

# UNCTAD MONOGRAPHS ON PORT MANAGEMENT

*A series of monographs prepared for UNCTAD in collaboration  
with the International Association of Ports and Harbors (IAPH)*

**9**

## **Multi-purpose port terminals Recommendations for planning and management**

*by*

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## NOTE

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## INTRODUCTION TO THE SERIES

In the ports of industrialized countries, operating systems and personnel development are based on skills acquired through experience, on emulation of other industries and on the innovation which is easily undertaken in advanced industrial environments. These means are generally lacking in developing countries, and port improvements occur only after much deliberation and often through a process of trial and error. Some means are required by which ports in developing countries can acquire skills that are taken for granted in countries with a long industrial history, or can learn from the experience of others of new developments and how to meet them.

Formal training is one aspect of this, and UNCTAD has devoted considerable effort to developing and conducting port training courses and seminars for senior management and to preparing training materials to enable middle-management courses to be conducted by local instructors. It was felt that an additional contribution would be the availability of clearly written technical papers devoted to common problems in the management and operation of ports. The sort of text that will capture an audience in the ports of developing countries has to be directed at that very audience, and very few such texts exist today.

Following the endorsement of this proposal by the UNCTAD Committee on Shipping in its resolution 35 (IX), the UNCTAD secretariat decided to seek the collaboration of the International Association of Ports and Harbours, a non-governmental organization having consultative status with UNCTAD, with a view to producing such technical papers. The present series of UNCTAD Monographs on Port Management represents the results of this collaboration. It is hoped that the dissemination of the materials contained in these monographs will contribute to the development of the management skills on which the efficiency of ports in developing countries largely depends.

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FOREWORD

When UNCTAD first decided to seek the co-operation of the International Association of Ports and Harbours in producing monographs on port management, the idea was enthusiastically welcomed as a further step forward in the provision of information to managements of ports in developing countries. The preparation of monographs through the IAPH Committee on International Port Development has drawn on the resources of IAPH member ports of industrialized countries and on the willingness of ports in developed countries to record for the benefit of others the experience and lessons learnt in reaching current levels of port technology and management. In addition, valuable assistance has been given by senior management in ports of developing countries in assessing the value of the monographs at the drafting stage.

I am confident that the UNCTAD monograph series will be of value to management of ports in developing countries in providing indicators towards decision-making for improvements, technological advance and optimum use of existing resources.

The International Association of Ports and Harbours looks forward to continued co-operation with UNCTAD in the preparation of many more papers in the monograph series and expresses the hope that the series will fill a gap in the information currently available to port managements.

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## I. INTRODUCTION

1. The multipurpose port terminal is not an innovation in port terminology and dates back for several years. 1/ It is however only in recent years that the concept has been given practical expression in a number of European ports.
2. In the light of his experience at a number of Spanish ports following the introduction and expansion of intermodal traffic, 2/ the author embarked on a study of the factors making for the application of the multipurpose principle to conventional general cargo handling facilities and presented a paper on the subject to the PIANC congress 3/ at Edinburgh in 1981. He later decided to formulate a series of recommendations embodying the philosophy of the multipurpose terminal and the major parameters in the planning and management of such terminals in the context of the Programmes of the Directorate General of Ports and Coasts of the Spanish Ministry of Public Works and Town Planning.
3. In view of the potential interest of these recommendations to other countries, particularly developing countries, it was decided to include them in the UNCTAD series of monographs on port management as an expression of the ongoing co-operation between UNCTAD and the Ibero-american Ports and Coasts Association (AIPYC).
4. This monograph is divided into four parts. The first defines the concept of the multipurpose terminal and its function in modern freight transport. The second sets out a series of practical recommendations for the planning and design of the infrastructure of such terminals in the light of experience in Spanish ports. The third is concerned with recommendations of particular importance to terminal management. The fourth describes a practical example, the multipurpose terminal at the port of Valencia.

## II. MULTIPURPOSE TERMINALS

### 1. The rationale of multipurpose terminals

5. For many years far-reaching changes affecting the shape of the industry as a whole and of specific sectors have been taking place at an ever-increasing pace in marine transport technology.

6. The share of traditional cargo vessels in marine traffic has gradually declined and new types of vessel, some specialized, others multipurpose, have come to the fore, among them:

- Container ships;
- Roll-on, roll-off vessels;
- Small bulk carriers for specialized trades;
- Bulk carriers adapted for semi-bulk cargoes (forest products, iron and steel, fruits);
- Mixed types of vessel for routes where cargo availability is unstable (container/bulk carriers, container/ro-ro vessels);
- Conventional vessels equipped to carry some containers.

7. Cargo is also shipped in new forms or variations of traditional forms, such as:

- Containers;
- Unitized cargoes, which may be palletized;
- Roll-on cargo;
- Bulk unbagged solid cargo;
- Unitized cargo replacing bulk (e.g., pulp);
- Unitized cargo of heavier unit weight.

8. These developments result in major changes in the demand for non-specialized port services and this demand cannot be satisfied technically or economically by the services offered by old-style general cargo or specialized terminals. In this context the multipurpose terminal comes into its own.

### 2. What is a multipurpose terminal?

9. As a starting point the multipurpose terminal can be defined as a complex of infrastructure, equipment and services which offers a combined and flexible response to the servicing demand of certain types of vessel and cargo, permitting the optimum utilization of manpower and equipment.

10. The use of the adjective "multipurpose" is not at odds with the fact that the terminals are specialized in flexibility. The terminals' response is to be combined and flexible because the flexibility is provided within a specific spectrum of trades having identical generic characteristics. This implies two requirements:

- The terminals must be planned to accommodate heterogenous cargoes, from general cargo in small consignments to containers, which does not mean that the terminals should accommodate every type of cargo.
- The specific subgroups of cargo to be combined must not be so large as to call for a special terminal or demand special handling within the multipurpose terminal in which they are grouped.

11. The philosophy implicit in the definition of a multipurpose terminal is that the operations must be such as to possess a degree of rational coherence in industrial terms although not at the level normal in a specialized terminal. This implies that although the terminals are used by one or more users, shipowners or shippers, operations must be directed by a single management guided by entrepreneurial principles.



### III. RECOMMENDATIONS FOR PLANNING

#### 1. Planning

12. Two possible cases need to be considered under this heading. The terminal may be planned as an adaptation of existing facilities or may be a completely new undertaking. In either case it can be assumed that physical and operational provision for the siting of a multipurpose terminal will have been made in the general or master plan for the port. The discussion below will therefore be concerned only with the points that need to be taken into account in dimensioning the terminal.

13. As a first step consideration needs to be given to the volume and character of the types of traffic to be accommodated. This assumes of course that general traffic surveys have already been made in the context of the general port planning exercise and have pointed to the existence of a sectoral demand justifying the siting of the terminal under the master plan.

14. With regard to the types of traffic, the following cargoes might among others appropriately be accommodated by a multipurpose terminal:

- Forest products;
- Articles of wood and cork;
- Wood pulp, newsprint, cardboard;
- Iron and steel;
- Containers and pallets;
- Roll-on cargoes;
- Heavy cargoes;
- Manufactures of fats, oils, fertilizers;

In more general terms the following might be included:

- Regular shipments;
- Traffic in scheduled modern vessels;
- Unitized cargo in complete shipments.

15. With regard to volume, the desirable throughput should in the case of some of the cargoes mentioned lie between:

- The higher volume technically and economically necessary for the operation of a specialized terminal;
- The lower volume which marks the limit of efficient operation of a conventional general cargo terminal.

The factor underlying the assessment of both volumes is the economy of scale needed for the efficient and economical operation of specialized terminals for particular types of cargo.

Thus, assuming that the critical level for a single berth container terminal is about 60,000 containers a year, the ceiling for a multipurpose terminal could be about 40,000 containers. For other types of cargo the range is wider. In the case of forest products the critical point for a specialized terminal may be about half a million tons a year, but a multipurpose terminal could successfully handle a substantially smaller volume.

16. Paragraph 14 mentions two general categories of cargo, unitized cargoes of one sort or another and cargoes currently considered as semi-bulk. A question that must be considered is whether a multipurpose terminal should handle bulk cargo. In principle, it would seem reasonable to exclude bulk cargo involving such operations as:

- Direct transfer of cargo from the ship to land vehicles using chutes or moving belts;
- Direct transfer from the ship to quayside storage;
- Transfer from the ship using fixed overhead belts.

These and similar operations are inconsistent with the philosophy and efficiency of a multipurpose terminal.

This does not apply to bulk liquid or semi-liquid goods such as bulk concrete, subject to the requirements that:

- The consignments are small and a minor part of the total operation;
- Shipments are regular, not occasional;
- Transfer is effected through underground, watertight pipes;
- Storage facilities are well away from the berths and do not interfere with other storage areas.

The objective of these conditions is to earn a marginal profit without interfering with the general efficiency of the terminal.

17. The expected growth of traffic in a multipurpose terminal has an important bearing on the fundamental objective of its design. In this connection there are two possibilities:

- The terminal may be intended eventually to become a specialized terminal, for which the volume of traffic needed for efficiency will not be available for some years. This would be the case in a port where container traffic is still on a small scale;
- The terminal may be intended to handle a number of specific trades with a balance between those trades and container traffic. This would be the case in a port with an established container trade at specialized terminals but where marginal traffic cannot be efficiently handled because of such factors as the type of ships, the schedule of arrivals and the size of cargoes.

18. These considerations are of crucial importance in planning the location, zoning and size of the terminal.

- So far as location is concerned, the site allotted in the master plan for the port will be conditioned by the expected growth of traffic, especially if the ultimate goal is to convert the terminal partly (one berth out of two, for example) or wholly into a specialized facility;
- As regards zoning, the location of the ro-ro berth, if any, or the allocation of storage areas and siting of sheds or warehouses will be very much conditioned by the likely development of the specialized trades, particularly container traffic;
- From the point of view of size, the initial allocation of space must be capable of adjustment without major upheavals to ensure that the terminal's development is not blocked by lack of, or badly distributed space.

## 2. Dimensioning

19. The discussion below and the formulas and numbers given are essentially based on experience in Spanish ports and should therefore be regarded as rough guides that may be useful in preliminary calculations and initial dimensioning exercises. The results must be checked in the light of experience in the individual port and the recommendations in various UNCTAD publications dealing with these matters.

20. Typically, the following elements must be taken into account in dimensioning a multipurpose terminal:

- (1) Length and specifications of berths suitable for the various types of vessel using the terminal;
- (2) Installation of ro-ro berth if needed;
- (3) Covered storage areas, open or closed, for divided cargo and the consolidation and break up of unitized cargo with the necessary equipment for receiving and shipping cargo;
- (4) Open storage areas for containers, including refrigerated containers, roll-on cargo and divided cargo not needing shelter from the weather;
- (5) Work area for the temporary storage and sorting of cargo;
- (6) Reception and delivery area for the reception and delivery of goods awaiting shipment;
- (7) Checkpoint at terminal entrance and exit;
- (8) Park for road vehicles;
- (9) Areas for ancillary services such as offices, workshops and weighbridges and internal roadways;
- (10) Segregated area for dangerous goods.

In siting and allocating space for each of these purposes the points discussed in paragraph 17 should be taken into account.

21. The equipment for lifting and moving cargo inside the terminal can be classified in the following categories:

- Equipment to load and unload ships using lift-on lift-off procedures;
- Equipment to load and unload cargo using roll-on roll-off procedures;
- Equipment to move and stack cargo in storage areas;
- Equipment for the delivery and reception of goods arriving by road and rail;
- Miscellaneous ancillary equipment.

22. The throughput in loading operations basically depends on the type of cargo and the handling system used. In general terms cargo can be grouped in three main categories, the average tonnage loaded or unloaded per ship per 7 hour shift being as follows:

(1) Low throughput cargo, usually small consignments and palletized and preslung cargo ... 400/500 t/shift;

(2) Medium throughput cargo, typically forest products and iron and steel ... 800/1,000;

(3) High throughput cargo, typically containers and roll-on cargo ... 1,200/1,500

Average throughput per shift for all traffic could be calculated for the year on the basis of the share of traffic in each category but the figures would not be representative as they might relate to cargo loaded and unloaded from ships of different types, the size and characteristics of the ship being major factors in the time taken to load and unload.

23. Because of the variety of ship types, it is difficult to set a target figure for the use of berths, but the figures given below can in principle be regarded as desirable:

Number of berths	Utilization rate (percentage)
1	30
2	50
3	65

With more berths, some of the trades would probably reach the critical demand point for a specialized terminal. This would probably occur after the saturation of the first two berths.

24. Procedures are set out below to estimate the potential traffic capacity of a multipurpose terminal, the terminal's operations being divided into four phases for this purpose.

- Phase I, the terminal's annual berthing capacity;
- Phase II, efficiency of ship/shore loading and unloading;
- Phase III, the terminal's road and rail capacity;
- Phase IV, the terminal's annual cargo storage capacity.

25. The following procedures are among those useful in considering Phase I:

(1) An imperial procedure represented by the formula:

$$C = R \times \emptyset \times N \times T$$

in which

C = potential annual capacity in tons

R = average throughput per ship (tons/ship/shift)

$\emptyset$  = berth utilization

N = number of working days per year

T = number of shift per day.

In the light of the comments in paragraphs 22 and 23 regarding R and  $\emptyset$ , allowance ought to be made for the various ship types and types of cargo. Proceeding simplistically and applying an average throughout of 1,000 t/shift, a figure frequently cited in the literature, with N = 300 days and T = 2, the following values are obtained:

C for one berth = 180,000 t/year/berth

C for two berths = 300,000 /year/berth

(2) A semianalytic procedure consisting of the following steps may also be used:

- Determination of the capacity ( $C_1$ ) of the terminal for each of the three cargo types assuming that only one type is handled in this case, queue theory can be used since we are dealing with homogeneous ships and cargoes, appropriate assumptions being made regarding

Average tonnage per ship

Average tonnage per shift

Sequence of ship arrivals

Time to service ship

Acceptable ratio of waiting to service time.

- Adoption of the percentage  $p_i$  of each of the three cargo types in the overall C of the terminal.
- Calculation of the ratio  $r_i = p_i \times C/C_i$ , which gives the time for each cargo type.
- Calculation of the percentage of time used  $+_i = c_i / \sum r_i$ , which multiplied by  $C_i$  gives the partial traffic for each cargo. The total (C) is obtained from the sum.

In practice the value obtained is a maximum and should be reduced by applying a factor allowing for the simultaneous arrival of ships of different types, which would reduce the time used  $t_i$  or increase waiting time.

(3) Given the variety of ships, cargoes and service times, computer simulation would be the most satisfactory method.

26. Capacity in Phase II is determined by the equipment used and the various possible combinations.

The following values in t/h can be accepted for typical equipment and cargoes:

Cargo equipment	General, broken C.	Forest p. Iron and steel	Containers
12/16 t crane	60/80	80/120	-
30/40 t crane	-	120/150	180/200
Container crane	-	-	250

27. In phase III the capacity of the roadways and railways are considered.

(1) In the case of roadways the volume of land traffic expressed in vehicles/hour has to be calculated. This can be obtained approximately from the formula

$$V = (0.130 CC + 0.625 CG)/1000$$

which expresses the difference between the movement of containerized cargo (CC) and non-containerized cargo (CG).

The traffic generated must be compared with the results of calculating the capacity of the roadways with and without congestion. 4/

(a) Capacity of a congested road

This is the possible capacity allowing for stoppages due to congestion, or saturation.

In vehicle hours per lane this is:

$$V = 2000 \times f_1 \times f_2,$$

in which

$f_1$  is a correction factor depending on the width of the shoulder and the traffic lane. In the special case of ports where the values are zero and 3.5 m it can be taken as 0.70;

$f_2$  is a correction factor depending on the percentage of heavy vehicles and the gradient. In the special case of ports where the values are virtually 100 per cent and zero, it can be taken as 0.40.

With these figures  $V = 560$  vehicles/hour.

(b) Capacity without congestion

There being no congestion  $V = 1200 \times f_1 \times f_2$ . With the values given above  $V = 336$  vehicles/hour.

(2) To calculate the capacity of railways and the tonnage that can be removed from the port, the following variables are considered:

- Number of hours for which line is open (normally 24 hours);
- Capacity according to the IRU scale, which will be the nominal figure if there are no bottle-necks; 5/
- If necessary the lower capacity of the critical sector can be used for port traffic by giving the latter priority or diverting other traffic.

28. In considering phase IV the number of tons (T) of cargo passing through a storage area annually for each category of cargo is obtained by means of the formula:

$$T = n \times q \times S \times K_1 \times K_2$$

in which

$n$  = number of entries and removals of goods during the year, which depends on the transit time of goods;

$q$  = cargo in storage in t/m<sup>2</sup>, the area being the area actually occupied by the goods;

$S$  = total area of storage area including space needed for operations but not general roadways;

$K_1$  = deduction from total area for operational requirements;

$K_2$  = deduction from total area to allow for containers and trailers.

The following are acceptable values of n and q for the three categories of goods:

Cargo type	Transit time in days	n	q
General cargo, (broken)	12	30	1.25/1.50
Forest products			
Iron and steel	14 1/2	25	1.50/1.75
Containers, roll-on	9-4 1/2	40/80	2.0

$K_1$  and  $K_2$  can be taken as 0.5 and 0.75. In the case of  $K_2$ , n and q allowance must be made for empty trailers and containers.

29. The values for phases II, III and IV having been obtained, the procedure described in paragraph 25 (2) is followed giving the total capacity in t/year for each phase and cargo type. The overall capacity of the terminal is the minimum figure for the four phases after addition of the sectors included in each. For detailed calculations, use should be made of the planning charts recommended by UNCTAD 6/ which simplify and speed up calculation and provide a good first approximation.

### 3. Zoning

30. As a first step in designing the layout of a multipurpose terminal the initial specifications of the berth or berths need to be determined.

For a single berth an optimum value is 225/250 m, which provides:

- 25/50 m for a ro-ro ramp; and
- 200 m to berth a modern 15,000 t cargo vessel 165 m long or a 500 TEU container ship.

In a two berth layout a length of 375/400 m will provide:

- 25/50 m for a ro-ro ramp;
- 350 m to berth a 1,500 TEU container ship (215 m long) and a 6,000 ton cargo ship (115 m long) or a 15,000 t cargo vessel and a 500 TEU container ship.

In both cases the depth of water required is determined by the draught of the larger vessel, the 15,000 t cargo vessel or 1,500 TEU container ship, both of which draw 11.00 m. The depth of water at the quay should therefore be 11.3 to 12 m, depending on whether a margin of 0.30 m (mud bottom) or 1.0 m (stone bottom) is allowed for safety.



If it is envisaged (see para. 17) that the terminal will eventually become a specialized container terminal, the depth of water should be reconsidered bearing in mind the possibility of increasing it to 13 m to accommodate third generation container ships of 2,500 TEU.

31. In view of the desirability of having a rectangular ground plan for the terminal, an initial decision is needed regarding the width. Bearing in mind that:

- The optimum width for a conventional general cargo terminal is 125/150 m, and that
- The optimum width of a container terminal is at least 300 m.

Consideration should be given to a width of 200/300 M for a multipurpose terminal, with the possibility of future expansion if the terminal is intended eventually to become a specialized container terminal.

32. On the basis of these general consideration schemes for a one berth multipurpose terminal (250 x 300 m) and a two berth terminal (400 x 300 m) are shown in figures 1 and 2.

The zoning of the two terminals is summarized below:

Zoning	One berth	Two berth
Operations	16	16
Open storage	30	28
Covered storage	8	11
Roadways	36	35
Reception and delivery	5	5
Parking	5	5

It will be noted that the roadway area is practically the same as the area allocated for storage (95 per cent in a one berth terminal and 90 per cent in a two berth facility).

In both schemes, if the terminal is expanded or a specialized container berth is provided, it is assumed that this would be done at the right-hand side of the figure. In figure 1 the covered storage area would remain if the terminal was expanded to serve ro-ro and non-containerized cargo. In figure 2 the covered storage area would be conveniently sited away from the quayside if the right-hand berth became a specialized container berth. In both terminals the ro-ro berth (shaded in both figures) is at the left-hand side with direct road access to covered storage in the first or second row. Rail access to the berths and delivery areas could easily be provided through minor modification of the zoning.

33. Figure 3 illustrates a terminal predominately accommodating container traffic but with facilities for handling other types of cargo. Figure 4 illustrates a 17.5 hectare multipurpose terminal with a layout similar to that shown in figure 2.

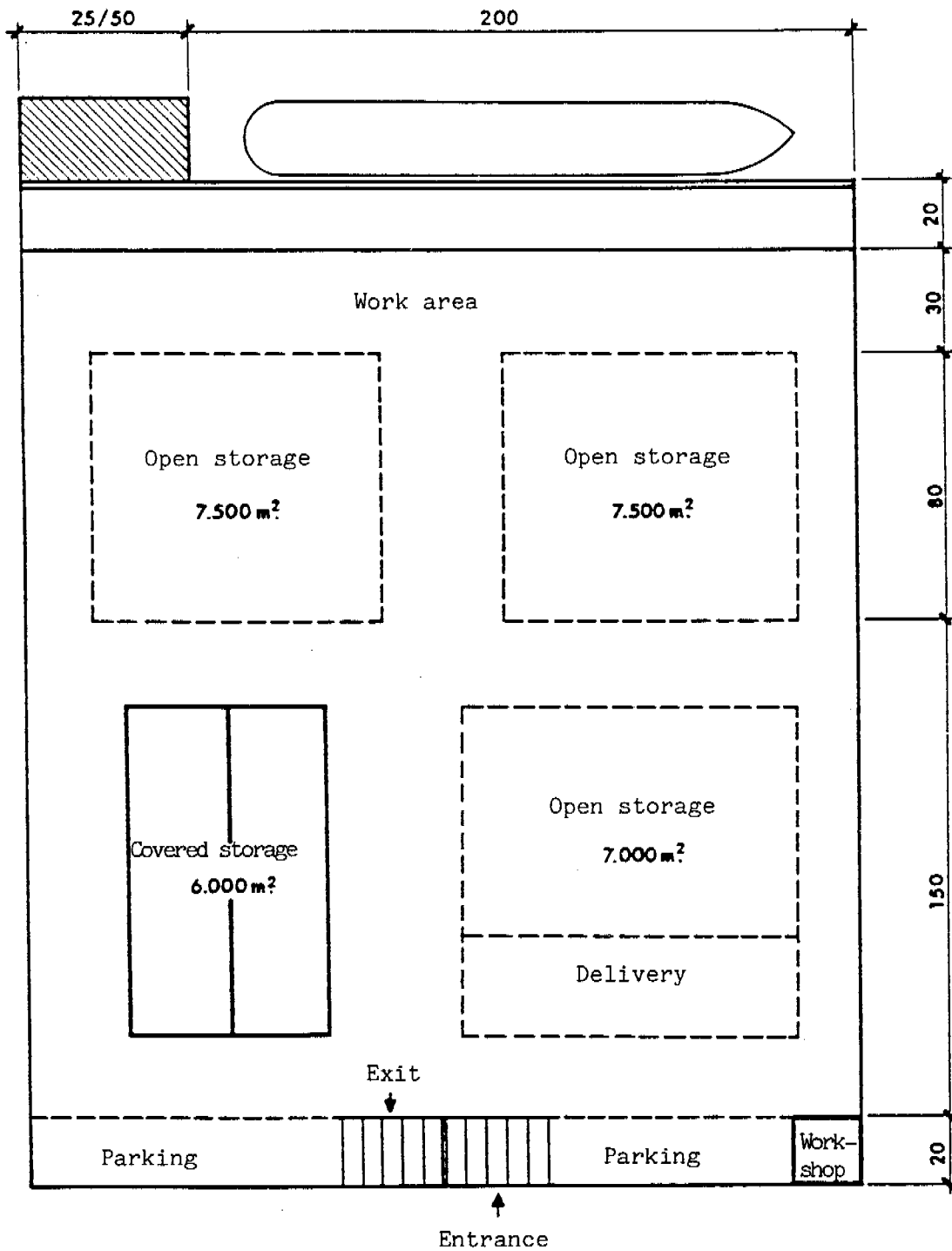


Figure 1: One berth multipurpose terminal

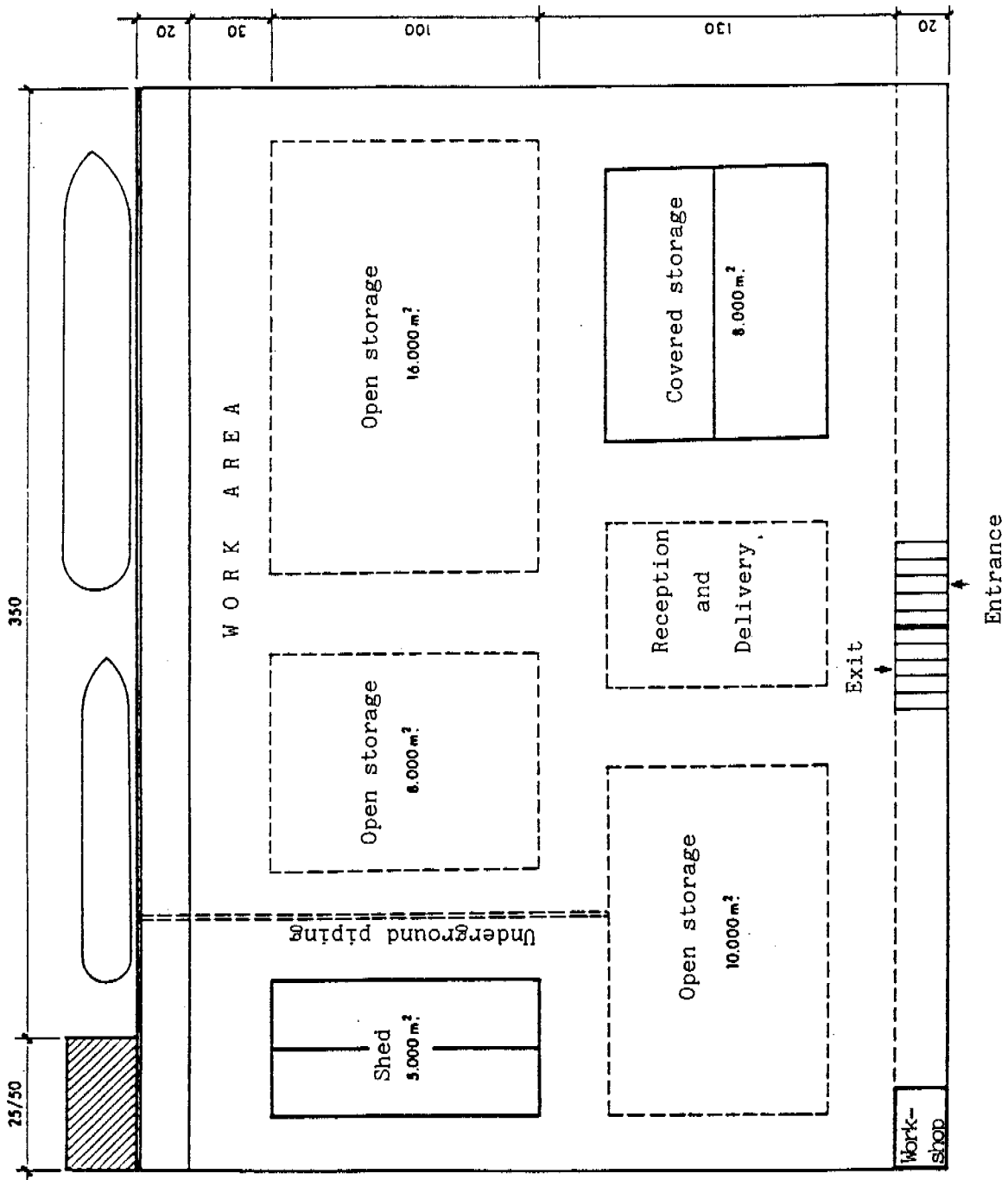


Figure 2: Two berth multipurpose terminal

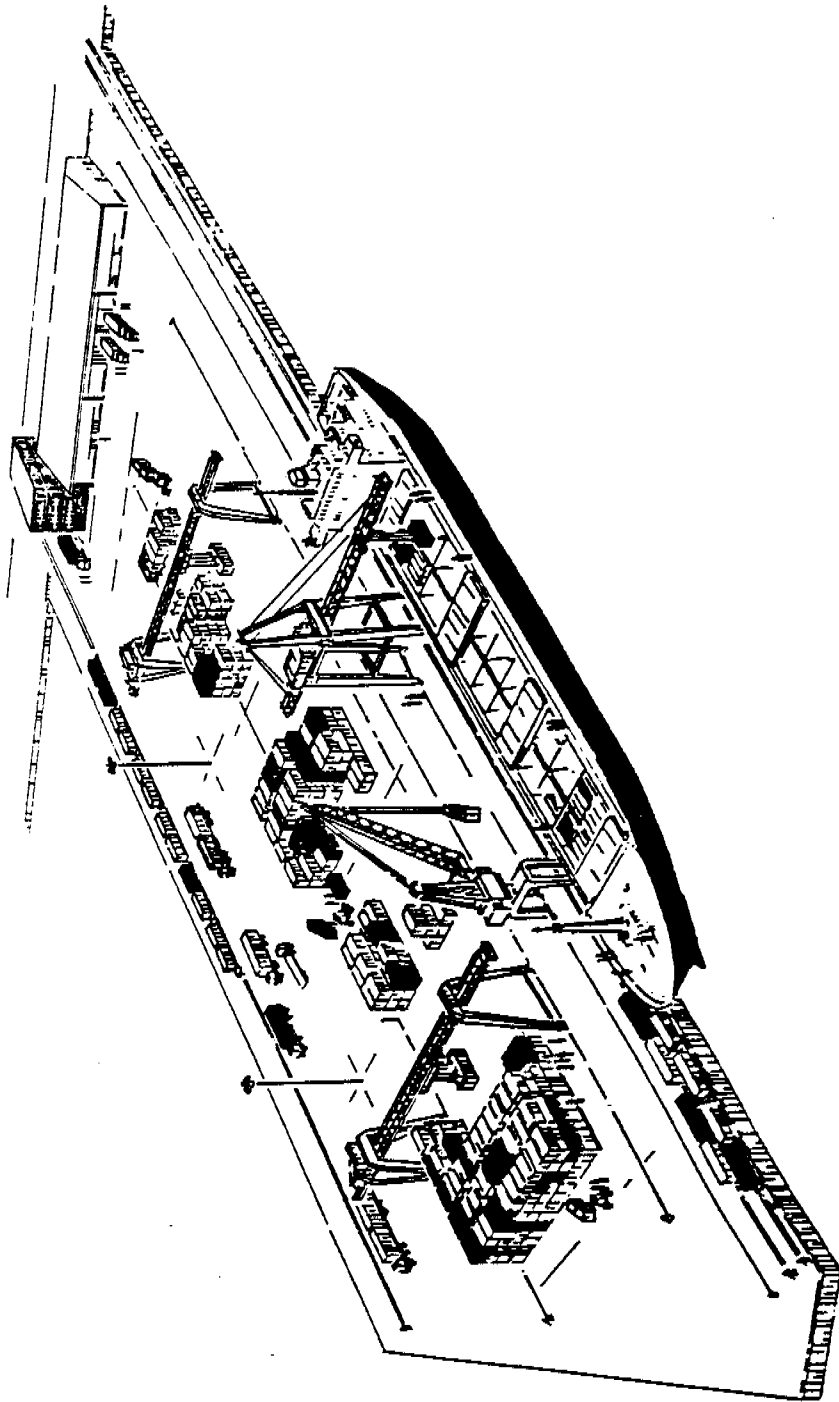


Figure 3: Multipurpose terminal with heavy container traffic

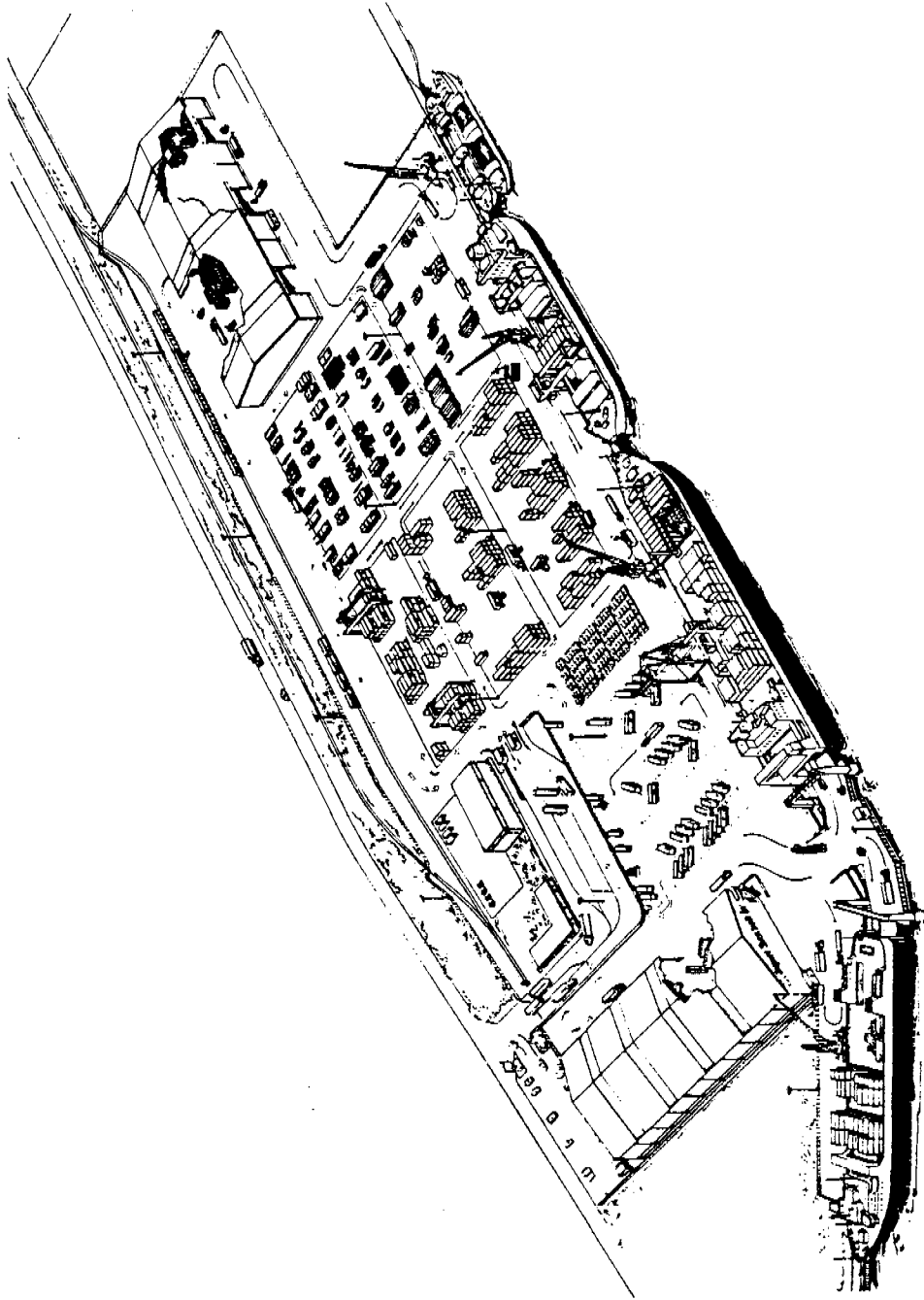


Figure 4: A two berth multipurpose terminal

4. Equipment

34. A range of port operating equipment is listed below with information on its most significant operating capabilities. More comprehensive information on container handling equipment, a major requirement in a multipurpose terminal is available in the training material prepared jointly by the World Bank and UNCTAD. 7/

35. Conventional cranes for unitized and non-unitized general cargo with lifting capacities ranging from 6 to 16 t.

Cranes may be fitted with a quadrilateral jib (figure 5 A) or a simple jib. The first type is heavier and costs about 10 per cent more but greatly facilitates the rapid handling of heavy loads such as coiled steel since the load and the pulley at the end of the jib travel horizontally thus reducing oscillation of the load.

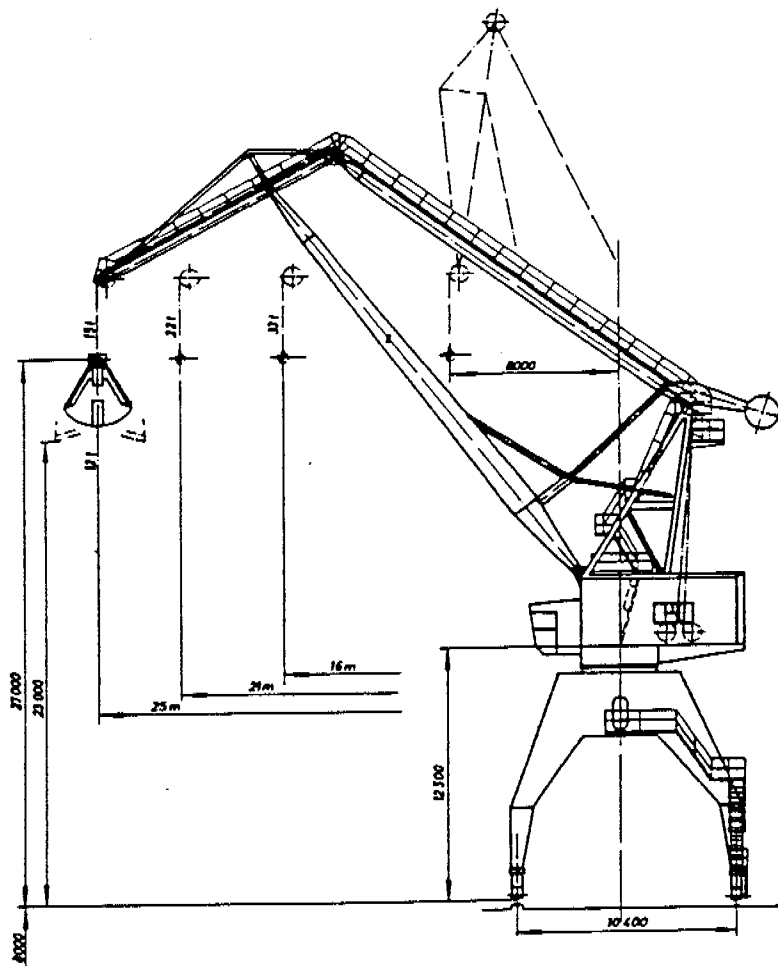


Figure 5 A: Crane with quadrilateral jib

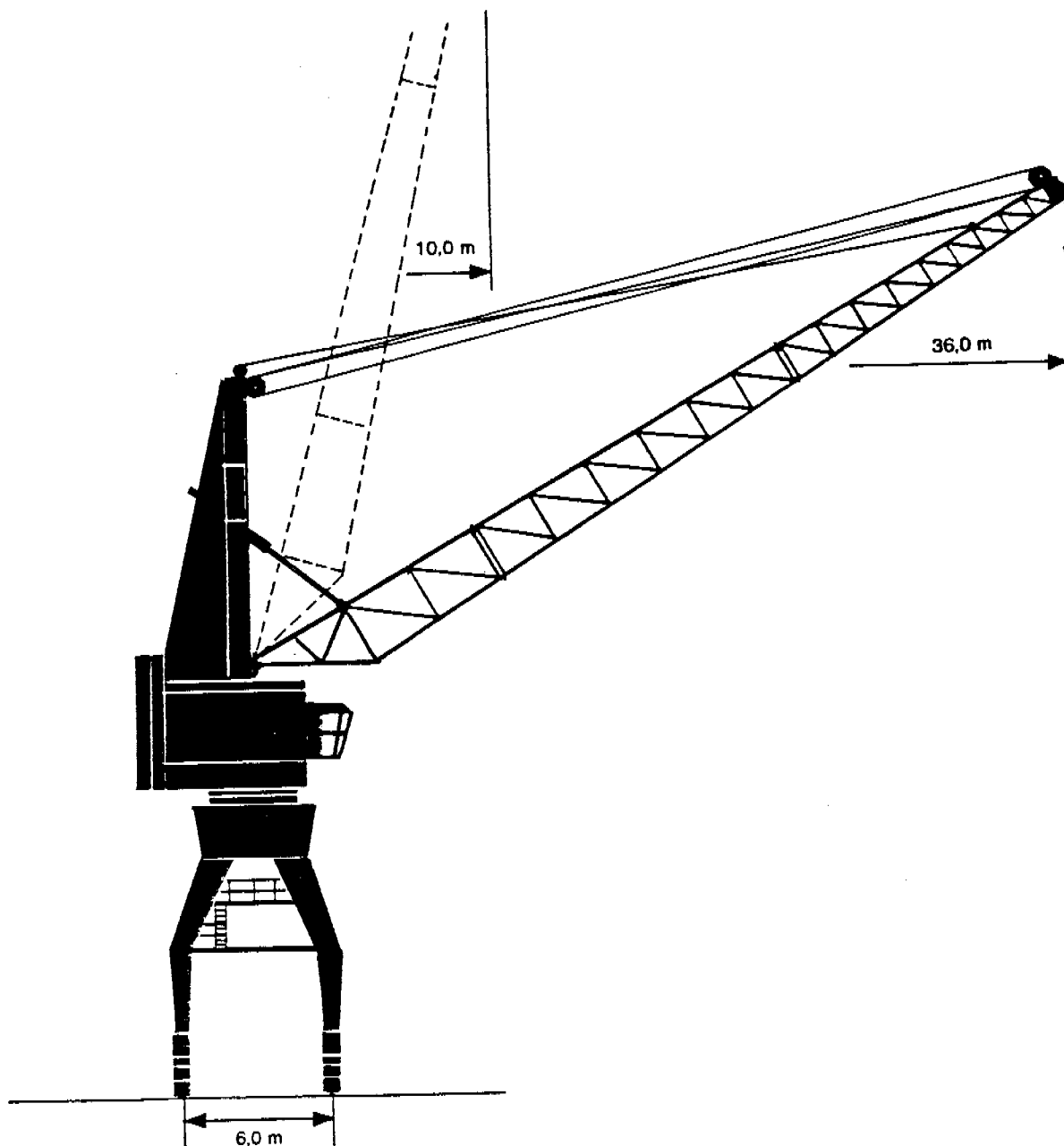


Figure 5 B: Crane with simple jib

36. Multipurpose heavy lift cranes with capacities ranging from 25 to 40 tons (figure 6) are usually rigged to handle heavy loads and containers with a main hook and lighter unitized loads with an auxiliary hook, bulk cargo with a grab, and sheet steel and the like with an electromagnet. The use of the latter may cause magnetic interference in the ship and the crane's electrical equipment. For handling containers cranes should meet the following requirements:

- Lift at maximum reach: 30 t, for a 40' container plus 10 t for the spreader, a total of at least 40 t.
- Maximum reach: although 1,500 TEU container ships have a beam of only 31 m, a small increase is desirable to enable the crane to handle 13 rows of containers (Panamax beam), which requires a reach of 32.5 m from the edge of the wharf.

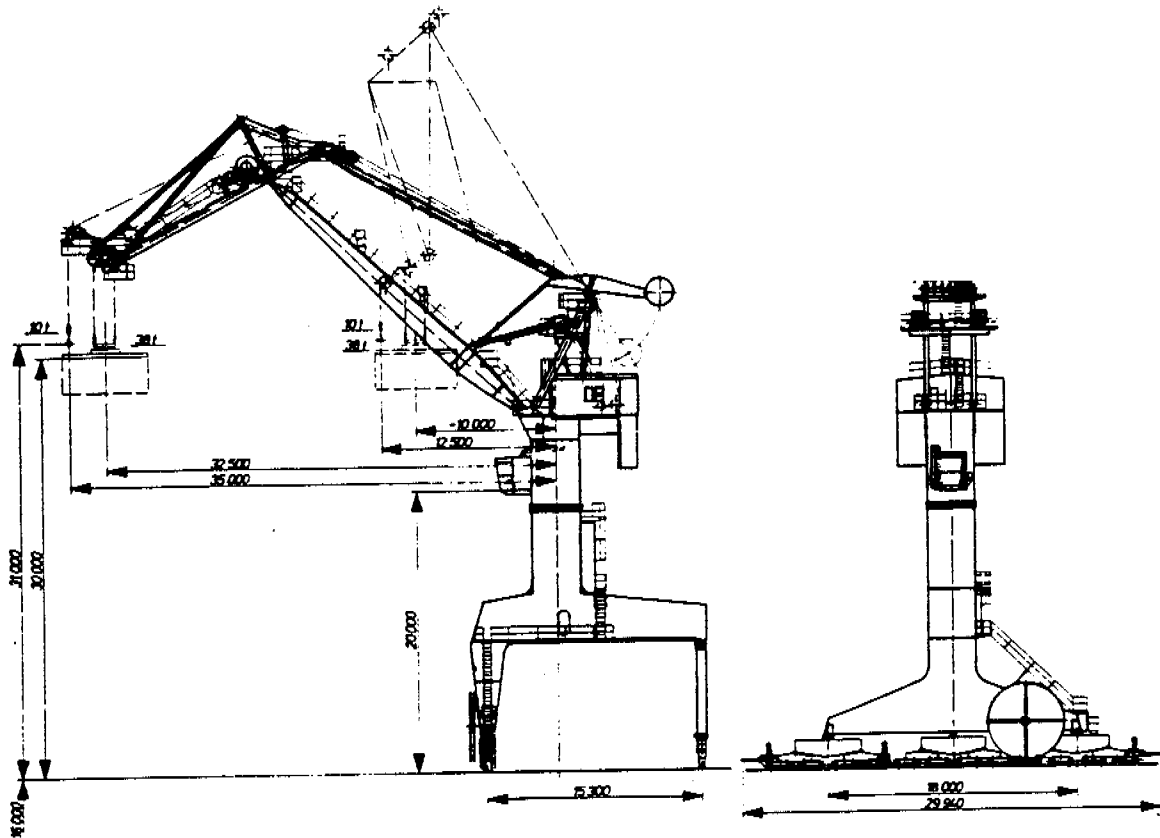


Figure 6: Multipurpose crane

37. A mobile crane in this context is specifically designed for port use and different from the self-propelled crane or crane mounted on a road vehicle. Mobile cranes are of great use in multipurpose terminals since they can be used to load and unload ships and also to handle heavy loads in the terminal cargo handling areas. On the other hand, their initial and maintenance costs are twice those of conventional cranes and positioning takes some time.

Their lift and reach are equal to those of the cranes described earlier. It should be noted that the jib is hinged sufficiently high to clear containers stacked on deck and can handle all rows without need for changes on board (figure 7 B).



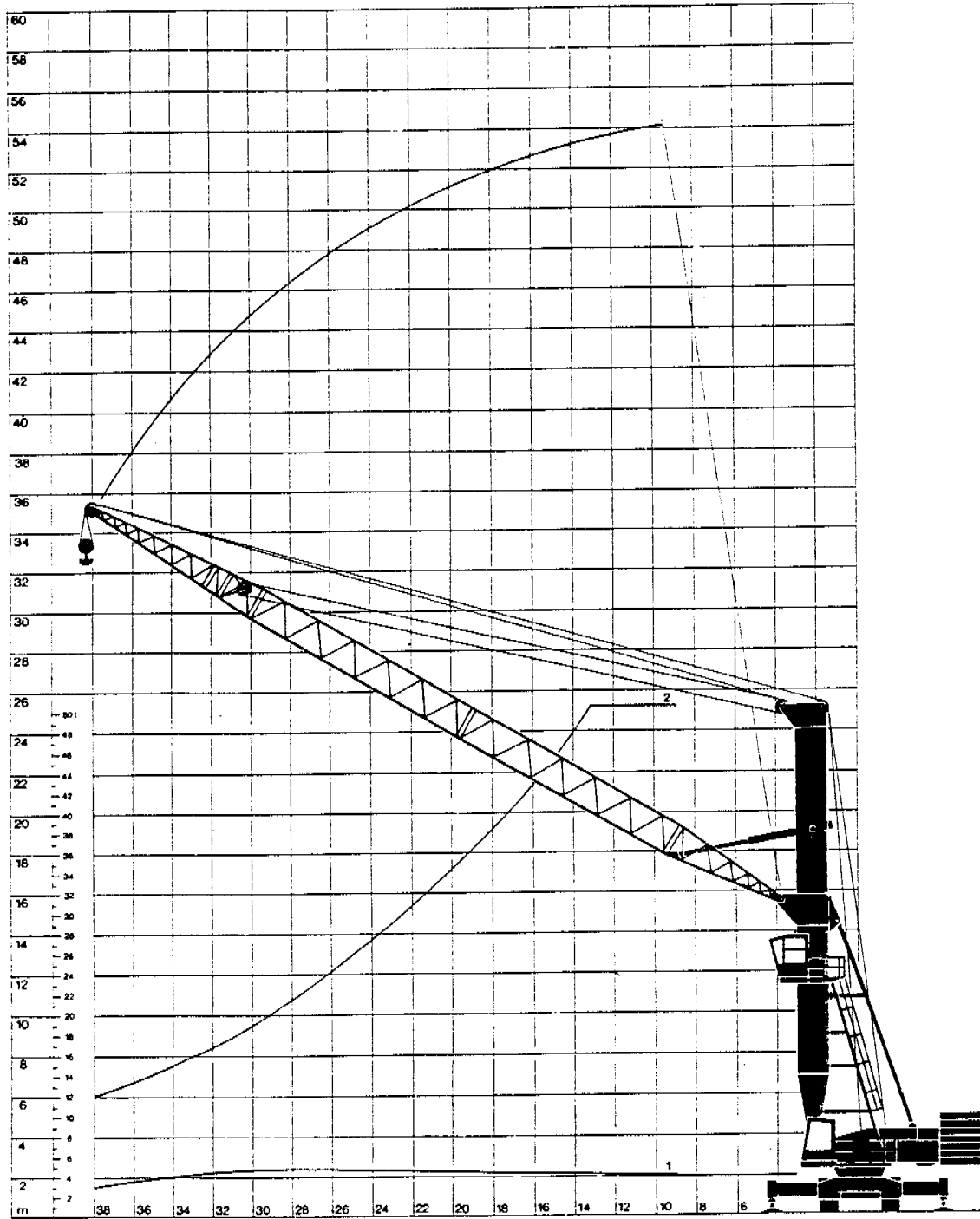


Figure 7 A: Capabilities of a mobile crane

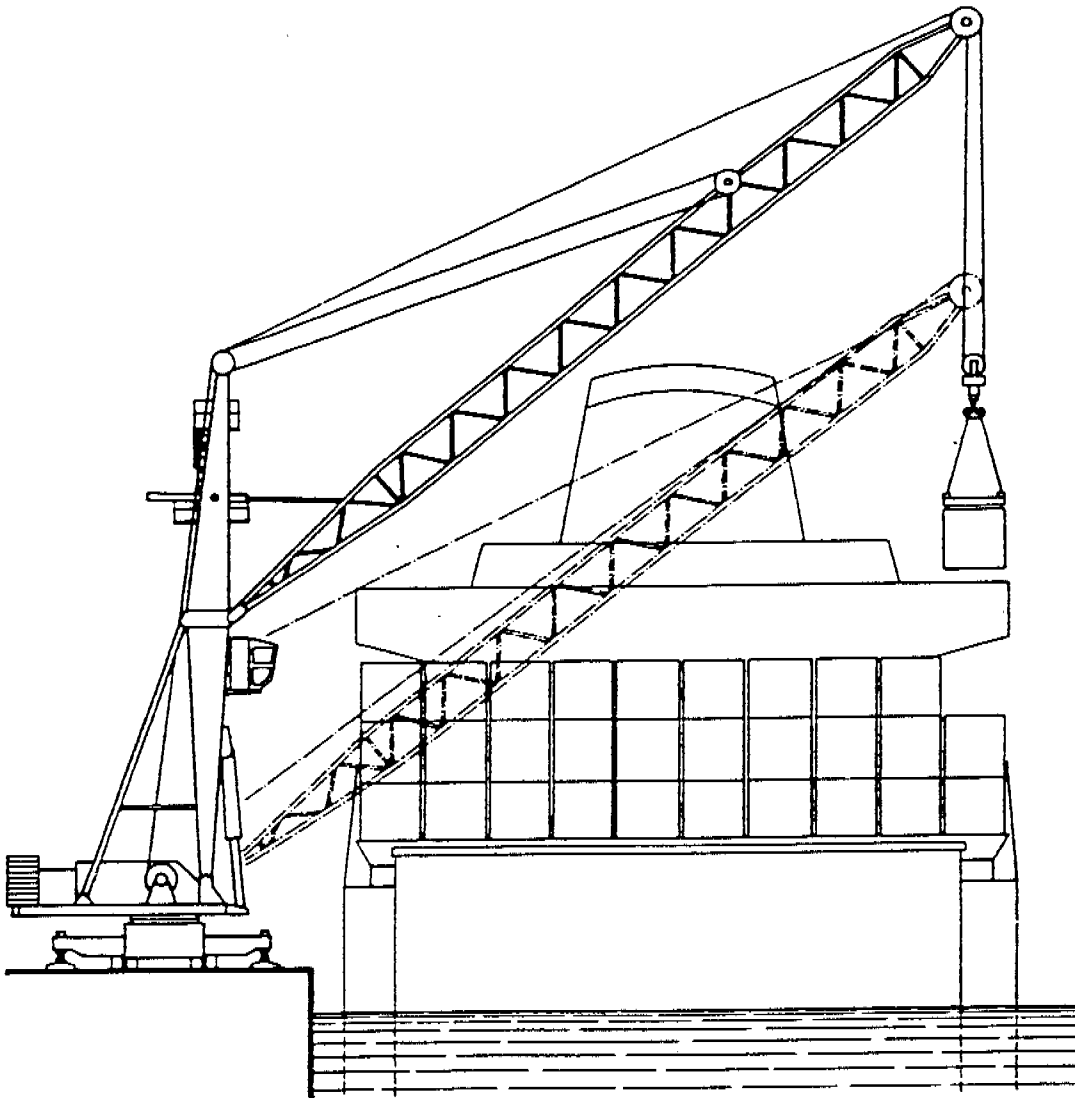


Figure 7 B: Versatility of a mobile crane

38. The capabilities of container gantry cranes (figure 8) make them essential in multipurpose terminals that may at any time be completely or partly converted to use as specialized container terminals. They are:

Lift: 40 t minimum

Maximum reach from edge of wharf: 32.5 m.

Height of hoist below spreader: at least 25 m.

Width of track: 15/18 m and up.

Reach on shore side: 15 m.

Clearance below gantry: 12 m.

With these capabilities the cranes can, with a small increase in cost, work container ships with Panamax beam. In order to handle containers over 40' the horizontal clearance between the front legs of the gantry must be the length of the longest container envisaged plus 2.0 m.

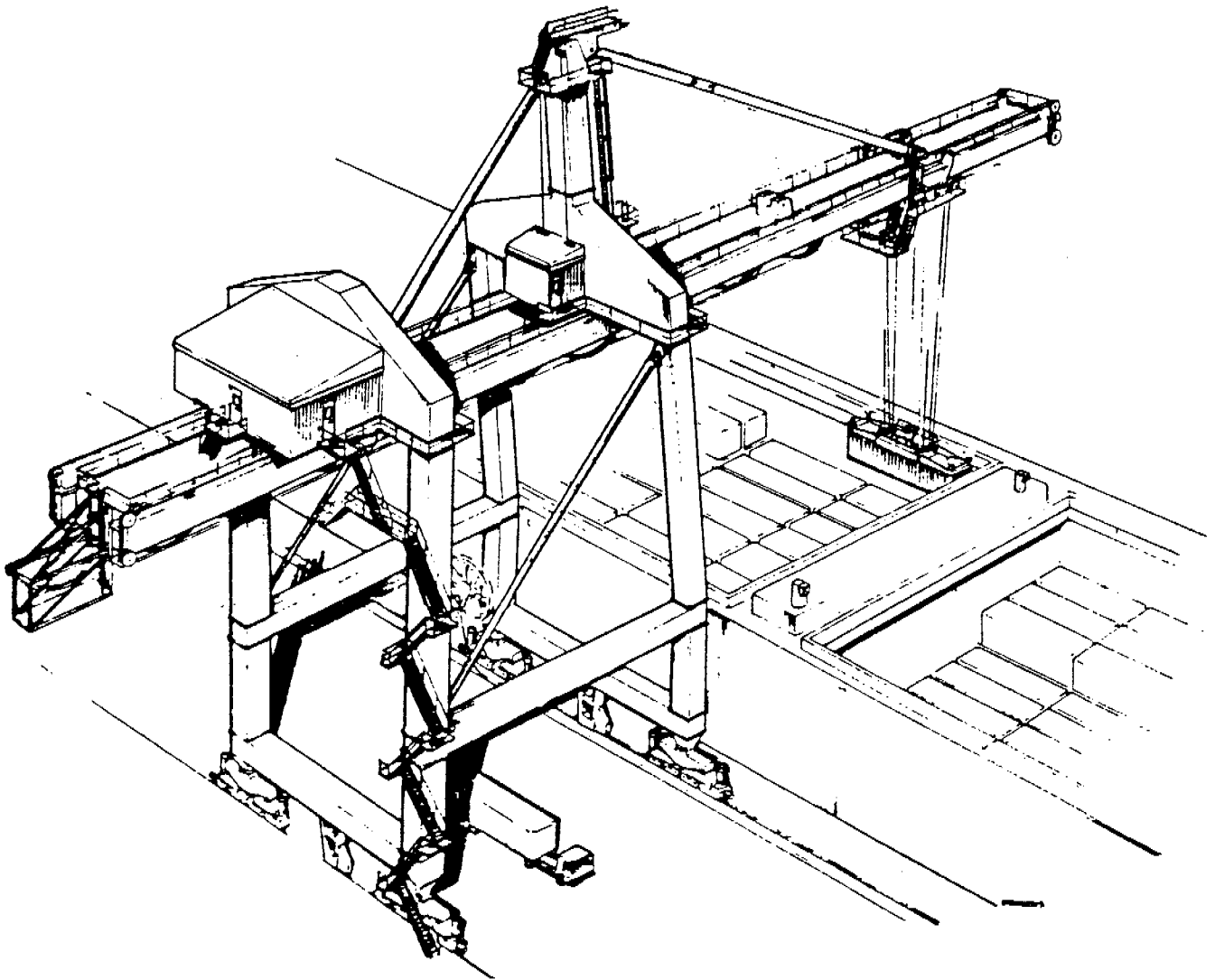
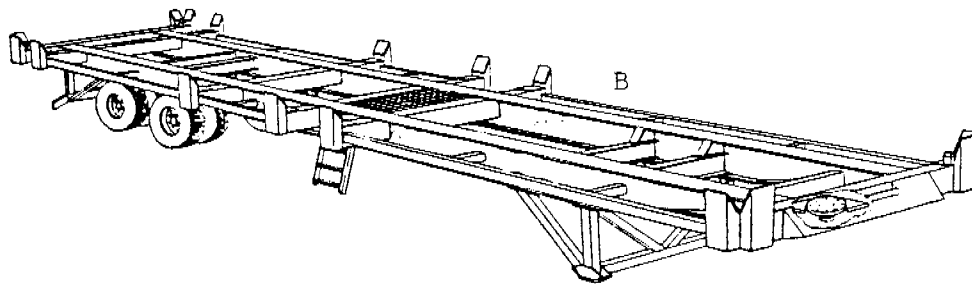
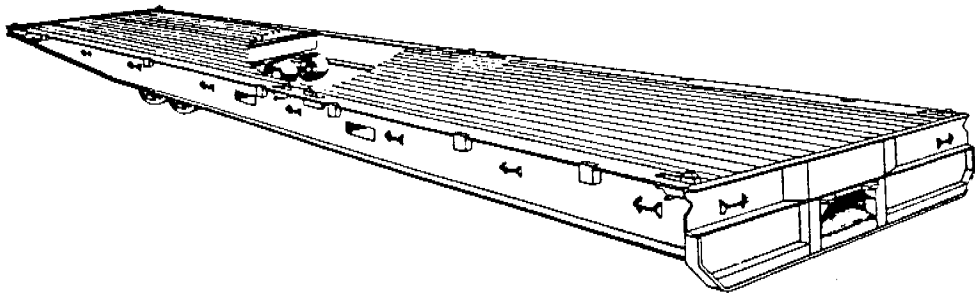


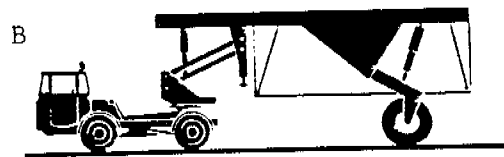
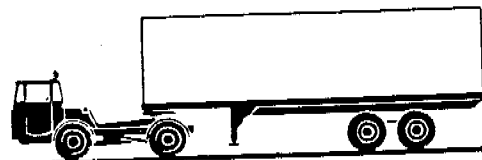
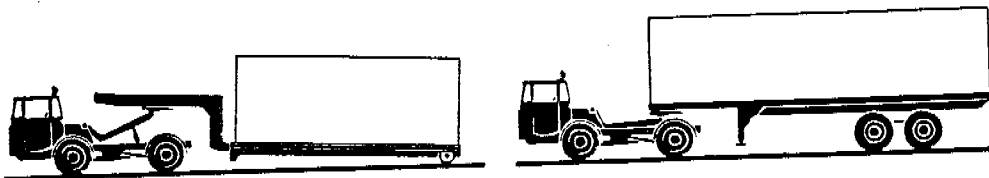
Figure 8: Gantry crane to move containers to and from the wharf

39. Three types of trailer are used to move cargo and containers within the terminal. They are:

- Low platform trailers (figure 9 A) which are best suited to ro-ro operations. Over long distances the low speed due to the small wheels is a handicap, as is the need to secure the gooseneck coupling with chains. They have the advantage of being able to be stacked when empty.
- Normal height trailers (figure 9 B), which are similar to trailers for road use but simpler and sturdier, with no suspension or extra connections.
- Hydraulic lift trailers (figures 9 A and B), which have the advantage over the other two types of not needing a machine to load them. A hydraulic lift raises the cargo but cannot be used for stacking.

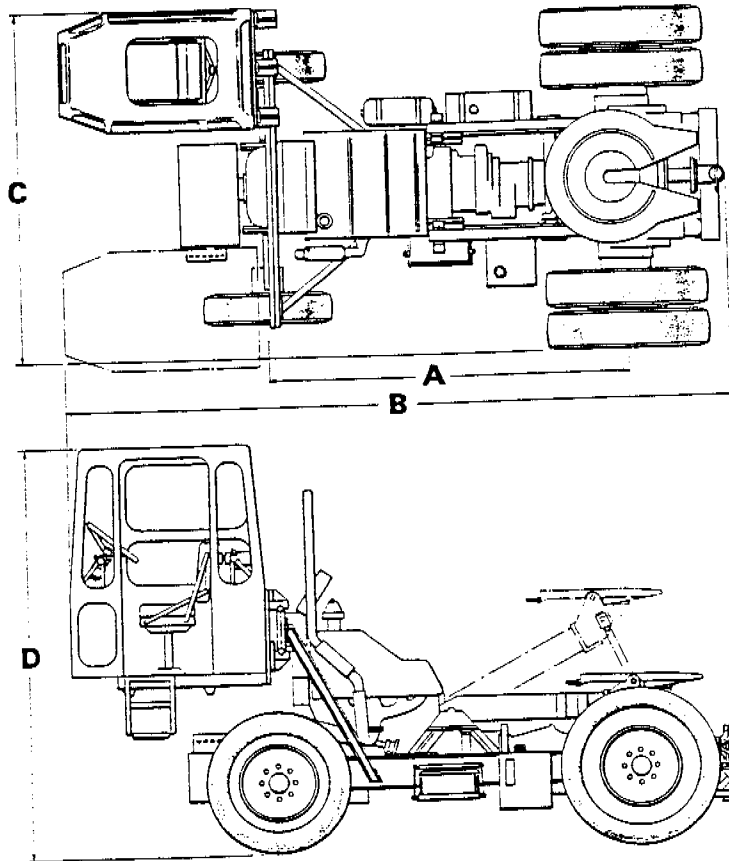


Figures 9 A and 9 B: Low and normal height trailers



Figures 10 A and 10 B: Trailer with hydraulic lift

The three types of trailer are towed by tug masters (figure 11) fitted with coupling devices. For ro-ro work tug masters with low cabs are used (minimum overall height).



Basic dimensions */		
Description	Identification on Figs.	Dimension (m)
Length between axles	A	2.60
Overall length	B	4.70
Overall width	C	2.30
Overall height	D	2.70

\*/ For reference only.

Figure 11: Tug master for towing terminal trailers

40. There are various types of cargo handling machines with stacking capability, the most widely employed being the following:

(1) The front lift truck (FLT). This is the workhorse of multipurpose terminals because of its cargo handling versatility and its ability to both lift and carry cargo, although its efficiency as a carrier falls off with distance. The FLT is available in various sizes. The smallest, used in sheds and loading and unloading containers, have a capacity of 2 to 3 tonnes. The largest with a capacity of 40 tons are used to handle containers, even in specialized terminals.

The lifting device used is of considerable importance. The simplest is the fork, which is used on the smallest trucks used to handle pallets and also on larger models used to handle containers in relatively unspecialized trades where there are still containers fitted with fork guides. In container operations spreaders are generally used to handle containers. Spreaders are available for full, empty and partly empty containers. Between these two extremes there is a variety of specialized machines for handling a range of loads.

Another point of importance is the height of the front column supporting the lifting device. Trucks are fitted with either standard or short columns. The short column is useful on the small models used to load and unload containers as well as on the larger capacity trucks used in ro-ro operations where it may be necessary to work in holds with little headroom.

Figures 12 A and 12 B and the basic specifications given below for reference illustrate heavy duty trucks with standard and short columns. Trucks of this kind are inexpensive and easy to maintain but the load on pavements is high and a great deal of space is needed for manoeuvring.

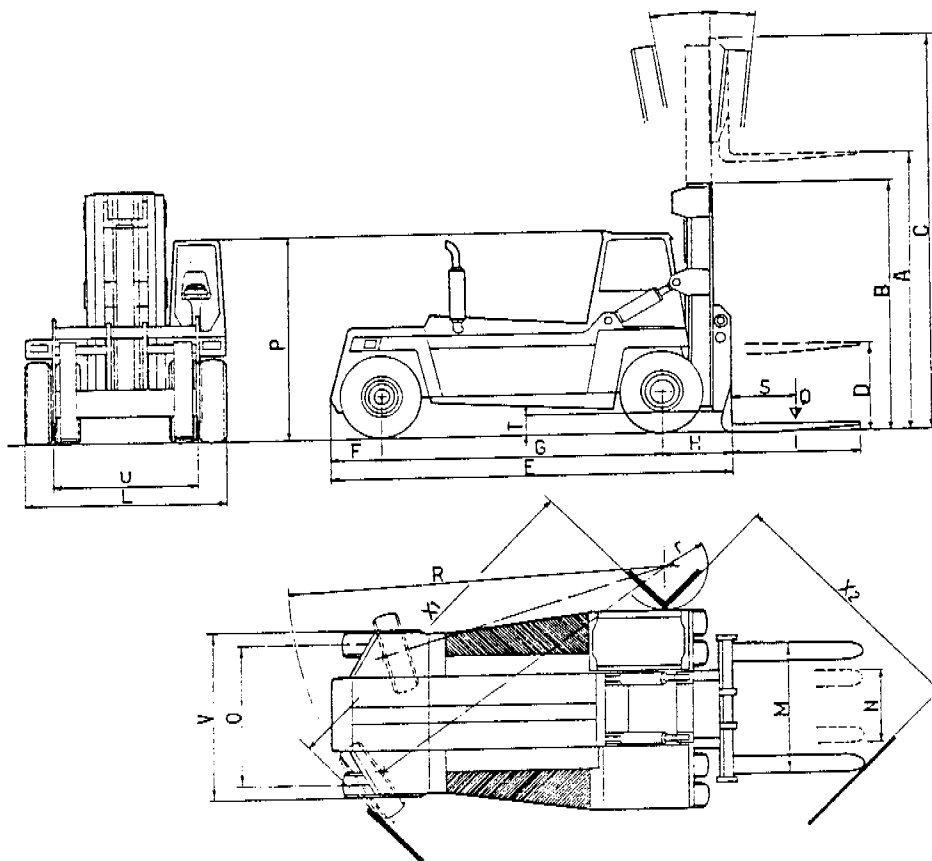


Figure 12 A: Front lift truck with standard column

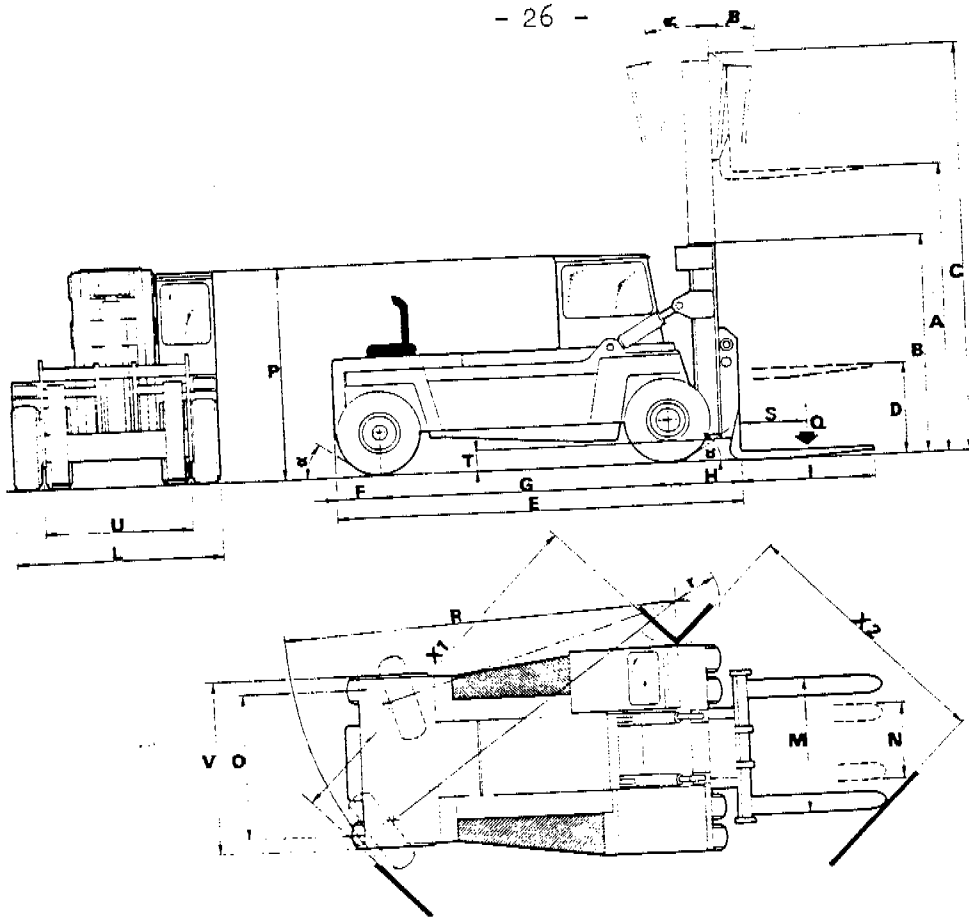


Figure 12 B: Front lift truck with short column

Basic dimensions of standard and short column front lift trucks (in metres)			
Description	Identification on figure	Standard	Short
Front width	U	2.30-2.70	1.75-2.68
Max. front width	L	3.15-3.85	2.60-3.75
Cab height	P	3.70-4.10	2.90-3.75
Height with column extended	C	6.40	4.45-5.40
Maximum lift	A	4.10	3.00-3.20
Column height	B	4.18	2.90-3.70
Total length (less forks)	E	5.90-7.85	4.83-7.10
Rear length	F	0.85-1.00	0.65-0.85
Length between axles	G	3.95-5.50	0.65-0.85
Front length	H	1.10-1.35	0.98-1.25
Fork length	I	2.45	2.45
Distance to centre of load (max. capacity)	S	1.22	1.22
Height of column above ground	T	0.35	0.25-0.35
Rear width	V	3.10-3.20	2.50-3.10
Width between rear wheels	O	2.73-2.70	2.15-2.58
Max. fork opening (outside)	M	2.40	2.35-2.90
Min. fork	N	1.45	0.75-1.30
Turn radius	R	5.80-7.80	4.45-7.00
Min. corridor for turn (forward)	X1	5.10-6.70	4.05-6.55
Internal turn radius	r	1.05-1.80	0.75-0.95
Min. corridor for turn (backing)	X2	4.50-5.00	4.10-4.95
Max. load in tonnes	Q	16-42	10-35

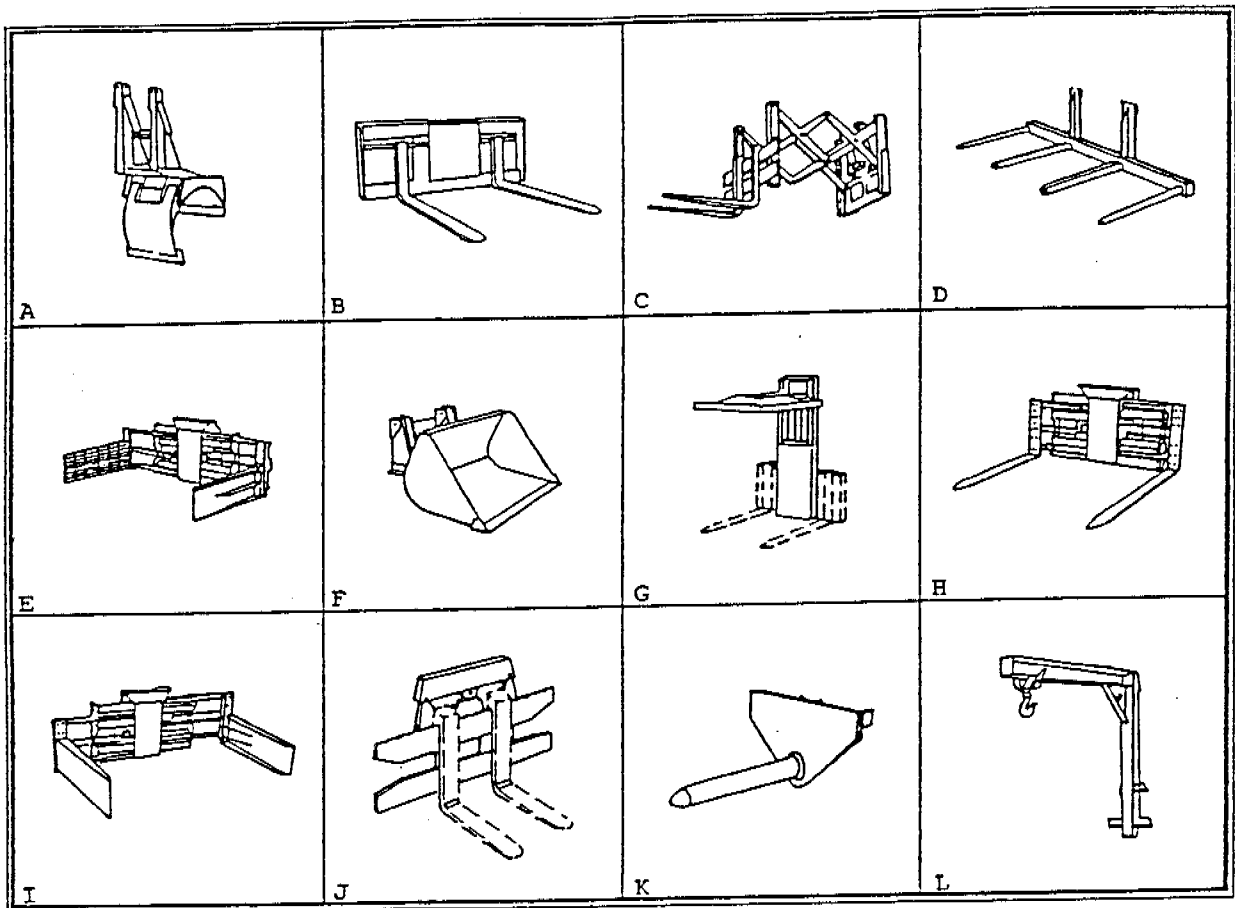


Figure 13: Special purpose fittings 8/

- A. Clamps for reels. There is a range of clamps for lifting and rolling reels of newsprint.
- B. Claws for pallets. Used in a wide range of applications. Can be adjusted manually to different pallet sizes.
- C. Extension forks. Used to stack goods to greater depth and to work on road vehicles and railway wagons from one side only.
- D. Claws for drums. Can be used to handle and stack standard 40 gallon drums horizontally.
- E. Load clamp. Basic or turning model to handle crates, boxes or other rigid loads. Arms generally fitted with changeable rubber cushions to avoid damaging load.
- F. Hydraulic shovel to handle bulk materials.
- G. Load stabilizer. For safe handling of bulky loads that cannot be properly secured.
- H. Movable hydraulic fork. Position of the fork can be changed quickly to accommodate different loads.
- I. Bale clamp. For handling bales of pulp, cotton or hemp.
- J. Lateral positioner. Essential to position loads quickly and accurately.
- K. Spindle. To handle cylindrical loads such as steel coils, tubes or carpets.
- L. Removable hook bracket for handling loads requiring the use of hooks and slings.



(2) Side loader truck (SLT), with capabilities similar to those of the FLT, but less versatile (figure 14).

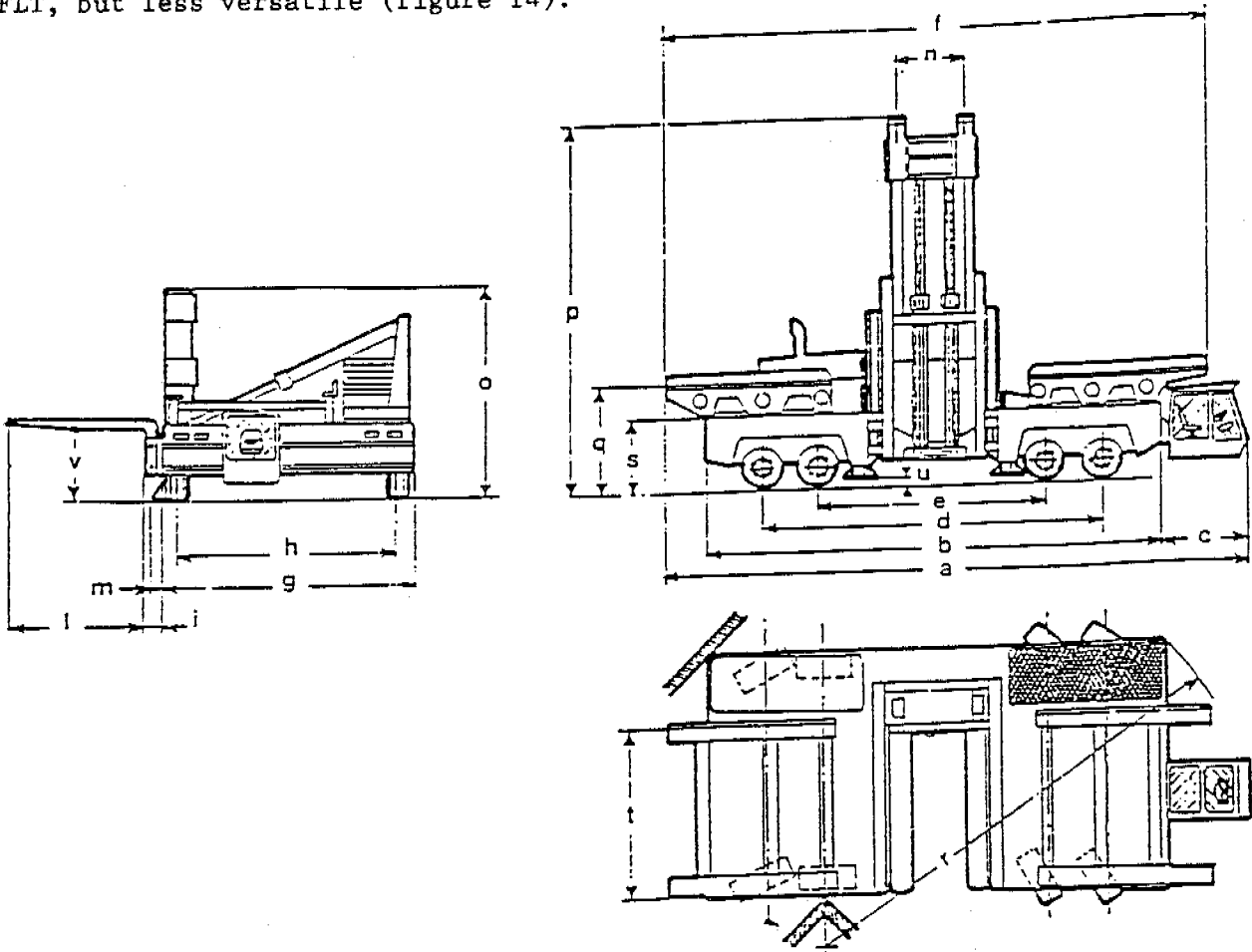


Figure 14: Side loader truck

Basic dimensions of side loader truck (metres)		
Description	Identification on figure	Dimension
Total length	a	10.86-11.70
Length of chassis	b	8.91
Length of cab	c	1.95
Length between outer axles	d	7.11
Length between second rear and second front axles	e	4.41
Length of platform	f	9.00-10.40
Width of column	n	1.16
Height of column extended	p	6.00-8.50
Height of column retracted	o	4.20-5.45
Height of platform	q	2.48
Height of chassis	s	1.78
Height of stabilizer in up position	u	0.30
Height of fork above ground	v	1.84-1.94
Width of truck	h	3.43
Overall width of truck	g	3.90
Projection of stabilizer	m	0.16
Projection of column	i	0.15
Projection of fork	l	2.50
Width of platform	t	2.50
Turn radius	r	8.83

(3) Carrier truck of the type shown in figure 10 B, but self-propelled and capable of stacking up to three containers. A simple and economical machine useful for relatively unspecialized operations (figure 15).

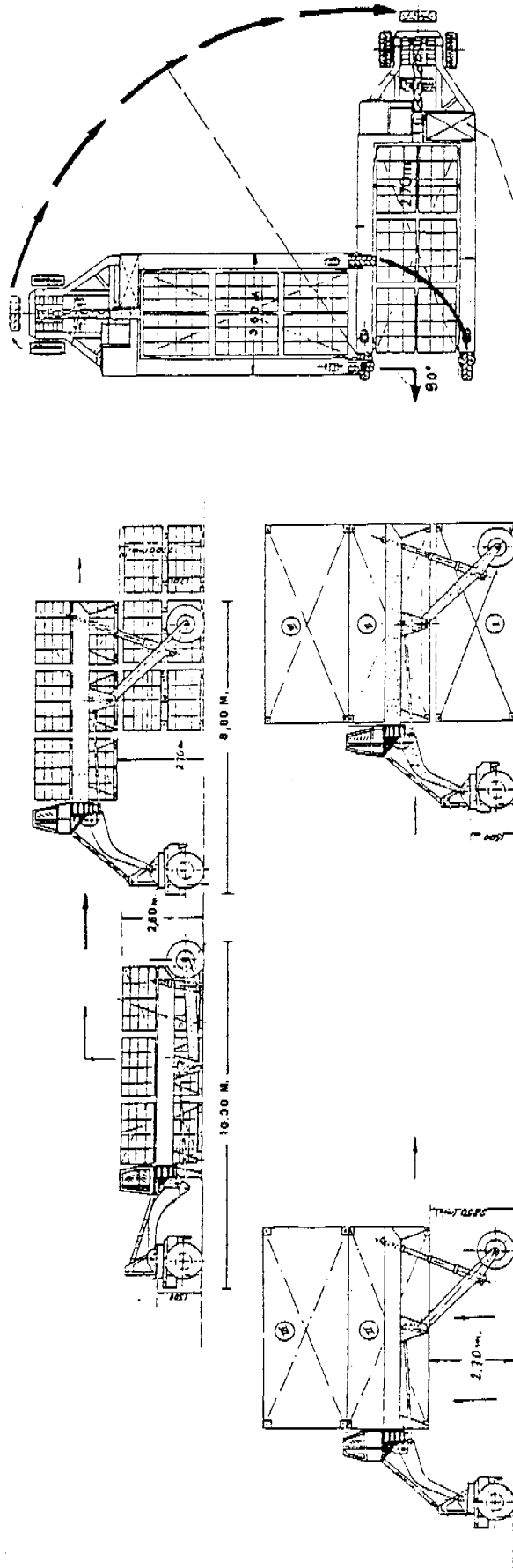


Figure 15: Carrier truck

(4) The reach stacker crane (RSC) performs functions similar to those of the side and front loaders and can stack containers in blocks of four rows four containers high (figure 16). This doubles the efficiency of use of the storage area in comparison with the blocks of two rows two containers high that could be stacked by earlier machines. At the same time the load imposed by the machine on the pavement is reduced and the spreader's 90 degree turning capability permits a further reduction in the width of the corridors between stacks.

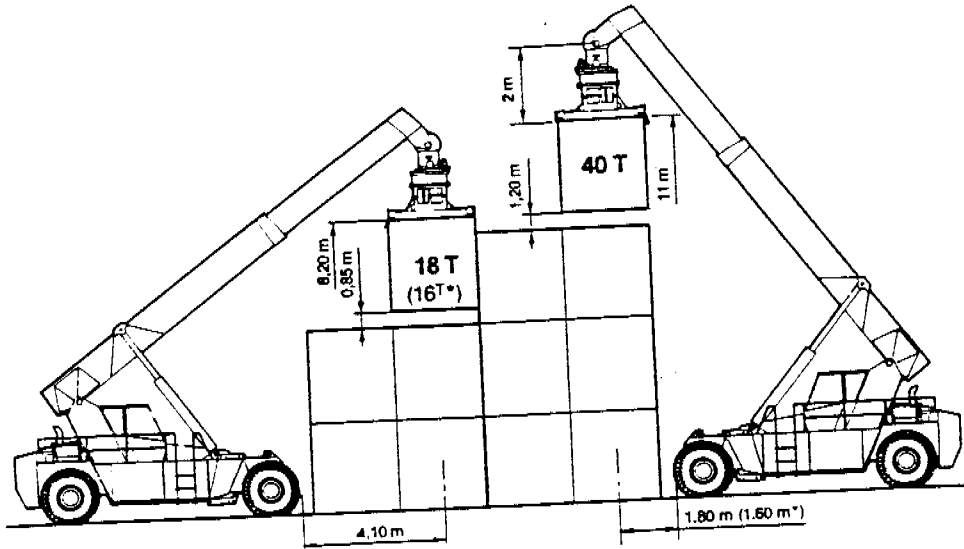


Figure 16: Reach stacker crane

(5) The mobile portal crane can perform the functions of the front lift truck, the reach stacker crane and the straddle carrier, offering the flexibility necessary even in highly specialized terminals at a purchase price and maintenance costs intermediate between those of an FLT and an STC (figure 17).

1. Turning a fully loaded 40' container.
2. Stacking two containers high in third row.
3. Carrying container, jibs retracted.
4. Working as "straddle carrier", 3+1.
5. Stacking sideways in first row.
6. Stacking first container in third row.
7. Spreader vertical extension (1.35 m).

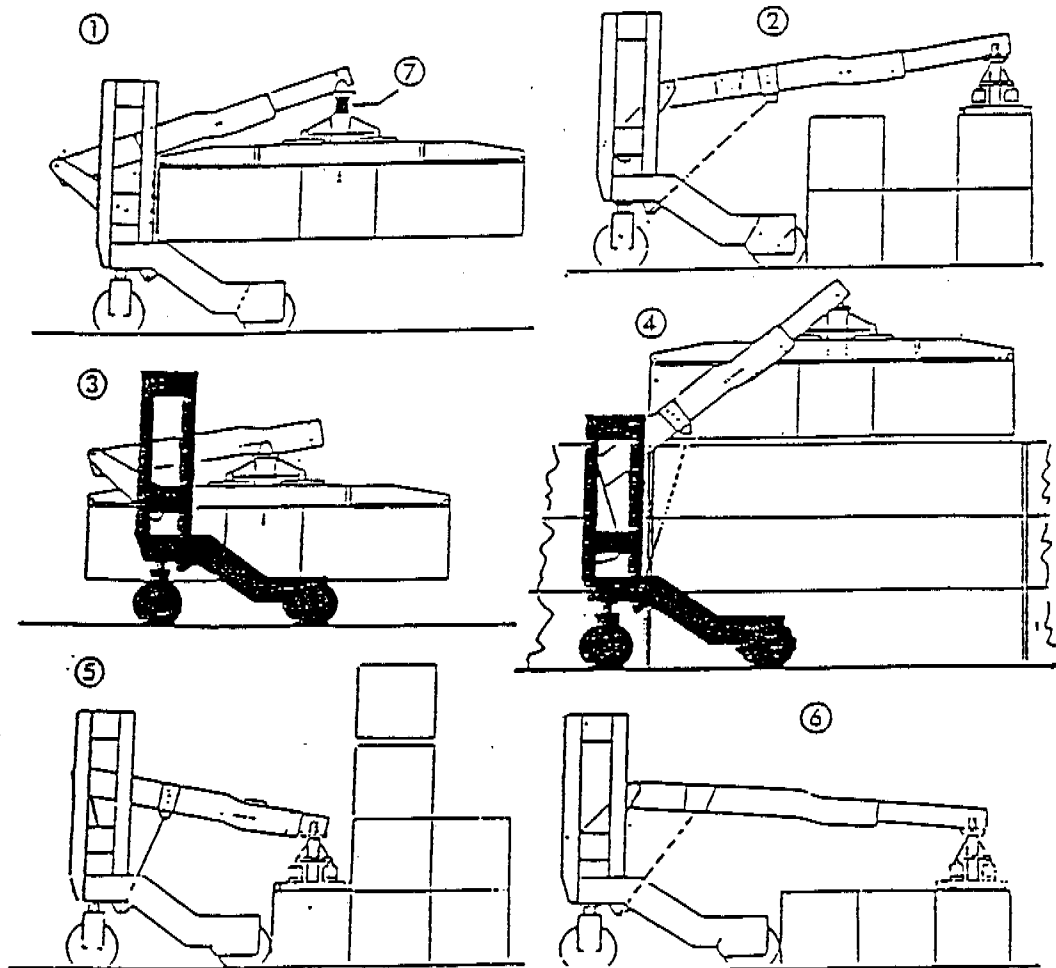


Figure 17: Mobile portal crane

(6) The straddle carrier (STC) is ubiquitous in container terminals. It offers high flexibility, but the purchase price and maintenance costs are also high and the load imposed on the pavement is heavy. Its stacking capability varies from one on one to one on three, one on two being the most common.

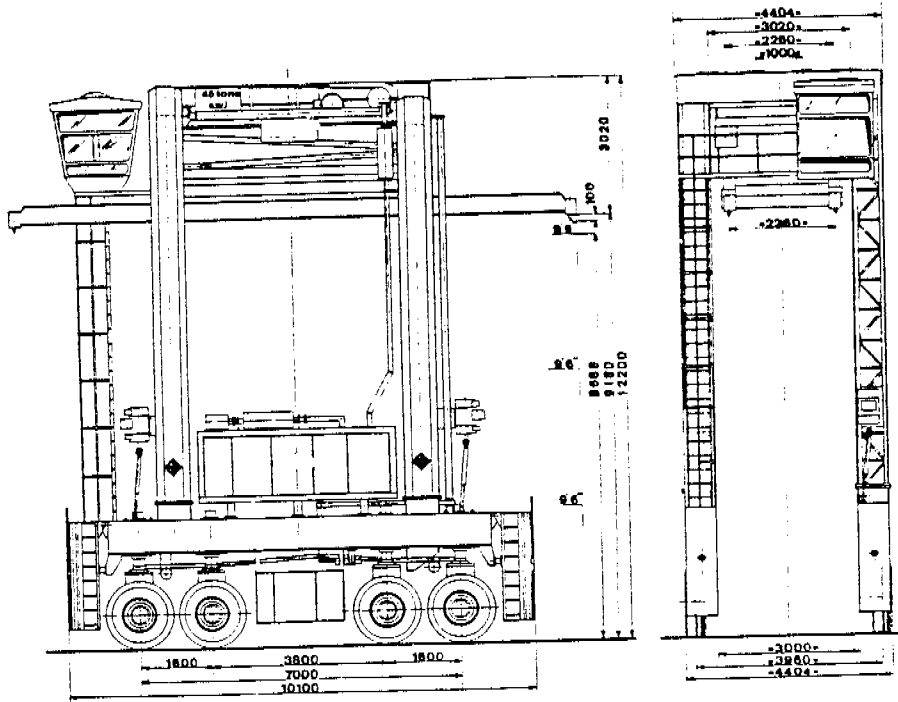


Figure 18: Straddle carrier

(7) Rubber tired and rail mounted gantries (RTG and RMG) are highly specialized pieces of equipment with high stacking capability well adapted to highly organized operations (figure 19). They are rarely seen in multipurpose terminals.

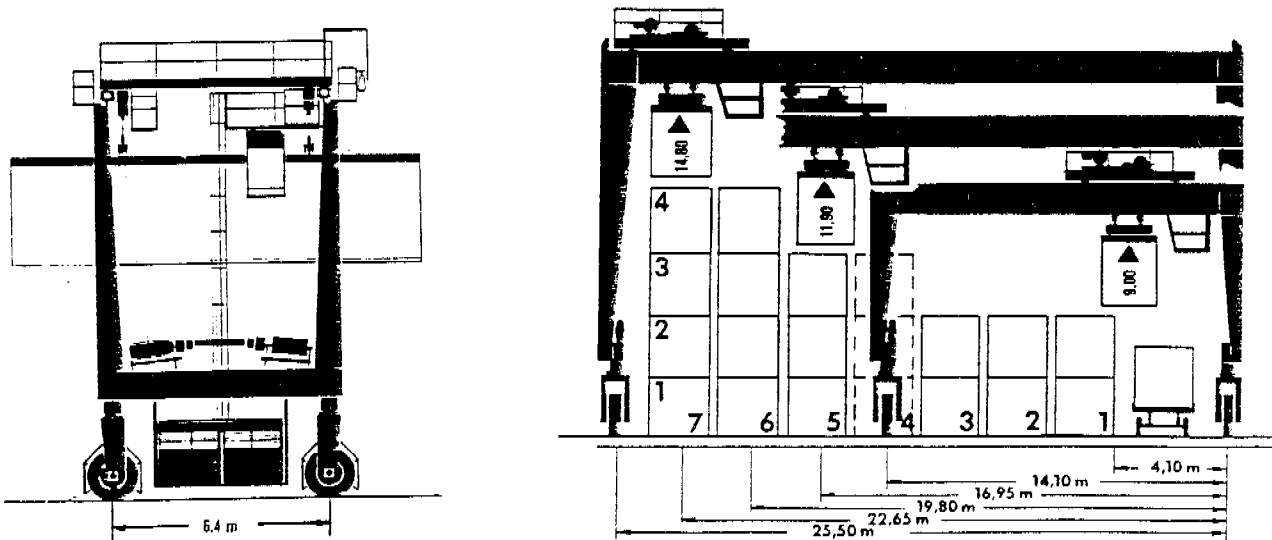
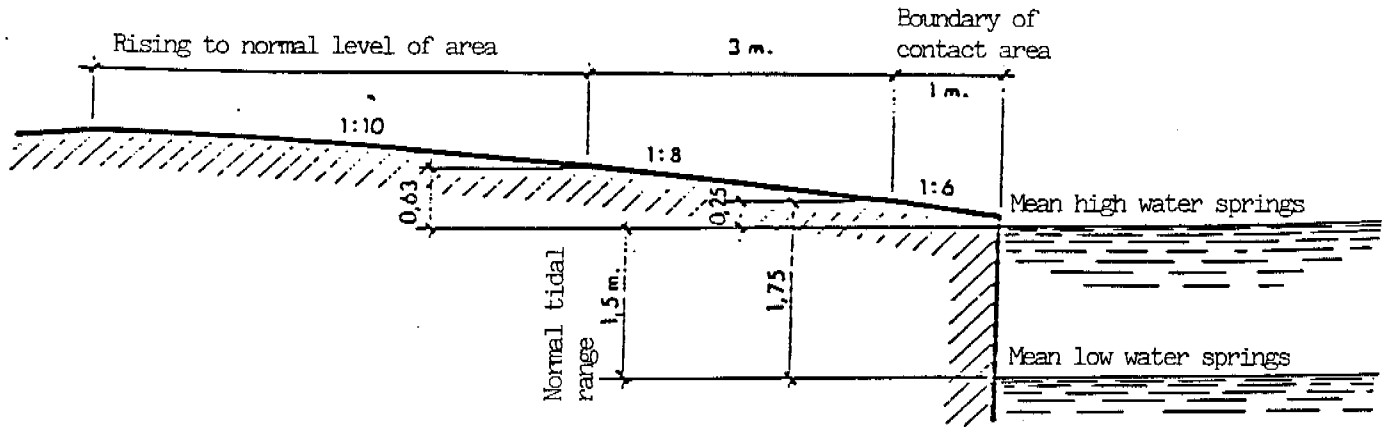


Figure 19: Rubber tired and rail mounted gantries

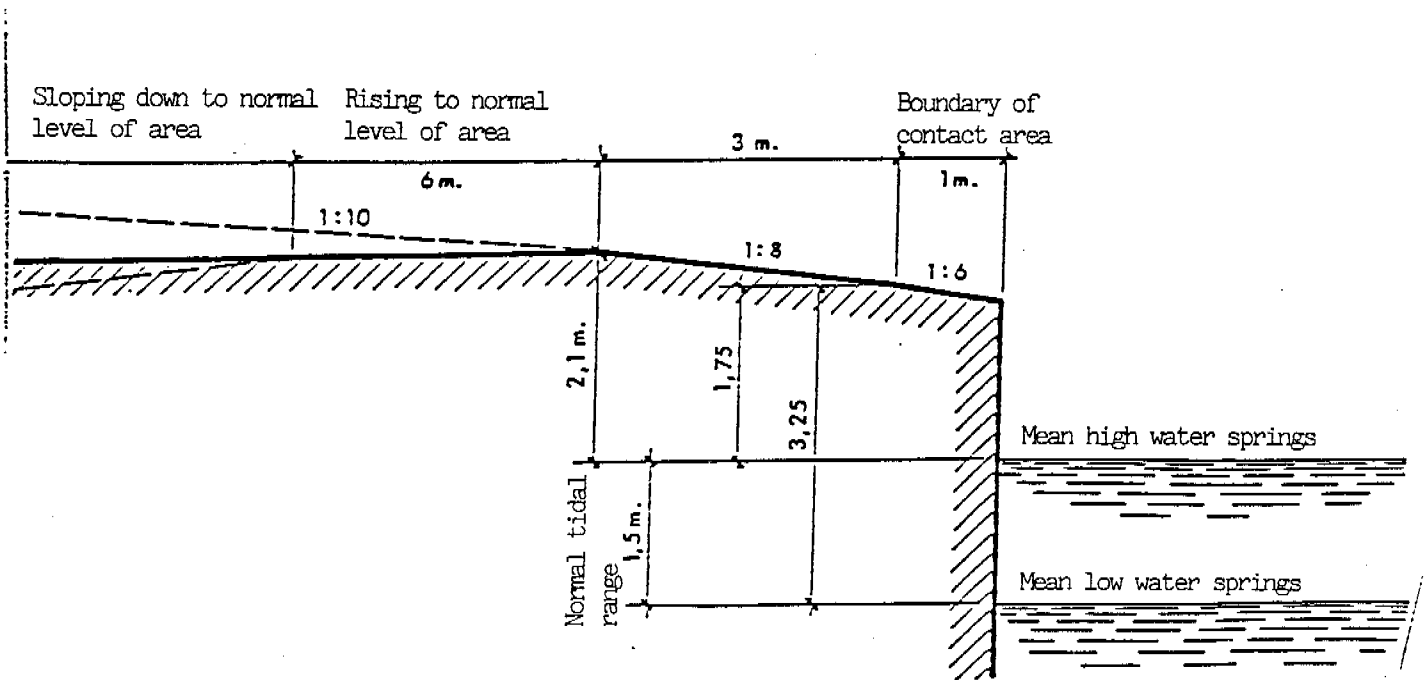
41. The ramps used for roll-on roll-off operations are of three types:

- Fixed masonry ramps, consisting of a simple masonry platform where there is no tide, or a masonry ramp of the type shown in figure 20 in tidal waters.

Figure 20: Examples of fixed ramps



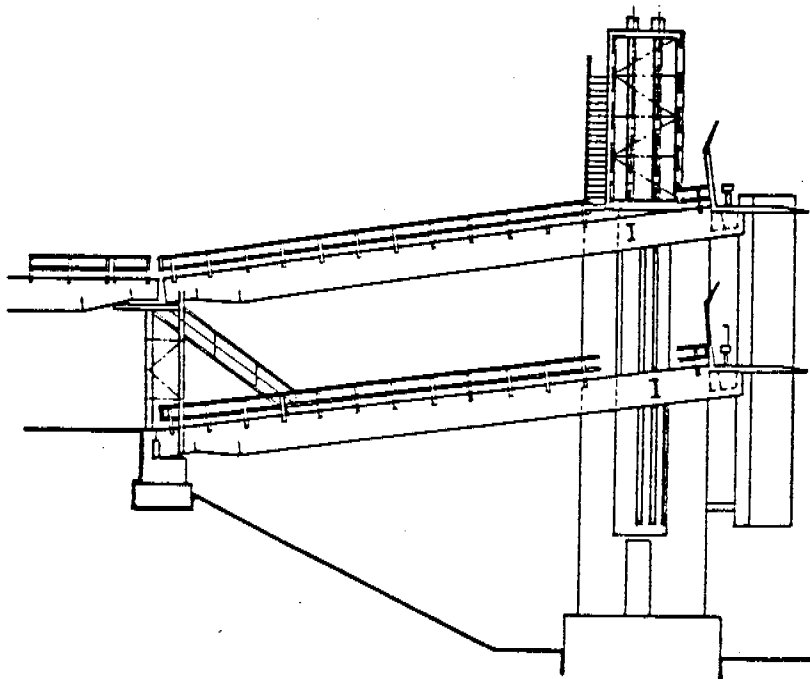
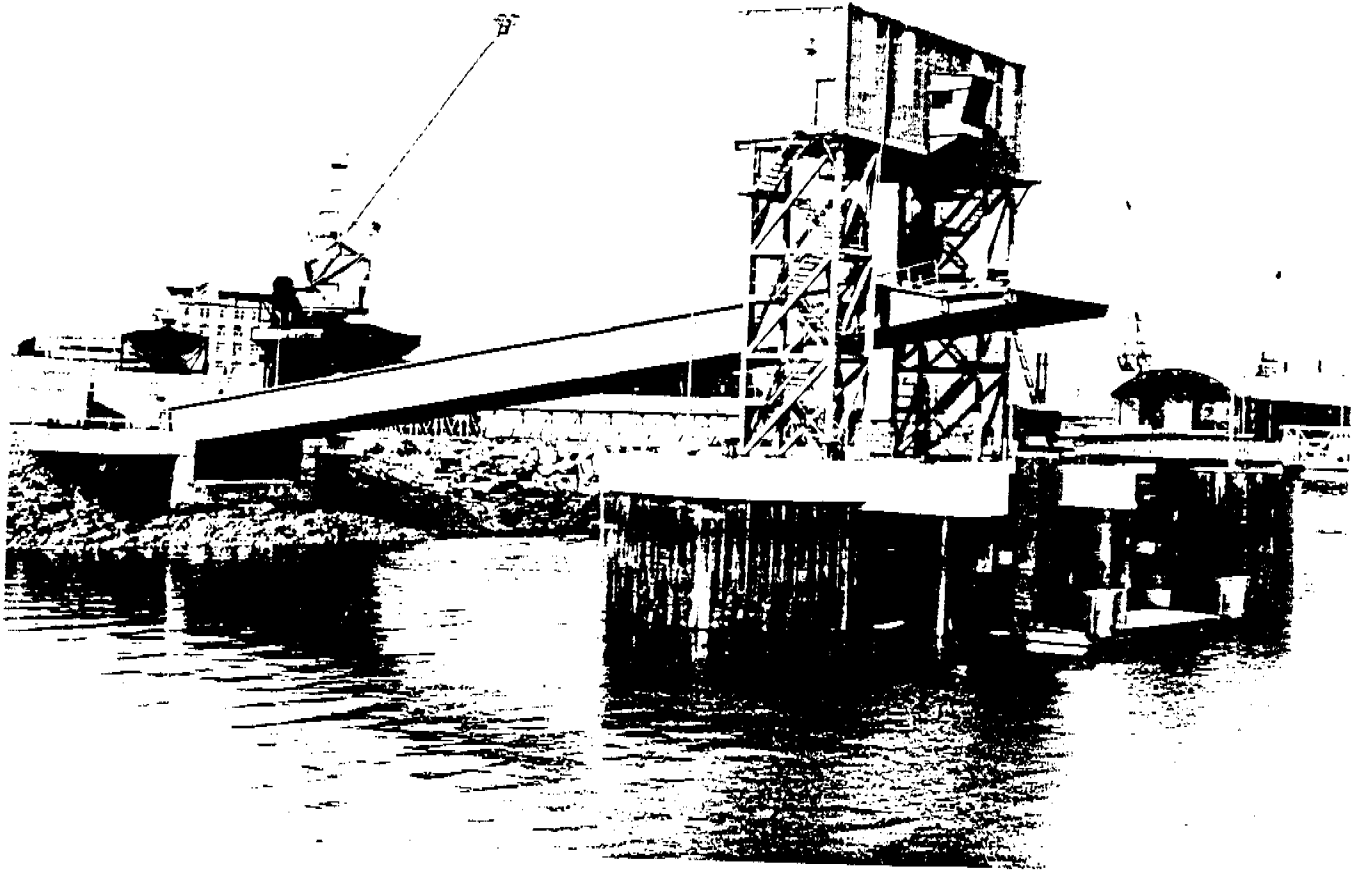
LOW FIXED RAMPS



HIGH FIXED RAMPS

- A mechanically or hydraulically operated bridge, usually metal, from the shore giving access to one (figure 21 A) or two (figure 21 B) decks of the ship.

Figures 21 A and 21 B: Ramps with bridge from shore



- Floating ramps, which are highly flexible and can accommodate different berthing requirements and states of the tide. A floating ramp should be given preference where demand is uncertain or changing rapidly and fixed infrastructures might soon prove a hindrance to development. The initial cost is higher than that of other types of ramp. (figure 22)

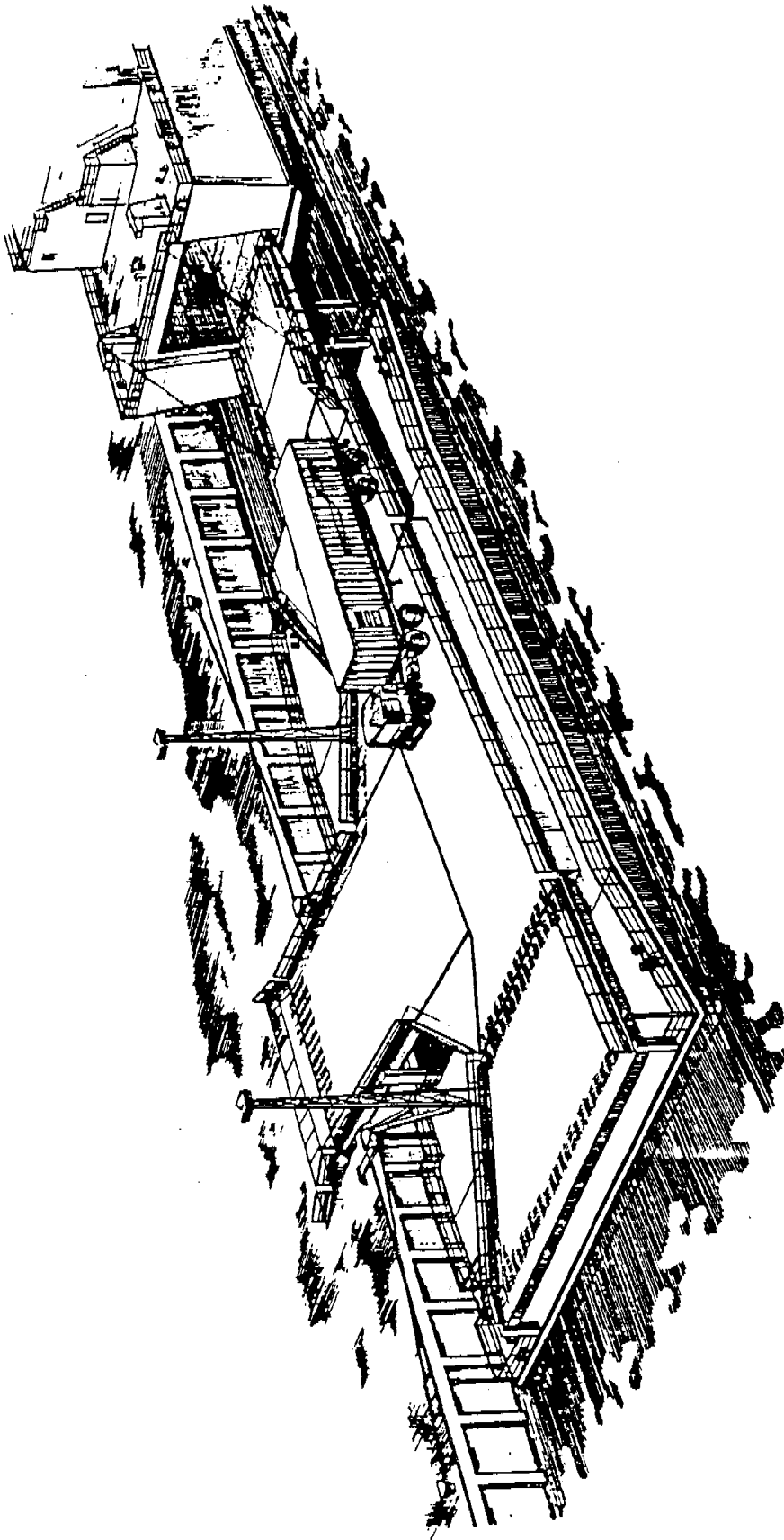


Figure 22: Floating ramp



Efforts have been made to standardize the design of roll-on roll-off ramps. In this connection the PIANC international committee report on the standardization of ro-ro vessels and berths is of particular interest. (Brussels, 1978).

#### 5. Selecting equipment

42. When the operator of a multipurpose terminal selects handling equipment, he must aim at an optimal solution combining speed of operation and economy, bearing in mind:

- The nature of the expected traffic
- The characteristics and capabilities of each machine and of the equipment as a whole
- The layout of the terminal and the expected development of its functions
- The size and phasing of the investment programme.

43. In functional terms a balance must be maintained between two conflicting concepts, specialization and flexibility, bearing in mind that:

- There is no guarantee that a more specialized machine will be more efficient given the variety of situations in which it will function
- Machines capable of performing many functions not uncommonly fail to perform any one of them well.

The listing of machinery given earlier starts with the most flexible and ends with a high degree of specialization as exemplified in such highly specialized machines as the straddle carrier or rail or rubber mounted gantry.

44. With regard to the layout of the terminal, an unduly large range of goods handled leads to the proliferation of types of machine and the expansion of their number. Throughput in the cargo handling areas is low and shortage of space necessitates high stacking calling for highly organized and complex operating methods, which encourages the purchase of highly specialized machinery.

Keeping in mind the expected development of the terminal, the ideal approach is to buy flexible machines initially and gradually to replace some of them by more specialized equipment with the goal of establishing a specific terminal with a well-chosen mix of machinery. In this context it is of the essence that in buying new machinery the possibility of development into a specialized terminal should always be borne in mind in order to ensure that future development is not shackled by equipment that to some extent dictates methods of operation.

45. The first decision that must be made concerns the capabilities of the equipment for loading and unloading cargo. From this point of view there are:

- Conventional cranes for light and moderately heavy loads

- Multipurpose cranes for containers and heavy loads
- Mobile cranes that can be used in cargo handling and storage areas as well as on the quayside.

Depending on the traffic, the number needed might be:

- For one berth
  - Two 12/20 t. cranes
  - One 30/40 t. multipurpose crane
  - One mobile crane of similar capacity
- For two berths
  - Three 12/20 t. cranes
  - Two multipurpose 30/40 t. cranes
  - One mobile crane of similar capacity.

In the latter case the possibility might be considered of replacing one multipurpose crane by a straddle carrier for containers. The crossover point is about 25,000/30,000 TEU annually and the medium-term objective is to work the specialized crane 2,000 hours a year handling about 50,000 TEU.

46. The second decision concerns the selection of equipment for cargo handling areas. The work can be divided into three phases:

- Horizontal carriage of cargo
- Storage and stacking
- Delivery to and reception from shore transport.

47. All the machinery described in paragraphs 39 and 40, except the rubber or rail mounted gantry, can be used to move cargo horizontally. As might be expected stacking cannot be performed by the simplest and least expensive machines. The most versatile are trailers of normal size. Typically one tug master and three trailers might be allotted to each crane, plus any additional equipment that might be needed for carriage between storage areas and delivery or reception.

48. In planning storage and stacking, it is important to consider the whole cycle consisting of:

- (a) movement from ship to shore
- (b) movement within the terminal
- (c) stacking in storage areas.

The object will be to optimize the equipment technically and economically and ensure a satisfactory throughput. Stacking can be undertaken by two types of machine:

- Machines that can also move loads horizontally, such as the FLT, SLT, RSC, STC and MPC.
- Machines which only stack, such as the rubber or rail mounted gantry.

Consideration must also be given to the stacking density permitted by the various machines. Figures are given below for containers (in m<sup>2</sup> per TEU):

Machine	Capacity (m <sup>2</sup> /TEU)
FLT and SLT	60
RSC	30
STC and MPC	25
Rubber or rail mounted gantry	25

It should be noted that the first three are capable of twice the movements per hour of the last.

In the case of machines combining transport and lifting, attention should be paid to their efficient use. A time and motion study could for example be undertaken to determine the economic distance through which goods should be moved. This should not in principle exceed 100/150 metres.

Other methods of moving cargo can be devised by combining machinery. One notable example is the use of trailers in conjunction with the rubber tyred gantry in container terminals. With regard to combinations suitable for multipurpose terminals:

- Trailer plus FLT is the most used initially
- Trailer plus SLT is less common
- Trailer plus RSC is gaining ground
- Trailer plus STC is the most sophisticated and expensive, and less well adapted to non-containerized cargo.

49. The machines described in paragraph 40 can be used to move goods both to storage areas and to delivery and reception. The SLT and STC are well suited to horizontal carriage. The STC is frequently employed as an all-round machine in container terminals, although the FLT, SLT and RSC are regarded as more versatile for handling non-containerized cargo. When used in combination with cranes, three machines are usually allocated to each crane.

50. The cost of this equipment is substantial. For quayside cranes the estimated cost is:

- Twelve t. crane                      \$600,000
- Sixteen/twenty t. crane              \$900,000

- Multipurpose crane           \$1.5/2 million
- Mobile crane                \$2/2.5 million
- Container gantry crane      \$3.5/4 million

The most expensive of the machines used to move cargo in cargo handling areas is the straddle carrier, which costs \$600,000. The mobile portal crane costs about 25 per cent less while the prices of the other machines are between \$300,000 and \$360,000. A tug master and three trailers could cost \$100,000.

51. It should be observed that it is not sufficient to compare the purchase price of the various machines on offer. A number of cargo handling systems should be selected and each should be subjected to cost benefit analysis taking into account operating and maintenance costs during the life of the machine as well as the purchase price. 9/

52. With regard to the phasing of investment, machines could be acquired in the order established in the study mentioned in the previous paragraph. As specialization (particularly in regard to container traffic) increases, the machines bought first will be used for marginal or ancillary functions and the ultimate equipment mix is likely to centre on the straddle carrier or the rubber or rail-mounted gantry or a combination of the two.

#### 6. Terminal yards

##### Planning and operation

53. In planning terminal yards a layout should be chosen that can be adapted at reasonable cost to the various cargo handling systems. Rectangular yards are the most convenient, the space being distributed among existing fixed structures in a way that permits use of the various cargo handling systems without reorganization of the area as a whole.

Storage areas should be planned on a generous scale and be adaptable to a variety of uses. The first, the working area next to the wharf, is basically used for the movement of vehicles and the temporary storage of goods during loading or unloading and the stowage of container ship hatch covers. The next area is for the storage of goods and must have easy access to the working area and to the delivery and reception areas. The latter must have ample parking for waiting vehicles and be equipped with signposts and signals, weighbridges, checkers' offices and workshops. Stacking areas need to be sufficiently large to accommodate the various handling systems. A distinction needs to be made between containers and other cargo.

54. Containers are normally stacked in rows or blocks, depending on the machine used and whether the containers are full or empty. Row stacking occupies more space but gives direct access to most of the containers and is therefore preferred in the case of full containers. Block stacking saves space at the expense of accessibility and is therefore used for empty containers or yards where sophisticated machinery such as rubber or rail-mounted gantries are available.

Figure 23 shows stacking arrangements for three commonly used types of machine, front lift trucks, straddle carriers and reach stacker cranes. The

diagrams show the space occupied by a 20 foot container or TEU using each of the three types of machine. The figures are indicative only and should be calculated for the whole stacking area instead of a small section of about 60m x 62m which does not include all the corridors needed. To calculate the stacking areas accurately the computation described in paragraph 28 would have to be undertaken and account taken of the annual throughput of containers, their turnaround time and stack height.

The notations used in the diagrams are as follows:

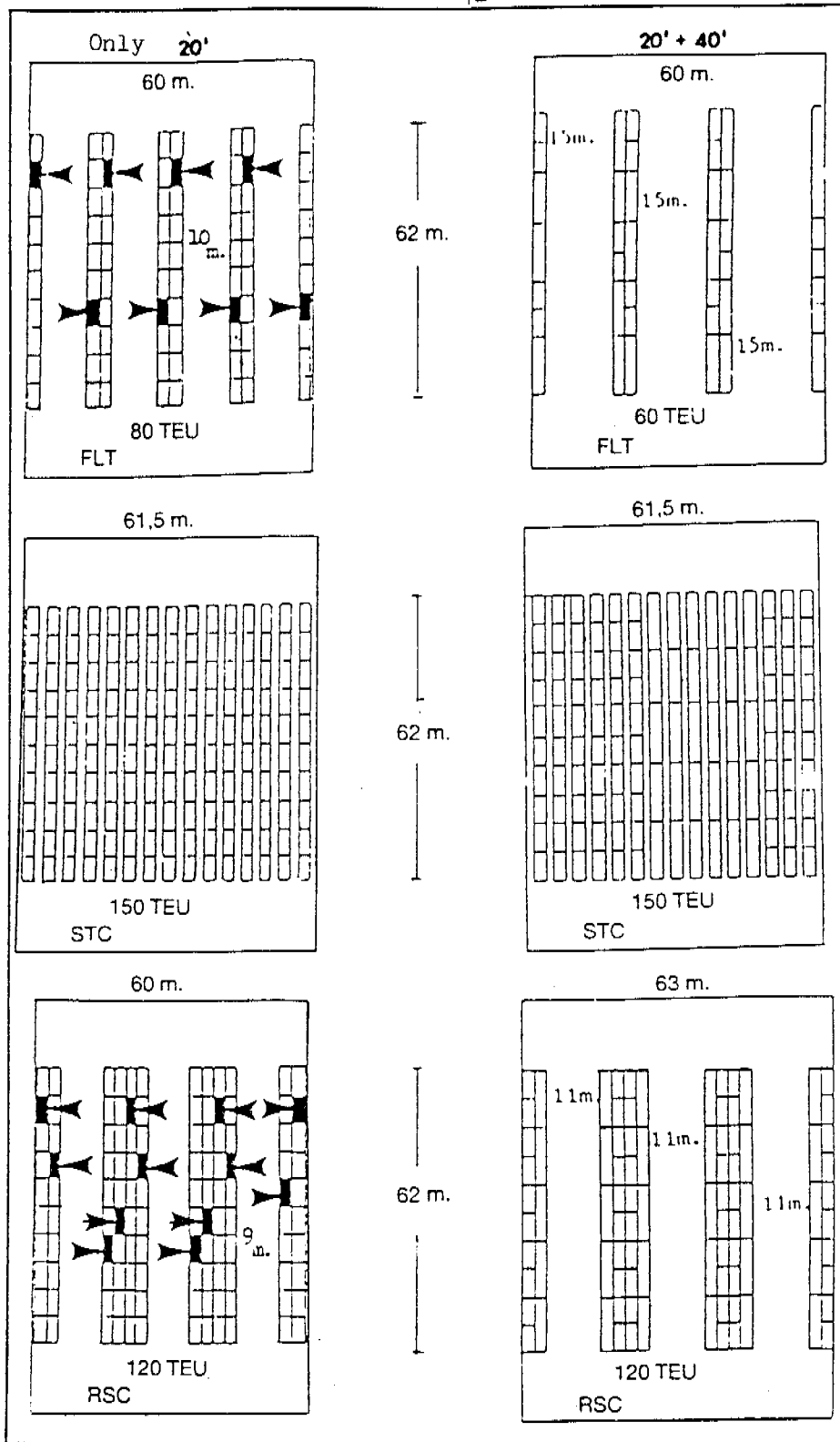
- FLT = Stacking by front lift truck
- RSC = Stacking by reach stacker crane
- STC = Stacking by straddle carrier
- Pa = Container positioning area
- Ma = Machine manoeuvring area
- Ta = Total area, the sum of the foregoing

55. For other types of cargo, bearing in mind that only a degree of dimensional homogeneity can be achieved, it is recommended that:

- In storing load vehicles, the applicable highway rules should be observed.
- Iron and steel goods should be stored in the open if they are to remain only a few days and under cover if they are to remain longer.
- In the case of other goods, it should be determined whether they can be stored in the open, under cover or in warehouses.

In calculating the area of terminal yards, stacking methods for particular goods, cargo density, stack heights and annual throughput need to be taken into account as described in paragraph 28. Examples of the densities of various cargoes are given below. 10/

Cargo	Density Cubic metre/tonne
Pig iron	0.30
Iron bars	0.40
Billets	0.30
Zinc ingots	0.40
Newsprint	2.5
Plywood	2.3
Wood sleepers	1.3
Vehicles	4.0 - 8.0
Bagged flour	1.3
Bagged cacao	1.9
Bagged rice	1.5



FLT		STC		RSC	
Ma :	45 × 62 = 2790 m <sup>2</sup>	24,0 × 62 = 1488 m <sup>2</sup>	37,5 × 62 = 2325 m <sup>2</sup>	33,0 × 62 = 2046 m <sup>2</sup>	30,0 × 62 = 1260 m <sup>2</sup>
Pa :	15 × 62 = 930 m <sup>2</sup>	37,5 × 62 = 2325 m <sup>2</sup>	61,5 × 62 = 3813 m <sup>2</sup>	30,0 × 62 = 1260 m <sup>2</sup>	63,0 × 62 = 3906 m <sup>2</sup>
Ta :	60 × 62 = 3720 m <sup>2</sup>	61,5 × 62 = 3813 m <sup>2</sup>			
	Pa/Ta = 0,25	0,62	0,48		
	Pa/Ma = 0,34	1,56	0,91		
	Ta/TEUS = 62,0 m <sup>2</sup>	25,4 m <sup>2</sup>	32,55 m <sup>2</sup>		
		TEU	TEU		TEU

Figure 23: Container stacking methods used in terminal yards

## Construction

56. The drainage system must be sufficient to prevent flooding. All services should be underground except for fire alarms, which can be incorporated in lampposts. The layout of cables and underground connections should be designed to ensure that every point in the terminal is within a stipulated distance of services. Cables should be laid in accessible ducts.

57. As the pavement will almost certainly be laid on partially compacted fill, it is recommended that the pavement specified should be capable of withstanding heavy machinery loads, except in parts of the terminal not accessible to heavy vehicles or handling equipment. In principle a range of pavements may be considered:

- Asphalt, which is easy to lay, but expensive and subject to damage by oil. It is very flexible, which is a disadvantage where loads are heavy and temperatures may be high
- Concrete slabs, which are unsuitable where the subgrade is uncompacted and settling may cause cracks
- Concrete paving blocks, which are well suited to partly compacted subgrades and easily repaired
- Gravel for areas worked by rubber or rail-mounted stacking gantries, as in a container park.

Figure 24 shows recommended types of heavy duty pavement other than gravel beds, which are omitted because of the limitations on their use in multipurpose terminals. Before a decision is taken on the selection of pavements, the available publications should be consulted. 11/

58. To operate the terminal by day and night, the lighting must meet the following requirements:

- Provide a uniform lighting level, with a uniformity factor 12/ of about 1/3
- Allow drivers and checkers to work without causing dazzling
- Use as few lampposts as possible. Posts should be high to provide ample clearance. Posts might be 20/25 to 40m high with a separation 4 times their height to ensure uniform illumination and easy maintenance.

59. The following are recommended lighting levels:

Terminal yards    80-100 lux  
Checking areas    50/60 lux  
Other areas and areas not in operation 5 lux.

The following should also be ensured:

- Illumination at ground level should be at least 25 lux
- The edge of the wharf should have a lighting level of at least 10 lux to assist vessels entering or leaving berths at night
- Ro-ro ramps need 100 lux in places where traffic is heavy
- The average level should be 50 lux where required to ensure the safety of workers or cargo.

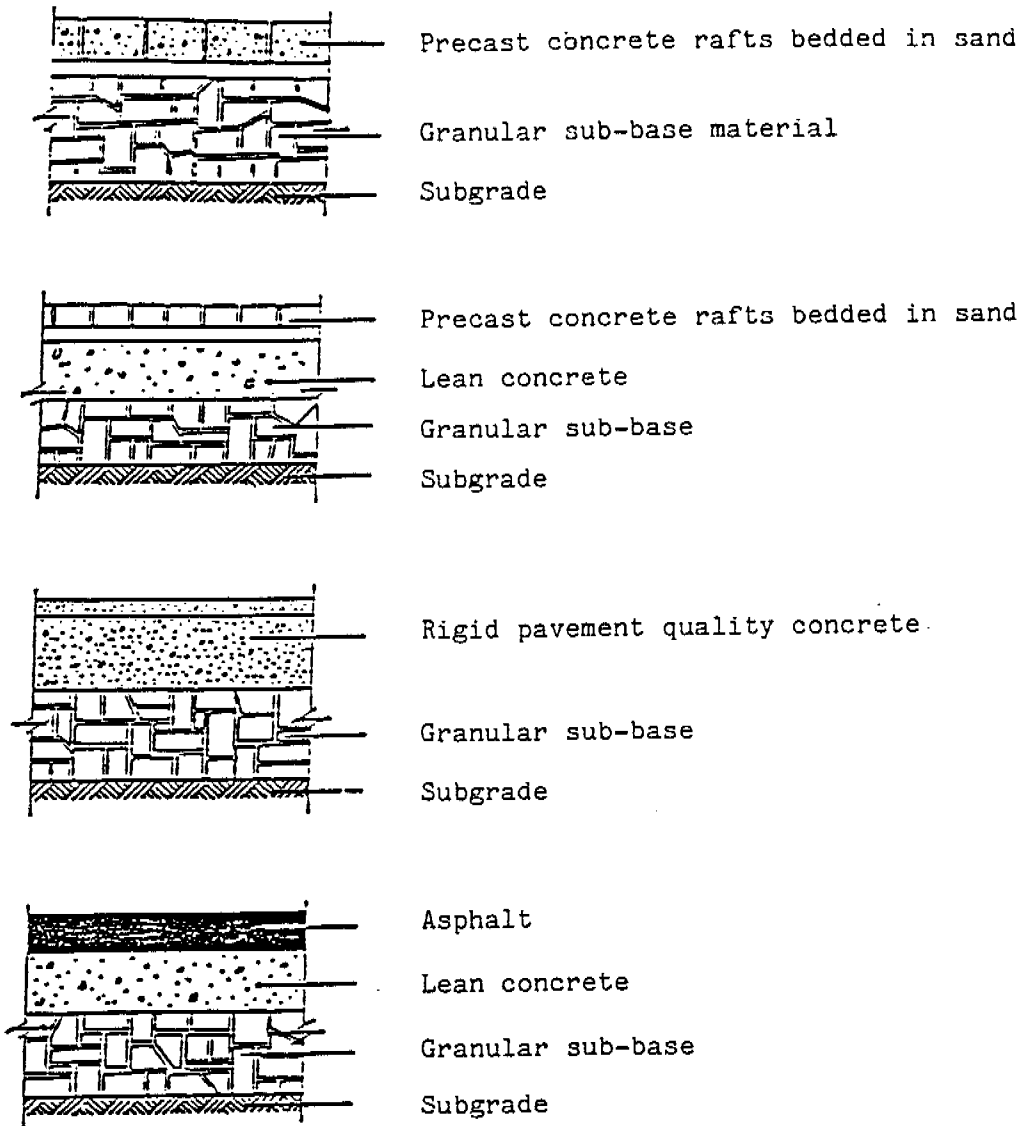


Figure 24: Pavements for terminal yards 13/



7. Covered storage

60. As was indicated in chapter III, section 3 on zoning, planning is based on two principles:

- Less space is allotted to covered than to open storage.
- Sheds are sited far enough from the wharf operating area so as not to obstruct movement.

Other requirements include:

- The shed floor must be level with the yard surface.
- The floor should be free of obstacles in so far as this is possible at a reasonable cost per square metre of covered space. If columns are needed, two rows equidistant from the centre line are preferable to a single row in the centre.
- Doors 7 m high and 9 m wide should be provided at 20/25 m intervals on all sides.
- The overhead clearance should be at least 7 m.
- The lighting level should be not less than 200 lux and at least 10/12 per cent of the roof should be used for skylights.
- Metal guards should be installed to protect walls and columns.
- Sheds should be equipped with fire extinguishers, hydrants, and an alarm system. Provision may also be made for fire screens and a clear space 0.6 m wide should be provided round the perimeter.

61. In the case of sheds used to unload and load containers, the entrance should be wide enough to admit a front lift truck to deliver 40 foot containers (minimum width 12.5 m). Overhead cranes must also be provided. If offices and workshops are attached to sheds, it should be ensured that they do not obstruct cargo handling. For further details concerning the design of sheds and recommendations for their management, Steps to effective shed management should be consulted. 14/

8. Access to the terminal

62. To ensure a smooth traffic flow and satisfactory throughput, the following should be borne in mind:

- A traffic survey should be made to determine the space needed for lorries at busy periods.
- A platform of suitable height should be provided for the inspection of loads.
- Space for administrative and related functions should be provided near the terminal entrance and exit.

- Fuel pumps should be provided near the vehicle repair and maintenance workshops.
- Weighing facilities should be provided at a convenient site.

9. Other installations

63. The following, among others, are recommended:

- The provision of drinking water and water for washing, with a minimum pressure of 2.5 kg/cm and a minimum flow of 50 l/sec. If the water is also to be used for fire fighting, the pressure must be increased to 7 kg/cm and the flow to 80 l/sec and hydrants of suitable height installed at intervals of not more than 100 m.
- The installation of fire alarms, with at least a manually operated system connected to the terminal control centre and automatic sound and visual signalling.
- Intercommunication system linking the operating areas, entrances and exits, and the control centre.
- Power outlets for refrigerated containers should be provided above ground and protected from damage. A range of voltages should be supplied.

#### IV. RECOMMENDATIONS FOR MANAGEMENT

##### 1. Flexibility and the multipurpose approach

64. Although the emphasis on these qualities might seem redundant given the essential purpose of a multipurpose terminal, it is necessary to consider them with a view to overdimensioning the terminal qualitatively in order to ensure:

- The long-term retention of the terminal's multipurpose character.
- Attention to future changes in demand which may bring in their train substantial modifications.

The object must be to embody both characteristics in the physical structure of the terminal and its operation.

65. To avoid the inherent rigidity of quays, two of their main characteristics must be given a measure of flexibility.

- Increasing the depth of water at quays is a major obstacle to the conversion of a conventional terminal into a multipurpose terminal. The depth of water at planned quays should therefore be overdimensioned by at least 1 m or designed in such a way as to permit future dredging without loss of stability. In this context massive wharves made of masonry blocks and the like are a source of difficulty if provision has not been made in advance.
- Crane loads may be substantially altered if conventional cranes weighing 200 t are replaced by container cranes (400 t and up). This must be borne in mind if wheel loads are imposed on the wharf or a separate foundation has to be built for the track on the shore side.

66. The width of cargo handling areas may prove a bottleneck when a multipurpose terminal is converted to a container terminal. If overdimensioning is impossible, machinery and organization will have to be changed, thus providing a more complex remedy to the lack of space.

67. Changes in ro-ro ship technology with the introduction of long beam ramps (50 m) make the ships independent of special port installations. The area adjacent to the berth must be free of obstacles, with bollards wider apart or housed in recesses below the level of the quayside.

68. The changes attendant on conversion to a specialized terminal customarily greatly affect ancillary services (electricity supply, and water and communications). If the wharf is topped with a deep concrete pavement, accessible tubes must be provided. Alternatively the pavement could be constructed with a filled cavity at least 1/1.5 m wide through which cables and pipes could be laid.

69. With regard to operations, the following recommendations should be kept in mind:

- Installations should be conceived in terms of intensive utilization, which maximizes throughput.
- In consequence equipment must receive sound preventive maintenance. 15/
- Management must be able to obtain traffic figures in time to plan operations.
- In order to optimize efficiency, operations and throughput must be kept under unified control.
- The terminal must be separate from near-by terminals but not cut off from them, so that equipment can be interchanged if necessary.
- The co-operation of users, if possible grouped in an association, is an essential aid to effective operation. Industrial relations with the labour force and fair and objective setting of wages and working conditions are essential.
- The terminal should be run under a system of unified control in accordance with entrepreneurial management principles.

## 2. Safety

70. Safety in a multipurpose terminal can be considered from a threefold point of view:

- The operational safety of ships, infrastructures and installations and the prevention of accidents, collisions and sabotage.
- The safety of staff working on ships and on shore.
- The safety of goods and prevention of pilferage and damage due to improper handling or stowage, with particular attention to the problem of dangerous goods.

71. With regard to the first point, there is nothing specific to add that is not applicable to safety measures at all docks. It should however be pointed out that modern container ships with their projecting prows are involved in many collisions causing damage to quayside cargo handling equipment. It is therefore advisable to site the ship side track at least three metres from the edge of the wharf and to move cranes to a place of safety when container ships are entering or leaving berths. Attention should also be paid to the effects of collisions between the bulbous prow and easily damaged structures such as piles.

72. Similarly, workers' safety does not raise problems peculiar to multipurpose terminals. In view of the variety of loads handled, legislation should be brought up to date in accordance with the provisions of the most recent ILO Convention. 16/ Strict precautions should be taken in view of the exceedingly wide variety of goods handled. This calls for special emphasis on training.

73. Attention should be drawn to a number of precautions that need to be taken with regard to containerized and non-containerized dangerous goods. Apart from compliance with the regulations in force, the following should be borne in mind:

- The reception and handling of dangerous goods should be the direct responsibility of a designated person and the latter should be clearly identified.
- A regularly updated record should be kept of all dangerous goods in the terminal, particularly those in containers.
- Dangerous goods should not be received or handled unless they are properly identified in accordance with the regulations.
- Dangerous goods should be carefully stowed in appropriate locations in compliance with the commercial and safety requirements applicable to their stacking.
- The storage area for dangerous goods should be clearly signposted.
- Precautions should be taken to prevent fire, explosions or spillage caused by the goods or their stacking or by activities in the area.
- Dangerous goods placed in containers must be stowed in accordance with special rules. Where less than complete loads are accepted, the goods accepted must not be incompatible. Liquids or heavy goods must not be stowed on top and the cargo must be secured to prevent movement within the container.
- When dangerous goods, whether containerized or not, are unloaded and stored in the terminal, they should be properly segregated.

Dangerous goods must be handled in conformity with the International Maritime Code on Dangerous Goods. 17/

74. In view of the risks incurred in handling dangerous goods, the risks should be analysed and suitable coverage should be arranged having regard to the large sums that may be payable as compensation for loss or damage. 18/

### 3. Remodelling of existing infrastructures

75. One key factor in decisions to develop a multipurpose terminal is the possibility of using some of the existing infrastructure for the purpose. The goal is to establish an efficient multipurpose terminal with as little capital expenditure as possible on infrastructure. This is important because if a new terminal is built from the ground up without regard to the possibility of using existing facilities the infrastructure cost may be unduly high and cripple the economic operation of the new venture.

76. Remodelling will normally involve three important features of the existing installations:

- The depth of water alongside the wharf.
- The area of the terminal yard.
- Load bearing capacity.

It is assumed that there is no barrier to extending the berthing area if necessary.

77. With regard to the depth of water, it is, of course, assumed that any problems affecting the accommodation of larger vessels in the port, including entry and space for manoeuvring, have been solved. Increasing the depth of water at an existing quay, if provision was not made for doing so earlier (see para. 65), is often a major challenge to the engineer in charge.

In the first place it is necessary to reconcile two conflicting objectives, increasing the area of the wharf, which is normally limited, and not encroaching on the basin in order to allow space for bigger ships to dock. Coupled with the usual requirement that there should not be major interference with the day to day working of the port, this dilemma greatly increases the complexity of this phase of remodelling.

The engineer must also grapple with the problem that the existing infrastructures are often more or less obsolescent and that their stability may be impaired during construction. At the same time the internal layout of the port must not be altered by remodelling in a way that will produce residual reflection or resonance effects of long period waves or swell, or accentuate existing effects.

In practice there are two ways of tackling the problem:

(1) By dredging to the required depth from the bottom of the quay and correcting the resulting instability by such procedures as:

- Consolidating the ground by injections or otherwise.
- Anchoring the existing infrastructure.
- Building pile screens or the like to strengthen the footing.
- Building buttresses.
- Stitching with micropiles. 19/

(2) Obtaining the desired depth at the required distance by means of a new structure that may be based on the old structure if the latter is reinforced (anchoring, micropiles) so as not to impair the stability of the footing of the old infrastructure.

Figures 25 and 26 illustrate some significant examples of procedures of this kind recently applied in Spanish ports. There are, of course, no general rules. Each situation has to be considered separately with a view to devising an appropriate solution.

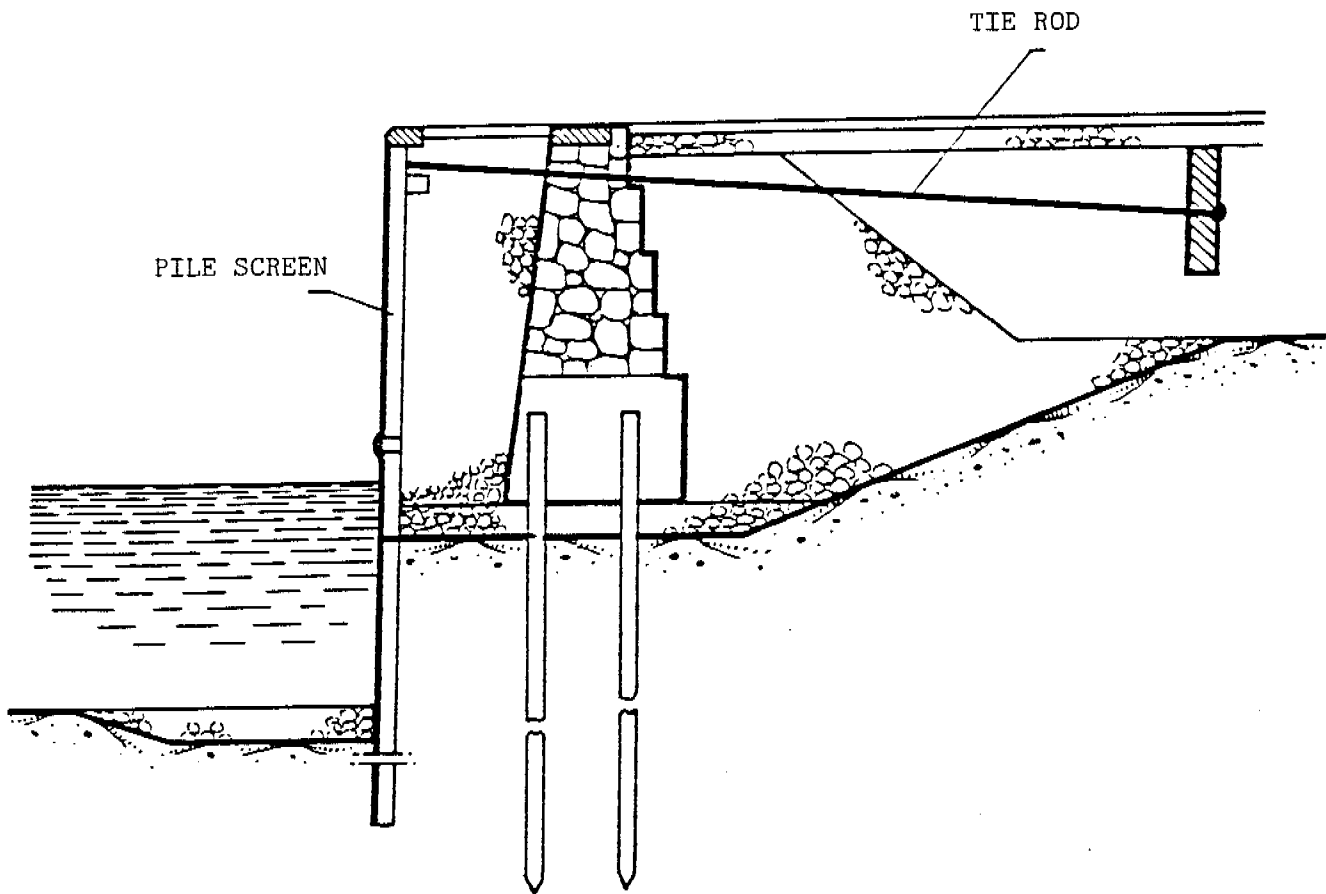


Figure 25: Increasing the depth of water at a wharf as described in paragraph 77 (1)

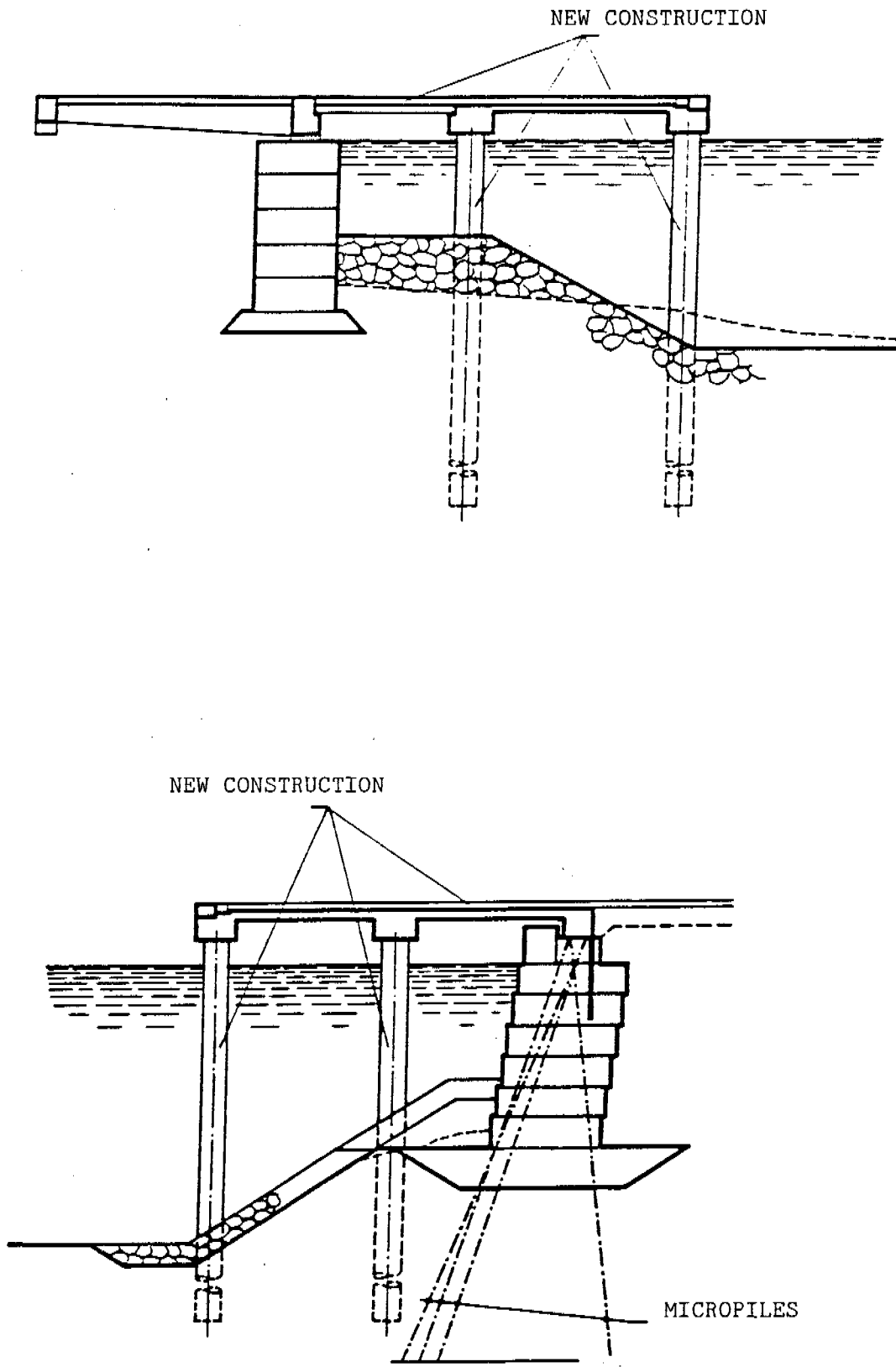


Figure 26: Increasing the depth of water at a wharf as described in paragraph 77 (2)



78. There are two ways of expanding the land area and obtaining more space for cargo handling:

- The addition, where feasible, of an area adjoining the existing area or sufficiently near not to inflate the cost of cargo movement.
- Clearing the present space by removing sheds, warehouses and obsolete buildings, taking up unneeded railway tracks, rearranging storage areas and improving the traffic flow.

In this connection stress should again be laid on the need to balance and properly co-ordinate the three parameters basic to the efficiency of the terminal.

- The area available.
- The quality of handling equipment and the inventory available.
- The organization and management of operations.

79. As regards the new loads that will be imposed on the old infrastructure when the multipurpose terminal is in operation, three problems should be underlined:

(1) There are two ways of coping with the new wheel loads imposed by multipurpose or container cranes:

- If the solution opted for is that described in paragraph 77(1), the seaward track might be carried by the present quay strengthened with new piles (in the case of a quay built with piles) or stitched with micropiles. The shoreside track could be carried on a new foundation (floating girder or piles) on the fill.
- If the solution opted for is that described in paragraph 77(2), there are two possibilities: either the new structure is wide enough to carry both tracks, or the shoreside track can be carried by the old infrastructure strengthened by means of new piles or stitched with micropiles.

Whatever the solution selected, it must be studied in conjunction with the method chosen to increase the water depth alongside the quay.

(2) The load-carrying capacity of many pile-supported wooden wharves is small and the planner should not risk overloading them.

There is no easy solution. Although more piles can be used in some cases, strengthening the platform poses more difficulties. It can be replaced by a new one, the old one being removed or left in position with no load carrying function under the new one, thus raising the level of the jetty.

(3) In most cases the pavement of a conventional terminal is not capable of carrying the new loads imposed in a multipurpose terminal. This situation can be remedied fairly easily, subject of course to the availability of funds. One of the solutions outlined in paragraph 57 could be adopted.

## V. THE MULTIPURPOSE TERMINAL OF THE PORT OF VALENCIA (SPAIN)

### 1. Introduction

80. Improving the efficiency of its installations by distributing traffic rationally between the various port units is a standing objective of the Valencia Port Authority. The Authority seeks to ensure that ships and cargoes with similar requirements can be handled appropriately at the lowest possible cost/service ratio. In the early 1980s the principal development was the entry into service of a quay for bulk cargoes and a container terminal. The second stage was concerned with general cargo. It should be noted that loading and unloading are undertaken by stevedore companies whose operations in the case of general cargo cover the whole range of procedures, both lift-off lift-on and roll-off roll-on operations involving containers, palletized cargo and non-unitized consignments. In the interest of rationality in the management of port operations one zone of operations is allotted to each cargo handling company. This concentration permits more efficient use of equipment and cargo handling areas and better supervision of operations. It embodies the principle of unified management.

Within this context the Authority decided to open a general cargo terminal managed by a single port operator.

### 2. The size of the terminal

81. The new terminal was intended to be capable of carrying out any type of general cargo loading and unloading operation covering the following:

- Modes of transport
  - pure container ships
  - mixed container ships
  - conventional cargo vessels
- Means of transport
  - containers
  - pallets
  - non-unitized cargo

The facility is thus a multipurpose terminal which does not handle bulk cargo because it is considered that bulk cargo operations interfere with general cargo handling and should therefore be undertaken at specialized quays.

The volume of traffic to be handled was determined on the basis of current traffic in the port and expected growth. Another factor was the potential for development of a first-rate stevedoring company in the port generally capable of operating the terminal. The size was set at 750,000 tonnes, 40 per cent in the form of lift-on lift-off containers, 25 per cent ro-ro traffic and 35 per cent general cargo. The breakdown is not the same as that for the port as a whole, in which container traffic accounts for 66 per cent because of the concentration of traffic at the container terminal with its specialized handling equipment. The design of the new terminal allows for changes in these proportions to accommodate changes in the trades using the port over time.

With regard to ship sizes, it was decided that the terminal would handle only second generation container ships on the ground that larger vessels would in preference use the container terminal.

In the light of these assumptions and experience in regard to operating ratios, it was established that the terminal should comprise:

- A quay with 2/3 berths, depending on the size of the vessel, one of the berths being for ro-ro vessels.
- Depth of water alongside quay: 12.00 m at equinoctial low water springs (astronomical tide is virtually unknown)
- Total area: 10 hectares.

### 3. Design of the terminal

82. The location of the terminal is shown in figure 27. The site was chosen to meet space requirements and provide a ramp for ro-ro operations. The depth of water at the quay, 9.0 m, was insufficient and remodelling was necessary to obtain 12 m.

The layout of the terminal is shown in figure 28. Its most important features are:

#### (1) Quay

The length of the quay is 430 m, the depth of water being 12 m. At one end a ro-ro berth is provided with a 25 m wide fixed ramp. Because of the terminal's location an adjoining berth 110 m long and a water depth of 8 m can also be used for ro-ro traffic, although not exclusively.

#### (2) Equipment

The quay is equipped with four conventional gantry cranes for loading and unloading.

- Two 12 t cranes with 25 m reach.
- Two 16/30 t cranes with 35/22 reach.

The latter two cranes are identical with the port's 16 t bulk cargo cranes but are equipped to lift 30 t with a safety device to limit the reach when lifting these loads.

#### (3) Area

The total area is 110,000 m<sup>2</sup>, contained in a rectangle 510 m long and 220 m wide. The size is believed to be near the economic limit for operations using conventional equipment.

The goods storage area, after deduction of the wharf area and space for roads is 81,500 m<sup>2</sup>, including a 6,000 m<sup>2</sup> shed for non-unitized or palletized general cargo. In siting the shed the following factors were taken into account:

- The distance from the edge of the quay is sufficiently short for the loading and unloading of non-unitized or palletized cargo and sufficiently long to provide an ample handling area.
- The site can serve two berths with minimum loading and unloading costs. Its slightly off-centre position towards the ro-ro berth provides a large open storage area for containers at one end of the terminal and the space needed for platforms for ro-ro operations at the other. The terminal's concrete pavement is designed to withstand the maximum loads imposed by front lift trucks carrying containers.

#### (4) Shore communications

The terminal has a single gate for lorries with a checkpoint covering arrivals and departures. It also has two emergency gates.

The terminal has two railway tracks, one near the quay permitting direct wagon to ship operation and one inside the terminal for wagon to storage operations.

#### 4. Remodelling the quay

83. The old gravity quay consisted of concrete blocks with a riprap foundation (figure 29). Dredging to provide a water depth of over 9 m would undermine the quay and bring about its collapse.

The first schemes explored to obtain greater water depth were designed to retain the existing alignment. Two solutions were considered. One relied on the construction of a pile screen to fix the riprap foundation. The second proposed to provide a foundation by means of micropiles drilled through the concrete blocks. Both schemes were abandoned because of the technical difficulty of drilling through the riprap foundation which would greatly increase costs and slow up the work.

The only remaining possibility was to move the edge of the quay further out. Various alternatives were considered and for reasons of economy and considerations of time the solution illustrated in figure 29 based on pillars built of concrete blocks joined by prestressed beams forming the edge of the quay was selected. A reinforced concrete platform stressed to withstand the existing workloads was built on the pillars and the old quay (through a supporting concrete block). To deal with the horizontal seaward forces ties were run from the land and attached to the heads of the pillars, two ties being used in the case of pillars carrying bollards and a single tie in other cases. Horizontal berthing forces were transmitted through the platform to the rear concrete support.

84. A general view of the terminal in operation is given in figure 30.

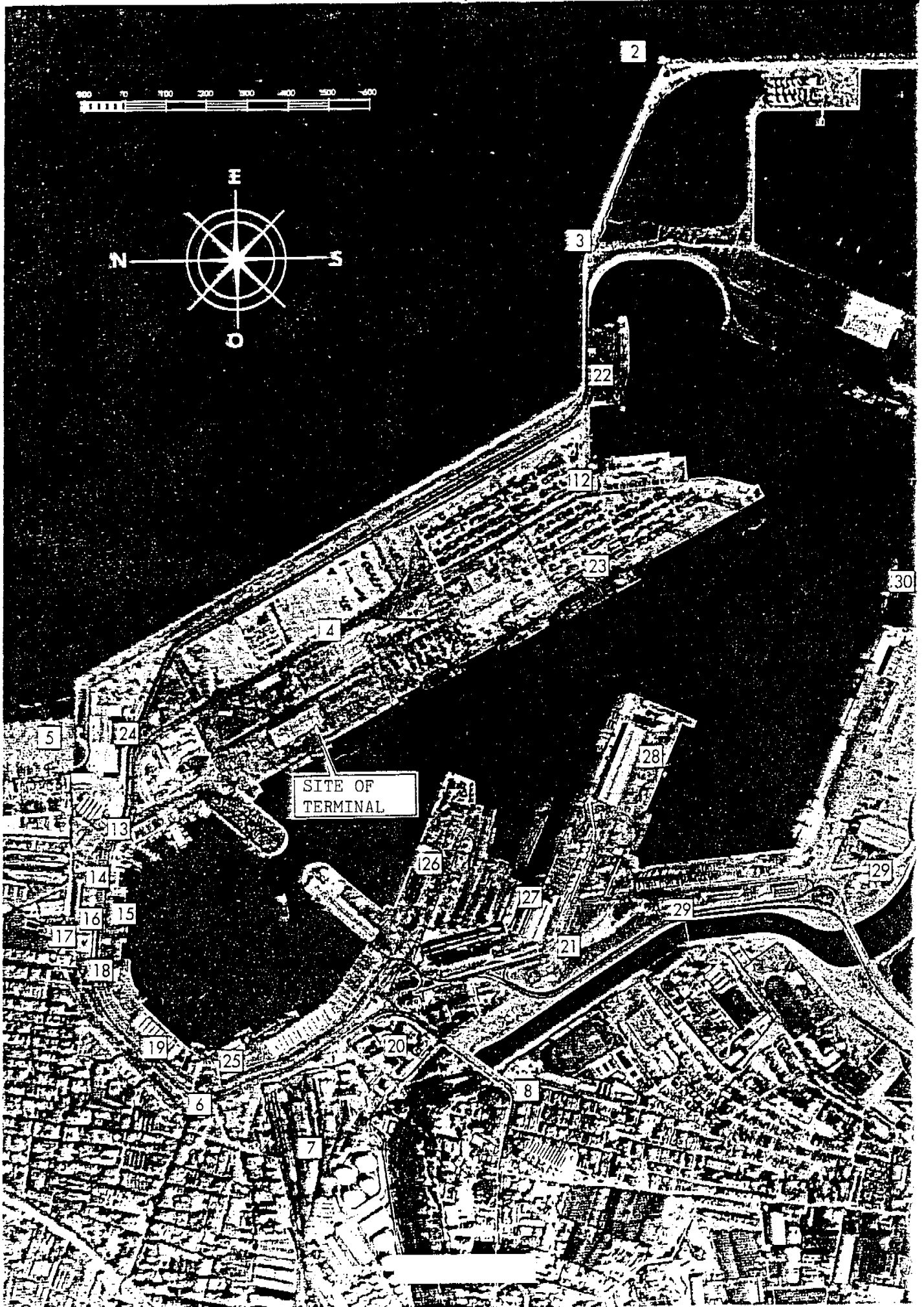
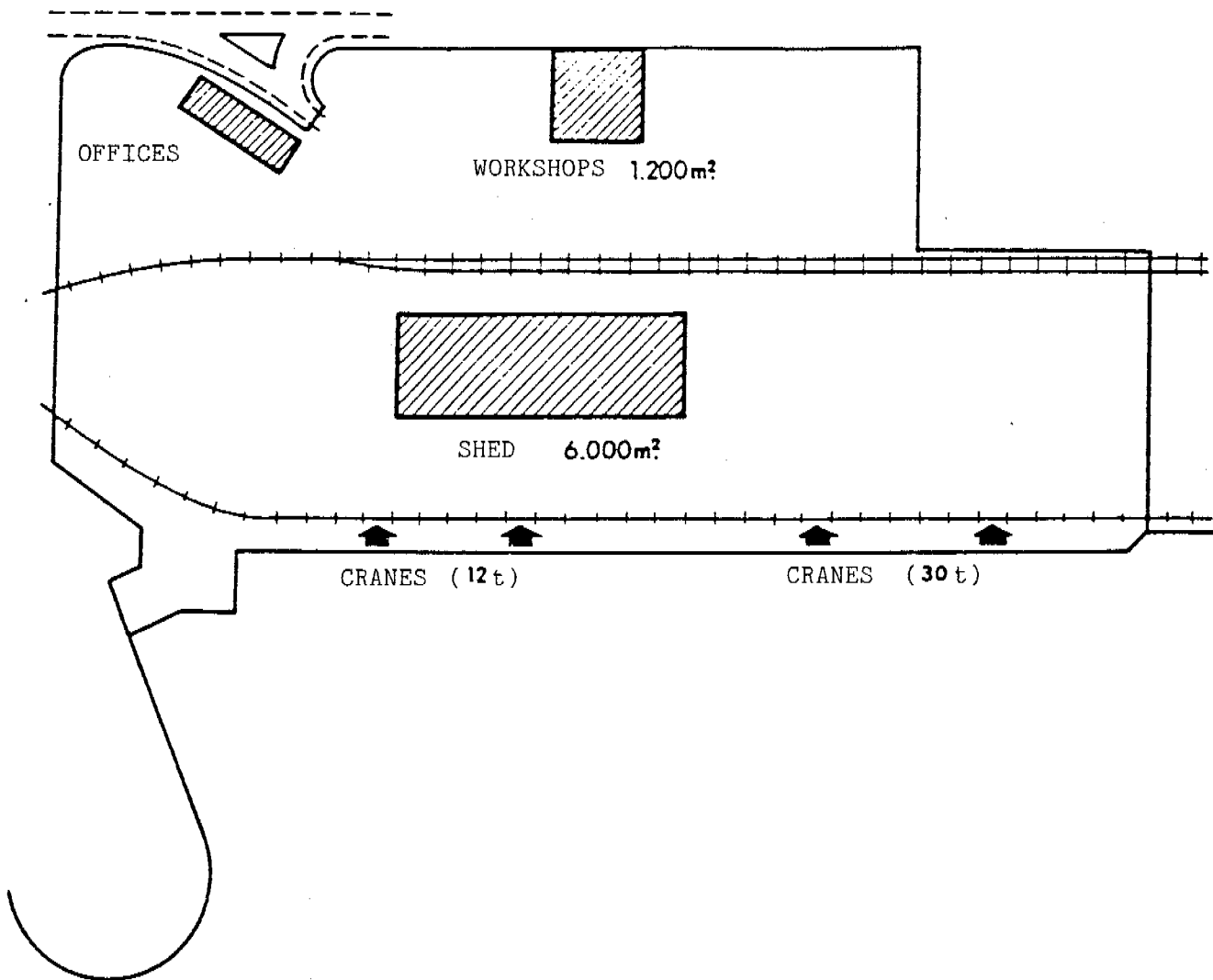


Figure 27: Location of the terminal in the port



AREA: 110,000 m  
QUAY LENGTH: 430 m  
DEPTH OF WATER: 12 m  
RO-RO BERTH  
SHED 6,000 m  
REPAIR SHOP  
CONTAINERS: 1,200 m  
REFRIGERATED CONTAINER AREA  
IMCO GOODS AREA  
TWO 12 TON CRANES  
TWO 30 TON CRANES  
LIFT TRUCKS 30, 12 AND 5 TONS

BULK, CONVENTIONAL AND CONTAINER  
CARGO HANDLING

GUARANTEED ROUND THE CLOCK  
SECURITY GUARD

Figure 28: Features of the terminal

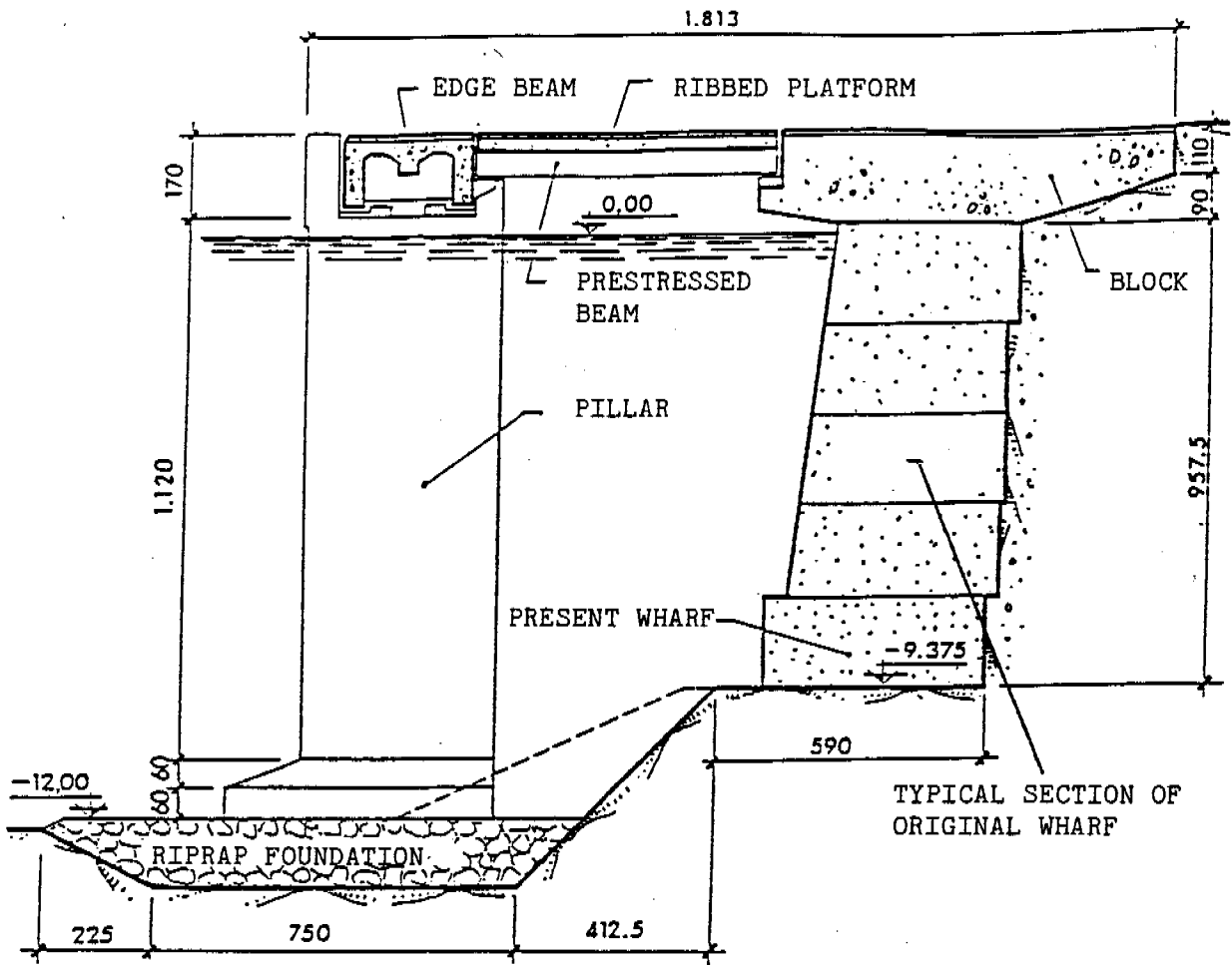


Figure 29: Remodelling of wharf

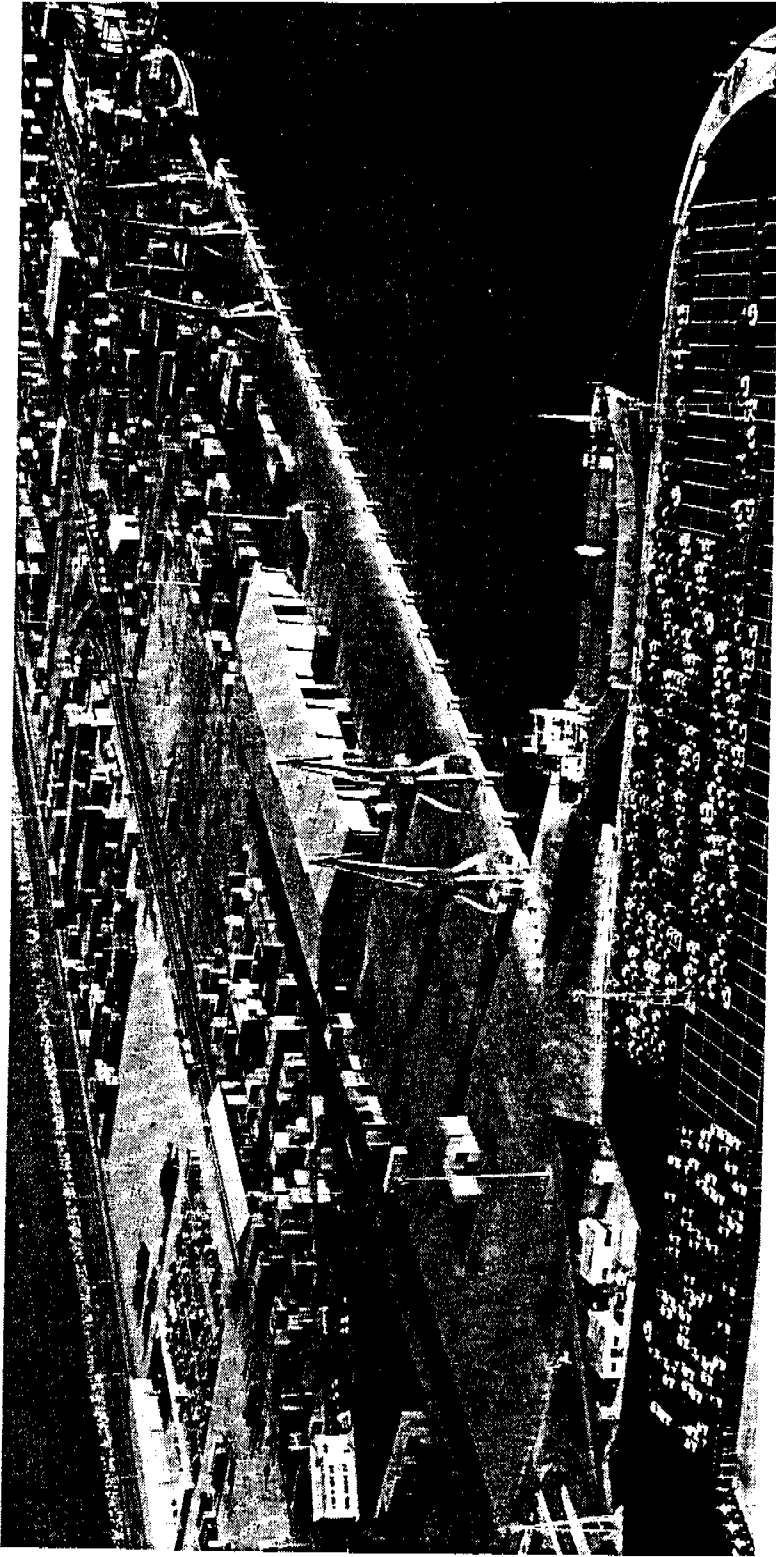


Figure 30: General view of the terminal



Notes

1/ See for example Manual on port management, pp. 205-228 (UNCTAD/SHIP/188 (part III) 1979) and Port operation, part two, chapter IV (UNCTAD TD/B/C.4/175 Rev. 1, 1985).

2/ Intermodal transport is the transport of goods by several modes of transport from one port or point of origin via one or more interface points to a final port or point where one of the carriers organizes the whole transport. This definition is taken from UNCTAD TD/B/C.4/315 (part III), 10 November 1989.

3/ Permanent International Association of Navigation Congresses.

4/ The capacity of a road with or without congestion is analogous to the capacity of a berth. A berth where congestion is not accepted will have a lower rate of utilization and will service fewer vessels than a berth where congestion is accepted.

5/ The Paris-based International Railway Union (IRU), of which all railway administrations are members, publishes a table of nominal capacities of lines. If there are critical sectors (bottle-necks) the nominal capacity is reduced to that of the critical sector.

6/ See Port Development. A Handbook for planners in developing countries. (UNCTAD TD/B/C.4/175/Rev.1, New York, 1985). Charts for general cargo and containers are given in part two, chapters 2 and 3.

7/ Operating and Maintenance Features of Container Handling Systems, which includes a 90-page handbook and a two and a half-hour video cassette. Available in English. The Fundación Argentina de Estudios Marítimos has prepared a Spanish version.

8/ Reproduced from UNCTAD seminar on improving port performance. Management of general cargo operations (IPP-1). Handbook for participants, chapter 4, p. 35.

9/ For a comprehensive discussion, see Port Equipment: policy, management and maintenance, chapter 2, Planning the port inventory (UNCTAD/SHIP/631, New York 1990, and World Bank publication INU 57, The management of port equipment maintenance.

10/ Taken from table 1, pages 217-223, Port Operation, Handbook for planners in developing countries (UNCTAD TD/B/C.4/175/Rev.1, New York, 1985).

11/ For a general introduction see Monograph No. 5 Container terminal pavement management (UNCTAD/SHIP/494(5), New York, 1987) and the supplement (UNCTAD/SHIP/494(5)/Supp.1, New York 1990. For more detailed standards see The structural design of heavy duty pavements for ports and other industries, British Ports Federation, London, 1989.

12/ This is the relation between minimum intensity, 1, and average intensity, 3.

13/ Taken from UNCTAD monograph No. 5, Container terminal pavement management. (UNCTAD/SHIP/494(5), New York, 1987)

14/ UNCTAD/SHIP/494(7), New York 1987.

15/ With regard to preventive maintenance see Port equipment: policy, management and maintenance (UNCTAD/SHIP/631, New York, 1990) and World Bank publication INU 57, The management of port equipment maintenance.

16/ Convention 152 and Recommendation 160 concerning occupational safety and health in dock work.

17/ Although the provisions of the code are principally addressed to seafarers, they are also of concern to manufacturers, consumers, packers and shippers, cargo handlers and haulage contractors.

18/ See Rights and duties of container terminal operators and users (UNCTAD/ST/SHIP/6, 1 October 1986) chapter VI.

19/ Micropiles are piles about 10 cm in diameter cast in situ. A 10 cm section is bored through the masonry or earth, the stiffener is inserted and the cavity is filled with fine concrete. The procedure is described as "stitching" because a great many micropiles are used to "stitch" together the loose parts of a monolithic structure and to stitch the latter to the foundation.

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