encourage other farmers to follow his example. These progressive farmers are usually the more educated and richer members of the community and quite influential. Due to their financial position, they are better able to take risks, which may not be the case for the less progressive and poorer farmers. However if a technology has been well evaluated and the benefits can clearly be seen, then the chances of wide-scale adoption through this extension technique are great;

(iii) focus and concentrate technique; In this case farmers are selected using criteria established by the extension officer according to the technology which is being extended, and they are given the technology (usually free of charge). The extension officers focus all their efforts on these farmers until the technology is adopted. If it is adopted then neighbouring farmers are likely to copy it. It is an expensive method of extension and in many cases the selection criteria result in the selection of only the progressive and influential farmers. Another disadvantage is that those farmers who are supposed to copy the technology later on will also expect a free initial input;

(iv) training and visit technique; This technique involves grouping farmers in groups of say 10-15 people with a group leader. These farmers then meet in a specified place and are given training on the new technology. This is followed by programmed visits to the farmers at specified intervals throughout the season when further training is given. It is an expensive method and it requires significant input in trained manpower resources as well as transport facilities.

Any of the above four techniques could be used to propagate the use of solar crop dryers. There may well be other methods which are more suitable. Again, the method to be selected will depend on local conditions as well as resources available to the extension officer.

One major problem to overcome is the cost of the dryer to the small-scale farmer. Even if the interested farmer could test the unit before buying it to satisfy him/herself of its usefulness, the purchase of a dryer or the construction costs involved still represent a major financial outlay for the poorest in the rural sector. This problem can be alleviated by encouraging co-operative ownership of the equipment where this is possible. A pricing mechanism based on the quality of the dried produce will also help to recoup the costs.

CHAPTER 4

FISH DRYING

Unless fish are preserved or processed in some way to retard spoilage they will start to decay within a few hours of being caught at the high ambient temperatures in tropical countries. Spoilage is caused by the action of enzymes (autolysis) and bacteria in the fish, and also by chemical oxidation of the fat which causes rancidity.

Salting and drying, used on their own or in conjunction with each other, are traditional methods of preserving fish which have been used for centuries. Dried salted products are still very popular in parts of Africa, South and South East Asia, and Latin America. Reducing the moisture content of fresh fish by drying to around 25 per cent will stop bacterial growth and reduce autolytic activity, but the moisture content must be reduced to 15 per cent to prevent mould growth. Salt retards bacterial action and aids the removal of water by osmosis. When fish are salted prior to drying, a final moisture content of between 35 per cent and 45 per cent in the flesh, depending on the salt concentration, is often sufficient to inhibit bacteria.

I. Types of fish

In tropical waters the catch is typically mixed and may include 300 or more species all of which can be consumed fresh or in processed forms. Each of these species will have different characteristics which will affect their handling properties. The fish preserver working in the tropics may therefore have to be prepared to preserve a range of species of different size and fat content. Some of the species will be delicate and require careful handling while others are more robust and less subject to damage.

The most important factors which affect the handling properties of a fish are:

1. size. Very small fish may be dried whole, whereas larger fish must always be cut open so as to increase the surface area available for salt penetration and/or moisture loss. Small fish may therefore be preserved

with the gut content intact, while this is almost always removed in larger species.

2. oil content. Fish oils oxidise readily and become rancid giving a bitter flavour to the product. Some communities show a preference for slightly rancid fish although rancidity is usually considered objectionable. Fish with a high oil content are difficult to convert into good salted and/or dried products since the oil acts as a barrier to salt penetration and moisture loss.

3. flesh texture. Fish with firm or moderately firm flesh are relatively easy to handle. They can be cut without falling apart and the dried product can be transported without breaking up. Fish which have a very soft flesh tend to tear when attempts are made to cut them, and the dried products are very fragile and tend to break up during transport.

I.1 Small pelagic species

Small pelagic species include fish less than 25 cm long. Such fish form characteristic schools or shoals, hence a catch containing these species will be comparatively homogeneous in composition. The group includes the herring-like and sardine-like fish which are slender and have relatively small scales and delicate flesh. Many species have a high oil content. These fish are sometimes dried whole without salting, but the products are then fragile and break easily. Rancidity is difficult to control, and unless the products can be marketed soon after drying, they will become progressively undesirable and unmarketable.

The small mackerels, such as the Indian chub mackerel, are also included in this group. These are sold fresh wherever possible, but may also be salted and dried. This group also includes anchovies and anchovy-like species of fresh waters. In Africa, near inland waters these are often sun dried without salting.

I.2 Large pelagic species

The most important fish in this group are the tunas which can attain weights in excess of 500 kg. Many other species reach a weight of 100 kg while some seldom reach 10 kg. The flesh is generally very firm and contains moderate amounts of oil. In some species the flesh is very dark and many of these bleed heavily when cut. The skin of most species is thin.

Most of the world tuna catch is canned but substantial amounts are sold fresh. Fresh tuna is often highly priced and is not commonly used to make dried salted products.

The large mackerels and horse mackerels, or jacks, have moderately firm flesh and a medium oil content. These are best sold fresh when possible, but good quality dried salted products can be made.

I.3 Small demersal species

Small demersal fish include bottom-living fish less than 25 cm long. They constitute a very diverse group including fish of very different shapes, but generally of deeper form than pelagic fish. Most have quite large, hard scales and moderately firm flesh. Some, such as the catfish, are scaleless and have soft flesh. The oil content is variable and is generally less than 5 per cent. There is less annual variation in oil content than is found in pelagic species.

The group includes many different types of sea-fish such as small mullets, snappers, sea-breams, croakers, jew fish and silver bellies, and small freshwater fish such as carps and breams.

Salted and dried products of good quality can be made from many small demersal fish but the products fetch generally low prices. However these products are useful in that they provide lower-income groups with a source of animal protein food.

I.4 Large demersal species

Large demersal fish also constitute a diverse group. They include the sharks and rays, as well as bony fish such as mullets, snappers, groupers, jew fish, breams and threadfins. Many of these bony fish are sold most profitably when fresh. However they can also be processed into excellent dried salted products when demand for the fresh product is not sufficient. Good salted dried products can also be made from sharks and rays.

The freshwater fish in this group incude tilapia, carp and catfish. These species are sometimes split or cut into pieces and dried in the sun without salting.

II. Pre-processing stages

Fish spoil very quickly and small-scale fish-processing enterprises can easily lose produce and, hence, income through avoidable wastage. A great deal of spoilage may occur before the fish is processed. The bacterial and chemical changes which cause spoilage proceed rapidly at tropical temperatures. In general, the lower the fish temperature, the lower the amount of spoilage. It may also be reduced if fish are handled properly and good hygienic measures are adopted. A few measures for avoiding or minimising spoilage are briefly described below.

(i) Improvement of landing facilities and distribution

Very often whenever large catches are taken, landing facilities and the distribution system are inadequate to handle the surplus. In these circumstances a long period of time may elapse before the fish can be processed, with the consequence that a high percentage of the fish may be spoiled. The ideal solution to this problem would be to increase the amount of cold storage facilities. One simple method of reducing such a bottleneck is to develop the drying facilities as close to the landing areas as possible to reduce transport time and cost.

(ii) Maintaining the fish at low temperatures

If tropical fish are well chilled with sufficient ice, they may remain in an edible form for up to three weeks, depending on the species. In many locations ice may not be available to the small processor, in which case the fish can be kept cool by other means including:

- keeping the fish in the coolest spot available, such as in the shade;
- placing damp sacking over the fish. As the water evaporates from the cloth it helps to keep the temperature of the fish down. The sacking must be kept wet and the fish must be well ventilated;

- mixing the fish with wet grass or water weeds in an open-sided box so that the water can evaporate and cool the fish. With this method, the fish should be kept continuously wet.

(iii) Maintaining a hygienic environment

Fish which have been handled cleanly and carefully will be in better condition than fish which have been handled carelessly; they can, therefore, be worth more money.

Before processing starts, attention should be paid to the following points:

- keep the fish as clean as possible. Washing with clean water will remove any of the bacteria present on the fish skin, especially if it is muddy;

- keep the fish cool, chilled in ice or chilled water, if possible, at all stages before processing starts. Fish spoilage is a continuing process: once a particular stage of spoilage has been reached no amount of good practice or processing can reverse it;

- avoid damaging the fish by careless handling. If the skin is broken this will allow bacteria to enter the flesh more quickly and spoilage will be more rapid. This sort of damage can be caused by walking on fish and by the use of a shovel. If the guts can be removed and the gut cavity washed carefully this will reduce the number of bacteria; however, in some areas, the purchaser requires whole fish, and this practice may lower the value of the catch.

III. Processing techniques

III.1 Fish preparation

It is important that fish for salting and drying be prepared in a way which allows rapid salt penetration and water removal. Very small fish are sometimes processed without any preparatory cutting with only the guts removed whenever necessary. Fish larger than 15 cm are split open so that the surface area is increased and the flesh thickness is reduced. With fish more than about 25 cm long, additional cuts or scores should be made in the flesh. Depending on consumer preference, the head can be left on - or removed. It is desirable to scale fish for easy salt penetration and drying, however again the preference of the consumer must be considered.

Fish should never be prepared at ground level since it will pick up dirt even if placed on a board or mat. A table or bench at comfortable working height should be used. The table can be made out of wood, metal or concrete and should have a smooth surface which can be easily scrubbed clean. A separate wooden cutting board should be used on this surface to cut the fish. This will prevent either the knives or the surface being damaged. Good knives are essential for fish preparation.

Short knives should be used for small fish, long flexible knives for filleting and stout knives for splitting big fish. Knives must be kept sharp. Blunt knives tear the fish and slow down the work. If a grind stone is available, it should be used to shape or profile the cutting edge and to remove nicks. An oilstone or water-lubricated stone may then be used to sharpen the cutting edge. A steel should be used to remove burrs on the edge. Proper grindstones are expensive and steels are not easily obtained in some countries. In any case, a fish processor should always have a good sharpening stone available.

III.2 Gutting and splitting

Different techniques for opening and cleaning fish are used depending on the location and the species. The method used should be the one which gives a product which is recognisable and acceptable to the consumer. In all cases the guts, gills and hearts should be removed cleanly. Any dark coloured blood should be cleaned out using a small brush, and all black membranes should be removed from the inside of the fish.

III.3 Salting

Whether or not to salt before drying depends on location, availability of salt and, of course, consumer preference. Salting reduces the possibility of spoilage before, during and after drying and gives a stable product of higher moisture content than unsalted fish with a reasonable shelf life in humid conditions. The salt and extra moisture in a salted dried product gives the producer more weight to sell than would be available from a comparable amount of unsalted dried fish. Marine fish destined for drying are normally salted. Salt is usually readily available at coastal locations and the preservative effect it supplies may be essential when sun drying fish with hot humid air. At freshwater fisheries, salt may not be readily available or may be relatively expensive. At these locations the preference may be for unsalted dried fish. If the ambient air at inland tropical locations is hot and dry, the fish can be dried to the lower moisture content and storage will present less of a problem. Where unsalted dried fish are transported to more humid areas care should be taken that the fish do not absorb moisture from the air and become spoiled.

Generally only small fish should be dried unsalted, as larger fish will spoil before the drying process is completed.

There are three main salting methods: kench salting, pickle curing and brining. The first two methods yield fish with a relatively high salt concentration, while the third method (brining) is commonly used for products with a low salt concentration. A method used in some fisheries, whereby fish are rubbed with salt and then hung to dry, is not recommended as it does not produce an even cure.

Kench salting

In kench salting, the fish are mixed with dry crystalline salt and piled up; the brine which forms as the salt takes water from the fish being allowed to drain away. This method is especially popular for large lean fish species. Kenching can be carried out in shallow concrete tanks fitted with a drain, or on raised platforms or racks of approximately 1 m^2 area and 8-10 cm off the ground. Starting at the centre of the rack, 2 or 3 rows of prepared fish are laid flesh side up over a bed of salt. Salt is then sprinkled or rubbed all over the fish, more being put on the thick parts of the fish than on the thin parts. Wherever scores have been made, these should be filled with salt. A pile of fish is built up by moving outwards from the centre, and sprinkling each layer of fish with salt before covering with the next layer. To ensure good drainage, the centre of the pile should be about 10 cm higher than the outside edges and the pile should not be higher than about 2 m.

Care should be taken in making the pile in order to ensure even salting of the fish and a good product quality. Brine should not be allowed to accumulate as this will produce an uneven cure and may discolour the fish. The edges of the kench pile should also be regularly sprinkled with salt to prevent contamination.

In the tropics, fish are usually left in the kench pile for 24 to 48 hours after which they are dried. However, the salt may not have completely penetrated the fish during this time, and penetration may continue during drying. In rainy weather, the fish may be left in the kench pile for longer periods. In this event, the pile should be broken down and a new pile made up, so that the top fish from the first pile are placed at the bottom of the new pile. In making the first kench pile, 30-35 parts by weight of salt should be used for each 100 parts of fish.

The advantage of kench salting is that the fluids are drained off leaving the flesh fairly dry. However, it also has a number of disadvantages: oily types of fish become rancid due to exposure to the air; insects and rodents have ready access to the fish; mould and bacterial attack can take place; and salting may not always be even.

Pickle curing

In pickle curing, a barrel or tank is used to hold the brine which forms as the salt mixes with the water contained in the fish. From 20 to 35 parts by weight of salt to 100 parts by weight of fish may be used depending on the cure required. Fatty fish, such as mackerel, are commonly pickle-cured.

In this salting method, a layer of dry salt is spread over the bottom of the tank upon which the first layer of fish is laid. There is, however, no need to stack fish higher in the centre as drainage is not required. The layers of salt and fish are stacked up, care being taken to ensure that no fish are overlapped without a salt layer between them, since this could cause the fish to stick together. As the pile is built up, the salt layers should become thicker. The top layer of fish must be placed skin side uppermost. A wooden cover should be placed on this top layer, so that weights can be used to keep the fish below the surface of the brine which forms.

Pickle curing is recommended in preference to kench salting as it produces a more even salt penetration and provides a better protection of the fish against insects and animals, since the fish are covered with brine.

3. Brine salting

In brining, or brine salting, the fish are immersed in a solution of salt and water. By varying the strength of the brine and the curing period, it is possible to control the salt concentration in the final product. The method is commonly used in developed countries when a smoked product is to be made and the salt concentration required in the final product must be lower than 3 per cent (e.g. as for hot-smoked mackerel). Brine salting may be used to advantage in developing countries as the process is more uniform and controllable than the dry salting techniques.

A fully saturated brine contains about 360 g of salt to each litre of water (3 lb 10 oz of salt per imperial gallon). A sack of salt should be hung in the brine to ensure that the latter remains at full strength. Full strength or saturated brine is called a 100^{o} brine. A 10^{o} brine - which is made up by mixing 1 part of 100^{o} brine with 9 parts of water - is sometimes used to soak fish before salting.

4. Salt quality

The salt used for curing fish (fishery salt) is a mixture of a number of chemicals. A good fishery salt contains from 95 to 98 per cent common salt, known chemically as sodium chloride. Since fishery salt generally originates from the sea, it contains impurities such as chlorides and sulphates of calcium and magnesium, and sodium sulphate and carbonates. Other types of fishery salt include rock salt (i.e. mined salt) and sun salt or solar salt (i.e. salt obtained through water evaporation from coastal lagoons or ponds).

The type and quality of salt used affect the appearance, flavour and shelf life of cured fish. If pure sodium chloride is used for curing, the product is pale yellow in colour and soft. A small proportion of calcium and magnesium salts is desirable, as the latter yield a whiter, firmer cure which is preferred by most people. However, if the proportion of these chemicals is too high, the rate at which the sodium chloride impregnates the fish is slowed down. Furthermore, the salt becomes damp as the chemicals absorb moisture from the air making the product taste bitter.

The composition of sun or solar salt is determined by various factors outside the control of the processed-fish producer. Therefore, if salt from one source proves unsatisfactory, another source should be sought or the curer should consider making his/her own salt.

Solar salt often contains some sand and mud, as it is usually scraped up from the bottom of the ponds in which it is made. The cheapest grades contain a large proportion of dirt and these should not be bought for fish curing. Salt should be kept in clean bags or covered bins so that it does not become dirty.

Salt may also contain both moulds and bacteria. The bacteria cause the pink colour sometimes seen in salted fish. These bacteria also make the fish slimy and produce an unpleasant odour. If the salt is kept in storage under dry conditions for 6 to 12 months, the number of bacteria present will be much reduced. Alternatively, the salt can be baked to kill the bacteria. Both storage and baking will increase the processing costs. These may be avoided if some consumers of traditional products prefer the strong flavours produced in cured fish by mild attacks of pink bacteria.

All processing equipment and surfaces must be thoroughly washed with fresh water to help prevent pinking. Light growths can be brushed off from the fish surface and the product redried, but severe attack leads to the destruction of the fish.

Solar salt often contains very large pieces which should be ground up before use. An ideal salt for dry salting operations contains some very fine grains which will dissolve quickly and some larger ones which will dissolve more slowly and prevent the fish from sticking together. Very fine salt is preferred for making brines, because it dissolves quickly.

III.4 Drying

Fish are subject to the basic principles of drying described previously, i.e. water is removed from the fish by evaporation in two phases. During the first phase, when only water on the surface of the fish or very close to the surface evaporates, the rate of drying is mainly dependent on the rate of passage of hot air over the fish and on the ability of that air to absorb moisture. The drying rate can be raised by increasing the fish surface area by splitting, scoring and so on.

During the second phase, or falling rate period of drying, evaporation from the fish surface will be dependent on the rate of moisture transfer from inside the fish to the surface. Moisture transfer rates will be lower for oily fish since the oil acts as a barrier to moisture movement. In common with all commodities the second phase of fish drying will depend on piece size (i.e. distance from the surface), temperature and the amount of residual water.

It should be noted that if fish are dried too rapidly a hard impermeable outer crust will form which will prevent the passage of any more moisture. This phenomenon is known as case hardening. Externally, case hardened fish look well dried but the centre of the fish will still be moist and could spoil. A fish which has been damaged in this way will be hard on the outside, but may feel soft or spongy internally when pressed.

Fish are rich in proteins which are denatured when heated. This means that the fish might start to cook at conventional hot air drying temperatures. Optimum drying temperatures for temperate salt-water species can be as low as 27°C, whereas tropical species can generally withstand higher temperatures before cooking and can be dried using air at 45-50°C.

1. Conventional sun drying

Natural drying methods use the combined action of the sun and wind without the use of any equipment. Since it is important to dry the fish quickly before they spoil, all the fish surfaces should be exposed to the drying action of the wind. Ideally the drying site should be in a breezy location with a dry prevailing wind coming from an inland direction.

Traditionally, many fishermen in tropical countries spread their fish on the ground, on rocks, or on beaches to dry in the sun. Some fish processors use mats or reeds laid on the ground to prevent contamination of the fish by dirt, mud and sand. Drying fish in this manner has many disadvantages and, in recent years, the use of raised sloping drying racks has been introduced as a simple, but often effective, improvement. The product obtained from rack drying is cleaner since the fish do not come into contact with the ground; they are also less accessible to domestic animals and pests, such as mice, rats and crawling insects, which contaminate or consume them. Protection from rain is simply accomplished by covering the rack with a sheet of waterproof material (e.g. plastic); if fish on the ground are covered, they are protected from falling rain but not from water on the ground itself. Drying rates are higher, because air currents are stronger at a metre or so above the ground and air can pass under the fish as well as over them. The use of a sloping rack allows any exudate to drain away.

Where only a few large fish are to be dried, this may be done by hanging the fish up. Split fish may be hung on hooks by tying them up with string, or by tying the fish in pairs by the tail and hanging them across a pole or line. Bombay duck is an example of a fish dried in India in this fashion. The fish are hung in pairs, joined jaw to jaw, on horizontal ropes at an optimum loading of 50-60 fish per metre.

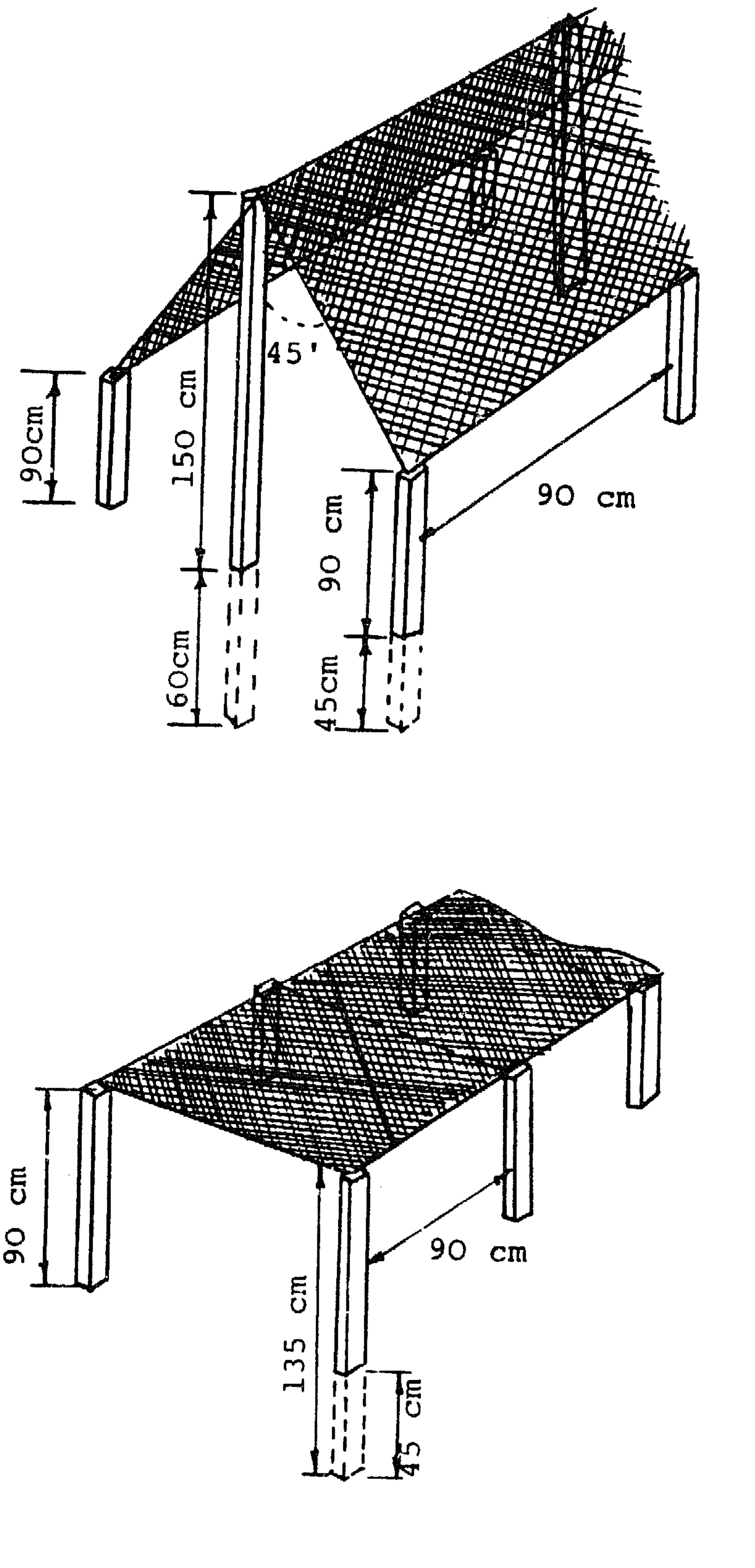
Large quantities of fish should be dried on racks (figure 7). Suitable materials for drying racks include chicken wire, old fishing nets, and thin rods or poles, such as reeds or sections of bamboo. The surface of the racks should be at a height of about 1 m from the ground and should slope if split large fish are to be dried. A flat surface is preferred for drying small intact fish. Where large quantities of very small fish are to be dried, a netting rack may be impractical. Suitable drying surfaces may be made instead, with raised floors of wood, concrete, bamboo strip or, where none of these materials are available, well-compacted clay.

At the end of the drying day the fish are usually heaped together and stored to prevent them becoming wet by dew or rain during the night. During overnight storage the fish should be covered by wooden boards weighted to apply pressure on the fish. This will flatten the fish, giving them a better appearance, and will also speed up the process by which water moves from the inside of the fish to the outside, so that they will dry more rapidly when set out the following morning.

However, even when racks are used, sun drying has many limitations: long periods of sunshine without rain are required; drying rates are low; and in areas of high humidity, it is often difficult to dry the fish sufficiently. The quality of sun-dried fish is likely to be low due to slow drying, insect damage, and contamination from air-borne dust. Also it is difficult to obtain a uniform product.

2. Solar drying

Thus, in the search for improved drying techniques, the use of solar



<u>Figure 7</u>

Fixed drying racks with flat and slanting drying surfaces dryers has been investigated as an alternative to traditional sun drying. As previously discussed, solar dryers employ some means of collecting or concentrating solar radiation with the result that elevated temperatures and, in turn, lower relative humidities are achieved for drying. When using solar dryers, the drying rate can be increased, lower moisture contents can be attained, and product quality is higher. The dryers are less susceptible to variations in weather, although drying is obviously slower during inclement weather, and they do provide shelter from the rain. The high internal temperatures discourage the entry of pests into the dryer and can be lethal to any which do enter.

The solar tent dryer described earlier was first developed in Bangladesh for fish drying. This and several further modifications of it have since been tested in many parts of the tropics. With an ambient temperature of 27°C, temperatures of around 48°C can be attained inside the dryer, which are ideal for tropical fish drying. The fish should be loaded onto racks built inside the solar tent in a similar fashion to sun drying.

In fine weather conditions fish can be dried within 3 days, compared with 5 days for sun drying. The quality of the solar dried fish is higher. During the initial constant rate period of drying (dependent largely on air movement), drying rates in the solar tent and on sun drying racks are broadly similar. However the second phase, or falling rate period of drying, occurs more rapidly within the tent. A suitable method for fish drying might be to use racks, in the first instant, and complete the process inside the solar tent. This would have the advantage of reducing the time spent by a batch of fish inside the dryer, allowing a greater throughput.

Solar drying reduces the effect of insect infestation on fish. In addition to causing losses in quality and quantity, insect pests are potential carriers of pathogenic bacteria and thus represent a serious health hazard. The temperatures found in solar dryers can kill any insects or larvae present on the fish, thereby presenting a means of disinfestation. A period of 20 hours at 45°C is recommended for a complete disinfestation of drying fish.

Flies, the major carriers of disease, lay eggs on fish during the early stages of drying, but become less attracted to them as the flesh dries and hardens. The larvae tunnel into the flesh, causing putrefaction and extensive physical damage. The most important pests of the dried fish are beetles of the family Dermestidae. They invade the fish flesh from the earliest stages of drying, but unlike flies, continue to be attracted to, and breed in, the dried product.

Prevention of spoilage of fish during processing

A number of measures may be adopted in order to minimise the spoilage of fish during processing. These include:

- keeping all tools, fish boxes and cutting surfaces clean. Where drinking quality water is available, it should be used to wash the fish before and during processing, such as after gutting or splitting the fish;

- prevention of fish offal (guts, heads, gills, etc.) from coming into contact with cleaned fish. In addition, the fish working area should be cleaned regularly, at least once a day, by removing all offal and dirt which might contain bacteria or attract insect pests such as flies. All offal should be removed from the working site. It may be used as fertilizer, or buried. It should not be thrown into the water near the work site, as this practice fouls the water and may attract insects;

- ensuring that high standards of personal hygiene are maintained. Fish processors are handling food, and hands should always be washed before starting work and particularly after visiting the toilet. People who have infected wounds, stomach complaints, or any contagious disease should not be allowed to handle the fish;

- speedy processing. The longer the time required for processing, the greater the amount of spoilage which will occur before processing is completed;

- keeping the fish in boxes and off the ground. Work, such as cutting fish prior to salting or drying, must be carried out on tables, not on the ground where the fish will become dirty and pick up bacteria;

- protection of the fish from rain and using salt during drying in order to avoid the spoilage of fish through bacteria, mould or insect attack;

- protection of the fish against insect infestation during processing. Blowflies lay their eggs in the fish while they are still moist and the larvae eat the flesh. Beetles, such as the hide beetle, lay eggs in the fish as they are drying and the larvae eat the flesh even when it is quite dry. Damage can be reduced by ensuring that processing waste is properly disposed of so that there are no places for insects to breed. Use of better salting techniques may help since insect larvae are not attracted by heavily salted fish. Techniques which speed the drying process are useful in countering blowflies.

IV. Packaging

Dried fish are sometimes brittle and easily damaged if not handled correctly. In humid conditions, dried fish also absorb moisture and become susceptible to spoilage by moulds and bacteria. They may also be attacked by insects (especially beetles of the genus Dermestes), rats and mice, as well as domestic animals. Packaging methods such as hessian sacks, wooden boxes, and baskets are generally inadequate in protecting dried fish from these causes of damage.

To protect dried fish properly, one of the following measures should be adopted:

- packing of the dried fish in a sturdy container, such as a wooden or cardboard box, fitted with a lid in order to totally enclose the product. Open boxes, although protecting the fish from physical damage, are not effective against high humidity and insect attack. Properly sealed cartons, made from waxed or plastic-coated board, should be sufficiently moisture-proof and rigid enough to withstand rough handling. Although this type of packaging is more expensive than traditional packaging, the additional cost should be more than offset by the decrease in the spoilage rate;

- packing of fish in plastic or polythene bags, thus reducing insect attack and the effects of high humidity. Care should be taken not to leave bags containing dried fish in direct sunlight or in hot places, since the increased temperature causes "sweating" (i.e. the removal of water still present in the dried fish). This water condenses on the inside of the polythene bag, wets the dried fish and makes them susceptible to mould attack. A further disadvantage is that some dried fish have sharp, hard points and edges, which puncture and rip the plastic or polythene bags, thus allowing air, moisture, dust, or insects to spoil the fish.

A suitable arrangement might be to use a polythene liner within a close weave basket. Disinfestation of stored dried fish can be achieved by fumigation. Since the chemicals used for fumigation are also toxic to humans, extreme care is necessary when fumigating any products. Experienced and trained personnel should carry out the process. Phostoxin and methyl bromide are effective fumigants. Fumigation should be carried out in an enclosed fish store or under gas-proof sheets in order to ensure a complete disinfestation of stored fish. 24 g of methyl bromide per cubic metre has been found to disinfest dried fish successfully when applied over a 24 hour period. However, phostoxin is considered more suitable for use in fish stores at a dose of 0.2 to 0.5 g phosphine per 50 kg for 2 or 3 days. Dried fish can also be disinfested by heat treatment, which can be supplied by a solar dryer as mentioned earlier.

V. Alternative processes

The reader should be aware that simple processing of fish is not restricted to drying. Other products which can be made include a variety of smoked and cured goods and also fermented fish products. These techniques may also be appropriate for use in the small-scale fisheries sector. Information on these processes can be found in some of the references listed.

VI. Extension work activities for fish drying

VI.1. Location

Fresh fish do not travel well in hot climates. Therefore for the purpose of demonstrating fish drying to extension workers, it is preferable to find a site near fish landing areas. Any national institute or agency involved in fisheries should be able to advise on a suitable location. It may be possible to work side by side or in cooperation with an on-going project, which should reduce the effort required to set up a demonstration unit and assist in the procurement of the raw materials. Any agency already working in fisheries development may also be able to recommend suitable extension workers and advise on their educational background.

VI.2 Current practices

Within the chosen location, the present fish drying practices should be established:

- what species (or groups) are dried?
- are the fish salted before drying?
- are the fish filleted, gutted, etc.?
- have any difficulties in production been recognised?
- who dries the fish?
- what are the uses of the product?
- does the market require a specific quality of product?
- what is the size of the market?
- are there any shortfalls/gluts in production?
- how much fish does a processor dry, and how does this relate to overall production?
- what route does a processor's output take to reach the market? (If it is bulked with the dried fish made by other people it may be difficult to introduce changes.)

The technologist should listen carefully to how the processor and the purchaser of the dried fish describe the product. It is unlikely that either will be totally objective, but it may be possible to infer whether an improved processs would give a better product acceptable to all. The technologist will be aware of any deficiencies in product quality because of his formal training, but these may not be immediately obvious to the layman.

VI.3 Demonstration units

In order to demonstrate the techniques to the fishermen it is essential that the extension workers become fully conversant with the methods the technologist is recommending. This is equally true whether you are attempting to introduce fish drying as a new technique or trying to improve on existing techniques. A demonstration unit should be constructed where all the processes associated with good fish drying can be carried out. Samples of dried fish produced in this fashion will illustrate the efficiency of the process to extension workers who will then be able to transfer the information to fishermen at a later date.

For the purpose of demonstration, a process line of about 10-20 kg capacity is sufficient. A small unit will help reduce costs and by keeping the time spent at each unit operation (gutting, salting, etc.) to a minimum, ensure that the demonstration does not become tedious.

Prepare a list of all training materials required:

- work surfaces, knives, fish boxes, clean water, etc. for cleaning the fish;
- salt and any containers necessary to salt the fish;
- wood (prepared or otherwise), carpentry tools, netting, wire mesh, nails, etc. needed to construct solar dryers and drying racks;
- plastic sheet to cover the solar dryer. The best way to obtain this will vary from location to location. Plastics manufacturers might not want to sell you a small amount, in which case you may either be given the amount you require or be sold a larger amount. If the latter is the case, you might be able to recover costs by acting as a central plastics store for any subsequent solar drying extension work. Polyethylene is also useful for forming into plastic bags for packaging;
- paint and preservatives to treat the wood;
- instruments to monitor drying. The number of these you have will depend on local availability and the extent of your budget. Spring or two-pan balances, and thermometers (wet and dry bulb) should be available in most principal cities;
- packaging materials: bags, boxes, baskets, and cartons;
- a lockable tool box. Useful items such as balances, knives, hammers, etc. have a tendency to be damaged or on occasion borrowed and not returned. In order to conserve your stock it is necessary to keep them under lock and key, for use only with your authority.

Security is also important when deciding on the location of the demonstration unit. The preparation techniques such as cleaning and gutting, and possibly even salting, may be best carried out indoors. The construction of drying racks and solar dryers will be done in the open. A secure site where the drying work will be seen and also protected from theft or damage will be needed. The drying site should of course be adjacent to the fish preparation area. It is essential to establish who will be responsible for maintaining the site and any drying material built on it. Where practical, the flat roof of any suitable building would be an ideal location.

Construct drying racks and solar dryers of an appropriate scale, making careful notes of the construction techniques and raw materials used. If any method seems impractical or unnecessarily complicated, improve upon the design.

Using the equipment available, carry out fish drying exercises until you are familiar with methods of gutting, salting, drying, etc.. Prepare dried fish at a level of quality you consider appropriate for the market, and obtain some opinions on your product from the trade. Having established that your development is acceptable, you are now in a position to make recommendations to extension workers.

VI.4 Involvement of extension workers

If possible, arrange for suitable extension workers to visit your demonstration units for training programmes lasting 1-2 weeks. Groups of 10-20 workers could be trained at a time depending on the level of interest shown and the manpower available.

Discuss the current fish drying practices, bringing their attention to spoilage and infestation. Then, you should describe the processes you have developed and explain the reasons for any modifications to traditional practices. The extension workers should carry out a programme of practical sessions in order to familiarise themselves with sun and solar drying processes and the construction methods used for the dryers. Encourage them to describe the techniques in their terms and in those understandable by artisans or fishermen/women. Carry out a simple costing exercise to indicate the cost of the drying units, and discuss whether this amount is feasible in relation to the price which can be obtained for the dried fish. By the end of the training programme the extension worker should have assimilated all of the necessary technical information and should be able to convey this to the end-user of the technology. He/she should also be capable of undertaking all the operations associated with the technology, from fish gutting to dryer construction, and be confident of the reasons for carrying out these tasks. He/she should be aware of all the advantages and disadvantages of each technique. The adoption of the technology now depends on the identification of a target group of artisans or fishermen/women by the extension services, where the approved methods can be demonstrated by the trained extension force. The technologist should be retained in an advisory capacity during this phase, to provide technical back-up as necessary.

CHAPTER 5

VEGETABLE DRYING

Vegetables are a desirable component of any diet, because they provide the complete range of nutrients required. Their production is often seasonal depending on annual rains and suitable growing temperatures. There are likely to be periods when surpluses are available which the farmer may not be able to use or sell profitably. At other times of the year there are likely to be shortages which can result in the variety and nutritional content of the diet being restricted. This is particularly evident in low income groups. The introduction of simple processing techniques to allow vegetables to become available all year, will go some way to alleviating this problem and will also help to raise the incomes of rural people.

Drying is a particularly suitable method of preserving vegetables. When deciding on which vegetables to dry the reader should make the distinction between vegetables which may be traditionally dried or consumed fresh in the locality - in this group we may include okra, chillies and various herbs - and vegetables which may be eaten exclusively in the fresh form. The introduction of dried versions of the latter may meet with consumer resistance which should be taken into consideration in any extension proposal.

Certain vegetables such as lettuce, melons, cucumbers, radishes and asparagus are not suitable for drying.

Vegetables are not subject to attack by the same range of pathogenic organisms which thrive on flesh foods such as fish. Poor drying techniques are more likely to lead to spoiled produce rather than dried foods which are dangerous to the health. However the reader should be aware that mould growth on incorrectly dried vegetables (and most other commodities) can contain toxins which are poisonous.

I. Pre-processing techniques

The best dried vegetables will be produced from freshly harvested produce and not from the second class remains of a batch the farmer was unsuccessful in marketing fresh. It is essential to plan at the time of harvest how much will be sold fresh and how much will be dried. The vegetables to be dried should be kept cool, shaded and, in the case of leafy vegetables, sprayed with clean water to minimise wilting. Correct handling practices will minimise bruising and damage to the crop. Ideally the crop should be transported to the drying site in manageably sized boxes and baskets rather than moved in bulk in a large cart and shovelled off.

It is important that all post-harvest operations should be carried out as soon as possible after harvesting to minimise the extent of spoilage.

I.1 Hygiene

The need for good hygiene during all processing operations cannot be over-emphasised. Frequent hand washing, regular cleaning of equipment, and rapid disposal of waste materials go a long way in preventing contamination of the dried product. Adequate provision of preparation equipment, for example, sharp (stainless steel) knives; availability of potable (or chlorinated) water; plenty of room for working; and people who have been trained in processing procedures and the need for hygienic conditions; together with correct location of the processing site are other factors which contribute to hygienic working conditions.

I.2 Cleaning

Following harvesting and transportation to the drying site, the first pre-drying operation is usually cleaning, although this is not an essential operation for all commodities. Cleaning serves to remove dirt, leaves, twigs, stones, insects, insecticidal residues, and other contaminants. The removal of these contaminants reduces spoilage rates. The easiest way to wash the crop is manually in a purpose-built tank made from concrete or plastic, or in clay pots. It is essential to change the water regularly especially when washing heavily soiled vegetables such as root crops.

I.3 Grading and sorting

Sorting is very important in the production of high quality foodstuffs. However it should be noted that the operation can be made much easier (and losses reduced) if correct harvesting procedures are followed. Sorting may be performed at the time the commodity is received at the drying site, but is sometimes done immediately after cleaning when the physical characteristics of the commodity are better exposed. Factors that may be considered in sorting are size and shape, colour, texture, density, chemical compositon, blemishes, and insect infestation.

Sorting serves to determine the value of the commodity for processing and assists in making the operation more profitable.

Quality aspects such as maturity, colour, flavour, and the absence of defects govern the acceptability of the finished product. Therefore sorting is second in importance to correct harvesting for producing high quality dried products. During sorting, all the substandard produce should be rejected. Sorting is usually followed by grading, where the vegetables are subdivided into groups based on the desired quality attributes. This may be done on the basis of size. For small quantities this process can be done manually.

Grading into lots according to shape or size has the following advantages:

1. any subsequent pre-processing operation such as blanching or sulphuring can be more easily controlled;

2. drying will be more uniform;

3. the market may pay more for an evenly sized product. In some cases a higher price may be obtained for a particularly desirable size at this stage;

Size grading is only relevant to vegetables which will be dried whole. Where the vegetables will be cut or sliced, size grading is carried out after this.

I.4 Peeling

Many vegetables require peeling prior to drying (see plate 5.1). Since a thick skin presents a physical barrier to moisture removal its removal aids drying. However, care must be taken not to remove too thick a layer in case

Preparation of vegetable

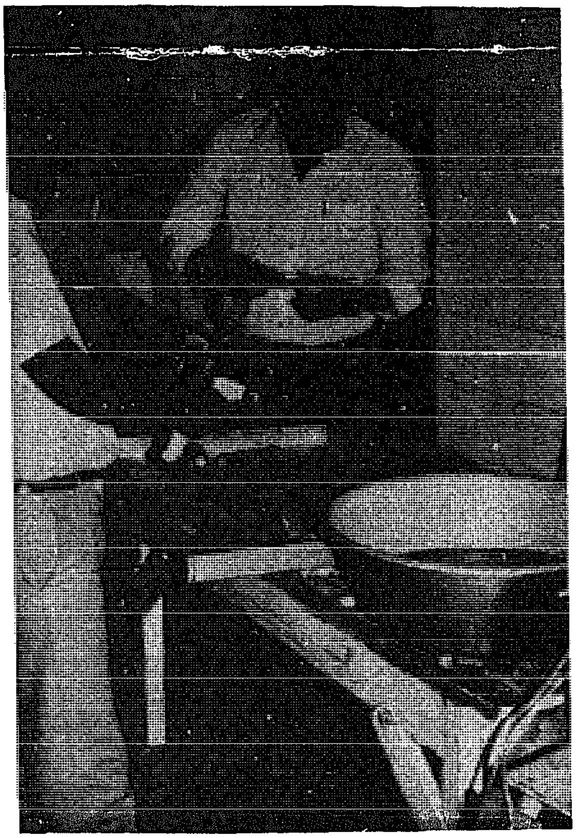


Plate 5.1
Peeling yams. Good sharp knives and a clean work suface are essential

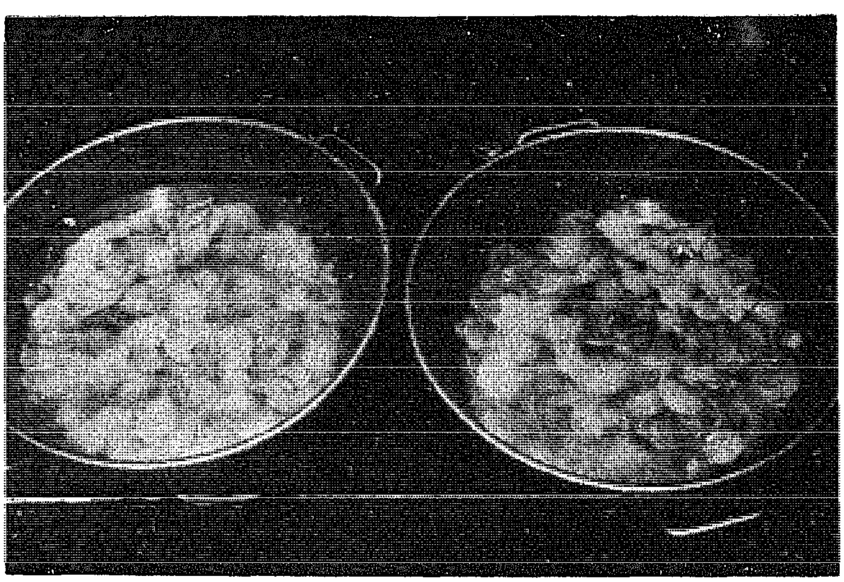


Plate 5.2
The peeled and sliced vegetables should be stored under water

the blanched, dried product is rehydrated. During blanching, the micro-organism count in foodstuffs is substantially reduced and sometimes the food becomes practically sterile. However, during exposure to the non-sterile conditions that can exist in subsequent processing operations, the product can easily become recontaminated.

All of the operations described, from harvesting to slicing, result in damage to the plant tissue. The response to this by the plant is the release of enzymes which can produce undesirable quality changes. For example, when potatoes are cut and exposed to the air, enzyme activity will result in the formation of undesirable brown pigments. Other than discolouration, the undesirable effects of enzyme activity are the development of off-flavours, the loss of vitamins, and the breakdown of tissue.

Enzyme systems in foodstuffs are extremely complex and vary with different commodities. Most of the enzyme systems are progressively inactivated at temperatures above 70°C and completely deactivated at around 90°C. Sometimes exposure of one or two minutes in the blanching vessel is sufficient, but longer times are usually used to ensure complete inactivation. Peroxidase is one of the most heat-resistant enzymes. The test for the destruction of this enzyme can be used to indicate the adequacy of blanching in the factory or laboratory.

During the blanching process, the time of exposure to the heating medium required for a given commodity depends upon several factors:

(i) piece size. To obtain effective enzyme inactivation all parts of the material should reach a temperature of at least 90°C. Longer blanching times are required for larger pieces to allow penetration of heat to the centres. However care should be taken in the case of large pieces that their outer surface does not become cooked;

(ii) temperature. Suitable uniform temperatures must be maintained throughout the blancher. In mountainous regions, where the barometric pressure is lower, immersion times must be increased to compensate for the lower boiling temperature of water;

(ii) depth of load. Heat must penetrate into the centre of the bed of material so that all pieces will reach the desired temperature;

(iv) blanching medium: Blanching in water usually requires less time than blanching in steam at the same temperature, because of the rapid application of heat to each piece in the liquid medium, as against the relatively slow penetration of steam into the food.

Blanching can either be carried out in water or steam. For water blanching, the commodity is immersed in a container of boiling or near boiling water for the necessary time. Care must be taken to avoid over-blanching which leads to loss of texture and difficulties in subsequent drying. On a small scale the easiest method is to use a muslin bag or wire basket for immersion which not only ensures the same immersion time, but keeps all the pieces together in a clean environment.

The product to be blanched can be placed on a muslin cloth, the corners of which are then tied to give a simple bag (see plate 5.3). The bag can then be attached to the end of a stick and dipped into a boiling pot. Care should be taken not to put too large a batch in the boiling water or it will cool the water excessively. The water temperature in the blancher should not drop below about 90°C and, if possible, should be rapidly brought back to the boil after immersing the vegetables (see plate 5.4). With pieces of 6 mm thickness adequate blanching can be obtained after about 4-6 minutes using this method. While the bag is in the pot it should be stirred around to ensure even heating. After blanching the bag should be rapidly cooled using cold water to prevent over-blanching or cooking.

Blanching by immersion has the advantage that comparatively large amounts of material can be processed at one time. However a high level of soluble solids can leach into the water from the vegetable, which may reduce the nutritional content or render the dried food less attractive.

Steam blanching produces a more attractive dried product and is often preferred to water blanching because there is a smaller loss of nutrients by leaching and, in some vegetables, the dried product has an enhanced storage life. It basically consists of subjecting the prepared commodity to an atmosphere of live steam. If the commodity is on trays, therefore, there need be no direct handling of the commodity between blanching and drying, thus aiding hygiene. On a small scale, this can be carried out by placing the tray in the upper section of a tank or pot, the lower section of which contains vigorously boiling water, and covering with a lid. The tray should not come into direct contact with the boiling water.

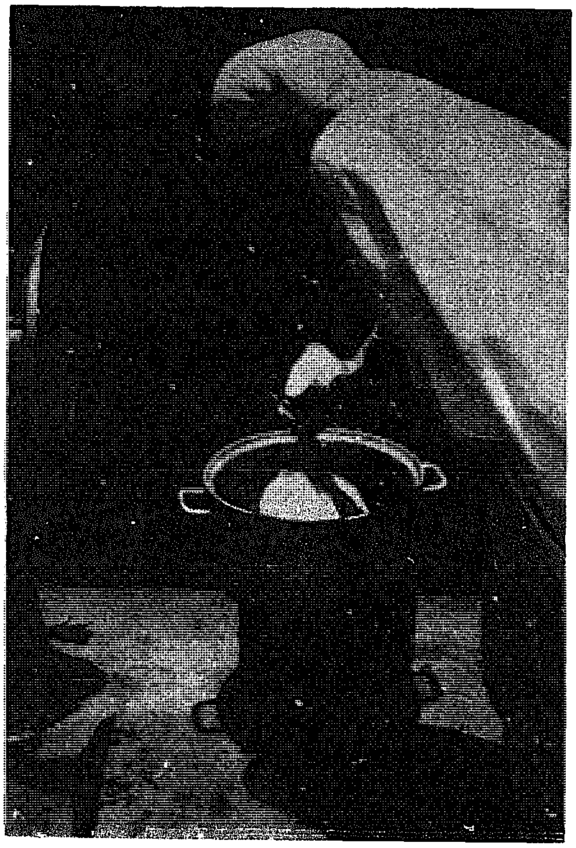


Plate 5.3
Blanching can be done in a cooking pot over a charcoal stove

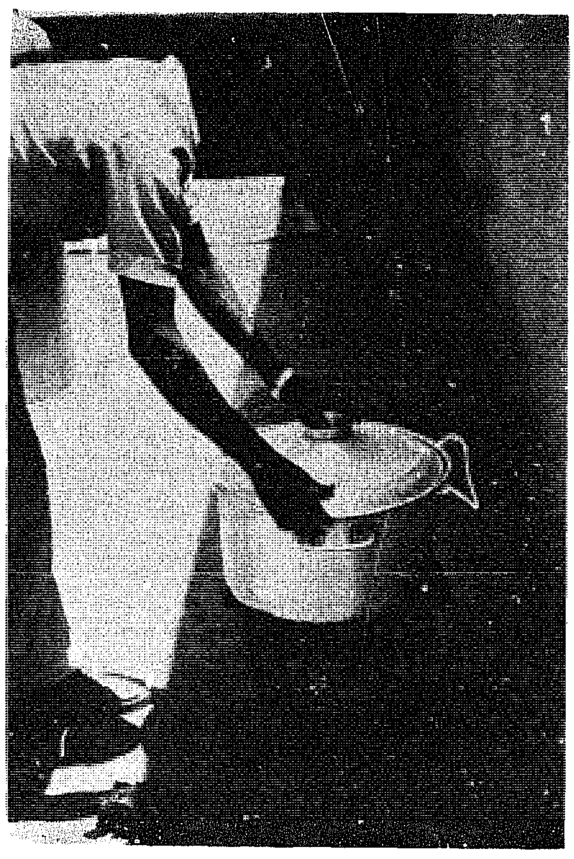


Plate 5.4
Ensure that the water temperature stays high

As previously mentioned, steam blanching times are usually a few minutes longer than water blanching times. Vegetable pieces of 6 mm thickness would be adequately blanched after 6-8 minutes. These times are given only as guidelines. Trial and error will determine the most suitable blanching time under local circumstances.

I.8 Colour retention

Blanching can be used as a tool to aid colour retention, especially in green vegetables. The green colour is due to the presence of chlorophyll which breaks down when green tissues are heated in the presence of acid. During blanching, since the contents of plant tissues are acid, the pH of the blanching water falls, bleaching the leaves. When green vegetables such as cabbage are blanched, it is necessary to use a sodium carbonate solution to maintain the pH of the liquor at 7.3 to 7.8 to prevent discolouration. A practical method of doing this is to use a 1 per cent sodium bicarbonate solution for blanching, using the immersion technique.

Blanching is not carried out with all vegetables. For example onions and garlic are not blanched, since this would result in a loss in pungency as the flavour compounds are very volatile and would be lost through blanching.

I.9 Sulphuring and sulphiting

With some dried products the use of chemical preservatives will improve the colour and increase the shelf life. The most common preservative used is sulphur dioxide. There are two methods of providing sulphur dioxide (SO_2) to commodities, sulphuring and sulphiting. Sulphuring is more commonly used for fruits, and sulphiting for vegetables.

Sulphiting involves introducing SO_2 into the commodity by the use of sulphite salts such as sodium sulphite or sodium metabisulphite, either by adding them to the blanching water or, when steam blanching is employed, by either spraying a sulphite solution on to the commodity, or by soaking it in a cold solution following blanching. Blanching in a sulphite solution is particularly useful since it combines two operations into one. The concentration of sulphite salts, and dipping, spraying or blanching times again depend on the commodity.

Concentrations used for spraying applications should be between 0.2-0.5 per cent. Sulphiting by the use of sprays or dips in not generally thought to be practical in the rural sector.

Where the chemicals can be obtained, immersion blanching in a sodium metabisulphite solution might be practical. It is important to control sulphiting accurately to obtain the correct levels of SO_2 in the food. Excessive amounts of SO_2 give the food an unpleasant smell and may cause the food to be unacceptable.

The strength of a sodium metabisulphite solution is expressed in parts per million (ppm) otherwise known as mg per kg. By way of conversion, 10,000 ppm of SO_2 means there is an overall concentration of 1 per cent. For example, 1.5 g of sodium metabisulphite dissolved in 1 litre of water will give 1,000 ppm (0.1 per cent) of SO_2. An easy way to prepare a stock solution is to dissolve 12 g (2 1/2 level teaspoons) in 1 litre of water to give an SO_2 strength of 8,000 ppm (0.8 per cent). By adding more water to this, different strengths can be achieved. Some examples of the use of a sulphiting solution are given in the techniques for drying vegetables below.

Sulphuring involves burning elemental sulphur in a sulphur chamber to produce SO_2 which permeates into food tissues. A sulphur chamber consists of an enclosure, with adjustable vents, housing perforated trays stacked one above the other. The amount of sulphur used and the time of exposure depend upon the commodity, its moisture content, other pre-treatments and the permitted levels in the final product. The food is placed on the trays inside the sulphur box and sufficient sulphur is placed in a container near the trays. For most vegetables 10-12 g of sulphur (2-2 1/2 level teaspoons) per kg of food is adequate. The sulphur is ignited and allowed to burn in the muffled environment for 1-3 hours.

Sulphuring has the advantage over sulphiting that it uses rock sulphur, which may be more readily available than sodium metabisulphite. The fumes of burning sulphur are unpleasant and can be dangerous to the processor. Sulphuring should always be carried out outdoors in a well ventilated location.

I.10 Quality advantages

Other than the discolourations caused by enzymes described for blanching, browning reactions caused by chemical reactions can occur during drying.

These adverse quality changes are referred to as non-enzymic browning. They are particularly noticeable in light coloured foods such as potato and cauliflower. The rate of most browning reactions is greatly dependent upon temperature, the combined effect of time and temperature, and the moisture content of the drying material. The chemical reactions involved occur in water and proceed slowly in the dilute solutions found in very moist foods. As the foods are concentrated during the drying process, the reactions proceed more rapidly.

The browning reactions continue after drying, and dried vegetables will continue to darken during storage unless they have been treated with SO_2. The presence of SO_2 in the dried vegetables will also inhibit microbiological spoilage and will help to deter insects both during drying and later in storage.

It should be emphasised that SO_2 is toxic at high concentrations and its use should be carefully controlled. Some countries have mandatory limits on how much SO_2 can be included. The limits for some dried fruit and vegetables in the United Kingdom are shown in table 2. If the dried product is intended for export, the possibility of national regulations should be borne in mind. In some countries, such as the Federal Republic of Germany, the use of SO_2 is not permitted.

Table 2
Maximum permitted levels of additives for some dried foods in the United Kingdom

Food	Preservative	Level (ppm)
Coconut, desiccated	Sulphur dioxide	50
Fruit:		
Figs	Sulphur dioxide	2,000
	Sorbic acid	500
Prunes	Sulphur dioxide	2,000
	Sorbic acid	1,000
Others	Sulphur dioxide	2,000
Vegetables:		
Cabbage	Sulphur dioxide	2,000
Potato	Sulphur dioxide	550
Others	Sulphur dioxide	2,000

I.11 Quality changes during drying

In order to select the correct drying conditions it is useful to be aware of some of the factors which affect vegetables during drying.

The product may be adversely affected by light. Sunlight triggers a whole range of undesirable reactions. It can cause oxidation of fats which causes rancidity. Light can initiate undesirable colour changes; green vegetables may become bleached, and pale coloured vegetables can darken. Sunlight can also cause a reduction in the nutritional value; vitamins can be destroyed. One method of overcoming these problems is to dry the vegetables in the shade wherever possible.

Excessively high temperatures during drying can result in high levels of shrinkage in the dried foods. This may render them irregular in shape and size, and unattractive to the consumer. High temperatures will also increase the tendency towards browning. Dried vegetables which are badly shrunken are more difficult to rehydrate.

The rehydration of a dried food product is another important factor, particularly in terms of consumer acceptance. It must not be thought that rehydration is a complete reversal of the dehydration process. Some of the changes produced by drying are irreversible. The outer layers of the dried food, crushed and malformed during drying, are unable to return completely to their original size and shape. Soluble constituents in the dried foods leach out into the rehydration water contributing to a loss in nutrients and also a loss in flavour and aroma.

The swelling power of starch and the elasticity of cell walls, both important rehydration factors, are reduced by heat treatment. With some products, such as dried fish, producing a rehydrated product similar in appearance to the original form is not so important, as the dried product is utilised in soups or stews and is added directly to the cooking pot. This may also be true for dried vegetables.

II. Choice of drying technique

II.1 Sun drying

The sun drying of vegetables on the ground should be avoided to prevent contamination by dust and insects. Where sun drying on the ground is the practice, attempts should be made to introduce simple improvements such as the use of mats. However, for the same reasons as described for fish drying, it is preferable to raise the drying vegetables off the ground by the use of trays on racks. Vegetables can be dried on horizontal racks. The trays should be perforated to permit the maximum flow of air around the drying vegetables. The trays should be loaded with no more than 6 kg of vegetables per square metre. The vegetables should be spread in an even layer and should be stirred or moved at least every hour during the first drying period. This will speed up drying and improve the quality of the finished product. Sun drying of vegetables on racks is illustrated in plates 5.5 and 5.6.

Shade drying should be carried out if it is necessary to prevent discolouration or to conserve nutrients. In this case the drying rack should be placed in a shaded position. Shade drying is more dependant on air movement through or over the drying vegetables. Therefore the drying rack should be positioned to take maximum advantage of any winds. In dry air conditions with ample circulation, shade drying can be accomplished almost as quickly as sun drying. In conditions of high sunshine and low humidity sun drying can be finished in one daylight period. Where a longer period is necessary the same precautions concerning protection from evening rains and morning dews, described for fish drying, apply.

II.2 Solar drying

Most vegetables can be satisfactorily dried using a solar cabinet dryer. During the initial stages of drying it is essential to ensure that there is no condensation of water inside the dryer. Condensation is caused by insufficient air flow and the operator should ensure that the air intake and outlet vents are sufficiently wide open to prevent this happening. Increased air flow inside the cabinet will reduce the temperature, but the reader will recall that the initial drying phase is more dependant on air flow than high temperature. The alternative, with no air flow, is a hot steamy cabinet which acts more as a blancher than a dryer. In the second phase of drying the air flow through the cabinet can be reduced allowing the temperature to rise. Cabinet temperatures in the range of 60-80^{o}C are adequate to dry most vegetables.

Sun drying

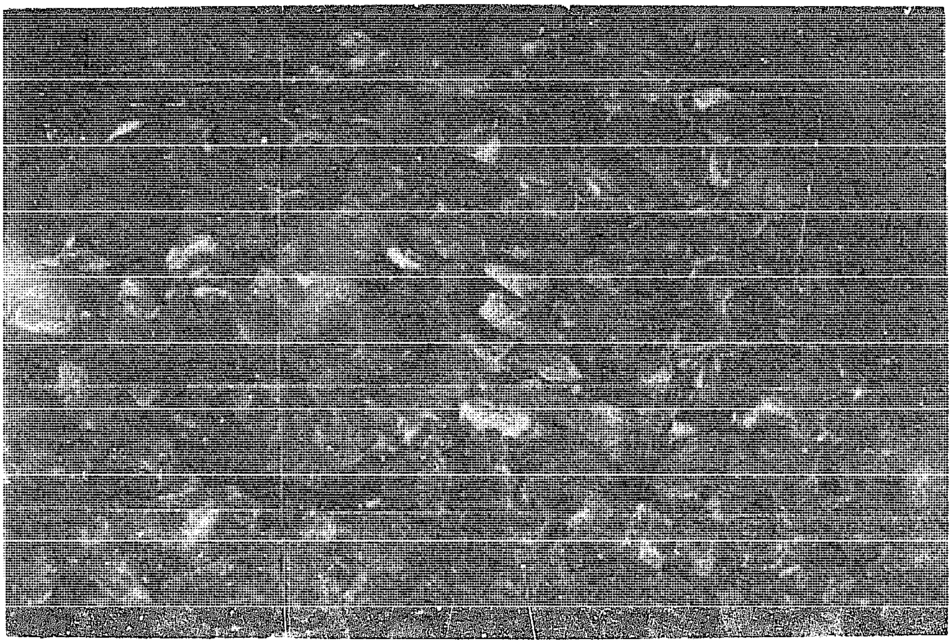


Plate 5.5

Sun drying potato slices on a raised tray

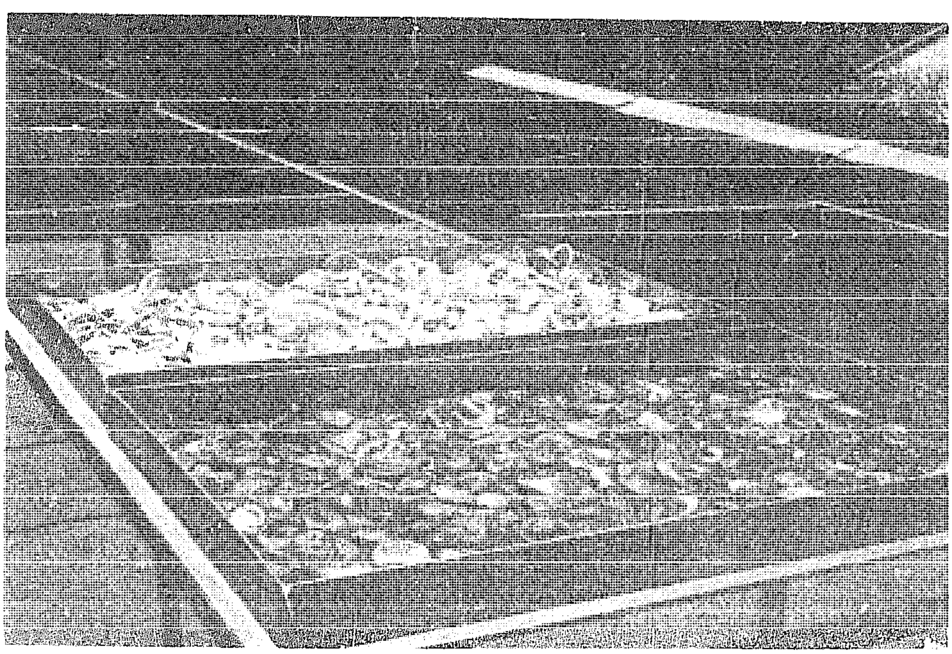


Plate 5.6

Sun drying tomato slices and onion rings. The trays are raised upon racks but these two foods should not be placed side by side as shown here

As described previously, the solar cabinet dryer can be used in the shaded mode by placing a black absorbant material directly below the cover. This absorber will transmit most of the heat received to the air inside the dryer. When drying more than one vegetable at a time it is essential to ensure that the correct combination of different varieties is placed side by side on the rack or in the dryer. For example, strongly flavoured vegetables such as onions and chillies should not be placed next to more bland foods such as tomatoes, otherwise, the tomatoes will pick up the strong flavour. Tent drying of tomatoes and solar cabinet drying of carrots are illustrated in plates 5.7 and 5.8.

III. Specific vegetable drying techniques

The following methods have been collected from various sources in different countries and give an idea of what processing techniques might be suitable. The reader may find it necessary to modify them to suit local practices.

III.1 General method - green legumes

After shelling, the outer skin of the pea or bean is gently punctured to assist the internal moisture to escape. This can be done by tapping a single layer of the legume under an open meshed tray. The legumes are then scarified by brushing a stiff-bristled steel wire brush lightly across the top of the mesh or by gently tapping the brush on the peas, allowing the bristles to penetrate slightly. Blanch by immersion in boiling water containing 1 per cent sodium bicarbonate (2 teaspoons of baking soda per litre) for 2 minutes. Spread evenly in a single layer and dry at 55-60°C until the legumes are brittle and crisp. Shade drying may help preserve colour.

III.2 Specific methods

Green soyabeans. Steam blanch the pods for 10-15 minutes until the beans are tender but firm. Shell and dry until brittle.

Green beans. (i) Remove strings from string varieties and split the pods lengthwise to hasten drying. Steam blanch for 15-20 minutes and dry until brittle.

Green beans. (ii) Cut the vegetables into 2 cm pieces discarding the end of the pod. Blanch in 1 per cent sodium bicarbonate solution for 4-6

Solar drying

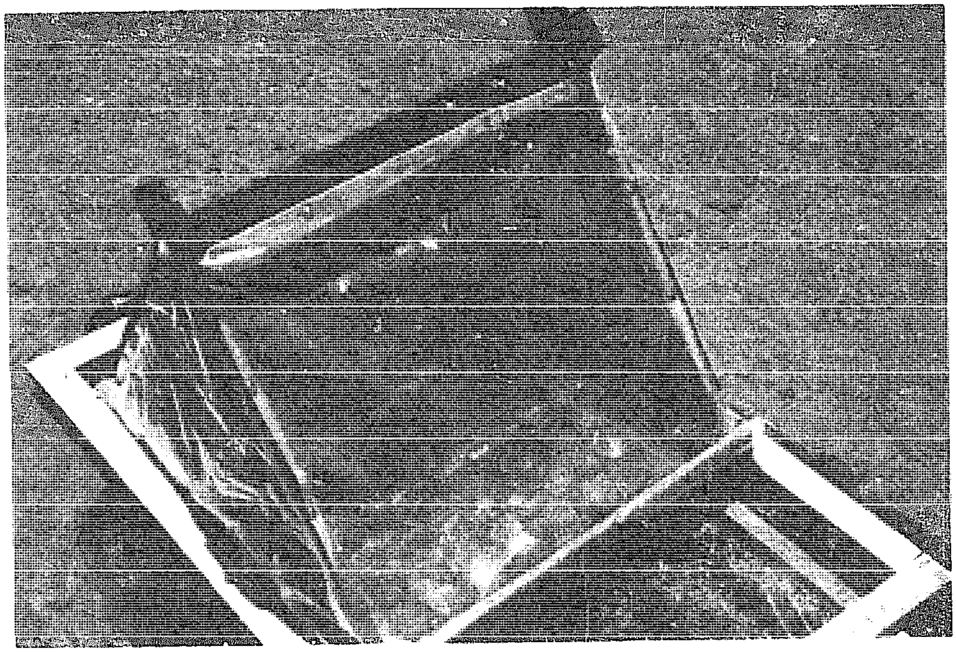


Plate 5.7
Tent drying of tomatoes

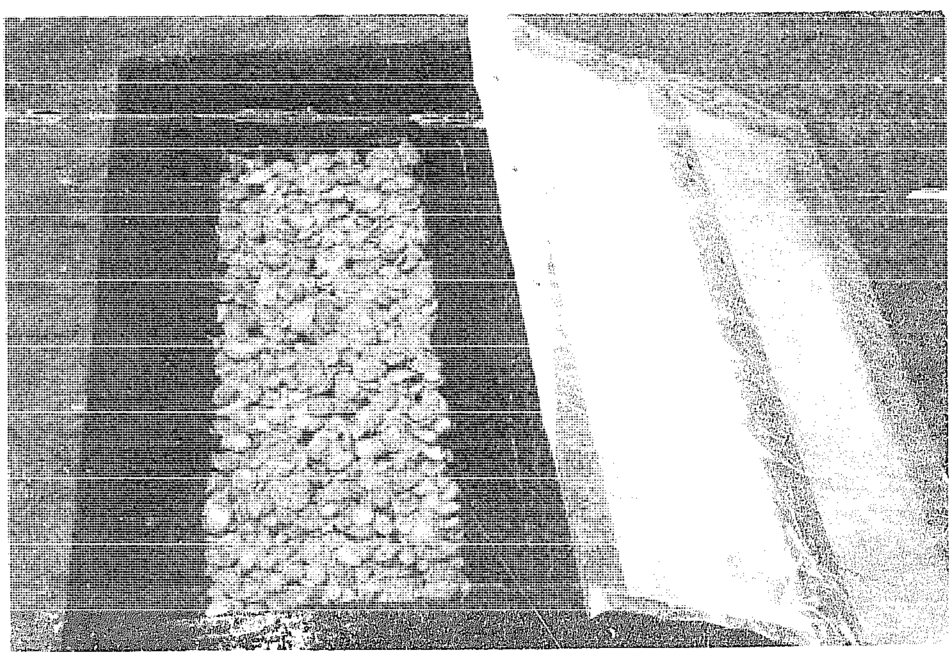


Plate 5.8
Cabinet-dried sliced carrots

minutes. Cool and dip the beans for 1 minute in a sodium metabisulphite solution containing 8000 ppm SO_2. Dry until brittle, equivalent to a moisture content of about 6 per cent.

Okra. (i) Okra may be dried whole or in halves or strips after blanching (6 minutes in boiling 1 per cent sodium bicarbonate solution). After blanching remove the slimy exudate. Dry in a single layer at 60-65°C, preferably in the shade.

Okra. (ii) Cut young tender pods into 1 cm pieces or split lengthwise. Steam blanch for 5-8 minutes. Dry in a bed not more than 1 cm deep until very brittle.

Peas. Shell young tender pods and then immediately steam blanch for 5-8 minutes. Dry, stirring frequently, until the peas are hard and wrinkled.

III.3 General method - green leafy vegetables

The vegetables should be washed, stems removed as necessary and the leaves cut into strips about 5 mm wide. Blanch by dipping in boiling 1 per cent sodium bicarbonate solution for 3 minutes. Sulphite (optional) by dipping in an 8000 ppm SO_2 solution for 1 minute. Spread the vegetables thinly and dry quickly, preferably in the shade, at 55-60°C. Drying may be achieved in as little as 4 hours.

III.4 Specific methods

Broccoli. Trim, cut, wash, etc. Steam blanch for 8-10 minutes and dry until crisp.

Cabbage. (i) Remove outer leaves, quarter, core, and cut into shreds. Steam blanch for 8-10 minutes. Dry until tough and leathery.

Cabbage. (ii) Prepare as for method (i), then blanch in a boiling 1 per cent solution of sodium bicarbonate for 3 minutes, followed by a 1 minute dip in an 8,000 ppm SO_2 solution. Dry to a moisture content of about 5 per cent.

Cauliflower. Separate into florets. Dip in salt solution (2 tablespoons of salt per litre of water). Steam until tender. Dry until the florets are hard to crisp and tannish yellow in colour.

Celery. Strip off leaves, cut into 1 cm pieces. Steam blanch until tender. Stir occasionally during drying. Dry until brittle.

Parsley, Jews-Mallow/molochea and herbs. No pre-processing necessary. After washing, spread loosely and shade dry, or alternatively, hang bunches of the whole plant in a dry warm shady place. Drying should be complete in a few hours. When dry and brittle crush the leaves and remove the stems.

Spinach. Select young tender leaves, wash and cut large leaves into several pieces. Steam blanch for about 4 minutes until wilted. Dry until brittle.

III.5 Roots and tubers

Potatoes. (i) Wash, peel, trim, and cut into thin slices. To prevent browning, place in a 1 per cent solution. Blanch in boiling water for 5 minutes. Sulphite (optional) for 1 minute in an 8,000 ppm SO_2 solution. Spread slices thinly and evenly, and dry at 60-70°C until crisp and brittle, equal to a moisture content of 6 per cent.

Potatoes. (ii) Wash, etc., and cut into long strips of 5 mm cross section or slices about 3 mm thick. Rinse in cold water and steam blanch for 4-6 minutes. Dry until brittle.

Sweet potatoes and yam. As for potatoes.

Turnips and swedes. (i) As for potatoes.

Turnips and swedes. (ii) Wash, trim, etc. as before. Quarter, peel and cut into 3 mm slices or strips. Steam blanch for 15 minutes and dry until leathery.

Carrots. (i) After washing and scraping, cut into 9 mm slices and blanch for 5 minutes in boiling water. Sulphite (optional) by dipping in 8,000 ppm SO_2 solution for 1 minute. Drying conditions as for potatoes. Shade drying will help to preserve colour and pro-vitamin A content.

Carrots. (ii) Crisp tender carrots free from woodiness should be washed trimmed and cut into strips or slices about 3 mm thick. Steam blanch for 8-10 minutes and dry until tough and leathery, equal to a moisture content of 6 per cent.

Parsnips. As for carrots.

Beetroot. Small tender beets of good colour and free from woodiness are washed and trimmed. The beets are steamed for 30-45 minutes to cook through, then cooled, peeled and cut into slices or strips about 3 mm thick. The beet pieces are dried until tough, leathery or brittle.

III.6 Other vegetables

Onions. After removal of tops, roots and outer leaves, the onions should be washed and sliced into thin (3 mm) rings. They should not be blanched since this destroys flavour. They do not require sulphiting. The rings should be dried until crisp at 55-70^{o}C and packed immediately in air- and moisture-proof containers. Onion rings are highly hygroscopic. The safe storage moisture content is about 5 per cent.

Leeks. As for onion.

Garlic. Separate the cloves and remove the outer skins. Finely chop the cloves into pieces smaller than 5 mm. Similar to onion, blanching or sulphiting is not necessary. Dry the pieces until the garlic is brittle, equal to a moisture content of 5 per cent. Separate off the dry skin by winnowing, and pack the garlic in air- and moisture-proof containers.

Peppers, sweet (capsicum). The washed, opened and cored peppers are sliced into thin strips. No blanching is necessary. Sulphite (optional) by dipping for 1 minute in 2,000 ppm SO_2 solution. Shade dry at 55-65^{o}C until crisp. equal to a moisture content of 7 per cent.

Tomato. (i) Steam or dip in boiling water to loosen skins. Chill in cold water and peel. Cut into sections not over 20 mm wide. Sulphur (optional) in box for 10-20 minutes. Dry until leathery.

Tomato. (ii) After washing and trimming, slice the fruit and dip for 3 minutes in a solution containing 600 ppm SO_2 and 10 per cent salt. Dry the slices until they are leathery, equal to a moisture content of about 6 per cent.

Chillies. (i) Wash and dry whole without blanching or sulphiting. Shade dry at 60-65^{o}C.

Chillies. (ii) Wash, trim, and cut into 1 cm strips or rings. Remove the seeds. Steam until tender, then dry the rings 2 layers deep until they are pliable.

Mushrooms. Peel larger mushrooms and dry whole or sliced, depending on size. If stems are tender, slice for drying, if tough, discard. No pre-processing is necessary. Spread not more than 1 cm deep, and dry until leathery to brittle.

IV. Packaging of dried vegetables

IV.1 Reasons for packaging

All dried foodstuffs are normally packaged in some way for storage and marketing. Whether the package is a large one, perhaps for distribution to an industrial or trade customer, or a small package for sale to a household consumer, three basic functions of the package can be recognised:

(i) it should contain the foodstuff, enabling the chosen quantity to be handled as one unit without loss, throughout the hazards of transport and storage;

(ii) it should protect the foodstuff and preserve its required attributes through a planned shelf life;

(iii) it should communicate information about the foodstuff such as its nature, origin, method of use, quantity, destination, and name of producer.

With dried vegetables the need to protect the foodstuff is of primary consideration when selecting the method of packaging. The prevention of typical moisture contents in the range of 2-8 per cent and require packaging which gives good protection against moisture uptake. This is particularly so in humid tropical climates.

The tendency to pick up water, as water vapour, is determined by the equilibrium relative humidity of the storage atmosphere, not merely by the moisture content of the food. With some foods, such as potato crisps, moisture content relates directly to a critical quality attribute (crispness), and in conditions where the food gains moisture during storage, the shelf life is simply the time taken to reach a critical moisture content. With many other foods the moisture content influences the rate of deterioration in quality through chemical and biochemical reactions or through microbiological spoilage.

High temperatures may have adverse effects on foods, but packaging cannot provide direct protection except in the very short term. Oxygen is a significant factor in deterioration of many foods, especially those containing fats or oils, and this can be taken into account in the packaging system. Light may have effects similar to those of oxidation, or may promote oxidation, and the package can be selected to exclude light from the food.

This is particularly important where processing steps, such as the use of sodium bicarbonate or shade drying, have been taken to preserve the colour of green vegetables. Any quality advantages which have been gained by these steps will be lost if light is not excluded from the packaged goods.

The package should also prevent tainting of the food by foreign odours. Good storage practise will also help reduce the likelihood of odour contamination. Strongly flavoured dried vegetables such as onions should not be kept next to blander products which would pick up the onion flavour.

A good package will also help to retain the SO_2 content of the dried vegetable. This will help retain the good appearance of the product and enhance the shelf life of the package.

Biological hazards to dried foods need attention throughout production and distribution, although they are usually a secondary consideration in relation to selection of a package. Bacterial spoilage will not be a problem in a dried food, and the action of a package is simply to exclude contamination, thereby preventing any increase in the bacterial load. However, if the package is unable to prevent the absorption of moisture by the dried vegetables, mould growth will occur which will spoil the food.

Infestation by mites or insects is a potential problem with most dried foods; packaging has a part to play in control, but will only be effective if combined with other measures. Protection against mammals (especially rodents) and birds cannot be provided economically through packaging, although good packaging practice will assist control through minimising spillage. These pests must be excluded from food stores, by appropriate store design and management procedures.

IV.2 Types of packaging

Traditional packaging materials used for long established products such as dried fruit and dried fish include baskets, bales, jute sacks, wooden boxes and cardboard boxes. These can only be used for packaging dried products which do not require water vapour or oxygen barriers under the prevailing climatic conditions. They are appropriate for commodities which are transported in large packages to a central marketing point and then sold loose. These packages can often be used several times and are usually cheap; but the need for good hygiene must be emphasised. Inclusion of a low density polyethylene film lining in a traditional package can add substantial protection against uptake of water vapour.

A wide range of protective packaging materials has been used for dried foodstuffs including metal cans, glass jars, and rigid moulded plastic containers, as well as the more commonly found flexible packs. Rigid packages may be assumed to have negligible permeation rates for water vapour and gases, if they are properly sealed, but they are relatively expensive and of limited relevance to the needs of the small-scale processor in developing countries.

A wide range of flexible packaging materials is available including paper, aluminium foil, plastic films, and also laminates incorporating two or more of these. Again the relevance of many of these is limited with the possible exception of polyethylene (low or high density) which may be manufactured locally, and is cheaply available. Low density polyethylene, while not the optimum dried-food packaging material because of its high permeability to oxygen, has two advantages. It is a moderately good moisture barrier and it can be easily sealed in a candle flame or by using aluminium foil and a soldering iron.

Flexible materials may be used as the sole component of a small package or as a barrier component in a package. A sturdy outer package is also required in each instance; this could comprise a basket, a fibreboard or wooden box, a paper wrap, or a textile or paper sack. This outer package provides much of the protection against transport hazards, and the choice therefore influences the strength required in the inner pack. In practice, therefore, the complete package system should be planned as a whole. It should be noted that in many circumstances the choice of packaging materials is limited, and it may be a case of utilising whatever material is available. The packaging of dried onions and tomatoes using simple plastic bags, a cheap and effective way, is illustrated in plates 5.9 and 5.10.

IV.3 Alternative processes

The reader should bear in mind that there are other methods for preserving vegetables. If the main purpose of preservation is to extend the period of availability, this can also be done by curing, in the case of onions, or simply by good storage practice, in the case of root vegetables. Other appropriate technologies which could be considered include salting and pickling. These are traditional methods with widespread applications in the rural sectors of many countries.

V. Extension work activities for vegetable drying

This will be discussed in the following chapter on fruit drying since the suggested techniques are similar for both commodity groups.

Packaging

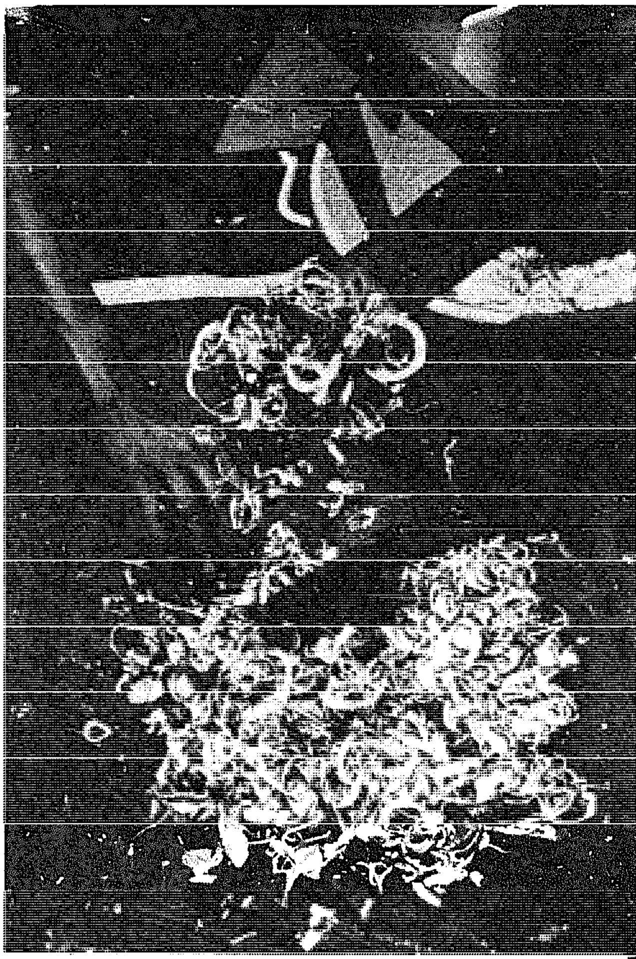


Plate 5.9

Dried onion rings
The food should be packed as soon as possible to prevent any moisture re-absorption

Plate 5.10

Dried tomato slices.
Polyethylene bags provide a reasonable barrier against moisture and can be sealed in a flame

CHAPTER 6

FRUIT DRYING

Fresh and dried fruit contribute a range of micronutrients to the diet and are particularly valued as sources of ascorbic acid (vitamin C) and beta carotene (pro-vitamin A). Fresh fruit consumption is often limited by seasonal availability and in some cases by high cost. Strangely, in some cultures fruit is considered to be almost a luxury item and consumed in small amounts whereas in others it is a dietary staple. Any steps which result in increasing the availability of fruit in deficient areas can only be considered as meritorious. In this context fruit drying can provide a means of increasing availability.

Two forms of dried fruit exist - semi-moist fruits and dried fruits. Semi-moist fruits, such as dried grapes, contain naturally high levels of sugar. This means that dried grapes can be preserved at a higher moisture content than other dried foods. Typically, semi-moist products can have a moisture content of about 25 per cent. This gives these products the advantage that they can be eaten directly in their preserved state without any need to rehydrate them. There is considerable world trade in semi-moist fruit, particularly dried grapes from Australia, the United States and Cyprus. The distinction should also be made between traditionally dried fruits, such as dates and apricots, and novel dried fruits such as papaya or in some cases mango. It will almost certainly be more difficult to sell dried mango than dried apricot to the uninitiated. Most fruit varieties are suitable for drying with the exception of citrus fruit, although there is a limited production of sun-dried limes in the Middle East.

I. Pre-processing techniques

Some fruits have a tendency to ripen rapidly, after which they start to deteriorate in eating quality. As with vegetables, it is essential that only the best produce be used for drying, and since the correct harvest period for fruits might be quite short, there is a greater time constraint placed on the processing methods used. There is considerable variation in the ripening characteristics of different fruit. Mangos and bananas ripen rapidly and can have short harvest periods whereas citrus ripen slowly.

All fruit to be dried should be hand picked and not shaken from the tree. This will prevent bruising. The fruit should be picked when just ripe and ready to eat. Over-ripe fruit will bruise easily and may be soft and difficult to slice. The copious amount of juice in some over-ripe fruit makes it sticky and difficult to handle. During subsequent processing, over-ripe fruit can absorb an excess of SO_2 during sulphuring which renders the dried product dark and unattractive. Conversely, under-ripe fruit may not absorb sufficient SO_2 and will give a hard, bitter, unattractive dried product. There is therefore little sense in preparing and drying fruits which have been harvested at the wrong time.

All of the information on the pre-processing of vegetables is pertinent to fruit with the exception that fruit are normally not blanched. Browning can occur when the flesh of fruits such as apples or bananas is cut. To prevent this the fruit should not be cut up until the last possible minute, and the cut pieces should then be stored under water until time for the next processing stage. It is customary to sulphur fruit, using a sulphur box rather than to use a sodium metabisulphite dip. Sulphuring is essential to preserve the light colour of some dried fruits such as apples and apricots. Sulphuring also helps to preserve the ascorbic acid and the beta carotene content during drying. As previously mentioned, it has the additional advantages of controlling microbial and insect activity and of protecting delicate flavours. Generally, about 3.5 to 4 kg of sulphur per tonne of fresh fruit is sufficient. This is about half the level recommended for vegetables.

II. Pre-processing methods specific to fruit

II.1 Checking

Some fruit with a waxy skin is dipped in a hot dilute caustic soda solution prior to sulphuring. This process is called checking. Typically, washed grapes (or plums) are dipped in a 0.3 per cent boiling sodium hydroxide solution for 3 or 4 seconds. This produces cracks in the fruit skin which speed up the subsequent dehydration process. The grapes are then washed in cold water to prevent any more chemical damage and to avoid cooking the product. Another cold water dip is used to eliminate all traces of sodium hydroxide from the skin. Where checking is not a feasible proposition, due to the lack of sodium hydroxide or a reluctance to use it, an alternative is steam blanching for 10-15 minutes. The fruit is then sulphured.

II.2 Sugaring

There are various methods of applying sugar (sucrose) to fruit. The simplest is to apply a dusting of fine sugar just before drying. This may help retard browning and give the dried product a sweet coating.

Fruit pieces can also be dipped in a concentrated syrup. This results in the movement of water out of the fruit by the process of osmosis. At the same time, a smaller amount of sugar will penetrate the fruit tissue. This phenomenon of osmosis, the diffusion of a solvent through a semi-permeable membrane from a dilute to a concentrated solution, proceeds until an equilibrium concentration is reached. The solute (sugar) is able to diffuse through the membrane in the reverse direction only very slowly, so that the net result is transfer of water to the concentrated solution.

By immersing fruit in a concentrated sugar solution, water equivalent to over 50 per cent of the initial fruit weight can be removed, thereby greatly reducing the load on the dryer in the subsequent solar drying stage. It should be noted that the product obtained is different to that obtained by drying alone. The process is analogous to salting fish. In the same way that saltfish do not require to have as much moisture removed as unsalted dried fish (because of the preservative effect of salt), fruit which has been osmotically treated will be shelf stable at high moisture contents and have textures similar to semi-moist fruits such as raisins. This is due to the preservative effect of the additional sugar absorbed from the syrup. Some of the advantages of including this osmotic step in the drying process are:

(i) during osmosis the material is not subjected to a high temperature over an extended time, so heat damage to colour and flavour are minimised;

(ii) a high concentration of sugar surrounding the material prevents discolouration by enzymic or oxidative browning. A good colour can be obtained in the dried product without chemical treatments, such as sulphiting;

(iii) as water is removed by osmosis, some of the fruit acid is removed along with it. This lower acid content, combined with the small amount of sugar added to the fruit during osmosis, produces a blander and sweeter product than ordinary dried fruit.

Some of the disadvantages are:

(i) a thin film of sugar is left on the surface of the fruit after drying, which may be undesirable. However, this can be removed by a quick rinse in water after osmosis;

(ii) the process produces a dilute syrup as a by-product. This can be brought back to strength by concentrating or by adding more sugar, and recycled. However, there is a limit to how often it can be used before becoming unacceptably contaminated. Suggested uses for the syrup have included fruit nectars;

(iii) the process may be unnecessarily complicated by including this step;

(iv) sugar may be expensive.

The concentration of solution and time of soaking are dependant on the material and the desired level of water removal. The technique has been tested with banana, mango and papaya. Suggested soaking times are up to 18 hours in a 67 per cent sucrose syrup, stirring occasionally. This will remove about 40 per cent of the original moisture. This soak is followed by a one hour soak in a 60 per cent sugar solution containing one per cent SO_2 (as sodium metabisulphite), and finally a rinse in cold water to remove subsequent stickiness. The fruit can then be sulphured and solar dried. Shade drying will help to conserve the colour.

A third method of introducing sugar is to immerse the fruit pieces in a boiling syrup for a few minutes. This will result in a change in the texture of the fruit, and a hard gel will form on the surface. A partially candied fruit product can be made in this fashion which can then be sulphured and dried. Care should be taken not to immerse the fruit in the syrup for too long or else extensive browning will occur. If over-ripe fruit is used, it will tend to disintegrate in the syrup.

The advantages and disadvantages of this process are the same as for the osmotic process described above.

Unlike most of the pre-processing operations described, sugaring is not essential to give a good dried product. The technique has been included as an example of an additional operation which may be useful. The reader must decide its relevance to his/her particular situation.

III. Drying methods

Most of the countries which dry fruit commercially have hot sunny climates which favour sun drying methods. Indeed exposure to the sun is essential to obtain the correct colour development in grape drying. Even in developed countries with access to sophisticated alternative techniques, sun drying of fruit is still the principle method of drying since it gives the desired product quality.

The drying methods described for vegetables are entirely appropriate for fruit drying. The simplest method which can be recommended is sun drying on racks. It is essential when drying fruit to keep it off the ground to speed the drying process and also to reduce theft or damage by predators. Drying fruits are particularly attractive to insects and animals and it is desirable to keep losses to a minimum because of the comparatively high value of the crop.

Generally speaking, fruit takes longer to dry than vegetables. This is due to the sugar content which can make the drying fruit sticky and retard the rate of moisture loss. Semi-moist fruits, such as dates, have a high invert sugar concentration. Invert sugars and fructose in particular, are hygroscopic. In a hot dry climate, sufficient moisture will be lost to give the desired semi-moist product with good keeping qualities. However, in humid climates the fruit may not lose sufficient water quickly enough to prevent spoilage. It is possible in some cases that drying fruit exposed to a sudden increase in humidity will reabsorb moisture from the air. Where fruit with a high sugar content cannot be dried sufficiently fast, moulds and yeasts are likely to grow which will ferment the sugars present.

In areas where sun drying is not feasible, due perhaps to high humidities, solar drying using a cabinet dryer is a possible alternative. Operating conditions are similar to those described for vegetables. When drying fruit which is valued for its vitamin content, such as mango, it is worth considering shaded cabinet drying. On the other hand where exposure to the sun is necessary, as in grapes, direct cabinet drying should be carried out.

III.1 Some specific fruit drying methods

Suitable drying temperatures for fruit are 60-80^{o}C.

Banana. The fruit should be ripe, and sweet, but not soft or brown. Cut into thin slices 5-7 mm thick, and sulphur. Alternatively sulphite by dipping in a 2000 ppm SO_2 solution for 1 minute. Dry the fruit in a single layer at 60-75^{o}C until it is hard and brittle, equal to a moisture content of about 12 per cent. Avoid overheating the banana to prevent darkening.

Breadfruit. Peel, core and cut into chips or thin slices. Dry as for banana.

Apples. Peel, core and cut into slices or rings. Sulphur for 60 minutes and dry until the fruit is leathery and has no moist area in the centre.

Pears. Peel, cut in half lengthways, core, and form slices about 3-5 mm thick. Sulphur for 60 minutes and dry until the fruit texture is springy.

Peaches. Peel carefully and avoid bruising. Dry as for pears until pliable, but leathery.

Apricots. Cut the fruit into half and pit. Apricots will dry more rapidly if qúartered or sliced but check that smaller pieces are acceptable in the market. Sulphur for 60 minutes. Dry until pliable, but leathery.

Plums. Cut in half and pit. Check and sulphur for 60 minutes. A handful of plums properly dried will fall apart after squeezing.

Berries. Wash and check. Sulphur for 60 minutes. Dry until the berries are hard and there is no visible moisture when crushed. Strawberries are not suitable for drying.

Figs. If the figs are small or have been partly dried on the tree they may be dried whole without checking or blanching. Otherwise cut in half, check and dry until pliable and leathery, but still slightly sticky.

Dates. Dates may be partially or wholly dried on the palm depending on the climate. Where they are partly dried they can then be sun or solar dried whole without any pre-processing. Direct sunlight is essential. Alternatively the dates can be pitted, halved and sulphured before drying. The semi-moist date-halves can be pressed together to form a paste.

Grapes. Wash, check and sulphur for 60 minutes. Dry until pliable and leathery. Seedless varieties are preferable for drying.

Mango. Peel and cut off the two fleshy cheeks. Cut into thin slices. Treat with sugar (optional) and sulphur for 60 minutes. Shade dry. Well dried mango will be golden brown and pliable. Different varieties of mango have different drying quantities. If excessive browning occurs, dry at lower temperatures.

Papaya. Dry as for mango.

The maximum permissible moisture content for the safe storage of some dried fruit is shown below.

Table 3

Fruit	Maximum permissible moisture content (per cent)
Raisins	25.0
Sultanas	20.0
Prunes	21.5
Apricots	20.0
Peaches	18.0
Dates	24.0

IV. Packaging

The packaging requirements of many dried fruits are similar to those of dried vegetables. However, the semi-moist products in particular have special packaging needs to prevent the reabsorption of water. Since dried fruits are a valuable commodity it may be possible to spend more on the packaging material. A moisture-proof, sealed plastic bag inside a cardboard box would be a suitable package. It is likely that the producer of dried fruit will be in an area where there are other growers. It might be possible to arrange for communal packaging facilities. This would minimise costs and could result in a standard package (with the producers own identification if so desired) which would be easily recognised by the consumer.

V. Alternative processes

Other methods of processing fruit include preserve manufacture to give jams, jellies and chutneys. Fruits rich in sugar can be fermented to produce wines. Starchy fruit such as bananas can be sliced and fried to give chips.

VI. Extension work activities for fruit and vegetable drying

VI.1. Location

Fruit and vegetables are highly seasonal and may well be harvested in different parts of the country at different times of the year. It may be difficult to find one single location where all or even a representative cross section of the crops will be grown and harvested at a convenient time for drying. Consultation with horticultural agencies should assist in finding the most suitable spot to set up drying demonstration units. As with extension work for fish drying, it may be convenient to work in co-operation with other post-harvest development projects, sharing overheads and providing complementary skills. Horticultural units may also be able to provide information on the types of fruit and vegetables which are grown and on the varieties suitable for processing.

VI.2 Current practices

Determine which fruits and vegetables are traditionally dried and what techniques are used. Establish whether any improvements to the process are desirable and who would benefit from the improvements. Consider whether any crops which are usually consumed fresh could be dried and what the dried product could be used for. For example, tomatoes could be dried and sold as a direct replacement for tomato paste at the village level. Chilli peppers could be dried and sold either whole or ground up. It might be possible to sell dried chilli profitably in large towns where the present supply is poor or non-existant.

Determine the major season(s) for each fruit and vegetable crop which you are going to dry. Work out a processing schedule which will enable you to dry different commodities at different times of the year. In this way, through time you will build up a collection of various dried foods to show to extension workers. When extension workers come for training, it is unlikely that you will be able to demonstrate drying techniques for more than a handful of commodities, but the dried samples with an explanation on how they were made will provide a broader picture of the merits of the process.

VI.3 Demonstration units

Draw up a list of all the unit operations you are going to cover and the equipment you will need. For demonstration purposes, batches of up to 10 kg of raw material will be sufficient to teach the basic skills. The pilot plant can therefore be designed around this amount. The equipment you will need at each stage will include the following:

(i) preparation - knives, work surfaces, chopping boards, clean water, salt and containers for washing, peeling, etc.;

(ii) pre-processing - charcoal stove or other heat source, and pots for blanching and/or sulphiting; a wooden box for sulphuring; rock sulphur or sodium metabisulphite, sodium hydroxide, sodium bicarbonate, sugar;

(iii) drying - materials and tools for building drying racks and/or solar dryers; plastic material for covering the dryer and also for packaging; other packaging materials as appropriate;

(iv) monitoring - a set of scales, and wet and dry bulb thermometers are desirable.

As noted in the fish drying extension work section, it is important to guard all tools to prevent them being misplaced or damaged. They should be stored under lock and key when not in use and only issued on your authority.

The preparation stages can be housed indoors if a suitable building is available. The pre-processing and drying units should be constructed at a secure outdoor location where full advantage of the sunshine and any prevailing wind can be taken advantage of. The flat roof of a building would be a useful site.

Construct or collect the full range of dryers and processing aids you are going to test, keeping a record of any procurement difficulties experienced. Determine the cost of the pilot plant. A useful exercise at a later date might be to ask trained extension workers to cost comparative pilot plants using alternative materials.

Become familiar with each of the processing steps using a variety of fruit and vegetables. Retain samples of the dried products with careful records of the methods used to obtain them. Obtain market reaction to your products. Establish which processes and products are preferred and can be recommended to extension workers.

VI.4 Involvement of extension workers

Arrange for a group of extension workers involved in fruit and vegetable post-harvest technologies to attend a one to two week training programme at your demonstration site. During the training programme you should explain the reasons for drying crops and the quality advantages which can be gained by using the recommended processes. The trainees should be made aware of the advantages of:

- cleaning, sorting and grading;
- blanching - but discuss also the extra labour and cost incurred by using fuel;
- sulphuring/sulphiting - but consider the availability of sulphur-containing materials and the extra cost and effort required;
- shade drying;

- solar drying.

Compare the quality of sun dried with solar dried products and discuss which material the market would prefer.

The extension workers should have practical experience preparing dried foods and become familiar with the construction techniques used to produce the pilot plant.

Display your previously prepared dried foods and present illustrations on the methods used to produce it. Ask the trainees to suggest what other fruit and vegetables might be suitable for drying and get them to devise suitable processes. The trainees should present the information in a method understandable by the farmer. The trainees could also devise methods or recipes for using the dried foods.

Before the end of the training programme the extension workers should be aware of processing constraints, the most suitable methods to use and, bearing in mind the construction costs of any recommended method, what the quality and/or price advantages will be in the market.

Dissemination of solar drying technology in the Sudan: a case study

Using the techniques described above, a training programme - part of an ILO project on appropriate technological advancement in the rural sector of the least developed Arab countries - was carried out in cooperation with the food technology staff of the Food Research Institute, Khartoum. The target audience was extension workers active in the rural sectors of the province of Khartoum Province. The objective of the course was to increase awareness of sun and solar drying techniques and thereby provide the extension workers with more information to disseminate to farmers and artisans. The training programme was divided into two parts. In the first phase, solar dryers were constructed and the principles governing their use were demonstrated. This was followed by a practical session when a range of commodities was dried using different techniques and the quality of the dried goods evaluated.

Three types of solar dryers were built: the cabinet, the tent and the modified paddy dryer. For ease of construction, prepared timber and other conventional building materials were used. The extension workers soon became familiar with the construction principles. They were, however, less willing to suggest alternative building materials. This may have been because of unfamiliarity with rural materials or a subconscious belief that the expensive, prepared materials were best because of their professional appearance. The danger exists that this belief could subsequently be passed on to the farmer who could ill afford the luxury of expensive raw materials. Since most of the prepared timber, woodworking tools, nails, etc. are imported, any general recommendation to increase their consumption will have widespread implications. It is essential therefore that the extension workers should be made to question the appropriateness of any construction technique.

A supply of plastics to cover the dryers was a problem. The local plastic manufacturer was sympathetic and willing to sell us a relatively small amount. However, the factory at that time was not working due to lack of (imported) raw material. Fortunately, this situation resolved itself shortly afterwards.

After the practical drying sessions, the extension workers were asked about their opinions on the various products and processes. It was agreed that the solar cabinet dryer gave a good quality dried product and was relatively simple to construct. It was questioned whether the improved quality (in this case the exclusion of substantial amounts of dust) would be recognised by the farmer. In the rural areas concerned, dust was ubiquitous and people learnt to live with it. Because of this familiarity, a high dust content would not necessarily be considered a negative quality aspect. In any case the dried food would be exposed to dust in the market place. Packaging to exclude dust was not realistic since people liked to see and touch what they were buying.

Blanching and sulphuring/sulphiting were recognised as steps which improved the quality, but the extension workers did not consider them as realistic recommendations. The extra cost and effort required would not be reflected by a higher price in the market for the dried foods. The overall impression received from the extension workers was that until the consumer was prepared to pay a high price for improved quality (or alternatively not pay the asking price for inferior goods), there was little incentive to introduce improved drying techniques in their particular sphere of activity.