## Chapter III

## CONTAINER TERMINALS

### A. Container ship development

105. Container ships are generally classified into “generations”, that is, as having characteristics typical of certain stages in container development and container shipbuilding. The main characteristics of each “generation” are shown in table 1. The term TEU (twenty-foot equivalent unit or equivalent in goods to a container of 20 feet) is a useful standard term for defining the carrying capacity of a container vessel: a 40-foot container therefore counts as two TEUs. The principal dimensions of 20-foot and 40-foot steel containers are given in table 2. The R-foot high 20-foot container has been largely replaced by the X-foot 6-inch unit. and for the 40-foot container the trend is towards units of 9 feet to 9 feet 6 inches.

TABLE 1

**Physical characteristics of container ships**

| | *Container capacity (TEUs)* | *Dwt* | *Overall length (metres)* | *Overall width (metres)* | *Draught (metres)* |
|---|---|---|---|---|---|
| “First-generation” container ships | 750 | 14 000 | 180 | 25 | 9.0 |
| “Second generation” container ships | 1 500 | 30 000 | 225 | 29 | 11.5 |
| “Third generation” container ships | 2 500–3 000 | 4owo | 275 | 32 | 12.5 |

106. To keep operating costs to a minimum, the maximum utilization of these large modern vessels must be achieved. Thus there has been a move to reduce the number of ports of call of the mother ships and to introduce feeder vessel services to the ports with smaller volumes of trade. The feeder ships have the task of relieving the long-haul container ships from making the extra calls which greatly increase the total time they spend in ports. Feeder ships vary in size from capacities of 50 to 75 TEUs up to 300 TEUs.

107. The rapid spread of container operations has been very fully documented. A detailed discussion of containerization and its impact on ports in developing countries is given in the UNCTAD publication on the subject” and in a series of reports prepared by the UNCTAD secretariat on the subject of technological change in shipping and its effects on ports.’ The last major trade routes between highly industrialized countries have been containerized. At the same time, there is an increasing trend towards containerization of certain specific services linking developing and developed countries.

[2] *Unitization* of Cargo (United Nations publication, Sales No. E.71.11.D.2).

[3] “Technological change in shipping and ifs effects on ports” (TD/B!C 4/129 and Supp.1–6).

TABLE 2

**Principal dimensions of typical steel containers**

| | *20 ft × 8 ft × 8 ft* | | *20 ft × 8 ft × 8 ft 6 in.* | | *40 ft × 8 ft × 8 ft 6 in.* | |
|---|---|---|---|---|---|---|
| | *Corrugated roof* | *Flat roof* | *Corrugated roof* | *Flat roof* | *Corrugated roof* | *Flat roof* |
| Inside (*in millimetres*) | | | | | | |
| Length ...................... | 5 897 | 5 897 | 5 897 | 5 897 | 12 022 | 12 022 |
| Width ...................... | 2 352 | 2 352 | 2 352 | 2 352 | 2 352 | 2 352 |
| Height ...................... | 2 246 | 2 221.5 | 2 395.5 | 2 371 | 2 395.5 | 2 371 |
| Door opening (*in millimetres*) | | | | | | |
| Width | 2 340 | 2 340 | 2 340 | 2 340 | 2 340 | 2 340 |
| Height | 2 137 | 2 137 | 2 280 | 2 280 | 2 280 | 2 280 |
| Inside cubic capacity (in *cubic metres*) | 31.5 | 30.8 | 33.2 | 32.9 | 67.7 | 67.0 |
| Tare weight (*in kilograms)* | 2 230 | 2 260 | 2 300 | 2 330 | 4 050 | 4 loo |
| Stacking capacity | 9 high | 9 high | 9 high | 9 high | 9 high | 9 high |

108. Examples of this trend are services between Europe and the Caribbean, between Europe and the Middle East, between Europe and West Africa, between Europe and the Far East, between Europe and South America, between North America and the Far East, between North America and South America and between North America and Central America. Generally the vessels involved are of the first generation or, on the shorter runs, feeder vessels. The basic problems with these services are the imbalance of trade and the labour problems caused by the reduced damage for manpower.

109. At present these and similar container services carry a fraction of the general cargo liner traffic between developed and developing countries, but in developed countries' ports container services already handle between 70 and 80 per cent of the cargo. Therefore port authorities in developing countries must consider the development towards containerization of their countries' trade, and the profound changes in port planning, management and operations which such development brings with it. Thus it is not a question of whether or not to containerize, but rather when to containerize.

110. Both the break-bulk berth group and the multi-purpose terminal must be capable of handling containers-even if, in the former case, only a small number of units are carried (mainly on deck) in a liner operation. This chapter is concerned with the specialized container terminal needed to handle the cellular container ships.

111. These large ships will not normally call at a port without a specialized container terminal offering a specified level of service. By investing in a specialized terminal a port can make calls by container ships possible, but such an investment cannot be financially justified until a satisfactory level of use is guaranteed. The container throughput must be around 50,000 TEUs per year if the investment is to be justified. Below this level, the port should either provide limited facilities for container feeder ships or adopt the transitional multi-purpose terminal described in the next chapter.

## B. Planning and organization

112. It is wrong to imagine that the planning, organization and running of a container terminal is a straightforward task. Figure 16 gives an indication of the main factors which have to be taken into consideration in planning a container terminal and can be used as a checklist in order to ensure that none of the most important issues have been overlooked. The complexity of this type of terminal coupled with its newness necessitates a comprehensive training programme of the senior operating staff, often in a well-organized and efficient container terminal.

## C. Productivity

113. There has been considerable inaccuracy in predicting container terminal productivity. In the course of its investigations into technological change in shipping and its effects on ports. the UNCTAD secretariat found that the average throughput for a sample of 21 ports was 442 containers per 24 hours in port,[4] a figure significantly below figures which are often quoted.

114. The average productivity per hour per vessel, even averaged over a long period, varies considerably from one terminal to another. from about 10 to 50 containers per hour, even on the same cellular ship operated by two gantries, averaged over a 24-hour period. This figure refers to single units either loaded or discharged and includes any idle time within a working period. The early operating objective of lifting one container off and one container on in a combined cycle is now rarely achieved or even attempted for any significant period.

115. The gross productivity per hour can be converted to a daily figure by using the ratio of working time to berth time. The working time includes any idle time within a working period, such as that due to equipment breakdown, and therefore for ports operating around the clock the ratio could be 100 per cent. A number of reasons prevent ports from achieving this 24-hour per day operation, however, and the ratios usually vary between a peak of 95 per cent and a low of 40 per cent. Clearly this variation in the intensity of working can have a significant effect on the annual throughput of the terminal.

116. The figures for throughput per 24 hours in the sample referred to above varied from a high of approximately 750 containers to a low of approximately 225 containers. The average throughput for these terminals was nearly 450 containers per 24 hours in port, Given that at most terminals 24-hour operation seven days a week is standard practice, the typical throughput was calculated as follows in the early 1970s:

Average output per gantry-crane 20 units per hour
Average number of gantry-cranes allocated to each vessel: 2
Working time/berth time ratio: 0.80

Thus, according to this earlier method,

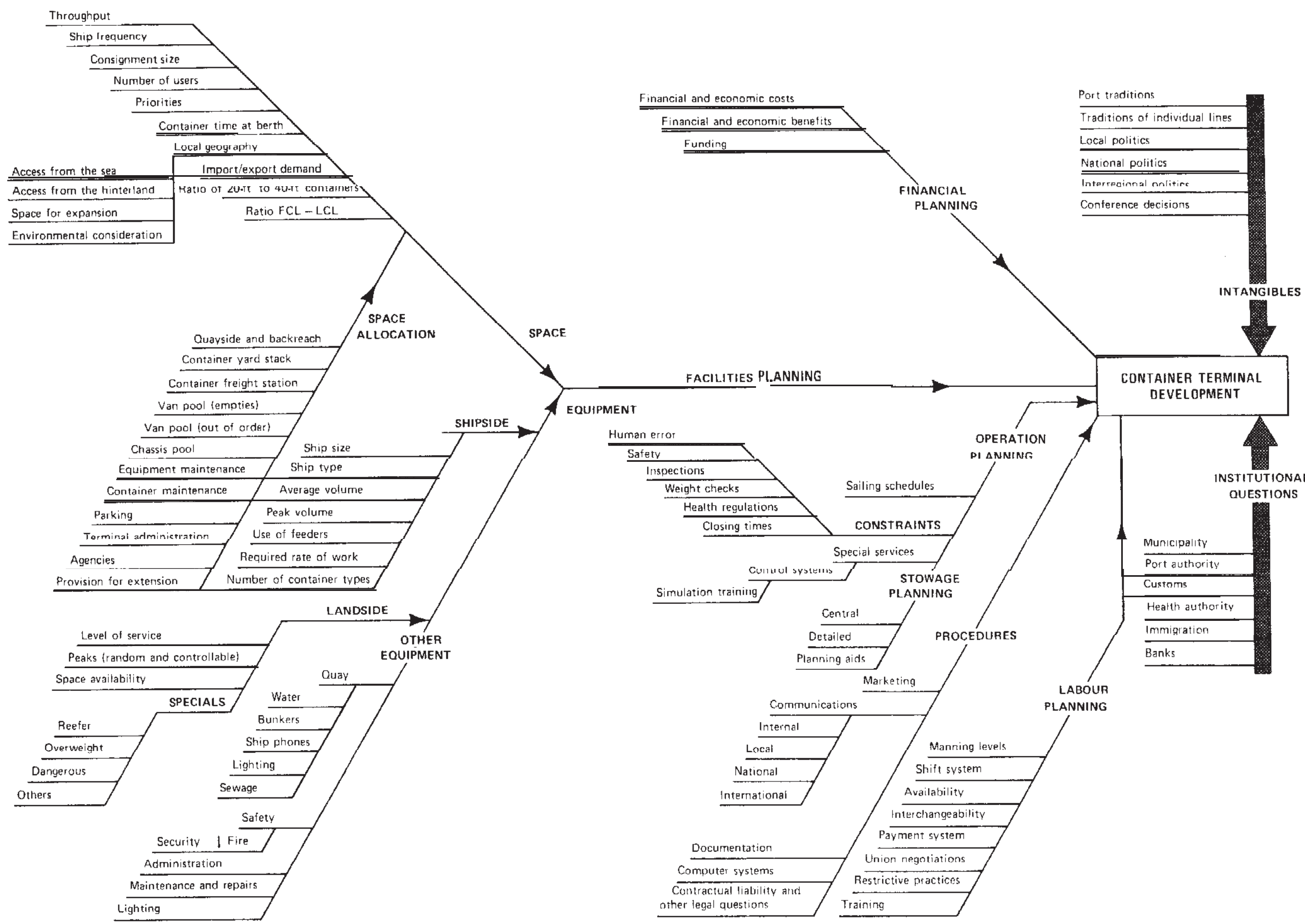
| | | |
|---|---|---|
| Average throughput per 24 hours | = | 24 (average output per crane) × (average number of cranes allocated) × (working time/berth time ratio) |
| | = | 24 (20 × 2) (0.80) |
| | = | about 770 containers. |

117. The actual average throughput of the sample is slightly less than 60 per cent of this theoretical figure. Clearly the figures used in this procedure are too optimistic for planning purposes and more realistic figures should be used when calculating ship turn-round time for the economic analysis, especially when one considers that this sample is for major terminals handling second- and third-generation cellular vessels and working three shifts with two cranes on average.

[4] "Technological change in shipping and its effects on ports: the impact of unitization on port operations" (TD/B/C.4/129/Supp.1), para. 90.

FIGURE 16

**Dependency tree for container terminal planning**



118. There is little doubt among container terminal experts that the present performance of container facilities throughout the world is far from optimum. No doubt part of the difficulty stems from the fact that there is excess capacity at the present time of economic slump and that fewer goods are being moved by this form of transport. However, there are also operational inefficiencies which are due to inappropriate planning decisions, operating procedures, equipment or manpower policies. The main reasons lie in the imbalance between the capacities of the various system parts at a terminal, which results in low hourly productivity per crane, and inadequacies in the inland transport system, which often results in long non-operational periods.

119. In general, the capacity which has been provided for the loading and unloading of containers exceeds the terminal's transfer, stacking, storage and delivery capacity. This has been due primarily to an underestimation of the transfer distances that would have to be covered and of the proportion of time that equipment would be out of service for maintenance purposes. A survey carried out in four ports in the United Kingdom showed that the proportion of time during which straddle-carriers were out of service for maintenance averaged almost 30 per cent.[5] The figure was even higher than this in ports with a high workload. This fact supports the UNCTAD secretariat's view that, for developing countries, tractors and trailers are likely to be the most economic system for the transfer operation and that straddle-carriers should be considered as merely one possibility for the stacking operation.

## D. Container handling systems

120. The four most commonly used container handling methods in operation today are the trailer storage system, the heavy-duty fork-lift truck system, the straddle-carrier system, and the gantry-crane system, the gantry-cranes being either rail mounted or rubber tyred. There can also be various combinations of these types of equipment at individual terminals. The essential features of each of the main systems are given in the following paragraphs.

### 1. Trailer storage system

121. The import containers discharged from a ship by crane are placed on a road trailer, which is towed to an assigned position in the storage area where it remains until collected by a road tractor. Trailers carrying containers for export are placed in the storage area by the road tractors and towed to the ship by port equipment. The containers are thus of necessity stored one high. requiring a large transit storage area (see figure 17). Limited soil improvement is required due to low loading. This is a very efficient system because every container is immediately available for removal by a tractor unit, but in addition to requiring a large area it also requires thousands of trailers, entailing considerable expense. This method is therefore normally used only when a shipping company provides the trailers and either operates at a leased or reserved berth or has access to a special trailer compound. This makes trailer storage generally unsuited for use by multi-user terminals. As a rough rule of thumb for 2,000 TEUs, a container storage area of 100,000 square metres is required.

### 2. Fork-lift truck system

122. A heavy-duty fork-lift truck with a capacity of 42 tons and a top-lift spreader is capable of stacking fully loaded 40-foot containers two or three high, with the most common stacking height of two high. A side spreader can be used for 20-foot containers, both full and empty, and for 40-foot empties. Empty containers can be stacked four high. This system places heavy loading on the surface of the terminal and adequate soil improvement and surfacing must therefore be provided. Most port authorities and cargo-handling companies have experience in both the operation and maintenance of fork-lift trucks. Such trucks can transfer containers from the ship's side to the stacking area, or tractor-trailer units can be used which will reduce the number of fork-lift trucks required. Typical aisle widths in the stacking area are 18 metres for 40-foot units and 12 metres for 20-foot units. As a rough rule of thumb for 2,000 TEUs, with an average stacking height of 1.5 boxes, a container storage area of 72,000 square metres would be required.

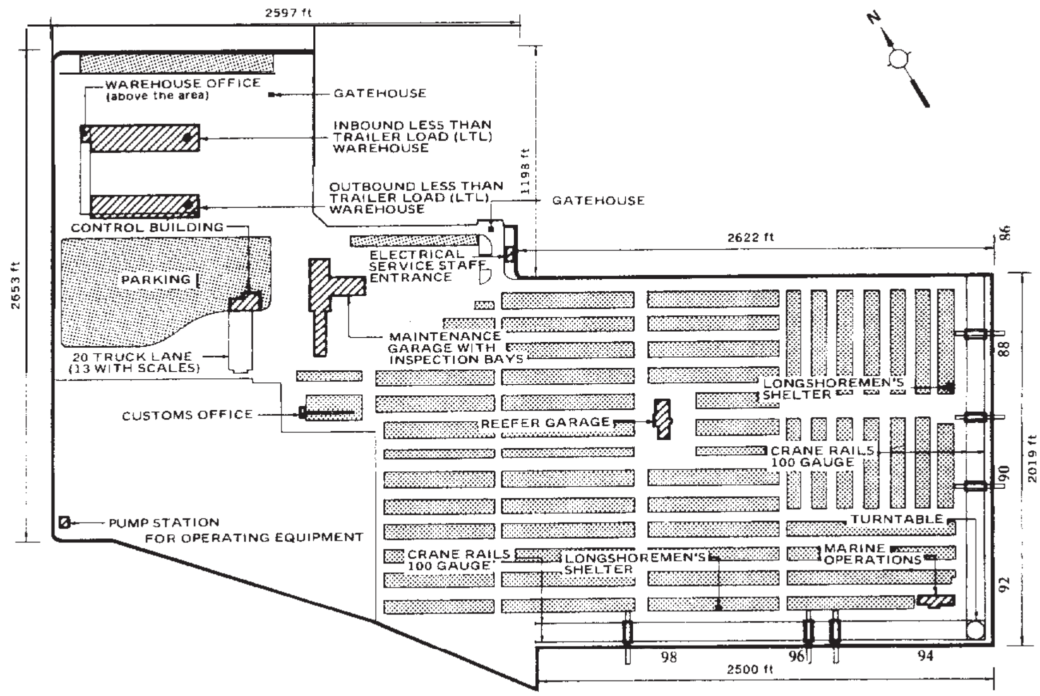
### 3. Straddle-carrier system

123. At the present time the straddle-carrier system is the predominant one. Straddle-carriers can stack containers two or three high, move them between quay crane and storage area, and load or unload them to or from road transport (see figure 18). In the past, however, these machines have had a poor reliability record. poor visibility, high maintenance costs and a short life. Leaks from joints in the hydraulic system and oil spillage from damaged pipework caused highly slippery surfaces, broke up asphalt paving and necessitated continual renewal of the white lines and numbers essential in stacking areas. Safe operation demanded that straddle-carriers should operate within a restricted area, and that workers on foot should be kept out of the working area. The fact that despite these drawbacks the straddle-carrier is so widely used is a testimony to its flexibility and its ability to meet peak requirements. Furthermore, major improvements have been made in the design of straddle-carriers, and most of their poor maintenance record resulted from a lack of preventive maintenance and the excessive use of the equipment for transfer operations. A variant of this system is the use of tractor-trailer units for the transfers between quayside and storage area, and the use of straddle-carriers only within the storage area for stacking and selecting containers. Approximately six straddle-carriers are required for each ship-to-shore gantry-

[5] H. K. Dally, "Straddle carrier and container crane evaluation". *National Ports Council Bulletin* (London), No. 3, 1972.

**FIGURE 17**

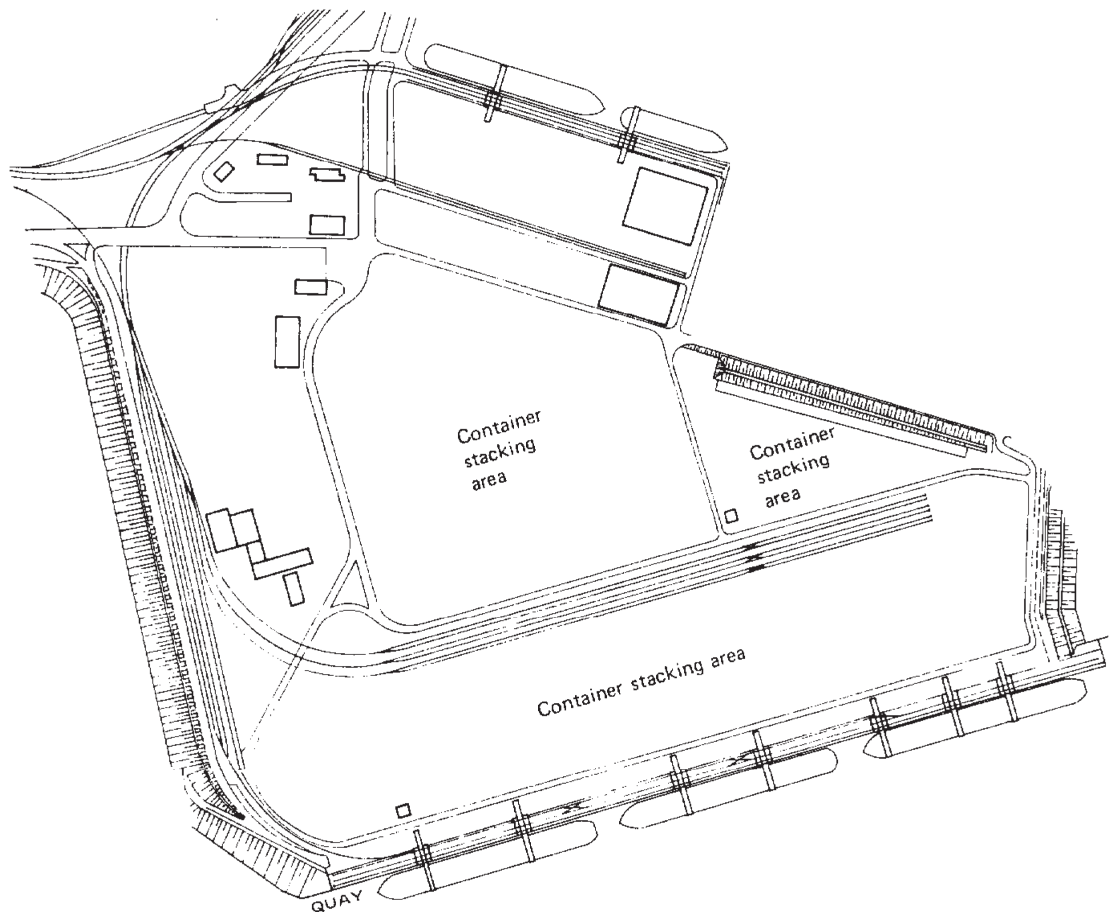
**Example of trailer storage container terminal layout**




*General plan of new sea-land terminal at Elizabeth, New Jersey.*
*(Parking space 3,757 35-ft containers and 2,498 40-ft containers.)*

**FIGURE 18**

**Example of straddle-carrier container terminal layout**




*Container terminal, Bremerhaven (Federal Republic of Germany)* crane. As a rough rule of thumb for 2,000 TEUs, a container storage area of 40,000 square metres for 1.5-high stacking, or 30,000 square metres for two-high stacking is required.

### 4. Gantry-crane system

124. In this system, containers in the storage area are stacked by rail-mounted or rubber-tyred gantry-cranes (see figure 19). Rail cranes can stack containers up to five high (although normally containers are stacked no more than four high). Rubber-tyred gantry-cranes can normally stack containers two to three high. Tractor-trailer units make the transfers between quayside and storage area. This system is economical in land because of the high stacking, and is suitable for varying degrees of automation. Gantry-cranes have a good safety record, are reliable and have low maintenance costs and a long life in comparison with straddle-carriers. They are far less flexible but to offset this, gantry-cranes (particularly the rail-mounted type) are better suited for automation. In the longer term, the need to economize in land is likely to be very important, and this favours the use of gantry-cranes. This system is especially useful where exports are a substantial proportion of the total traffic, but perhaps less than optimum where import cargoes constitute the major portion of the traffic. This is because import containers need to be retrieved in a random fashion and, with high-stacking freight, many units need to be shifted. As a rough rule of thumb for 2.000 TEUs, a container storage area of 16,000 square metres is required for 3.5-high stacking.

### 5. Mixed systems

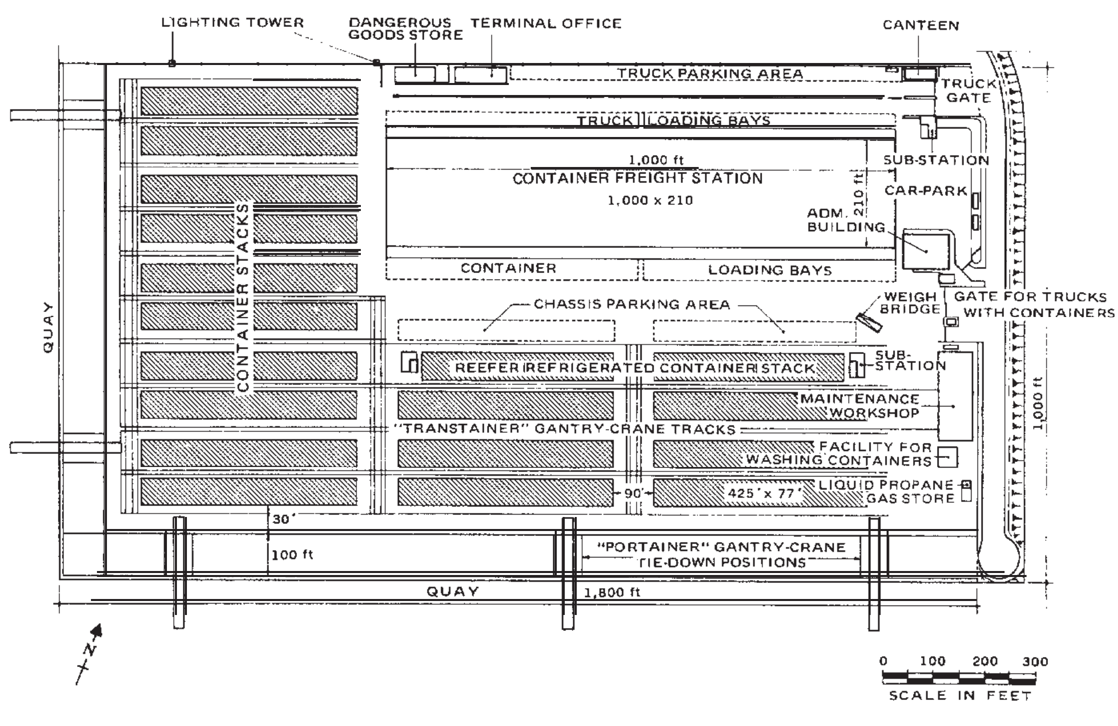
125. Mixed systems employ the best equipment for the particular operation. However, for such systems to be successful, a comprehensive information system and rigid operating policies are required, together with excellent management. For example, straddle-carriers are used for extracting individual import containers and delivering them to road vehicles, but gantry-cranes are used in the container park for feeding exports to the ship where it is possible to work straight off an export stack. Another mixed system is one using straddle-carriers for stacking full containers and fork-lift trucks for empty containers.

## E. Area requirements

126. The choice of operating methods and equipment, and thus the area of land needed for a container terminal, depends to a high degree on the availability of local land and on soil conditions. If the terminal is located far from urban agglomerations and land is plentiful and inexpensive, a system of storing containers only one high may be the most economical. For this layout, no costly equipment is needed for stacking containers but transfer distances may become long, resulting in additional transfer equipment being needed. Also, on reclaimed land with relatively soft soil, this one-high method is particularly advantageous since the carrying capacity of the soil does not need to be reinforced as it would for heavy stacking equipment. On the other hand, if land is scarce and expensive, the stacking of containers as high as physical conditions and commercial requirements allow becomes a necessity

FIGURE 19

Example of gantry-crane container terminal layout



127. Lack of container storage space has been another serious constraint on operations. It is true that, since the introduction of containerization on the major trade routes, there is a trend towards larger storage areas for container terminals. but in many. planned developments the space requirements are still underestimated. Sufficient operational area must be left for interchange areas for both ship-to-shore and stack-to-inland operations, as well as for vehicle parking, maintenance, workshops and administrative buildings.

128. The most frequent error has been to assume that the maximum stacking height can always be attained. In practice the average stacking height is much lower, depending on the amount of shifting of containers necessary in the storage area. and the need for containers to be segregated by destination, weight class. direction of travel (inward or outward). sometimes by type and often by shipping line or service. The need for storage of empty units and of unserviceable containers has also often been overlooked.

129. A further serious mistake is the belief that containers have a shorter terminal transit time than break-bulk cargo. In fact, the same constraints which cause break-bulk cargo to stay in the port will often have a similar effect on container cargo. In practice it is not unusual to find that the transit times for both are very similar. The following are typical delay times for containers at container terminals taken from a number of terminals:

| | *Days* |
|---|---|
| Containers carrying import cargo | 7 |
| Containers carrying export cargo | 5 |
| Empty containers ... ...... | 20 |

130. Planning charts similar to those whose use is explained in section G of chapter II, "The break-bulk berth group", are also helpful in container terminal planning.

131. When sufficient space is set aside for the container park, container freight station (CFS), marshalling and other administrative areas for a terminal operating adjacent to the quay, then there are bound to be enough berths for the traffic. For this reason, the terminal area requirements are calculated first, and then the number of berths checked to see if there is enough berthing capacity.

132. Container terminal, planning chart I (see figure 20) is used to determine the most important dimension of a container terminal, the container park area. The figure for the number of TEUs to be handled across the quay per year is entered on the planning chart. The planner descends vertically to the turning-point where the vertical line meets the line representing the average time the container spends in transit at the terminal. He then moves horizontally to the left to the next turning-point defined by this horizontal and the appropriate line for the area requirement per TEU.

133. The area requirement per TEU depends on the type of container-handling equipment used and the consequent access requirements and maximum stacking height. Typical area requirements are as follows:

| | *Stacking height (number of containers)* | *Square metres per TEU* | |
|---|---|---|---|
| | | *20-ft container* | *40-ft container* |
| Trailer ............. | 1 | 60 | 45 |
| Fork-lift truck ...... | 1 | 60 | 80 |
| | 2 | 30 | 40 |
| | 3 | 20 | 27 |
| Straddle-carrier .... | | 30 | |
| | 2 | 15 | |
| | 3 | 10 | |
| Gantry-crane ...... | 2 | 15 | |
| | 3 | 10 | |
| | 4 | 7.5 | |

134. The planner then descends again to the ratio of the average to the maximum stacking height of containers. The average height is the level at which operationally the container park area is considered full. For example. although a straddle-carrier can stack containers three high, it would not be practical for the operator to stack the entire park three high as it would then be impossible to remove individual containers. An adjustment factor must therefore be applied to allow for this fact. The planner now moves horizontally to the right to the reserve capacity safety factor-the factor which allows the park to handle peaks in demand.

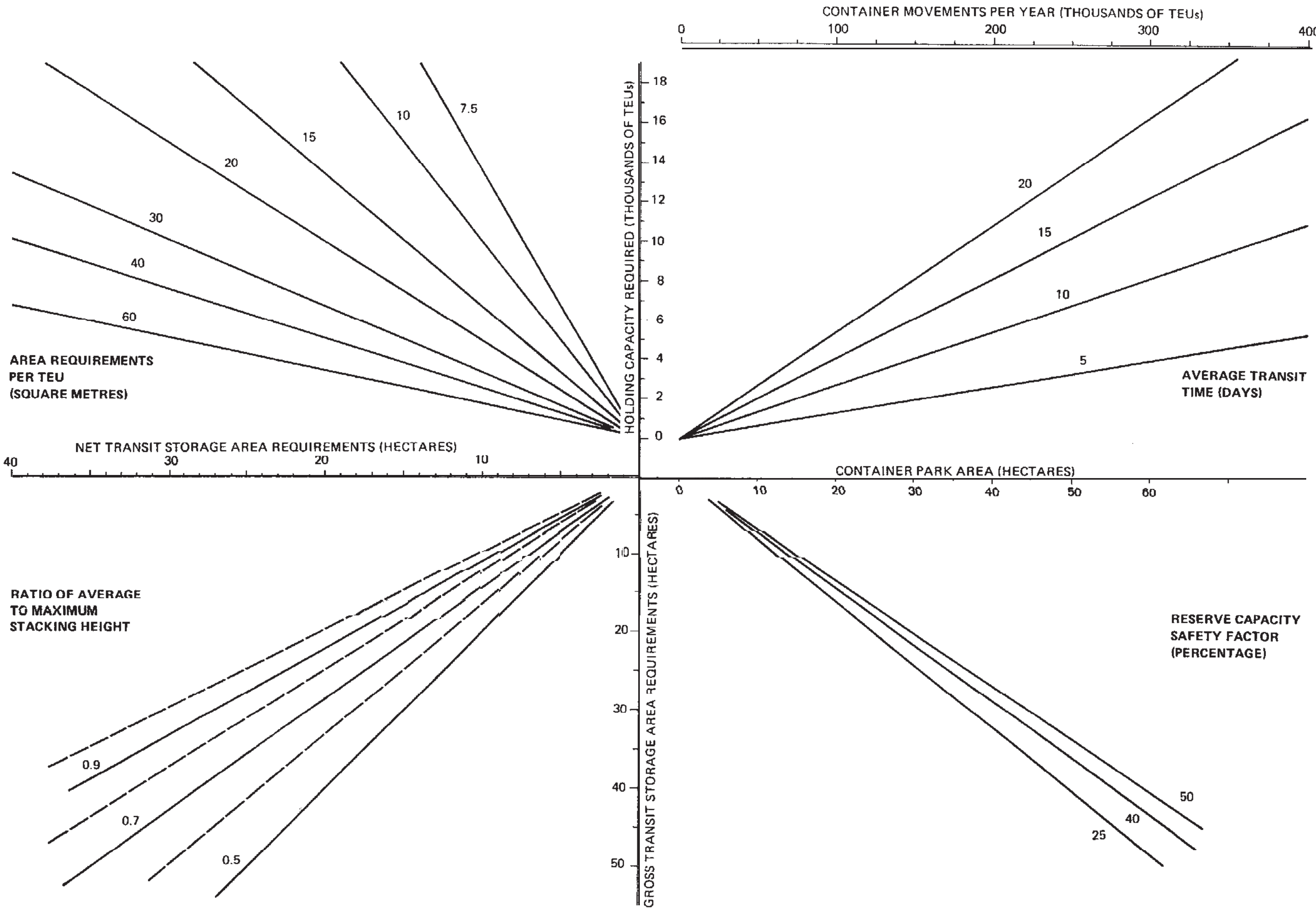
135. Finally he moves upwards to the container park area required. The intersections of the trajectory and the axes give the planner the following information: holding capacity required, in TEUs; net transit storage area requirements; gross transit storage area requirements; and container park area. The chart may be used repeatedly to determine the effect on area requirements of different handling equipment in order to find the most economical solution for local conditions.

136. The planner must now estimate the area requirements for the CFS, the structure used for "stuffing" and "stripping" containers and for consolidating and sorting consignments in the port area. Assuming that each TEU container handled via the CFS requires 29 cubic metres of space, the CFS storage area can be determined by using planning chart II (see figure 21). The following turning-points are used: average transit time of consignment; average stacking height in CFS; access factor to allow for circulation and operational areas in the CFS; and reserve capacity safety factor for periods of peak demand. For example, a terminal at which 20,000 TEUs per year pass through the port CFS, with a mean transit time of 10 days. a stacking height of 2 metres, an access factor of 0.4 and a safety factor of 25 per cent, would require a CFS storage area of 14,500 square metres[6]. The structure should also have a large roof overhang to allow protection of the container loading bays from the weather (see figure 22).

[6] This figure can be compared with other CFS areas at the following container terminals: Guam: 2 berths. CFS 3.066 $m^2$; Keelung: 5 berths, CFS 2,700 $m^2$; Port Kelang: 2 berths. CFS 6,771 $m^2$; Singapore. East Lagoon, 3 berths. CFS 21.000 $m^2$; Kwai Chung berth 4: 3 berths, CFS 23.241 $m^2$

Figure 20

Container terminal, planning chart I: container park area




*Note:* 1 hectare = 10,000 m$^2$.

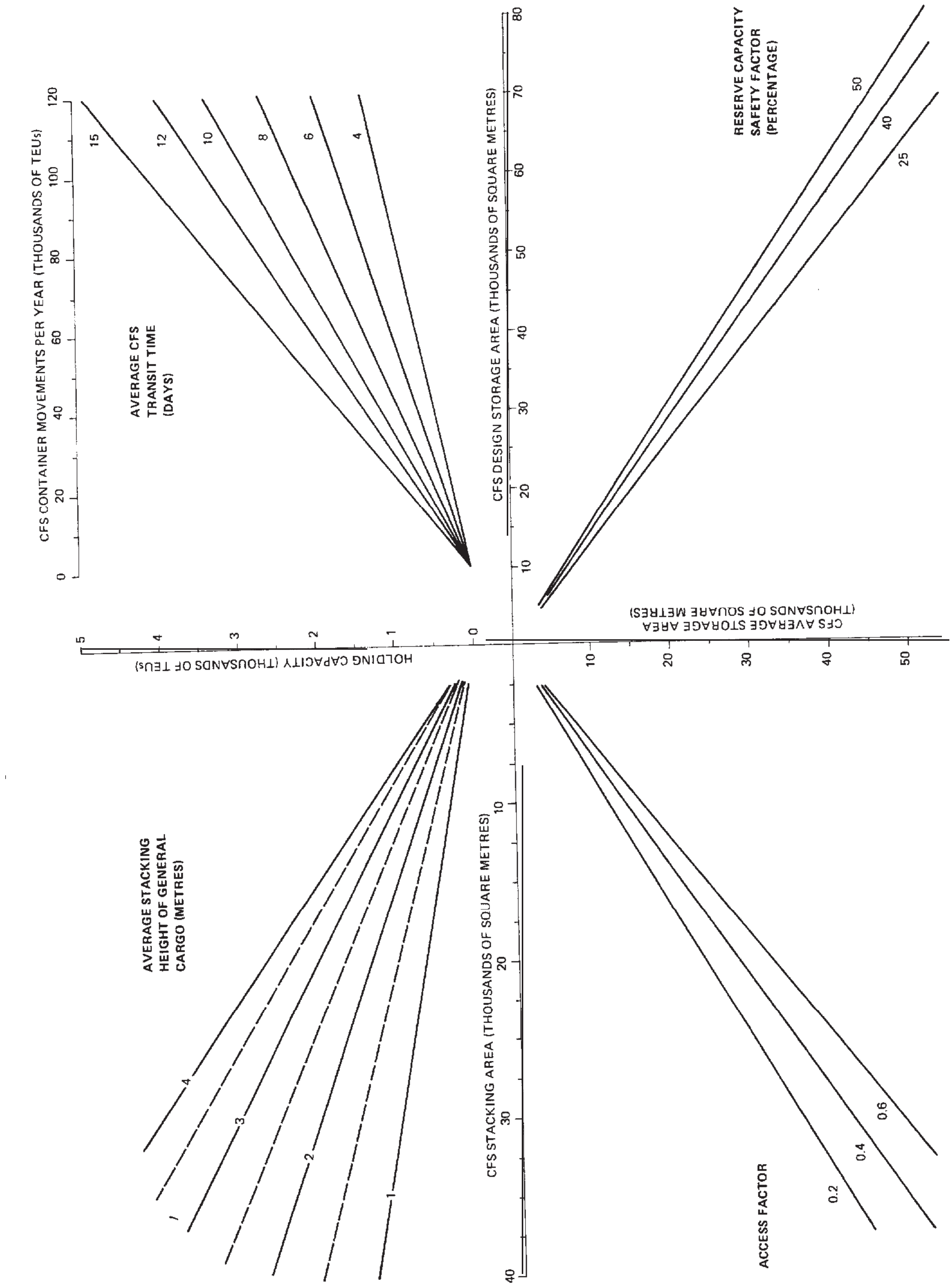
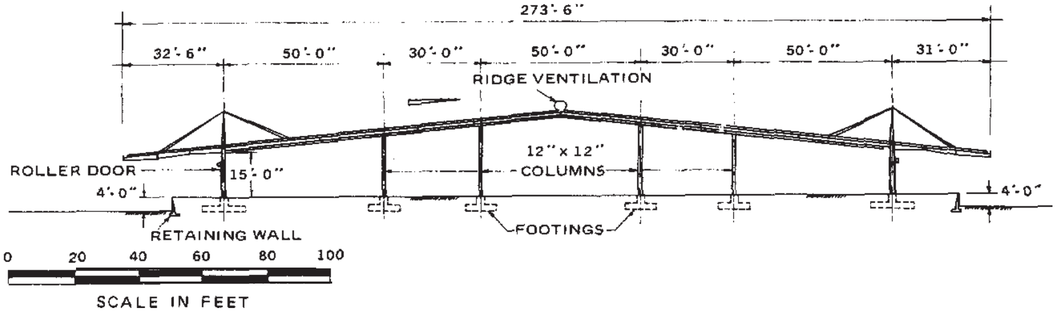

CFS CONTAINER MOVEMENTS PER YEAR (THOUSANDS OF TEUs)
0
20
40
60
80
100
120
AVERAGE CFS TRANSIT TIME (DAYS)
15
12
10
8
6
4
CFS DESIGN STORAGE AREA (THOUSANDS OF SQUARE METRES)
10
20
30
40
50
60
70
80
RESERVE CAPACITY SAFETY FACTOR (PERCENTAGE)
50
40
25
HOLDING CAPACITY (THOUSANDS OF TEUs)
0
1
2
3
4
5
CFS AVERAGE STORAGE AREA (THOUSANDS OF SQUARE METRES)
10
20
30
40
50
AVERAGE STACKING HEIGHT OF GENERAL CARGO (METRES)
4
3
2
1
CFS STACKING AREA (THOUSANDS OF SQUARE METRES)
10
20
30
40
ACCESS FACTOR
0.2
0.4
0.6

FIGURE 22

Cross-section of container freight station




137. As previously mentioned, in addition to the container park and CFS areas, the terminal requires space for marshalling areas, vehicle parking, rail and road access, customs, damaged containers, reefer cargoes, staff, administration, maintenance and dangerous goods storage facilities. Typical additional requirements per berth could be from 20,000 to 30,000 square metres.

### F. Berth occupancy at specialized unit terminals

138. Specialized berths such as container terminals can achieve cargo-handling rates five or even ten times higher than conventional berths. In addition, unitization results in a considerable reduction in the number of calls through the pooling of services, with larger consignments per vessel, which further increases the productivity per call. Thus, in unitized form, a given quantity of cargo can be handled at fewer berths, and it will be rare that a container terminal investment decision will involve more than two berths in the initial phase. Therefore the berth occupancies which will be appropriate in order to keep waiting time to an acceptable level will be low. The fact that container ships are much more expensive than general cargo vessels reinforces this need to minimize waiting time. In the planning procedure given below, the basic economic effect of waiting time will be a main factor in the investment decision, but there will in addition be the need to consider other criteria.

139. In the case of any special-purpose or advanced type of installation, the following three criteria should normally be considered:

(a) Whether the resulting berth occupancy will give the right balance between ships waiting for a berth and berths waiting for a ship;

(6) Whether the average ship turn-round time will satisfy the normal user, irrespective of what this implies with regard to berth utilization;

(c) Whether there is sufficient peak capacity to give a satisfactory individual service to the exceptional, more demanding, user and to ensure generally against congestion during periods of exceptional traffic.

140. Performance calculations should be carried out to demonstrate that all three of these criteria are satisfied. There will often be a difference in the capacities which will satisfy the different criteria, and it will be necessary to reach a compromise. In reaching this compromise the port management will often need to take an entrepreneurial decision: there may be no clear cut single solution with an economic justification which at the same time gives a level of service that will satisfy customers. It will be for the decision authority to consider these investment risks, and in order that it may do this the planning team should present separate proposals, according to each of the three criteria, for purposes of comparison. These will be more useful to the decision authority than a single proposal that attempts to meet all three criteria.

141. The container terminal planning chart III (see figure 23) is utilized to determine the berth-day requirement. The method used is similar to that used for the previous charts, starting with the standard working hours per day that ships will be worked when at the terminal, and with the following turning-points: average number of units per hour per crane, which should include an allowance for equipment down-time; number of cranes used per ship (gantry-crane effectiveness factor per crane = 1 crane : 1; 2 cranes: 0.9; 3 cranes: 0.8); average number of moves per ship; and number of ships per year. This path gives the average number of units per day per berth, the average number of units per day per crane, the average berth time per ship (which includes a one-hour period for berthing and deberthing the ship) and the annual berth-day requirement.

142. As we are now considering the performance of the terminal, note that we are using units (i.e. number of containers) rather than TEUs (i.e. twenty-foot equivalent units). When the containers to be worked to and from a ship are estimated in TEUs, this figure must then be converted into units by estimating the proportion of 40-foot units among the total number of units. The number of moves for discharging and reloading hatch covers should also be included.

143. Starting with the berth-day requirement, the following turning-points should be used in planning chart IV (figure 24): number of berths; commission days per year; number of berths; and average daily ship cost. The path traced gives the total time at port and the annual ship cost. Operators of expensive container ships may wish to know, in addition to the average ship time in port, the probability of a ship having to wait before agreeing to use the terminal. For this reason, additional scales are given on the lower left of the chart which show, for one, two or three berths, the probab-

FIGURE 23

**Container terminal, planning chart 111: berth-day requirement**

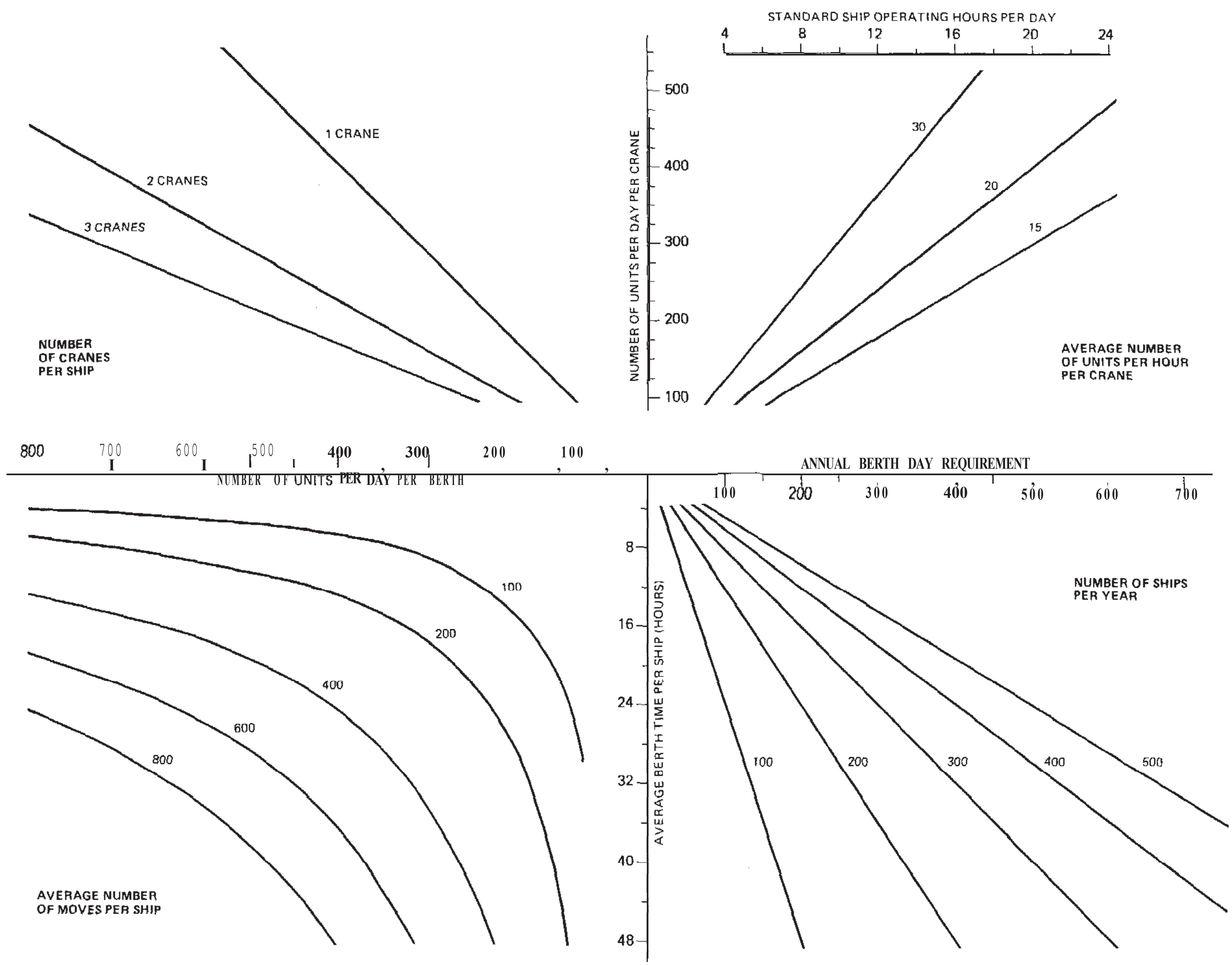
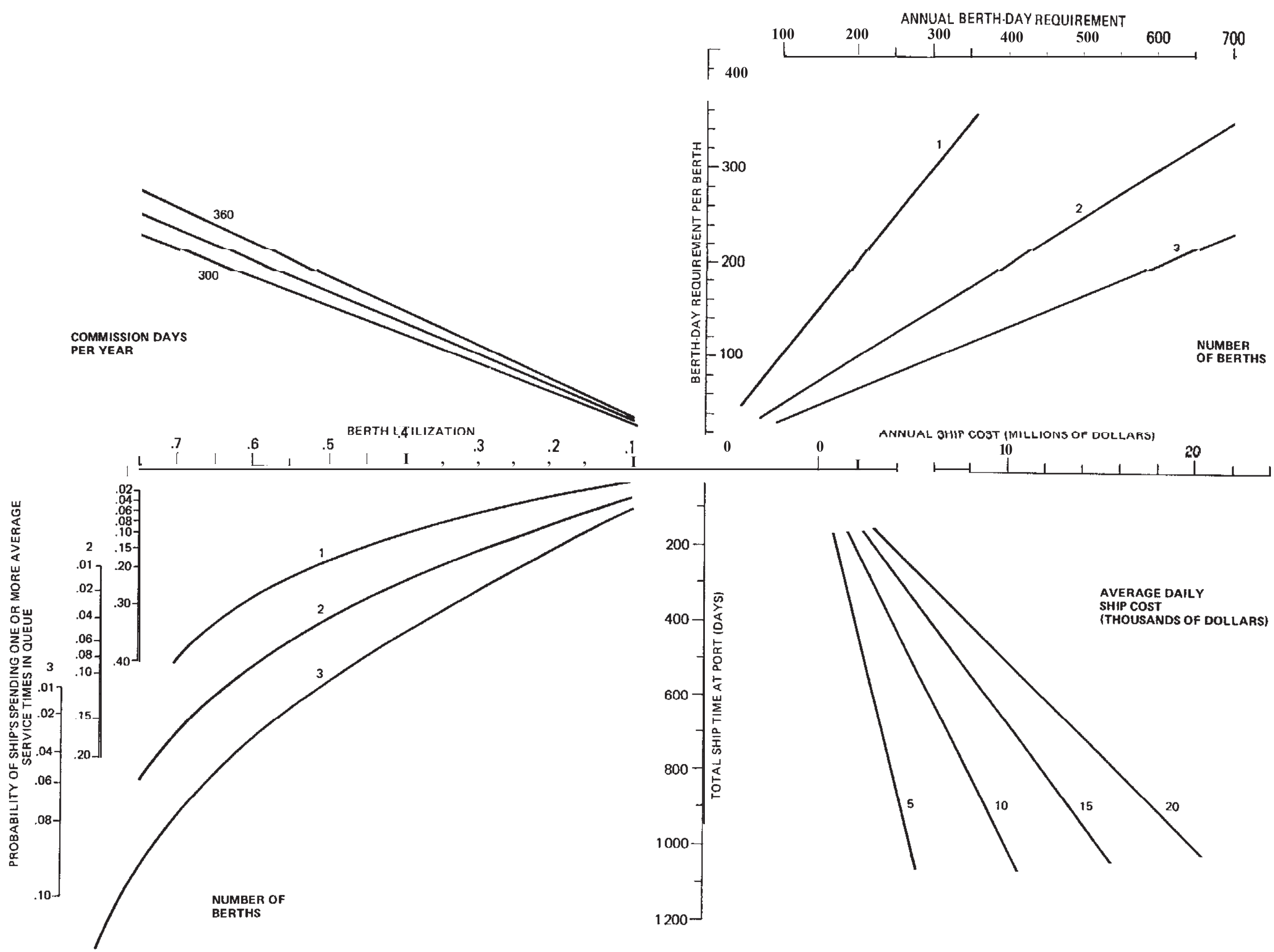


FIGURE 24

**Container terminal, planning chart IV: ship cost**



ility of a ship having to spend one or more average service times queueing for a berth. For example, if the average time at berth is 12 hours, then the probability shown is the chance of a ship having to wait 12 hours or more for a vacant berth. The probabilities are given as a fraction; thus 0.10 equals a 10 per cent chance. To use these probability scales, draw a line horizontally to the left from the "number of berths" turning-point.

144. The relationship between berth utilization and total time at port is based on queueing theory. The assumption has been used that the service time and the inter-arrival time follow an Erlang 2 distribution. A more detailed discussion is given in annex II, section D. For a terminal servicing a near-sea route for one or two operators, the arrivals would be more regular and the berth waiting time for a given berth utilization would be less. However, these curves can be used with a high degree of confidence for most container terminals.

### G. Information systems

145. Many terminal operators have decided to utilize an electronic data processing system to assist in the collection and processing of the required information. It is generally accepted that for terminals handling 100,000 or more containers a year, a manual system, which may have proved very satisfactory up to that point, becomes far less practicable. A computer system can be introduced to handle the large quantity of information. There are, however, cases where efficient manual systems have been successfully used for much larger throughputs.

146. At present, many container terminals have both a manual and a computerized system, but each has a specific function. The manual system serves mainly to assist the terminal operator in the control of all terminal operations (including the location of the containers at the terminal). The computer-assisted system, on the other hand, is used to process invoices, gather statistical data and to present the container operators with detailed information, for example, on the type and number of units at the terminal, the availability of empty units and productivity rates on the ship. The project proposal for a container terminal should include any such data processing equipment as a terminal equipment cost item.

### H. Schedule-day agreements

147. The need to achieve a reasonable level of berth occupancy without increasing the probability of ships having to wait has raised the question of the scheduling of arrivals. If vessel arrivals can be scheduled, a much higher berth utilization is possible without significant waiting. It may be possible for agreements to be concluded between container terminal operators and shipping lines for specified schedule-days, particularly with short-sea services. Ships that arrive in the scheduled slot are then guaranteed immediate berthing.

148. Unfortunately. the risk that vessels will be slowed down on deep-sea routes, for example by weather, means that large safety margins normally have to be provided. These destroy much of the advantage of the scheduling, and experience has shown that the ships from several lines arriving at a deep-sea container terminal are only slightly more systematic in their arrival patterns than the traditional liners they replace, The arrival pattern at a terminal is also affected by the hours of work at other ports. For example, if other terminals in the area do not work at the weekend, one that does is likely to find a group of vessels arriving at the end of the week.

149. Faced with this situation, the best that a large container terminal operator may be able to do is to give the fastest turn-round service possible on a first-come first-served basis. The use of a buffer stack of cargo to speed up service is a possibility. There could. for example, be a "post-stack" for import cargoes and a "pre-stack" for export cargoes, the stacks being placed directly on the quay near the vessel.

### I. Container feeder services

150. The trend towards concentrating traffic at a small number of pivot or gateway ports is particularly pronounced on the long-distance container routes. The specialized container vessels have become larger and more sophisticated, while the cost of building a modern container terminal is very high. The economics are more and more in favour of unloading and loading all containers at one well-equipped port, and distributing them by coastal feeder vessels to other ports in the region.

151. It is difficult to forecast such developments, and close discussion is needed between the planner and the shipping lines concerned. The attitude of shipping lines is liable to change, and while they may initially wish the mother ships to call at every port, at a later date they may wish to introduce feeder services. Shippers prefer direct calls as this reduces both transport time and the chance of damage to goods.

152. Feeder ships are normally designed for a specific service, with the characteristics of the port in mind. They are relatively small (usually having between 10 and 20 per cent of the capacity of the trunk route vessel), and can be built without ship's gear in order to increase their carrying capacity, to improve their stability and to reduce costs. The majority are probably ro/ro ships, but there are also pure cellular feeder ships and combination ro/ro and lift-off vessels.

153. The load factor of feeder vessels is normally very high, approaching unity. At the ports serviced only by the feeder vessels. however, handling rates—although much higher than with the traditional break-bulk operation-will be lower than at the pivot or gateway specialized terminal because only one gantry-crane can work the feeder vessel. A typical figure of 15 units per hour may be achieved for a feeder ship with a capacity of 100 TEUs. Table 3 gives the principal characteristics of several ships in this class.

TABLE 3

Typical container **feeder ships**

| *Type* | *Dwt* | *Container capacity (TEUs)* | *Overall length (metres)* | *Overall width (metres)* | *Draught (metres)* | *Special features* |
|---|---|---|---|---|---|---|
| Roll-oniroll-off | 4 580 | 176 | 130 | 17 | 6.25 | Catamaran design |
| Lift-on/lift-off | 1 260 | 106 | 77 | 13 | 3.70 | Gearless |
| Roll-on/roll-off Lift-on/lift-off | 6 500 | 330 | 115 | 19 | 7.40 | Equipped with angled stern ramp and one 38-ton gantry-crane |
| Roll-on/roll-off Lift-on/lift-off | 2 080 | 111 | 87 | 14 | 4.70 | Equipped with stern ramp and one 30-ton gantry-crane |

**J. Types of container handling equipment**

154. The large size of IS0 containers necessitates large equipment for handling. The choice of a particular handling method is related to the type of traffic (for example, ship to shore, train to truck or truck to ground), the number of containers to be handled per hour and the distance of travel, which depends on the size and the shape of the site and the number of containers to be stored.

1.55. Ship-to-shore gantry-cranes are specially designed for container traffic. They are capable of substantial cantilever lifting, with spreaders mounted on rotating tables so that containers can be aligned straight into a stack, or on to a vehicle (figure 25). These are expensive pieces of plant, a 35-ton capacity crane for ship-to-shore operation costing approximately $4.5 million (mid-1981 values), including the rail track. The planner must design circulation routes so that any stoppage will not interfere with crane movement. For reliability, a terminal will normally require a minimum of two ship-to-shore gantry-cranes.

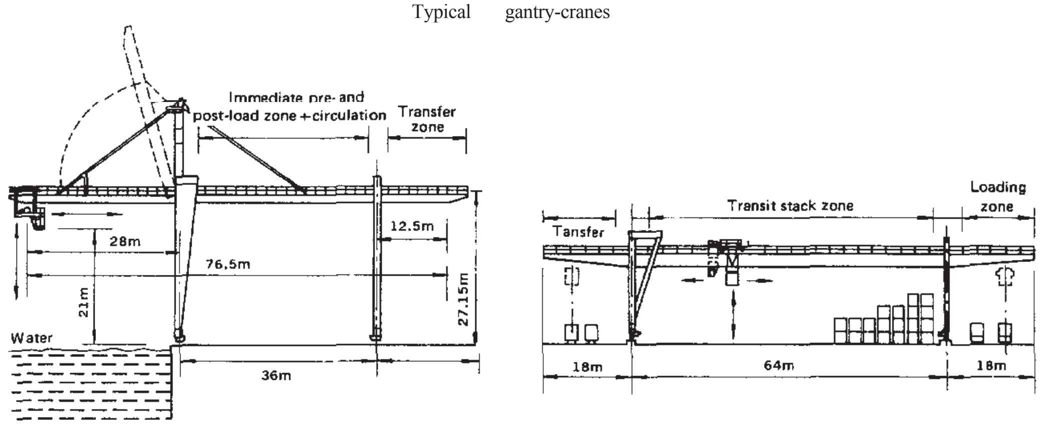
156. Gantry-cranes can also be used in the container yard, where they combine the mobility of straddle-carriers, although slower, with the wide span and height of the ship-to-shore gantry-crane. The yard gantry-cranes may be on rubber tyres, which allows them to move to another task at a different part of the site. The weight of the gantry requires special runways to avoid damage to the terminal surface. Rail-mounted gantries allow wider spans and higher stacking heights. A rubber-tyred gantry crane costs approximately $0.75 million and a rail mounted gantry, including rails, about $1.5 million (mid-1981 values).

157. Straddle-carriers are efficient for linear stacking operations up to a height of three containers. While these carriers are fast and manoeuvrable, they are expensive to buy and operate, with a typical purchase price of $0.5 million (mid-1981 values) for a carrier capable of stacking containers three high. Among the reasons for the high operating costs are maintenance costs and down-time. Modifications are improving the reliability of this type of equipment.

158. Fork-lift trucks can be used for container handling. Operators equip their fork-lift trucks with top-lift or side-lift spreader beams as well. The use of these attachments for container movements by fork-lift truck removes the risk of damage by forks. Normal fork-lift trucks can be used for the handling and stacking of empty containers with fork tunnels, while a special heavy-duty truck is required for full units. The investment for a 35-ton fork-lift truck, including the spreader, is around $300,000 (mid-1981 values). A 3-ton capacity fork-lift truck would cost approximately $30,000 and a 10-ton capacity truck $100,000.

FIGURE 25

Typical gantry-cranes




A. *Ship-loading gantry container crane*

B. Gantry-crane *for stacking and sorting containers and feeding ship-loading crane*

## Chapter IV

# THE MULTI-PURPOSE GENERAL CARGO TERMINAL

### A. Economics

159. The sequence of changes in the kind of traffic arriving at ports, as a result of growth and transport economics, was discussed in part two. chapter I, "Terminal planning considerations". The need for a multi-purpose terminal to handle both break-bulk cargo and a variety of unit loads during the transitional phase (denoted as phase 4 in part two. figure 1) was pointed out.

160. The role of the multi-purpose terminal is to provide efficient handling facilities for the period—which may last many years-when general cargo ships calling at the port may carry a variety of cargoes transported in modern ways: containers, flats. pre-slung cargoes, large units of iron and steel, large units of packaged timber, as well as cars and heavy machinery, together, of course, with a basic load of break-bulk cargo, increasingly palletized. These modern methods of transporting cargoes were introduced in order to reduce the cost of handling cargoes at ports in developed countries, and the cost of carriage by sea. However, they can actually cause a decrease in cargo-handling productivity and disrupt operations at a port not equipped to handle them efficiently.

161. In order to be able to handle all these cargoes efficiently, the terminal needs to have a greater variety of mechanical equipment than is required for a conventional break-bulk terminal, and a different range of equipment than is normal for a specialized container terminal. The terminal needs a different layout, and modern management. These requirements are summarized below, and are given in more detail in the reports of the UNCTAD secretariat on technological change in shipping and its effects on ports, already referred to several times.[7] Although the initial cost of the terminal is high, a high throughput can be achieved in view of the terminal's flexibility, and furthermore it can be fully utilized soon after commissioning in view of its suitability to handle whatever traffic may come. The resulting cost per ton of cargo handled and the total investment can therefore be significantly lower than the alternative of continuing to build extra conventional berths.

162. For example, a two-berth multi-purpose terminal working two shifts per day and 200 days per year should achieve a throughput of some 650,000 tons per year, assuming a productivity of 800 tons per ship-shift for a typical mix of cargoes with a different productivity for each type of cargo, as follows:

| | *Tons per shift* |
|---|---|
| Conventional general cargo. palletized and pre-slung cargoes .. | 450 |
| Packaged forest products and bundled iron and steel products | I 000 |
| Containers and ro/ro units | I 500 |

163. Using 1980 cost figures. the UNCTAD secretariat found that such a terminal would cost in the region of $33.3 million and give a handling cost of $20 per ton (including the cost of ship's time in port). If the same cargo were handled over conventional berths, the throughput would probably be no higher than about 175,000 tons per year, and would thus require four conventional berths costing approximately $50 million and giving an effective handling cost per ton of about $33. The figures given for a multi-purpose terminal, which imply very significant savings, are based on typical costs and interest rates in developing countries.

164. The multi-purpose terminal offers full utilization of a high-capacity facility from an early date and offers the possibility of reducing the total port cost for some neo-bulk cargoes. In view of the added long-term advantage that a multi-purpose terminal can more easily be converted later to a specialized unit load terminal, there is a strong argument for ports in developing countries to think of general cargo development mainly in terms of multi-purpose facilities.

### B. Layout

165. Figure 26 shows a proposed layout for such a two-berth terminal. The following features should be noted: the placing of unit load transit and consolidation sheds at the rear of the quay, so that trucks can be served alongside the sheds without interfering with the transfer operations; the substantial open storage areas closer to the quay for any form of unit load, including containers, or for open storage general cargo; the large quay apron operational areas; the areas for road and rail transport through the terminal; provision of a ro/ro ramp.

166. The concept as shown, adapted to local conditions, has been applied in a number of new port developments for handling semi-bulk and neo-bulk cargoes, although mostly in developed countries. The latest developments in layout are noted and are to be referred to when studying figure 26.

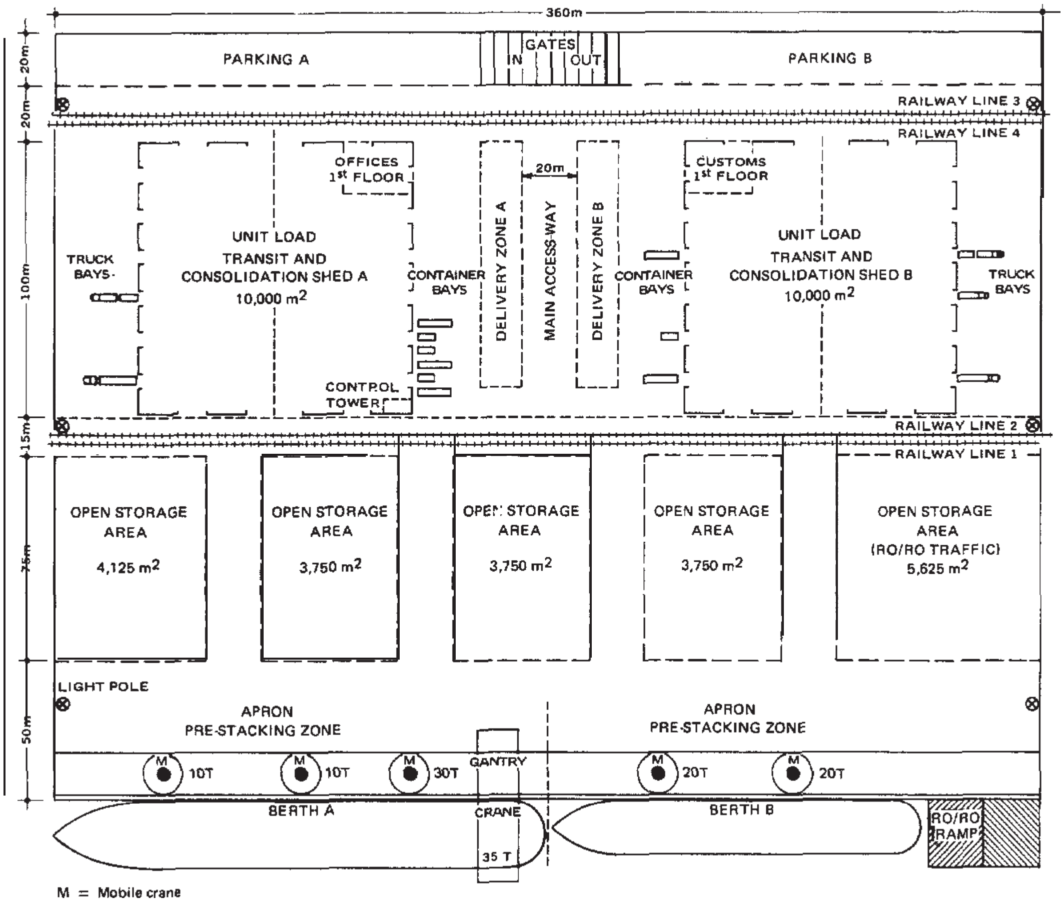
(a) Extension of berth length to 400 or 450 metres to handle larger ships and ship-based ramps;

*(b)* Increase in storage area to handle larger consignments and longer cargo transit times resulting in total terminal area of 120,000 square metres versus an original area of 100,800 square metres;

[7] TD/B/C.4/129 and Supp.1-6

FIGURE 26

**Proposed layout for a two-berth multi-purpose general cargo terminal**




(c) Increase in unit-load weight has led to higher-capacity equipment. The flexibility offered by heavy-duty fork-lift trucks with attachments has led to their greater use. Large quantities of homogeneous cargoes have allowed the use of overhead stacking or gantry-cranes.

167. Since such a terminal is designed to serve a transitional phase, it might be advisable-depending on the traffic forecast-to proceed in two stages. Figure 27 shows a layout for a single-berth first phase, in which a single berth can handle the traffic and when the traffic mix demands a higher proportion of open rather than shed storage. Figure 28 shows a layout that is more suitable where there is a higher proportion of shed cargo, where two berths are justified, and where the second-phase development areas have been clearly allocated and partly surfaced. In this version, the transit and consolidation shed must be of a type which can be dismantled and re-used with additional material for the erection of two sheds further back during the second phase.

## C. Equipment

168. The main method of ship handling is either by ship's gear or by mobile tower crane. No rail-mounted portal cranes are normally provided and only one gantry-crane in the first instance. A 30-ton mobile tower crane may, however, be on the same rails as the gantry-crane. The standard method of transfer for virtually all classes of cargo is by tractor/trailer combinations, using trailers of a size generally associated with container operations but without corner fixings, of a low profile design, and equipped for easy coupling and uncoupling. While the cost of equipment listed in table 4 is substantial, it can be readily justified. This cost is included in

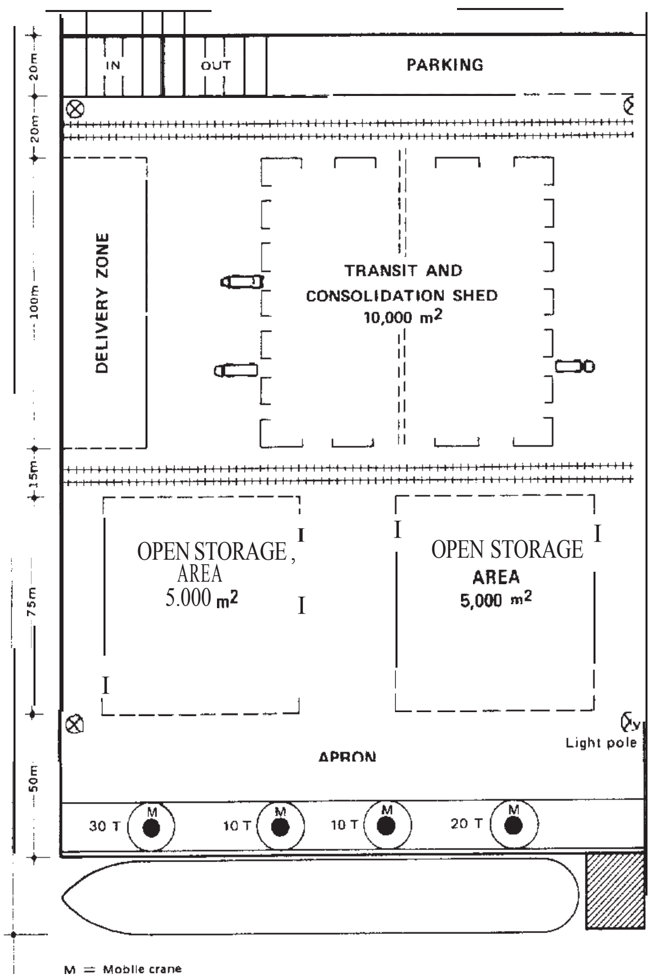
TABLE 4

**Handling equipment required for multi-purpose general cargo terminals**

| | *Single berth, first phase, alternative 1 (predominantly open storage)* | *Two-berth, first phase, alternative 2 (predominantly shed storage)* | *Two-berth terminal, second phase* |
|---|---|---|---|
| 35-ton gantry | — | — | 1 |
| 30-ton heavy lift crane .. | 1 | 1 | 1 |
| 20-ton mobile tower crane (for ship working) | 1 | 2 | 2 |
| 10-ton mobile tower cranes (for ship working) | 2 | 2 | 2 |
| 20-ton mobile cranes (for yard working) | 1 | — | 1 |
| J-ton mobile cranes (for yard working) | 1 | 2 | 2 |
| Straddle-carriers .. | 2 | — | 3 |
| 3-ton fork-lift trucks | 8 | 15 | 15 |
| 10-ton fork-lift trucks | 2 | 3 | 5 |
| Tractors (tugmasters) | 3 | 6 | 6 |
| Trailers/chassis | 9 | 18 | 18 |
| Ro/ro ramp | 1 | 1 | 1 |

FIGURE 27

**Firsl phase of the multi-purpose terminal, alternative 1**




the total terminal cost estimate given above. The list given is for the initial equipping of the terminals illustrated. Perhaps the main reason for difficulties in the operation of unitized cargo terminals has been the failure fully to recognize the need for transfer equipment, and for this reason the quantity of transfer equipment suggested should not be reduced. As a particular traffic develops, the terminal may start to take on a more specialized role and further equipment (such as additional container gantry-cranes and, straddle-carriers) may be justified.

### D. Management

169. To take full advantage of the multi-purpose terminal, a modern port management approach is needed. At the planning stage, special consideration should be given to the new status of the dock worker, and to the need for integrated planning of the operation. One of the most sensitive areas in a changing port environment is the status of the dock worker. Early action on the part of management can help to pave the way for a gradual change towards an improved labour management policy. The mangement effort in this respect should include:

(a) Training of specialized personnel (drivers of mechanical equipment, mechanical and electrical technicians for equipment maintenance, traffic controllers);

(*b*) Advance planning of the requirements for manual and office workers, with a regular revision of the quotas required;

(c) Gradual improvement of the status of the dock workers by conversion from a casual to a permanent working force, at least for a substantial proportion of the workforce;

(d) Development of a time-based payment system, incorporating adequate social security provisions.

170. The port management must fully involve the unions in these developments and be willing to accept proposals from both manual and office workers. Changes will always occur more smoothly if there has been extensive consultation.

171. Another area of preliminary action concerns the operational organization of the terminal. Often, the activities on the ship, on the quay apron and in the shed have been considered as separate activities. The net result, even in the case of break-bulk general cargo handling, has been a considerable loss in operating capacity. At a specialized terminal, such separation is completely unacceptable, as a unified responsibility for the overall operation and unity of control of the specialized terminal becomes an increasingly important requirement for its efficiency. On the other hand, it is desirable that the specialized terminal should be operationally independent of the conventional break-bulk berths.

172. Management methods should concentrate on control and continuous monitoring, of the type associated with specialized container operations, for all traffic handled. This will require provision to be made at the planning stage for the following:

(a) Management training;

(h) A supporting administrative organization with planned information flow;

(*c*) The planned preventive maintenance of equipment based on good repair facilities;

(d) The collection and use by management of statistical performance indicators. as suggested in the UNCTAD publication on the subjects;

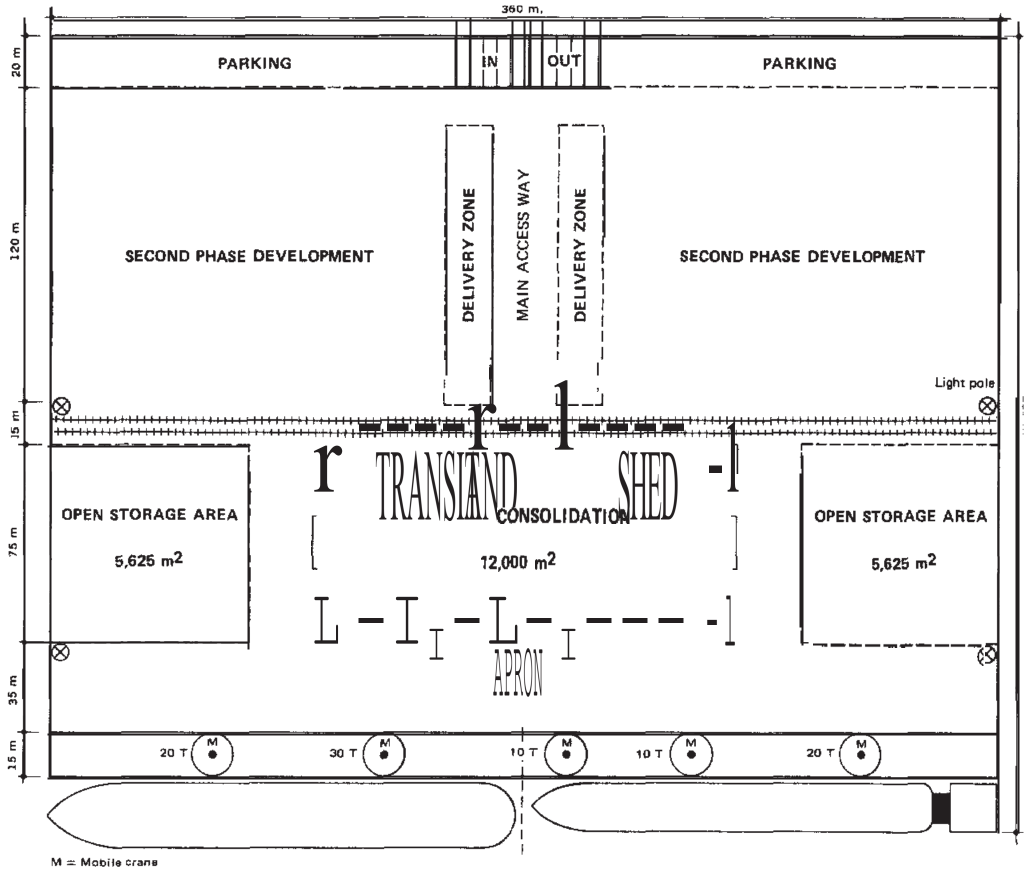
(*e*) Close collaboration with shipping agents, forwarding agents and railways, which should have representatives at the terminal.

---

[8] *Port Performance Indicators* (United **Nations publication. Sales No.** E.76.II **D.7).**

FIGURE 28

**First phase of the multi-purpose terminal, alternative 2**



## Chapter V

## TERMINAL REQUIREMENTS FOR ROLL-ON/ROLL-OFF TRAFFIC

### A. The role of roiro services

173. The spread of roiro services to the deep-sea trades is a development which will be of increasing importance to developing countries in view of the great flexibility of the operation. As of mid-1980, the deep-sea roiro fleet consisted of 220 vessels totalling just over 3 million dwt. The deep-sea fleet is predominantly a young fleet, with only 20 ships in existence before 1970, and a total of 125 ships entering service between 1977 and 1979. The most popular type is the pure roiro (55 per cent of total dwt) followed by roiro general cargo (23 per cent) and roiro container ships (20 per cent). By mid-1980 there were 63 vessels of 1.12 million dwt on order that could enter the deep-sea roiro fleet over the next 2 1/2 years, representing an increase of 37 per cent.

174. In mid-1980, 45 per cent of the fleet consisted of vessels up to 9,999 dwt, 31 per cent between 10,000 and 19,999 dwt and 24 per cent over 20,000 dwt. The trend towards increasing vessel size can be expected to continue in the long term as roiro operations extend to more long-haul trades and those high-throughput trades where larger vessels will be used for larger loading per sailing.

175. As listed in part one, chapter III ("Traffic forecasting"), the variety of cargo types which can be carried on roiro vessels-in various combinations-include vehicles, loaded road trailers or semi-trailers and containers on chassis, as well as any general cargo on pallets or flats which can be carried on and off the ship by fork-lift trucks. In addition, roiro vessels are often used to carry passengers. Moreover, the majority of ro/ro ships are equipped for a percentage of lift-off operations for containers and heavy lifts, and in some cases also for bulk cargo. Because of the priority berthing which is often given to this type of service, it can bypass port congestion ship delays. Furthermore, where quays have a suitable load-bearing capacity, large, long, heavy or awkward loads can be worked without special heavy-lift cranes, and in certain cases with less berth length.

176. Several types of vessel of varying sizes are in operation. Vessel design differs with respect to the ramp facility, which may be placed at the stern, in the bow or on the side. The ship itself may dock either alongside a quay or at right angles, for access through the bow or the stern. Cargo is carried on several decks, and access is often provided between these decks by ramps or elevators within the vessel. In some cases, connections can be made to the shore at each separate deck level.

177. In general, for liner deep-sea trades, three main types of ship can be identified:

(a) Type 1: roll-on/roll-off ships with multiple decks and/or holds with side-ports requiring a quay ramp;

(b) Type 2: roll-on/roll-off ships with a ship-based angled stern ramp;

(c) Type 3: mixed roll-on/roll-off, lift-on/lift-off ships requiring a quay ramp.'

178. Ships of the second type, with a ship-based angled stern ramp and multiple decks connected by ramps, are of particular promise for developing countries. The need for sophisticated and relatively expensive port-based link spans is avoided, while a large variety of cargoes can be handled. Moreover, these ships often employ their own fleet of straddle-carriers, fork-lift trucks and other mechanical handling equipment. Hence the investment cost for the port is considerably reduced.

179. An examination of the development of cellular container services and ro/ro services shows that, because of local conditions and differences of approach, the two modes of carriage are in competition on a number of trade routes. However. the true economics of the situation are likely to show that there is room for both on the major routes where there is at present competition. The economics of container services are such that they will usually capture all substantial containerizable cargoes, leaving non-containerizable general cargo to be carried by conventional means. As traffic grows, a point is reached where this residue becomes sufficiently substantial, or cargo-handling cost and ship waiting-time cost sufficiently great, for this merchandise to be divided into the "cream" cargo, cargo of higher value needing rapid handling, and the remainder. The "cream" cargo will tend to be carried on roiro service vessels.

180. Often, the more important factors are flexibility and the cutting-down of port investment, particularly where there are smaller traffic volumes, as in many ports in developing countries. Here, there is no competition between cellular container services and ro/ro services, and the roiro ships will therefore be equipped to carry whatever container traffic there may be.

[9] Further information is given in an ICHCA Survey of 1978 entitled *Ro-Ro Shore and Ship Romp Characteristics* and in a 1978 report of the PIANC International Study Commission on the Standardisation of Roll-on/Roll-off Ships and Berths (Supplement to Bulletin No. 33 (Vol. 1111979)).

181. It is also interesting to note that operators choose the roll-on/roll-off vessel for a specific commodity and not for the more diversified cargo-mix of the traditional liner trade. For example, automobiles may be carried on the outward voyage and forest products on the return voyage; or, say, steel products may be transported by roiro vessel between ports of the same country. In such cases, cargo flexibility is a less critical factor than cargo-handling productivity and the ease with which changes can be made in ports of call.

### B. Ro/ro demand forecasting

182. In any attempt to forecast the extent to which roiro services will penetrate a given route, the following two principal characteristics of the roiro service as opposed to the container service should be borne in mind:

(a) The ability of a ro/ro service to attain high cargo-handling speeds in a highly developed port at one end of the route and satisfactory speeds in a conventional port at the other end;

(b) The ability of a roiro service to switch its ports of call easily in an area of changing trading patterns because it requires the minimum in the way of special port equipment.

183. At the same time, when a route capacity builds up to the point where a cellular container service is introduced, a roiro service will in general be phased out. This will happen because the carrying capacity of a specialized container vessel can be more fully used than that of a ro/ro ship. In broad terms, the nature of roiro cargo is that it is the high-value portion of the miscellaneous cargoes left over after containerization.

### C. Berth requirements

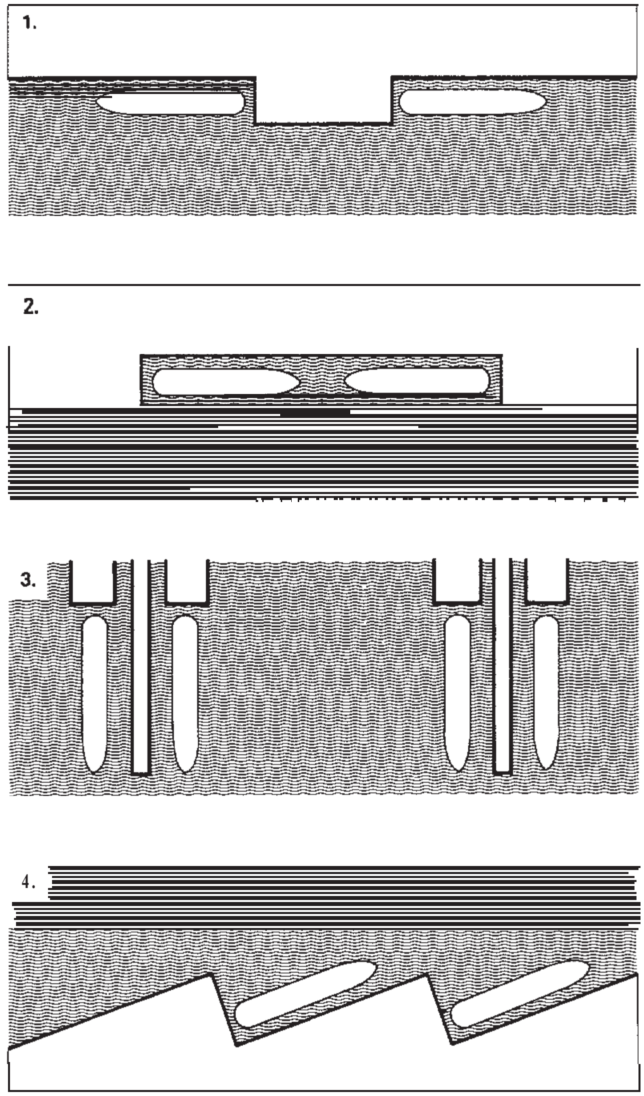
184. Thus, apart from the need for good access and suitable storage areas, roiro operations place little demand on ports for speciahzed facilities and can be fully self supporting in smaller ports. However, this very flexibility means that it is difficult to forecast which class of ro/ro ship, carrying what cargo mix, will use any particular port.

185. Since a ro/ro berth can be prepared and equipped more quickly than most other kinds of berth and since, in many cases, the ship design will be known, the shore facilities should be designed to meet the ship's needs. But it is important to recognize that a berth will outlast most ships and that ships may be moved to other routes if traffic patterns make it desirable to do so. Therefore berth planning should be as flexible as possible, even though only one vessel type is expected at the outset.

186. Four alternative fixed layouts are shown in figure 29. Alternative 1 offers a high degree of flexibility for the future, since it is easily converted to the handling of other types of ship, but a portion of the quay length is lost (usually about 60 metres). The total quay length necessary is large and represents a costly investment.

FIGURE 29

**Alternative layouts for a ro/ro quay**



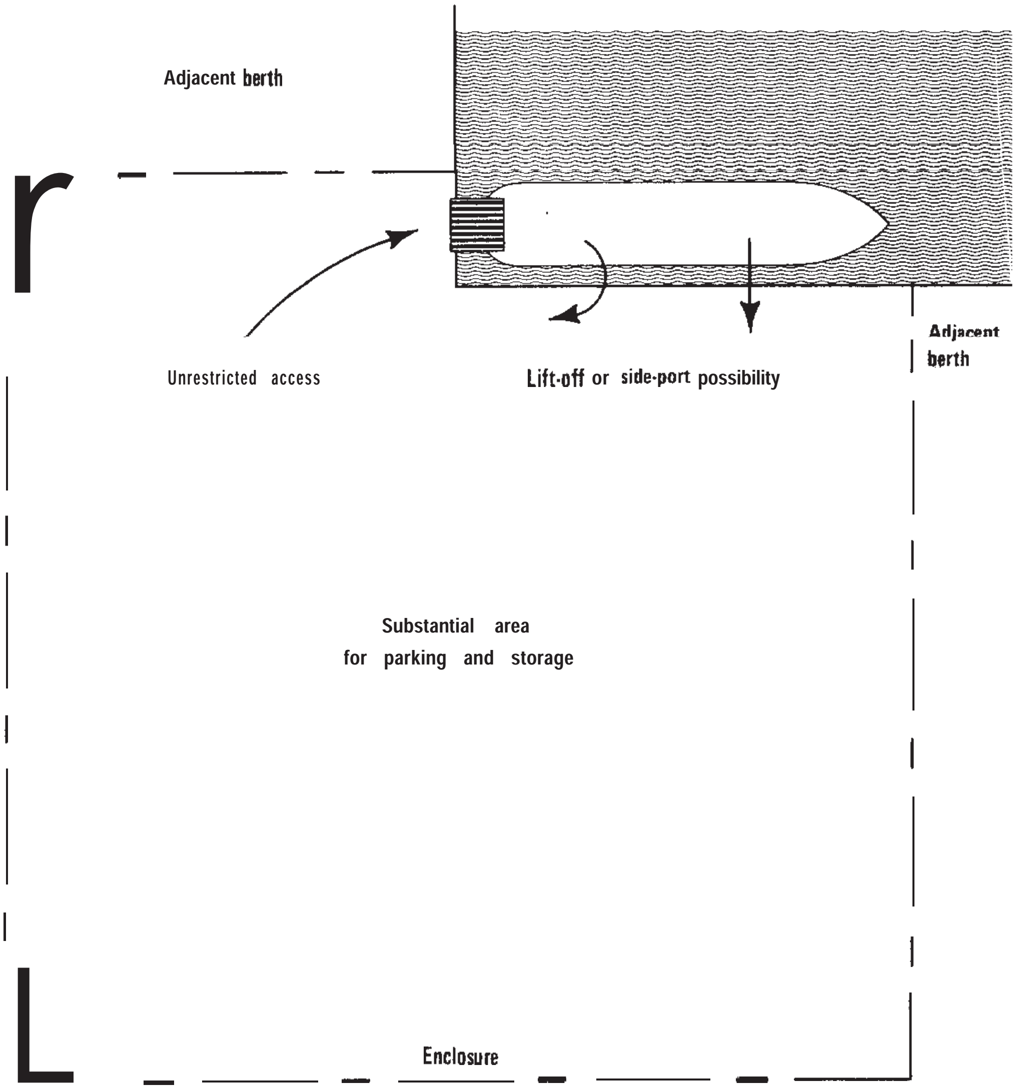

187. Alternative 2 is feasible only if the length of the vessels calling at the port remains unchanged during the lifetime of the facility (30-40 years). In general, this cannot be guaranteed, and, given the trend towards larger ships, few ports may be prepared to take the risk of building a quay which might become inadequate within a time span of five to ten years. However, its advantage is that it separates traffic flows on the quay.

188. Alternative 3, although the least expensive in cost terms, is not generally appropriate since it can be used only for roiro vessels with stern or bow cargo-handling arrangements. This eliminates a large number of ships and any lift-off operation.

189. Alternative 4 has a number of advantages. It combines the flexibility required to handle different types of ships with the possibility of receiving vessels of increasing length. This staggered layout for two berths is a natural development of the single roiro corner berth, which is the preferred layout when only one ro/ro ship at a time is to be handled. The typical layout of the single corner berth is shown in figure 30.

FIGURE 30

Preferred layout of a single roiro corner berth




190. A roiro berth needs to be in a well-protected location in a port. Although some down-time can be accepted at any berth in a port, roiro traffic is, more than any other, dependent for its overall transport economy on rapid turn-round times and it can be more seriously affected by swell and by tides than a lift-off operation.

191. In a location where there is no tide, roiro facilities can dispense with adjustable ramps and are very cheap to construct. The simplest form of roiro berth comprises a surface on to which the stern or bow ramp of a ship is lowered during loading/unloading. A slewing or fixed quarter ramp allows a roiro ship to use a normal berth and can be supported by a system of tension cables, with an automatic winch which limits pressure on the wharf. Figure 31 illustrates the typical design for a slewing ramp, which gives the ship a greater flexibility in berthing choice. In high tidal ranges, the necessary adjustable bridge ramp and supports add considerably to the cost of the basic facility. With a tidal range of 5 metres, a bridge ramp from 25 to 50 metres long[10] would be needed, capable of carrying the heaviest trucks and trailers. Under such conditions, the economic and operational possibility of an enclosed dock should be examined, as discussed in part one, chapter VII, "Civil engineering aspects".

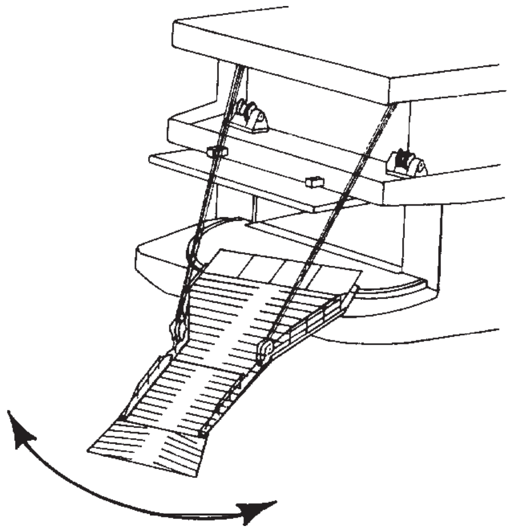
192. In more sophisticated systems, an adjustable bridge ramp forms a suspended roadway hinged at the inshore end and supported near the outer end to provide a connection between the shore approach and the ship. The outer end may have a telescopic or hinged connection. There is, therefore, a much greater interaction between ship design and berth design than for many other maritime facilities.

193. Several basic designs have been put forward for the bridge ramp, which differ essentially in the method adopted for the adjustment of the ship end of the bridge ramp to accommodate changes in level due to loading and discharging and tidal fluctuations. Two alternatives are normally considered. The first consists of a floating pontoon or bridge ramp which automatically rises and falls with the change of tide. Figure 32 illustrates one form of this bridge ramp. The second possibility is for the ship end of the bridge ramp to be

[10] The exact length depends on the maximum difference in elevation between the ship's exit and the quay surface.

FIGURE 31

Example of slewing ramp for ro/ro service



connected to a fixed gantry structure either by cables or by hydraulic means, which provide the necessary adjustment.

194. An important feature of a floating bridge ramp is its capability of being moved from one part of the quay wall to another. This is desirable in many cases, to increase berthing flexibility. It is usually possible to tow pontoons to other locations fairly quickly.

**D. Terminal area requirements**

195. One characteristic of the ro/ro terminal is the need for adequately fenced, protected and surfaced storage areas with a wide, well-paved access way. The transit storage area needed for a ro/ro terminal may be even larger than that needed for a container terminal, which is normally 10 hectares per berth. To determine the storage area requirements, the ro/ro cargo forecasts should be grouped under the following four headings:"

(a) Containers;

(b) Cargo carried by intermediate methods;

(c) General cargo;

(d) Wheeled cargo.

196. The container forecast is in TEU units and therefore the container terminal planning chart I, for the container park area, can be used. The appropriate area requirement per TEU factor, together with other factors such as transit time, will allow the planner to calculate the corresponding area requirements for the ro/ro terminal.

[11] See part one, chapter III. section F, on forecasting cargoes carried by ro/ro ship.

FIGURE 32

Example of adjustable bridge ramp for ro/ro service

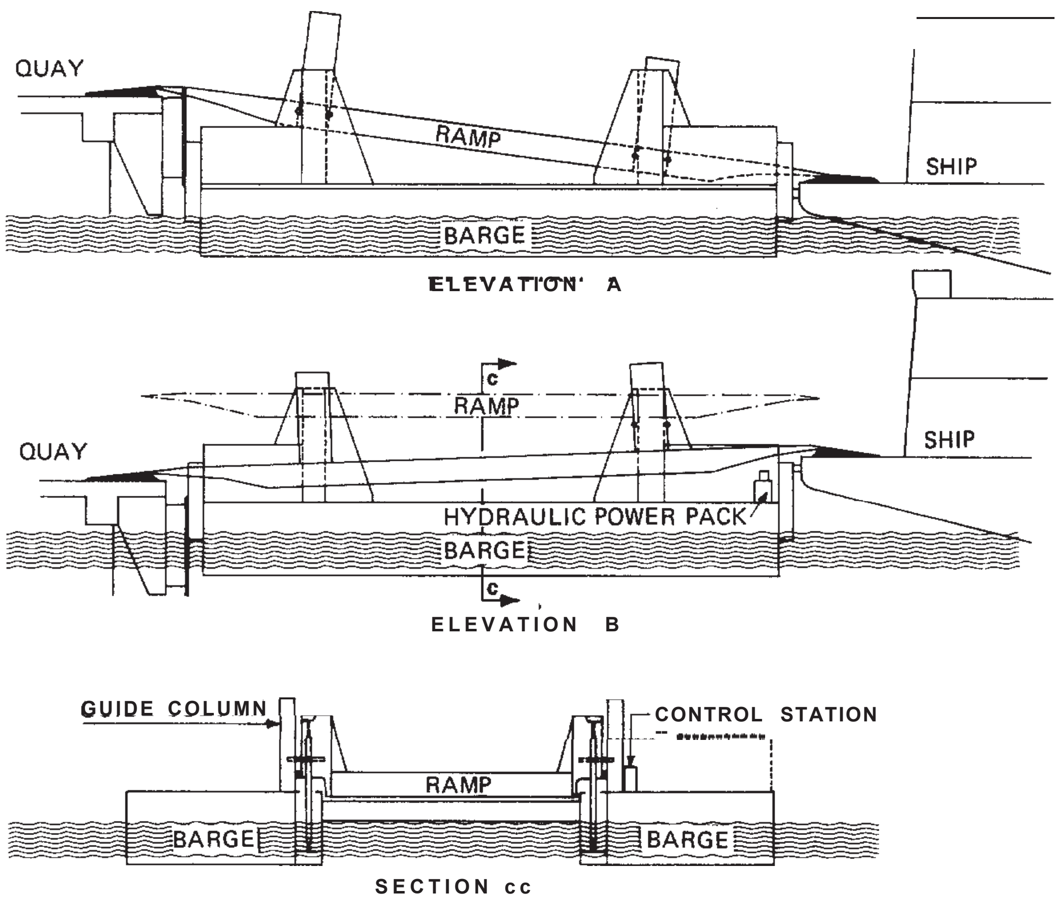
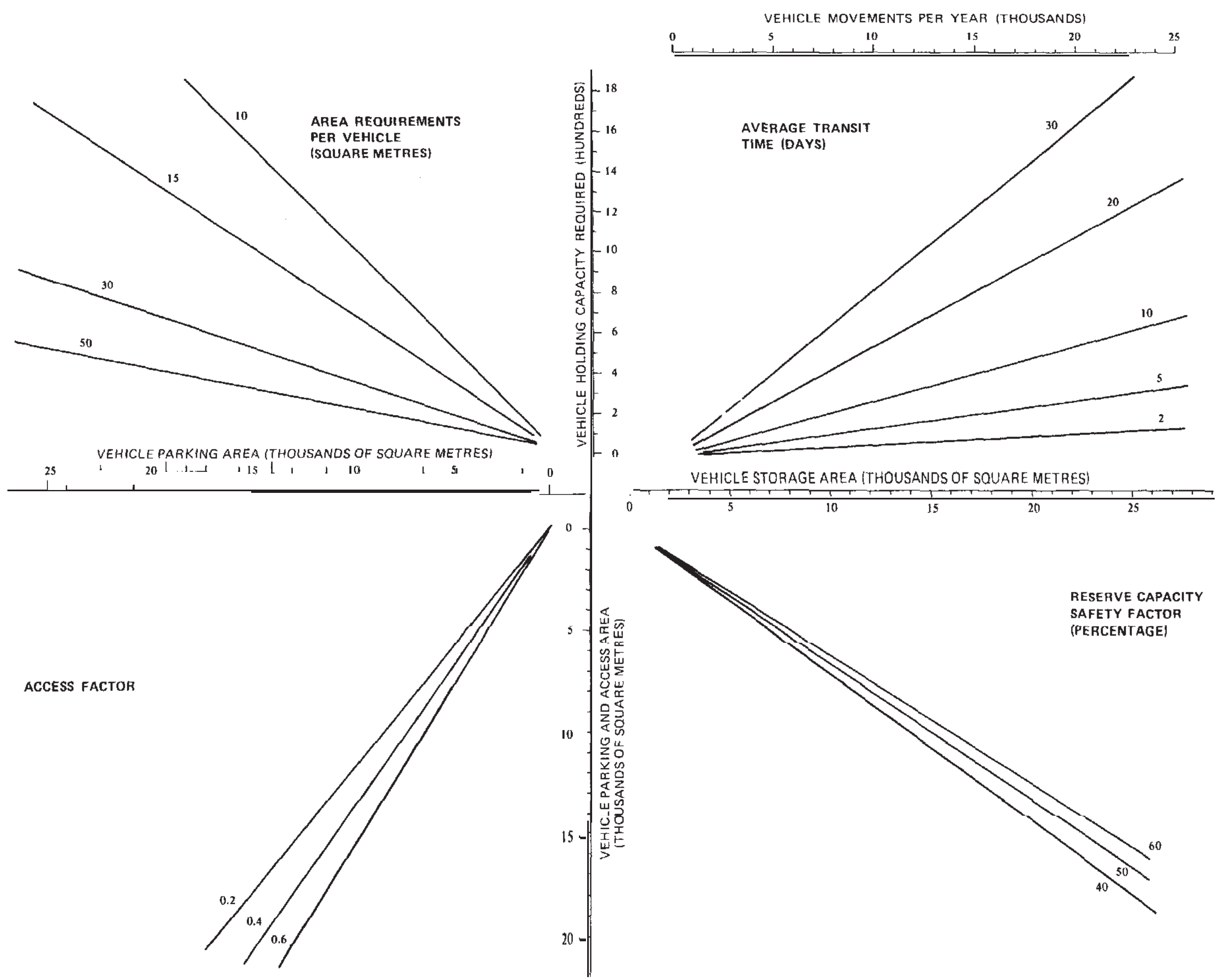


FIGURE 33

**Ro/ro terminal planning chart: vehicle storage area**



197. The storage area requirements for the second and third categories of roiro cargo can be determined by using the break-bulk terminal planning chart III for storage area requirements. The appropriate stowage factor, stacking height and transit time must be used for each category.

198. The area requirement for roiro wheeled cargo can be determined from the roiro terminal planning chart for vehicle storage area, illustrated in figure 33. Typical area requirements, excluding access area, for various road transport vehicles are as follows:

| | *Square metres* |
|---|---|
| Articulated truck, 15-metre | 46.5 |
| Rigid truck, 16-ton | 26.5 |
| Automobile | |
| large | 11.0 |
| small | 7.0 |

A sufficiently large area should be allocated to this category of cargo to accommodate the largest shipment of vehicles envisaged. For example, a shipment of 500 small automobiles would require a minimum area of approximately 4,500 square metres, assuming a 2.5 per cent allowance for access.

## E. Ro/ro terminal equipment

199. Transfer and stacking operations are carried out with a large variety of equipment on one terminal. For transfer operations, the main piece of equipment will be the port terminal tractor. The tractor will have the ability to haul a fixed load up a specified gradient at a certain speed, as well as a port-adapted, heavy-duty fifth wheel to allow crossing ramp connections. This fifth wheel will have lateral inclination allowance and a locking device to reduce torsional stress. The cab of the tractor will have swivelling controls or dual seats for forward and reverse manoeuvring.

200. Other equipment used for both transfer and stacking would be low-profile straddle-carriers and heavy-duty fork-lift trucks with a low-profile cab and triplex mast.

201. For working in the ship's hold via side ports, an electric fork-lift truck is preferable to a diesel-driven vehicle. Slopes and cambers can reduce fork-lift performance seriously. The gradient should never exceed 1 in 10. For example, where there is a slope both to the ship's deck and to the shed or stack, battery-driven fork-lift trucks may need recharging three times in one shift, and diesel lift trucks are more appropriate.

## Chapter VI

## TERMINAL REQUIREMENTS FOR BARGE-CARRYING VESSELS

### A. Barge-carrier systems

202. The impact of barge-carrying vessels on port operations in developing countries is discussed in more detail in the reports of the UNCTAD secretariat on technological change in shipping and its effect on ports, which have already been referred to several times.” Five types of barge carriers are in commercial service: BACAT, LASH, BACO, SEABEE and Danube Sea Lighter. The LASH system is the one chosen by the majority of lines. The principal dimensions of the barge carriers and their barges are given in tables 5 and 6.

203. The barge carrier requires few, if any, port facilities and is designed to discharge offshore its cargo of loaded barges, which are then moved by tug either into port or into an inland waterway system. The carrier is then free to accept pre-loaded barges for the return trip. The great advantage is that the carrier spends most of its time at sea and is not penalized by inadequate facilities or congestion.

204. In practice, however, these systems have not proved themselves, largely because few barge carriers have been operated on the type of routes for which they were designed. In addition, the almost parallel development of containerized and ro/ro handling systems have proved more versatile and, in the long run, cheaper to operate.

205. The most successful barge-carrying operations to date have tended to be between highly industrialized regions, namely between the United States (region of the Gulf of Mexico) and northern Europe. Other routes are between Europe or the Gulf of Mexico and the Middle East. A new operator is the Soviet Interlighter joint venture, which has a service linking the Danube river ports via the Black Sea to India, Pakistan, Malaysia, Viet Nam and Kampuchea. Two new barge carriers will provide, with two tug units, feeder services for the existing ships.

206. The other barge carrier operator is the Baco-Liner company. The ships utilize opening bow doors to float on and off BACO barges 24 metres long, each capable of loading 800 tons. The free upper decks can be used to stack TEUs in three tiers.

207. As table 5 shows, barge carriers may be equipped to carry containers or may be pure barge carriers. The former vessels are provided either with cellular holds or special frames for the carriage of containers on deck and they have a ship-based gantry-crane for handling the containers.

[12] TD/B/C 4/129 and Supp 1-6.

### B. Barge-carrier handling requirements

208. The initial idea of barge carriers was that the barges should be loaded and discharged from the mother ship while the latter was at anchor outside the port, and that the cargo carried by the barges should be loaded and discharged at any shallow-draught berth, tugs being used for towing the barges to the berth. Thus, aside from tugs, the port facilities required would be minimal.

209. In practice, more sheltered water has been found desirable for the purpose of loading and unloading the barges, and the mother-ship operation normally takes place inside the port area-at moorings, alongside container or break-bulk berths, or even at a special T-shaped jetty. In either case, a deep entrance channel is required; in addition to the operating draught of the vessel, a minimum of 1 metre must be allowed for trim changes during the operation. The water areas required for the manoeuvring of such large vessels are also substantial, as is the area needed around the mother vessel for manoeuvring the barges.

210. Furthermore, barge carriers with a cellular container complement must call at a terminal with facilities for handling containers.

### C. Barge-handling requirements

211. Handling the barges within the port requires “barge park areas” which are large water surfaces, well separated from the other water-based traffic in the port, where laden export barges await shipment, laden import barges stay until such time as they are sent inland or can be discharged, and empty barges are kept in stock. The area needs careful attention from the point of view of port security.

212. The requisite size of a park area can be considerable, since the inland penetration of the barges is at present low, and thus the great majority are destined for port loading and discharge. Although large water areas may be available in river ports, in breakwater ports the lack of water area proves a major impediment to the smooth functioning of the barge-carrier service. As a rule of thumb, a minimum barge park area of 10,000 square metres should be provided, this area allowing for an average discharge of eight barges per call and a peak of 25 barges.

213. In ports where the necessary areas have been provided. significant investment costs have been involved. At Bremerhaven, 31 pontoons have been constructed, offering mooring space for 140 barges. The

TABLE 5

Principal barge-carrier dimensions

| Operator and vessel | Dwt | Overall length (metres) | Overall width (metres) | Maximum draught (metres) | Barge-carrying capacity | Container capacity (TEUs) With barges | Container capacity (TEUs) Without barges |
|---|---|---|---|---|---|---|---|
| BACAT SYSTEM: | | | | | | | |
| Mackinnon-Mackenzie & Co. | | | | | | | |
| Bacat 1 ........................... | 2 682 | 103.5 | 18.8 | 5.4 | 13 | — | |
| LASH SYSTEM: | | | | | | | |
| Central Gulf Lines Inc. | | | | | | | |
| Acadia Forest ................... | 48 303 | 261.4 | 32.6 | 12.1 | 80 | — | — |
| Atlantic Forest .................. | 48 327 | 261.4 | 32.6 | 12.1 | 80 | — | |
| Bilderdyk ........................ | 44799 | 261.4 | 32.3 | 11.3 | 83 | — | — |
| William Hooper .................. | 46 892 | 272.3 | 30.5 | 12.4 | 89 | | — |
| Button Gwinnett ................ | 46 892 | 212.6 | 30.5 | 12.4 | 89 | — | |
| George Wythe ................... | 46 890 | 272.3 | 30.5 | 12.4 | 89 | — | — |
| Spruce (non-propelled) ........ | 2 600 | 112.7 | 34.2 | 3.4 | 15 | — | — |
| Oak ................................ | 11550 | 134.5 | 34.2 | 4.8 | 18 | | 108 |
| Willow ............................ | 11496 | 134.5 | 34.2 | 4.8 | 18 | — | 108 |
| Condock Rederei | | | | | | | |
| Condock I ........................ | 3 170 | 92.4 | 19.6 | 4.6 | 3 | — | 383 |
| Condock II ....................... | 3 170 | 92.4 | 19.6 | 4.6 | 3 | — | 383 |
| Delta Steamship Lines | | | | | | | |
| Delta Caribe ...................... | 30 292 | 249.9 | 30.5 | 10.7 | 70 | — | 840 |
| Delta Mar ......................... | 41048 | 272.3 | 30.6 | 11.6 | 85 | 72 | 1728 |
| Delta Norte ....................... | 41 048 | 272.3 | 30.6 | 11.6 | 85 | 72 | 1 728 |
| Delta Sud ......................... | 41 048 | 272.3 | 30.6 | 11.6 | 85 | 72 | 1728 |
| Prudential Lines Inc. | | | | | | | |
| LASH Italia ...................... | 30 298 | 249.9 | 30.5 | 12.4 | 70 | — | 840 |
| LASH Atlantico ................. | 30298 | 249.9 | 30.5 | 12.4 | 70 | | 840 |
| LASH Pacifico .................. | 30 298 | 249.9 | 30.5 | 12.4 | 70 | — | 840 |
| Waterman Steamship Corp. | | | | | | | |
| Robert E. Lee .................... | 41 578 | 212.3 | 30.6 | 11.6 | 89 | — | — |
| Sam Houston ..................... | 41 578 | 272.3 | 30.6 | 11.6 | 89 | — | |
| Stonewall Jackson ............... | 41578 | 272.3 | 30.6 | 11.6 | 89 | | — |
| Benjamin Harrison .............. | 21 500 | 272.3 | 30.5 | 11.6 | 80 | | 665 |
| Edward Routledge .............. | 21 500 | 257.6 | 30.5 | 11.6 | 80 | — | 655 |
| Navilash | | | | | | | |
| One on order ..................... | 9 640 | n.a. | n.a. | n.a. | 22 | — | |
| BACO SYSTEM: | | | | | | | |
| Baco-Liner GmbH | | | | | | | |
| Baco-Liner 1 ..................... | 21 801 | 204.1 | 28.5 | 6.7 | 12 | 501 | 501 |
| Baco-Liner 2 ..................... | 21 801 | 204.1 | 28.5 | 6.1 | 12 | 501 | 501 |
| Baco-Liner 3 (on order) ......... | 21 800 | 204.1 | 28.5 | 6.1 | 12 | 501 | 501 |
| SEABEE SYSTEM: | | | | | | | |
| Lykes Bros. Steamship Co. | | | | | | | |
| Doctor Lykes ................... | 39 026 | 267.0 | 32.3 | 11.9 | 38 | 400 | 1 800 |
| Almeria Lykes ................... | 39026 | 267.0 | 32.3 | 11.9 | 38 | 400 | 1 800 |
| Tillie Lykes ....................... | 39 026 | 267.0 | 32.3 | 11.9 | 38 | 400 | 1 800 |
| DANUBE SEA LIGHTER SYSTEM: | | | | | | | |
| Interlighter | | | | | | | |
| Juluis Fucik ....................... | 31850 | 266.5 | 35.1 | 11.0 | 26 | 720 | 1 552 |
| Tibor Szamueli ................... | 31850 | 266.5 | 35.1 | 11.0 | 26 | 720 | 1 552 |
| Two on order ..................... | 8 563 | n.a. | n.a. | n.a. | 6 | — | 513 |

*Source: Lloyds Shipping Economist* (London), October 1982.

total length of the pontoons exceeds 650 metres, and the total cost of the project was almost $4 million. The basin and barge park areas are illustrated in figure 34.

214. Barges can be handled at existing break-bulk and lighterage berths, even of old-fashioned design. However, it might be advisable to provide special handling facilities for the barges where:

(a) Existing facilities are inadequate because they do not provide weather protection or sufficient space for assembling cargo and loading it on to barges;

(6) Existing facilities are fully utilized and the handling of additional barges would lead to congestion;

(c) The distance between the barge park area and the existing break-bulk berths is excessive;

(d) A combined terminal for handling containers and barges is preferred from a cost-effectiveness and operational point of view.

215. The higher the cost of labour in a port, the greater will be the need to build well-equipped and suitable barge-handling facilities. Only then can the operations be expected to achieve the considerable increase in productivity which is an essential requirement in ports with high labour costs if port cargo-handling charges are not to become prohibitive. Similar reasoning provides an incentive for the increased use of pal-

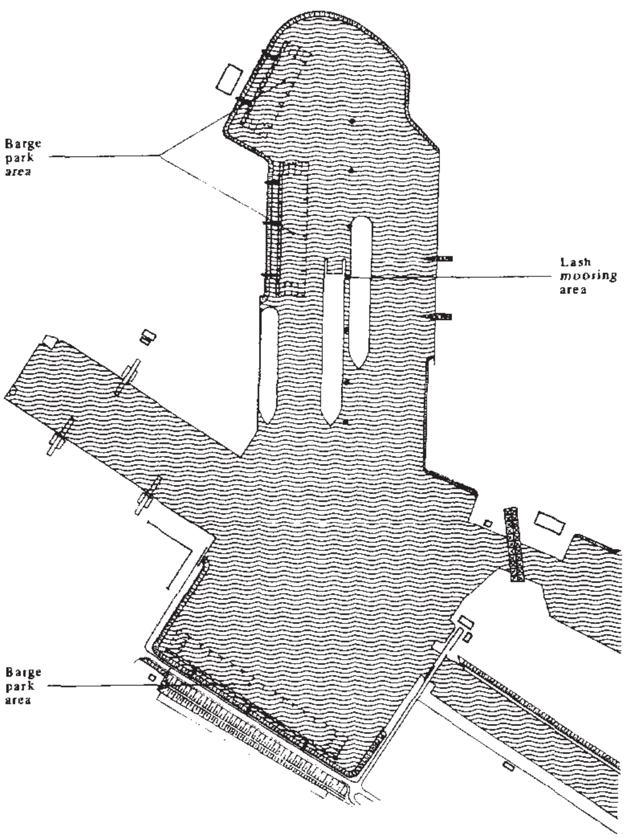
TABLE 6

Barge dimensions

| Type | Length (metres) | Breadth (metres) | Maximum draught (metres) | Carrying capacity (tons) | Bale capacity ($m^3$) |
|---|---|---|---|---|---|
| BACAT ............ | 16.82 | 4.65 | 2.5 | 140 | 164 |
| LASH ......... ....... | 18.76 | 9.50 | 2.1 | 370 | 554 |
| BACO ............... | 24.00 | 9.50 | 4.1 | 800 | 1 020 |
| SEABEE ........... | 29.72 | 111.67 | 3 2 | 844 | 1 108 |
| DANUBE SEA LIGHTER ..................... | 38.25 | 11.40 | 3.3 | 1 070 | 1 300 |

FIGURE 34

LASH facilities at Bremerhaven




lets, bundled units and pre-slung units in a barge-carrier operation.

216. In Singapore. a large warehousing complex (providing 200,000 square metres of covered storage space) at Pasir Panjang, which was built independently from the barge-carrier development, has now been partly set aside for the receipt of cargo from barge carriers. This development has made it necessary for the Port of Singapore Authority to install in the Pasir Panjang area six mooring buoys, which will permit the safe anchorage of 120 barges. The buoys are approximately 700 metres apart and are all in line, thus stretching out over 3,500 metres.

217. Although there is thus a variety of alternatives in providing facilities for barge-carrying vessels, combined with or indepedent of break-bulk or unitized berths, indicative planning figures for an annual throughput of 250,000 tons made up of 1,000 barge units with an average cargo load of 250 tons per barge would be as follows:

| | |
|---|---|
| Number of mooring areas | 1 |
| Number of mooring buoys | 4 |
| Required barge park area (assuming a peak of 50 barges at one time) | 20,000 $m^2$ |
| Number of tugs required to tow barges between the mother-vessel and the barge park area (depending on the distance between them) ... | 3 |
| Number of pontoons (assummg an inland penetration of less than 10 per cent) .... | 20 |
| Length of quay and area required to load and discharge the cargo of the barges in port | As for two break-bulk berths |

## Chapter VII

# DRY BULK CARGO TERMINALS

### A. Introduction

218. This chapter is concerned with dry bulk cargoes, but it is necessary first to note that the word "bulk" can be used in two different senses. Traditionally, the expression has been used to indicate that a commodity was loaded or discharged in loose or fluid form, for example, grain or petroleum. More recently, however, there has been a tendency to talk about "bulk shipments" in the sense of shipments by the full shipload or substantial part-load, whether or not the commodity in question is handled by bulk cargo methods in the traditional sense. Thus it is now common to speak of "bulk shipments" of steel plates or bundled timber. The term "semi-bulk" is also used, for example, with reference to large shipments of bagged cargo. This chapter considers dry bulk cargoes in the traditional sense only.

219. Dry bulk cargo is customarily divided into two groups, the "major bulk cargoes" and the "minor bulk cargoes". The major bulk cargoes consist of a group of five commodities which almost invariably move by non-liner methods in full shiploads. In 1980, the traffic in these products was as follows:

| | *World sea borne trade (millions of tons)* | *Percentage carried by bulk and combined carriers greater than 40,000 dwt* |
|---|---|---|
| Iron ore ..... | 314 | 91 |
| Grain | 207 | 43 |
| Coal | 206 | 65 |
| Bauxite | 48 | 40 |
| Phosphate ... | 48 | 17 |

*Source*: *World Bulk Trades 1980*, Featrnleys

The majority of shipments of these commodities are made by specialized bulk carriers and combined carriers (over 40,000 dwt), but general cargo vessels are also used to a certain extent. When a traditional 'tween-deck vessel is used, however, a severe reduction in handling speed results. Separate descriptions of a typical coal import terminal and a typical phosphate rock export terminal are given later in this chapter.

### B. Main characteristics of a major bulk cargo terminal

220. A radical difference exists between the character of a major bulk cargo terminal, especially one for the export of mineral ores, and the average all-purpose commercial port. The requirements with respect to location, depth of water, type of infrastructure, layout, equipment, storage facilities and auxiliary services are basically different from those in a typical general cargo port. Also, the administrative, operating and labour problems must be approached in a different way.

221. Unlike a general cargo port, a terminal for the export of mineral ores does not need to be located close to the main centres of commercial and industrial activities of the country. The nearest possible distance from the mining area, with good land communication, is the most desirable place, subject, of course, to there being favourable natural conditions at that sector of the coast. Depth of water requirements are more stringent, as the trend is towards the transport of most ores in the largest possible vessels with a draft often in excess of 15 metres.

222. Vessels of this size require huge stocks of ore at the terminal and therefore extensive storage facilities. In order to minimize expensive ship time at port, it is necessary to ensure a relatively low berth occupancy to avoid the risk of ships having to wait for a berth, and a very high rate of loading while they are at berth. To achieve the required speeds of loading, a network of belt conveyors is needed, linking powerful reclaimers to ship-loaders. The mechanization of cargo handling has eliminated the need for a large labour force, and the uniformity and simplicity of the material handled at a dry bulk cargo terminal means that the many commercial services needed at a general cargo berth are not required.

223. The handling techniques used allow vessels to be berthed up to a kilometre or more away from shore, if necessary, with the ores being carried to the ship by belt conveyors placed on a light structure. A typical ore berth consists of at least two berthing dolphins, two mooring dolphins and some buoys. In-shore of the berthing dolphins, an independent structure supports the loading equipment, composed of a ship-loader connected to land by belt conveyors. The storage area on land requires the proper equipment for unloading vehicles from the mines, for stacking the ores on the stockpiles and for reclaiming ore for delivery by belt conveyor to the ship-loader. In addition, facilities for direct transport from unloading hoppers to the ship-loader should be provided.

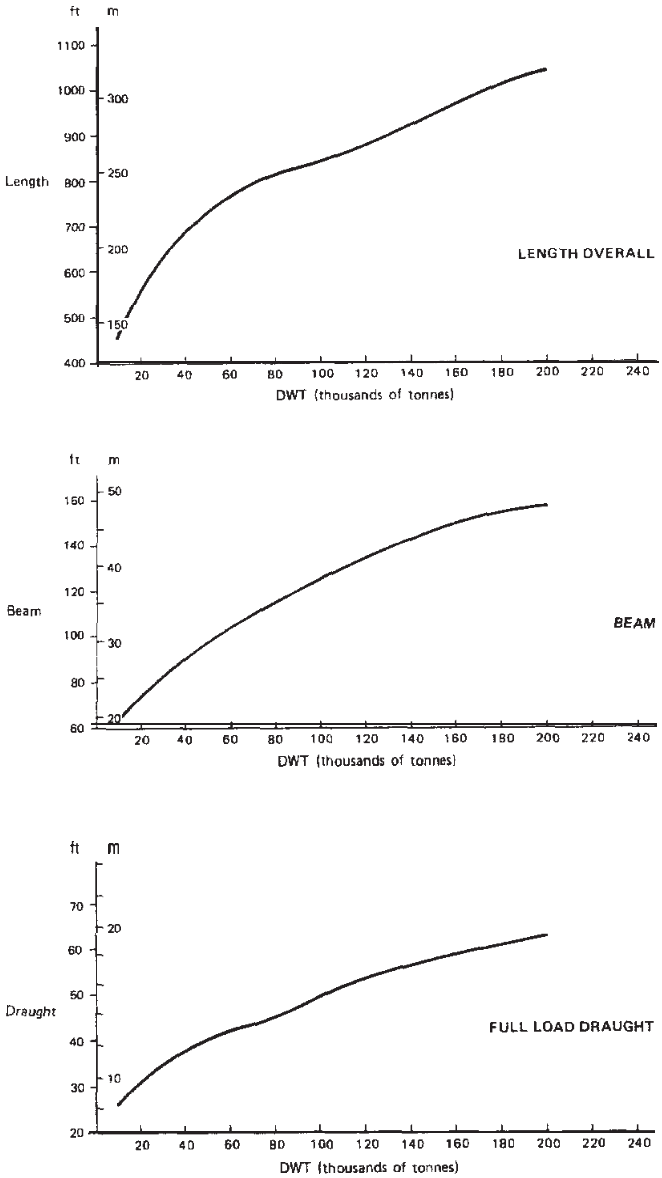
224. Although the basic elements will remain approximately the same from one terminal to another, the particulars of the design will vary considerably, according to local conditions, the nature of the material and the scope of the operation. Normally each installation will have to be designed and built to suit the particular circumstances.

### C. Bulk carriers

225. Wherever possible, bulk cargo installations should be designed for specific ships known to be call-

FIGURE 35

**Principal dimensions of dry bulk cargo carriers**




*Source:* University of Liverpool, Marine Transport Centre, *The Principal Dimensions and Operating Draughts of Bulk Carriers.*

ing. Detailed discussions with the shipowners and shippers should therefore be held to agree on the requirements for ship-loaders and unloaders. However, other ships will call and the specifications will need to take account of both maximum and minimum ship sizes.

226. The phenomenal growth of the dry bulk cargo fleet in recent years is comparable to the growth, in both numbers and size, of oil tankers. In the mid-60s there began a trend towards combination carriers able to transport two or more different types of commodities. Most of the larger vessels are capable of transporting both dry and liquid bulk commodities. Bulk carriers are classified into six types, designated as follows: B (bulk), 0 (ore), B/O (bulk/ore). O/O (ore/oil), OBO (ore/bulk/oil) and OSO (ore/slurry/oil).

227. Figure 35 gives curves showing the relationship between the length overall, beam and full load draught. and the dwt, for the majority of dry bulk carriers. Where information on specific vessels to be employed is not available, these curves are sufficiently accurate for preliminary planning purposes.

228. Ideally, all water areas which ships may have to pass through or lie in should be designed for their maximum (fully-loaded) draught. even though the occasions when ships will enter or leave port at this draught will be few in number. However, substantial economies can sometimes be made by providing less depth than this when there is certainty as to the loadings to be expected. A rough general relationship between load factor and draught for dry bulk carriers is given in figure 36.

229. It is possible for there to be certainty as to the dry bulk cargo loadings to be expected when there is an integrated transport service, for example, bulk carriers chartered by a chemical works. In such a case. the maximum load factor and hence the draught can be determined from the known stowage factor of the commodity in question and the specification of the ships to be chartered. Planning for a limited draught may also be justified when the draught of ships arriving or departing is linked to and limited by draught restrictions elsewhere.

230. The planner should thus be aware that facilities designed for a fully loaded 100,000-dwt carrier may also have to handle a partially loaded 200,000-dwt carrier. While the draught limitation of the entrance channel is overcome by the reduced load factor of the vessel, the beam and length may prevent the vessel working at the terminal. This factor should be borne in mind when specifying mechanical handling equipment. The facilities may also be required to handle smaller vessels and appropriate steps would be necessary; for example, fendering may need modification.

## D. Bulk handling equipment performance specifications

231. The exact meaning of the manufacturer's performance specification for a piece of bulk handling equipment must be understood by the planner of a terminal. In fact, the various items of equipment for bulk cargo handling are subject to wide variations in performance. This applies particularly to ship unloaders and reclaimers.

232. In the case of a grab unloader, for example, the discharge rate depends on all of the following factors:

(a) Volumetric capacity of the grab;

(b) Density and nature of the material;

(c) Grab hoisting speed and acceleration;

(d) Trolley travelling speed. acceleration and braking;

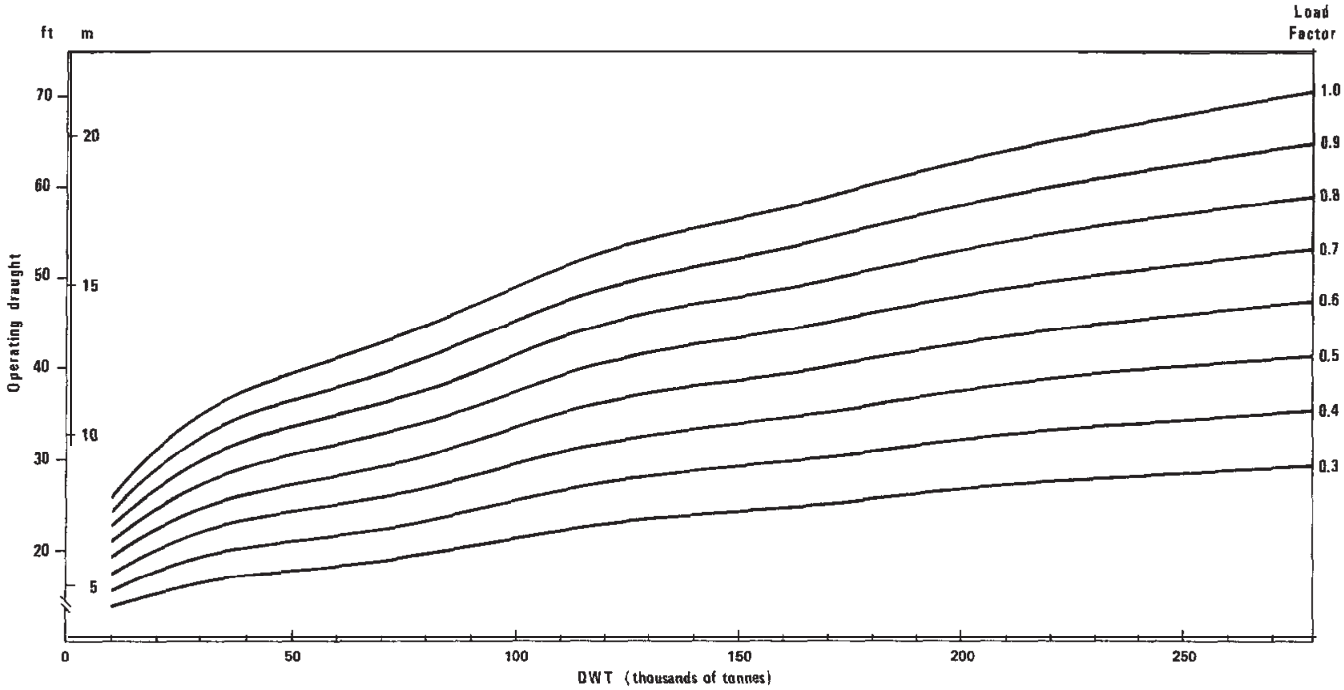
(e) Skill of unloader operator;

(*f*) Shape of hold and hatch opening;

(*g*) Method of trimming in the hold;

FIGURE 36

**Operating draughts for different load factors against dwt for dry bulk cargo carriers**




*Source:* University of Liverpool, Marine Transport Centre, *The Principal Dimensions and Operating Draughts of Bulk Carriers.*

(h) Ship's beam and unloader outreach;

(i) Depth of hold and tidal height;

(*j*) Travel distance from ship's rail to hopper.

233. Thus there is little meaning to a capacity figure for an unloader taken in isolation from the ship and the layout of the installation. The following three capacities should be defined in proposals, tender requests and design specifications: (a) peak capacity; (b) rated capacity; (c) effective capacity.

234. The peak capacity is defined as the maximum hourly unloading rate which can be achieved by the unloader when the cross traverse and hoisting distances in the unloading cycle are the absolute minimum, for example, when a full ship at the highest tide is discharging to a full hopper, and when the operator can exploit the maximum capacity of the hoisting and traverse speeds with a full grab. This rate is the capacity to which the connecting belt conveyors and weighers should be designed in the absence of other overriding economic factors.

235. The rated capacity differs from the peak capacity: it is the unloading rate during unloading from a specific point in a vessel. This point is generally located, horizontally, at the centre of the vessel to be unloaded, and vertically, at mean low water level for the port. The payload of the bucket divided by the time taken to perform one cycle from the digging point to the receiving hopper on the quay and back gives the rated capacity. This figure is a useful definition for the comparison of equipment proposals and the classification of alternative solutions to a specific requirement.

236. The effective capacity is the average hourly rate of tonnage discharged during the unloading of the entire cargo of one ship, taking into account the time lost in trimming, cleaning up, moving between holds and the requisite breaks during the working periods, but excluding scheduled non-working periods, for example night-time and weekends. The effective rate is the figure used for port planning. The ratio of the effective capacity to the rated capacity gives the through-ship efficiency factor which for grabs is usually about 50 per cent. The effective rate and the factor for the fraction of time berthed ships are worked per day are used to determine the daily throughput and then the average ship service time.

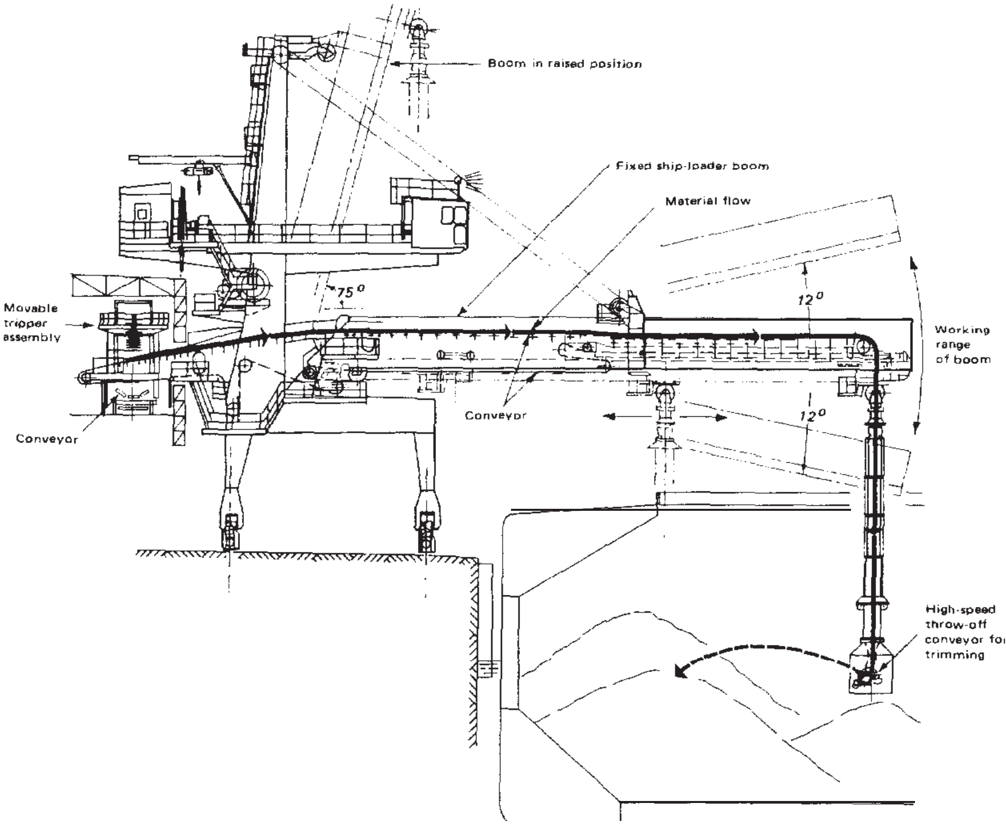
237. The "peak capacity" and "rated capacity" are also known as the "cream digging rate" and the "free digging rate" respectively. In a typical case, where the peak capacity is 2,500 tons per hour, the rated capacity may be 2,000 tons per hour and the effective capacity not more than 1,000 tons per hour. The effective unloading capacity can be even lower than 40 per cent of the peak capacity if the ship has unsuitable holds, narrow hatches and bad conditions for trimming.

### E. Ship loading

238. Ship-loading systems are simple in comparison with ship-discharging systems. They normally require only a feed elevator or conveyor, a loading chute and the force of gravity. With such technically simple systems, phenomenal rates can be achieved. Other loaders are fitted with flight conveyors or spiral chutes to reduce the degradation of friable materials, or with telescopic tubes fitted with chutes or centrifugal slinger belts for distributing the material in the hold. Shiploaders can normally be positioned adjacent to the hatch to be loaded, and they receive the material from high-capacity belt conveyors. The loading boom can be

FIGURE 37

**Example of travelling ship-loader with material from high-level conveyor**




hoisted or lowered to suit the height of the vessel being loaded. In addition to continuous loading with a ship-loader, grabs can also be used for loading bulk cargoes.

239. Ship-loader capacities are usually limited by the other parts of the installation such as the conveyors or reclaimers, but normal capacity ranges are between 1,000 and 7,000 tons an hour. In special cases, 16,000 tons per hour handling ship-loaders are possible for very large bulk vessels. At higher loading speeds, the limit may be imposed by the rate at which the ship can be de-ballasted.

240. Ship-loaders are designed to permit the holds to be loaded in a definite sequence to avoid putting structural stresses on the vessel. Telescoping spouts at the end of the boom are frequently provided to direct the discharge into specific parts of the vessel. The boom can be raised to pass clear of a vessel's superstructure when changing from hatch to hatch, but this may require the conveying system to be stopped in order to prevent spillage of material. To avoid this, the material can be conveyed into a surge hopper at a point before the loader and returned to the normal flow when loading is resumed. The loader belts must then run faster than the supporting conveyors to handle the additional flow.

## F. Types of ship-loaders

241. The travelling loader (see figure 37) is on a gantry running parallel to the quay. The ship-loader is usually fed by a conveyor with a movable tripper. The tripper feeds the material from the conveyor to the ship-loader boom conveyor. The ship-loader consists of a mast superstructure from which a hinged boom is suspended. The boom is raised or lowered to suit the vessel and to clear the vessel's superstructure when moving from hatch to hatch. The vessel end of the boom can be constructed to telescope or a shuttle section can be arranged to travel inside the fixed boom. A take-up system must compensate for variations in belt length due to the boom movements. A design feature of this type of loader is that there is only a slight shift of the centre of gravity within the structure for all the jib and boom movements, and the loader can therefore be placed on somewhat narrower rails than other types.

242. The radial loader was developed for use as an offshore unit and consists of a pivoted boom which can rotate or slew through an angle of approximately 90 degrees about one end, whilst the other end is carried on a curved track supported on suitable piles. The boom supports a conveyor which extends over the vessel. This section, in addition to travelling backwards and forwards, can also be made to luff. Material is discharged from the approach arm conveyor at the pivoted end of the boom conveyor, where. if required, a surge hopper can be located.

243. The main advantage of slewing bridge-loaders as compared with the travelling loaders is the lower capital cost of the total installation, that is, of the loader and related conveyors, together with the marine structures. Another favourable feature is that it is

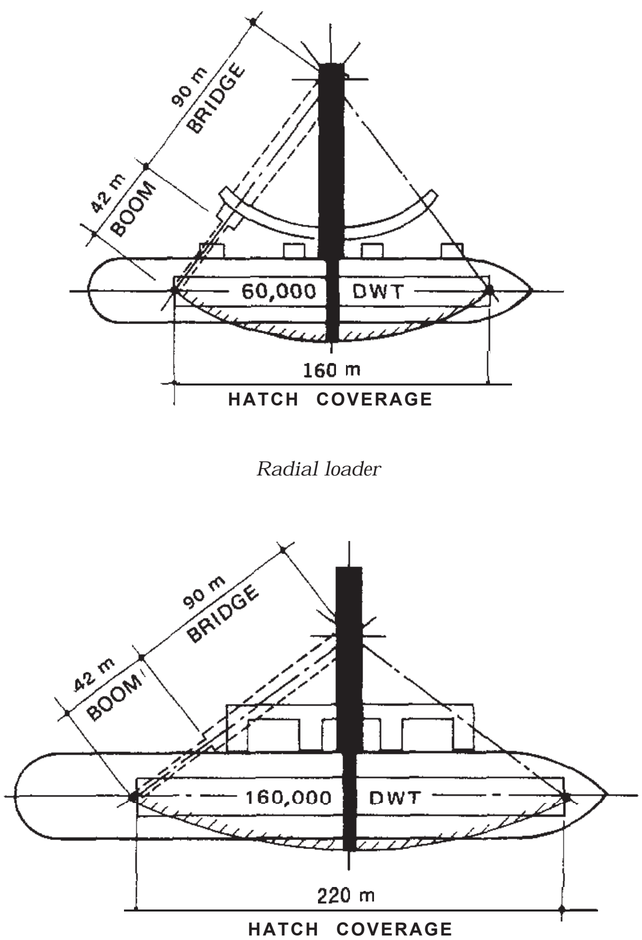
easier to enclose the conveyor belts and transfers and to install dust control systems. A disadvantage is that this type of loader can completely fill, without final trimming, only a modern bulk carrier with no intermediate masts and derricks. This prevents carriers which are so equipped from using the terminal.

244. The liner loader achieves the same purpose by a combination of translation and rotation (the two methods are shown in figure 38); when the front turntable travels on a linear runway parallel to the ship, the turntable pivot is allowed to slide as well as rotate. Construction is usually simpler and less expensive with a straight runway rather than a curved one, and ship coverage is increased.

245. The travelling and slewing type of loader is a combination of a radial and travelling unit. It is particularly suited for use on both sides of a "finger" jetty, i.e. one extending out to sea with berthing facilities on either side. A travelling gantry with a rotating superstructure has a luffing boom conveyor which is fed from a jetty conveyor centrally located between the travelling gantry rails. By means of a tripper, the material is transferred from the jetty conveyor to a receiving hopper located over the pivoted **end** of the boom. Although only one vessel can be loaded at a time, the fact that vessels can be berthed on both sides of the jetty can eliminate delays in operating due to berthing and de-berthing. This may be important under conditions of high berth occupancy and tight scheduling.

FIGURE 38

**Radial and linear loader comparison**




*Radial loader*

*Linear loader*

246. The fixed ship-loader is generally used for smaller installations. As the vessel size is usually small, the output rarely exceeds 500 tons per hour. The movement of the loading boom between hatches is either non-existent or restricted, and it is therefore necessary to move the vessel. This may not present any problems with the smaller type of vessel having two or three holds only, and has been used extensively for the export of raw sugar.

247. The approach conveyor from the land is carried to the berth on a series of trestles and terminates with a tower structure. The conveyor is either extended in a short sliding section terminating with a telescopic chute or is carried in a luffing boom fitted with a telescopic chute. In some cases a limited amount of radial movement is provided to enable the whole area of the hatch opening to be covered and so reduce the amount of final trimming.

## G. Ship unloading

248. There are four basic systems available to the terminal operator for the discharge of dry bulk material: grabs, pneumatic systems, vertical conveyors and bucket elevators. For a throughput per unit of between 50 and 1,000 tons per hour, pneumatic or vertical conveyor systems are adequate. For throughputs from 1,000 up to 5,000 tons per hour, grabs or bucket elevators are the only alternative. Grabs are the most widely used methods of loading and discharging bulk cargoes.

### 1. GRABS

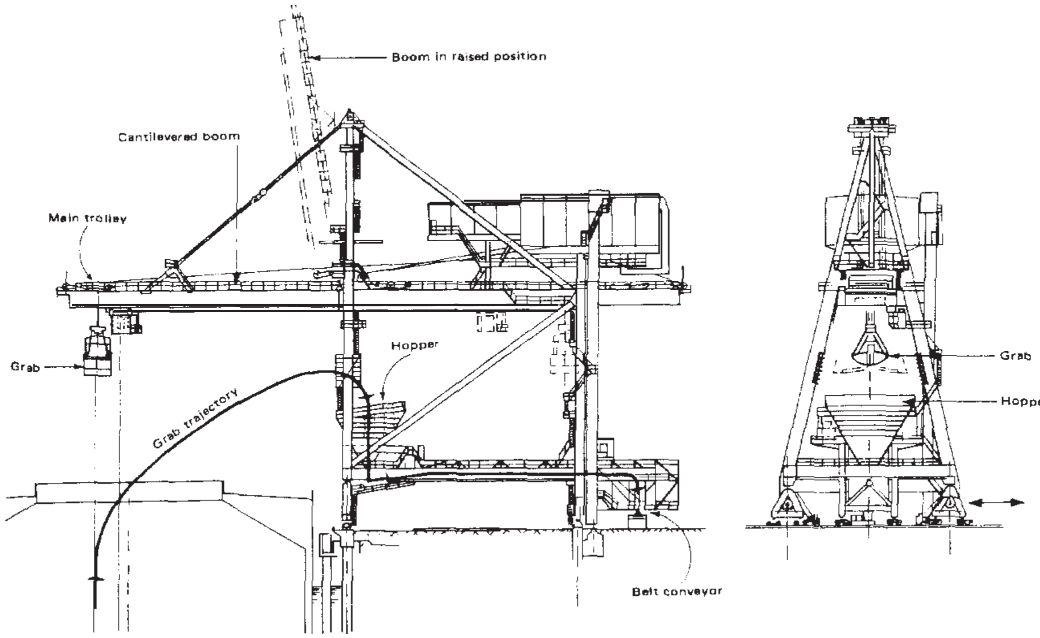
249. The main principle of unloading bulk commodities by grab has not undergone any change in the past 50 years. However, the grab is now normally used only for picking material up from the vessel hold and discharging it into a hopper located at the quay edge feeding on to a belt conveyor, as illustrated in figure 39. In previous practice the grab trolley travelled further, discharging to the stockpile.

250. The attainable handling rate for each grab is determined by the number of handling cycles per hour and the average grab payload. The time of a handling cycle is a function of the hoisting speed and acceleration of the grab bucket, the travelling speed and acceleration of the trolley, the horizontal and vertical distances and the closing time of the grab. Further factors affecting it are the skill of the operator, the properties of the material being handled, the shape of the hatches and cargo holds and the degree of cleaning required at the end of each hold-emptying. Operator fatigue in any case places a limit of about 60 cycles per hour. Two operators can be provided, each working alternately for one hour.

251. For a given lift capacity, the main method of increasing productivity is increasing the payload/deadweight ratio of the grab bucket. The normal ratio is 1:1,

FIGURE 39

Travelling overhead trolley unloader grabbing crane




but newer high-capacity designs are approaching 2:1. A bulk cargo terminal handling a range of commodities will require a set of two or three grab buckets for each crane (one on the hook, one on standby and/or one in repair), plus a set of grabs for each commodity which has significantly different physical characteristics. The number of available designs is very large, ranging from the light grabs for handling products such as animal feedstuffs and grain, to the massive 50-ton-lift ore handlers. Specialist advice should therefore be sought to allow the choice of the correct unit for a specific material and crane type, and for specific working conditions

252. To achieve the desired rate of unloading, it is often necessary for a single vessel to be served by two unloaders. This has an important advantage in providing operating capacity during the failure of one of the units.

253. The principal materials for which the grabbing bulk unloader is used are the main bulk products, namely, iron ore, coal, bauxite, alumina and phosphate rock. Other commodities handled by smaller mobile grabbing cranes include raw sugar, bulk fertilizers, petroleum coke and various varieties of bean and nut kernels.

254. There are three main forms of grabbing crane. The travelling overhead trolley unloader (see figure 39) has a cantilevered boom which projects over the hatch. The trolley transfers the bucket from the hold to the hopper on the quay, The structure travels parallel to the quay to allow working the full length of the ship. Typical free digging rates for these units range from 500 to 2,000 tons per hour.

255. The revolving grabbing crane, as shown in figure 40, is generally of the level luffing type and is probably the most commonly used type for unloading. The crane grabs and lifts the material and discharges it into a hopper, generally at the front to eliminate slewing during operation. The hopper feeds a jetty conveyor in the usual way or it can discharge directly to trucks or rail wagons. These cranes can attain a free digging rate of between 500 and 700 tons per hour. When a normal general cargo crane is being used for grab unloading, the hopper must be located on the same track as the crane. The 90-degree slewing movement for each grab cycle limits the free digging rate to 250 tons per hour, a good average rate being about 180 tons per hour.

256. The third form of grabbing crane is the mobile port tower crane which is useful in smaller ports handling a wide range of mixed cargoes to and from smaller vessels. This unit comprises a standard mobile crane with an additional tower structure fitted with an elevated cab to allow the operator to look down into the ship's hold. Productivities are similar to those achieved with the revolving grabbing crane.

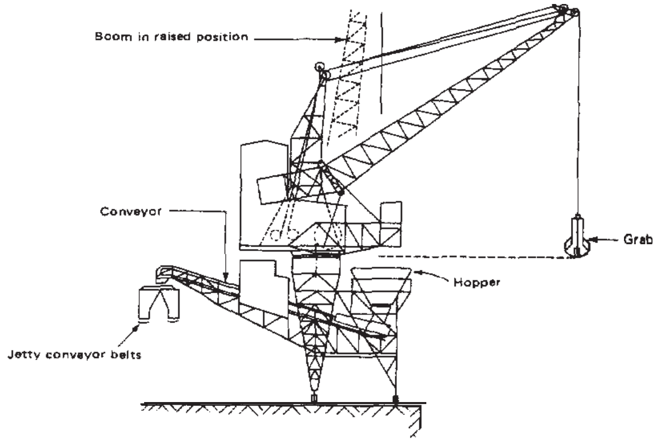
## 2. PNEUMATIC SYSTEMS

257. Pneumatic systems are suitable for handling bulk cargo of comparatively low specific gravity and viscosity such as grains, cement and powdered coal. Pneumatic equipment is classified into vacuum, or suction types and pressure, or blowing types. The former are suitable for collecting materials from several places to one spot while the latter are suitable for delivering cargo from one spot to several places. However, the blow type tends to create dust problems. A combination of the two systems is also used, but it is generally restricted to portable equipment. Typical uses of this equipment are shown in figure 41.

258. Vacuum pneumatic conveyors are simple in construction and materials are not lost through spillage during transportation. However, the power consump-

FIGURE 40

**Revolving grabbing crane**

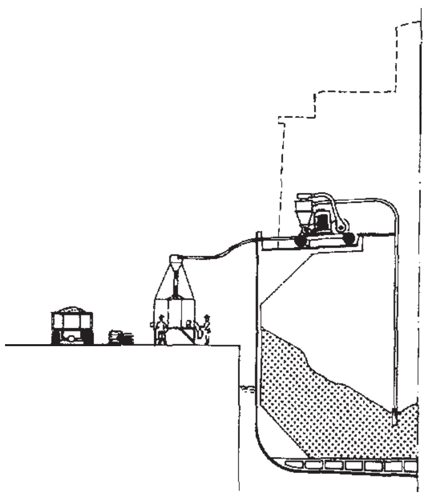



tion is high compared with other transporting media. Before a decision is taken whether to adopt a pneumatic handling system or a conventional mechanical handling system, not only must the capital, maintenance and operating costs be considered, but also health, cleanliness and other factors which cannot be directly evaluated.

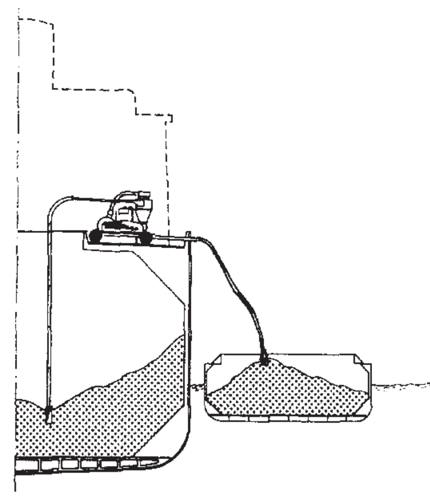
259. Certain materials are potentially dangerous and should be handled carefully to ensure the health of the operators. Some hazards to health can be overcome by the wearing of face masks and protective clothing. The adoption of a fully enclosed pneumatic handling system, although initially more expensive, often improves working conditions and reduces material loss as well. Cleaner conditions improve morale, facilitate plant maintenance and reduce health hazards.

FIGURE 41

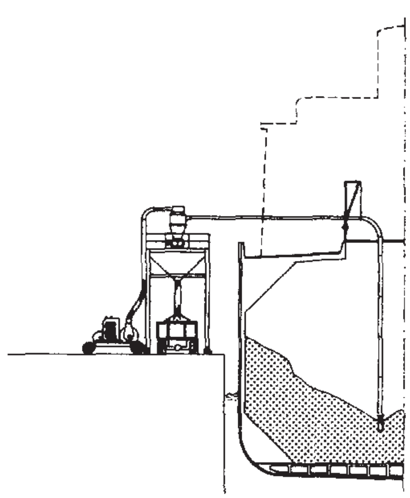
**Portable pneumatic handling equipment**



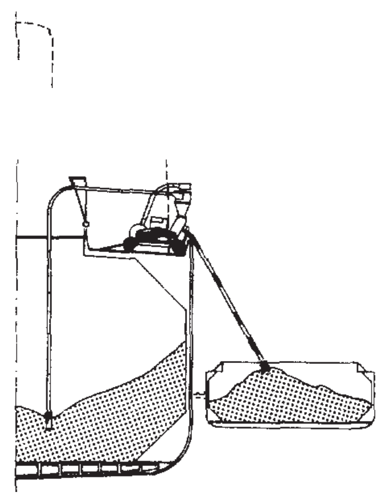
1. *Combination vacuum/pressure system; conveying grain from ship into bagging hopper.*



2. *Combination vacuum/pressure system;* conveying *from* ship *to* barge.



3. *Vacuum-only system : transferring grain from ship into truck or rail wagon loading hopper.*



4. *Vacuuming grain from ship; loading grain by gravity into barge.*

260. The travelling pneumatic elevator consists of a rail-mounted gantry with a total enclosed superstructure for housing the major items of equipment. Generally, two units are housed in one gantry, and the usual limit of unloading rates is about 200 tons per hour per unit. The unloading arms terminate in flexible intake tubes which allow very efficient cleanup of the hold. Material sucked through the nozzle is collected by cyclone-type separators and discharged on to the onward conveying system, very often a belt conveyor.

261. There exist also waterborne versions of the travelling pneumatic elevator. They are self-contained and self-propelled machines, with a throughput similar to that of the rail-mounted kind. They can be used for discharging directly to shore storage or, in the case of onward transport, to barges. They can also be arranged to operate in reverse, from barge to vessel for export.

262. In addition, there are portable pneumatic units on wheeled trailers which can be positioned on the quay or aboard the vessel, as shown in figure 41. The handling rates of this light portable equipment are low, usually about 50 tons per hour.

### 3. Vertical conveyors

263. The chain conveyor unloader (see figure 42) is a self-contained unit working on the en *masse* principle. The free digging rate is generally limited to 150 tons per hour. The conveying chain is carried inside a rectangular casing and its motion carries material from the hold. A second unit can be used as a connection to hinterland transport as the unit can be adapted for inclined and horizontal conveying. The units are restricted to dry, friable materials that are compatible with direct contact with moving parts. For intermittent use, it may be more economical to employ this type of unit rather than the grab ship unloader, in spite of its high maintenance cost.

264. The vertical screw conveyor is a full blade screw contained in a tubular casing. The unit can be used at any angle from the horizontal to the vertical. Screw conveyors can efficiently deal with all fine powdered and granular materials, lumpy (provided the lumps do not exceed a specified size in relation to the screw diameter), semi-liquid and fibrous materials. Free digging rates of up to 600 tons per hour have been achieved. The throughput is restricted to the rate at which material can freely flow into the feed aperture. A proprietary type of screw auger has an independently driven spiral around the feed intake to combat this feed problem.

### 4. Bucket elevators

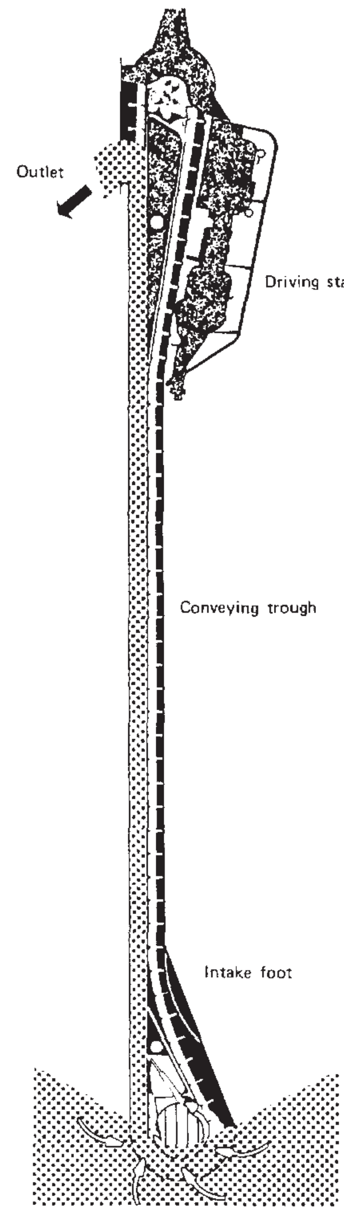
265. Bucket elevators are another alternative for handling rates in the 1,000–5,000 tons per hour range. At present these continuous unloaders appear less efficient in terms of cost per ton unloaded than grabs, taking account of total capital expenditure and operating costs. However, the free digging rates for these units will approach 5,000 tons per hour, while grabs have a maximum rate of 2,500 tons per hour. Developments in this matter should be watched in view of the high theoretical handling rates.

266. One concept involves a continuously rotating bucket wheel suspended from the luffing boom of the travelling unloader. This bucket wheel digs up the material and feeds a continuous bucket elevator. The weight of the structure plus the dynamic digging forces require a heavier and more expensive quay than for the usual grab cranes.

267. An alternative approach uses a bucket chain elevator with the buckets acting as digging scoops. As in the case of the wheel and elevator, the bucket elevator is suspended from the luffing boom. A heavy foundation is again required to absorb the digging forces, and maintenance costs may be considerable. At smaller installations, for example, those for the unloading of coal and phosphate from barges, purpose-built facilities utilizing the bucket chain elevator can be very useful.

FIGURE 42

Chain conveyor unloader



### 5. Slurry system

268. Certain materials, such as iron ore, salt, bauxite, heavy mineral sands and certain coals may be suitable for transportation via the slurry method. This method basically consists of making a slurry-water mixture with 70 per cent ore and 30 per cent water at a mine site, and then pumping it aboard specially equipped mineral tankers. Excess water is decanted prior to ship departure, leaving a concentrate with over 90 per cent solids. At the discharge port, rotating water jets in the bottom of the holds undercut and liquefy the ore concentrate so that it can be pumped ashore. This system eliminates loading and discharge cranes, elaborate docking arrangements and other facilities.

269. The slurry process is a clean one which minimizes material loss that occurs with other, dust-inducing ore-handling procedures. Decanted liquid during the loading process may have to be returned to a settling pond to avoid pollution and to recover ultra-fine particles. The slurry form of the cargo makes it economic to locate the storage area some distance from the port area. The rate of discharge will be dependent upon the size of ship and the installed pumps, but for large vessels it will normally be 6,000–8,000 dry tons per hour. Material can be loaded dry by conventional systems and unloaded using the slurry process.

### 6. Self-discharging vessels

270. At the beginning of 1982, 56 per cent of the bulk carriers were equipped with gear for self-discharge, while only 12 per cent of the ore carriers were so equipped. The average size of vessels so equipped was markedly smaller than that of vessels without gear. The gear usually consists of bucket cranes or derricks with a safe working load varying from 3 to 30 tons.

271. A limited number of carriers have been built which utilize gravity reclaiming on to a belt, chain, or screw conveyor in the bottom of the holds to feed an elevator system within the ship. These vessels require only a hopper and conveyor arrangement at the discharging terminal to transfer material from the ship's system to the storage area.

## H. Horizontal transport

272. Conveyors are the most extensively used piece of equipment in dry bulk handling and reappear in a variety of forms in elevators, ship-loaders, packers and reclaimers, as well as purely for horizontal transport. For horizontal transport, unlimited distances can theoretically be covered by conveyor, although transport economics will usually limit conveyor systems to a few kilometres before rail or road transport becomes more appropriate.

273. The conveyor system layout has a major effect on the whole terminal area requirements, and on its flexibility. The routes taken, and the choice between raised, ground-level or underground systems should be given a similar degree of attention to the layout of a road system in a built-up area. On long runs, design for ease of maintenance is paramount.

274. The general adoption of the belt conveyor as a mechanical carrier for bulk materials has been due to its inherent merits:

(a) Simplicity of construction;

*(b)* Dependability and economy of upkeep;

(c) Efficiency, with small driving power requirements.

(d) Complete discharge of the material handled;

(e) Adaptability.

The material is received directly on to the belt and is carried with a minimum of friction and noise to its destination. There are no joints or other projections to break or wear, and abrasion or friction between the material and the belt exists only at transfer points.

275. The limited vertical angle at which belt conveyors can carry materials necessitates a considerable amount of space to enable the material to be lifted to the required height. The supporting structure for long conveyors also requires routine maintenance work such as painting. These disadvantages have to be considered.

276. Belt conveyors are either flat or troughed, with the former used for packaged material. Two flat belt conveyors with their carrying surfaces located in a vertical plane at an appropriate distance apart can form a "pinch" belt elevator suitable for the unloading and loading of bagged material. Peak rates of 4,000 bags per hour have been achieved.

277. Developments have made possible the production of stronger and wider rubber belts with canvas plies. In addition to these belts with canvas plies, belts with steel wire to increase tensile strength have been produced. In combination with improvements in the associated belt idlers, belt conveyors are capable of transferring several thousands of tons per hour.

278. The chain conveyor has a flighted chain which moves around inside a totally enclosed casing with a dividing partition. Material can be introduced at any point in the top of the casing; it falls through an opening in the partition plate to the bottom of the casing, and is then conveyed by the chain until it reaches a discharge opening. The conveyor can be used up to an angle limited by the characteristics of the material. Any free-flowing material can be handled by this means, and the process is dust free. Grain is the most common material handled, and rates up to 500 tons per hour are possible. For small port installations, in combination with chain-type unloaders, this type of equipment is very useful.

279. The en ***masse*** conveyor is similar to the chain conveyor but is different in operating principle and has a casing of smaller cross-section. The unit works on the principle that the friction between the material and the specially designed chain is greater than the friction between the material and the casing. The material shifts as one body, en masse. This method permits vertical as well as horizontal conveying, and multiple inlets and outlets can be used. The construction can be made dust-tight. One disadvantage is that a certain amount of product degradation occurs.

280. Screw conveyors are a very compact form of handling with a totally enclosed casing, either U-shaped or tubular. The selection of the correct type of screw and trough cross section for the material to be handled is essential if maximum efficiency is to be obtained. Generally, capacities do not exceed 500 tons per hour. The power required is much higher than for other conveyors. Provision has to be made to accommodate end thrust due to the reaction of material along the casing. These conveyors can be inclined from the horizontal.

281. The powder pump can be used for the onward transport of dry pulverized free-flowing materials. Capacities of up to 200 tons per hour at distances up to 1,200 metres have been obtained. A high-speed screw feeds material through a non-return valve into a chamber fed with compressed air which conveys the material to the receiving vessel. Powders composed of fragile aggregates are unsuitable for this technique.

282. The fluidizing gravity conveyor can be used for horizontal transport, particularly for powders. The principle of the conveyor is that when air is passed upward through the material, the mass expands and behaves as a fluid. The conveyor consists of a sloping trough with a porous medium extending across its width. Powder fed into the conveyor flows freely down it.

283. The mono-cableway is the simplest form of aerial ropeway and is the cheapest to install and maintain. A single endless cable serves both to support and transport the load, which is carried in buckets. A single section rarely exceeds 8 kilometres in length but multiple sections can be used. Buckets are disengaged from the cable at transfer stations and are pushed or run automatically on to the next section. At the terminals the loading and unloading can be either manual or automatic. The maximum capacity is generally taken at 150 tons per hour with a typical bucket capacity of 0.5 tons.

284. The bi-cable system separates the supporting and hauling functions of the cables. Two parallel carrying cables are provided on each side of the ropeway centre line. Each cable is anchored at one end and is provided with a tensioning device at the other. An endless hauling cable is used to move the buckets supported on the carrying cables. The relatively heavy single loads which can be supported permit handling rates of up to 500 tons per hour.

## I. Weighing and sampling

285. Material must often be weighed immediately prior to loading or after unloading for payment purposes, or for checking against shipping documents. A simple method is to weigh the material continuously while it is being conveyed. and according to the type of equipment used, varying degrees of accuracy are obtainable. Essentially, the loaded side of the belt is carried over an independently supported section of conveyor structure. The weight of material on this section of the belt is instantaneously recorded. and in conjunction with the speed of the belt the quantity conveyed at any flow rate can be calculated automatically. Various forms of obtaining weights give different degrees of accuracy, and range from simple mechanical/electrical devices to electronic strain gauge units. Two standard levels of accuracy may be provided: an accuracy to within l-2 per cent of the actual weight, and an accuracy to within 2-4 per cent. The degree of accuracy attained is dependent on the placing of the weigher, which is a skilled task.

286. Batch weighing methods are also employed, normally through the use of a weighing bin in conjunction with a surge hopper. Material is temporarily diverted to the hopper while the full bin is automatically weighed and dumped. Weighing towers are often incorporated into the conveyor network, an inclined conveyor being used to feed the top of the tower.

287. Sampling is sometimes a requtrement in a transfer of material, generally to satisfy the purchaser that the material is in accordance with specifications. Any attempt to take a sample by hand could result in incorrect representation of a particular batch. It is therefore essential to take a series of samples automatically at timed intervals. In order to obtain a representative sample from the whole series of primary samples, they can be mixed together and a further sample taken. This procedure can be repeated until a very representative sample of the batch is obtained.

288. Several methods of obtaining samples are available according to the characteristics of the material and the accuracy required. A usual type of sampler consists of a scoop which is quickly swung through the material either on the belt or through the falling stream of material, and deposits its contents either into a sample box or into a mixing hopper for further sampling. The decision as to the best method of sampling and type of sampler to use should be left to the specialist.

## J. Stackers and reclaimers

289. The stacker is a specialized machine designed for the continuous stacking up of various kinds of bulk materials in storage areas, and comprises a tripper (see figure 43) and a stacking-out conveyor. Material is discharged by means of a tripper which allows the stacker to be positioned anywhere along the whole length of the belt conveyor in the storage area. The material is then fed on to the stacking-out conveyor carried in a boom which is capable of being slewed and/or derricked, or may be fixed. Figure 44 shows a typical stacker arrangement. Sometimes, material can be discharged direct from the tripper to allow the area adjacent to the tripper to be used for storage. The capacities of stackers are constantly being increased. and outputs up to 6,000 tons per hour or more are possible, the limiting factor normally being the rate of feed from the unloading equipment. Blending is achieved by the right mode of stacking.

290. The modern reclaimer is a machine that can continuously reclaim and discharge the stored material from the storage area. and consists of the reclaiming mechanism and the intermediate belt conveyor. The reclaiming mechanism may be a revolving wheel on

which buckets or gathering arms are attached. Reclaimers are high in efficiency provided that care is taken in stockpile planning. Typical rated capacities of individual units vary from 1,000 to 3,000 tons per hour. Peak capacities must be used for designing conveyor systems. There is a limitation on the order in which piles of different grades of material can be reclaimed according to their accessibility. It may also be necessary to use a bulldozer to push the farthest parts of the pile into positions accessible to the reclaimer arm. Large-capacity machines are very heavy and require substantial track foundations, so that the existing ground conditions could be the limiting factor.

291. Stacker reclaimers, as illustrated in figure 45, have the two functions of stacking and reclaiming in a single unit. The belt conveyor on the boom travels in the discharge direction with the reclaim wheel stationary when discharging, and in the reverse direction with the reclaim wheel in operation when reclaiming.

292. When the storage area is small, stacker reclaimers have proved to be extremely useful. In a small area, the installation of a separate stacker and a reclaimer will sometimes limit the working area of each machine and cause areas of inaccessible material. If the need for stacking and reclaiming at the same time does not arise, for example, when for a single material the

FIGURE 43

**Principle of belt loop or tripper**

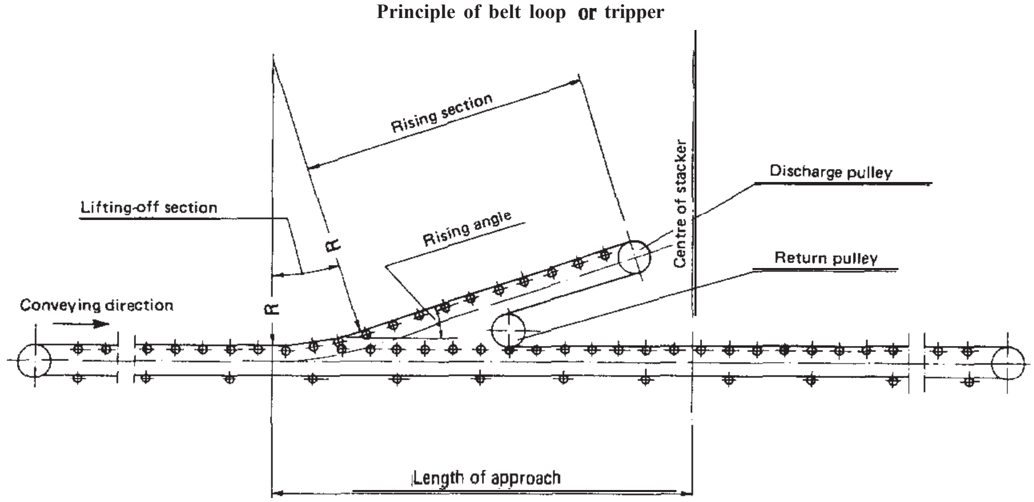



FIGURE 44

**Arrangement of stacker for feeding stockpiles**

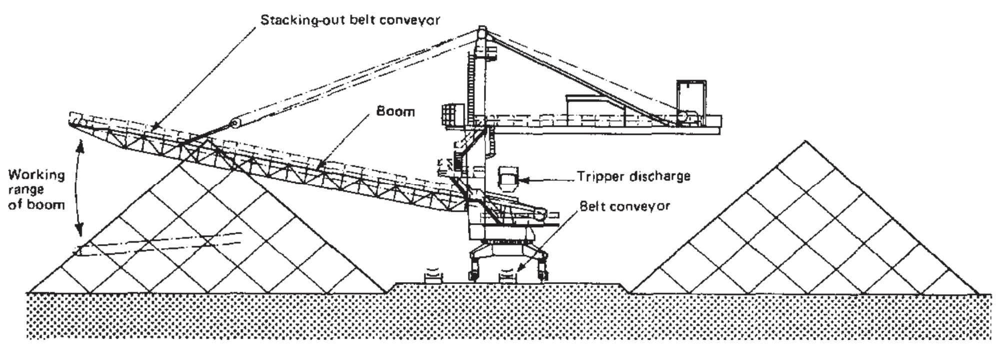
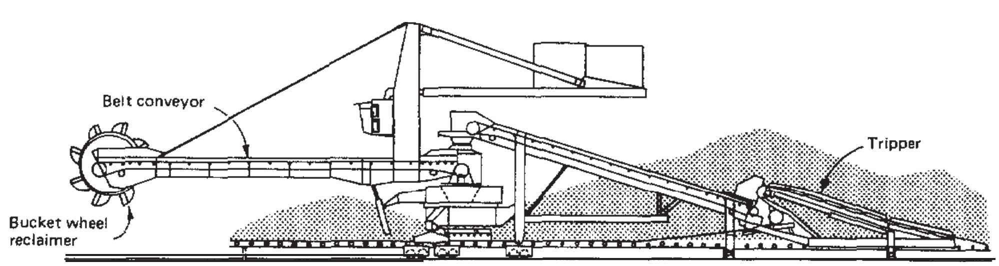



FIGURE 45

**Typical stacker/reclaimer**



arriving flow can be routed direct to the ship-loader in addition to the reclaimed flow, then it is recommended that a stacker/reclaimer should be used. with reduced initial investment. On the other hand, if both operations are required simultaneously, then separate-function machines are required.

293. An alternative to the bucket wheel stacker/ reclaimer is a scraper/reclaimer, also known as a "back-stacker" reclaimer. Here the boom conveyor consists of two heavy-duty chains with flights of substantial proportions at regular intervals. For stacking, the boom conveyor flights scrape the material into the stack from the hopper feed. and for reclaiming, the chain conveyor is reversed and the material is scraped down the pile into a trough to a normal conveyor. This system is lower in maintenance costs and raises less dust. The method has been successfully used at a phosphate rock terminal.

294. A further alternative stacker/reclaimer arrangement, which in the past was used extensively, is the overhead travelling transporter. Here a travelling gantry spans the storage area and contains a belt conveyor at high level with travelling tripper. Also mounted in the gantry are usually two travelling bucket elevators which can discharge on to the belt conveyor.

295. In the stacking operation, material from the store yard conveyor is elevated to the gantry belt conveyor for discharge direct to store by the travelling tripper. For reclaim, the elevators, of open-frame construction, are lowered into the material which is reclaimed in the buckets and discharged on to the reversed gantry conveyor. This discharges into the store yard conveyor which is also reversed. The reclaim rate of the elevators is limited to about 500 tons per hour and considering the extensive steel-work required to carry this equipment, with the subsequent high maintenance costs, this type of unit has generally been superseded by the other forms of reclaiming.

296. There is another scraper/reclaimer type of machine which is usually installed in a storage building, although it can be used outside for materials that do not require weather protection. Capacities of up to 1,000 tons per hour are available. In this unit the material pile is reclaimed by a scraper chain conveyor suspended from a portal frame and pivoted at its lower end. The frame is mounted on travelling bogies running on rails throughout the whole length of the building. A belt conveyor in the terminal receives material from the pivoted end of the chain conveyor, whilst an additional chain scraper is sometimes suspended from the other leg of the portal frame to push the material into the path of the main chain conveyor.

297. This approach has several advantages:

(a) Fully automatic operation of the machine is possible, although it is usually operator controlled;

*(b)* Reclaiming is continuous;

(c) Reclaiming output is independent of the skill of the operator.

A disadvantage is that the substantial space required for the plant causes loss of storage space inside the building.

298. The underground reclaim system can be used for either covered or open storage, and it is probably one of the most common, although it has certain disadvantages. It normally consists of one or more underground conveyors running the whole length of the storage and enclosed in tunnels, as shown in figure 46. The system relies on gravity for the discharging of the material on to the underground conveyors. The shape of the tunnels is dictated by the method used for controlling the rate of discharge.

299. In one example of the system, there is a series of feed openings in the floor of the store, each fitted with a chute and an adjustable cut-off gate. The flow of material through an opening can reach a speed of up to 1.000 tons per hour, and the total reclaim rate will be dictated by the number of openings which it is feasible to control. Normally, three or four openings can be discharging at any one time on to each conveyor.

300. The main advantage of this system is that the capital costs are relatively low, but these mav be outweighed by the operating costs and the inefficiency of the reclaim. Each feed opening will be able to reclaim only a limited amount of material, depending on its angle of repose. Moreover. the rate of flow through each feed opening will decrease throughout the discharge, requiring constant attention from an operator to ensure that the total reclaim rate is maintained. As it is usually necessary to have more than one outlet in operation at any one time, the extract rate will be dependent upon the skill of the operator, and some loss in output is inevitable. Another disadvantage is that it will not be possible to empty the store completely without resort to the use of bulldozers, and this may not be acceptable when handling dusty or dangerous materials. It can also be difficult to avoid severe dust levels underground and arduous working conditions for the feed operators. Another important consideration to be borne in mind in the designing of underground reclaiming systems is that of drainage.

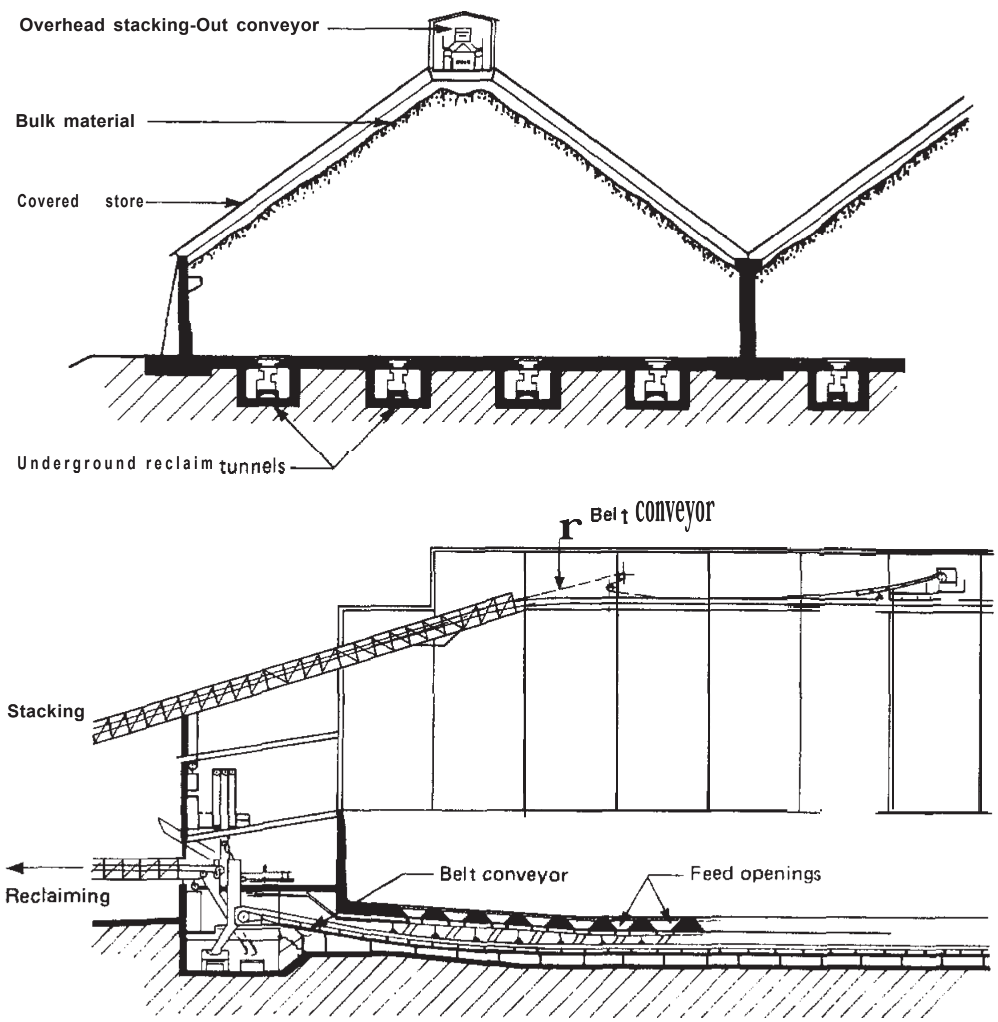
301. A form of extraction which overcomes the operational disadvantages is the provision of a paddle wheel extractor to feed on to the belt conveyor. Here a specially formed base to the store is required, having hopper sides and a continuous slot running the whole length of the store. The paddle wheel extractor, which has slowly revolving arms moving in a horizontal plane, is mounted in a travelling carriage which travels backwards and forwards along the slot. Material is therefore continuously taken equally from the whole store, and the whole operation can be carried out automatically by an operator from an isolated control room, which could be advantageous when dusty material is handled. The main disadvantage of this system is in the cost of construction of the special slot opening, which can be high.

302. The dragline scraper has been used quite successfully in the past. but has been superseded to a large extent by the mobile bulldozer and large-capacity front-end loading shovel. It is, however, still useful where very dusty materials are handled and the use of mobile equipment in an enclosed store would be undesirable.

303. The equipment consists of a winch house. generally situated in a tower superstructure. which has a reception hopper at its base, and a pair of hauling ropes

FIGURE 46

**Underground reclaim with gravity feed to belt conveyor**




which extend from the tower to a travelling frame. This frame is power driven and moves around in an arc on the outside of the stockpile. A travelling scoop, attached to the ropes, can be moved backwards and forwards across the stockpile. During its forward motion, it moves material into the receiving hopper, whence it passes on to the conveying system.

304. For very small installations having an appropriately sized storage area adjacent to the quayside or to a reclaim conveyor system, it may be convenient to use a front-end loader and a mobile belt conveyor having a suitably sized feed hopper. In some installations, a small feeder conveyor below the surface must be used with a wide ground-level hopper having an open side through which material may be directly pushed. With a front-end loader, capacities up to 100 tons per hour are within the capabilities of each driver. The mobile belt conveyors can also be used for direct loading into barges and lighters from tipping trucks. The rate of loading is determined by the vehicle tipping speeds.

305. A scraper is standard equipment used in civil engineering for site preparation, and for the open pit working of certain minerals. It has been used very successfully for emergency stock reclamation, when a machine with a capacity of up to 20 cubic metres can be used. When the bowl is full, the clam-shell gate is closed and the bowl raised clear of the ground; the machine then travels to the discharge point. It is only possible to discharge into a suitably sized ground hopper, which will add to the civil engineering capital costs. This type of reclaim can be used only when degradation of the material, due to the heavy machine travelling over the storage area, is acceptable.

## K. Storage

306. The availability of land for the stockpile is limited either by the natural conditions or by the cost of acquisition. The stockpile must therefore be planned so that a maximum amount of material can be stored in a minimum area. The volume of material which can be stored in a given area will depend, not only on the bearing capacity of the ground and the characteristics of the material but also on the outreach and height of stackers and reclaimers. The function of the stockpile is to enable transportation facilities with different times

and rates of working to function independently of each other, so as to avoid delays caused by one facility having to wait for another.

307. The most common form of bulk storage is the wind-row arrangement (see figure 47). where material is arranged in an elongated pile, the width of which is determined by the height of discharge and the angle of repose of the material. On smaller sites. a circular pile may he arranged, with stacking out and reclaim from a central rotating stacker/reclaimer. The storage area may he open to the elements or completely covered, according to the material and the prevailing weather.

308. For material affected by weather, a covered store. normally a portal-framed structure spanning the width of the pile and extending for the whole length, is used. Feed-in is generally from a high belt conveyor situated along the apex of the building and reclaim is by means either of a scraper/reclaimer or of an underground conveyor. When dusty materials are being handled, it may not be possible to reclaim with a scraper/reclaimer at the same time that material is being fed into the store. The two options are then either to erect a second storage building. or to use an underground reclaim system.

309. When unloading a vessel it may be necessary to use road vehicles or rail trucks for onward transport. In this case it may be convenient to use a storage bunker or truck silo in conjunction with the open storage. The bunker takes the form of an elevated store of limited quantity that can be fed at the same time as the main flow to the stockpile. The onward loading of transport vehicles is carried out from bottom-opening doors. Control is usually effected from raised platforms giving an unobstructed view of the loading operarion and of the traffic movements. Bunkers may be constructed from reinforced concrete or structural steel and plating, and arranged to be fed from overhead conveyor systems or pneumatically.

310. When storage bunkers are empty, material entering could have a considerable distance of free fall, which would result in segregation and in degradation of friable materials. One device to prevent this degradation is a specially designed chute in the form of a spiral which arrests the fall of material by friction in the chute sides. Segregation occurs when particles of a well-mixed material. being delivered from a single point. fall on to the cone of material. Fine particles tend to lodge in gaps, while large particles tend to roll down the surface of the cone and collect near the walls. Where segregation is to be avoided. care must be taken to ensure that material is withdrawn evenly from the whole cross-sectional area of the bunker. This can be achieved through careful design by specialists.

311. A silo may be a single unit or a multiple unit in which various grades of material may be stored. Silos are generally used for the storage of grain and animal feeds where provision must be made for sealing against the ingress of moisture and vermin. Construction materials used can be reinforced concrete or steel, in which case the steel wall plates should preferably be coated with vitreous enamel to provide a surface which is virtually impervious to corrosion. This protection is important. as a silo unit in close proximity to the sea would be adversely affected by salt sea spray. Internally, any corrosion would adversely affect the quality of grain. The silo is fed from an overhead system and discharged through bottom doors.

312. The tote bin system has been developed in recent years for the handling of minor bulk cargoes. especially where a sealed container is required. The bin is both a shipping container and an intermediate storage unit which becomes a discharge hopper when mounted on special tipping equipment. Thus the material remains in a single container throughout the process of transportation.

313. The usual material used for the bin construction is aluminium, which is light in weight, resistant to corrosion and capable of being stacked. Unfortunately. as in the case of all bulk bins. the return journey of the empty bin adds considerably to the cost of transportation, and this becomes a serious constraint for long journeys and for export materials. If the bin can be reduced in volume for the return journey, this disadvantage is minimized. Alternatively. a cheap throw-away container can be used.

314. A surge hopper is often necessary to act as temporary storage during a certain phase of a conveying operation. For example, during a loading operation a ship-loader will need to be moved from hatch to hatch. While it moves, the material flow from the ship-loader must be stopped to prevent spillage on the deck of the vessel. The conveyor system from the stockpile can be kept in motion if the material flow to the jetty conveyor is bypassed into a surge hopper.

315. When the ship-loader is in position again, the ship-loader and jetty conveyor are restarted, taking material from the approach conveyor plus the material temporarily stored in the surge hopper. The ship-loader and the jetty conveyor are sized to suit this increased flow of material.

316. This method can give considerable improvements in throughput, but for smaller throughputs the installation of a surge hopper may not be justified. The size of the hopper depends on the rate at which material flows along the approach conveyor and the time taken for the ship-loader to travel between the hatches furthest apart.

### L. Vehicle reception

317. There are four main ways of discharging bulk cargo from rail wagons:

(a) Bottom discharge;

(b) Rotary tipping;

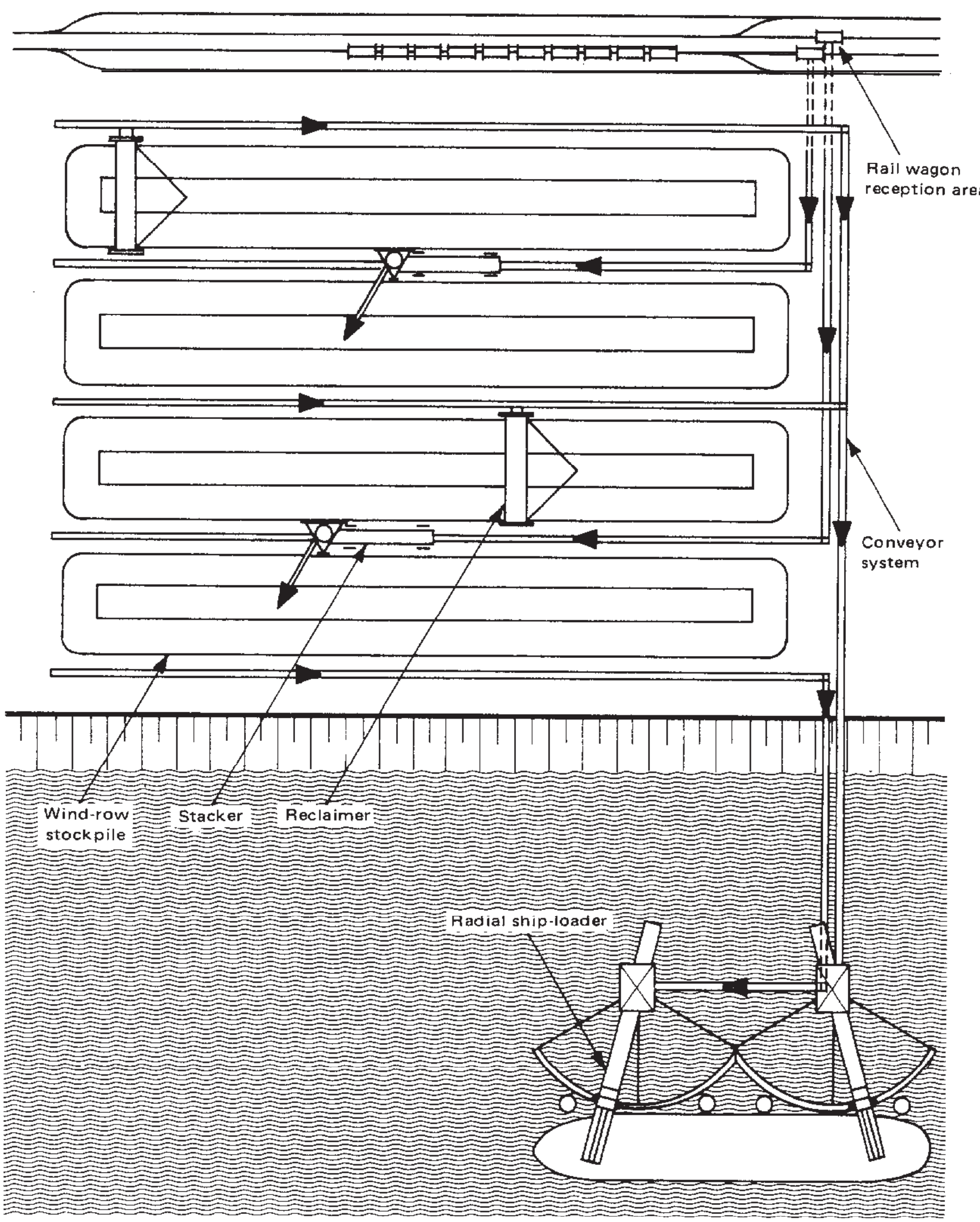
(c) End tipping;

(d) Pneumatic discharge.

In the first three methods, the material is discharged into a hopper which is emptied via a transfer conveyor. Bottom-discharge wagons are fitted with bottom doors which open to empty the vehicle. For the rotary and end-tipping facilities the rail car is physically rotated or tipped to discharge the wagon. With the rotary tipper, the rail wagons do not have to be uncoupled if they are fitted with rotating couples.

FIGURE 47

Export port showing arrangement of wind-row stockpiles




318. For powdery free-flowing materials, a combination of compressed air and gravity can be used to discharge the wagon. The wagon consists of a pressure vessel and is discharged via hoses to the receiving store.

319. Road trucks have the same method of discharge as rail, but can often be self-tipping. High-capacity tippers have a gross weight of over 32 tons, while smaller tippers have gross weights of 24 and 16 tons. Trucks with pressure vessels for pneumatic discharge can be fitted with a diesel-engined blower unit to make deliveries independent of an external air supply. Self-tipper trucks can discharge directly to stockpiles via a mobile belt conveyor with a hopper.

**M. Stand-by facilities**

320. The high cost of the vessel's time makes it essential that equipment should be available at all times while the vessel is alongside the jetty. A plant breakdown during unloading/loading operations can result in high demurrage payments. Preventive maintenance will go a long way to reduce this down-time, but stoppages through plant breakdown will still occur. In addition to a skilled maintenance force to repair the fault quickly, provision must be made for the duplication of certain conveyors and for the necessary rerouting of material flows. The provision of other stand-by equipment for unloading/loading should also be considered. This

could take several forms; for example, either two reclaimers can be arranged to cover one stockpile, or the use of high-capacity mobile front-end loaders can be resorted to. Stand-by mobile front-end loaders can also supplement the normal rate of reclaim during seasonal peaks, using emergency reclaim hoppers which are mounted on tracks alongside the reclaim conveyors.

321. The grab bucket has high reliability, with only few components subject to wear, and any necessary repairs to the digging lips, shells and bearings can easily be effected at low cost in a workshop. Several sets of grab buckets for a single bulk unloader are normally purchased so that the correct type is available for each of the different bulk commodities and vessels, and reserve buckets are available for each commodity. Where two unloaders are in operation, one machine can continue operatmg during the short period needed to change the bucket on the other. Adequate provision for storage and for transportation of grabs to the workshops for repair should be provided in the jetty design.

## N. Environmental considerations

322. Pollution prevention is a major cost item and at the outset of any scheme it will be necessary first to establish an environmental policy. It will be necessary for the appropriate authority to specify the importance it attaches to the local environment. and how much extra it is prepared to pay to maintain it. In order to take a decision. the planner will need to prepare a statement on the probable effects of the installation on the local environment in the absence of any special precautions. In addition, a study of working conditions within the terminal will have to be made. At this stage, experts should be called in and proper specifications agreed upon satisfying the policy laid down.

323. The characteristics of the material handled may be that it is very dusty. or dangerous to health, or even liable to form explosive mixtures with air or moisture. Several problems arise with respect to dust suppression or extraction. First, the degree of pollution tolerated must be clearly specified, the minimum requirements being stated quantitatively, for example, that the area within a specified distance from the installation should not contain more than a specific number of grams of material per cubic metre. Imprecise statements such as “nearly dustless” or “to the satisfaction of the engineer” should be avoided. A large amount of dust will emanate from a poorly maintained plant; thus simplicity of design and easy maintenance should be sought when a choice of equipment is being made.

324. A study should be made of equipment actually in use for the handling of similar material in order to determine the environmental effects. For example, many attempts have been made to seal the receiving hopper of a grab unloader effectively when material is being discharged from the grab into the hopper. The use of an air curtain will prevent dust spreading on discharge, but it should be remembered that the grab has to pass through this curtain to its discharge position and that a certain amount of material will be blown off the surface in the process. A more effective method may be to put the hopper into a chamber sealed with rubber curtains.

325. Often the prevailing wind will assist in preventing dust pollution by blowing the dust out to sea-a condition that may be acceptable. However, a port installation sited upwind of a community could find itself in serious trouble at times of high wind when a dusty product is being handled without effective dust control. Operations might have to cease at such times, with resultant high costs for ship delay. For certain cargoes, a water spray system may be used to prevent dust, or an enclosed storage area may he used to contain it.

326. Attention must be paid to the risk of corrosion, and all structures should be adequately treated to protect them from the effects of the moist, salt-laden atmosphere and of the materials being handled. Specialist advice should be obtained as experience can be drawn on from existing installations. Should protective sheeting be fitted to structures, this should receive the same consideration. High daytime temperatures in hot climates produce extensive condensation during the hours of darkness. This is especially apparent on the insides of silos.

327. Wind can also blow dusty material off a belt if it is not protected by wind boards, a simple housing, or a totally enclosed gantry. In addition, wind forces can cause the belt to track very badly and, under extreme conditions, to lift off the idlers completely, especially when unloaded.

328. In the case of ship-loaders and unloaders, full account must be taken of needs for operating under wind conditions. The power applied to each operation must be adopted accordingly. especially when loaders or unloaders are being moved along the quay. Due allowance must he made for the opposing wind forces when the equipment is travelling into wind and, likewise, when it is travelling with the wind, due allowance must be made for the wind in determining the braking force required to arrest travel within the specified distance. Under storm wind conditions, special anchoring positions must be provided where the equipment can be positively secured.

## 0. Planning tasks

329. The argument is sometimes advanced that the planning of a bulk cargo port terminal should be done entirely by the industry planners for the bulk commodity concerned, as part of the total physical distribution system from, say, up-country mine to overseas customer. A coherent overall plan, based on through-transport economic principles, should certainly be drawn up by the industry planners at the appropriate time. There are often large gains to be made by coordinating the production rate, land transport, port stockpiling and handling, and maritime transport. However, the work done by the industry sector planner does not relieve the port management of the need to plan and control the main design parameters of all dry bulk cargo installations within the port area.

330. The port planner will need to know at an early stage of the planning the genera1 implications for land and water areas of long-term developments in the

sphere of dry bulk cargo transport. Also, during the stage of the preparation of detailed designs by the industry sector planner, there is a need for close consultation with the port planner to ensure that the main design parameters of the terminal are correct.

331. In addition, there are often common users of a dry bulk cargo terminal, and as far as they are concerned the design responsibility is clearly that of the port authority. There will be common parts of an installation that are used by several different bulk cargo carriers, for commodities that are to a varying extent compatible. It will be necessary for compromises to be reached between the demands of a number of different users.

332. For these reasons the port planner should carry out his own calculations for each of the following points, procedures for which are given in this handbook:

(a) The effective hourly capacity of each handling installation and the combined capacities of all the handling installations;

*(b)* The number of berths and the number of ship-loaders at each berth;

(c) The capacity and location of surge storage installations, stores and stockpiles;

(d) The capacity of the inland transport vehicle fleet.

333. Ideally, the industry sector planner should be able to give the port the specifications of the service the port should provide, and a target port cost per ton, based, in the case of exports, on the acceptable f.o.b. export selling price. Where the service specifications and a target cost are not provided, the planner may have to make broad estimates of the acceptable levels of cost and ship service.

334. From the point of view of port interests, one high-capacity dry bulk cargo terminal is preferable to two or more terminals with moderate yearly capacity. When growth in exports seems possible but uncertain, it may be advisable to start with modest and not too expensive facilities. Allowance should, however, be made for the possibility of installing additional ship-loaders and higher-capacity conveyors and increasing the stockpile area, if necessary, at a later stage, without any serious interruption of operations. With careful planning, expansion in this way should prove more economical than the construction of a second terminal for the same kind of material.

335. The whole terminal operation must be systematically set out showing the rate of tonnage per hour for each piece of equipment, and for each situation that may arise during the sequence of loading or discharging. Special buffer arrangements will be required when one part of the installation has to be halted.

336. Often there will be alternative operating modes and routes for the flow of the commodity. The matching of flows will need to be calculated for each of these modes. The design must be carried out by a specialist for the installation concerned, but the port planner can however check on the part of the design concerning the ship operation by using the following planning charts.

337. The ship-handling capacity of the terminal is determined by a joint analysis of the number of berths and the number and handling rates of the ship-loaders or discharging installations at each berth. The handling rates of ship-loaders are governed largely by the reclaiming rate. Planning charts I and II, illustrated in figures 48 and 49, should be used for this analysis. Where seasonal effects are important, special attention must be given to the investment advantages and disadvantages involved, as discussed in part one, chapter II, on planning principles.

338. The planning charts for the dry bulk cargo terminal have been developed to assist the port planner in his economic analysis of the effects of various handling rates on ship turn-round time. In addition to the economics, the planner is also interested in the service times that various sizes of shipment will entail. These charts can be used for either an import or an export dry bulk cargo terminal.

339. As has already been made clear, the productivity of each ship-loader or unloader varies according to the characteristics of the ship and the cargo, and the position of the cargo in the ship. Manufacturers often publish rated capacities for a particular commodity which are based on near-optimum operating conditions. However, to obtain the effective hourly capacity when working, an efficiency factor covering the total ship working time (through-ship efficiency factor) should be applied. This factor should be determined by a specialist, but as a rough check it could be taken as not more than 0.5 for unloading and 0.7 for loading.

340. The law of diminishing returns applies as regards the number of ship-loaders or unloaders which can work one ship. That is to say, doubling the number of facilities at a berth will not necessarily double the throughput of the berth. For the purposes of the planning chart, the following throughput factors have been assumed for two., three, four and five ship-loaders/unloaders per berth respectively: 1.75; 2.25; 2.60; and *2.85.*

341. Dry bulk cargo terminal planning charts I and II are used in the same way as break-bulk cargo terminal planning charts I and II. The planner needs the following basic information in order to be able to utilize these charts: ship-loader/unloader rated capacities; average shipment size; number of ships per year; average ship cost per day; and number of berth commission days per year.

342. The planner enters planning chart I with the figure indicating the rated capacity; he then draws a vertical line to make a turning-point where it meets the through-ship efficiency factor. He then moves horizontally to the left to the next turning-point with the appropriate line for the number of ship-loaders/unloaders employed per berth. He descends again to the standard number of ship operating hours per day, then moves horizontally to the right to the turning-point with the curve indicating average shipment size and finally draws a vertical line up to the average berth time for individual ships. A typical two-hour delay for berthing and deberthing ships has been added to this average time. When the actual delay differs from this, the average berth time can be adjusted accordingly.

FIGURE 48

**Dry bulk cargo terminal, planning chart I: berth time**

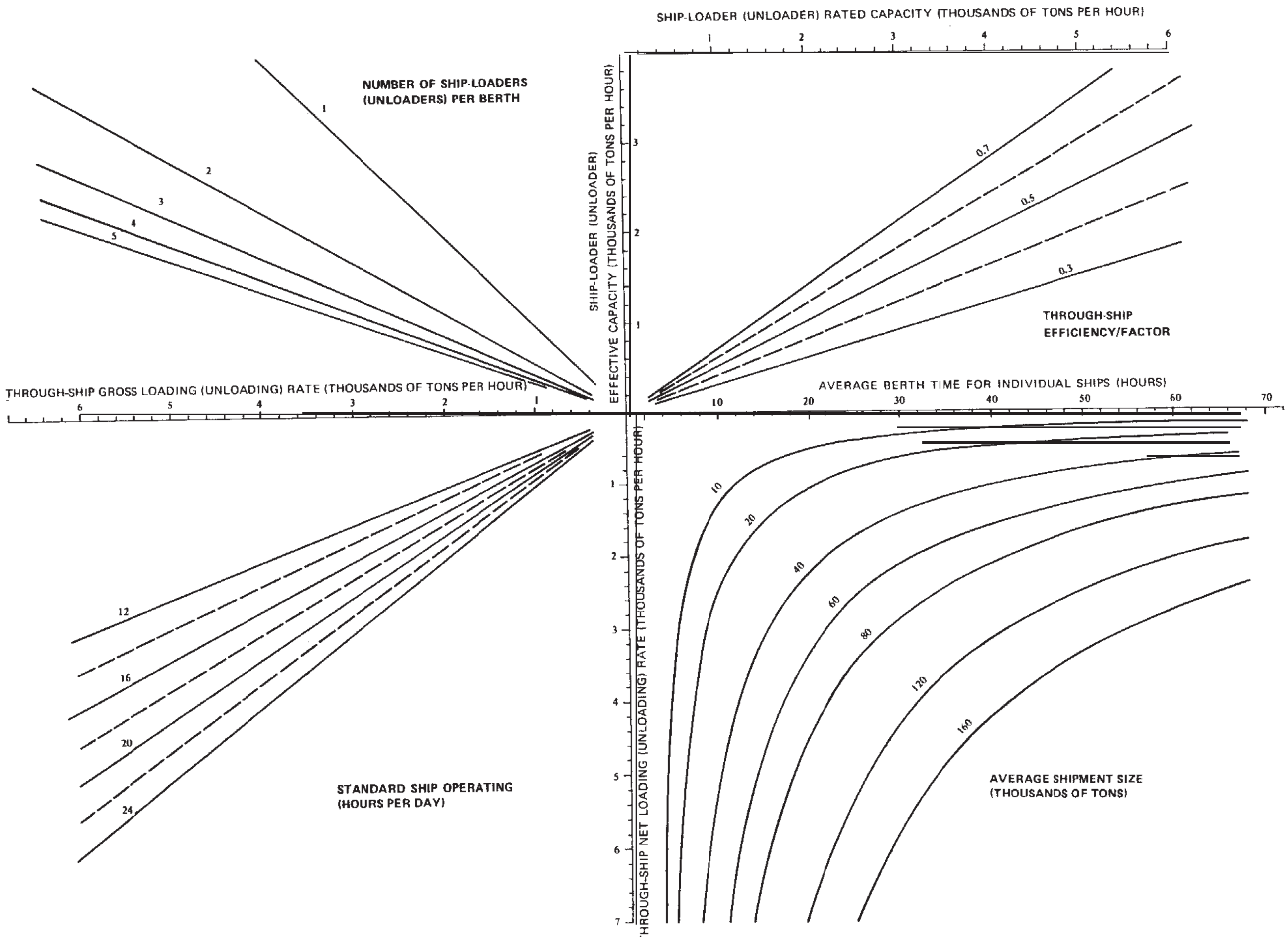
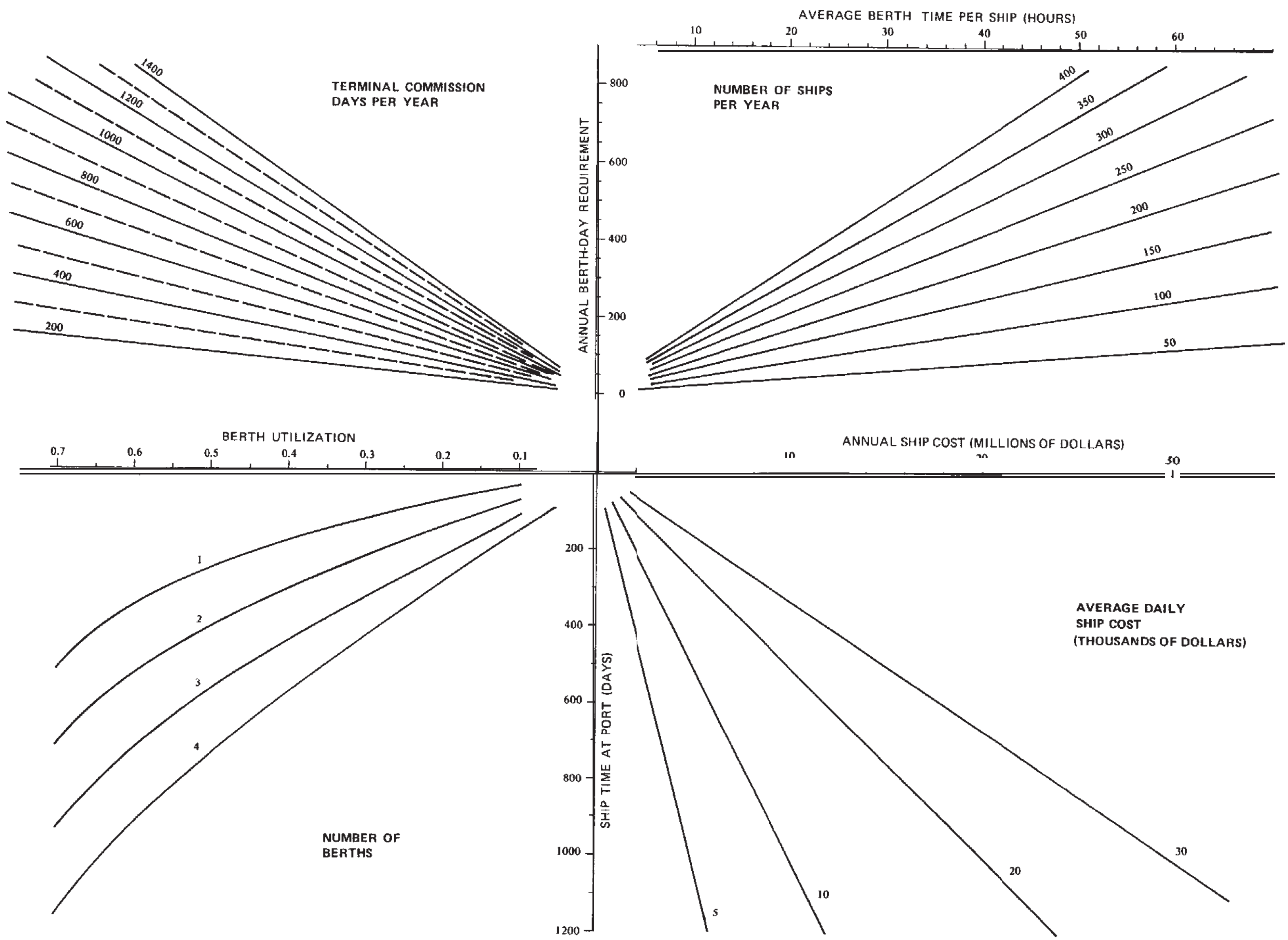


FIGURE 49

**Dry bulk cargo terminal, planning chart II: ship cost**



343. The turning-points on the axes give the planner the following information: effective capacity of each ship-loader or unloader; through-ship gross loading or unloading rate: through-ship net loading or unloading rate (which is equivalent to the gross rate if the berth is worked 24 hours per day); and average berth time for individual ships. The through-ship net rate is a key figure in describing the productivity of a bulk berth.

344. For planning chart II. the planner starts with the average ship berth time. A similar method is used as for planning chart I, with the following turning-points: number of ships per year; number of terminal commission days per year; number of berths; and the average daily ship cost while at port. The number of terminal commission days per year is the sum of the number of commission days for each berth. For each set of turning-points, the intersections of the trajectory and the axes give the planner the following information: annual berth-day requirement; berth utilization; ship time at port; and annual ship cost while at port.

345. The relationship between berth occupancy and ship time at port is based on queueing theory. The Erlang 2 distribution was used for both the service time distribution and the inter-arrival time distribution. Unlike break-bulk cargo terminals, there is a tendency, in the case of dry bulk cargo terminals, towards some scheduling of arrivals, and for this reason the slightly smoothed Erlang 2 arrival distribution has been assumed rather than the Erlang 1 (i.e. negative exponential) distribution. These distributions are discussed in annex II, section D.

346. The first chart can also be used by the planner to determine the best combination of rated capacity, number of facilities and daily operating period necessary for a specified berth time for a particular shipment size. When a suitable combination has been found, the planner can then use the second chart to select the number of berths necessary for the forecast annual throughput. The approximate number of ships per year is calculated by dividing the annual throughput forecast by the average shipment size. In order to determine the optimum number of berths, estimates must be made of total ship times at port with different numbers of berths. The optimum number of berths will be the number at which the total of berth costs and ship costs is lowest.

347. The export stockpile is needed as a buffer between the delivery system to the terminal and the ship-loading system. The delivery system's arrival distribution is dependent on the production rate and the inland transport system. Generally, the rate of arrival is much slower than the ship-loading rate, and the economics are such that the ship should not be kept waiting. Therefore, when a ship arrives, the quantity for shipment should be in port storage.

348. With regard to the import stockpile, the converse is true. the hinterland transport system operating at a much slower rate than the ship unloading rate. The stockpile should never be so large that a ship is prevented from unloading, nor so small that inland distribution is disrupted and the industries using the bulk commodities are affected.

349. The planner is faced with the problem of selecting an inventory level and storage capacity which will minimize costs by acting as a buffer between the variable demand and supply. If the level falls too low, the situation will occur where either the ship or the industrial zone is kept waiting for cargo. If the storage capacity is insufficient. the system supplying cargo to the stockpile-either the hinterland transport or the ship—will have to wait. As against these waiting costs, there are the capital and operating expenditures involved in creating and maintaining the stockpile.

350. The area required for the stockpiles is dependent on the following factors: shipload size; ship arrival distribution; hinterland transport distribution; and ship-loading and unloading rates. For export cargo, the hinterland transport requirement depends on production rates. The above factors are stochastic and thus there is no deterministic solution to the question of the appropriate inventory level and storage capacity. Figure 50 shows a typical variation in inventory level over a period of time.

351. Simulation or Monte Carlo methods, as described in annex II, can be used to evaluate the economics of various stockpile policies. However, information regarding the above-mentioned variables will often be limited. Certain assumptions have therefore been made (see the annex to this chapter). The curves based on these assumptions, which are given in figure 51, show the average and maximum stockpile levels which reduce the probability of the disruption of operations for ships, production areas or industrial zones to less than 1 per cent. The full line curves are annotated with the proposed annual throughput of the terminal. They give a relationship between the average shipload size on the horizontal scale and the stockpile capacity on the vertical scale. The cost of holding such an inventory level and developing the necessary capacity may be greater than the cost of the disruptions.

352. The charts should be used with some caution owing to the simplicity of the model, but they should give a good first approximation to the stockpile requirements. Thus, for a terminal handling 1 million tons per year with ships carrying an average of 20,000 tons, the maximum capacity of the stockpile should be 140,000 tons and the average amount of cargo held should be 75,000 tons. These figures must be increased by the amount of the dead stock, which is the residual material not loaded on to the ship in order to prevent ship delays arising from the slow process of clearing up the stockpile. The process of clearing up which is done during idle periods must be completed within a given time-limit.

353. Bulk commodities must often be segregated according to their properties. For example, with regard to imports, each stockpile area must be of sufficient size to accommodate at least a full shipload from each source. One iron-ore importing terminal has made each stockpile area 50 per cent larger than the capacity of the largest ship used. This allows the accommodation of a subsequent shipload of similar ore before the earlier shipload has been fully used up. The need for segregation is thus a factor to be taken into consideration in the planning of bulk cargo stockpiles.

FIGURE 50

**Typical variation in dry bulk cargo terminal inventory level**

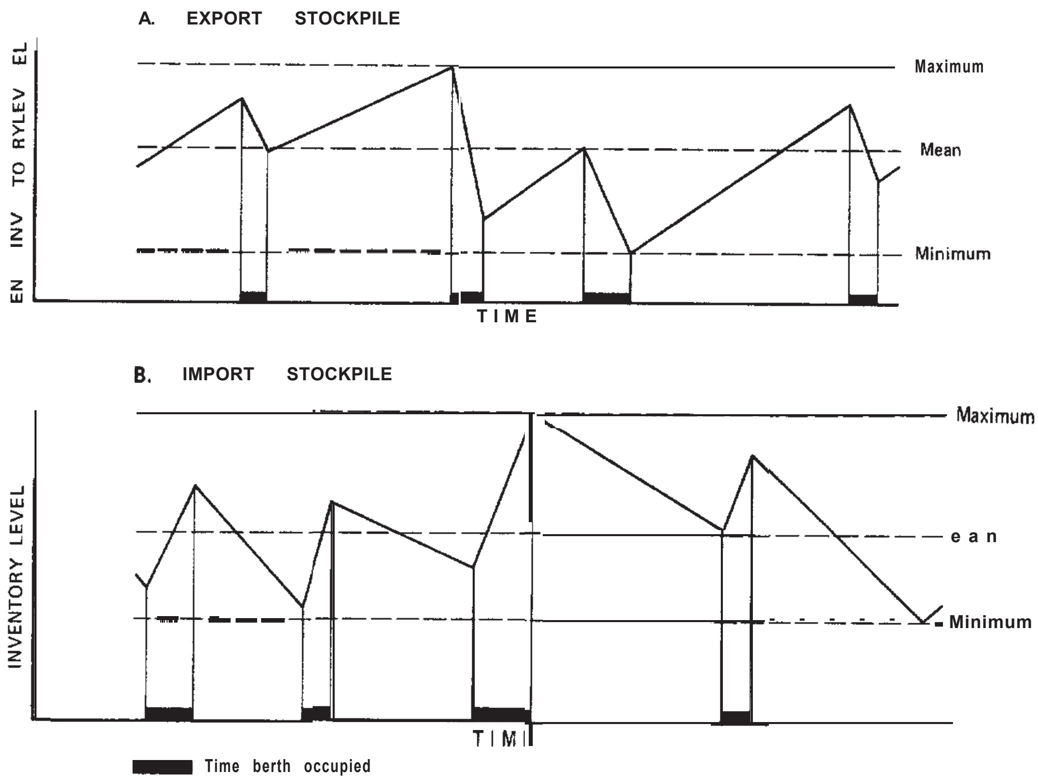



FIGURE 51

**Guidelines for export stockpile dimensioning as a function of annual throughput and average shipload**

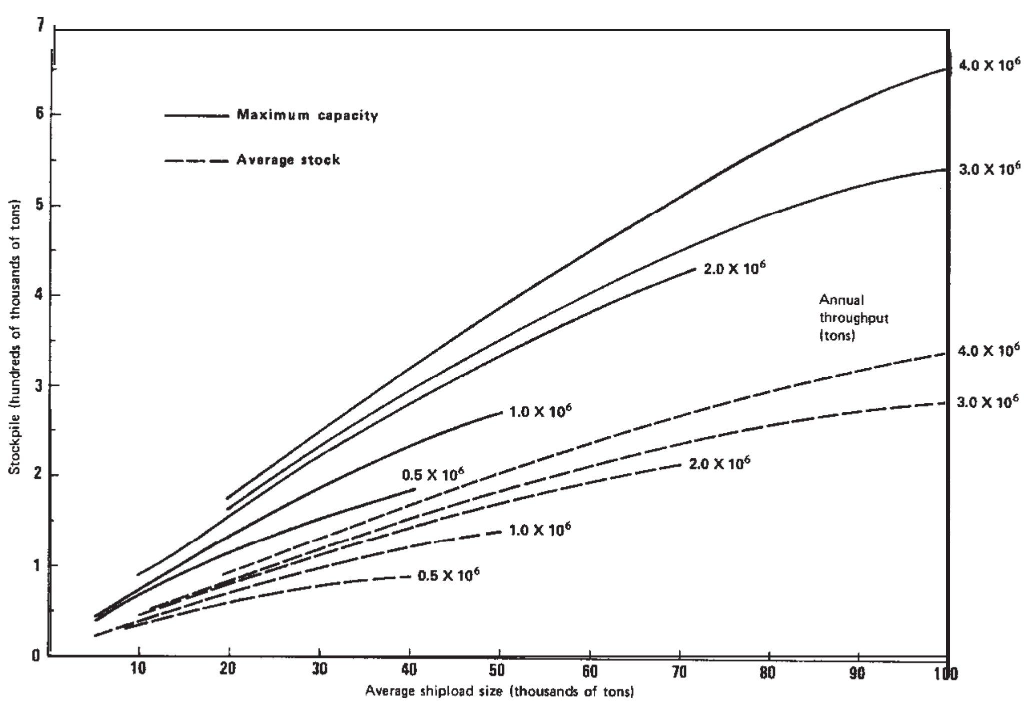
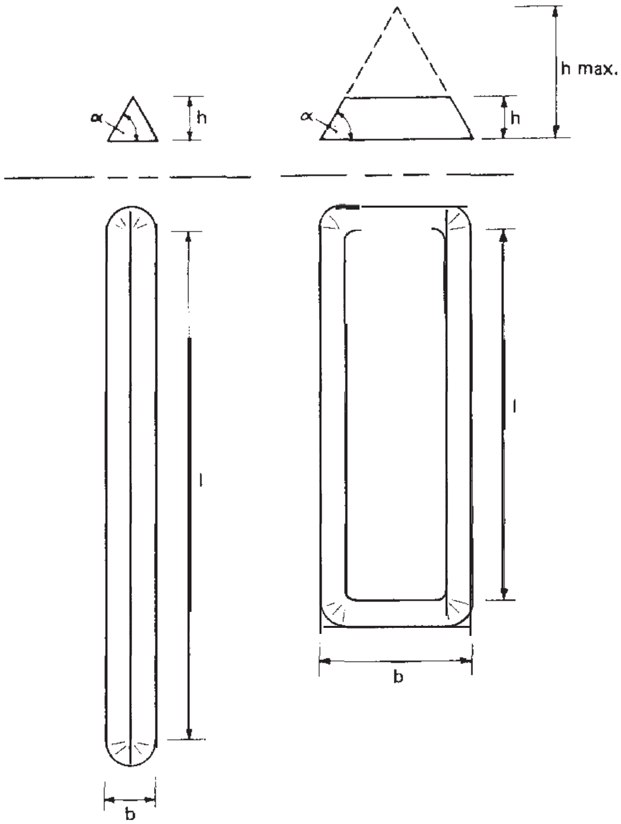


FIGURE 52

Stockpile layouts




354. If a storage facility at the terminal is planned to overcome seasonal or market fluctuations by providing for a continuous supply in spite of a non-continuous consumption. or vice versa, large areas must be set aside. Obviously a high degree of mechanization of the whole storage area in this case is uneconomical, and an appropriate design must be selected.

355. Upon determining the stockpile requirements in tonnes. the planner must then determine the layout and the area required to store this tonnage. Possible layouts are shown in figure 52 where: α=angle of repose, h=height, l=length and b=base. The height and base dimensions of the stockpile are determined by the characteristics of the material, the bearing capacity of the ground and the reach of the stacker/reclaimer. With these dimensions the planner may use the stockpile dimensioning dry bulk cargo terminal planning chart III, shown in figure 53.

356. The figure for the base or width of the stockpile is the starting-point for the use of the chart. The planner descends to the angle of repose of the commodity, which is the angle between a horizontal surface and the cone slope obtained when bulk cargo is emptied on to this surface. Angles of repose for various commodities are given in annex I. He moves to the right to determine the maximum height to which the material can be piled, and to the left to determine the maximum cross-sectional area. The ratio of actual height to maximum height determines the next turning-point. The planner descends from this point to the line indicating the length of the stockpile. The cross-sectional area of the stockpile is given by the intersection of this path with the axes. From the appropriate line he moves to the right to the stowage factor, and then rises to the horizontal indicating the capacity of the stockpile. For a given base and height, the length can be varied to give different stockpile capacities.

357. The task of planning the land transport fleet is simple, but it should never be omitted in forward planning lest the often daunting size of the transport fleet needed is overlooked. Three elements regarding which mistakes in planning are likely to occur are the following:

(n) The number of transport working days per year:

(b) The average number of trips per day;

(c) The number of road vehicles out of action for maintenance and repair.

358. With these cautions in mind, the method of calculation for a single commodity is straightforward and a numerical example is shown in table 7. Here. the implications of carrying the whole output either by road or by rail are given first, followed by a suggestion for a sharing of the load. Reserve capacity is needed, not only for maintenance purposes, but also to make it possible to augment the vehicle fleet temporarily to cope with peak demands.

359. A complication occurs when several different commodities have to be transported by the same facilities. For example, an aluminium smelter may require

TABLE 7

Transport fleet planning for a single commodity

| *Annual terminal throughput (tonnes)* | *Number of transport working days per year* | *Daily transport demand (tonnes)* | *Average vehicle capacity (tonnes)* | *Daily vehicle demand* | *Average number of trips per day* | *Vehicle fleet size* |
|---|---|---|---|---|---|---|
| All by road: 2 000 000 | 278 | 7 200 | 24 | 300 | 3 | 100, plus maintenance reserve = 110 trucks |
| All by rail: 2 000 000 | 330 | 6 060 | 20 | 303 | 1 | 303, in 5 trains of approximately 60 wagons each |
| Suggested combination: | | | | | | |
| 20 per cent by road 400 000 | 278 | 1 440 | 24 | 60 | 3 | 20 plus reserve= 24 trucks |
| 80 per cent by rail 1 600 000 | 330 | 4 850 | 20 | 242 | 1 | 242, in 4 trams of approximately 60 wagons each |

FIGURE 53

**Dry bulk cargo terminal, planning chart III: stockpile dimensioning**

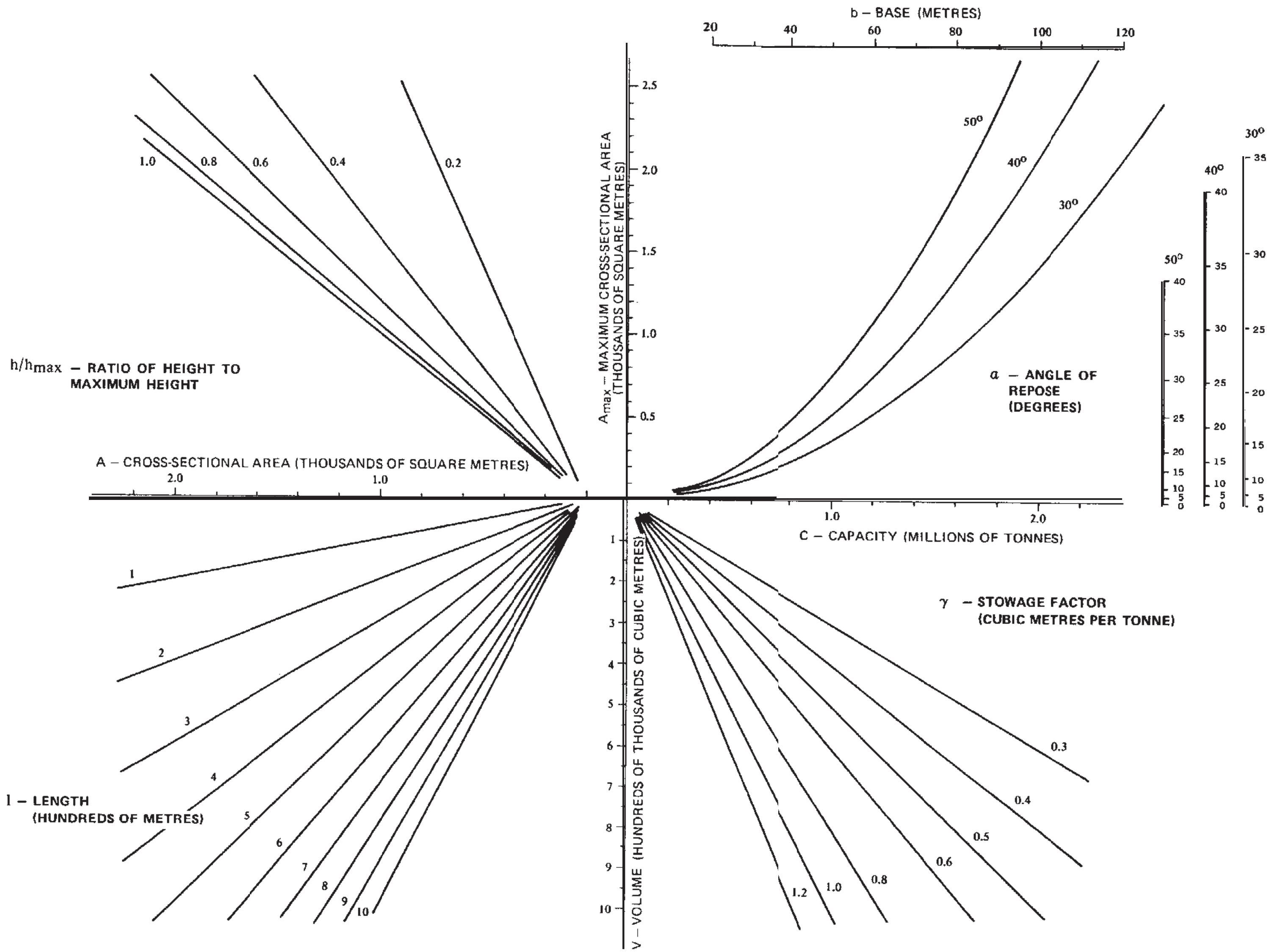


TABLE 8

**Transport fleet planning for multiple commodities**

*Annual smelter throughput*

Output : 120 000 tonnes aluminium metal;
Input 240 000 tonnes alumina;
72 000 tonnes petroleum coke.

| Weekly requirement (tonnes) | | Number of days per week scheduled | Tonnes per day | Average vehicle capacity (tonnes) | Daily vehicle demand | Average trips per day | Fleet size |
|---|---|---|---|---|---|---|---|
| Alumina ...................... | 4 615 | 4 | 1 154 | 20 | 58 | 6 | 10 |
| Coke ......................... | 1 385 | 1 | 1 385 | 20 | 69 | 6 | 12 |
| | | *Proposal:* 12 vehicles plus 3 reserve = 15 trucks. | | | | | |
| Aluminium metal | 2 310 | 5 | 462 | 22 | 21 | 4 | 5+ |
| | | *Proposal* 7 tractor/trailer units, including reserve. | | | | | |

the import of 1,500 tons of petroleum coke for each 5,000 tons of alumina imported, and it may then export via the same route 2,500 tons of aluminium metal. In such a case it would be normal to plan the transport of these three commodities jointly. In a rail operation it might be possible to introduce a closed-loop train system. In a road operation it might be possible to co-ordinate the haulage of different commodities using a common vehicle fleet. In the aluminium smelter example, since there is no prospect of balancing the import and export flows. and *since,* further, the type of vehicle suitable for alumina and coke is quite unsuitable for aluminium bars and ingots, it would be appropriate to introduce two separate transport systems and tolerate the poor return-load operation.

360. Table 8 gives a numerical example for this solution. An additional feature as compared with table 7 is that the common alumina and coke fleet needs to be scheduled with, say, four days of hauling alumina and then one day of hauling coke. Such a schedule will be dictated by, and will in turn dictate, the buffer stock

TABLE 9

**Check-list of questions for planning dry bulk terminals**

1. Has there been a search for the best site for the terminal along the coastline, without limiting the search to existing port boundaries? The place of origin or point of processing of the material may be more important than the location of an existing port organization.
2. Has a coherent overall plan for the commodity been prepared? There are often large gains to be made by designing an integrated transport service which incorporates:
   (a) Production and processing of materials;
   *(b)* Land transport;
   (c) Part stockpiling and handling;
   *(d)* Maritime transport.
3. Has the industry planner specified the level of service that the terminal is expected to give, and a target port cost per ton related to the commodity selling price?
4. Will the terminal be dedicated to a single user, or will there be several users on a common-user basis?
5 Will the terminal be used for a single commodity (will the commodity require segregation by different grades) or will parts of the installation be used in common with other commodities? In the latter case, have compatibility questions been dealt with?
6. Have facilities for long-term growth been considered? Economically it is preferable to have one high-capacity terminal rather than two low-capacity terminals. Thus expansion must be considered in terms of:
   (a) Installing additional ship-loaders;
   *(b)* Installing higher-capacity conveyors.
   (c) Increasing the stockpile area.
7. Has the terminal been planned for specific ships in the case of an integrated system. or for a range of ships in the case of a common-user terminal? The ship characteristics to consider are:
   (a) Operating draught;
   *(b)* Beam and length;
   (c) Type of ship (bulk, combined, general cargo);
   *(d)* Shape of hold and hatch opening.
8. Has an economic criterion been used for the ship handling rate and the resulting berth occupancy? The high cost of ship's time results in high rates with low berth occupancy (calculations can be checked on the planning charts).
9 Has the cost and suitability of an offshore berthing point been considered versus the cost of dredging?
10. Has pollution of all types--dust, explosive mixtures, health risks-been considered and related to the prevailing wind?
11. Has the pollution prevention scheme been based on a clear specification (quantitatively precise) of what is to be permitted?
12. Has a study of working conditions on the terminal been made? There may be lobs in adverse locations which require special prowsions.
13 Have the local conditions of a prevailing hot climate and salt-laden atmosphere been considered with regard to corrosion of structures and night-time condensation"
14. Have all wind conditions been allowed for, including anchoring of ship-loaders during storms?
15. Has an unambiguous rated capacity for an unloader (loader) been specified, for example. the rate which can be sustained for one hour when unloading (loading) from the centre-hne of the vessel horizontally and from the mean low water level vertically?
16. Have the above considerations been based on actual experience with a similar type of installation rather than manufacturers' figures'!

capacity both at the port and at the smelter, and will be influenced by the economies involved in cleaning vehicles and changing common reception/delivery installations from one commodity to the other.

361. To conclude this section on planning tasks, a check-list of the main questions that the planner of a dry bulk terminal must answer are given in table 9.

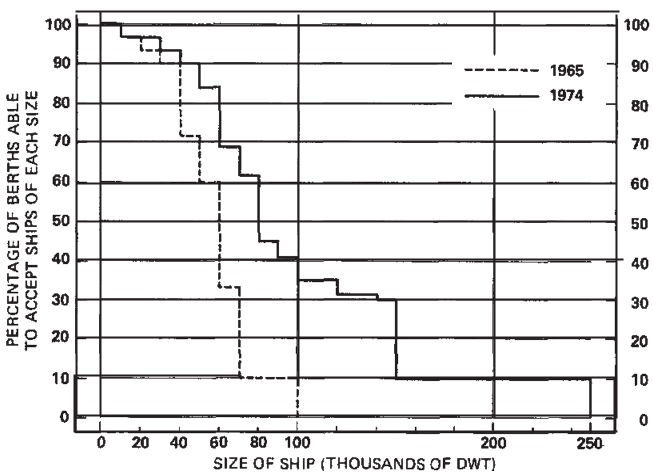
## P. Major bulk commodities

### 1. Iron ore

362. Iron ore is the most important dry bulk commodity in international sea-borne trade, representing in 1980 16 per cent of total dry cargo trade (dry bulk as well as general cargo). Iron ore includes ores such as magnetite, hematite, limonite, siderite and roasted iron pyrites. It is seldom sold in the form in which it is extracted from the ground, normally being processed to improve its characteristics or to increase its iron content. Washing, grinding, screening, agglomerating processes (pelletizing, sintering, briquetting) and various methods of concentration are used for this purpose. Traditionally the separation of waste from the ore took place at the consumer end. However, this is changing, and the trend is towards taking steps at the producing end to increase the iron content of the ore.

FIGURE 54

Iron-ore loading berths: maximum acceptable ship sizes




*Source*: M. Latham, "Developments in handling dry bulk cargo", in ICHCA, *Progress in cargo handling*, vol. 6, *Changing user requirements* (London, Gower Press, 1976).

363. The ore shipped has a stowage factor which varies between 0.3 and 0.8 cubic metres per tonne. Iron ore is always transported in bulk and in full shiploads. Over the past decade, iron ore trade has been the subject of considerable competition between alternative suppliers, characterized by increasing distance between sources and markets and the employment of the largest possible carriers. With the increased distances, the quick turn-round of specialized ore carriers in ports no longer compensated for the loss of time involved in lengthy ballast voyages. Thus, combined carriers offering greater versatility in the employment of vessels have been replacing the specialized ore carriers. In 1979, 95 per cent of total iron ore shipments were carried by bulk carriers and combined carriers of over 18,000 dwt, and 81 per cent in vessels of over 60,000 dwt.

364. While there are no major discharging terminals for iron ore in the developing countries, there are several loading terminals. For loading terminals, figure 54 illustrates the distribution of berths relative to vessel size, and its evolution with time. Generally, iron ore ports serve as transfer terminals linking two modes of transportation, and hence some stockpiling capacity is almost always necessary to provide a surge capability between the more or less continuous overland movement and the intermittent ocean shipments. Figure 55 shows a typical iron ore export terminal.

365. Ore varies both in the nature of its constituents other than iron and in the percentage of its iron content. Iron ores are generally dusty and, although there is a variation in dust pollution between the various qualities and particle sizes, it is normally necessary to provide dust extraction equipment and to consider terminal siting carefully. Because of the importance of producing steel of a suitable grade for a particular purpose, control is necessary over the blending of ores for blast furnaces. This necessitates the segregation of ores according to their properties. The density of iron ore limits the stacking height because of the limits of the load-bearing capacity of the ground. The angle of repose is normally less than 40 degrees.

### 2. Grain

366. In 1980 the sea-borne trade in grain was 198 million tonnes, forming 10 per cent of total dry cargo

FIGURE 55

Material flow in ore export port at Nouadhibou, Mauritania

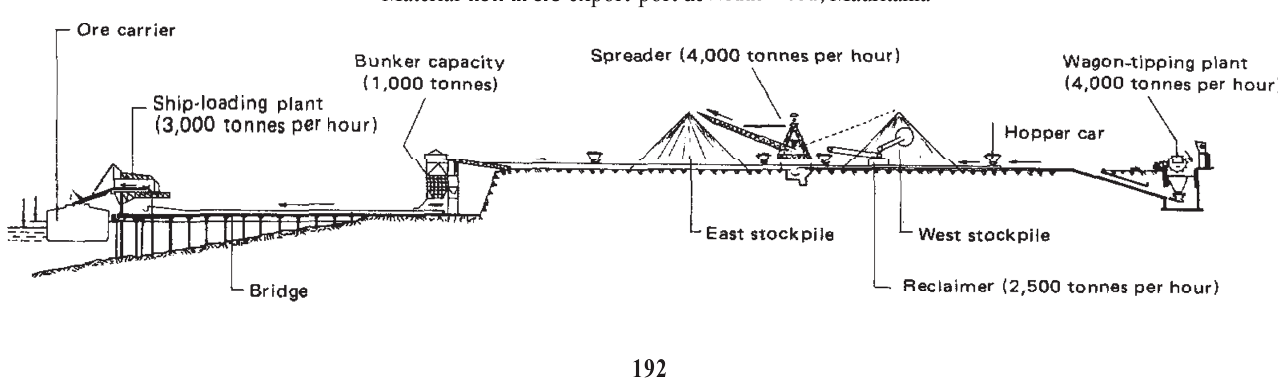


TABLE 10

**Sizes of ship employed in the grain trade**

*(Percentage of world sea-borne trade in grain)*

| Ship size (dwt) | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|---|---|---|---|---|---|
| Under 18 000 . . . . . . . . . . | 41 | 37 | 2Y | 32 | 33 | 21 | 15 | 10 | 11 | 10 |
| 18–25 000 . . . . . . . . . . . . | 21 | 18 | 20 | 18 | 15 | 13 | 11 | 13 | 10 | 10 |
| 25–40 000 . . . . . . . . . . . | 27 | 32 | 36 | 37 | 36 | 35 | 35 | 3h | 3h | 34 |
| 40–60 000 . . . . . . . . . . . . . . . . | 10 | 12 | 14 | 12 | 11 | 15 | 18 | 18 | 18 | 17 |
| 60 000 + | 1 | 1 | 1 | 1 | 5 | 16 | 21 | 23 | 25 | 29 |

*Sources*: Fearnley & Egers Chartering Co. Ltd., HPD Shipping Consultants Ltd.

shipments. These shipments were composed of wheat (79.2 million tonnes), maize (70.7), soya beans (26.9), barley/oats/rye (11.4) and sorghum (9.9). In addition, some 10 million tonnes of rice were shipped in the short sea trade. These grains have different densities, which means different stowage and handling requirements. Furthermore, grain is a perishable commodity which requires proper ventilation and protection from the weather and pests during shipment and storage.

367. Sea-borne grain shipments come under two headings: commercial shipments and international aid shipments. Commercial shipments take place, in order of importance, to Western Europe, Japan, the USSR and Eastern Europe from the main exporters, the United States, Canada and Australia.

368. In the grain trade, variations in climatic conditions result in large variations in supply and demand, with consequent fluctuations in transportation requirements. Without the incentive of a sustained level of import demand within each country, and considering the high capital cost of facilities, port development for vessels carrying grain is often not feasible. One solution is the use of mobile pneumatic equipment. Also, the trend to standardization of vessel type and size has been less pronounced than in the other bulk cargo trades. Many types of vessel are employed, ranging from small traditional 'tween-deckers through various bulk carrier types and sizes, into the smaller ranges of combined carriers and even some small tankers. While the size of the average carrier has increased over the years, with the transfer to the trade of combined carriers of approximately 150,000 dwt[13], the ships most commonly used are bulk carriers, the majority being in the 25,000–40,000 dwt range. Ships in this range built during the period 1971-75 were, on the average, 182 metres in length, 25.3 metres in maximum breadth and 10.8 metres in summer draught. The trend towards the use of larger vessels is shown in table 10.

369. An example of a grain terminal is the one owned and operated by the Port Authority of Marseilles for common users, which is primarily used for discharging cereals from vessels. A plan of the terminal is shown in figure 56. Cereals or other materials suitable for pneumatic discharge may be stored in the bulk warehouse.

[13] These large vessels were transferred to the grain trade following the slump in the oil trade which took place from 1974 onwards.

370. At the terminal. two berths having a total length of 297 metres are used for discharging or loading vessels with a draft of up to 9.8 metres. There are four pneumatic extractors on rails with four intake tubes for discharging vessels, each with a rated capacity of 250 tonnes per hour and an effective capacity of 200 tonnes per hour. Two of the extractors, each with two separate discharge tubes, can also be used for loading but have an actual performance of only 100 tonnes per hour.

371. There are four conveyor belts, two of which are reversible for loading ships, each with a rated capacity of 250 tonnes per hour. The four belts lead to the vertical silo where the cereal is lifted to the top of the weighing and distribution tower. There are four weighing bins, each with a capacity of 3 tonnes, which allows the recording of cereal movement before storage. The vertical silo is made of 57 cells of 420 cubic metres each and 40 cells of 110 cubic metres each, permitting the storage of about 20,000 tonnes of cereals. The silo can discharge to trucks or rail wagons. The manning requirements vary from 14 to 41 depending on the number of pneumatic extractors in use.

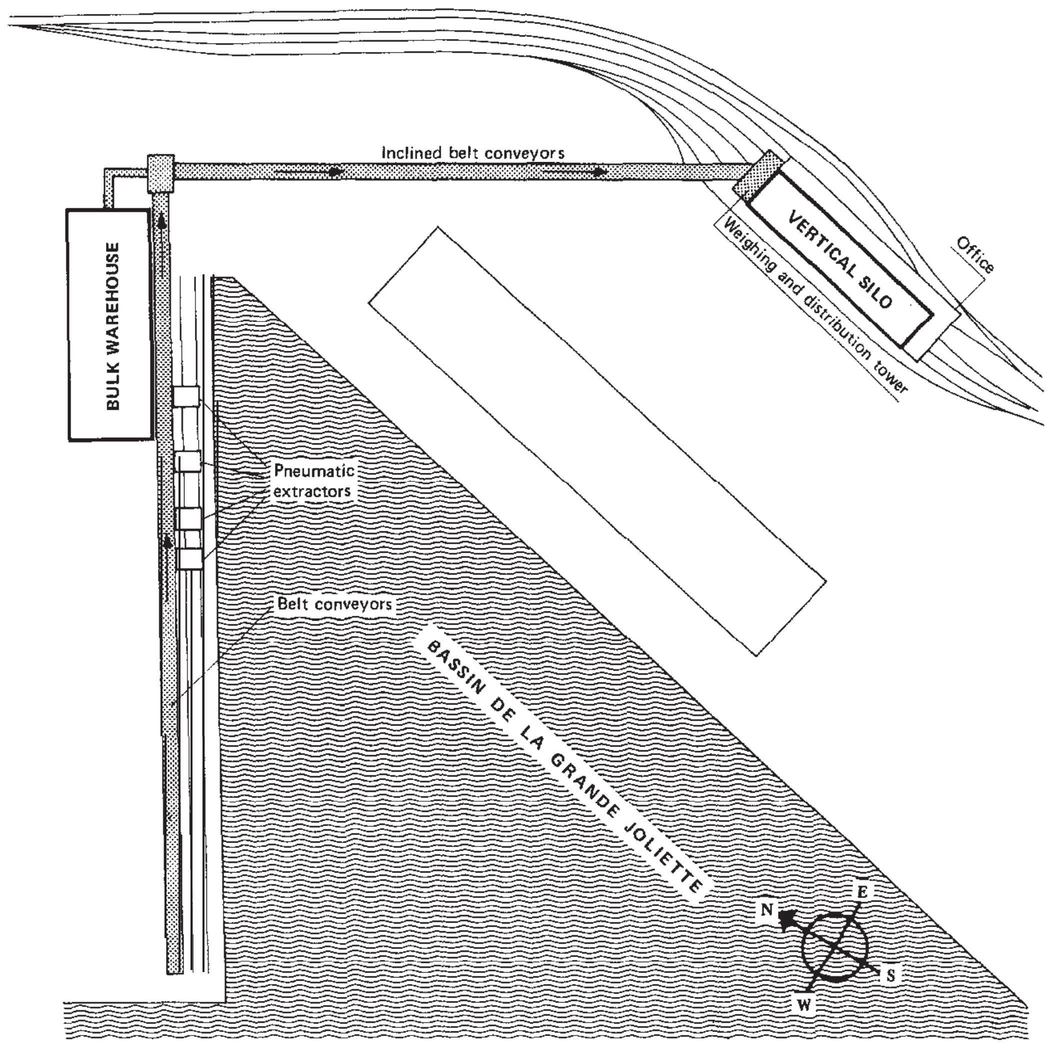
### 3. COAL

372. The sea-borne coal trade has grown substantially since the 1960s, and in 1980 reached a volume of 188 million tonnes, about 9 per cent of all dry cargo shipments in tonnes. The major importing areas in order of importance are Japan, the United Kingdom and continental Europe, Eastern Europe and the Mediterranean, while the major exporting areas are North America, Australia, South Africa and Eastern Europe. In 1980 Japan accounted for 50 per cent of shipping demand. The majority of the coal transported is coking coal for use in steel-making, and the remaining 45 per cent is thermal coal.

373. With the exception of the near-sea trades, there has been a continual increase in the average size of ship employed to transport coal. In near-sea trade, a wide variety of sizes and types of ship, including barges, are employed; however, bulk carriers are superseding other smaller ship types. In 1979, 74 per cent of the total coal trade in tonnes was transported by bulk carriers or combined carriers of over 40,000 dwt. The bulk of this long-haul trade is handled by full shipments on conventional bulk carriers and combined carriers, with carriers of over 100,000 dwt on some routes. Coal makes up 22 per cent of the total dry bulk shipments by

FIGURE 56

**Plan of typical grain terminal al Marseilles**




bulk vessels of over 40,000 dwt and only 11 per cent of the shipments of combined carriers.

374. Coal has a stowage factor which varies between 1.0 and 1.4 cubic metres per tonne. All types of coal, even anthracite, are subject to spontaneous combustion caused by heating of the coal as it absorbs oxygen from the air. This characteristic must be borne in mind when planning the working of the coal stockpile, so as to prevent portions of the stock from lying dormant for long periods of time. Generally high-ash, low-volatile coals, as used for power stations, can be safely stacked, although some loss from oxidation will be inevitable. On the other hand, high-volatile, strongly caking coals used for coke production in the iron and steel industry will require constant monitoring for the indicative temperature rise in the store, whilst some coals such as steaming coals cannot be stored at all. Generally the dust nuisance is minimal and the use of water sprays at transfer points and discharge positions in extreme cases will reduce this type of pollution. A description of a typical coal import terminal follows.

375. Coal is unloaded by means of two trolley-type grabbing unloaders, the rail-mounted legs of which straddle one or more lines of ground conveyors. Also mounted on the rail tracks is a travelling hopper which receives coal discharged by the unloader grab. By means of a feeder unit fitted to the base of the hopper, coal is discharged on to the jetty ground conveyor. The travelling hopper can be coupled to the unloader so that they travel along the jetty in tandem, or it can be uncoupled and stored out of the way during occasional general cargo operations.

376. The jetty conveyor transfers material via a further system of belt conveyors to the stacking area, where it is received by stacking belt conveyors running the whole length of the storage area. Mounted on rail tracks on each side of the stacking conveyor is a travelling boom stacker. This is a specialized machine consisting of a tripper which discharges on to a boom conveyor capable of being slewed through 270” and derricked from below horizontal to a maximum incline of 15”. The stacker travels under its own power, under the control of an operator, and places the coal in windrows.

377. Reclaiming is carried out by a bucket-wheel reclaimer consisting of a revolving wheel carrying buckets with digging teeth. This wheel is attached to a boom, which also carries a belt conveyor on to which the buckets discharge. This conveyor in turn discharges on to a reclaim belt conveyor which runs parallel to the

stacking conveyor. The reclaimer. which is capable of being derricked and slewed, is designed to reach to the extremities of the coal piles. and is always under the control of an operator. To recover any material normally out of the reclaimer's reach, a bulldozer is used to push the coal within the range of the reclaimer.

378. From the reclaim conveyor. coal is transferred by a further system of conveyors to a tripper located over loading bunkers. These elevated bunkers have surge capacities to act as buffers between the discharge rate to onward transport and the reclaim rate at the coal stack. The tripper is usually under the control of an operator whose duty is to maintain the level of material in the bunkers, although this operation may he performed automatically by the introduction of sophisticated equipment.

379. Below the loading bunkers are situated weigh hoppers which receive a pre-determined quantity of coal from the bunkers. after which all further flow from the bunker is automatically cut off. Empty rail wagons are located beneath the discharge outlets from the weigh hoppers. They are positioned accurately by an automatic wagon positioner under the control of an operator. The same operator controls the opening of the weigh hopper doors. permitting rapid discharge of the material into the wagons.

380. The entire unloading system from the ship to the storage area could be under the control of the ship unloader operator himself in the case of a small terminal. whereas for a larger terminal it would be necessary to install a central control room communicating with all sections and with the operators in the unloading section. Similarly. the loading into onward transport and the associated stack reclaim could be controlled by the operator of the tripper conveyor maintaining the material levels in the loading hoppers. With a larger installation and an extension of automatic controls, the wagon-loading operator could be in control. An important feature of such an installation is an automatic interlock system which prevents any section from being operated before the next section has been run up to the right speed. The total manning requirements of such a terminal per shift would be in the region of 28, made up of four supervisors, 14 operators and 10 shift maintenance staff and conveyor attendants. This figure excludes the main workshop repair staff.

### 4. Phosphates

381. Phosphate *rock* (minerals containing the fertilizer nutrient phosphorus) is the main raw material for the fertilizer industry and the most important commodity for sea-borne trade within the fertilizer group. This class of minerals accounts for 2.5 per cent of total dry cargo shipments, The 48 million tonnes shipped in 1980 were exported from Morocco. the United States of America, other African countries and the Pacific Islands. An interesting development is the productron of the phosphate intermediate. phosphoric acid. This step significantly increases the $P_2O_5$ content, a measure of the value of the commodity to the fertilizer industry. The terminal facilities are completely different, as the acid is a liquid which is carried in specialized tankers.

382. The size distribution of vessels employed in the phosphate rock trade shows that 38 per cent of the sea-borne trade was covered by vessels of less than 18.000 dwt, 15 per cent by vessels of 18.000 to 25.000 dwt. 31 per cent by vessels of 25.000 to 40.000 dwt and 16 per cent by vessels of over 40,000 dwt. The majority of phosphate rock loading ports cannot accommodate vessels of more than SO.000 dwt.

383. Phosphate rock is very dusty and absorbs moisture very readily. which can create problems for unloading. It has an average stowage factor of 0.92 to 0.9 cubic metres per tonne. Practically all shipments are in bulk as a powdery concentrate. A large proportion of the crushed rock is very fine and a great deal of dust is given off whenever a transfer of material takes place. It is therefore necessary to ensure that. for example, when material is discharged from a wagon or road vehicle into a ground hopper, provision is made for the dispersal of the heavily dust-laden air. The material itself is non-toxic, but it can be a nuisance to the operator in constant close contact with it at a discharge point.

384. For a typical phosphate rock export terminal. the phosphate can enter the port area by two routes. The first is via a railway direct from the mmes in specially designed, totally enclosed hopper wagons with roof feed openings and bottom discharge. The wagons are positioned over a series of under-rail discharge hoppers. and the phosphate is discharged by the manual operation of the discharge doors from operating platforms running each side of the wagons. The whole operation takes place under cover with appropriate provision for dust extraction. The second route is by road vehicle. Since special tipper trucks are not available, the trucks are discharged with the aid of tipping platforms, again into hoppers.

385. Phosphate is extracted from the hoppers via controllable sliding valve doors on to a belt conveyor, a section of which automatically records the weight of the phosphate passing over it. The phosphate then travels via conveyors to one of two closed stores. depending on quality. where it is distributed by means of an overhead tripper. The storage shed has an "A"-frame design with the slope of the roof equal to the angle of repose of the material.

386. Phosphate for shipping is extracted through the floor of the store by means of underground belt conveyors. the flow through each discharge point being controllable by means of rack-and-pinion-operated clam-shell doors. The angle of repose of the material is such that a sizeable residual quantity is left to form a contingency stock. To recover this material it is necessary to use small bulldozers or remote-controlled drag scrapers.

387. The store's underground extraction conveyors discharge on to a main conveyor and. via an approach arm belt conveyor and a transfer tower. on to two Jetty conveyors situated in a high-level structure running the whole length of the jetty. Each of these conveyors is fitted with a tripper which feeds a ship-loader.

388. The ship-loaders can traverse the full length of the quay and have a fixed boom with a telescopic extension. Attached at the end of each telescopic section is

an extending chute capable of loading ships at all states of the tide. The end of the extending chute is provided with a flexible dust hood for the control of dust emission, together with a deflector plate to help distribute the cargo in the hold of the ship. It is thus possible by means of the long travel motion along the jetty, together with the telescoping of the conveyor boom, which has in addition a luffing operation, to reach any part of the ship being loaded. At the same time, the boom can be retracted to permit clearance of deck superstructure and fittings when the ship-loader is moved from one hatch to another.

389. The whole operation is under the control of the operator of each ship-loader, the preceding conveyor systems being interlocked with its operation. Owing to the relative closeness of the store to the ship-loader, the conveyor system will be allowed to clear itself before the ship-loader is moved between hatches, so no surge storage is required.

390. A typical manning per shift for an installation of this size would be 37, made up of three supervisors, 20 operators and weighmen, six shift maintenance engineers and eight plant labourers and conveyor attendants. Because of the dust generated, several of the jobs can be arduous and dirty, thus requiring a substantial level of relief manning as well as adequate shower facilities.

### 5. Bauxite/alumina

391. Bauxite ore when processed into alumina is the basic raw material for the production of primary aluminium. Some 5.2 tonnes of bauxite produce 2 tonnes of alumina, which produce 1 tonne of aluminium. Shipments of bauxite ore and the intermediate product, alumina, represented about 3 per cent of total dry cargo shipments, or 48.3 million tonnes, in 1980. The two raw materials differ greatly in bulk, in density (bauxite typically stows at 0.878 cubic metres per tonne and alumina at 0.585) and in handling characteristics. The trend is towards the conversion of bauxite to alumina at source, which more than halves transportation requirements and therefore limits the growth of bulk shipping and terminal requirements, The share of bulk vessels of over 25,000 dwt in total sea-borne trade was 65 per cent in 1979, the size of vessel employed depending on the route.

392. The major exporters of bauxite/alumina are Australia, West Africa, Jamaica and Central and South America. In the short-sea trade between the Caribbean/South America and United States ports in the Gulf of Mexico, increased use has been made of medium-sized bulk carriers to reduce transport costs, but a proportion of the shipments are still handled by small ore carriers and multiple-deck ships owned or chartered by the aluminium companies. The Australian bauxite shipments to Europe are more suitable for large bulk carriers, with the long haul and growing volume of trade pointing to an optimum size of around 100,000 dwt. This trade is mainly serviced by carriers of 40,000 to 70,000 dwt, which have also been employed for alumina. For the trade between Australia and Japan/North America, medium-sized carriers of up to 40,000 dwt are the preferred size.

393. The integrated structure of the world's aluminium industry results in many terminals being owned and operated by the industry. These commodities, particularly alumina, are dusty and require precautions against plant and area pollution. A conveyor system feeding a closed system ship-loader, with the loading chute in close proximity to the loaded material, will minimize material loss due to dust. Generally, pneumatic or closed screw conveyor systems are used to discharge the vessel.

## Q. Multi-purpose bulk cargo terminals

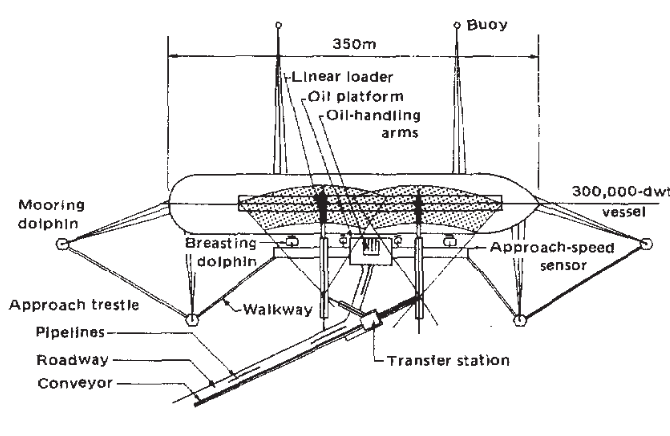
394. If within a reasonable period a separate berth will be justified to cater for a single trade, the installation can be planned on that basis, permitting the most economical use of plant and avoiding problems of contamination between materials.

395. If more than one bulk cargo trade is forecast but throughput for each trade is insufficient to justify separate berths, it may be feasible to establish a bulk cargo handling terminal for more than one material. Commodities such as coal and sugar, petroleum, coke and alumina, as well as ore and coal, can be handled with dual-purpose facilities. In some cases the same equipment may be used for different materials, but separate storage will be necessary for each commodity, and particular care must be taken to ensure that the commodities handled are compatible and that all systems can be thoroughly cleaned after use. Care must be taken in handling and storage to ensure that windblown dust does not contaminate other products. In other cases, only, the berthing point can be shared and separate equipment must be used for each material. Figure 57 illustrates a multi-purpose terminal designed for importing oil and exporting iron ore and other dry bulk materials.

396. Equipment will have to be sized to give the best compromise between the requirements of the various materials handled, considering such factors as bulk cargo density, size and type of ships and size of individual cargoes. Imports and exports can be handled at the same berth provided that there is sufficient capacity

FIGURE 57

**Example of multi-purpose oil-bulk-ore pier**



to permit this and that there is no conflict in scheduled ship arrivals and departures. Sufficient length must be available on the berth to store idle equipment in a position which permits the full length of ships' hatches to be worked by the other equipment. It is simpler to install separate conveyor systems for imports and exports, and the size chosen is usually more economical than is the case when one set of reversible conveyors is used.

397. Combining bulk cargoes and general cargo on a berth is not desirable unless annual bulk tonnages are clearly too low to warrant a separate berth. In that case it is advisable to check on two features:

(a) Loaders and unloaders should be mobile or, if they are rail mounted, the layout of the berth should be such as to provide sufficient quay length for parking them clear of the general cargo operational area;

(h) Conveyor systems should be either elevated on gantries at the rear of the berth or placed in tunnels so that the working area for general cargo is not obstructed. However, the use of tunnels should be considered as a last resort because of the difficulties of maintenance and cleaning.

## ANNEX

### Bulk stockpile planning

1. The following assumptions on the statistical distributions of the variables affecting the size of the stockpile in conjunction with a simple model have been used to estimate the stockpile requirements as a function of shipload and annual throughput. The interval between ship arrivals follows an Erlang 2 distribution. The shipload size follows a uniform distribution with a range of ±10 per cent. The arrival or delivery distribution of the commodity to or from the terminal also follows a normal distribution with a percentage coefficient of variation of 10 The loading or unloading rate has been set to give a berth utilization of 0.4 and the loading/unloading follows a normal distribution with a percentage coefficient of variation of 5

2. The model records the flow of bulk commodity in and out of the terminal over a period of time and calculates the maximum and the average amounts of the commodity present. Through repeated use of the model, an estimate of the maximum stockpile requirements and the average amount of commodity stored can be determined.