An evaluation of structures suitable for emergency storage in tropical countries (ODNRI Bulletin No. 10)

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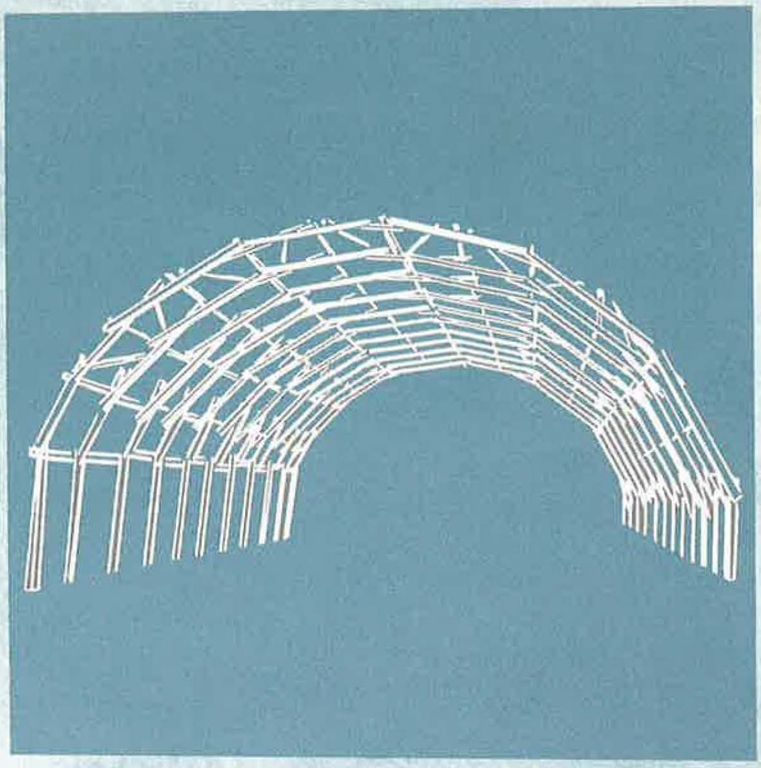

OVERSEAS DEVELOPMENT
NATURAL RESOURCES INSTITUTE
BULLETIN

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AN EVALUATION OF STRUCTURES SUITABLE FOR EMERGENCY STORAGE IN TROPICAL COUNTRIES

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Appendices

ACKNOWLEDGEMENTS

We wish to acknowledge the help we have received from Relief Agencies, the World Food Programme and ODA's Relief and Disaster Unit, also the many manufacturers who have helped with details. All errors are our responsibility.

Erratum - ODNRI Bulletin No. 10

p. 30 - price of storage structure 24'x17'x7' should read:

£1,797.00 ex-works.

Summaries

SUMMARY

The bulletin provides technical, economic and managerial assessment of emergency storage systems. It is based on investigations conducted by ODNRI and on information provided by users from the World Food Programme and five relief agencies.

Where the priority was provision of food shelters quickly and easily, with facilities for rapid relocation, users favoured a combination of tarpaulins, tents and plastic-covered metal frame structures. Where the priority was security/ease of management, traditional warehouses or frameless modular structures were superior, more permanent and had a lower annual cost after four years of use. In either case if stores **could** be provided locally this was generally preferable — for reasons of speed and economy — to provision of imported stores, of which there are a number of well-tested types.

Part I of the bulletin provides background, research and tables showing operational comparisons, capital costs, procurement times, packed weights and annual costs for the main store types. Recommendations for research on design of stores capable of resisting tropical wind loads and on bumper crop storage are made.

Part II summarizes the results in Part I and provides for users/donors/ governments: (a) a practical decision tree for choosing a store, (b) a method for calculating store capacity, and (c) a catalogue of suppliers giving product details for freight, costs and telex numbers. Suppliers of pallets are included.

RÉSUMÉ

Ce rapport présente une évaluation des aspects technique, économique et de gestion de systèmes de stockage provisoires. Cette évaluation repose sur des investigations effectuées par l'ODNRI ainsi que sur des informations fournies par des utilisateurs rattachés au Programme Alimentaire Mondial et à cinq sociétés de secours.

Lorsqu'il s'agissait d'obtenir avant tout, avec rapidité et facilité, des réserves pour denrées alimentaires, pouvant être rapidement déplacées, les utilisateurs ont préféré des toiles goudronnées, des tentes et des structures en métal recouvertes d'une toile plastique. En revanche, lorsque priorité était donnée à la sécurité/facilité de gestion, les entrepôts traditionnels ou les structures modulaires sans cadre étaient supérieurs, moins temporaires et représentaient un coût annuel plus avantageux après quatre années d'utilisation. Lorsque, dans les deux cas, il était *possible* de se procurer localement ces structures de stockage, celles-ci étaient généralement préférables (pour des raisons de rapidité et d'économie) aux structures de stockage importées dont un certain nombre de types ont été testés à fond.

La première partie du rapport contient un préambule, la recherche effectuée, ainsi que des tableaux indiquant les comparaisons d'exploitation, les côuts de capitaux, les délais d'obtention, le poids du matériel emballé et les coûts annuels pour les principaux types de structures de stockage. Cette partie contient également des recommandations pour la recherche dans la conception de structures de stockage pouvant résister aux vents tropicaux et aux charges, ainsi que dans le stockage de récoltes exceptionnelles.

La deuxième partie résume les résultats de la première partie ét contient, à l'intention des utilisateurs/donateurs/gouvernements: (a) un diagramme arborescent facilitant le choix de structures de stockage, (b) une méthode permettant de calculer la capacité de stockage, (c) un catalogue de fournisseurs indiquant les détails relatifs aux produits pour le fret, les coûts, ainsi que les numéros de télex. Y sont également inclus les fournisseurs de palettes.

RESUMEN

Este informe, en el que se proporciona una evaluación técnica, económica y administrativa de sistemas de almacenamiento de emergencia, está basado en investigaciones llevadas a cabo por el ODNRI y en información suministrada por usuarios del Programa Mundial de alimentos y por cinco agencias de asistencia.

En aquellos casos en que lo más importante era la provisión rápida de abrigos sencillos para alimentos, con posibilidad de reubicación rápida, los usuarios preferían una combinación de lonas, tiendas y estructuras con bastidor metálico y revestimiento de plástico. Cuando los factores prioritarios eran seguridad/facilidad de gestión, los almacenes tradicionales o estructuras modulares sin bastidor eran consideradas como superiores, más permanentes y con menores costos anuales, tras cuatro años de uso. En ambos casos y por razones de rapidez y economía, es prefería, en general, que dichos almacenes estuvieran ubicados, *a ser posible*, en la localidad, a la provisión de almacenes importados, de los que existen diversos tipos bien probados.

La Parte I del informe ofrece información de fondo, trabajos de investigación y tablas, en las que se presentan comparaciones operacionales, costes de capital, momentos de adquisición, pesos embalados y costes anuales para los principales tipos de almacén. También se presentan recomendaciones sobre actividades de investigación sobre diseño de almacenes capaces de resistir cargas eólicas tropicales y sobre el almacenamiento de cosechas récord.

En la Parte II, se ofrece un resumen de los resultados de la Parte I y se proporciona a gobiernos/usuarios/donantes: (a) un árbol práctico de toma de decisiones para la selección de almacenes, (b) un método para realizar el cálculo de la capacidad de un almacén y (c) un catálogo de proveedores, junto con detalles de sus productos relativos a transporte, costes y números de télex. También se incluyen los proveedores de bandejas.

Part I

Survey and analysis

INTRODUCTION

In all countries the system which distributes food from producers to consumers is planned on the basis of 'normal' conditions. Typically cereals not retained by farmers for their own consumption are collected through a network of procurement centres and moved to towns and cities, or for export; imports of cereals may be distributed in the cities. The system always includes storage facilities, to buffer the distribution process, as well as to accommodate seasonal cropping.

Abnormal conditions may lead to food shortage or surpluses. Shortages may arise suddenly, as a result of disasters such as earthquakes or hurricanes, or with some warning, in the case of crop failures, for example through drought. In emergencies the vital need is to get supplies to beneficiaries quickly. In addition to logistic problems, the climate is often hostile. High temperatures and relative humidities can accompany torrential rainstorms and gale-force winds. Any exposed foodstuffs will be wetted and will deteriorate rapidly if left undried. Any vulnerable structure will be severely damaged by storms or winds (Eaton, 1980). Therefore storage is a vital part of the distribution system which can provide food security especially when transport fails. Already-existing storage space in schools, army barracks and the like (FAO, 1983) can be used for transit storage in an emergency; but such temporary stores must be secure, because pilferage is a problem, and conveniently sited. Unfortunately, disasters can occur in inaccessible areas with little or no existing storage space.

Disasters may strike urban or rural areas, and existing infrastructure including food storage facilities may be inoperable. In the initial phase, food distribution is part of a general relief operation, and limited storage capacity is required very rapidly. Subsequent rehabilitation may (perhaps especially in rural areas) require new stores, to permit food distribution for an extended period, although there may be no long-term requirement for these facilities. Similar considerations apply to the feeding of refugee groups.

Crop failures affect rural areas directly and urban areas indirectly. The existing system can probably distribute imported (donated) cereals to the normal urban population. It is, however, common in these circumstances for large numbers of the rural population to move to the towns, and additional emergency facilities may be needed to enable food to be distributed to them (UNCDF, 1985). To supply the rural areas it is often not sufficient to operate the normal grain procurement chain in reverse; storage may be in the wrong place, of the wrong kind, or too small to handle the quantity of food required by the rural population (UNCDF, 1985). Consequently there is a need for emergency food stores for a limited period until the next good crop is harvested. The supply of food aid to development projects may lead to similar physical requirements for storage facilities, but the time for planning and installation is greater.

A sudden food surplus resulting from an unusually good crop also gives problems. Once the national storage capacity is filled, there is a risk that the remaining harvested grain will suffer high losses. Emergency storage facilities should enable post-harvest losses to be kept to economically acceptable levels during the time the grain is held before entering the normal logistic system. Such storage is therefore distinct from food relief and will be treated separately in this study.

In Africa in 1985 relief food needs stood at 7 million tonnes; 24 countries were affected of which 15 have recurrently acute food shortages (*see* Table 1). The countries total 31% of developing Africa's population; nearly all have low incomes, negative changes in food production with high and continuing cereal food needs per capita. In parts of Latin America the situation is similar. On the other hand, in 1985 Burma and Indonesia had bumper harvests. (FAO, 1986a).

Table 1

Cereal food aid needs (1980-82). Annual changes in food production (1983) and GNP (1982) all per capita for African countries recurrently affected by food shortages (1977-82)

	Annual data, per capita		
COUNTRY	Cereal food aid needs (kg)	Change in food production (%)	GNP (US $)
Cape Verde	120	−1.9	350
Lesotho	26	−3.4	510
Botswana	15	+0.7	900
Angola	10	−1.9	490
Comoros	12	−1.7	340
Zambia	20	−2.8	640
Mauritania	43	−3.2	470
Ethiopia	6	−0.3	140
Somalia	45	−2.8	290
Burkina Fasso	8	−2.0	210
Ghana	7	−6.5	360
Tanzania	11	−0.4	280
Mozambique	14	−6.4	290
Chad	4	−1.7	80
Uganda	3	+0.5	230
Mean:	22.9 kg	−3.42%	$372

Source: FAO (1985) extracted from Tables

In 1986 there was adequate rainfall in most of Africa; 12 countries produced exceptional surpluses or bumper crops of cereals. At the time, Angola, Botswana, Cape Verde, Ethiopia, Mozambique and Sudan needed high levels of food aid. The total for Africa was 3.2 million tonnes (FAO, 1986a). In Asia in one country alone — Pakistan — the World Food Programme (WFP) were distributing food for 2.2 million refugees (Hauser, 1986) and in Bangladesh WFP had an even larger relief programme (FAO, 1986a).

These data suggest that the need for high volumes of food aid inputs into Africa, Latin America and Asia will continue. In combination with erratic occurrences of bumper crops, this will cause continuing severe logistical and storage problems. For successful future food relief operations FAO suggest three guidelines.

A Improve early warning systems.
B Get food to the needy more quickly.
C Ensure that emergency food supplies are always available (FAO, 1985).

In this bulletin our concern is primarily with B, where emergency storage is an essential element in the race to distribute relief food without delay.

Logistical problems of the most critical commodities — bagged cereals — include their passage from often congested ports to main distribution centres or rail heads where they face bottlenecks; unloading ships can be delayed, warehouses are often already full and open-air storage with its associated losses is unavoidable. In this bulletin we describe how the appropriate emergency storage can be supplied to reduce stock losses.

Problems up-country are usually even more severe, with poor roads and unreliable transport. Correct choice of store type is therefore vital if facilities are to be installed rapidly and without excessive demands on resources. This study aims to make these choices easier. It does not consider questions of strategic storage which arise in connection with FAO guideline C.

The Overseas Development Administration (ODA) is directly involved in emergencies through funding, through its Disaster and Refugee Unit, and through the Overseas Development Natural Resources Institute (ODNRI)*. ODNRI advises WFP, other multilateral agencies and individual countries on food loss reduction, in particular on grain store management and construction.

PROJECT BACKGROUND

ODNRI has been asked by WFP and other agencies for practical advice on emergency storage operations, frequently in circumstances where the need for storage has not been recognized until after the relief food has arrived in the recipient country. In these circumstances the only option open may be to airfreight tarpaulins or temporary structures as near to the site as possible. ODNRI has contributed to the continual process of redesign and modification of one type of structure which has been used in this way. Gough (1979) carried out exposure trials of various types of sheeting used for these structures.

In 1980 reported failure of flexible silos for emergency use in the tropics prompted ODNRI to conduct a field survey (O'Dowd and Kenneford, 1982). A team of engineers visited seven tropical countries and one of their recommendations was that donor agencies should investigate alternative systems for bagged stock. The present study was commissioned by ODA to evaluate different systems and structures suitable for emergency storage and currently available.

OBJECTIVES

The aim of the study is to make the choice of emergency storage system easier for donors and governments. To achieve this there are three objectives: (a) to provide donors with a technical, managerial and economic assessment of storage systems currently used for emergencies, (b) to identify critical factors in system selection and lastly (c) to suggest new systems suitable for testing overseas while providing manufacturers with guidelines on design and materials.

For donors' convenience we summarize these findings in a users' guide, including a list of suppliers, in Part II of the bulletin.

METHOD

An ODNRI engineer visited five food relief sites in Botswana in 1984 to advise on construction of stores for emergency supplies. He visited again in 1985 to report on the condition and performance of these stores as well as other emergency storage systems in operation (UNCDF, 1985; O'Dowd, 1986). To this assessment was added that of the ODNRI officer assigned

*The Overseas Development Natural Resources Institute was formed on 1 September 1987 by the amalgamation of the Tropical Development and Research Institute (TDRI) and the Land Resources Development Centre (LRDC).

to manage the food relief operation following Hurricane Isaac in Tonga (Morley, 1987) where similar warehouses were erected.

To achieve wide coverage of emergency store users, ODNRI enlisted the assistance of professional relief workers by contacting the WFP, the Catholic Fund for Overseas Development, Christian Aid, Oxfam, Save the Children Fund and the Tear Fund, obtaining names and addresses of workers with experience of emergencies and writing a letter to each (*see* Appendix 1) asking for their assessment of field performance and qualities essential for such structures. ODNRI officers supplied details of food relief in Ecuador (Calverley, 1987) and Nicaragua.

To these reports were added ODNRI officers' recent notes of emergency storage for bumper crops in Burma, Indonesia, Liberia and Zambia. ODNRI engineers contacted 40 manufacturers for details of a wide variety of rapidly erected structures suitable for consideration. (*see* Appendices 2 and 3). The information was checked with each manufacturer and is provided in Part II of this bulletin.

Lastly, from all the available information, the most pressing design problem was selected to formulate a research proposal.

RESULTS

The use of steel warehouses for emergencies

In the 1985 assessment in Botswana four criteria applied:

(1) do the stores function adequately or are additions required?
(2) were they built to schedule?
(3) were costs approximately as estimated? and
(4) was permanent storage justified or would temporary storage have sufficed?

The store specifications (*see* Appendix 4) were for locally manufactured 500-1000-tonne capacity portal-frame steel-clad warehouses, prefabricated for rapid erection and with the function of providing transit protection for relief food.

Storekeepers and depot managers stated that these new drive-through stores functioned well (*see* Plates 1 and 2); they were secure and easy to manage, and truck turn-around time was 65-75% faster than when using the old stores, using the same labour and transport as before. The roofs were designed for maximum wind loads as were the structures themselves. Despite severe storms, no complaints have been received regarding construction. No buildings are perfect on completion and in this operation the main omissions were site-roads, hard-standings, drains, and emergency storage plinths which had been specified. Besides site roads, hard-standings at all sites are essential in wet weather for easy truck turn-around. The urgency of this building project, shortage of trained staff and the remoteness of the sites meant that topographical surveys and searches were not made. Skimping site surveys caused extra costs later and one site choice had to be discarded; at another the site slope required large quantities of earth to be moved. These operations caused delays but once contractors were mobilized, store construction took less than four months on average.

These operations also, of course, caused capital costs which therefore exceeded estimates by approximately 9% and the above-mentioned omissions also had to be paid for. Actual storage costs/tonne were calculated from capital costs using the annual throughput, the useful life of the store and the rate of interest. The annual cost per tonne in 1985 varied from £4 at stores near the capital to £5 for remote stores.

To calculate financial viability, estimates of losses in temporary and permanent storage as well as costs of temporary storage were obtained.

Storekeepers and depot managers were unanimous: the combination of tarpaulin storage and inexperienced management resulted in severe losses. This was particularly true with vulnerable food like Corn-Soya-Milk (CSM) when there was a lot of damage to sacks and tarpaulins caused by baboons and rats, which in turn caused considerable spillage (O'Dowd, 1986). But it was in the wet season when there was flooding and moulds and insects were most active that heaviest losses occurred. With these increased losses and without good management, temporary storage was more costly than permanent storage (using annual costs). With good management, temporary storage was cheaper unless it was stipulated that permanent stores had a useful life of from 4 to 7 years combined with a throughput ratio greater than 6:1. (The throughput ratio is the quantity of produce passing through the store each year divided by the store capacity).

In theory, storage costs/losses were minimized when permanent stores were used for vulnerable foods and tarpaulins used for durables. In practice, managers stated that this is difficult to implement because supplies arrive on site in random order. Storekeepers and depot managers considered that transport was the most critical factor in store operations, and in 1985 every tonne of food at remote locations bore £8 transport cost.

In this relief operation the role of government had been vital. Only by involvement at the highest level could the government harness resources, predict emergencies in good time and instil a sense of urgency to provide adequate relief.

In Tonga, following Hurricane Isaac in 1982, tarpaulins were initially used for emergency storage, followed by the importation of prefabricated steel-frame, steel-clad warehouses not dissimilar to those manufactured in Botswana (Morley, 1987). The stores were donated by ODA but supplied by a New Zealand firm because this was faster and because standard buildings in New Zealand are designed for high wind loads. Storage was satisfactory using low-cost, low-weight, polyethylene-coated, woven polyethylene tarpaulins until the prefabricated buildings were erected. The building was used with a temporary coral rock floor until a concrete floor could be laid six months later. An important point which arose out of the Tongan experience was that the combination of skilled management and labour was essential to work tarpaulins and permanent storage satisfactorily. When management and labour were unmotivated and untrained, damage to tarpaulins, warehouses and stock resulted.

Reports by relief workers

In Asia and South America relief workers reported the use of local materials for emergency storage. Calverley (1976) inspected local store construction in Ecuador, where timber framework supported plastic cladding to provide 250-tonne capacity 'green-house' type structures (*see* Plates 3-4). Morton (1987) describes how in Thailand local manufacturers provide similar large frame tents to WFP specifications. These structures were easy to transport by lorry, could be relocated as necessary and could also be used as mobile clinics and supplementary feeding centres. Relocation was a very important operation and function. In Pakistan, Hauser (1986) reports on earth-built stores being upgraded to locally made brick stores which were part of the relief food distribution chain. With the exception of southern Africa (where, for example, Botswana used local materials) in the rest of the continent and especially in north-east Africa, relief workers reported that local materials are rarely used for emergency storage, although locally built warehouses were planned in Sudan (O'Shea, 1984). Eucalyptus poles are sometimes used for frames and for dunnage but usually this item had to be made up from imported timber shipped to the port of Assab (Morton, 1987).

With regard to imported emergency structures, all relief workers stated that the highest priority was fast easy erection by local staff to provide shelter quickly. Ease of transport and relocation were also important. In this context, lightweight tarpaulins or plastic sheeting were a good first-aid measure (Reece, 1987) and essential, combined with other store types, to the success of every emergency opertion. Initially, tarpaulins protected the first relief food to arrive at a crowded port. One donor actually shipped tarpaulins with relief food, but normally tarpaulins are supplied by air freight. Tarpaulins with eyelets and ropes were particularly useful because these could be tied down and even nailed and were worth the extra cost over plain plastic sheeting (*see* Plate 5). Tarpaulins are flexible and easily transported/relocated (Morton, 1987) but do not provide the shelter necessary for mixing food rations or the facility of easy stock management, especially in wet weather. Timpson (1987) speaking from seven years' experience of relief food operations in Africa states:

> '....the ideal store should not require expatriate assistance for assembly and erection. It should be light and manoeuvrable enough with the minimum of parts so that a group of relatively unskilled local staff can erect it in as short a time as possible but certainly within four days....'

Other relief workers echo this reluctance to use expatriate assistance, but Timpson goes on to say that in 1980 relief agencies in Uganda purchased a number of mansard-shaped, steel-frame, plastic-clad stores which were erected in three days with the firm's instructor helping initially. These structures proved robust, any tears were easily repaired and the stores have lasted until the present time (1987). Several stores were relocated without problems. More of the same stores (300 tonnes) were purchased from Eastern Sudan. One criticism of the stores was their vulnerability to pilferage; people will cut through the plastic cladding and remove food. For examples of this type of store and its erection *see* Plates 6-11.

Another relief agency purchased 500-1000 tonnes stores of a different design. With the services of two engineers each larger store took 2-3 weeks to erect. Later one store was completely destroyed by a violent storm (suffering wind damage) while the 300-tonne stores were undamaged. The dangers of high winds are emphasized by Winer (1987) who reported that structures are more vulnerable to strong winds when flaps and ventilators are open (for essential ventilation). In Mali, Hodges (1987) reported severe wind damage to two plastic-clad stores (*see* Plate 12) designed for wind speeds of 46 metres per second where winds of 67 metres per second prevailed*. In this instance the store doors would not close, leaving a gap which may have allowed wind to enter and, because the manufacturer's instructions were ignored, the structure foundations consisted only of steel pins in the sand. These errors may have combined to cause failure: Fortman (1987) reports that in 1985 no fewer than 15 aluminium-framed buildings were destroyed by winds in the Sudan.

In the United Kingdom, tents are known to be vulnerable to wind damage (Houghton and Carruthers, 1976). Overseas, several workers reported that tents were successful. These were quick to erect and easy to relocate. In Eritrea the satisfactory use of tents was reported by Hill (1987), who mentioned that tents lasted up to five years and there was no security problem, while other workers drew attention to the vulnerability of tents to pilferage in some countries. Plastic-clad stores, tents and tarpaulins all require dunnage in the wet season to raise food sacks above ground. Rain can also damage steel-framed structures. We recently saw a relocated store in Ethiopia where the cover had been inadequately fixed to the ground; this caused it to sag and lodge rainwater which in turn caused partial collapse.

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*This is the once-in-50-years gust speed.

Prefabricated, curved-steel-clad, frameless, modular stores (*see* Plate 13) functioned satisfactorily, were secure and were more durable than plastic-clad types but were reported to be slower to erect. Timpson (1987) relates that these frameless structures often took two weeks or more to erect and therefore frustrated plans for pre-positioning storage. It is reported that frameless structures require a higher degree of skill to erect than plastic-clad structures. Foundation work must be to a high standard (Winer, 1987) and in one instance an engineer took some three weeks to erect the first structure and then a further three weeks to erect two more. Rees (1987) in the Sudan saved the firm's erector's fee (£4000 with all items) by erecting one of the structures in two weeks and Morton (1987) refers to 'fairly quick' erection over a concrete plinth.

It was stated that frameless structures were more difficult to move from the port to the rural area than plastic-clad structures. In addition, plastic is an easier material to repair. Frameless steel structures in Ethiopia were corroded and will need maintenance to last the 15 years that the manufacturers guaranteed (Timpson, 1987). That frameless steel structures are damaged and rust in transit is confirmed by Winer (1987). Morton (1987) and Rees (1987) both considered these structures functioned satisfactorily for the period of the emergency but they were criticized because they were somewhat inadequate for long-term storage of food commodities and unsuitable for alternative uses. It should be noted that these reports are based on a limited response to our wider survey while the manufacturers, Conport Structures Ltd. report that they have commissioned 150 modular buildings in Ethiopia and these have had a totally favourable response. Large stores of 1000-tonne capacity were particularly unsuitable after the initial emergency phase when there is need for longer term rehabilitation assistance (*see* below). Frameless structures were useful at the beginning and end of the major supply lines, for example, between Port Sudan and Nyala, but required fork-lift trucks to fill to capacity, either because unskilled workers could only stack 10 plastic sacks high, or the sacks split at the bottom if built more than ten high, because they were poorly stitched by piece rate labour in the port (Walker, 1987). In subsequent calculations we assume that bag stocks are 2 metres high. This limitation increases the capital cost per tonne of warehouses.

The range of imported and locally built stores available

There is a wide range of emergency stores available, both imported and local, bag and bulk. When classified in terms of cladding, frame and foundations, they fall into five types (*see* also Table 2.):

A Structures with rigid frame, rigid cladding and concrete foundations — typically traditional warehouses (Type A1), and Nissen huts (Type A6) for bag storage. *See* Plate 14.

B Structures usually without a frame but often with pre-stressed modular panels and concrete foundations — typically silos (B4) and similar frameless structures for bulk grain (Type B3). *See* Plate 13.

C Structures with flexible cladding, a variety of lightweight frames and ground anchors — typically rapidly erected bag stores (Type C1). *See* Plates 6-11.

D Structures with flexible cladding, rudimentary frames and a variety of foundations — typically tents (Type D1) or tarpaulins for bag stack storage (Type D3). *See* Plate 5.

E Quasi-structures without frame or foundations like bunkers (Type E3), clamps (Type E2), pyramids (Type E1) and pits (Type E2) for bulk grain storage.

Table 2

Available emergency store types: local and imported, with examples of both bag and bulk

Symbol	STRUCTURE Cladding	Frame	Foundations	EXAMPLE	Local	Imported	Bag	Bulk
A 1	Rigid	Rigid	Concrete	Conventional portal/ lattice frame warehouse, steel or r.c. cladding	X	X	/	
2	Rigid	Rigid	Concrete	ditto, with retaining walls		X		/
3	Rigid	Rigid	Concrete	Framed warehouse, unconventional design, *see* list		X	/	
4	Rigid	Rigid	Concrete	Emergency design warehouse		X	/	
5	Rigid	Rigid	Concrete	Crane-erected foldaway type		X	/	
6	Rigid	Rigid	Strip	Nissen type		X	/	
7	Rigid	Rigid	Stone	Wood pole, earth brick, thatch with or without canopies	X		/	
B 1	Rigid	No frame	Minimal	Terrapin prefabricated panels		X	/	
2	Rigid	No frame	None	Terryboard prefabricated panels		X	/	
3	Rigid	No frame	Strip	Pre-stressed curved steel panels	X	/	/	/
4	Rigid	Optional	Concrete	Steel silos — aerated		X		/
C 1	Flexible	Rigid	Anchor	Steel or aluminium frame, plastic cover		X	/	
2	Flexible	Rigid	Anchor	Wooden frame, canvas/ polyethylene cover	X		/	
3	Flexible	Rigid	Concrete	Wooden frame, woven mat cladding	X		/	
4	Flexible	Rigid	None	Flexible silos		X	/	/
5	Flexible	Air supported frame	Anchor	Air supported, open door type		X	/	
D1	Flexible	Poles and rope	Anchor	Marquee tent, poles and rope support		X	/	
2	Flexible	None	Plinth	Cover and plinth (CAP)	X		/	
3	Flexible	None	None	Tarpaulin only (rope)	X	X	/	
4	Flexible	None	Strip	Airwarehouses		X	/	
5	Flexible	None	None	Polyethylene and poles	X		/	
E 1	None	None	None	Paddy pyramids, dry season, earth floor, with or without plastic covers	X			/
2	None	None	None	Clamps/pits with or without bunker storage				/
3	None	(Retaining wall)	Concrete		X			/

Source: ODNRI: Excludes existing storage space available in schools, railway waggons, ships' containers, etc.

As a general rule, bag stores (Types A, C and D) are more often used for food relief while bumper crops are often stored in bulk (Types B and E). There are exceptions — for example, structures of the frameless, steel-clad (Type B3) have been used for both bag and bulk storage.

Each type discussed above is part of a storage system composed of a store, handling methods and transport, all controlled by management to achieve a stated function. Thus in Southern Africa drive-through bag stores

(Type A1) are part of a rapid-transit storage system involving the intensive use of scarce transport vehicles and limited numbers of store labourers (UNCDF, 1985) (*see* plates 1 and 2). On the other hand, cover and plinth (CAP) bag stores (Type D2) are part of a seasonal overflow storage system which demands high levels of on-site management and intensive labour input (Garg, 1985). The system has been adapted in India for storage of surplus production at buying centres (*see* Appendix 5). These two examples give some clue to the distinct natures of food relief and bumper crop emergencies. For instance, drive-through stores are filled and emptied 6-9 times a year, while CAP stores are usually constructed and emptied once in a season. Further examples of emergency storage systems are given in Appendix 6 and further information on storage structure sub-categories is given in Appendix 7. A comprehensive computer literature search was carried out by ODNRI library but revealed no published data on bag or bulk stores for food relief/bumper crops. Data were obtained from relief agency, WFP and ODNRI sources, including bumper crop storage in the next section.

Bumper crops

Bumper crops need extra storage space initially near the production site, and/or at buying centres later (O'Dowd and Kenneford, 1982). In Burma, bulk paddy is stored on the ground out of doors, in pyramid-shaped heaps sloped at the angle of repose (*see* Plate 15). Security is achieved by spreading paddy husk ash around the pyramid perimeter. If the grain is disturbed in any way, it will roll down, cover the ash and signal pilferage. The bulk is moved by basket into temporary stores as the rains approach. These stores are constructed of locally obtained wooden frames covered with woven fibre matting (*see* Plate 16). This system is subject to losses (Tyler, 1987). A more commercial version employs a concrete floor and a perimeter wall. Grain is heaped on the floor mechanically as high as its angle of repose will allow, covered with a PVC sheet which is anchored and sealed to the wall. Hermetic conditions can be achieved and the system has been tested by CSIRO and is used for overflow storage in Australia and the United States (Murray, 1987).

For bagged grain (see above), Garg (1985) described the development of CAP storage in India over 30 years. CAP storage is designed for bumper or surplus storage and, it is claimed, costs about one-tenth of the initial capital cost of warehousing. But CAP storage requires very careful management (*see* Appendix 5).

Flexible silos have been used successfully for bumper crop storage (Kenneford and O'Dowd, 1981), but are unsuitable for food relief because frequent opening and closing of the silos causes wear and tear. Like CAP storage, flexible silos require careful management. The silos are suitable for bag or bulk storage, the standard size being 500-tonne capacity. The silos are supplied with rodent guards and currently use a cup-shaped liner of PVC-coated polyester fabric. This liner is supported by a circular welded mesh frame composed of bolted sections. Bags are loaded into the cup until level with the mesh and then into a cone. A conical cover fits over the cone, is rolled into the cup liner and tied down to form a waterproof and hermetic container suitable for fumigation. For full details see Part II.

Emergency overflow storage is also possible in steel silos. In Liberia the overflow from the central buying point was stored in imported steel silos. Bulk storage has the advantage that no bags are required, but the disadvantage that silos require to be aerated to reduce the risk of moisture migration for safe storage exceeding one month (Gough, 1987).

The choice between bag and bulk may depend on a number of factors including which type of transport a country has adopted.

Relief food stores

Locally built warehouses

Locally built warehouses made financial sense where throughput was high (1:6), where the emergency was longer than four years and where there were existing temporary storage facilities. Technically and from the management standpoint, warehouses are demonstrably superior to tarpaulin storage in Botswana (O'Dowd, 1986). But for a short-lived emergency with no existing storage the situation is different. O'Shea (1984) suggests that for local store building to succeed (in Sudan) prerequisites are: swift decision-taking, a careful selection of suitable contractors, availability of diesel fuel and proper contract supervision. In a short-lived emergency these are the very factors in short supply. Even in Botswana when food relief stores were built to high standards, unavoidable delays and cost over-runs caused omission of items vital to efficient operations. Unless store building can receive continual skilled management input, monitoring progress and quality, locally built warehouses are not an option; if there is any doubt reliance can be placed on well-tried imported emergency storage structures.

Imported steel warehouses

The warehouses imported into Tonga functioned satisfactorily but were slow to procure and erect, even though obtained by the shortest method from New Zealand. As shall be shown, a standard warehouse specially designed for easy freight and rapid erection (*see* Appendix 8), cannot, allowing for all delays, be procured in less than four months. The size of warehouse chosen should be influenced by its likely use post-emergency. In general, two buildings of 500-tonne capacity are likely to be more valuable locally than one 1000-tonne capacity building, for storage, factory work, community hall, etc.

Imported 'temporary' stores

When urgency is the keynote, procurement of traditional warehouses is usually too slow, the warehouses need too much time to erect and also require scarce and costly expertise. Even a specially designed warehouse is at least 50% heavier than a plastic-clad store and is therefore difficult to relocate (see below). Given that traditional warehouses are slow to erect and difficult to relocate, the alternative choices for emergencies which have been tested and tried overseas are limited: Relief workers found that frameless structures functioned well and were secure, but were relatively slow to erect and, it was reported, too difficult to relocate, because of their weight and because level strip foundations are needed at the new site. Besides that type of structure, only plastic-clad stores, tents and tarpaulins have been tested overseas, all of which require dunnage or ground sheets. Plastic-clad structures were quick to erect and straightforward to relocate. Stock management of bag stacks in such stores was not a problem. These structures are not, however, secure from theft, and certain designs with inadequate foundations were destroyed by wind. Similarly, tents were quick to erect and easy to relocate; stock management was adequate but security was poor. Tents are also vulnerable to wind damage. Tarpaulins were very flexible but presented more stock management problems than plastic-clad stores or tents especially in wet weather. For comparative purposes these operational factors are contrasted for each type of store in Table 3 (*see* p.13). Operationally no one store is superior in their qualitative assessment, but where ease of erection and ease of relocation have priority, tarpaulins, tents and plastic-clad stores in combination or singly are preferable, according to reports from relief workers, to frameless (steel) or portal-frame stores.

Table 3

Relief workers' reports of operational factors in store choice

Structure: description and type	Operational factors: Ease of erection	Ease of relocation	Level of security	Ease of management
Tarpaulin cover and base (D3)	****(1)	****	†	†
Marquee tent with poles (D1)	***	***	*	**
Steel/Al frame, plastic-clad warehouse (C1)	***	**	*	***
Steel frameless prefab. store (B3)	**	*	****	****
Steel portal(2) frame (A4)	*	†	****	****

Source: WFP/ODNRI/relief workers' reports

Notes:
(1) **** represents very easy erection/relocation/security/management
*** represents easy erection/relocation/security/management
** represents fair erection/relocation/security/management
* represents difficult erection/relocation/security/management
† represents very difficult erection/relocation/security/management, especially in wet season
(2) Specially designed emergency warehouse — *see* Appendix 8

Table 4

Capital costs, procurement periods and packed weights of imported structures for food relief

Description type and capacity (tonnes)	Capital* cost/tonne £	Procurement period: Freight etc. (days)	+ Erection (days)	= Total (days)	Weight packed (tonnes/unit)
Tarpaulin cover and base (D3)					
32 t	11	14	+ 1	= 15**	0.33
Marquee tent with poles (D1)					
80 t	45	20	+ 1	+ 21†	0.45
Steel or A1 frame plastic clad (C1)					
235 t	56	94	+ 3	= 97‡	4.4
Steel frameless prefabricated (B3)					
180 t	66	101	+ 10§	= 111	4.4
(Special) Steel portal frame (A4)					
257 t	75	115	+ 20§	= 135	6.5

Source: Appendix 9

Notes:
* Capital costs/tonne are for the 50% utilization capacities shown with 2m high stacking. For 90% utilization and 2.5m stacking the following obtains:

Store type	A4	B3	C1	D1	D3
Capacity (t)	413	273	383	133	51
Capital cost/t	£47	£44	£34	£19	£7

** and † Marquees and tarpaulins are airfreighted
‡ If airfreighted and 90% utilized, capital costs remains at £56 and total precurement period falls to 27 + 3 = 30 days.
§ Erection time includes laying foundations

This qualitative view is reinforced by quantitative data. Using a stacking height of only 2 metres, capital costs/tonne, procurement periods and packed weights are compared for each store type (*see* Table 4, p.13). Tarpaulins and tents have lower capital costs, are faster to obtain and erect, and are one-tenth the packed weight of other store types. Plastic-clad stores are fast to erect on site and are often lighter in weight than the example shown in Table 4, especially when the capacity is smaller. For the two years' length of most emergencies, annual costs of tarpaulins and tents are also lower than for other stores (*see* Table 5). The effects of longer store life are discussed below. The data for Tables 4 and 5 are derived from Appendices 9 and 10 respectively.

Table 5

Effect of store life on annual costs per tonne (£/t)

Store Type	Life in years 2	4	6	13	25
Tarpaulin cover and base (D3)	2.29	—	—	—	—
Marquee tent with poles (D1)	2.65	1.45	—	—	—
Steel/Al frames, plastic clad (C1)	3.42	1.87	1.36	—	—
Steel frameless prefab. (B3)	4.07	2.23	1.62	0.99	—
Steel portal-frame (A4) warehouse	4.64	2.54	1.85	1.13	0.89

Source: Appendix 10

Note: Structure life expectancies, based on ODNRI/WFP/relief workers' experience of ardous emergency conditions are — Tarpaulin (max.) six months; tents 4 years; plastic-clad structures 6 years; steel frameless prefabs 13 years and warehouses 25 years, with average maintenance in each case

Bumper crop storage

The main types of bumper crop store have been described in the section *Bumper crops*. The main distinctions from relief food storage are that farm-gate prices for bumper crops are far below the on-site cost of relief food (FAO, 1986a). The throughput ratio is the quantity of produce (tonnes) passing through the store each year divided by the store capacity (tonnes); many relief food stores have a throughput ratio of 9:1 (King, 1987) while bumper stores usually have a throughput ratio of 1:1. Assessment will be possible with on-site investigations of operation, flows, loss levels and costs. We have attempted to arrange suitable visits without success, but hope to in the future.

CRITICAL FACTORS IN SYSTEM SELECTION

On a relief food site, typically subjected to high winds, rains and to pilferage, four main factors influence system selection (imported or local) in the following order:

- how much warning was there?
- what level of funding is available?
- what level of site management prevails?
- what local transport and available store labour is there?

As mentioned in the introduction, FAO (1985) emphasize the need for early warning; in practice there is seldom much time left to instal a storage system; funds are usually scarce although relief agencies praise the generosity of donors (Reece, 1987).

Management is all-important for efficient operation and relocation of stores and also for coping with unforeseen problems (O'Dowd and Kenneford, 1982). Transport is often the limiting factor, together with available labour in relief food operations, (UNCDF, 1985).

In Part II of this bulletin these factors are taken into account using a decision tree for users' guidance (*see* p.21). One of the many options available — airwarehouses — requires special mention. ODNRI's experience is that airwarehouses require a higher level of day-to-day management because they are dependent on continuous operation of an electrically powered fan. If the store is deflated it must be protected against wind damage. Wind can be a problem for all structures and in selecting a storage system donors must check that the store has the correct design wind speed. Many manufacturers consider that a design wind speed of 47 metres per second is sufficient. Eaton (1980) states that while mean wind speeds in tropical storms may exceed 33 metres per second the gust speeds are far greater locally and the design wind speed for Mopti in Mali, based on 12 years data, is 72 metres per second (Meteorological Office, 1987). Donors must also ensure that manufacturer's instructions for adequate foundations are adhered to, especially when the soil is sandy. Therefore when preparing tenders for emergency structures, donors should include the following questions:

A What is the structure design wind speed?
B What form of foundation is supplied for use on sandy soils?
C Is the structure designed for tropical exposure?

Other points mentioned earlier include:

D How many structures are available ex stock?
E Is erection without a supervisor practical? Are visual instructions/local-language manuals available?
F How long should erection take?
G Is the structure easily relocatable?

These points are summarized in Part II of this report.

An additional critical factor in system selection is the need for co-operation between the donor and structure supplier to achieve the objective of getting food to the needy quickly. Donors and suppliers must be flexible to take account quickly of congested ports and overcome obstacles and delays, for example by using airfreight for a portion of the order. At the recipient country the role of government is critical, for example, in allowing freight to be cleared duty free without delay.

DISCUSSION

For relief food the priority is to provide shelter quickly. FAO (1986b) plan to pre-position stocks of relief food; could emergency structures for these stocks be included? For the moment we might approach ODA Relief and Disaster Unit and some British manufacturers to suggest that a minimum number of tarpaulins, tents and plastic-clad stores — which relief workers use and approve of — be held in stock in readiness.

Tarpaulins, tents and plastic-clad stores are easy to handle/ repair, quick to erect and easy to relocate with the very slender resources available. Managerial, technical and financial evidence supports this view (*see* Tables 3, 4 and 5). However a pressing need is to help United Kingdom manufacturers of plastic-clad stores (*see* para. 3, *Objectives*) to design for tropical wind loads, which are often double United Kingdom loads. Farm Building Division, AFRC Institute of Engineering Research, are investigating the effect of wind on plastic-clad structures and are keen to collaborate with

ODNRI as are the Overseas Development Research Unit of the Building Research Establishment who have experience of tropical conditions.

We first investigated the use of steel-clad portal frame warehouses for relief food and concluded that warehouses have certain advantages over more temporary stores, like plastic-clad structures. Over six years' life costs and benefits can be compared, from Table 5:

	£
Steel-clad portal frame warehouse, annual cost/tonne	1.85
Plastic-clad steel frame warehouse, annual cost/tonne	1.36
difference:	£0.49

If labour and maintenance costs are equal, the steel-clad portal frame structure is justified if losses are reduced by only 1 kilogram per tonne of relief food priced at £500 on site. Such reductions in losses have been recorded where steel portal-frame warehouses with smooth concrete floors replace temporary structures on hardcore floors. Spillage from burst bags can be recovered from concrete floors and wear and tear on sacks is less (UNCDF, 1985, O'Dowd, 1986) Management is also easier.

Supporting the provision of permanent locally built warehouses for emergencies, O'Shea (1984) reporting to the Sudan Government, stated: 'the problems of storage in the long term have been somewhat overlooked in the desperate need to relieve the drought victims'.

In theory, if early warnings were the rule, locally built steel warehouses would be selected. In practice, warnings are late (FAO, 1986a) and relief agencies and governments are fully stretched to beat the clock. Initially, at least, there are no opportunities and no resources for long-term planning. When the worst of the emergency is over, some form of collaboration between relief agencies and governments may be possible.

In some countries there may be an opportunity for permanent and temporary (emergency) storage to complement each other in improving relief food distribution to famine-affected areas. In Ethiopia permanent storage for 'normal' relief food flows will be developed initally, but it may be uneconomic or impractical to provide permanent storage at all levels for the additional irregular grain flows occuring during a major emergency such as the 1984/85 famine. Instead, preparations should be made to provide at short notice safe and economic emergency storage at strategic locations for these additional and irregular flows.

Finally, there is some difficulty in arranging visits to bumper crop sites to see the intake and storage operation because notice is short, but we hope to overcome this problem and to obtain information comparable to that obtained for food relief.

CONCLUSIONS AND RECOMMENDATIONS

From this investigation we **conclude** the following:

(a) There is no pressing requirement for new design of emergency storage buildings, but there is an urgent and over-riding need for re-designing existing patterns of fabric/sheet-clad structures to ensure safety from tropical wind loads.

(b) There are insufficient data available on 'on-site' studies of bumper storage systems and a lack of reliable measurements or estimates of losses to support claims that losses are either unacceptably high or acceptably low.

(c) The appropriate choice of an emergency storage system for food relief can be readily obtained by use of the critical factors in system selection in conjunction with operational and cost considerations. These are summarized in Part II of this bulletin.

We **recommend** the following:

(a) Donors should select an emergency storage system for relief food heeding critical factors in system selection; by use of the decision tree shown in Part II, users can combine managerial, technical and financial assessments shown in Tables 3, 4 and 5, and summarized in Part II. The list of emergency stores suppliers is included.

(b) Donors should collaborate with appropriate firms to ensure that a minimum level of tarpaulins, tents and fabric-clad structures are held in stock in readiness for an emergency, and should study the feasibility of funding, in whole or in part, such a stock.

(c) A research and development project should be undertaken in collaboration with industry to redesign and cost selected emergency storage structures so as to obtain units that are suitable for high wind loads.

(d) A sequel should be undertaken to the study here reported to:

  (i) up-date the information presented; and
  (ii) obtain 'on-site' data of bumper crop storage and the losses occurring in such systems so that a full evaluation of the various structures available can be undertaken.

Part II

Users' guide to relief food stores

INTRODUCTION TO USERS' GUIDE

This guide is intended to assist those responsible for procuring emergency food stores in selecting an appropriate system. It outlines the factors to be considered, most of which have been more fully discussed in Part I, and provides a decision tree to help in making a choice. Manufacturers of structures are listed and their products described, under four categories.

A Warehouses
B Frameless buildings
C Framed structures with flexible cladding
D Frameless flexible systems.

This guide assumes that the structures, or critical components of them, are imported; however, there will be times when structures can be locally manufactured, thereby probably reducing the procurement time.

STORAGE OPERATIONS

Information on examples of five of the most important types of store is summarized in Table 6. From this it is clear that where speedy procurement and erection of a store is essential, tarpaulins (for bag stacks), tents and plastic-clad stores can be obtained rapidly by air and erected quickly. Because these stores are relatively light-weight and because they have simple foundations or ground anchors, they are also easy to relocate. Their drawbacks are that they are difficult to manage and vulnerable to theft because the canvas or plastic sheet can be easily cut open; hence they require security fences and watchmen. They are also vulnerable to water (both ground moisture and flooding) in wet weather, and dunnage or pallets should be regarded as essential. They are easily damaged by wind and precautions against this are needed.

At railheads, ports or where an emergency is prolonged, more permanent storage with concrete damp-proofed floors is appropriate. These stores (whether warehouses or frameless buildings) are easier to manage and more secure. However, they are slow to procure and erect and not easy to relocate. Construction often requires expatriate supervision.

STORAGE COSTS

Costs of emergency storage are considered in two ways. 'Capital' costs for imported stores include packing, freight, insurance, customs' clearance and erection costs as well as the ex-works price of the structure. These 'once and for all' costs can be spread over the life of the structure and with the appropriate addition for interest are then called 'annual' costs. If warehouses are utilized for their whole working life, their annual costs (*see* Table 6) are much lower than tarpaulin annual costs, for example. But for a short emergency of, say, one year's duration this is not so. The 'break-even' point will depend on factors unique to each individual emergency. Where a warehouse has a turnover of relief food once every two months and the

Table 6

Procurement period, capital and annual costs per tonne for different structures

Type and capacity	Procurement period* Freight, etc. (days)	+	Erection (days)	Capital costs/tonne capacity (£)	Annual** costs/tonne throughput (£)
Tarpaulins† (four sets) 32 tonnes	14	+	1	11	2.29
Marquee tent with poles 80 tonnes	20	+	1	45	1.45
Plastic-clad steel frame 383 tonnes	27	+	3	56	1.36
Steel frameless prefabricated 180 tonnes	101	+	10§	66	0.99
Special steel portal frame 257 tonnes	115	+	20§	75	0.89

Source: Tables 4 and 5, Part I

Notes:
* Includes airfreight for tarpaulins, tents and plastic-clad structures, sea freight for steel buildings
** Structure life expectancies, based on ODNRI/WFP/relief workers' experience of arduous emergency conditions are: tarpaulin (max.), six months; tents, 4 years; plastic-clad structures, 6 years; steel frameless prefabricated buildings, 13 years; and warehouses, 25 years, with average maintenance in each case
† Maximum life 6 months, hence four sets for cover and base required

Dunnage is required but is not included because this is usually a local cost
§ Erection time includes laying foundations

emergency lasts for 4-6 years, then depending on management, the price of relief food, the losses saved, etc., the annual costs for warehouse storage can be lower than tarpaulin storage. (For more details of costs see Appendices 9 and 10).

WHAT SIZE OF STRUCTURE TO ORDER

The following questionnaire and worked example in Table 7 is based on one transit store but could be applied to a whole emergency distribution system of port store, regional stores and district stores.

Table 7

Store size calculations

Question	Units	*Answer* Symbol	Example
What is the maximum number of (adult) beneficiaries to be fed each day?	Number	a	20,000
What is the appropriate ration?	kg	b	0.25
What flow rate is this?	kg/day	a × b	5000
How many days' stock to be held	days	c	60
Maximum stock to be held?	kg	a × b × c	300,000
	tonnes	d	300
Volume of 1 tonne food (milled rice)?	m^3/t	e	1.5
Volume of maximum stock?	m^3	d × e	450
Planned stacking height?	m	f	2
Theoretical floor area required	m^2	d × e/f = A	225 m^2
What is the estimated floor utilization with the preferred stacking arrangement (*see* Appendix 11). (Four stacks with wide central gangway)	%	g	40
Actual floor area required	m^2	A × 100/g = B	562.5 m^2

When the actual required floor area, B, has been calculated, the warehouse dimensions can be determined. For economy these should be chosen from the supplier's standard range. Thus, if a 15 m span is standard, length required is 562.5 / 15 = 37.5 m. The nearest multiple of the standard bay length may then be selected, e.g. 39 m for 3 m bays.

For tarpaulin quantities it is economical to order standard sizes of sheet, e.g. 7.5 x 10 m. Using one as the ground sheet, allowing 1 m margin all round, this will support a stack of 5.5 m x 8 m x 2 m high as before.

Then stack volume = 88 m^3
Stack weight (calculated as rice) = 88 / 1.5 tonnes
= 59 tonnes.

Two further tarpaulins 7.5 x 10 m each will easily cover the stack allowing for 1m overlaps. Hence a total of three will be required for a 2 m high stack of 59 tonnes.

CHOOSING EMERGENCY STORES

In Section *Storage operations* it is shown that temporary stores are preferable where speed is essential, but more permanent stores are easier to manage. From Section *Storage costs* a guide to 1987 costs is available and in Section *What size of structure to order* a simple method of calculating store size is suggested. The decision tree (*see* Figure 1, p. 22) allows all these factors to be taken into account and in addition takes account of the following priorities in order of importance:

A: Is the warning of the emergency early or late?

If the warning is early, use the left-hand branch where more permanent structures, either local or imported, are feasible. If the warning is late, more temporary storage systems must be employed. However, the food store only has a function once a flow of relief food supplies is established, and the assessment of urgency should take into account the time needed to achieve this.

B: Is funding ample or scarce?

Many relief agencies can command appropriate funds but this priority is included to help keep capital costs in mind. For example, plastic-clad stores are about £56 per tonne stored while tarpaulins are £11 and therefore can, in the short term, afford five times as much protection for the same expenditure.

C: Is site management good or poor?

Branches stemming from poor management include the decision that imported supervision will be needed for store erection. Branches stemming from good management embrace difficult-to-manage systems like cover and plinth (CAP) storage and air-supported warehouses.

D: Is site transport and labour availability good or poor?

Branches stemming from poor transport/labour include facilities to speed up the turn-round of lorries. Hence, for example, drive-through stores or stores with canopies are recommended.

In the majority of food-relief emergencies warnings are late but there is ample funding; on-site management is usually good but in our experience transport is often poor. In this case the locally made plastic-covered wooden frame structure is ideal. If such structures are not easily available locally, imported plastic-clad structures should be used. Whatever the type of preferred store, selected by means of Figure 1 or otherwise, it is recommended very strongly that IN EVERY EMERGENCY STORAGE

SITUATION AS AN INSURANCE AGAINST DELAYS AND AS A FIRST-AID MEASURE, TARPAULINS SHOULD BE PURCHASED AND DESPATCHED BY AIR TO COVER THE INITIAL STORAGE REQUIREMENT. THE PROCUREMENT OF OTHER STRUCTURES FOR THE TOTAL REQUIREMENT CAN THEN PROCEED NORMALLY.

In dry weather additional storage can be obtained with temporary bag stacks (covered with tarpaulins). This is particularly useful at intermediate storage centres between port and distribution points (Friendship, 1987).

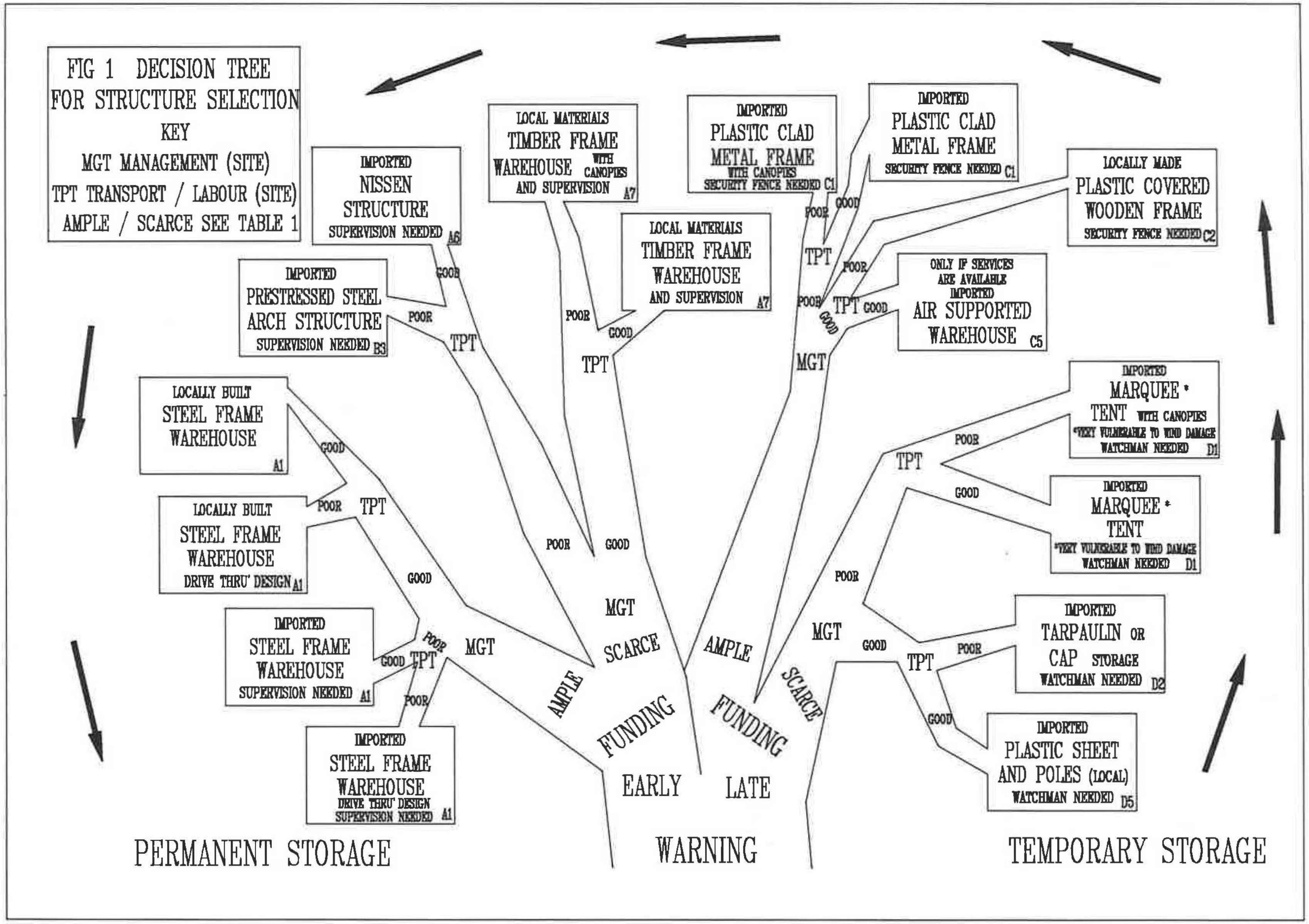


FIG 1 DECISION TREE
FOR STRUCTURE SELECTION
KEY
MGT MANAGEMENT (SITE)
TPT TRANSPORT / LABOUR (SITE)
AMPLE / SCARCE SEE TABLE 1
IMPORTED NISSEN STRUCTURE SUPERVISION NEEDED A6
LOCAL MATERIALS TIMBER FRAME WAREHOUSE WITH CANOPIES AND SUPERVISION A7
LOCAL MATERIALS TIMBER FRAME WAREHOUSE AND SUPERVISION A7
IMPORTED PLASTIC CLAD METAL FRAME WITH CANOPIES SECURITY FENCE NEEDED C1
IMPORTED PLASTIC CLAD METAL FRAME SECURITY FENCE NEEDED C1
LOCALLY MADE PLASTIC COVERED WOODEN FRAME SECURITY FENCE NEEDED C2
ONLY IF SERVICES ARE AVAILABLE IMPORTED AIR SUPPORTED WAREHOUSE C5
IMPORTED PRESTRESSED STEEL ARCH STRUCTURE SUPERVISION NEEDED B3
LOCALLY BUILT STEEL FRAME WAREHOUSE A1
LOCALLY BUILT STEEL FRAME WAREHOUSE DRIVE THRU' DESIGN A1
IMPORTED STEEL FRAME WAREHOUSE SUPERVISION NEEDED A1
IMPORTED STEEL FRAME WAREHOUSE DRIVE THRU' DESIGN SUPERVISION NEEDED A1
IMPORTED MARQUEE * TENT WITH CANOPIES *VERY VULNERABLE TO WIND DAMAGE WATCHMAN NEEDED D1
IMPORTED MARQUEE * TENT *VERY VULNERABLE TO WIND DAMAGE WATCHMAN NEEDED D1
IMPORTED TARPAULIN OR CAP STORAGE WATCHMAN NEEDED D2
IMPORTED PLASTIC SHEET AND POLES (LOCAL) WATCHMAN NEEDED D5
TPT
MGT
GOOD
POOR
AMPLE
SCARCE
FUNDING
EARLY
LATE
WARNING
PERMANENT STORAGE
TEMPORARY STORAGE

SUPPLIERS' DATA

Product details, addresses, foundation descriptions, freight and price data will be found under the following headings:

A Warehouses
B Frameless buildings
C Framed structures with flexible cladding
D Frameless flexible systems

The lists of suppliers are not comprehensive; inclusion or omission of a supplier does not represent a recommendation or criticism of the company or its product. All addresses are in the United Kingdom unless otherwise stated.

A Warehouses

	Information given for each type	Also supply types
ARD Brooker Engineering Ltd.	A1	A2
Conder Export Buildings Ltd.	A1	
Coseley Insulation Products Ltd.	A1	
Dexion Ltd.	A3	
Machinery & Building Exports Ltd. (600 Group)	A6	A5, B3
Naylor Buildings Ltd.	C1	A1, A6
Powys Industrial Buildings Ltd.	A3	
Presco International Ltd.	A3	
John Reid & Sons (Strucsteel) Ltd.	A4	A1
Rent-a-Unit Mexborough Ltd.	A1	
Ward Brothers (Sherburn) Ltd.	A1	
J Wareing & Son (Wrea Green) Ltd.	A1	

Sub-categories:

A1 Traditional warehouses, with or without drive-through facilities or raised floors and shelter canopies for easy unloading/loading bags from lorries

A2 Warehouses with retaining walls take bulk grain and, depending on storage period, will require aeration of stock

A3 Warehouses similar in appearance to A1 when built, but unconventional in detailed design; includes types with frames fabricated on site, and types with prefabricated cladding sections

A4 Emergency design warehouse, *see* Appendix 8.

A5 Foldaway type, requires crane

A6 Nissen type, semi-circular cross-section

ARD BROOKER ENGINEERING LTD.

Address:	Goldicote Bridge Banbury Road Stratford-upon-Avon Warwickshire CV37 7NL
Telephone:	0789 740282
Telex:	312255

Product details	Steel portal-frame buildings, especially for agricultural applications. Details as required.
Foundations	Conventional.
Example	No details available.

CONDER EXPORT BUILDINGS LTD.

Address:	Wellington Road Burton-on-Trent Staffordshire DE14 2AA
Telephone:	0283 45377
Telex:	34656

Product details	Steel portal-frame buildings with metal-clad or locally supplied block walls. Standard spans: 18 m, 24 m, 30 m; any length. Doors and ventilation: any type as required.
Foundations	Concrete pad.
Price	Competitive over 1500 m^2.
Erection	Crane or derrick pole required.
Example	For a 30 x 50 m building with crew of three men + crane driver: Steel work, 2 weeks, total with cladding, 4-5 weeks depending on skill of labour.
Supervisor	£800 per week + expenses. Full erection crew can also be provided if required.

COSELEY INSULATION PRODUCTS LTD.

Address:	Hardwick View Road Holmewood Industrial Estate Holmewood Chesterfield Derbyshire S42 5SA
Telephone:	0246 855070
Telex:	54219 Cosins G

Product details Lattice steel portal frame, clad in laminate of steel/polystyrene/steel 50 mm thick to give lightweight structural rigidity, and high thermal performance.

Spans:	10-110 m; any length, eaves height 3-7.5 m.
Doors:	any type as required.
Ventilation:	incorporated in standard design.

Foundations Concrete beam, metal skids or self-supporting bases.

Example

Store:	3 m x 10 m x 30 m.
Price:	£32,400 ex-works, doors extra.
Shipping measurement:	greater than for steel clad structure.
Delivery:	3-4 weeks.
Erection time:	within 5 days, depending on base. Small crane or lifting equipment, 1.5 t capacity required.

Supervisor £15 per hour + expenses.

DEXION LIMITED

Address:	Maylands Avenue Hemel Hempstead Herts. HP2 7EN
Telephone:	0442 42261
Telex:	825794
Facsimile:	0422 217145

Product details Steel-framed buildings in which the frames are fabricated on site from galvanized-steel slotted angle and channel. Steel or aluminium-cladding. Spans from 16 ft (4.9 m) to 40 ft (12.2 m) in 4 ft (1.2 m) increments; height from 8 ft (2.4 m) to 14 ft (4.3 m) in 2 ft (0.6 m) increments; any length.

Doors: normally side-hung, aluminium plywood or steel.

Ventilation: at eaves by leaving out-cladding; ridge ventilation if required.

Foundations Light slab with column bases cast into concrete block.

Example No details available.
Note that Dexion slotted angle is available in many countries.

Supervisor Available at £200 per day, plus expenses.

Note: A kit form building which can be erected in about half the time of the above type is under development.

MACHINERY AND BUILDING EXPORTS LTD. (600 GROUP)

Address:	23/25 Sunbeam Road London NW10 6JP
Telephone:	01 995 7662
Telex:	922569

Product details* Nissen building — curved steel galvanized Tee ribs with galvanized pressed steel purlins. Clad with corrugated sheeting. Widths 5 m or 7.5 m with centre heights 3 m and 3.75 m respectively; any length.

Doors: double timber 3 x 2.75 m

Ventilation: ridge ventilators can be provided, also dormer windows.

Foundations Strip foundations are advisable, drawings provided; railway sleepers have been used.

Example

Store:	3.75 m high x 7.5 m wide x 22 m long.
Volume:	480 m^3; capacity at 50% utilization, 160 t.
Price:	£3,653 ex-works.
Shipping:	7 bundles weighing 2960 kg.
Delivery:	ex-stock, to 7 days for a large order.
Erection time:	5 days with supervisor and 3 helpers. A scaffolding tower is recommended for erection.

Supervisor £90 per day + expenses.

* In addition to the Nissen building described above, the company manufactures a complete range of buildings including Romney Buildings and Foldaway Buildings.

POWYS INDUSTRIAL BUILDINGS LTD.

Address:	Pentre Near Nesscliffe Shrewsbury Shropshire SY4 1BP
Telephone:	0743 81495
Telex:	35438 Telcom G (POWYS BUILD)

Product details All steel lightweight fully clad sectional panels when assembled give structure similar characteristics to a portal frame building. Spans 5.2-9.1 m; eaves height 2.1 m or 3.6 m; lengths as required in increments of 1.8 m.

Doors: steel hinged doors as standard.

Ventilation: at eaves.

Foundations Perimeter foundations required.

Example

Store:	7 ft (2.1 m) x 17 ft (5.2 m) x 24 ft (7.3 m)
Price:	£16,000 ex-works
Shipping weight:	1 t approximately.
Delivery:	14 days.
Erection time:	2-3 days with three helpers.

Supervisor Available at approximately £150 per day + expenses.

PRESCO INTERNATIONAL LTD.

Address:	Small Products Division Delta Way Cannock Staffordshire WS11 3BE
Telephone:	05435 2671
Telex:	334723 Facsimile: 05435 72710

Product details Steel-framed building with prefabricated wall and roof panels clad with galvanized corrugated steel.

Span:	17 ft (5.2 m), multi-span designs available; eaves height 12 ft (3.6 m); length from 18 ft (5.5 m) in 6 ft (1.8 m) increments.
Doors:	steel, hinged, full height of building.
Ventilation:	gap at eaves only.

Foundations Concrete column bases required.

Example

Store:	SU/DD/30. 12 ft (3.6 m) x 17 ft (5.2 m) x 30 ft (9.1 m)
Price:	£2,133 ex-works.
Shipping weight:	2064 kg.
Delivery:	ex-stock or under 10 days.
Erection time:	1 day with four men.

Supervisor Not required. Construction manual provided.

JOHN REID & SONS (STRUCSTEEL) LTD.

Address:	Reid Street Christchurch Dorset BH23 2LT
Telephone:	0202 483333
Telex:	41260 REID G
Facsimile:	0202 47013

Product details Steel portal-framed building, designed for containerisation and ability to be manhandled. Supplied as basic structure with Aluzinc coated roof but without wall cladding or doors; or with Aluzinc coated steel walls and doors 2 x 2 m at each end.

Standard size 2.5 m to eaves and 11 m wide, 29.5 m long in five bays of 5.9 m. Designed for wind loads of 60 kg/m^2.

Capacity with 60% utilization of volume is 400 tonnes of bagged maize.

Doors: 2 m x 2 m sliding type.

Ventilation: ventilated ridge capping suggested, £90 extra.

Foundations The building can be staked to the levelled ground with steel pins, bolted onto existing slabs or bolted onto purpose-made slabs or footings.

Example Standard building as above.

Price Ex-works for four basic structures loaded into container is £15,230. Ex-works for three clad structures loaded into container is £18,940.

This is equivalent to £6,313 per-clad structure.

Shipping Basic structure fits four per 20 ft container, weight 4.2 t. Structures with walls clad and doors fit three per container, weight 6.5 t.

Delivery 2-6 weeks.

Erection time 3-5 days for supervisor and four helpers for the basic building. 7-10 days for the enclosed building. No power tools or equipment needed; cost of hand tools £30.

Supervisor Available at £100-150 per diem plus expenses and air fare.

(For design details *see* Appendix 8).

RENT-A-UNIT MEXBOROUGH LTD.

Address:	Edward House Whitelea Grove Mexborough South Yorkshire S64 0QP
Telephone:	0709 585591
Telex:	547657

Product details Portal-frame building with rectangular hollow section frames and galvanized corrugated steel-cladding.

Span:	5.3-9.1 m; eaves 3.75 m; length as required.
Doors:	hinged, 3.15 m high. Roller shutter doors also available.
Ventilation:	gap at eaves.

Foundations Detail drawings supplied.

Example

Store:	3.75 m high x 9.1 m wide x 30.8 m long.
Price:	£11,242 ex-works.
Shipping:	9 bundles. Total weight 8.55 t. Volume 31.1 m^3.
Erection time:	10 days with supervisor and 3 helpers. No crane required.

Supervisor Available at £800 per week + expenses. Alternatively, supervisor training would be provided in the United Kingdom at no charge.

WARD BROTHERS (SHERBURN) LTD.

Address:	Widespan Works Sherburn Malton N. Yorks.
Telephone:	0944 70421
Telex:	52354 Facsimile: 0944 70777
Product details	Steel portal-frame buildings with spans from 12 m to 36 m. Also farm kit buildings with spans from 9 m to 18 m. Doors: Top-hung sliding doors, or as required.
Foundations	Conventional.
Example	No details available.

J WAREING & SON (WREA GREEN) LTD.

Address:	Wrea Green Preston Lancashire PR4 2NB
Telephone:	0772 628159/682914
Product details	Steel portal-frame buildings with asbestos or steel cladding, supplied in kit form. Span and eaves height as required; length normally in multiples of 15 ft or 20 ft (4.6 m or 6.1 m). Doors: can be supplied at extra cost. Ventilation: can be supplied.
Foundations	Concrete pad for each column; 1 m^3 or as required by local conditions or regulations.
Example	Store: 10 ft high x 30 ft wide x 45 ft long (3 m high x 9.2 m wide x 13.8 m long) Price: £2,175 ex works. (Doors extra) Delivery: 1 month Erection time 2-24 days depending on experience. Require 3-4 men, light crane or digger (alternatively pole and chain blocks)
Supervisor	Not available; instructions and a video can be provided.

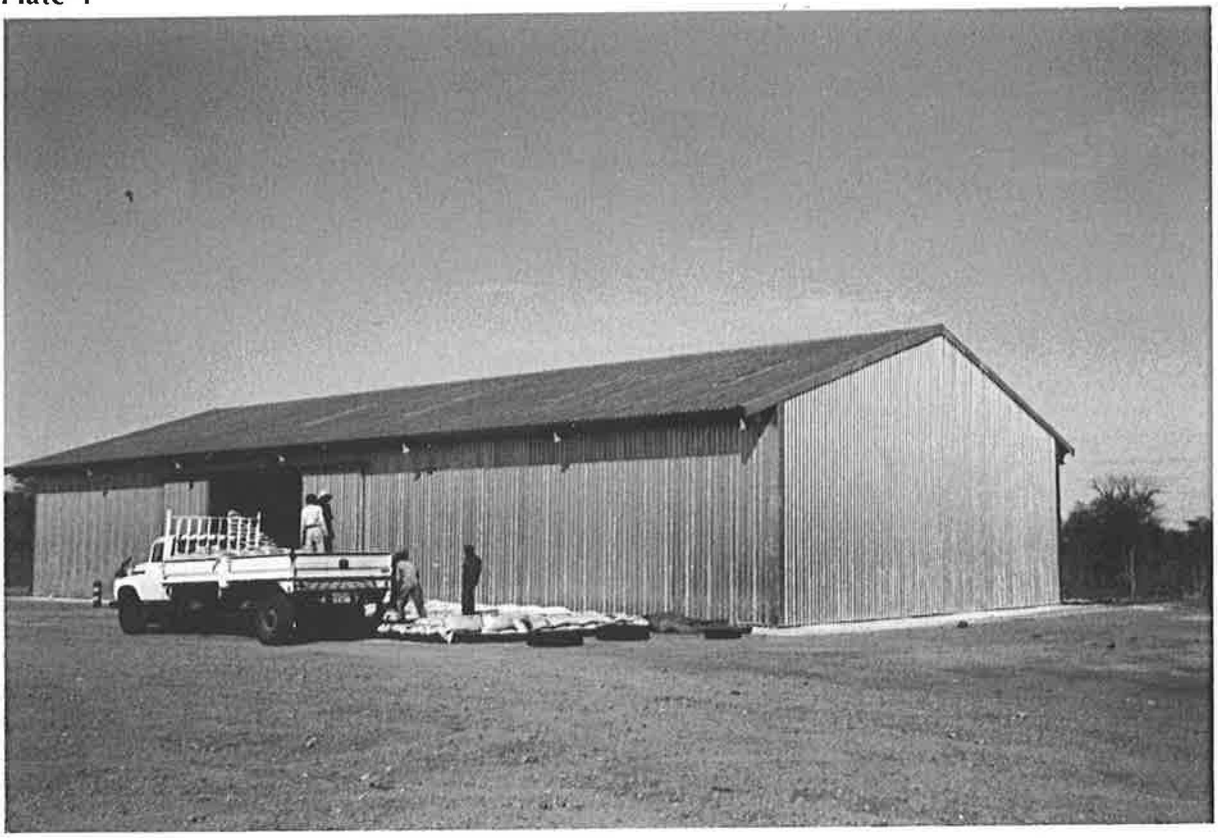
B Frameless buildings

	Information given for each type	Also supply types
Ardenlea Enterprises Ltd.	B3	
Conport Structures Ltd.	B3	
Machinery & Building Exports Ltd.	A6	B3
Monatta Ltd.	B2	
Quadrem Buildings Ltd.	B3	
Terrapin Ltd.	B1	

Sub-categories:

B1 Terrapin type
B2 Terryboard experimental panels
B3 Prestressed modular, no-frame type
B4 Steel silos with aeration ducts or plenum floor

Plate 1



Local portal-frame warehouse, Botswana

Plate 2

Drive through facility, Botswana

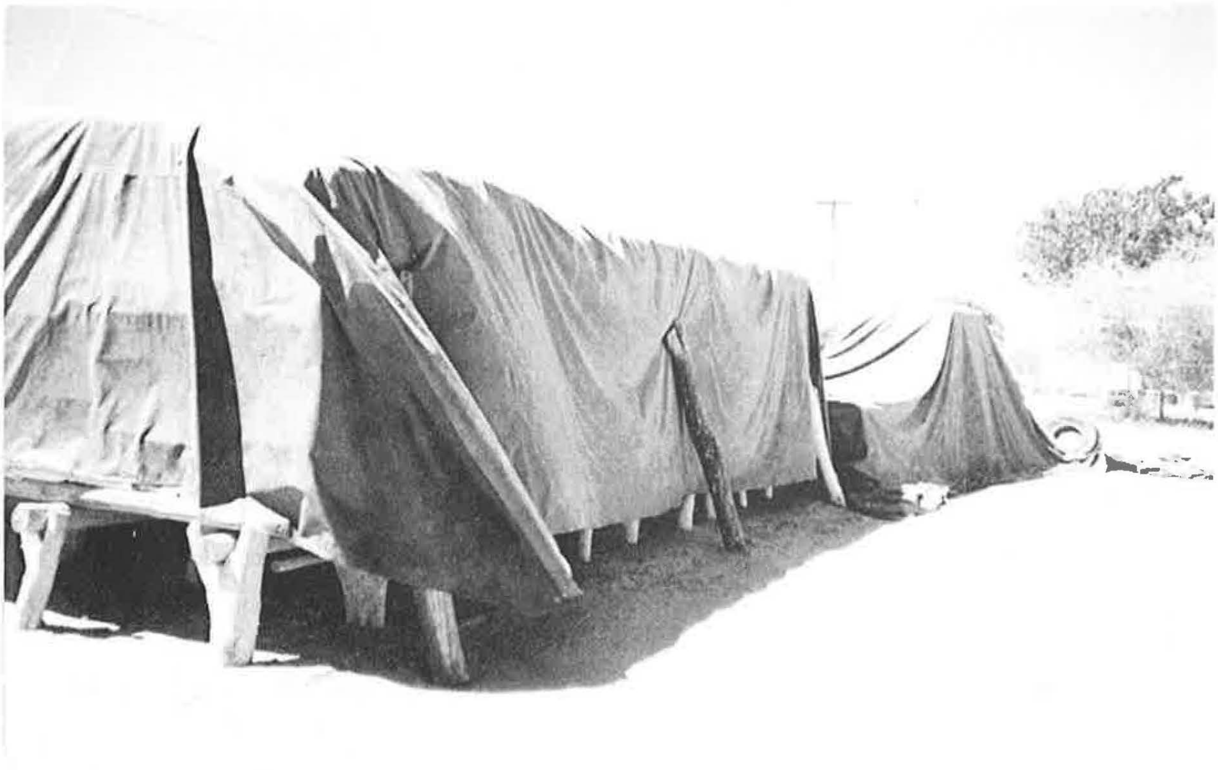
Plate 3

Frame for locally made stores in Ecuador

Plate 4

Completed stores with cladding, Ecuador

Plate 5



Tarpaulins covering relief food: note timber supports lift bags clear of ground. Botswana

Plate 6

(Photograph Courtesy Cherwell Valley Silos.)

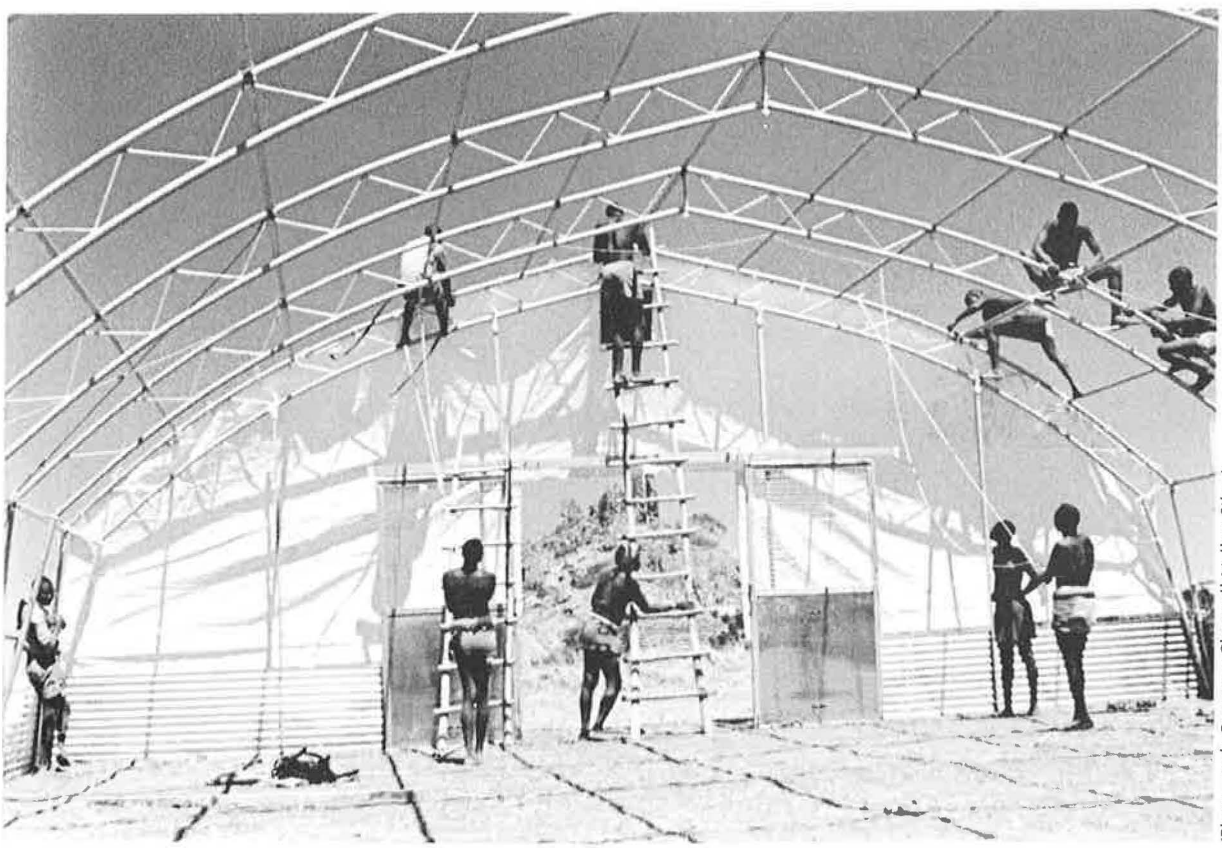
Plastic-clad steel-frame stores

Plate 7

(Photograph Courtesy Cherwell Valley Silos.)

Assembly of components by local unskilled labour

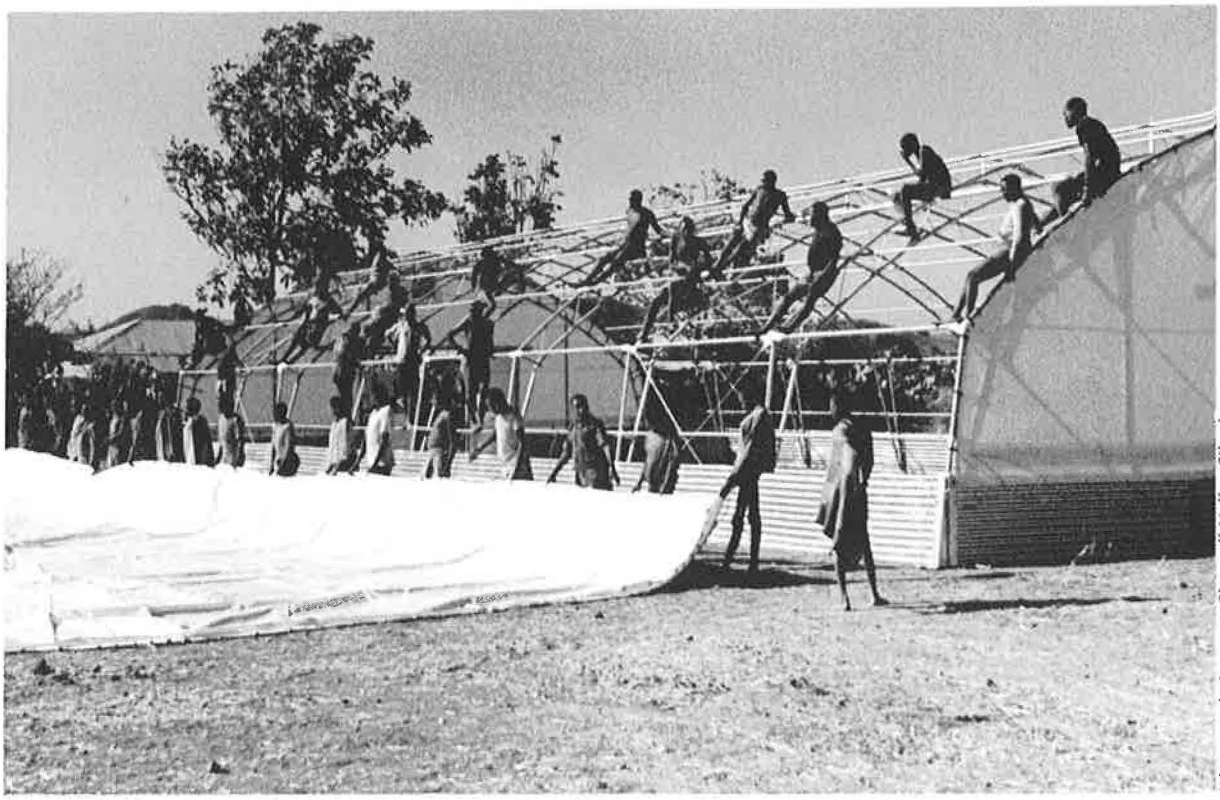
Plate 8



(Photograph Courtesy Cherwell Valley Silos.)

Completing frame of building

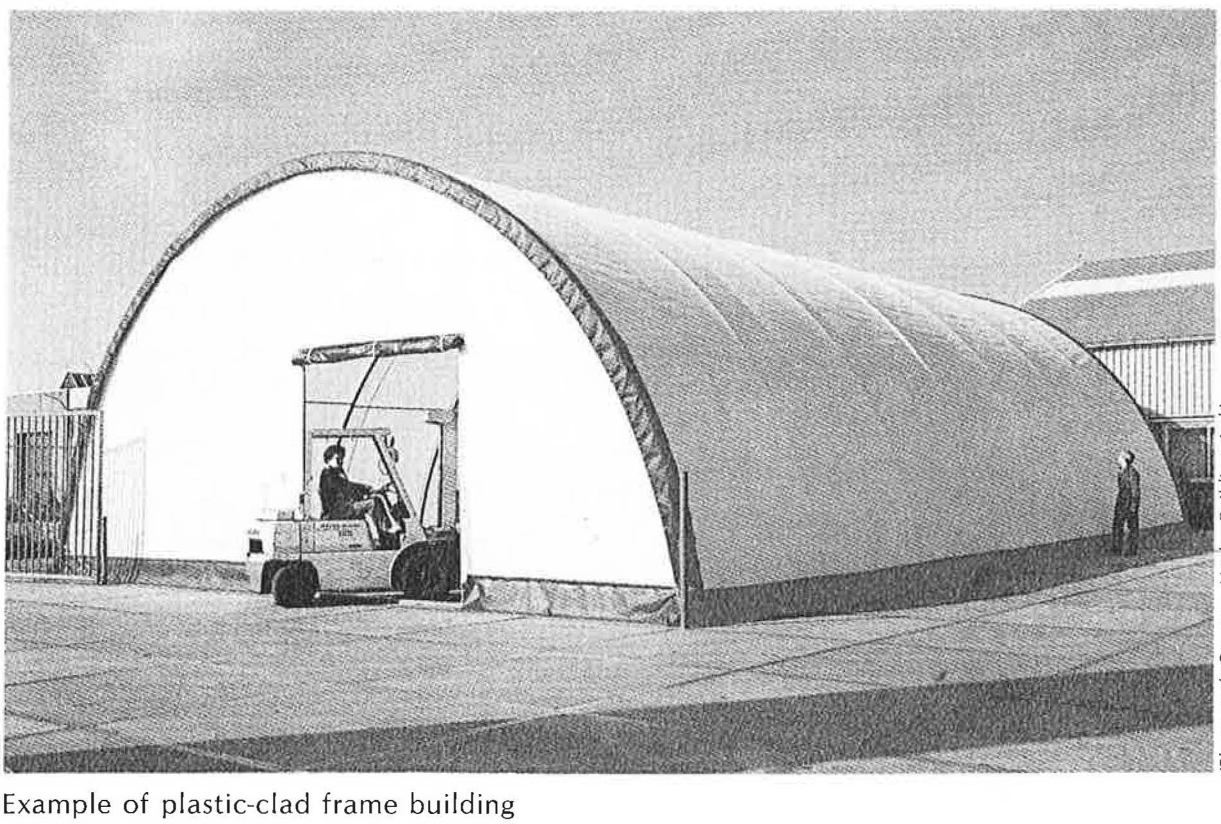
Plate 9



(Photograph Courtesy *Cherwell Valley Silos*.)

Attaching reinforced UV-resistant roof

Plate 10



(Photograph Courtesy Naylor Buildings Ltd.)

Example of plastic-clad frame building

Plate 11

(Photograph Courtesy Rubb Buildings Ltd.)

Example of plastic-clad frame building

Plate 12

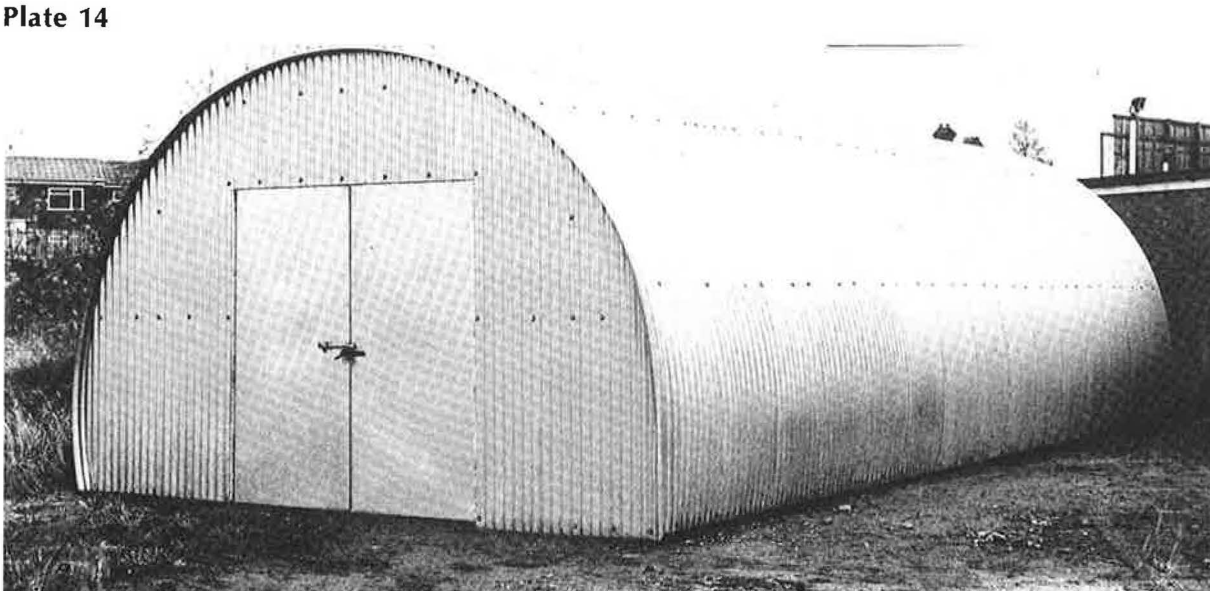
Failure of plastic-clad building caused by wind forces. Mali

Plate 13

Prefabricated store

(Photograph Courtesy Conport Buildings Ltd.)

Plate 14



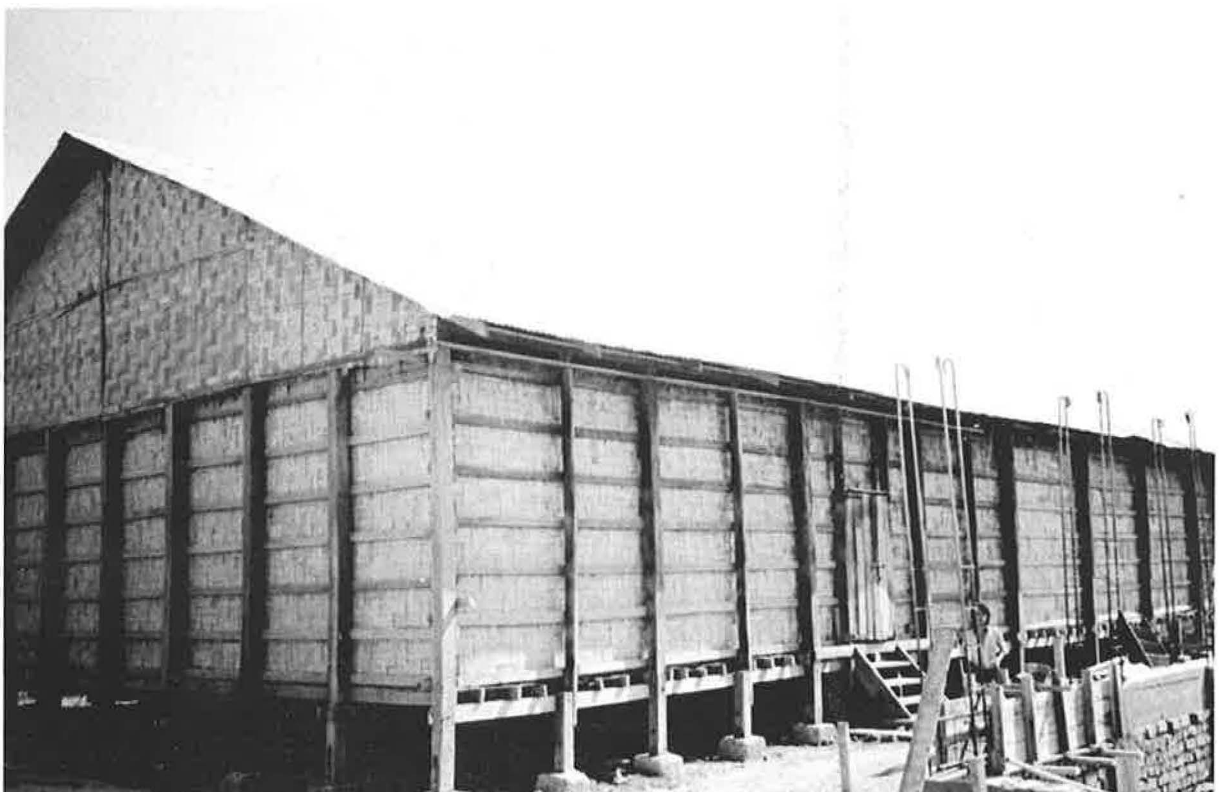
Nissen hut

(Photograph Courtesy Naylor Buildings Ltd.)

Plate 15

Paddy pyramids for bumper crop storage in Burma

Plate 16



The next stage: temporary covered bag stores of woven matting and timber frame

ARDENLEA ENTERPRISES LIMITED

Address:	Aylesbury Road Princes Risborough Aylesbury Buckinghamshire HP17 0JP
Telephone:	08444 5572
Telex:	837014 GAIN

Product details ARCHIDROME buildings with semi-circular cross-section. Built from self-supporting sections of galvanized steel; no trusses, rafters or stanchions. Standard range spans 6.5-21.6 m, with centre heights 2.9-6.1 m; other spans and building profiles also available. Steel gauge according to span.

Doors: double sliding doors.

Ventilation: side or ridge ventilators available as extras.

Foundation Simple concrete perimeter foundations required.

Example

Store:	14 ft (42.7 m) centre height, 30 ft (9.1 m) internal span, 40 ft (12 m) overall length, double doors one end. Capacity 130 t bagged maize at 50% utilisation of volume.
Price:	£6,027 f.o.b. Rotterdam (based on minimum order 5 buildings).
Shipping:	weight 3026 kg, palletized; load can be broken down for easy manhandling if required. Can be containerized.
Delivery:	4-6 weeks.
Erection time:	10 days with supervisor and 3-4 helpers. Scaffolding required.

Supervisor Available at approximately £165 per day + expenses.

CONPORT STRUCTURES LTD.

Address:	11 Kings Road Sloane Square London SW3
Telephone:	01 730 9105
Telex:	919645 CONPRT G
Product details	Relocatable modular frameless building designed for quick erection and easy transport. Galvanized steel construction, colour coating available. Basic buildings 3.1 m height to eaves, either 7.5 x 19.9 m or 9.3 x 21.6 m; lengths can be increased in units of 1.8 m for both.
	Doors: double hinged, 2.6 m wide.
	Ventilation: ridge and gable-end ventilators available.
Foundations	Concrete perimeter strip usually required in sandy soil; ground spikes usually sufficient in clay.
Example	Store: 3.1 high x 9.3 wide x 23.4 m long with 4 ridge and 1 gable ventilator. Capacity 250 t at 50% utilization of volume.
	Price: £6,068 including erecting tower, tools and ground spikes.
	Shipping: 4.2 t, palletized: 4 buildings fit one 20 ft container (open topped)
	Delivery: ex-stock to 4 weeks
	Erection time: 1½ days with supervisor and 3 helpers if foundation strip ready.
Supervisor	Available at a charge of about £750 per week + expenses.

MONATTA LTD.

Address: 2 St Andrew Street
Plymouth
Devon
PL1 2AH

Telephone: 0752 221569

Product details A quick-assembly/dismountable building system, comprising 'Terryboard', a sandwich board of weather-and-boil-proof plywood and insulated corkboard, and plywood linking strips, wedges or bolts. Basic board available in 600 mm width, 70 mm thickness, lengths 2.4 m, 3 m and 3.6 m.

Doors: as required.

Ventilation: apertures easily cut, or ventilators inserted.

Foundations Not required — ballast used to anchor buildings.

Example Store: 12 ft high (apex) x 10 ft wide x 20 ft long (3.1 x 3.0 x 6.1 m).

Price: basic board £15 per square metre.
Weight: basic board 12 kg/m^2.
Delivery: 2 weeks.
Erection 1½ hours with 4 people, using prepared components. Alternatively can be constructed from basic board using hand drill and hand saw.

Supervisor Not required — assembly diagrams available.

QUADREM BUILDINGS LTD.

Address: Quadrem Buildings Ltd.
Frogmore Mill
Hemel Hempstead
Herts.
HP3 9RY

Telephone: 0442 54595
Telex: 825815

Product details A stressed skin structure composed of heavy gauge galvanized steel arches. No structural framework required: 10 ft x 2 ft corrugated panels are bolted together to form an arch. Arches then raised and linked to complete the building. Available in spans from 20 ft to 80 ft (6.1 m to 24.4 m) and in any length.

Doors: standard sliding doors supplied 24 ft (7.3 m) wide, 14 ft (4.3 m) high; door and endwall combinations are variable to suit requirements.

Ventilation: circular ventilators, wind driven turbo-type fitted at the ridge £107 extra each.

Foundation: The normal foundation is a concrete perimeter strip only 16 inches deep, in which is formed a trough to receive the ends of the arch panels. This is then grouted to form a weathertight seal.

Example Typical store 42 ft (12.8 m) wide x 60 ft (18.3 m) long; centre height 21 ft (6.4 m); capacity 400 tonnes of bagged maize at 70% utilisation.

Price: arches only: £6,500 ex-works United Kingdom
endwall and doors: £2,500 ex-works United Kingdom

Shipping weight: arches only: 3400 kg, 2 pallets 2 ft x 10 ft x 4 ft (0.6 x 3.05 x 1.2 m)
endwall and doors: 1600 kg, maximum length 14 ft (4.27 m)

Delivery: ex-stock or 2-3 weeks ex-Toronto

Erection time: 5 days for first store, with supervisor and 4 helpers, if foundation strip is ready. Only light lifting gear or scaffolding is required.

Supervisor Available at a charge of approximately £125 per day plus airfare and expenses.

TERRAPIN LTD.

Address:	Bond Avenue Bletchley Milton Keynes MK1 1JJ
Telephone:	0908 74971
Telex:	82468

Product details 'Incremented unit construction' using mass produced modules comprising rolled-steel structural members and composite insulated roof and wall cladding. Prefabricated units are transported in packs and then erected with speed.

Spans are 7.2 m, 9.6 m or 12.0 m; height 3.6 m or 4.8 m; length in increments of 3.6 m.

Doors: double sliding or 'up-and-over' doors.

Ventilation: trap door type available.

Foundations Concrete pad.

Example No specific details available.

Erection time: Approximately 400 m^3 of floor area per day with a supervisor and three helpers. Scaffolding required, crane advisable.

C Framed structures with flexible cladding

	Information given for each type	Also supply types
Airclad Ltd.	C5	
Aldek AS	C1	
Owen Brown & Son (Tents) Ltd.	C1	
Cherwell Valley Silos Ltd.	C1	
Clyde Canvas Goods & Structures Ltd.	D4	C1
CY Inflatables Ltd.	C5	
Germex-Gerhard Meyer & Co.	C4	
Andrew Mitchell & Co. Ltd.	D3	C1, D1
Naylor Buildings Ltd.	C1	A1, A6
Rubb Buildings Ltd.	C1	
Spandrel Hire Ltd.	C1	

Sub-categories:

C1 Steel or aluminium frame with plastic cover
C2 Wooden frame and canvas/plastic cover
C3 Wooden frame and woven mat cover
C4 Flexible silos supported with weldmesh
C5 Air-supported frame type; need powered fan for inflation

AIRCLAD LTD.

Address:	Langley House Langley Hill Nottingham NG16 4AN
Telephone:	0773 768352/530777
Telex:	377985 LANHSEG

Product details Structure comprises a double skin membrane of UV-inhibited, fire-retardant PVC/nylon, supported by inflated air under low pressure. A wide range of sizes is available.

Doors: flexible, soft-sliding

Ventilation: any area can be specified at no extra cost.

Foundations None; structure is held down with ground anchors and tensioned ropes.

Example

Store:	5 m high at centre x 10 m wide x 20 m long. Capacity 780 m^3 or 200-250 t bagged maize at 50% utilization.
Price:	£9,483, including a 2 kW 3-phase electric fan for inflation.
Shipping weight:	building 820 kg, fan 30 kg; total 3 m^3. Building can be sectionalized for easier handling, at additional cost.
Delivery:	5 weeks.
Erection time:	1-2 hours maximum.

Supervisor Not required.

ALDEK AS

Address: 7 Thorslundsveg
DK-5100 Odense
Denmark

Telephone: (09) 1122 33
Telex: 59912. Cable: aldekaldek

Product details Four ranges of structures, comprising a galvanized steel lattice frame with a cover of PVC-coated nylon or polyester fabric. One range of frames may also be clad with steel sheets.

Seven spans available in the range 5-25 m. Lengths according to requirements in increments of 2 m, 3 m or 4 m.

Doors: usually hinged, wood or metal; sliding doors also supplied.

Ventilation: by arrangement.

Foundations Concrete pad foundations for permanent installations. All except one range of buildings may also be anchored by strong earth rods.

Example No details available.

OWEN BROWN & SON (TENTS) LTD.

Address:	Bishop Meadow Road Loughborough Leicestershire LE11 0RQ
Telephone:	0509 214334
Telex:	342392 OBROWN G

Product details Structure of portal frame or polygon design made from anodised hollow aluminium profiles, covered with PVC-coated Trevira fabric. Eaves height 3.4 m or 4.2 m; spans from 3.87 m to 40 m; lengths as required in 5 m modules. Steel sheet cladding can also be used on vertical walls.

Doors:	fabric or rigid doors can be installed in any position.
Ventilation:	eaves ventilation possible at additional cost.

Foundations 0.75 m stakes in well-prepared ground; concrete ring beam required for sand.

Example

Store:	3.4 m high x 12.5 m wide x 30 m long. Ref. KF 125.
Price:	£19,500 ex-works.
Shipping weight:	approximately 3750 kg.
Delivery:	6-8 weeks.
Erection time:	under $\frac{1}{2}$ day (1000 m^2/day). For 25 m span crew of 8 required but fewer for this building. No special equipment needed.

Supervisor Available at £132 per day + expenses.

CHERWELL VALLEY SILOS LTD.

Address:	Twyford Banbury Oxfordshire OX17 3AA
Telephone:	0295 811441
Telex:	83477

Product details Low profile steel-framed plastic structures designed for rapid erection with minimum site preparation. Cover of heavy-duty PVC-coated polyester, UV-resistant. Lightweight tubular steel arches and purlins. A butyl rubber floor is optional.

Standard span 11 m, length in modules of 12 m, height 3 m (average).

Alternative designs are available for structures up to 30 m span.

Doors: double sliding 2.5 x 2.5 m are standard.

Ventilation: gable-end ventilators included.

Aluminium framed designs also available.

Foundations Ground anchors, or bolted to existing concrete slab.

Example

Store:	3 m high x 11 m wide x 24 m long. Capacity at 60% utilisation, 320 t bagged maize.
Price:	£18,000 ex-works, floor extra.
Shipping weight:	5200 kg, 16 m^3; floor 660 kg, 2 m^3 extra.
Erection time:	2 to 3 days with supervisor and 3-4 helpers. No special tools needed.

Supervisor Available at approximately £150 per day + expenses.

CY INFLATABLES LTD.

Address:	Unit 1A, Queniborough Industrial Estate Melton Road Queniborough Leicestershire LE7 8FP
Telephone:	0533 602506

Product details Flexible structure with inflated tubular 'frame', constructed from nylon-reinforced PVC. Designed in units, maximum 10 m width, 10 m length, which can be joined, but each unit requires a fan. A floor sheet can be included.

Doors: PVC flexible doors on end.

Foundations None required.

Example

Store:	10 m wide x 10 m long.
Price:	£5,350 ex-works.
Shipping weight:	350 kg, 1.5 m^3 approx.
Delivery:	4 weeks
Erection time:	10 minutes.

Supervisor Not required.

GERMEX — GERHARD MEYER & CO.

Address:	2000 Hamburg 76 Landwehr 25 Federal Republic of Germany
Telephone:	(040) 2 50 10 88
Telex:	213051 GERMX D

Product details Flexible silos comprising bottom liner and roof cone each of one piece, hf-welded. Material polyester-fabric coated with several layers of different plastic coatings. Specifically developed for grain storage. Liner material offers high resistance to PH_3 penetration. Seal of bottom liner against roof cover by special spring-loaded peripheral cord plus roll-connection of aprons with locking rope and padlock. Surrounding wall of welded steel mesh, pre-shaped segments of about 127 cm width x 245 cm height, screwed together by high tenacity steel bolts. All segments hot-dip galvanized. Rodent barrier of corrugated galvanized-steel sheet.

Storm net: pre-knit net of weather-resistant plastic ropes, pulled over the roof and fixed to the grill wall.

Nominal capacities of 250 t, 500 t, 750 t and 1000 t available.

The silos may be used for grain in bags as well as for loose grain. Usually they are loaded with bagged grain. The silos are supplied with an anti-condensation liner, which is fitted under the roof cover to ameliorate the effects of moisture migration.

Foundations None. Level site free from debris is required.

Example

Standard:	500 t silo.
Price:	DM 41 000 ex-works.
Shipping weight:	2500 kg approximately.
Erection time:	4-5 hours with 4-6 semi-skilled workers. Toolkit and repair kit supplied.

NAYLOR BUILDINGS LTD.

Address:	Romney House Wolverhampton Street Darlaston West Midlands WS10 3UB
Telephone:	021-526 3851
Telex:	338499 Romney G

Product details* Super lightweight Romney; tubular aluminium frame with aluminized canvas/plastic cover giving semi-circular cross section building. Basic size as example below but other sizes available.

Doors: roll-up flexible door is standard.

Ventilation: gable-end screened ventilators available.

Foundation Concrete strip foundation essential, drawing supplied.

Example

Store:	5.5 m maximum height x 12.3 m wide x 25 m long. Volume 1280 m^3, will store 500 t bagged maize at 50% utilization.
Price:	£7,150 ex works.
Shipping weight:	1010 kg, 5.2 m^3; 4 packages.
Delivery:	2-4 weeks.
Erection time:	2 days with supervisor and 3 helpers. Scaffold tower advisable

Supervisor Available at approximately £150 per day + expenses.

* The company also supply a complete range of buildings including Nissen and portal frame buildings, also the Omni-structures range of prefabricated structures.

RUBB BUILDINGS LTD.

Address:	Dukesway Team Valley Trading Estate Gateshead Tyne and Wear NE11 0QE
Telephone:	091 482 2516
Telex:	537756 Facsimile: 091 482 2516.

Product details Structures have galvanized steel frames and PVC-coated polyester covers; for tropical use the cover is fire-retardant, UV-stabilised, and pigmented white. The THA range has spans from 6 m to 15 m, with lengths in multiples of 3 m, and includes a foundation beam. Other ranges permit spans up to 40 m and eaves heights of 6 m or more.

Doors: PVC folding doors, lockable. Lace-up door available at reduced price.

Ventilation: sloping ducts in gable ends.

Foundations Depending on site conditions, steel spikes, ballast weight or concrete ringbeam may be used.

Example

Store:	3.3 m high (eaves) x 12 m wide x 24 m long. Capacity at 60% volume utilisation, 400 tonnes maize.
Price:	£9,080 ex works.
Shipping weight:	4439 kg, 8.5 m^3. Estimated that 4 units can be shipped in a 20 ft container.
Delivery:	normally from stock.
Erection time:	1 day for first store; supervisor and 3 helpers. Crane not required for erection; hand tools and ladders supplied with the store.

Supervisor Available at £15 per hour plus expenses.

SPANDREL HIRE LTD.

Address:	Armadale Road Feltham Middlesex TW14 0LR
Telephone:	01 751 4464
Telex:	24851
Product details	Aluminium-framed structures with covering of PVC-coated high-tenacity polyester. Spans from 20 ft to 60 ft (6.1 m to 18.3 m) available. Doors and ventilation as required.
Example	No details available.

D Frameless flexible systems

	Information given for each type	Also supply types
Calnay Ltd.	D3	
The Canvas and Nylon Company	D1	
Clyde Canvas Goods and Structures Ltd.	D4	C1
Fell-Fab (United Kingdom) Ltd.	D3	
Andrew Mitchell & Co. Ltd.	D3	
Moreland Tarpaulins Ltd.	see Visqueen	
Scandinavian Hovercraft Promotions AS	D4	
Singleton Flint	D3	
Visqueen Polythene Film Products Imperial Chemical Industries Plc	D3	
WS Surplus Supplies Ltd.	D1	

Sub-categories:

D1 Marquee tents, often used for refugees, can be used for stocks
D2 CAP, *see* Appendix 6.
D3 Tarpaulins only or plastic sheeting preferably with reinforced eyelets.
D4 Airwarehouse pressure supported.
D5 Polyethylene (black) sheet with eucalyptus poles.

CALNAY LTD.

Address:	Maerdy Industrial Estate Rhymney Gwent NP2 5XG
Telephone:	0685 840672
Telex:	497666
Product details	Polyethylene film up to 17.5 m wide without joins, of thickness from 100 μm to 1000 μm (400-4000 gauge). Reinforcing, UV-inhibitors and colours as required. Also: emergency tent comprising one-piece white polythene cover with sectional frame of polypropylene/PVC pipe.
Examples	1) Sheet 13 x 18 m, 375 μm, with eyelets at 1 m spacing. Price: £76 Shipping weight: 82 kg. Delivery: 1-5 days. 2) Emergency tent 2.2 m high, 4 m wide, 3 m deep. Price: £115 f.o.b. United Kingdom airport. Shipping weight: 30 kg. Crate of 12 units 400 kg, 3.15 m^3. Delivery: ex-stock.

THE CANVAS AND NYLON COMPANY

Address:	North Street Winkfield Nr Windsor Berkshire SL4 4TF
Telephone:	0344 882539

Product details Marquee tents; cover of white canvas, 15 oz/yd^2 (510 g/m^2), solar reflectant, UV-protected and weatherproof; wooden poles.

Foundations Not required.

Example

Tent:	6 ft high (eaves) x 20 ft wide x 63 ft long (1.8 x 6.1 x 19.2 m)
Price:	£2,800
Shipping weight:	not available.
Delivery:	limited supplies ex-stock
Erection time:	½ day with 10 people, and Landrover to pull up.

Supervisor Not available.

CLYDE CANVAS GOODS AND STRUCTURES LTD.

Address:	42 North Bar Banbury Oxfordshire OX16 0TH
Telephone:	0295 61511/2
Telex:	837912

Product details Single-skin flexible structure supported solely by internal pressure from a continuously running fan. Standard shapes are designed to give maximum usable space compatible with optimum performance under wind loadings; widths 15-35 m, lengths 15-120 m, centre height 7-9 m. Normally the main fan is electric, requiring a 3-phase supply of adequate rating, with a diesel engine driven fan as stand-by.

Doors: double airlock doors, normally timber construction.

Ventilation: the designed leakage from the structure (1.4 m^3/min per metre linear circumference) provides some ventilation (about 1 or 2 air changes per hour); this can be increased using flaps in the roof fabric or louvres in emergency doors.

Foundations Concrete ring beam or ground anchors.

Example No details available.

Supervisor Necessary for erection, at customer's expense.

Note: The company also supplies steel and aluminium-framed flexible-clad structures.

FELL-FAB (United Kingdom) LTD.

Address:	7 Lenton Drive Parkside Industrial Estate Leeds LS11 5JW
Telephone:	0532 70467
Telex:	557948
Product details	Tarpaulins of reinforced polyethylene sheet: reinforcement 10 x 10, 1000 denier synthetic threads, laminations of 30 microns polyethylene. Standard sizes: 18 x 12 ft; 21 x 15 ft; 24 x 18 ft; 30 x 23 ft; 40 x 23 ft. (5.5 x 3.6 m; 6.4 x 4.6 m; 7.3 x 5.5 m; 9.1 x 7.0 m; 12.2 x 7.0 m)
Example	Sheet: 9.1 x 7.0 m. Price: £23 each, reducing for large orders. Shipping weight: 10 kg (estimated). Delivery: 3-5 days.
Supervisor	Not applicable.

ANDREW MITCHELL & CO. LTD.

Address:	Bishop Works Amulree Street Glasgow G32 7SL
Telephone:	041 778 5461
Telex:	77393

Product details Tarpaulins supplied complete with eyelets and ropes. Two materials are available: V12P PVC-coated polyester, 17 oz/ yd^2 (578 g/m^2), and AMPLS, a laminated PVC-reinforced with polyester netting, total 348 g/ m^2. The materials can also be supplied as rolls 1.5 m and 1.37 m wide respectively, for local fabrication. Both of these materials are suitable for use in undersheet fumigation.

Example

Sheet:	60 x 40 ft (18 x 12 m) nominal
Price:	using V12P, £540 f.o.b. United Kingdom port. using AMPLS, £395 f.o.b. United Kingdom port.
Shipping weight:	V12P, 137 kg AMPLS, 90 kg
Delivery:	6-8 weeks.

SCANDINAVIAN HOVERCRAFT PROMOTIONS AS

Address:	Stortingsgt. 14 Oslo 1 Norway
Telephone:	41 49 74 / 41 30 31
Telex:	16128

Product details Air warehouse comprising skin of PVC-coated polyester supported by increased air pressure from continuously-running fans. Span 16-35 m, lengths 24-90 m in standard range.

Doors: variety of airlock doors available, normally folding steel.

Ventilation: air exchange due to inflation fan only.

Foundations Concrete ring beam, ground anchor cable, or ballast according to site conditions.

Example No details available.

Supervisor Available at about £200 per day, plus expenses.

SINGLETON FLINT

Address:	Newland Works Deacon Road Lincoln LN2 4LE
Telephone:	0522 24542
Telex:	56246

Product details 'Lynkon Nicotarp' tarpaulins made from woven polyethylene tape fabric laminated with polyethylene both sides, UV-inhibited; supplied complete with eyelets and ropes. Range of standard sizes and to order, maximum width normally 6 m. Tarpaulins of other materials also available.

Example

Sheet:	20 x 80 ft (6 x 24 m) nominal
Price:	£112 each (for order of 10 or more sheets)
Shipping weight:	30 kg
Delivery:	usually ex-stock or 7 days.

VISQUEEN POLYTHENE FILM PRODUCTS IMPERIAL CHEMICAL INDUSTRIES PLC

Address:	Yarm Road Stockton-on-Tees Cleveland TS18 3RD	Distributor: Moreland Tarpaulins Ltd. Britannia Works 25 St Pancras Way London NW1 0QB
Telephone:	0642 672888	Telephone: 01 387 5210
Telex:	58509	

Overseas enquirers should contact Visqueen initially

Product details Toughened black UV-inhibited polyethylene sheet, 250 m or 375 m thick. Supplied as rolls, or as cut sheets with eyelets and ropes, maximum width 7.5 m.

Example	Sheet:	7.5 x 10 m, 375 m; with eyelets and ropes.
	Price:	£67.76, f.o.b. Reduction for orders of 10 sheets.
	Shipping weight:	33 kg.
	Delivery:	ex-stock to 7 days.

WS SURPLUS SUPPLIES LTD.

Address:	Mill Street Eynsham Oxford
Telephone:	0865 881541
Product details	Renovated marquees 20 ft (6.1 m) wide x 63 ft (19.2 m) long x 6 ft (1.8 m) to eaves. Packed in six packages weighing 400 kg in total for export.
Price	£950 ex-works.
Delivery	Ex-stock.

WOODEN PALLET MANUFACTURERS

The following manufacturers may be contacted if no local timber or dunnage is available:

W Groom Ltd.
Benner Road
Pinchbeck
Spalding
PE11 3UG

R Jewson & Sons
Toynbee Road
Eastleigh
Hampshire
SO5 4YF

Tilgate Pallets Ltd.
Brighton Road
Crawley
RH11 9BH

Unit Pallets Ltd.
Golborne
Warrington
WA3 3RN

The trade association:

Timber Packing and Pallet Confederation (TIMCON)
5 Greenfield Crescent
Edgbaston
Birmingham B15 3BE

can advise names of additional manufacturers.

Pallets are costly to send by sea or air freight and local assembly of pre-cut components is a possible alternative.

RESPONSIBILITIES FOR PURCHASERS AND USERS OF TEMPORARY STORES

Tendering

It is the purchaser's responsibility when preparing tender forms to request the vendor to answer the following:

(i) What is the structure design wind speed?

(ii) What form of foundation is supplied for sandy soils? Does this affect (i)?

(iii) Is the structure designed for tropical exposure, i.e. are all parts, including ropes, UV-resistant?

(v) Is erection without a supervisor practical? Have visual instructions and local language manuals been printed and are 6 copies supplied?

When evaluating tenders, the purchaser must check the data on designed wind loading against recorded local gust speeds, to determine that the structure is safe.

Where possible, purchasers should ask for a demonstration to judge for themselves ease of erection/relocatability.

Site selection

A level site protected from flooding with good access is vital. If possible the site should be in an area without strong winds or it should be protected from wind. ALWAYS ASK LOCAL PEOPLE ABOUT POTENTIALLY WINDY SITES.

Installation

The purchaser should ensure

(i) That the supplier's engineer/supervisor will be available for erection overseas.

(ii) That erection and loading only take place in dry calm weather.

(iii) That the relief food is inspected to prevent wet sacks being loaded.

and should take these steps prior to erection of stores:

(i) Clear vegetation from site.

(ii) Mark out store bases at least 6 m apart to allow for lorry access.

(iii) Clear the base of stones and sharp objects which can damage tarpaulins, etc.

Suppliers should provide supervision and training in erecting the structures as part of the contract, even if charged separately. Users should recruit a reliable foreman and understudy at each site to take full advantage of this service. With the foremen and his understudy as the nucleus, a trained erection team can be formed to ensure the success of future operations.

Appendices

APPENDIX 1 LETTER TO RELIEF WORKERS

Dear

EMERGENCY FOOD STORAGE METHODS

suggested that I write to you because you have special experience of emergency operations. I am writing some guidelines for donors on emergency storage structures which include tarpaulins, prefabricated warehouses, etc. and I should be grateful for your help which I will, of course, acknowledge on behalf of this Institute.

I am particularly keen to know about any emergency storage structure/method/operation that was unsatisfactory and for what reasons. For example, the structures may not have functioned adequately or were late arriving. By the same token I should like to hear about emergency storage structure/methods/operations that went well and, if possible, the reasons for this success. This of course will depend on the scale of the emergency and at which level of operation. Above all, I should like your comment on *what you think is most important about the emergency storage structures you have encountered.*

I realize how busy you must be, but if you can find time to pass on your professional experience, this will be very valuable for others who find themselves confronted within an emergency storage situation.

Yours sincerely,

APPENDIX 2 QUESTIONNAIRE FOR FIRMS

1 Have your structures been sold overseas for emergencies?

2 Cost ex-works?

3 Any typical freight charges?

4 Do you send a supervisor? Cost?

5 Sizes of buildings available?

6 Delivery against firm order?

7 Estimated erection time with supervisor?

8 Number of people needed for erection?

9 Details of strips or foundations needed

10 Details of equipment needed

11 Ventilation

12 Experience overseas?

APPENDIX 3 LETTER TO FIRMS

Dear

ODA GUIDE TO EMERGENCY STORAGE IN THE TROPICS

Thank you for providing us with information; I enclose a fact-finder sheet for your firm's emergency storage product.

I should be most grateful if you could telephone or write to me if there are any mistakes or omissions. This will ensure that your product is correctly described and meets the deadline for our 'Guide to Emergency Storage'.

We want to keep this format with a maximum of one A4 fact-finder sheet for each company to be as fair to everyone as possible.

Again, many thanks for your co-operation.

Yours sincerely

APPENDIX 4 MAIN FEATURES OF BOTSWANA RELIEF STORES

Outline specifications. Store function was:

(a) to keep relief food dry, cool, clean, pest free and secure;
(b) to keep capital and maintenance costs low;
(c) to enable rapid erection and completion of the food stores;
(d) to ensure rapid and easy movement of relief food in and out of the stores.

To achieve the objectives, the buildings and site were treated as an integral unit with major design features described in Table A below.

Table A

Main design features for relief food stores

No.	Design feature	Purpose
1	Steel portal-frame structure and roof designed for maximum wind loads, clad with galvanized steel sheet	Rapid erection, low costs, minimal supervision
2	Large (4 x 4 m) doors opposite each other on long walls, combined with specially reinforced concrete floor	Provides drive through facility for 35 tonne vehicles
3	Adequate site space. Hard standing. Good drainage	Speedy truck turnaround in all weathers
4	Copious eaves ventilation plus ventilation from doors opposite each other	Keeps relief food cool and provides conditions for efficient labour
5	Chain link fence. Support buildings separate from store	Ensures security and good conditions for staff to manage relief operation.
6	Concrete floor has hardwearing screed and damp-proof course. Floor is 300 mm above grade	Relief food is clean dry, safe from flash floods
7	Concrete bollards at doors	Protects building from damage by trucks
8	Canopies/guttering	No wind-blown rain wetting relief food
9	Concrete plinths for emergencies	For overflow food at peak period and for fumigation
10	Bird screening for ventilators. Rodent proofing for doors.	Pest control

Source: UNCDF, 1985 (Annex I).

APPENDIX 5 PYRAMID-SHAPED CAP STORAGE SPECIFICATION*

Site selection

Site with good access should be on high ground for natural drainage. Firm sub-soil with bearing pressure 100 kN/m^2 or 16 pounds force per square inch. Avoid areas prone to cyclones, flooding or high winds.

Plinth

Construction raised to 0.3 m above ground, measuring 9.6 x 6.1 m. Build in batteries with short side facing prevailing wind to minimize wind damage to covers. Dig trench around plinth perimeter; construct brick wall in this with concrete foundations to a height of 0.6 m; remove top soil and fill inner space with sand**, compact to wall level and top with bricks. Site 36 hooks evenly in concrete blocks around plinth to provide purchase for lashing. The hooks are 20 mm, mild steel, 76 mm from ground. Construct a brick apron 0.6 m wide around the plinth, pointed with concrete.

Dunnage

Use wooden pallet or poles; bamboo mats are placed between the bags and the dunnage to prevent spilling of grain onto the plinth which helps reduce losses.

Covers

Black, low-density polyethylene 250 microns thick, shaped to suit the stack specified below. Separate cover tops provide additional protection. These are composed of high density polyethylene (HDPE) 125 microns thick with 36 eyelets each reinforced with a 50 mm diameter disc of 250 micron thick HDPE on both sides. Nets of HDPE rope 2 mm in diameter, colour black and UV-stabilized, are provided for sites with high winds. Net mesh is 450 x 450 mm. Net size is 10.35 x 7.2 m.

Ropes and lashings

Use 6 mm HDPE ropes or similar for tying stacks. Lash four times on long side, three times on short side. To prevent damage to covers, place gunny sack pads under ropes at stress points between cover and ropes.

Insulation

To prevent moisture migration, place a layer of paddy husk bags on top of the stack. A similar layer on the bottom of the stack will give additional protection.

Stacking

Clean plinths before laying out first wooden pallets and then woven mats, ensuring nothing juts out from the plinth. Stack bags criss-cross-wise for stability and ensure mouths of bags face inward. To ensure proper drainage,

---

*Adapted from Garg (1985)
**anti-termite treatment may be necessary at this point

shape the top of the stack into a pyramid (after the 13th bag); one pattern is as follows:

Alternate layers of 10 bags lengthwise x 11 bags breadthwise, then 7 lengthwise, 16 breadthwise, into 12 layers,

i.e. 6 x 110 = 660
6 x 112 = 672
1332

From the 13th layer the following pattern is adopted:

13th layer	9 x 11	= 99
14th layer	14 x 7	= 98
15th layer	8 x 11	= 88
16th layer	11 x 7	= 77
17th layer	6 x 11	= 66
18th layer	8 x 7	= 56
19th layer	3 x 11	= 33
20th layer	3 x 7	= 21
		508

Thus with a total of 1850 bags x 80 kg each plinth carries about 150 tonnes.

Management

At receipt, sample and analyse before accepting only sound stocks to the plinth. Wheat and paddy are acceptable; do not accept milled products. Stocks in sound or new B-twill gunnies only are acceptable. Non-standard, loose bags or brimful bags are not suitable. Maximum moisture content 14%. Bag mouths should have 12-14 stitches.

Aeration is provided by raising the covers with the minimum labour. Aerate at least one per week in dry season. In rainy season on a clear day raise the covers to the 7-8th layer without removing lashings so that covers can be replaced quickly if sudden rain threatens. This partial aeration is insufficient because it leaves the top of the plinth untouched. Therefore, aerate fully on a sunny day. Sample fortnightly for pest and quality control. During aeration the mats and aprons should be swept clean and any spillage collected. Pest control will be necessary for prolonged storage.

Security is difficult to enforce with CAP storage. Fencing is a minimum requirement and floodlighting is a necessary addition. Of course, 24-hour watchmen are essential.

Salvage if stock does get wet, by destacking and separating the damaged bags. Remove grain cakes and lumps and re-bag. Re-stack after sundrying.

Note: CAP storage is very vulnerable to wind damage. The covers are easily damaged and so rain can damage stock. The system should only be used for emergency storage when dynamic management is available.

APPENDIX 6 EXAMPLES OF EMERGENCY STORAGE SYSTEMS

No.	System components store type	Handling equipment	Transport type	System function or use	Throughput rate (approximate)
A1	Traditional warehouse	manual	bag lorry	transit food relief	low-medium
A1	Drive-through store	fork-lift	bag lorry	railhead transit	high
B3	Frameless pre-stressed steel	pneumatic conveyor	bulk lorry	dockside transit	high
B4	(Aerated) steel silo or pit	augers elevators	bulk trailer	holding over-flow grain	low
B1	Prefabricated panels, terrapin type	manual	bag cart or small truck	final food distribution	medium
C1	Plastic cover light frame	manual	bag lorry	transit storage regional	medium
D5	Polyethylene sheet and eucalyptus poles	manual	bag lorry etc	initial storage	medium
E3	Bunker storage	tipper trucks, scrapers, elevators	bulk lorries, railway waggons	bumper crop storage	low

APPENDIX 7 SUB-CATEGORIES OF EMERGENCY STORES

Symbol	Description where necessary
A1	Conventional frame warehouse with steel portal or lattice frame. Metal roof cladding; metal, r.c. or other wall cladding. Concrete floor. Drive-through design requires large doors in opposite walls and reinforced floor to withstand loaded lorries. A permanent building.
A2	As A1 but with retaining walls for bulk grain. Aeration facility may be built in. A permanent building.
A3	A category including a variety of warehouses generally similar to A1, but unconventional in detailed design, therefore erected differently. Designs with prefabricated wall sections incorporating load-bearing members and steel claddings are quick to erect but more bulky for transport. Designs with structural members made up on site from components are slow to erect but economical to ship.
A4	A warehouse as type A1 but with design optimized for easy shipment and erection.
A5	Prefabricated steel building which folds for transport and is very rapidly erected using a crane. Size limited by the need to transport the complete folded building on one vehicle.
A6	Nissen-type steel-framed steel-clad building of semi-circular cross-section. Doors normally in the ends.
A7	Traditional buildings of wood pole, earth brick and thatch, or other local materials.
B1	Industrial building system of load-bearing prefabricated flat panel sections for walls and roof.

B2 Low-technology building system employing wood and cork panels and plywood components, for small buildings only (under development).

B3 Frameless steel buildings constructed from prestressed shaped steel panels to give a mansard-shaped structure.

B4 Bulk silos of corrugated steel; must be provided with handling plant and normally also aeration facilities.

C1 Flexible-clad warehouses with a frame of steel or aluminium and clad with PVC-coated synthetic fabric. Drive-through design may be possible with some types.

C2 Flexible-clad structure, locally built with wood frame clad with plastic sheet.

C3 Traditional grain store, wooden framework with woven matting covering for roof and walls.

C4 Flexible silos for bulk or bagged grain, with plastic film, plastic-coated fabric or rubber container and roof, and walls supported by welded steel mesh.

C5 Air-supported structure — flexible building supported by inflated double-wall sections. Requires a fan only for inflation. No increase in air pressure in storage space.

D1 Marquee tents, canvas with main supporting poles and subsidiary poles around vertical walls; ropes and ground anchors keep the tent erected.

D2 Cover and plinth system; outdoor stack on raised plinth with shaped plastic sheet cover. *See* Appendix 5.

D3 Outdoor stack covered with flat sheet tarpaulins of waterproof natural or synthetic fabric or tough plastic. Sheets preferably provided with reinforced eyelets and ropes to assist fixing.

D4 Airwarehouse supported by increased air pressure inside building, provided by continuously running fan. Requires air-lock doors to enable the slightly elevated pressure to be maintained during loading.

APPENDIX 8 A NOTE ON STEEL FRAME WAREHOUSE DESIGN FOR EMERGENCY

The following factors contributed to design (Reid, 1987):

1 Having observed feeding stations, refugee camps, rehabilitation schemes and even re-housing schemes in many unfortunate parts of the world, we became convinced of a need for a cheap yet efficient standardised steel structure.

2 The following factors influenced the design:

(i) The cost of the basic element should be very low (the target price was £10/m^2 though this has now crept up slightly — see paragraphs 6 and 7.

(ii) All the items should be containerable, with several structures in one 20 ft container.

(iii) Each element should be manhandleable and portable, and thus should be able to get into difficult spots.

(iv) No power tools and plant or equipment should be needed.

(v) The building should be quick to erect, using unskilled labour with minimum supervision.

(vi) The building should be relocatable.

(vii) The building should be durable to full permanent standards.

(viii) The building should be able to evolve from simple overhead cover to enclose store to high standard lined and insulated buildings for use as hospitals or schools or community centres.

(ix) The building should be able to sit on flat soil, or existing concrete, tarmac or concrete pads or almost anything.

(x) The finish inside and out of the rafters and cladding rails and purlins should be flush to make lining, insulating, etc. very simple.

3 The structure decided upon was a steel portal-framed building 2.5 m to eaves and 11m wide, and usually 29.5 m long in 5 bays of 5.9 m.

4 It is nominally designed for 40 kg/m^2 of snow or imposed load or 60 kg/m^2 of wind (equal to a 50 year gust of perhaps 168 km/hour (47 m/s).

5 The most cost-effective and economical cladding is Aluzinc coated profiled steel. It has a life expectancy of about 3 times that of galvanized steel and has better reflective/emissive properties.

6 The basic structure consists of 6 frames, 10 purlins, the roof sheeting and ridge capping and all fixings and necessary bracings. It is easy to pack 4 such structures into a 20 ft container and sometimes possible to carefully fit in 5 buildings. The price for 4 roofed buildings ex-works loaded into a container is £15,320. Each shelter weighs about 4.2 t.

7 The same building but clad on the walls and incorporating sliding doors 2 x 2 m in the ends costs a bit more. Three can be fitted into a 20 ft container for a price of £18,940. Each enclosed store weighs about 6.5 t.

8 Every normal option of sheeting could be more available. For example in arid and sunny regions (such as the Sahel) the roof sheeting should be white polyester enamel-coated steel, at a modest extra price. Near humid sea shores, white-coated aluminium or white PVF2-coated steel may be a better choice. If buildings are to be air-lifted, or transported by helicopter then mill finish aluminium may prove the overall cost-effective solution. Drawbacks of different sheeting options include increased prices, minimum quantities (usually equivalent to about 6 units) and sometimes delayed deliveries.

9 Every option of window and ventilation and door is available. The drawbacks are increased costs and delays. Small quantities of exotic items cost more out of all proportion. A common requirement which is simple, is to have a band of translucent sheeting 0.3 m deep under both eaves. This only costs £120 extra per unit and gives a good internal light.

10 The lining of the walls can be done simply with a wide variety of materials, from local blankets to anodised aluminium panels. The list is too long to elaborate but a cost effective option is white enamelled galvanized steel liner plus 50 mm of fibreglass which costs £1,950 for each simple shelter or £2,750 for each enclosed shelter, giving a really nice clean looking interior and reasonable insulation.

11 The building can be staked to the ground with steel pins; bolted onto existing slabs; bolted onto purpose-made slabs or footings or staked first and slabbed later (which does make relocatability more difficult). A typical simple shelter should be erected in a few days although the record with an experienced crew of three men is $2\frac{1}{2}$ days.

12 Tools are only two spanners, one drill, one speed brace and one pop rivetter. Such a tool kit costs £27 and should serve to erect many shelters, but three spare drill bits (value £3) are needed for each new shelter.

APPENDIX 9 DERIVATION OF TABLE 4 DATA

Sources of data

Manufacturer's ex-works or f.o.b. prices for structures — see Part II. No provision is made for discounts.

Prices for containers, sea/air freight, rail and road charges in Sudan from Dacair Transport Ltd.

Erection costs include all expenses for supervisor (Part II), but no allowance for local labour because this regarded as a site cost.

Costs for foundations and floors are from Spon's, 1987.

Notes:

Building height are to eaves except where stated.

Dunnage is assumed to be locally procured (Morton, 1987) and a cost is estimated here; this is not included in the capital cost used in Appendix 10 because, with a 4-year life, this becomes an operating cost. Similarly, no charge is made for maintenance. The omission of these costs may or may not affect all stores equally, but is covered by the 15% contingency charge.

Sea freight rates are quoted in US$ and an exchange rate of $1 = £0.71643 has been used.

The cost of handling freight containers in port Sudan is unobtainable; the estimate used, $400, is above typical United Kingdom rates.

The most important assumption (Walker, 1986) is to have a stacking height of 2.0 m only; this is also discussed in the text. However, higher stacking and one single stack in each store have been included, to represent the pressure on storage that occurs on most sites from time to time.

A4 Steel portal-frame warehouse

2.5 m high x 11 m wide x 29.5 m long
Capacity: 2 stacks 2 x 3.5 x 27.5 m = 385 m^3 = 257 t maize
1 stack 2.5 x 9 x 27.5 m = 619 m^3 = 413 t maize

1 Capital costs

	£
3 warehouses complete, packed in 1 container, f.o.b.	18,940
Container, 20 ft, non-returnable	750
Sea freight, United Kingdom to Port Sudan $1750	1,268
Rail freight, Port Sudan to Khartoum $1000 + $400	1,014
Erection supervisor:	
30 days @ £100/day + expenses	7,200
Concrete foundations and 150 mm (6") floor	
3 x 324.5 m^2 @ £20/m^2	19,470
Dunnage, local	
3 x 324.5 m^2 @ £2/m^2 nominal	1,947
Total	50,598
Contingencies 15%	7,588
Grand total	£58,177

Capital cost for each warehouse	19,392
Capital cost per tonne stored @ 257 t capacity	75.5
Capital cost per tonne stored @ 413 t capacity	47.0

Capital cost for Table 4 and Appendix 10 excludes dunnage, i.e. £19,392 — 1/3 (1947 x 1.15) = £18,646.

2 Procurement period

	Days
Delivery from receipt of firm order to f.o.b.	28
Waiting for ship, maximum	14
Voyage to Port Sudan	21
Clearance from Port Sudan in emergency sitution	28
Transport (road or rail) to Khartoum, say	14
Transport, Khartoum to site, 6.5 t load (1 warehouse), say	10
Total:	115

B3 Steel frameless prefabricated store

3.1 m high x 9.3 m wide x 23.4 m long
Capacity: 1 stack 2 x 6.3 x 21.4 m = 270 m^3 = 180 t maize
1 stack 2.5 x 7.3 x 22.4 m = 409 m^3 = 273 t maize

1 Capital costs

	£
4 modular stores complete, packed in one container, f.o.b.	24,272
Container, 20 ft, non-returnable	750
Sea freight, United Kingdom to Port Sudan $1750	1,268
Rail freight, Port Sudan to Khartoum $1000 + $400	1,014
Erection supervisor:	
2 weeks @ £600/wk + expenses	3,800
Concrete foundations and 100 mm (4″) floor,	
4 x 217.6 m^2 @ £10/m^2	8,705
Dunnage, local	
4 x 217.6 m^2 @ £2/m^2 nominal	1,741
Total	£41,550
Contingencies 15%	6,232
Grand total	£47,782
Capital cost for each warehouse	11,946
Capital cost per tonne stored @ 180 t capacity	66.4
Capital cost per tonne stored @ 273 t capacity	43.8

Capital cost for Table 4 and Appendix 13 excludes dunnage, i.e. £11,946 = 1/4 (1741 x 1.15) = £11,445.

2 Procurement period

	Days
Delivery from receipt of firm order to f.o.b.	14
Waiting for ship, maximum	14
Voyage to Port Sudan	21
Clearance from Port Sudan in emergency situation	28
Transport (road or rail) to Khartoum, say	14
Transport, Khartoum to site, 4.46 t load (1 warehouse), say	10
Total:	101

C1 Steel frame plastic-clad store

3.3 m high x 12 m wide x 24 m long
Capacity: 2 stacks 2 x 4 x 22 m = 352 m^3 = 235 t maize
1 stack 2.5 x 10 x 23 m = 575 m^3 = 383 t maize

1 Capital costs

	£
4 steel/plastic stores complete, packed in one container	36,320
Container, 20 ft, non-returnable	750
Sea freight, United Kingdom to Port Sudan $1750	1,268
Rail freight, Port Sudan to Khartoum $1000 + $400	1,014
Erection supervisor:	
4 days @ £120/day + expenses	2,080
Floor cover sheet: 4 x 288 m^2 @ £2/m^2	2,304
Dunnage, local: 4 x 288 m^2 @ £2/m^2	2,304
Total	£46,040
Contingencies 15%	6,906
Grand total £	52,946
Capital cost for each store	13,236
Capital cost per tonne stored @ 235 t capacity	56.3
Capital cost per tonne stored @ 383 t capacity	34.6

Capital cost for Table 4 and Appendix 10 excludes dunnage, i.e. £13,236 — 1/4 (2304 x 1.15) = £12,573.

Alternatively:

1 steel/plastic store, complete, packed for export	9,080
Air freight, United Kingdom to Khartoum,	
4440 kg @ £1.50/kg	6,660
Erection supervisor, 3 days @ £120/day + expenses	1,860
Floor cover sheet: 288 m^2 @ £2/m^2	576
Dunnage, local: 288 m, @£2/m^2	576
Total	£18,752
Contingencies 15%	2,813
Grand total	£21,565
Capital cost per tonne stored @ 235 t capacity	91.8
Capital cost per tonne stored @ 383 t capacity	56.3

2 Procurement period

	Sea (days)	Air (days)
Delivery from receipt of firm order to f.o.b.	7	7
Waiting for ship, maximum	14	—
Voyage to Port Sudan	21	—
Air transport, United Kingdom to Khartoum	—	7
Clearance, Khartoum airport	—	3
Clearance from Port Sudan	28	—
Transport, Port Sudan to Khartoum, say	14	—
Transport, Khartoum to site, 4.4 t load, say	10	10
Total:	94	27

D1 Marquee tent

1.8 m high x 6 m wide x 19 m long
Capacity: 2 stacks 2 x 4 x 7.5 m = 120 m^3 = 80 t maize
1 stack 2.5 x 5 x 18 m = 225 m^3 = 150 t maize

1 Capital costs

	£ New	£ Secondhand
1 tent complete with poles, pegs, etc.	2,800	1,050
Air freight, consolidated, 450 kg @ £1.50	675	675
Erection, local supervision, nominal	50	50
Floor cover sheet, 114 m^2 @ £2/m^2	288	288
Dunnage, local: 114 m @ £2/m^2	288	288
Total	3,981	2,231
Contingencies 15%	597	335
Capital cost per tent	4,578	2,566
Capital cost per tonne @ 80 t capacity	57.2	32.1*
Capital cost per tonne @ 150 t capacity	30.5	17.1

Capital cost for Table 4 and Appendix 10 exclude dunnage,
i.e. New £4578 — (228 x 1.15) = £4,316
Secondhand £2,566 — (288 x 1.15) = £2,304.

2 Procurement Period

	Days
Delivery from receipt of firm order to f.o.b.	7
Air transport, United Kingdom to Khartoum	7
Clearance, Khartoum airport	3
Transport, Khartoum to site, 0.5 t, say	3
	20

D3 Tarpaulin cover

Set of 3 tarpaulins 6 m x 10 m finished dimensions
Stack: preferred 4 x 8 m base, 2 m peak height = 48 m^2 = 32 t maize
alternative 5 x 9 m base, 2.5 m peak height = 76.5 m^3 = 51 t maize

1 Capital costs

	£
3 tarpaulins complete with eyelets and ropes, 180 m^2 @ £0.79/m^2	142
Net, polypropylene, 8 x 13 m	19
Air freight, 42 kg @ £1.50/kg (consolidated rate)	63
Erection, local supervision, nominal	25
Dunnage, local: 4 x 8 m stack, 32 m^2 @ £2/m^2	64
Total	313
Contingencies 15%	47
Capital cost per stack	360
Capital cost per tonne @ 32 t per stack	11.2
Capital cost per tonne @ 51 t per stack	7.6†

Capital cost for Table 4 and Appendix 10 excludes dunnage, i.e. £360 — (64 x 1.15) = £286.

*average capital cost used in Table 4 = (57.2 + 32.1) ÷ 2 = £44.7
†allows for additional dunnage

2 Procurement Period

	Days
Delivery from receipt of firm order to f.o.b.	5
Air transport, United Kingdom to Khartoum	5
Clearance, Khartoum airport	3
Transport, Khartoum to site, 42 kg	1
	14

APPENDIX 10 DERIVATION OF ANNUAL COSTS

A Dunnage and maintenance are regarded as local operating costs and are excluded.

B No residual values are allowed, although these can be calculated from Table 4 for relocatable stores from annual costs and use of tables.

C A useful life of 25 years for portal frame warehouses (normal practice)
13 years for frameless modular structure (Timpson, 1987)
6 years for plastic-clad warehouse (Timpson, 1987)
4 years for canvas army tents (estimated)
2 years for length of 'average' emergency (FAO, 1986)
0.5 years for life of reinforced polythene tarpaulin (Reece, 1987)

D A rate of interest of 10%

E An annual throughput of six weeks or nine times a year with 2 m stacking and store capacities given in Table 3.

		A4 Steel portal-frame	B3 Steel prefabricated	C1 Steel frame plastic-clad	D1 Marquee tent	D3 Tarpaulin
Capital cost		£18,646	£11,445	£12,573	£3,310**	£1,144*
Capacity, tonnes		257	180	235	80	32
Capital cost/tonne throughput/year		£8.06	£7.06	£5.94	£4.60	3.97
Annual cost £ per tonne *throughput/year* (y)						
Life (y)	Factor					
2	0.576109	4.64	4.07	3.42	2.65	2.29
4	0.315471	2.54	2.23	1.87	1.45	
6	0.229607	1.85	1.62	1.36		
13	0.140779	1.13	0.99			
25	0.110168	0.89				

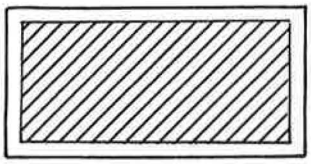
Notes: * Average of new and second-hand or renovated tent prices
** Four sets of tarpaulins @ £286 purchased every 2 years

APPENDIX 11 STORE CAPACITY FOR BAGGED PRODUCE

Store size	Small	Medium
Length, m.	20	40
Width, m.	10	15
Floor area, sq.m.	200	600

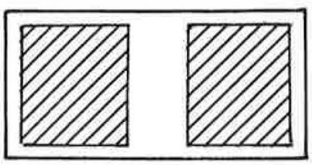
Stacking condition

Maximum



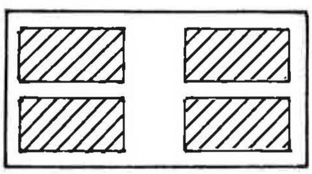
% of gross floor area:	72	82
Stack volume with 2 m high stack, m^3:	288	988
Sugar, tonne	240	823
Rice, ,,	192	659
Wheat flour, ,,	194	668

Two stacks with 4 m central gangway



% of gross floor area:	56	74
Stack volume with 2 m high stack, m^3:	224	884
Sugar, tonne	186	737
Rice, ,,	149	589
Wheat flour, ,,	151	597

Four stacks with 4 m central gangway



% of gross floor area:	49	68
Stack volume with 2 m high stack, m^3:	196	816
Sugar, tonne	163	680
Rice, ,,	130	544
Wheat flour, ,,	132	551

NOTE: All stacks are one metre clear of walls.

Tonne/volume:

One tonne of sugar occupies 1.2 m^3
One tonne of milled rice occupies 1.5 m^2
One tonne of wheat flour occupies 1.48 m^2

REFERENCES

CALVERLEY, D.J.B., (1987) personal communication.

EATON, K.J. (1980) How to make your building withstand strong winds. Pap. pres. at Building Research Establishment Seminar on low-income housing, St. Vincent, 26-27 March 1980.

FAO (1983) Food Storage Manual, 2nd Edition (revised and condensed). Prepared by TDRI.

FAO (1985) The state of food and agriculture, FAO, Rome.

FAO (1986a) World Food Report. FAO, Rome.

FAO (1986b) Repositioning of food stocks to expedite delivery of emergency food aid. FAO Committee on World Food Security. Agenda Item b. CFS 86/5 FAO, Rome.

FORTMAN, M. de G. (1987) Officer in charge WFP Sudan. Personal communication.

FRIENDSHIP, C.A.R. (1987). Personal Communication.

GARG, M.K. (1985) CAP storage, an economic warehousing technique. Pap. pres. at the 1985 Conference of International Federation of Public Warehousing Association, London.

GOUGH M.C. (1979) Studies of tropical weathering properties of selected plastics and rubbers. *Journal Applied Polymer Sci.*, 35, 387-394.

GOUGH, M.C. et al (1987) Physical Changes in Stored Bulk Rice. J. Agric Engng Res (1987) *37*, 59-71.

HAUSER, R. (1986) WFP Pakistan, personal communication.

HILL, J. (1987) Personal Communication.

HODGES, R.J. (1986). TDRI Internal Report: Mali. File OM/1 Annex.

HOUGHTON, E.L. and CARRUTHERS, N.B. (1976) Wind forces on buildings and structures, an introduction. Edward Arnold, London, p 150.

KENNEFORD, S. and O'DOWD, T. (1981) Guidelines on the use of flexible silos for grain storage in the tropics. *Trop. stored Prod. Inf.*, 42, 11-20.

KING, S. (1987) Catholic Fund for Overseas Development. Personal communication.

METEOROLOGICAL OFFICE, Bracknell: Overseas Section. (1987) Design wind speed data. Personal communication.

MORLEY, G.E.J. (1987) Personal communication.

MORTON, D. (1987) WFP Director of Operations, Addis Ababa. Personal communication.

MURRAY, A. (1987) Commodity Storage Ltd. Personal communication.

NICHOLLS, R. (1986) OXFAM, Kenya. Personal communication.

O'DOWD, E.T. and KENNEFORD, S.M. (1982) Field performance of flexible silos in the tropics. TDRI Report No. G.179.

O'DOWD, E.T. (1986) Assessment of emergency storage for drought relief in Botswana. Interim Report, Project A.1271. TDRI mimeo.

O'SHEA, S. (1984) Report on existing storage facilities. Ministry of Finance and Economic Planning, Democratic Republic of the Sudan.

REES, R. (1986) Catholic Fund for Overseas Development. Personal communication.

REID, R. (1987) John Reid & Sons Strucsteel Limited. Personal communication.

ROBERTSON, A. (1987) AFRC. Personal communication.

TIMPSON, A. (1987) Save the Children Fund, Uganda. Personal communication.

TOOMEY, G. (1987) IDRC Report Vol 16 No 2. Predicting Famine. April 1987.

TWIDALE, J.M. (1987) Sudan Interior Mission. Personal communication.

TYLER, P.S. (1987) Personal communication.

UNCDF (1985) Food Stores for Drought Relief. United Nations Capital Development Fund. BOT/84/COL UNCDF, New York.

WALKER, D.J. (1987) ODNRI Personal communication.

WALKER, P. (1986) OXFAM, Sudan, Personal communication.

WINER, N. (1987) OXFAM, Ethiopia. Personal communication.

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