BS 6349-3:2013

BSI Standards Publication

Maritime works –

Part 3: Code of practice for the design of shipyards and sea locks

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Publishing and copyright information

Published by BSI Standards Limited 2013

ISBN 978 0 580 78084 4

ICS 47.020.99; 93.140

The following BSI references relate to the work on this document:
Committee reference CB/502
Draft for comment 13/30259247 DC

Publication history

First published August 1988
Second (present) edition, December 2013

Amendments issued since publication

Date	Text affected

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 126, an inside back cover and a back cover.

Foreword

Publishing information

This part of BS 6349 is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 31 December 2013. It was prepared by Technical Committee CB/502, *Maritime works*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This part of BS 6349 supersedes BS 6349-3:1988, which is withdrawn.

Relationship with other publications

BS 6349 is published in the following parts [1)]:

- Part 1-1: *General – Code of practice for planning and design for operations*;
- Part 1-2: *General – Code of practice for assessment of actions*; [2)]
- Part 1-3: *General – Code of practice for geotechnical design*;
- Part 1-4: *General – Code of practice for materials*;
- Part 2: *Code of practice for the design of quay walls, jetties and dolphins*;
- Part 3: *Code of practice for the design of shipyards and sea locks*;
- Part 4: *Code of practice for design of fendering and mooring systems*;
- Part 5: *Code of practice for dredging and land reclamation*;
- Part 6: *Design of inshore moorings and floating structures*; [3)]
- Part 7: *Guide to the design and construction of breakwaters*;
- Part 8: *Code of practice for the design of Ro-Ro ramps, linkspans and walkways*.

The recommendations in this part of BS 6349 are intended for use in all global locations, but taking into account local conditions. As a British Standard, this part of BS 6349 makes reference to other British Standards and to other publications commonly used in the UK, but it is recognized that in some locations there will be alternative local or international publications that are equally applicable. It is the responsibility of the designer to take steps to be fully cognisant of the prevailing codes and standards in any particular location.

Information about this document

This is a full revision of the standard. The principal change is to broaden the scope to include all principal maritime waterfront structures designed for shipyards and their interrelationship in the design of the whole shipyard. The general criteria for maritime works have been removed in this revision, as they are now collected together in the four subparts of BS 6349-1 [4)], which includes general planning and design for operations, actions, geotechnical conditions and materials. BS 6349-3 covers the criteria which are specific to works in shipyards and sea locks.

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1) A new part 9, covering port surfacing, is in preparation.
2) In preparation.
3) Some of the recommendations in BS 6349-6:1989 have now been incorporated into Clause **9** of the present part of BS 6349, and brought up to date. It is anticipated that these recommendations will be removed from BS 6349-6.
4) At the time of publication of BS 6349-3, BS 6349-1-2 is still at drafting stage.

Shipyards incorporate industrial processes which determine the operational requirements of the facilities and hence their design. To assist the designer in the use of BS 6349-3, a common format has been adopted for each clause from Clause **4** onwards. This common format is as follows.

a) **Operational parameters**. The operational parameter is defined as the requirement of a system or element necessary to be incorporated or designed in, to undertake a defined function or facilitate operations either alone or in conjunction with other elements or systems, i.e. what is the facility for and why is it necessary?

b) **Siting**. The siting is defined as the location, routing and/or position of the respective element or system with respect to its requirements and other structures, services or elements necessary to be provided as part of the facility, i.e. where should the facility be located?

c) **Elements**. The element is defined as the important minimum individual items, components or elements that are necessary for a system, structure or unit serving the facility that need to be considered in the design, i.e. what are the key factors or items that need to be included and what are their specific design parameters?

d) **Equipment**. The equipment is defined as the individual key items of plant or equipment that are critical in that system, structure or service which it is necessary to incorporate, i.e. what equipment is needed to make the facility work?

Use of this document

As a code of practice, this part of BS 6349 takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this British Standard is expected to be able to justify any course of action that deviates from its recommendations.

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Presentational conventions

The provisions in this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

1 Scope

This part of BS 6349 gives recommendations and guidance on the design of shipyard waterfront layouts, dry docks, piers, quays, slipways, shipbuilding berths, shiplifts, floating docks, sea locks, hydrolifts, dock and lock gates, mechanical and electrical services distribution and control systems.

It focuses on shipyard-specific design considerations. It does not apply to general maritime works design or to the detailed planning and design of sea locks, as well as their hydraulic design, which are covered by other parts of BS 6349 and PIANC publications.

This part of BS 6349 is applicable to the design of both commercial and naval base facilities.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 6349-1-3, *Maritime works – Part 1-3: General – Code of practice for geotechnical design*

BS 6349-2, *Maritime works – Part 2: Code of practice for the design of quay walls, jetties and dolphins*

BS 6349-4, *Maritime structures – Part 4: Code of practice for design of fendering and mooring systems*

BS EN 1991-1-4, *Eurocode 1 – Actions on structures – Part 4: General actions – Wind actions*

BS EN 1992 (all parts), *Eurocode 2 – Design of concrete structures*

BS EN 1993 (all parts), *Eurocode 3 – Design of steel structures*

BS EN 1997 (all parts), *Eurocode 7 – Geotechnical design*

BS EN 13001 (all parts), *Cranes – General design*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purpose of this part of BS 6349, the following terms and definitions apply.

3.1.1 bilge block

ship support unit under the hull sides of a ship when it is drydocked

3.1.2 declivity

longitudinal inclination

3.1.3 dry berth

area of dry land to which ships can be moved for repairs

3.1.4 dry dock

fixed and gated structure with a floor below water level into which ships can be floated and subsequently be made dry

NOTE Dry docks are sometimes referred to as "graving docks".

3.1.5 drydocking
putting a ship in a dry condition for repair

3.1.6 floating dock
structure with variable buoyancy than can be submerged for a ship to enter and then be raised to lift the ship into a dry condition

NOTE Floating docks are called "dry docks" in some countries.

3.1.7 hydrolift
fixed and gated structure which uses water to lift or lower ships to or from the level of dry land

3.1.8 keel block
ship support unit along the line of a ship's keel when it is drydocked

3.1.9 operation
activity required to undertake ship repair or shipbuilding

3.1.10 pumphouse
location of pumping equipment

3.1.11 shipbuilding
industrial process of building a new ship

3.1.12 shipbuilding berth
berth dedicated to shipbuilding

3.1.13 shiplift system
method of lifting or lowering ships to/from the level of dry land

3.1.14 ship repair
industrial process of repairing a ship

3.1.15 sill
fixed structure forming the bottom of a gated entrance through which ships pass

NOTE This is sometimes spelled "cill".

3.1.16 slipping
inclined retrieval or launching of ships

3.1.17 slipway
inclined system for retrieval and launching of ships extending from dry land to below water level

3.1.18 sue point
ship contact with a support unit at one location along its length before the full keel length is in contact

NOTE This is sometimes spelled "sew".

3.1.19 under-drained floor
floor which has the natural ground water pressure beneath it reduced

3.2 Abbreviations

For the purpose of this part of BS 6349, the following abbreviations apply.

DCS	distributed control systems
EHWL	extreme high water level
HAT	highest astronomical tide
HAZID	hazard identification
HAZOP	hazard and operability
LAT	lowest astronomical tide
LBP	length between perpendiculars
MDL	maximum distributed load
MHWN	mean high water neaps
MHWS	mean high water springs
MLWS	mean low water springs
PLC	programmable logic controllers
SCADA	supervisory control and data acquisition

4 Shipyard layout

4.1 Operational parameters of shipyards

4.1.1 Shipyard life cycle

The life cycle of a shipyard starts at the early concept stage and follows through to the decommissioning stage, and includes each and every stage in between. The design of the shipyard should be developed with a holistic approach, such that the consequences of decisions made at a particular stage are taken into account for all subsequent stages of the life cycle.

4.1.2 Consultation

Throughout the life cycle of a shipyard, timely coordination should take place with all identified stakeholders. The stakeholders should include, but are not limited to, the following:

- shipyard owner;
- shipyard operator (management, procurement, engineering and maintenance);
- port authority;
- fire authority (authority having jurisdiction);
- host country governing departments;
- local business, people and representative bodies;
- country utility providers (power supply, water supply, phone, sewage disposal and data services);
- insurance companies.

4.1.3 Input to shipyard layout design

The shipyard layout should be able to achieve a set of facilities which provides an operationally efficient shipyard. In order to achieve this, the input to the design should include the following principal parameters and constraints:

- intended shipyard types of business (see **4.1.4**);
- throughput mix of ships, including offshore work where applicable, which the shipyard is intended to accommodate (see **4.1.4**);
- potential shipyard physical site data;
- local construction capability constraints;
- stakeholder constraints and opportunities.

The final layout should be the result of a progressive iterative optimization of all of the input information and applied to each of the individual facilities. The designer should have a good understanding of the operational purpose of each facility and of the following constraints:

a) operational parameters of the facility;

b) siting of the facility;

c) structural elements of the facility;

d) equipment of the facility.

4.1.4 Target throughput

The basis of design for the shipyard should be defined clearly in terms of the type of business it is intended to undertake, such as shipbuilding, ship repair, ship conversion, ship recycling or a mix of these, together with the target throughput mix of ships to be accommodated subdivided into ship size, ship types and numbers.

For commercial shipyards, the target throughput should be derived from a market study which has identified the potential revenue, which should be taken into account as a budgetary parameter for the scale and affordability of the shipyard facilities.

For naval bases, the current and planned fleets usually provide the target throughput parameters with an associated support facilities budget.

4.1.5 Landside and waterfront

The shipyard layout should be planned to optimize the overall capacity of both the landside and waterfront facilities, taking into account the combined operations and construction. The designer of the waterfront marine works should be aware of and contribute to the operational layout planning.

4.2 Siting of shipyards

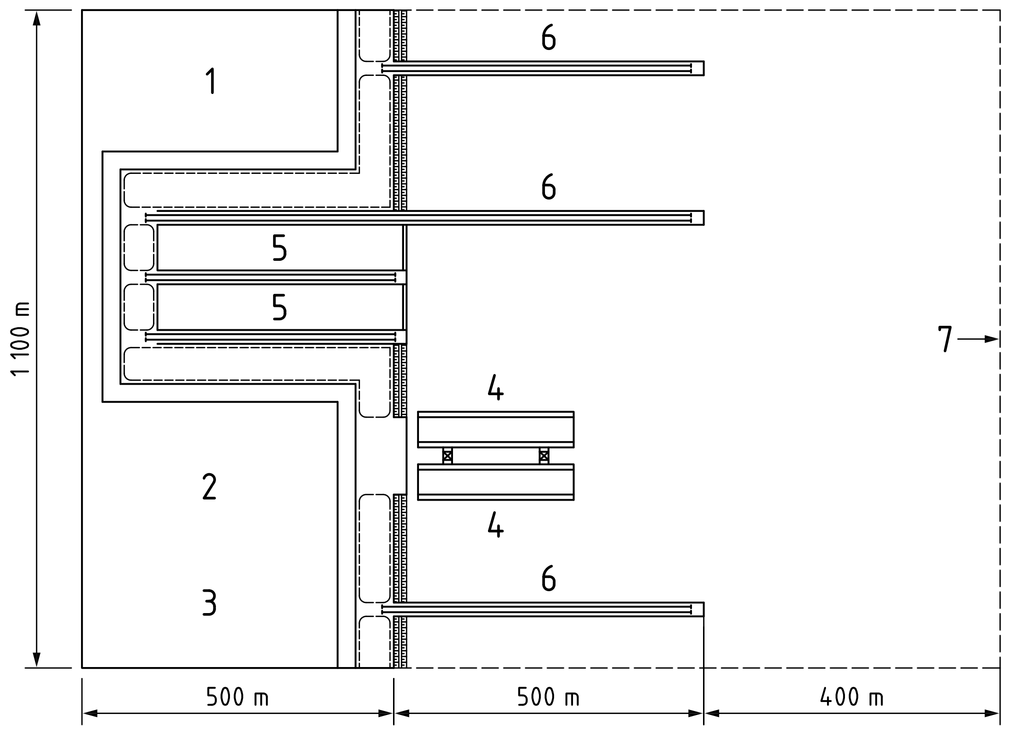
4.2.1 Site selection

For the design of a new greenfield site shipyard, the site selection process should take account of the full range of parameters which encompass both the physical site constraints and operational needs. There should be an informed balance for the physical site needs of landside and waterfront facilities. A simplified shipyard footprint area of the waterfront and land requirements should be derived from the target throughput mix of ships (see **4.1.4**), as a basis for the scale of the site needed (an example is given in Figure 1).

For the upgrading of existing shipyards or for predefined locations, the optimum layout should be determined from the combined opportunities and constraints for both the landside and waterfront facilities.

Figure 1 **Example of a shipyard footprint**

Dimensions in metres



Key

1 Surplus area created by the required waterfront – could be used for support industries

2 Workshop space

3 Main office/admin space

4 Floating dock

5 Dry dock

6 Pier

7 Ship manoeuvring boundary

The physical site data should be collated for all sites under consideration, and should be sufficient to make a preliminary assessment of the scale of resources required to develop each site. The principal data headings should be:

- topography and bathymetry;
- geology and ground conditions;
- wave climate and currents;
- climatic conditions;
- environmental constraints;
- hinterland infrastructure;
- existing facilities.

As much data as possible should be collected through a desk study to inform the decision on whether or not new survey data is required and to what level of detail it should be specified. A risk assessment should be used to determine the value of having sufficient information to provide high confidence in a selected site versus using resources on detailed survey work which might only be used at the detailed design stage.

Survey data, particularly for the ground conditions, should therefore be acquired in two stages, firstly sufficient for the site selection to determine the shipyard layout and secondly, after the shipyard layout has been agreed in detail, for the specific structural elements anticipated.

The environmental constraints should include the results and recommendations from environmental impact assessments where present.

4.2.2 Conceptual layouts

To derive the optimum layout of a selected site, a minimum of two concept layouts should be derived which can accommodate the target throughput. Through a comparative principal quantities estimation exercise, the preferred layout should be derived through optimization.

On completion of the site selection, the actual site opportunities and constraints adjust the actual throughput capacity and this should be fed back to the target throughput mix of ships. In turn the conceptual layout should be reviewed to accommodate significant changes in throughput, as part of an iterative optimization process. The preferred layout should maximize the opportunity for phased development to enable early start-up of some operations. Flexibility to alter the throughput mix of ships in line with changing markets during the design life of the shipyard facilities should also be incorporated in the layout.

4.2.3 Preferred layout principal quantities estimate

A preliminary design for the principal facility items in the preferred concept layout should be prepared to enable a reliable principal quantities estimate to be made for the development evaluation. This principal quantities estimate should be provided for input to the financial model for the shipyard to help to determine the overall feasibility. The phasing of the development should reflect the financial model.

The principal quantities estimate should be used to identify areas for construction optimization arising from the interaction of the individual facility structures, and the preferred layout should be adjusted accordingly.

4.2.4 Designing for risk

The identification of hazards should be undertaken at the concept layout stage, as the earlier they are identified, the more efficient is their mitigation.

NOTE The primary consideration is the identification of potential hazards which could lead to personnel injury or death, including outside the shipyard site boundary. Unidentified hazards have the potential to become major obstacles later in the detailed design phase of the shipyard and equipment. Identifying and subsequently risk ranking the hazards early in the project provides a focus for the design so that early mitigation can be implemented. The risk assessment process yields a level of risk (probability of occurrence of harm and the severity of that harm).

A method should be adopted of systematically identifying hazards, such as through a hazard identification (HAZID) study.

Safety and asset-loss scenarios should be assessed with the considered input of all discipline designers (mechanical, electrical, control, civil), the operations designer and maintenance departments of the operator of the shipyard. The result of the HAZID study should be a schedule of identified risks for each system, structure or item of plant and the associated mitigation measures which should subsequently be integrated into the design and equipment specifications.

4.2.5 Hierarchy of hazard control

The application of protective measures should be appropriate to the desired degree of risk reduction. Protective measures should be applied in a hierarchical order as follows:

a) elimination of the hazard source;

b) substitution by a lower risk hazard source;

c) engineering controls;

d) administrative controls;

e) collective protective equipment;

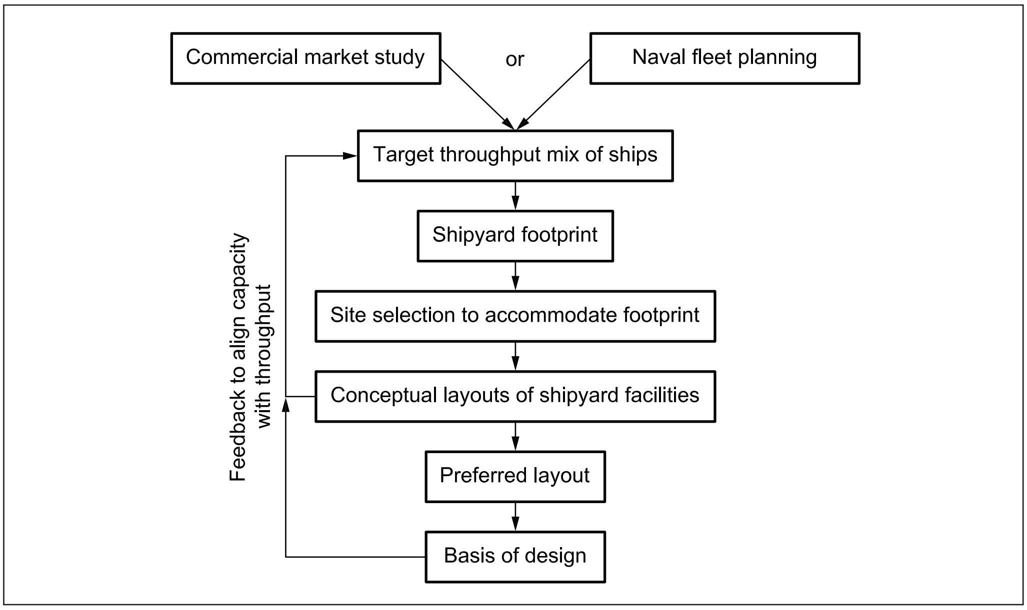
f) personal protective equipment.

4.3 Elements of shipyards

4.3.1 Basis of design

The basis of design and site-wide parameters for the shipyard should be documented and agreed by all parties. Each facility within the preferred layout should be clearly indicated in the documentation, and the physical area of that facility should be defined. Within the basis of design documentation, each facility should have the facility-specific design parameters recorded as discrete sections for clarity. The process which should be followed to achieve the basis of design is summarized in Figure 2.

Figure 2 **Process to achieve basis of design**



4.3.2 Structure specific surveys

From the preliminary design work on the preferred layout, the types of structural elements should be identified, and a set of structure-specific site data surveys and studies should be defined, targeted at providing good quality design information. These surveys, including testing, should be carried out in accordance with BS 6349-1-3.

4.4 Equipment of shipyards

4.4.1 Equipment and structure optimization

When the preferred shipyard layout is established, a list of principal shipyard waterfront equipment, such as cranes, should be prepared. A review should be carried out of the effects and actions associated with the principal equipment on the preliminary structure designs, and an exercise carried out to optimize the equipment specified and the associated structure principal quantities.

For clarity, within the basis of design documentation, the integral waterfront structure and ship handling related equipment, such as winches, pumps and capstans, should be distinguished from the landside shipyard production process equipment, such as cranes.

4.4.2 Standardization

The equipment should be standardized where practicable across the shipyard facilities, for ease of maintenance and spares planning. Where an existing shipyard is being upgraded, due account should be taken of the specifications, performance and condition of existing equipment which is to be retained, whilst ensuring that up-to-date equipment is specified.

4.4.3 Equipment within each facility

The equipment and the mechanical and electrical services within each facility should be treated as an integral part of the facility design. This is to ensure that sufficient space for and actions arising from installation, operation and maintenance are incorporated in the design of the structures.

4.4.4 Piped services and electrical systems

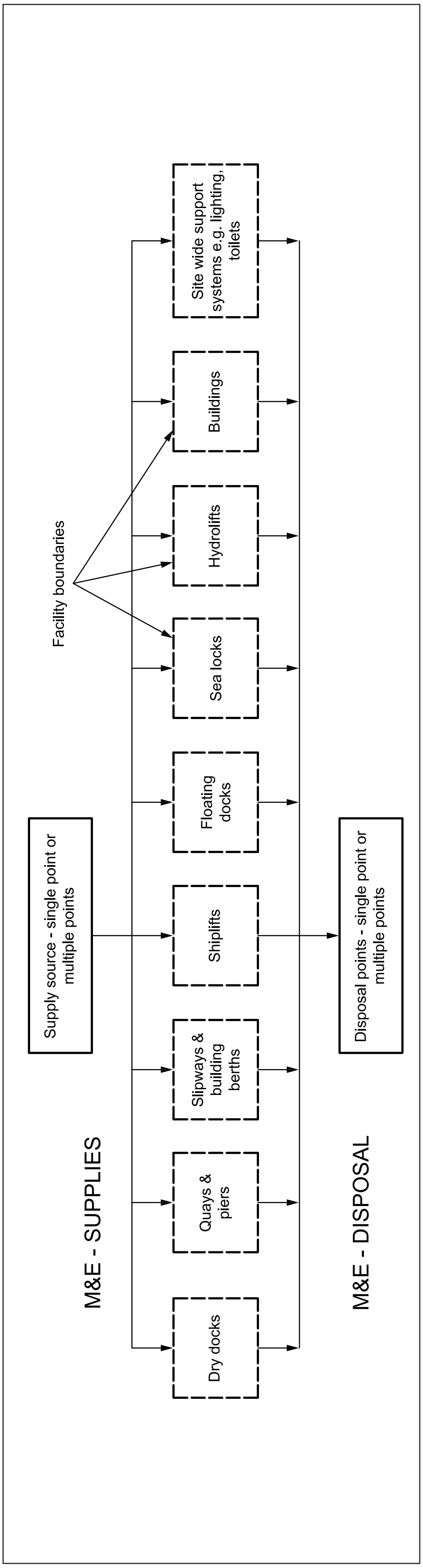
The waterfront and landside facilities should be assessed together in the design of the mechanical piped services and electrical distribution system. For clarity, the distribution system should be taken as the shipyard-wide provision of each service from the source or disposal point to the interface boundary of the facility as defined for the basis of design.

NOTE Figure 3 shows the definition of the distribution system interface boundaries.

4.4.5 Control systems

A control system should be provided for all equipment. The overall shipyard control system design should be in accordance with Clause **14**.

Figure 3 **Distribution system definition**



5 Dry docks

COMMENTARY ON CLAUSE **5**

Dry docks within this clause refer to fixed structures, usually of concrete construction with mobile dock gates at the seaward end. The gates are closed and the water removed from the dock to form the dry dock. The nomenclature for this type of dock varies, both geographically and historically. Dry docks have often been referred to as graving or basin docks. For the purpose of this part of BS 6349 they are referred to as dry docks.

5.1 Operational parameters of dry docks

5.1.1 Shipbuilding versus ship repair

The operational purpose of the dry dock should be determined at the outset as there are fundamental differences between shipbuilding and ship repair dry dock requirements. The principal parameters which should be defined include flooding, speed of handling ships, pumping times, access to dock floor, services and cranage.

5.1.2 Capacity

The capacity of the dry dock should be described in terms of:

- length, breadth and depth, together with working space at the sides and ends, the heights of keel blocks and the tidal conditions;
- ship docking displacement.

The use of deadweight tonnage (dwt) when defining dock capacity should be avoided as it does not define the size with any precision and can, on occasions, be misleading.

5.1.3 Entrance depth and floor level

The sill level should be calculated from the required depth of water for a ship to enter the dry dock in conjunction with the height of the dock blocks. The calculation should allow for the declivity of the dock floor and the dock block height, which is typically in the range 1.6 m to 2.2 m.

The under keel clearance of the ship during drydocking should be assessed according to the site water level parameters and drydocking duration, but should be not less than 0.5 m.

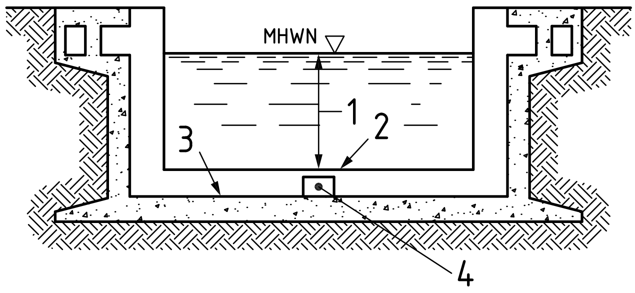
The maximum entrance docking draught should be measured from mean high water neaps (MHWN) to the top of the sill or top of the keel blocks adjacent to the sill, whichever is the higher. The keel block declivity should be stated.

NOTE Figure 4 shows the dimension which defines the depth of the dock entrance in conjunction with entrance docking draught.

The potential for accommodating damaged ships, which might require a depth of water over the sill greater than that which would be required under normal docking conditions, should be defined in the dry dock requirements.

An optimization of the principal quantities should be undertaken to finalize the dock floor level according to the actual site conditions, as in some locations increased depth of the dry dock can result in disproportionate increases in principal quantities, whereas in other locations there is only a minimal associated increase in principal quantities.

Figure 4 **Cross-section of dry dock: depth of entrance**



Key

1 Depth of dock entrance

2 Sill

3 Floor

4 Keel blocks

5.1.4 Entrance width

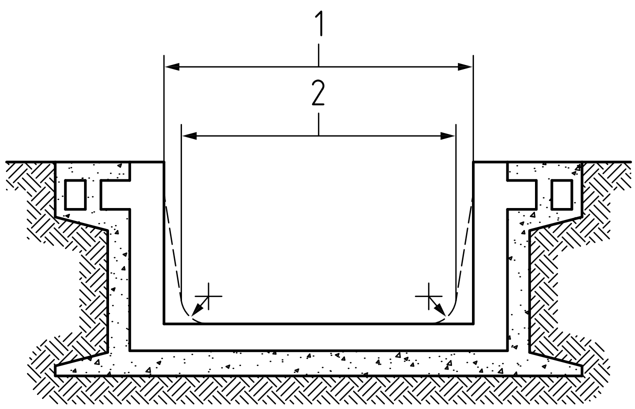
The width at the dock entrance normally controls the maximum beam of ship able to enter the dock. Due allowance should be made for clearances, which can vary according to wind and tidal conditions, the ship handling facilities available and the type of ship to be docked. The clear width should normally be not less than 0.6 m greater than the beam of the largest ship to be docked.

Some dock entrances are trapezoidal in shape and are often curved at the bottom corners. In this case, the width should be measured between the bottoms of the battered sides at the tangent points of the curves.

The width of the entrance should be calculated as the clear distance between the permanent fenders or structure at the dock entrance (subject to the variation for battered sides).

NOTE Figure 5 shows the dimension which defines the width of the entrance.

Figure 5 **Cross-section of dry dock: width of entrance**



Key

1 Width of entrance (vertical quoins)

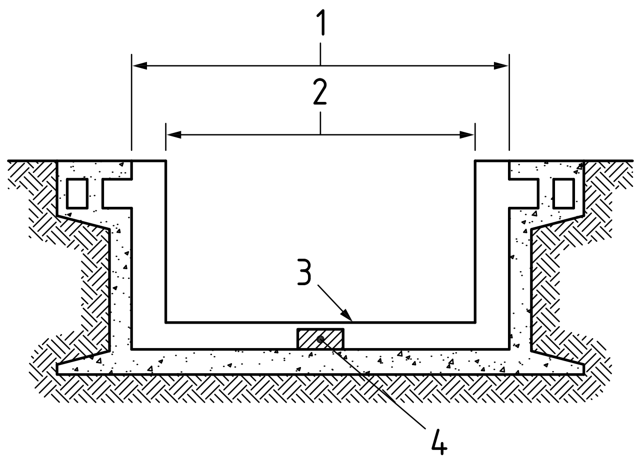
2 Width of entrance (trapezoidal)

5.1.5 Internal width

The width between dry dock walls, often termed the dry dock barrel, should be not less than the width of the dry dock entrance. The internal width should allow for working space at the side of the ship and for operation of equipment, such as dock arms, travelling along the face of the dock walls. The dry dock width should be calculated as the minimum clear distance between the faces of the dock wall (or projecting altars) above keel block level.

NOTE Figure 6 shows the dimension which defines the operational width of the dock.

Figure 6 **Cross-section of dry dock: operational width of dock**



Key

1 Operational width of dock

2 Dock entrance

3 Dock sill

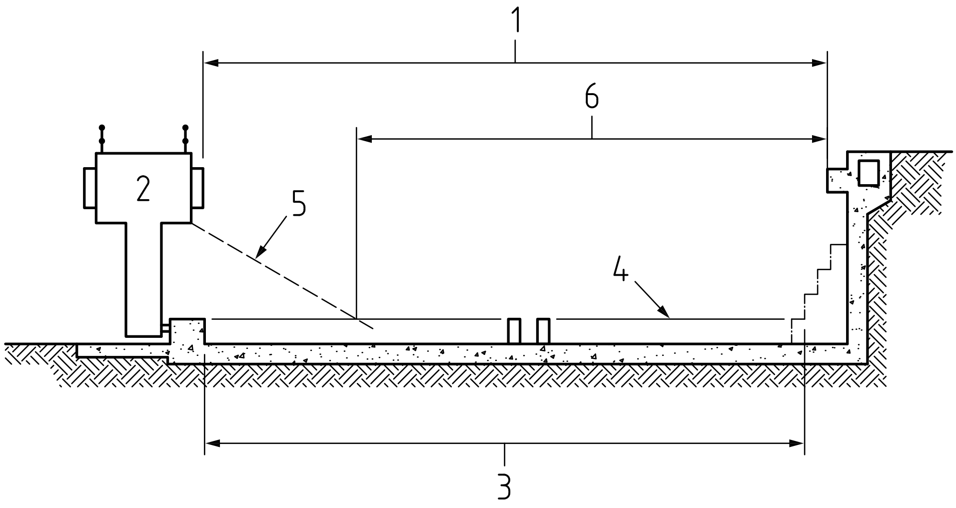
4 Keel block

5.1.6 Internal length

The length of a dry dock should be measured on the centre line of the dock. It should be the minimum horizontal distance between the internal face of the head wall, or the furthest projecting fender thereon, and the furthest internally projecting part or fender of the dock gate. In cases where the head wall is stepped, the length should be measured to the vertical face of the step at keel block level. Some dock gates are supported by internal inclined struts, which can restrict the effective length of the dock; therefore, measurement should be taken to the appropriate point on the strutting system at keel block level.

NOTE Figure 7 shows the dimension which defines the operational length of the dock.

Figure 7 **Operational length of dry dock**



Key

1 Length of dock at cope
2 Dock gate
3 Operational length of dock with stepped headwall
4 Keel block level
5 Gate strut
6 Operational length of dock with strut

5.1.7 Working space between ship and dry dock

At the sides of the dock, the working space clearance between the side of a ship and the face of the wall should normally be not less than 1.5 m. The use of dock arms should be taken into account according to their actual size. Working space should also be allowed for special equipment removal or fittings such as stabilizers at the side of ships which might require recesses to be formed in the dock walls.

At the ends of the dock, the removal of tail shafts can require an extra length of dock and due allowance should be made for this process.

Working space should be provided by high keel blocks or pits in the dock floor for sonar domes and other protuberances below the keel of ships of sufficient dimensions to facilitate their removal and refitting. Keel blocks should be not less than 1.8 m high for the use of mechanical equipment on wheeled vehicles to clean and paint the underside of ships.

The expected shipbuilding strategy should be used to define the block heights for shipbuilding docks. The height of blocks in building docks should normally be smaller than in repair docks due to a lesser working space requirement.

5.1.8 Height of dry dock cope

When selecting the height of the cope above dock floor level, the following should be taken into account:

- the highest water level likely to be attained outside the dry dock entrance, allowing for fluvial flooding, wave swell and surge;
- the highest water level likely to be attained in the dock;
- the need to provide services near the dock cope and the necessity or otherwise for them to remain in the dry when the dock is filled;

- the general level of the ground surrounding the dock and the advantage of maintaining the cope level similar to that level;
- the provision of rails for dock arms or ship leading equipment below dock cope level, which normally should remain in the dry.

5.1.9 Dewatering of dry dock

The dewatering time for a dry dock should be specified as the time taken to empty the dock from MHWN without a ship in dock. Before undertaking the design or specification of the pumping system, the dewatering time should be defined by the dry dock owner and user.

For a ship-repairing dry dock, the specified time should be between 2 h and 4 h. The specified time adopted should take account of several factors including the range of the tide at the site and the influence of the tide on ship movement operations.

At locations with a large tidal range, the dewatering rate should be designed in conjunction with the ability of the gate design selected, to withstand a reverse head if the dock water level lags behind the falling tide level.

For a shipbuilding dry dock, the specified dewatering times should be in the range of 4 h to 12 h.

The design dewatering time adopted should be determined from an analysis incorporating at least the following factors:

- frequency of annual dockings;
- tidal range;
- increase of equipment needed to reduce dewatering time;
- multiple uses of the dock;
- floor profile;
- working hours in shipyard.

5.1.10 Filling of dry dock

Filling times should be limited to reduce the amount of time during which the dry dock is unusable for hull repair work between dockings. The rate of filling and resultant water velocities should be limited so as not to induce scouring or disturbance of the dock blocks. This can be achieved by providing inlets or cross-dock culverts with sufficiently large cross-sectional areas.

The filling time for a ship-repairing dry dock should be between 1 h and 2 h, and is normally expressed as the time taken to fill the dock with the outside water level at MHWN without a ship in dock.

The filling time for a shipbuilding dry dock, should be between 4 h and 12 h, with the adopted time determined from an analysis in a similar manner to the dewatering time in **5.1.9**.

5.1.11 Floor profile

The floor profile should be adopted to suit the particular functions and usage of the dry dock.

Ship repair docks should generally be provided with a longitudinal slope of between 1:200 and 1:400.

NOTE 1 The slope is normally arranged as being down towards the dock entrance, which coincides with the normally stern-down trim of a ship entering the dock bow first and so tends to reduce sue loads when the ship settles.

Shipbuilding docks should generally be provided with a flat floor profile, as shipbuilders normally prefer the keel of a ship to be horizontal when under construction and the keel blocks to be of constant height.

NOTE 2 To increase the rate of floor drainage where the keel line is flat or has very small gradients, transverse falls of the order of 1:100 can be incorporated in conjunction with longitudinal channels connected to the dock sump.

In dry docks fitted with an intermediate gate, provision should be made for drainage of surface water from the head end of the dock when the gate end is flooded. A separate sump and pump should always be provided.

5.1.12 Floor waste collection and contaminants

The use of shot blasting and high pressure water methods of cleaning ships in dry dock produce a large quantity of debris/contaminants to be removed from the dock floor. Provision should be made for the collection of debris before it is washed into the pumphouse sump, where it can cause damage to the pumps. The use of mechanical dozer equipment on the floor should be taken into account and upstanding steelwork gratings, holdfasts, etc. should be avoided. Joint sealants in the floor should not project above floor level for the same reason.

A system to divert contaminated water to a holding tank or treatment plant should be incorporated into the design.

5.1.13 Services at dock floor level

Provision should be made, commensurate with the dock use, for services at dock floor level, both near the walls and across the dock floor. Services should be located in transverse ducts with flush covers or dual-use transverse drain channels able to accommodate the service pipes.

For both shipbuilding and ship repair dry docks, holdfasts should be provided on the dock floor and lower parts of the walls to assist work on the ships. They should be flush-fitted or recessed.

5.1.14 Access to dock floor

The dry dock design should incorporate provision of adequate access for personnel and materials to the dock floor to support the operations for which the dry dock is built.

A vehicular ramp should be provided where rapid mobilization of vehicles, personnel and materials to the dock floor is necessary, in particular for ship repair operations. The ramp slope should not exceed 1:10 for wheeled vehicles travelling to and from the dock floor. However, where space is a constraint the slope should not exceed 1:8. The design should include vertical transition curves where vehicles with lower ground clearance will be used.

Stairs should normally be provided at the head and entrance of the dock with additional intermediate stairs for long walls. Where possible, stairs should be in the open for ease of construction and maintenance. If stairs have to be placed behind the dock wall, as much ventilation as possible should be provided, since the enclosed space can trap floating and other debris after the dock is pumped out.

Emergency escape from the dock floor should be provided at a maximum spacing of 60 m. Emergency ladders from dock floor to cope should be provided along both side walls and the head of the dry dock in addition to stairs or ramps to achieve this maximum spacing. They should preferably be set in recesses to avoid damage and to protect personnel. Access to and from the top of the emergency ladders should be open at all times. Manhole or access hatch covers should not be provided on openings.

5.1.15 Arrangement at dry dock copes

The arrangement of various installations and details at the cope of a dock is a major design task involving sometimes conflicting requirements. Account should be taken of the following items which influence the optimized design, with due regard to the use of the dock for ship repair or shipbuilding:

- ducts and subways for electrical and piped services;
- connections of services to the ship and dock floor;
- track for shiphauling trolleys;
- upper track for dock arms;
- personnel access to dock arm platforms;
- electrical pick-up or trailing cable groove for dock arms;
- safety handrails;
- dockside crane tracks including storm anchors, jacking points and cable turnover pits;
- bollards;
- capstans;
- fairleads;
- staircase to dock floor;
- ladders to dock floor;
- access towers to ships' decks;
- fendering;
- piped services take-off pits and isolation valve pits;
- electrical services take-off points;
- propeller winches and sheaves;
- substations;
- lighting;
- drainage.

5.1.16 Surrounding area

The area surrounding the dock should be of adequate dimensions to provide for shipbuilding or ship repair operations, as appropriate.

Modern shipbuilding methods require considerable layout space for prefabricated parts of ships, depending upon the particular techniques used. Layout space should be determined by the ship production process designer. Part of the area is likely to be covered by a goliath crane which also straddles the dock and/or by heavy dockside cranes, and this should be taken into account in the layout. The whole area should be well drained, and should be suitable for the passage of heavy trailers and for the high concentrated loads arising from the temporary storage of prefabricated ship parts on trestles.

Ship repairing also requires an area surrounding the dock for the storage of equipment removed from the ship to enable repairs to be carried out, or for new equipment to be installed on the ship, as well as for temporary mobile machinery. The area provided should be sufficient for these purposes and should be suitable for wheeled vehicles to travel freely. In addition, an adequate space should be provided for the dockside cranes to operate.

The area surrounding a dry dock should be designed for a minimum uniformly distributed load of 25 kN/m^2, as well as for concentrated loads, which should be determined from the type of wheeled vehicles and trestle foot loadings, etc. likely to be used.

5.1.17 Equipment housing requirements

Large items of equipment such as pumps, compressors and substation electrical equipment can have significant housing requirements, especially if they are to be located underground in order to maximize working space at cope level. Such requirements and locations should be determined at an early stage in the design, as they can impact on the choice of structural form and many of the design elements.

Equipment rooms should be provided with sufficient space to allow good access into the room and any lower levels. They should also be provided with ventilation to suit the housed equipment so as to maintain a suitable working environment. Access should be suitable to allow personnel to carry tools and spare parts. Sufficient space should be provided inside the rooms for maintenance personnel to work.

A typical model or size of equipment should be assumed at the early design stage. During subsequent procurement and installation, alternative models of differing dimensions might be introduced. A generous space should therefore be made available for plant and equipment in the early design stages, allowing additional equipment, modifications and expansions to be incorporated at a later date if necessary.

5.1.18 Covered dry docks

Dry docks should be covered under the following circumstances:

- where protection is required against adverse environmental conditions;
- where security is a critical factor, e.g. in naval ship repair or shipbuilding dock facilities;
- where there is a particular need to support overhead travelling cranes.

The width of deck at cope level to be provided under cover should accommodate the width required for the shipbuilding or ship repair technique to be adopted.

In addition to the usual shipbuilding or ship repair services, appropriate lighting, heating, ventilation and fire precautions should be provided in covered dry docks to suit the operational requirements.

End doors provided at the dock entrance should have sufficient width and height to provide clearance to the superstructure and top of any ship likely to be built in the dock. The dock gate should be designed to provide support and/or guides for such doors. Doorways of sufficient size to accept prefabricated units of ships carried on transporters should be provided at the landward end.

5.2 Siting of dry dock

5.2.1 General

The siting of the dock can significantly affect future shipyard expansion options and hence should be planned as part of any long-term layout.

5.2.2 Navigational approach

A repair shipyard should be provided with an easy navigational approach, if possible, as some vessels might be under tow.

Where the navigational approach is more difficult, lead-in jetties or dolphins should be provided.

5.2.3 Anchorages and quays

A sheltered anchorage and/or a mooring facility should be provided, to allow for a delay before the ship is accepted in the dry dock. The design should allow for repair work to be carried out afloat before or after docking, to minimize dock occupation. A minimum of two repair/fitting out quays should be provided in conjunction with each dry dock for normal shipyard operations. The depth of water should be sufficient at all states of the tide at quays and anchorages.

5.2.4 Position with respect to subsoil conditions

The position of a dry dock should be determined in conjunction with subsoil conditions, as they can greatly influence the scale and extent of the construction required to create the dry dock.

Where possible, positioning should be arranged to take advantage of rock formations.

NOTE Rock at floor level can produce a very efficient floor construction and, whilst excavation in rock material might be difficult, no temporary works to support the sides of the excavation are generally required. The dock walls, in this case, can be simple or even eliminated.

As a drained dry dock floor is generally more structurally efficient than gravity or tied down floors, a site should be researched with the benefit of suitable impervious substrata, in close proximity to dock floor level, such that an economic ground water cut-off can be formed.

The location should be identified with adequate depth of water at the completed dock entrance and associated piers and/or quays, but due account should be taken of the scale of temporary cofferdams, which are easier to construct in shallow water. The removal of bunded cofferdams and the entrance dredging should be combined for efficiency. Dredging in rock is relatively difficult and can extend the construction programme significantly, and therefore should be minimized, wherever possible, by suitable positioning of the dock and other structures.

The final position of the dock should be selected by optimizing the many competing factors. The final dry dock location suitability should be verified by accurate subsoil investigation together with land and bathymetric surveys.

The level of detail in the surveys should be sufficient to provide the structure-specific data needed for the detailed design.

5.2.5 Prevailing wind

In order to allow for frequent ship movements, dry docks used for ship repair should be oriented with the centre line as close as possible to the direction of the prevailing wind.

Where ship movements are infrequent, such as for shipbuilding, priority should be given to the shipyard layout efficiency if this conflicts with prevailing winds, as launches can usually be delayed to await suitable weather conditions.

5.2.6 Tidal flow and currents

Account should be taken of currents and tidal streams, if the dock is to be located on an unprotected coast or on a tidal river. Docking and undocking is generally carried out around high water, but the tidal streams before and after high water should be checked to confirm that there is sufficient time for the operations to be carried out before an unacceptable velocity develops.

5.2.7 Geotechnical investigation planning

5.2.7.1 General

Site investigation prior to the planning, design and construction of dry docks should be thorough, with special attention given to the control of ground water flows.

NOTE 1 The subsoil conditions can greatly influence the choice of design which, in turn, controls the final scale of the construction required.

NOTE 2 General recommendations on geotechnical investigation are given in BS 6349-1-3 and BS EN 1997.

5.2.7.2 Desk study

Prior to designing the site investigation and carrying out site reconnaissance, a desk study should be undertaken in accordance with BS EN 1997-2. The desk study should be used to help design any intrusive investigations and inform a project risk register.

5.2.7.3 Site reconnaissance

Site reconnaissance should be conducted in accordance with BS 6349-1-3 and BS EN 1997, and is of great importance particularly with respect to the early recognition of cavernous/karstic features, which can make conventional dry dock construction very difficult if the cavernous/karstic features are connected to the sea. Where cavernous/karstic features are suspected, additional investigation through non-intrusive methods (e.g. geophysical investigations) should be undertaken.

5.2.7.4 Design of ground investigations

The design of a ground investigation should ensure that sufficient investigation will be carried out to provide all relevant ground information required to design and construct the proposed dry dock. All methods of investigation should be assessed at this stage, and an appropriate method chosen to obtain this comprehensive design and construction information.

NOTE The investigation might require two or more phases, depending on the findings of the desk study, site reconnaissance, findings on site during the intrusive investigation, the stage of the project, and changes made to final dock design and construction requirements as the project proceeds.

The geotechnical investigation should obtain soil/rock samples, and should include relevant in situ and laboratory testing as well as describing the soil/rock. From the results of the investigation, post-investigation interpretation should be carried out to produce a working ground model and all necessary soil/rock properties for design purposes.

The ground investigation should involve several investigation points, the total number and type of which should be determined by the size and type of structures to be designed and constructed. The level of investigation should be not less than that specified in BS EN 1997, and the number of points significantly increased where the ground is thought to be highly variable.

Due to the nature of dry dock design and construction, the design of the ground investigation should also include the installation of water level monitoring standpipes (or similar) to allow ground water levels to be assessed. If necessary, the water levels should be monitored over an extended period to obtain the relevant data required. Field trials involving full scale pumping tests and borehole permeability tests should also be carried out if necessary to establish ground permeability and information for ground water control measures.

5.2.7.5 Depth of boreholes

The depth of boreholes should be sufficient for all types of dock design and should be much deeper than the depth of the dock in order, for instance, to investigate ground which might be used to anchor the dock floor to prevent uplift or construct a ground water cut off wall for drained dock floor design. Boreholes are typically required to a depth of at least 30 m below the anticipated dock floor level, but the depth should be determined according to the specific site.

5.2.8 Location of pumphouse

Pumphouses for dry docks are usually located near the dock entrance to achieve a short discharge distance to the sea, but other locations should be assessed for suitability before a final decision is made.

- For dry docks that have a declivity down towards the dock entrance, the pumphouse should be located at the entrance resulting in a simpler culvert system.
- For dry docks with longitudinally horizontal floors, the location of the pumphouse should be midway along the dock so as to halve the maximum length of dock floor to the sump. This arrangement should only be used if the length of discharge culvert is short.

The discharge system should be as short as possible, for both pumping and construction efficiency.

5.2.9 Multiple use of pumphouse

If two docks are to be built in close proximity, a design featuring multiple use of the pumps and common dewatering culverts and sumps in the form of a combined pumphouse should be evaluated against that of dedicated pumphouses for each dock. The factors that should be evaluated and compared include:

- scale of construction;
- whole life maintenance;
- space requirements;
- complexity of pumping and dewatering culverts and control system including interlocking;
- hydraulic conditions;
- safety and isolation.

If a multiple use/combined pumphouse is to be adopted, the design of the sump, culvert and isolation system should be capable of allowing one dock to be flooded and dewatered when the other is dry. At the same time it should be possible for the seepage drainage system to be maintained in operation for the dock that remains dry.

In the case of under-floor drainage systems for each dock, these should each be independent and not connected to another dock.

NOTE It might be feasible to utilize a combined pumphouse for more than two docks, but this can result in the culvert system and means to isolate each dock becoming more complex.

5.2.10 Dry docks with intermediate gates

Some dry docks feature intermediate gates which allow filling of part of the dock whilst allowing the other part to remain dry. This can be advantageous when smaller ships are being constructed or repaired.

The dewatering (and other water removal systems) should operate satisfactorily when these gates are in position.

5.2.11 Locating equipment underground

Pumps require a minimum suction head to operate efficiently. The suction head is determined by the design of the pump and the operating conditions under which it is being used. As dry docks are usually deep structures, the pumps should be sited well below the cope level.

Other equipment should be located underground where the benefits outweigh the drawbacks. Siting of equipment underground should be adopted where clear space is required above ground, or to protect equipment from hazards such as vehicle impacts.

Where equipment is located below ground, it should be protected from detrimental effects including:

- flooding;
- overheating;
- fire;
- accidental impacts from falling loads from cranes.

5.2.12 Availability of services

The availability of electric power, fresh water and other services should be established in relation to the siting of the dry dock.

5.2.13 Position of buildings, workshops etc.

The position of buildings, workshops etc. should normally be arranged to suit the best position of a dry dock in a new or existing shipyard, and it might be advisable to relocate existing buildings based on the overall efficiency of both dry dock and the buildings.

5.3 Elements of dry docks

5.3.1 Design of dry dock floors

5.3.1.1 Loading sources

Dry dock floors should be designed in reinforced or unreinforced concrete to carry safely all loads and worst combination of loads to which they are subjected, including:

- uplift from ground water, including the possible presence of artesian conditions;
- concentrated loadings from ships when docked;
- uniform water loading when the dock is full;
- horizontal loading from earth and water pressure on walls;
- seismic loading.

NOTE 1 Depending on the ground conditions, the following types of floor can be used to resist uplift from ground water:

- *under-drained (see **5.3.1.8.1**);*
- *gravity (see **5.3.1.8.2**);*
- *tied (see **5.3.1.8.3**).*

NOTE 2 Depending on the ground conditions, concentrated loading from ships may be carried by the following means:

- *by floors bearing directly on the ground (see **5.3.1.8.4**);*
- *by floors supported on piling (see **5.3.1.8.5**);*
- *by ground improvement (see **5.3.1.12**).*

A minimum partial factor of 1.5 should be applied for all ship-derived dock floor loads.

5.3.1.2 Loading distribution on ship-repairing dock floors

The loading to which the dock floor will be subjected through its design life will not be known with precision, and in the absence of data provided by the dock operator, the design load values derived in **5.3.1.4** and **5.3.1.5** should be used for preliminary studies.

The average loadings follow directly from the docking displacement of the design vessel (see **5.3.1.3**), but the magnitude and application of local concentrated loads depends upon the relative stiffness of the ship structure and the dock floor, as well as the ballasting and positioning practice of the dock operator.

The loadings described in **5.3.1.4** and **5.3.1.5** are those which can occur when the dock has been dewatered and the ship is supported by the blocks. The design should incorporate those loads which occur only as a ship sues or settles on to the blocks.

Ships are normally docked on a line of keel blocks plus two or more symmetrically disposed lines of bilge blocks arranged on each side of the keel blocks. In large dry docks, the design should allow for ships not necessarily positioned centrally on the dock floor.

5.3.1.3 Docking displacement

The docking displacement, D_d, should be estimated from:

$$D_d = 0.7 \times (\text{LBP}) \times B \times (\text{MDD})$$

where:

B	is the ship's beam;
LBP	is the length between perpendiculars;
MDD	is the mean docking draught.

Until accurate information is available, preliminary approximate mean docking draughts should be taken as:

- for container ships: light ship draught plus 3 m;
- for passenger vessels: three-quarters of the summer draught;
- for tankers and bulk carriers: 5 m.

5.3.1.4 Keel and bilge block load distribution

Design loadings should be chosen after consultation with the dock operator but, for the purpose of preliminary design, ships can be divided into two categories:

- those which are stiff transversely, i.e. most of their weight rests upon a central line of keel blocks;
- those larger vessels in which the weight is more evenly spread transversely over all the blocks.

The boundary between the two categories should be taken as ships with a docking displacement of 30 000 t.

For ships larger than 30 000 t docking displacement, the design should assume 60% of the docking displacement on the keel blocks, and 50% of the displacement should be assumed to be distributed between bilge blocks placed at distances from the keel blocks of between one-twelfth and two-fifths of the ship's beam.

For ships of 30 000 t or less docking displacement, 95% of the docking displacement should be assumed to be carried on the keel blocks and 15% distributed between the lines of bilge blocks. The bilge block loading should be positioned at distances from the keel blocks of between one-sixth and one-third of the ship's beam.

The design should apply the ship load as a line load equal to the average keel and bilge block loading intensities together with local concentrated loads, representing the effects of:

- unequal block loadings;
- local increases in distributed load associated with concentrations of mass within the ship.

  NOTE 1 Load concentrations typically occur beneath the engine room and the tanks used for ballasting.

Much greater load concentrations than those occurring in keel blocks have been observed in bilge blocks. Keel blocks should be assumed to extend for 100% of the length between perpendiculars (LBP).

Bilge blocks should be assumed to extend for about 90% of LBP in the case of larger vessels and for between 50% and 70% of LBP for smaller vessels, depending upon the fineness of the hull shape.

*NOTE 2 The keel and bilge block loadings on which the recommendations given in **5.3.1.4** and **5.3.1.5** are based were derived from measurements taken in a dock with a floor founded on rock, which is a very stiff foundation. The large load intensities observed were probably accentuated by the stiffness of the floor foundation. In other circumstances, the loads represented by those intensities might be spread over a greater area.*

In the design of any dock floor, provision should be made for the support of similar total loads to those given in **5.3.1.4** and **5.3.1.5**, spread in a manner appropriate for the particular design.

Semi-submersible platforms, FPSO type vessels and other anomalous structures have different load application arrangements to those for standard vessels. The requirement to allow for any such loading should be identified and defined in the basis of design documentation.

The dock floor should have sufficient capacity in local shear to be able to support individual block loads located anywhere beneath the ship, based upon an extreme contact pressure over the area of the block cap of up to 3 000 kN/m^2 (300 t/m^2). This extreme block load should be treated as an accidental load.

5.3.1.5 Keel block load design values

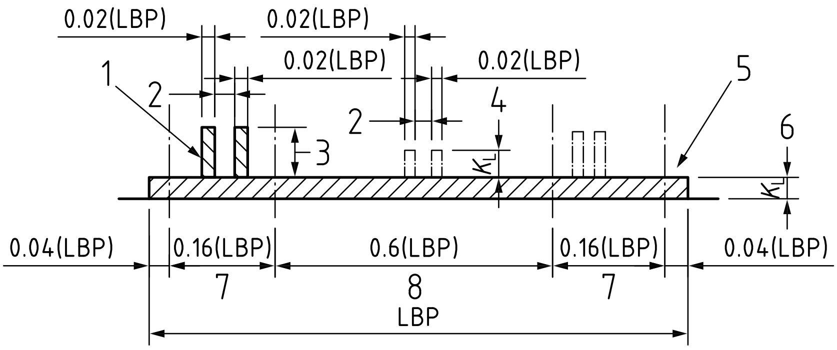
The keel block loading, which in every case assumes that reverse docking might take place, should be taken as a uniformly distributed line load operating over the full length of the keel (i.e. LBP), plus two local concentrated loads each of finite length placed anywhere along the length of the keel. The distance between the two local concentrated loads should be varied to produce the maximum sagging and hogging bending moments and shear at each point in the floor.

The intensities of the uniformly distributed load and the local loads should be calculated from the formulae given in Figure 8.

NOTE The intensity of the local loads is higher when they are located in the end sections of the keel for vessels larger than 30 000 t docking displacement.

No local loads should be applied nearer than 0.04(LBP) to the ends of the keel.

Figure 8 **Keel block loading on dock floor**

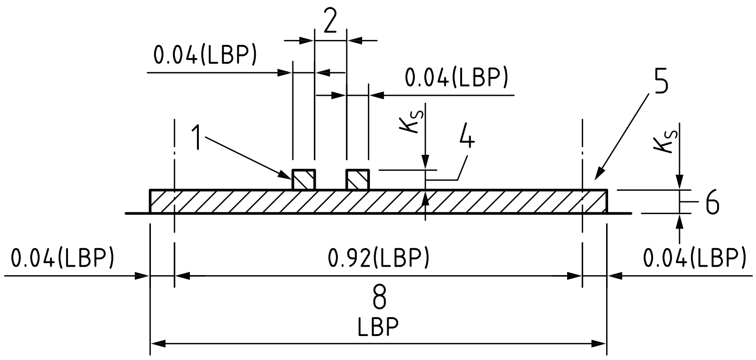


$$K_L = \frac{0.6D_d}{(LBP)}$$

where:

K_L is the intensity of uniformly distributed load in a large vessel;
D_d is the docking displacement of the vessel.

a) For ships larger than 30 000 t docking displacement



$$K_S = \frac{0.95D_d}{(LBP)}$$

where:

K_S is the intensity of uniformly distributed load in a small vessel;
D_d is the docking displacement of the vessel.

b) For ships of 30 000 t or less docking displacement

Key

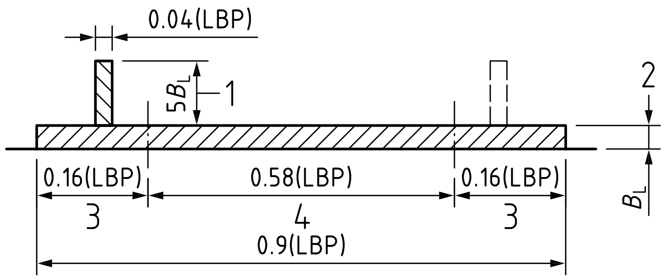
1 Local concentrated loads
2 Variable length
3 Local load increase in end sections $2K_L$
4 Local load increase in centre
5 No local load in this or corresponding section at opposite end
6 Intensity of uniform loading
7 End section
8 Centre section

5.3.1.6 Bilge block load design values

The bilge block loading, which in every case assumes that reverse docking might take place, should be taken as a uniformly distributed line load operating on a fraction of the length of the keel plus, in the case of vessels over 30 000 t docking displacement, a single local concentrated load of finite length operating at any location in the end sections (see Figure 9).

The bilge block loading in Figure 9 should be applied to each side of the dock. Where more than two lines of bilge blocks are used, the loading for each side of the dock should be divided equally between the bilge blocks on that side of the dock.

Figure 9 **Bilge block loading on dock floor**

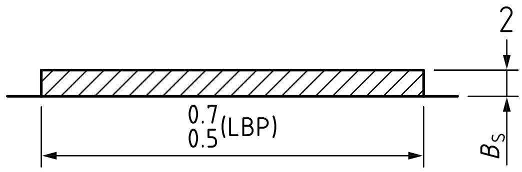


$$B_L = \frac{0.25D_d}{0.9\ (LBP)}$$

where:

B_L is the intensity of uniformly distributed load in a large vessel;
D_d is the docking displacement of the vessel.

a) For ships larger than 30 000 t docking displacement



$$B_S = \frac{0.075D_d}{0.5\ \text{to}\ 0.7\ (LBP)}$$

where:

B_S is the intensity of uniformly distributed load in a small vessel;
D_d is the docking displacement of the vessel.

b) For ships of 30 000 t or less docking displacement

Key

1 Local load increase in end sections only
2 Local load increase of uniform loading
3 End section
4 Centre section

5.3.1.7 Loading on shipbuilding dock floors

The design loading applied to shipbuilding dock floors should be determined to accommodate the block loading during the construction process for the types and sizes of ships for which the dry dock is planned.

The designer should develop the design loading as a set of line loads and point loads each of which can occur at any position on the floor. The development of the set of loads should take into account the following factors.

a) The arrangement of blocks for shipbuilding is related to the size of prefabricated units of the new ship's hull. The blocks are normally more evenly spread under the hull than the blocks required for ships docked for repair.

b) A ship can be constructed on one side of the dock floor, or two or more ships might be built simultaneously side by side in a large dock. The designer should not assume that the major loading will occur on the centre line of the dock or that the loading will be symmetrical about the centre line of the dock.

c) Drilling rigs under construction produce different loading conditions from those produced by ships, and the conditions vary greatly from rig to rig.

d) It is possible that a newly constructed ship might have to return to the shipbuilding dock after fitting out afloat, when normal ship repair docking supports would be used but docking might not be on the centre line of the dock.

To facilitate future dry dock operational flexibility, the design should include an assessment of whether the ship repair loading described in **5.3.1.2** can be efficiently accommodated within the shipbuilding design capacity.

5.3.1.8 Types of dock floors

5.3.1.8.1 Under-drained floors

An under-drained dock floor should be adopted where the ground water below the floor can be controlled such that it can be collected to be pumped away, so that no net uplift of the floor is allowed to develop.

The underfloor drainage system should include a layer of gravel or no-fines concrete, combined with a series of porous pipes and culverts which are led to a sump in the pumphouse. The pumping from the sump should be continuous throughout the life of the dock, so that the ground water regime surrounding the dock can remain as constant as possible whether the dock is full or empty.

The design should allow for the possibility of the dock being full of water for an extended period and the underfloor pumping being stopped, leading to a rise in ground water levels immediately surrounding the dry dock. The basis of design documentation should clearly state the minimum duration that the underfloor pumping has to be operating prior to commencing the dewatering of the dry dock.

NOTE 1 This is to prevent excessive uplift pressures on the floor outside the safe design values.

Where docks are founded on hard formations, or where on piled dock floors the requirement for a constant ground water regime might not be deemed necessary, a separate enclosed sump for underfloor drainage should be omitted from the design.

Where the dock is founded on rock of low permeability, the underfloor water pressure should be relieved by allowing it to discharge directly into the dock. Non-return valves should be installed on the inlets into the dock to prevent water from the filled dock flowing back into the ground. These valves can be subjected to damage from shipbuilding or ship repairing operations and should be regularly inspected and maintained.

A simple pressure relief system should be introduced into all under-drained floor installations. The system should be such that, if for any reason (such as pump failure) an unacceptable underfloor pressure develops, it is dissipated by direct discharge over the dock floor.

For fully pumped schemes, manhole covers should be provided over the underfloor drainage culvert, to lift off if unacceptable pressure develops and to allow maintenance of subfloor drainage collection pipes.

The system should be capable of being vented to the atmosphere at its upper extremity by a vent pipe rising above maximum sea level, to avoid high air pressures developing during filling of the dock.

Dry docks with underfloor drainage fitted with intermediate gates should be arranged so that the underfloor pumping is maintained for the whole floor at all times.

Account should be taken of the need to ensure that, where intermediate gates are present, inadvertent flooding does not occur due to downward leakage from an intentionally flooded part.

NOTE 2 Simple vented floors are not usually possible for docks with intermediate gates, unless the underfloor stratum has very low permeability and a cut-off seal is formed on the line of the intermediate gate.

5.3.1.8.2 Gravity floors

Gravity floors should either have sufficient mass themselves, or be able to call upon sufficient mass, to overcome the upward pressure of the ground water.

Where equilibrium is provided by taking into account the mass of the dock walls and backfill, it should be ensured that the floor can span across the width of the dock, thereby providing a uniform resistance to the uplift pressure.

Where the soil is highly permeable and the continuous pumping of large volumes of ground water would be required throughout the life of the dock, a gravity design should be adopted if appropriate.

NOTE Narrow docks can more easily be designed as gravity structures than wide ones, since the walls form a greater proportion of the whole dock self-weight.

5.3.1.8.3 Tied floors

A tied dock floor should be used where there is insufficient weight to withstand the hydrostatic uplift of the ground water and the floor has to be tied to the soil below the dock for equilibrium.

Tension piles, which also act as compression piles when supporting ship loads, should only be used with caution, since the reversal of load can tend to break down the adhesion between the soil and the pile. Failures of dock floors designed on this principle have been recorded, and fatigue issues should be taken into account before adopting this method of support.

The designer should assess the potential severity of the consequences to dock operations and also to a ship in the dock of an upward failure of a tied floor.

The prestressing of piles can avoid reversal of stresses. However, the use of steel at high stress for prestressing should be adopted with caution as all types of prestressing tendon are susceptible to stress corrosion cracking.

NOTE Only small quantities of water need to be present to provide a source of hydrogen, so the exclusion of all moisture is important. Anchorages and tendons are not normally subjected to large water pressure heads along their length as occurs when a dock is empty. Therefore, the exclusion, displacement and sealing of tenders has to be to a very high specification and proven by testing.

The present state of knowledge of stress corrosion cracking and hydrogen embrittlement of highly stressed steel in concrete is such that the risk of failure from these causes cannot be evaluated with high confidence, and therefore the use in dock floors of highly stressed anchors should be avoided.

5.3.1.8.4 Floors bearing directly on the ground

Where adequate bearing capacity exists, the ground immediately under the dock floor should be used to support the concentrated loads from ships and the distributed load from the water in the filled dock.

If the dock has been designed as a gravity structure, it is likely that it will be sufficiently stiff to spread the concentrated load from ships adequately without reinforcement, but this should be checked in relation to the soil conditions and floor thickness.

If the floor is relatively thin, it should be designed as a reinforced concreted plate to accommodate the imposed loads moments and shear forces.

5.3.1.8.5 Floors supported on piling

*COMMENTARY ON **5.3.1.8.5***

Piles can be used in conjunction with an under-drained floor, in which case they can be designed solely as compression piles supporting only the downward vertical loads.

The use of piles tends to limit flexibility in the layout of ship supporting blocks, unless there is a considerable excess of piling used.

Where weak soil is present at the subfloor level, piling should be provided to resist vertical loads and control settlement.

The floor and piles should be able to carry the maximum moments and loads indicated by the design loading.

5.3.1.8.6 Floors constructed under water

Where dewatering of the site is impossible or where inordinate temporary works are required, the dock floor should be designed to be constructed under water, by methods including bottom-opening skips, tremie pipes and grout intrusion of pre-placed aggregate.

Dock floors constructed under water should normally be a gravity design and therefore thick, but are difficult to make watertight.

The design should include an impervious layer of concrete on top of the mass concrete, placed after dewatering. The impervious layer may either be tied to the mass concrete below, or be laid on top of a thin porous concrete layer from which the seepage has to be continuously pumped. The finishing layer of concrete should be used to provide the required accuracy of profile of the dock floor.

5.3.1.9 Joints

The design should allow for initial shrinkage in the concrete of the dock floor by incorporating dowels, joggled joints or other methods together with water bars and seals at joints to give structural continuity. The order of casting bays should be defined by the designer, e.g. by casting from the dock head towards the entrance in an arrowhead formation, rather than chequerboard.

NOTE This facilitates both drainage and cleaning of the bays about to be cast whilst accommodating the necessary time lapse between casting adjacent bays.

The design should include an assessment of the need for expansion joints in dry dock floors. The average temperature of a dock floor is controlled, to some extent, by its mass and the proximity of ground water and tends not to vary appreciably. Expansion joints should, therefore, be used only in exceptional circumstances as the design has to ensure the transfer of loads across the joints and to maintain watertightness.

5.3.1.10 Structural analysis

The structural analysis of a dry dock floor should include the stability of the structure generally, as well as the incidental bending moments and shear forces from ship loading in accordance with **5.3.1.1** to **5.3.1.7** inclusive. The design should incorporate the elasticity of the subsoil or piles, as appropriate, including the potential variation of the elasticity across the dock floor area.

The floors of gravity docks should also be analysed for transverse bending moments generated by net upward water pressure and resulting in the dock floor spanning between the dock walls. The moments should be capable of being resisted by the dock floor acting as an inverted arch or by the introduction of reinforcing steel. The effect of ship loading on gravity docks should be analysed to check that the thickness of such a floor is sufficient to spread the load to the subsoil without reinforcement.

5.3.1.11 Factor of safety of dry dock against flotation

Dry docks designed as gravity structures and those tied down with piles or ground anchors should have an adequate factor of safety against flotation. The limiting condition generally arises with the dry dock empty and sea and/or ground water levels at their highest. The following parameters and their potential variation should be assessed in the selection of the factors of safety:

a) ground water level causing flotation;

b) density of ground water;

c) density of concrete or other materials forming structure;

d) density of soil which can be used to resist uplift;

e) construction tolerances and, therefore, variation in the mass of the structure subject to uplift.

Due to the potentially severe consequences of floor uplift, conservative figures should be adopted for the parameters listed in a) to e), to calculate the total mass resisting uplift and to compare that with the total uplift force. The factor of safety calculated in this way should be not less than 1.2.

Semi-probabilistic limit state methods should not be used to assess the factor of safety.

During the detailed design and then later during construction, checks should be made that the parameters used in the initial calculations, including the densities of concrete, ground water and soil, remain valid in order to verify that the factor of safety is achieved.

The contribution made by prestressed ground anchors in calculating the factor of safety should be conservatively assessed. The contribution should be limited to 0.75 times the load in stranded cable anchorages and 0.85 times the load in solid rod anchorages. Normal allowances for corrosion and creep, etc. should also be included.

5.3.1.12 Ground improvement

The bearing capacity of poor ground at subfloor level can, in some cases, be improved by ground improvement methods, and hence the appropriateness of carrying out ground improvement for docks should be assessed where underfloor drainage is envisaged.

NOTE This is because such a permanent drainage scheme can itself cause shrinkage of some soils with the consequent risk of long-term settlement of the floor. Under those conditions, ground improvement is unlikely to prove appropriate.

The viability of the removal of the soft material and replacement with a suitable granular material should be assessed where the soft layer is of limited depth overlying a stronger soil.

In areas where timber is readily available, the viability of driving of timber piles at close centres to stiffen the ground should be assessed. Timber in saturated ground is normally expected to remain in good condition, but care should be taken to prevent the tops of the piles drying out.

Vibration methods or dynamic methods of ground improvement are theoretically possible, but acceptability of the impact on the project delivery programme for these processes should be assessed, since the work has to be carried out in a deep, open excavation before adjacent permanent work is carried out.

5.3.2 Design of dry dock walls

5.3.2.1 General

Dry dock walls should be able to carry safely all loads to which they are subjected, and should be so shaped as to suit the services and equipment which might be carried on the walls.

Concrete and steel structures should be analysed and designed as described in BS EN 1992 and BS EN 1993, respectively.

The walls form part of the overall structure of the dock and their design should therefore not be undertaken in isolation, except during the temporary construction stage when the dock floor might not yet be constructed.

The range of types of dock wall should be assessed to select the most appropriate for the full range of design parameters.

Walls should be designed in accordance with BS 6349-2.

5.3.2.2 Horizontal loads on walls

Dry dock walls should be able to withstand the worst combination of loading that can apply at any given time.

The loadings that should be taken into account include, but are not limited to, the following:

- earth pressure, including surcharge effects;
- ground water pressure;
- ship hauling gear loading;
- dock arm loading;

- dockside bollard loading;
- crane surge loading;
- access tower loading;
- seismic loading.

5.3.2.3 Vertical loads on walls

Dry dock walls should be capable of withstanding the worst combination of loading that can apply at any given time.

The loadings that should be taken into account include, but are not limited to, the following:

- surcharge loading;
- crane loading;
- dock arm loading;
- access tower loading;
- soil;
- ground water;
- water in the dock;
- seismic loading.

5.3.2.4 Types of dock wall

5.3.2.4.1 Gravity dry dock walls

*COMMENTARY ON **5.3.2.4.1***

Gravity dock walls rely on their own weight to overcome all loading to which they are subjected. The majority of gravity dock walls of modern design are constructed with in situ mass, or partially reinforced, concrete.

The dry dock construction sequence should be planned to obviate, where practicable, critical design cases for gravity dock walls.

NOTE For example, the dock floor might not be constructed and resistance to sliding might not be sufficient temporarily when the ground is excavated for the floor construction.

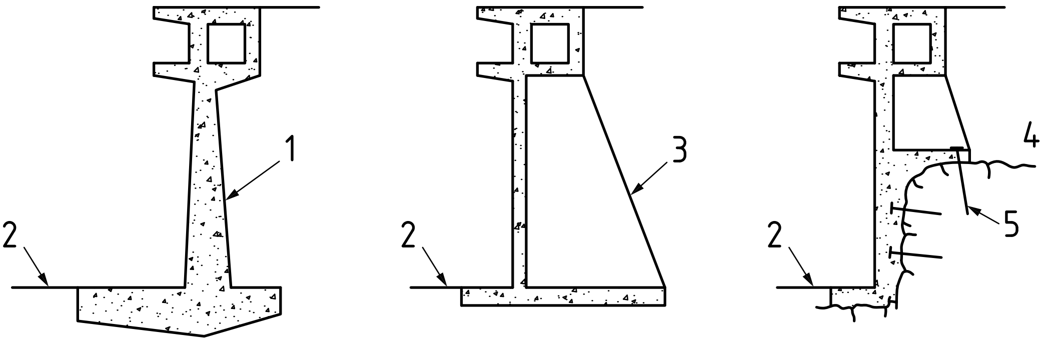
5.3.2.4.2 Reinforced concrete walls

The full range of reinforced concrete options for dock walls should be assessed, from simple cantilever construction to relatively thin walls spanning between counterforts with base slabs utilizing the mass of backfill for stability (see Figure 10). In suitable conditions, the wall might be tied to a rock formation.

The integration of the wall with part of the dock floor should be assessed, forming a toe to the wall. The possibility of this design producing high bearing pressure under the toe of the wall should be taken into account and appropriate measures, such as piling, introduced.

Account should be taken of the alternate wet and dry states of the dry dock, which produce severe conditions for the reinforced concrete of the dock wall, especially where sea water is usually present. The quality of the concrete and the cover to reinforcement should be carefully controlled to provide high performance resistance to corrosion of the reinforcement.

Figure 10 **Types of dry dock wall construction in reinforced concrete**



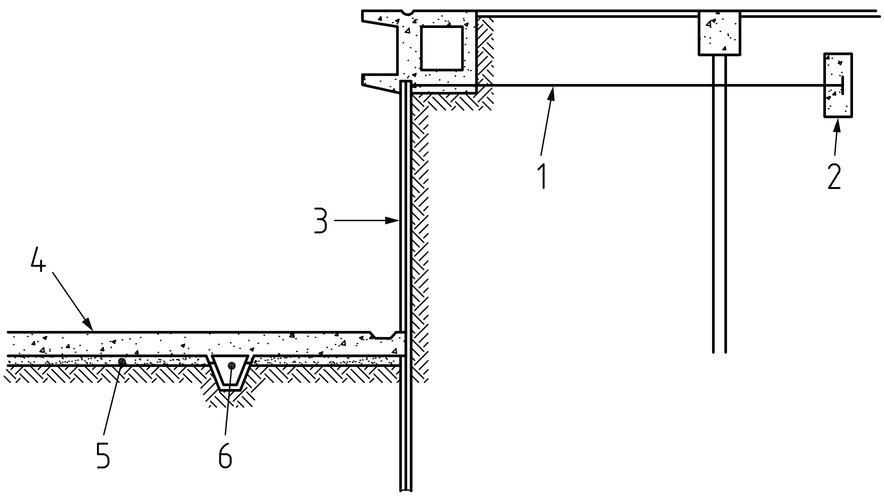
Key

1 Cantilever
2 Dock floor
3 Counterfort
4 Rock
5 Anchorages

5.3.2.4.3 Sheet-piled walls

Steel sheet piling can be used successfully for dry dock walls (see Figure 11), but the use of concrete sheet piling for this purpose is not common, and should not normally be used owing to the difficulty of making watertight joints between concrete sheet piles. The resulting relatively flexible structure should be taken into account in the torsional design of the dock cope.

Figure 11 **Sheet-piled dry dock wall with drained dock floor**



Key

1 Tie rods
2 Anchorage
3 Steel sheet piling
4 Dry dock floor
5 Underwater drainage layer with porous drains
6 Underfloor drainage culvert

Where space behind the walls during the construction stage is limited or where ground conditions do not favour an open-cut excavation, the use of steel sheet piles should be adopted if appropriate, as they effectively form part of the temporary works.

NOTE 1 In suitable conditions, steel sheet piling has the advantage that it might be able to terminate in an impervious layer below dock floor level and thus act as a ground water cut-off, permitting an under-drained floor to be provided.

Where ground water is present behind the wall, the sealing of pile clutches can be difficult, and solutions should be developed to solve this problem before pile driving is started.

NOTE 2 A relieving platform to limit the effects of high surcharge loading surrounding the dock and high soil pressures when the dock is empty can be viable in the design of deep docks. Another form of steel sheet-piled wall consists of straight web piling in the form of cells, normally filled with granular material. Various patterns of cells are possible, but the curved face of the piling on the dock face can present difficulties with some details such as dock arm beams and staircases.

Account should be taken of the horizontal deflection associated with sheet-piled or cellular structures when they resist horizontal earth and water loading. The cope superstructure and sensitive components, such as crane tracks, which might possibly be supported by the wall, should not be constructed until the initial horizontal deflection has taken place.

The construction programming implications should be incorporated into the design, as the external ground water pressure might not be present until all the piling for the dock has been completed and a complete water barrier formed.

The design of the joint between the sheet piling and the dock floor should address potential leakage from the dock into the under-drainage system, which has been experienced in some docks when the dock has been filled and the piling has deflected outwards under the reverse pressure of the water in the dock.

The potential corrosion of sheet piling should be incorporated in the design through a combination of:

- regular painting of the exposed face undertaken;
- added thickness of steel as a corrosion sacrificial allowance;
- cathodic protection.

Where necessary there should be a corrosion allowance on the concealed unmaintainable faces of the piling.

A suitable section for the sheet piling should be chosen for driving to a depth of penetration capable of achieving the design requirements.

5.3.2.4.4 Diaphragm walls

Diaphragm walling for dock wall construction should be adopted where a combination of the following features are of particular advantage and where ground conditions permit:

a) the installation can take place from ground level negating open excavation;

b) the construction process provides a continuous record of the actual soils along the line of the wall verifying the ground conditions adopted for the design;

c) the depth of the wall can be extended to terminate in impervious layers below dock floor level and hence form the ground water cut-off for an under-drained dock floor;

d) the need for anchorages or ties might be eliminated by the use of a stiff plan section such as a T-shape.

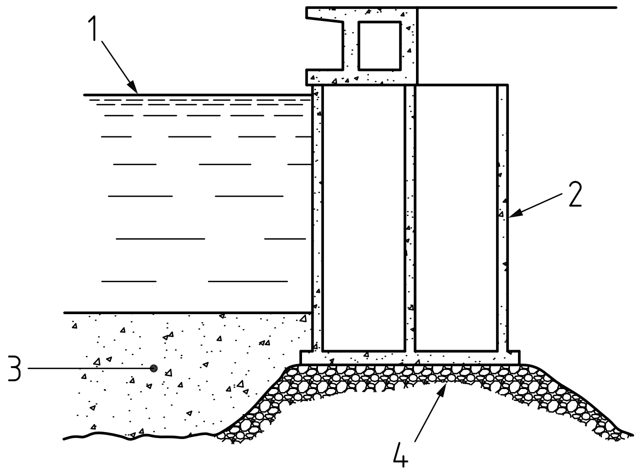
Where the constructed rough face of the diaphragm wall exposed within the dry dock is unacceptable for aesthetic or operational reasons, a high quality in situ finish should be designed and an adequate space allowed for in the initial design. A water-bar should be provided between diaphragm wall panels to reduce ground water leakage into the dock.

5.3.2.4.5 Caissons forming dry dock walls

Reinforced concrete caissons should be designed as a form of construction for dry dock walls where the initial dewatering of the site is difficult or impossible.

NOTE The caissons can be constructed in a nearby dry dock, floating dock, shiplift, or slipway, and then floated to site and sunk on to prepared foundations which consist, usually, of a levelled stone bed. (See Figure 12.)

Figure 12 **Caissons forming dry dock walls**



Key

1 Water level

2 Caisson sunk on rock bed

3 Concrete dock floor – poured underwater

4 Rock fill

Provision should be made in the design for inaccuracies in the placing of the caissons.

All super-structure work above sea level should be formed after the caissons have been bedded and subjected to the majority of the horizontal pressures which can cause movement.

The design should incorporate the construction stages required to maintain stability until the dock floor has been constructed and the final permanent design case achieved.

Caissons should be used where the dock is to be constructed in deep water and where the foundation material is hard and relatively impervious and an under-drained floor can be provided. The caissons, in this case, form a cofferdam that encloses the site, and great care should be taken to form the seal under the caissons. Precision dredging or grouting of the bedding of the caisson should, if necessary, be undertaken before dewatering. In general, the use of temporary cofferdams with all permanent dock structures being built in the dry should be fully investigated before resorting to the use of floating caissons for dock walls.

5.3.2.4.6 Soil or rock slope walls

*COMMENTARY ON **5.3.2.4.6***

Subject to appropriate site conditions and user requirements, the perimeters of dry docks can be formed without structurally defined walls. Dry docks of this type can be suited to the construction of oil drilling rigs, which are often approximately square in plan. This type of construction normally shows considerable construction saving when compared with docks with vertical walls. In particular, the cranage associated with rig building might be more effectively located on the dock floor than as dockside travelling cranes. The ship handling equipment, travelling stages, dock arms, etc. usually carried on dock walls are not normally appropriate in this case.

The life of a sloping face is likely to be limited, even if an extensive drainage and filter system is introduced. The alternate dewatering and flooding of the surrounding soil produces extremely onerous conditions for any such system. However, the construction savings might make such a scheme viable for the period for which the dock is required.

In suitable rock conditions, and with appropriate treatment where necessary, an exposed rock wall can have an indefinite life and can be used for dry docks designed for all purposes.

The sides of dry docks without walls should be designed as slopes to suit the safe angle of repose of the ground. They may be vertical or near vertical if suitable rock formations are present.

The profiles of unfaced sides of docks built wholly in rock cannot be defined without a detailed study of the rock structure at each point along the length of wall. It is possible that, due to inclined bedding planes, the safe profile will differ on the various sides of the dock. Rock bolting or other measures to secure the face should be applied to produce a relatively constant profile if required.

For sloping sides in soft or granular soils, the design should incorporate means of preventing slips forming during the dewatering process. A drainage and filter system should normally be provided. The design should incorporate the effects of relatively rapid draw down during dewatering.

5.3.2.4.7 Combinations of wall design

The types of wall described in **5.3.2.4.1** to **5.3.2.4.5** inclusive can be combined with exposed rock faces, where appropriate, to produce an overall efficient structure. Since the exact profiles of the rock and its condition are very difficult to establish until excavation is undertaken and an inspection of the rock face is made, the design of the superstructure above the rock should be such that it can be adjusted quickly to suit changes in the exposed rock profile.

Other combinations of various dock wall designs can be made and it should not be assumed that the design of one side wall of the dock is necessarily appropriate to the other, if the site conditions are different.

5.3.3 Design of pumphouse

5.3.3.1 Pumphouse arrangement

The arrangements for dewatering the dry dock are crucial to its operation and should be agreed with the dock operator as early as possible.

The pumphouse should be arranged such that all required equipment can be accommodated with suitable space allowed for access. Sufficient space should be allowed to install, inspect, operate, maintain and remove each piece of equipment.

A means of lifting each component should be determined. Where components are too heavy to lift safely by hand, overhead travelling cranes or monorail/underhung cranes should be provided and their requirements incorporated into the building design. Crane coverage should allow the lifting of heavy components directly above their centre of gravity. Adequately sized and located hatches should be incorporated into the building roof/cope level to enable components and equipment to be lifted in and out of the building using either the dockside cranes or mobile cranes. Areas where components can be laid down whilst being transferred from one crane to another should be provided beneath the hatches.

NOTE 1 It is beneficial if these areas can also be used for repair work when necessary.

Where available to the designers, 3D computer-aided drafting should be used, as this brings many benefits, such as allowing easier assessment of whether the proposed layout provides adequate access to the required areas and identifying clashes in piping and electrical systems.

The design of the piping systems is often complex as there might be multiple systems occupying a limited space. The number of bends and changes of direction should be minimized. Priority should be given to providing access to serviceable components such as valves, pumps, motors, strainers and flanges. Isolation valves should be provided where practicable, to enable serviceable components to be removed for maintenance or repair (combined with the use of blank flanges) and also to isolate piping systems in case of leakage.

It is likely that the exact size and layout of equipment will not be known at the beginning of the design stage. If this is the case then a staged design process should be adopted to allow time for consultation and liaison with the various designers and client team as the design develops. During procurement and installation, alternative models of differing dimensions might be introduced, so generous space allowances should be incorporated.

When designing the access into and around the pumphouse, account should be taken of the numbers of personnel who are expected to use the building, and of the need to move tools and equipment within the building.

Slopes or steps should be the primary means of moving between levels. Ladders should be avoided where possible, except where provided for emergency access/escape. Lifts are also a good means of moving between levels, but should not be used where there is a risk of flooding unless fail-safe measures are incorporated to prevent personnel from becoming trapped.

The design of the building should include features and materials to help protect against fire and the spread of fire, and also to limit the extent of a flood incident. Emergency escape routes should be provided.

An assessment should be made of likelihood of the need to increase the dewatering system capability, which can become necessary if the dry dock function is changed, for example, from shipbuilding to ship repairing. If this is deemed to be sufficiently likely, the dimensions of the room, the piping design, the electrical supply, the control system and the ventilation system should be able to accommodate the additional equipment necessary. Similar provision should be made if it is likely that the pumphouse will need to be modified to house other additional systems and equipment in the future.

Equipment which should normally be included in the pumphouse design includes:

- pumping equipment (see **5.4.10.1**);
- dock filling valves;
- penstocks;

- gate winches;
- pipework and valves;
- electrical equipment;
- control equipment;
- cable and cable containment infrastructure;
- fire detection and alarm equipment;
- fire-fighting system;
- lighting, including emergency lighting;
- flood detection equipment;
- ventilation equipment (also air conditioning equipment where required).

NOTE 2 Hydraulic power units are also sometimes located in the pumphouse when this provides a convenient location. Depending on the layout of the shipyard, it might also be convenient to site other equipment in the pumphouse.

5.3.3.2 Design of dry dock sump

A large sump, in which the main dewatering pumps' suctions are located, should be provided below dock floor level.

The drainage pumps' sump invert level should be deep enough to allow the drainage pumps to empty completely the main dewatering pumps' sump, thus enabling safer and more convenient access into the sump.

The arrangement of culverts, ducts or channels leading to the sump(s) should be designed such that water can flow from the dock floor to the sump(s) as smoothly and quickly as possible, to prevent starvation of the pumps towards the end of the pumping operation. The sump and channels should be designed such that vortices are not induced and air entrapment is prevented. Specialist services should be used where necessary to undertake computer and physical modelling of the pumps' inlet flow path.

Where multiple pumps draw water from a common sump, baffles should be incorporated into the design.

To determine the sump invert levels, the following parameters should be taken into account:

- the lowest required dock water level;
- the selected pump's dimensions and installation requirements;
- the selected pump's characteristics from the manufacturer's recommendations, i.e. net positive suction head required.

When it is not possible to make the final pump selection before setting the invert level, the characteristics of a number of suitable pumps should be investigated and the level should be set to suit the worst case (lowest invert level).

The entry to the dock sump and culvert should be protected with suitable grids or screens to prevent large debris entering the intakes and damaging the pumps.

Bar screens are recommended for this purpose and should have a clearance between the bars of 40 mm to 50 mm. In cases where a wider bar spacing is required, a secondary mesh should be provided, which can either be removed for cleaning or be easily replaced. Secondary meshes should be constructed in sections and secured in place by a simple retaining system, to prevent displacement if reverse flows occur after pumps are stopped, but allowing easy removal for maintenance purposes. An adequate screen area should be provided to prevent starvation of the pumps in the event of parts of the screen being fouled. A trap should be provided to restrict the entry of shot-blast and other waste particles into the pumps.

5.3.3.3 Design of discharge system

An evaluation should be made of the advantages and risks associated with discharging each individual pump through a siphon instead of over a weir in order to improve the pumping efficiency and power consumption. Where a siphon system is used, each siphon should be fitted with a siphon breaker valve which de-primes the siphon to prevent backflow when pumping ceases.

NOTE 1 Siphon breaker valves can be either mechanically or electrically operated. Mechanical types utilize a paddle, which is located in the flow of water and works against a spring or gravity, to maintain the air valve in a closed state. Electrically operated types offer a more sophisticated alternative which can be connected to the control system more readily. They usually employ a solenoid valve to keep the air valve closed and the design means there are no moving parts exposed to the flow of water.

The siphon breaker valve, if used, should be located well above the maximum anticipated water level.

Where silt build-up on the seaward side of the dock gates is anticipated, the discharge from one or more of the main pumps should be directed across the apron in front of the dock gate to disperse silt.

*NOTE 2 Details of pumps are given in **5.4.10**.*

5.3.3.4 Control and sequencing of dewatering and drainage pumps

*COMMENTARY ON **5.3.3.4***

During dewatering, a vessel needs to be located on the keel blocks in accordance with the vessel docking plan. Failure to locate the vessel accurately could result in its damage. Accurate positioning of the vessel generally requires the dewatering sequence to be stopped at strategic vessel draught levels while visual inspections are carried out. It is also necessary to provide a reduced dewatering rate as the vessel is seated (either by varying the pump speed or by reducing the number of dewatering pumps running).

The control system and associated operator interface (control console) and the method of motor starting should provide the necessary features to enable the operator to control the pumps adequately.

NOTE This generally consists of an emergency stop pushbutton, individual pump start and stop pushbuttons and confirmation (indicators) of the pumps that are currently running or stopped.

The control console should display the current dock water level. The mimic of the control console user interface should clearly state the dock floor and sill levels. Sea level instrumentation and indication should also be provided as a reference for the operator.

In order to optimize the dewatering time, a sequential start-up of all pumps should be provided which can be selected during the initial stages of dewatering.

In all cases there should be interlocks to prevent the pumps from operating out of their designed operating head range (implemented by water level measurement instrumentation set to effect pump stopping at pre-determined levels). Pump protection should also be implemented, which, depending on the type of pumps selected and manufactured, could include:

- motor overload (from motor starter);
- vibration;
- high temperature (winding and bearing);
- low water suction level or pressure;
- lubrication system failure;
- moisture detected (submersible pump type).

Starting and stopping of large pumps should be sequential to minimize the potential for voltage disruptions. Sequential stopping should also be provided to prevent excessive hydraulic fluctuations in the dewatering culvert and sump.

The dewatering pumps are usually the largest of the pumps in the pumphouse, and should be selected and designed so that they can be used over as large a range as possible to reduce the dewatering time. The smaller drainage pumps should be used to complete the removal of water in the dock and the culvert/sump. The dewatering and drainage pumps should be selected to operate over the desired head range with a level of overlap.

The reliability of the pumping system should be sufficient to reduce the probability of system failure, which could result in the pumps being run outside their operating range, leading to pump damage.

The method of starting the motor should be selected in consultation with the electrical supply engineers and pump supplier.

Pump emergency stop pushbuttons should be provided as a minimum at each control location, at the pump motor control centre and adjacent to each pump (where possible).

The control system and motor starters should be sufficiently reliable so as to limit the likelihood of damage occurring to the pumps due to running dry. Notwithstanding this, there should also be a level of redundancy of components. For example, it is likely that water level switches will need to be duplicated.

5.3.3.5 Precautions against accidental flooding of pumphouse

Precautionary measures should be incorporated to guard against accidental flooding of the pumphouse. All pipes penetrating the pumphouse walls should be fitted with puddle flanges and valves should be fitted directly after the entry.

Valves should be fitted on the suction side of pumps to enable them to be removed for maintenance.

Where practicable and where space and financial provisions allow, the pumphouse should be arranged to limit the extent of a flood.

NOTE This could consist of dividing the pumphouse in half or siting the equipment in a number of rooms designed so as to prevent flood water from reaching all the equipment (or at least until it had overtopped a certain level).

Sump drainage pumps should be provided to deal with water accumulations from small leaks.

5.3.4 Piping systems

5.3.4.1 Calculations

As part of the piping systems design process, the following calculations should be undertaken:

- required working pressures;
- pressures encountered under fault conditions;
- relief valve pressures;
- maximum flow rates;
- pressure drops.

Water hammer calculations and pipe stress analysis should also be undertaken where deemed necessary.

Calculations should be repeated for different variations until the optimum solution is found.

5.3.4.2 Drawings

The following drawings should be produced during the design process in order to convey essential information to other designers and stakeholders, to prevent design clashes and for the orthographic drawings to be developed into construction drawings:

- process flow;
- isometric – as a minimum, simplified representations should be prepared (showing pipes as single lines; components as symbols) which include component references, orientation of piping, bends, supports and components and piping lengths between components;
- orthographic – general arrangement and detail drawings.

Where available to the designer, 3D computer-aided drafting should be used.

5.3.4.3 Piping routing

Piping should be located to provide the best compromise between the following factors:

- operational efficiency;
- ease of construction and installation of other components;
- routine and emergency access and egress to/from the pumphouse;
- access for operation, inspection and maintenance;
- provision for future expansion if deemed likely;
- siting to protect from mechanical damage;
- future decommissioning and demolition.

Where required, pipe bridges, gantries and access platforms should be provided.

5.3.4.4 Material selection

The selection of materials for piping and fittings should take the following factors into account:

- the medium being transported and its effect on the proposed piping material (the medium is assumed to be seawater, fresh water or contaminated water for pumphouse systems);

- temperature extremes of the medium, both high and low, including secondary effects such as risk of ice formation;
- operating speed of the medium;
- presence of debris or particles in the medium;
- design life;
- resistance to internal and external corrosion;
- normal operating and relief/fault pressures;
- preferred jointing methods;
- resistance to erosion;
- resistance to mechanical damage;
- resistance to fire;
- resistance to ultraviolet radiation (if exposed).

Seawater can cause significant corrosion, particularly when at elevated temperatures and when salinity levels are high, e.g. in the Arabian Gulf. If there is doubt over the water's likelihood to cause corrosion, a water analysis should be conducted, and the working temperature should be determined and taken into account.

5.3.4.5 Design of fire and ballast pump suction intakes

The entry to the ballast and fire pump suction mains (and cooling water mains if seawater is used) should be placed on the seaward side of the dock gate, or seaward facing wall. It should be well above the sea bed and at least 1 m below lowest water level (taking maximum wave effects into account). This entry should generally be protected by a bar screen with 25 mm to 30 mm clearance between the bars. This screen can, in some cases, have a wider bar spacing with a secondary mesh, and should either be positioned to be visible and accessible for hand raking from above, or be easily removable for cleaning.

Anti-fouling measures to prevent build-ups of marine growth should be provided where systems are anticipated to be used infrequently.

5.3.5 Filling system for dry dock

5.3.5.1 General

Where the required filling times permit, filling should be carried out by gravity alone.

Where this is not achievable owing to other design constraints, pumps should be provided to augment filling, with the attendant greater complexity of control and piping systems, higher energy consumption and higher maintenance.

The factors which should be taken into account to optimize the filling system design include:

- the location of the intakes and valves;
- the type and size of valves;
- the number of valves;
- the arrangement of culverts (if any);
- pump selection and siting (if required).

5.3.5.2 Filling near entrance

The location of the intakes and the filling valves should normally be near the dry dock entrance.

NOTE This usually presents the simplest solution, as the culvert system is short and can either enter through the main sump or be clear of the pumphouse and enter the dock independently.

However, with this arrangement, if the filling water is silt-laden, material can be deposited at the head of the dock during the filling process. This material is unlikely to be fully dispersed during the subsequent dewatering operation. This has the disadvantage that the dock is not self-cleansing resulting in a slippery and dirty dock floor. In this situation, a means of sluicing the floor should be provided.

5.3.5.3 Filling near head wall

Where the configuration of the site permits, efficient filling of the dry dock from a point near the head wall should be adopted.

NOTE If this is done and the pumphouse is near the dock entrance, a self-cleansing system will be developed such that the dock floor remains clear of sediment.

5.3.5.4 Filling through culverts

The majority of dry docks are filled through a simple single culvert from each filling valve direct into the dock. In these cases, care should be taken to prevent the sudden inflow of water from overturning the keel and bilge blocks on the dock floor. This should be achieved by diverting the flow, restraining the blocks or by directing the flow through a culvert system with numerous discharges into the dock.

NOTE This arrangement produces a smoother flow into the dock with less risk of tipping of the keel and bilge blocks. These filling culverts can be arranged along the length of the dock, but are more commonly located across the width of the dock behind the sill.

The velocity of flow in culverts should be limited to about 4 m/s to minimize erosion.

5.3.5.5 Filling through dock gate

Filling through the dock gate should be achieved by installing valves within the gate structure. The valves should be arranged such that an external temporary blanking plate can be fitted by divers to enable valve maintenance with the dock in operation. The locations of the valves within the gate should be selected to minimize the risk of keel and bilge block movement during filling.

5.3.5.6 Control of filling

When the filling rate needs to be adjusted, a control system should be provided to control the gradual or staged opening of the filling valves.

NOTE 1 A control system is preferred to allowing the operator to have full manual control of the valves, which would not prevent unrestricted opening (in the case of operator error).

NOTE 2 The sophistication of the control system could range from a system which features a number of predetermined automatic filling sequences, to a system which relies more heavily on operator intervention whilst still providing some control constraints.

5.3.5.7 Types of filling valve

The following types of valve for filling dry docks should be evaluated in conjunction with the requisite civil engineering works, to optimize the design.

a) Sluice or penstock valves should be power-operated. Single faced penstocks should be used only where impounding of the dock is not required or an accidental off-seating pressure head cannot occur.

b) Butterfly valves are suitable for use in gates and can be powered or hand operated. They can also be used when fitted into concrete culverts.

c) Equilibrium valves are simple to operate and reliable with the advantage of very large flow capacity.

Two valves should be provided as a minimum for each dock, so that one can be removed or taken out of service for maintenance when required. The valves should be powered, which allows operation to be controlled from a central control room.

5.3.5.8 Safety precautions related to filling of dry dock

Precautions should be taken to avoid the inadvertent filling of a dock before personnel are clear of the dock floor.

5.3.6 Design of entrance

The entrance to a dry dock comprising the sill and quoins should be able to safely carry all loads to which they are subjected. A robust structure should be provided, as the entrance to the dry dock is potentially the most vulnerable to an accidental impact from a ship entering the dock.

The loadings which should be taken into account include the following:

a) dock gate loading;

b) earth pressures including surcharge effects;

c) ground water pressures.

The risks and consequences of extreme/accidental conditions, such as blockage of the under-floor drainage system (if provided), should be evaluated and taken into account.

5.4 Equipment in dry docks

5.4.1 Dock arms for dry docks

5.4.1.1 Components

Ship repair dry docks should be fitted with at least one dock arm on each side of the dock to provide easy access to any part of the ship's sides and greatly speed up the process of cleaning and painting.

The design of the area of the dry dock in which the dock arm is accommodated should include space for the following items:

- a carriage, which is usually self-propelled, running on rails and/or wheels along the face of the dock wall;
- a hinged cantilever arm (boom) fitted to the carriage, at the end of which is an operating platform which carries the cleaning and painting equipment, together with an operator, if necessary. The arms are capable of slewing and luffing movements and can traverse horizontally along the length of the dock wall, thus able to position the platform adjacent to any part of the ship's side;

- a control cabin, which is located on the carriage, providing good visibility such that all possible positions of the dock arm platform can be viewed. During traversing along the dock, the operator should be able to see any obstructions that might impair the movement of or clash with the dock arm structure.

During operation, the dock arm should conform to the following recommendations.

- Traverse movement along the dock wall should be accompanied with automatic visual and audible alarm systems to alert personnel in the adjacent area of the impending movement of the dock arm. These should operate a few seconds before movement can occur, and should continue while the dock arm is moving.
- The dock arm design should not interfere with any of the mooring operations, either by fouling the vessel or by interfering with the hauling-in/rendering of winch lines.
- The dock arm carriage should be provided with a means of preventing the dock arm from jumping off the upper rail.
- The upper rail carrying the dock arm carriage should be arranged with two running surfaces, to which are transmitted the vertical and horizontal loads from the upper carriage wheels.
- The lower carriage wheels should be arranged with only one running surface, to which are transmitted the horizontal loads from the lower carriage wheels. The lower carriage wheels should run either on a lower rail or directly on the hardened surface of the dock wall.
- The upper rail carrying the dock arm carriage should be located above water level so that the driving mechanism of the carriage always remains in the dry when the dock is filled.

5.4.1.2 Power

Dock arms should be electric powered or diesel powered.

NOTE The two systems are described below. Each system has its advantages and disadvantages.

- *Electric powered dock arms utilize the site-wide power distribution network and generally run on LV power. The electric motor requires power pick-up from collector rails or flexible power cables situated in an area that can be congested by other dockside services and the track of the ship hauling system.*
- *The use of semi-exposed pick-up rails requires the assessment of various inherent operating hazards. Shipyards frequently use piped welding gas distribution points at the dock wall interface and can require hazardous area classification which would potentially prohibit the close proximity of the potential ignition source.*
- *Diesel-powered dock arms mitigate the problem of igniting hazardous gases as the engines can be sited away from the hazardous zones. In this option, the integrated diesel engine/generator provides power for the drive motors and also provides power for any electrical equipment on the platform. Diesel engines require fuel storage and provision for replenishment.*
- *In both options it is common to use hydraulic actuators to control the slewing movement of the arm (horizontal rotation of the arm), luffing elevation of the platform and provide positioning along the dock wall.*

Whichever system is used to control the motion of the dock arm and platform, it should be able to perform a controlled and gradual stop in the event that power is lost. The system should be capable of being controlled from both the cabin and the platform itself.

Hydraulic fluids which have good biodegradability and low-toxicity characteristics should be used.

5.4.1.3 Movement

The carriage should have as a minimum the normal control functions associated with a travelling crane designed for lifting personnel, such as drive braking, operational braking and a parking brake, all of which should be controllable from both the carriage and the platform.

Accelerations and decelerations should be limited and smooth. Emergency braking should also be of limited power to avoid the risk of personnel being thrown from the operating platform.

The dock arm should incorporate a self-levelling system for the platform, so that at any angle of incline of the boom, the platform is always maintained in a horizontal orientation. The platform should be fitted with safety rails and toe plates.

Means to prevent the platform, boom or carriage from moving into an unsafe position should be provided. When practicable this should be designed out or prevented by fixed mechanical stops; where this cannot be achieved the control system should limit and/or provide audible or visible warnings depending on the level of hazard.

In the event of power failure, the dock arm should provide safe emergency egress from the platform along the boom to the dock walls, even when the dock arm is positioned at extreme inclines. Walkways, fall arrest harness rails and handrails should be provided.

5.4.1.4 Platform services

Where high-pressure water jet cleaning equipment is to be used on the platform, a low pressure water supply should be provided, supplied via flexible hoses from either the dockside or the dock floor.

NOTE 1 Facilities to support the hoses from the dock arms are not usually provided, and the hoses generally have to be moved manually and reconnected before the dock arm is moved a significant distance.

NOTE 2 Where shot blasting is to be carried out from the platform, flexible hoses are usually connected to the air mains on the dockside or dock floor in a similar fashion to provide compressed air.

It is common for the dockside area lighting to be used as the source of illumination for work which is being carried out from the platform at night. However, the need for additional task lighting fitted to the boom or platform should be evaluated at the design stage.

5.4.1.5 Maintenance

When not in use, a dock arm is normally parked with the platform away from the dock over the dock wall where it cannot interfere with vessel movements, mooring lines, or hauling/rendering operations. Where practicable, a mobile maintenance stand should be provided to support the platform and boom and allow maintenance operations to be carried out more easily.

NOTE Where provided, this is expected to enable hoses and hydraulic cylinders to be changed by providing support to the dock arm platform.

5.4.2 Ship hauling systems for dry docks

Ship repair docks should be equipped with ship hauling systems which, combined with tug assistance, control the ships entering and leaving the dry dock.

The complexity of the hauling in systems should be determined according to the dock size and expected rope forces.

In large ship repair docks a hauling in system should be adopted, comprising on each side of the dock:

a) winches (with adjustable tension control);

b) wire rope;

c) trolleys (or mules);

d) rails along the cope edge.

In smaller docks, more basic systems should be provided comprising:

- capstans;
- fairleads;
- bollards;
- ropes.

The winch capacities should be in the range from 10 t to 25 t.

NOTE 1 To accommodate the required length of the hauling-in ropes, multi-layer winches are required. When multi-layer drums are used with fixed speed motors, the rope speed and line-pull varies as the number of layers changes. It is therefore difficult to maintain the same pulling force and speed along the length of the dock.

The design of the system should accommodate the variable angular pull exerted on the trolley whereby the high upward and outward component is resisted by the trolley and in turn the rails and the dock wall. The design of rails is therefore complex, often requiring up to six running surfaces. The structure should be capable of resisting the various combinations of loading.

The rails along the cope on each side of the dock should extend approximately 10 m beyond the face of the head wall of the dock, to enable the ship to be hauled all the way to the dock head.

Systems should be of either the two-winch or the four-winch design.

NOTE 2 The two-winch system employs two winches situated at the dock head, each with one trolley. The trolleys are pulled longitudinally by the winches, usually by a wire rope, which in some cases passes through a sheave on the trolley and onto the ship, and in others is attached directly to the trolley with a separate rope taken from the trolley to the ship, the latter arrangement giving more positive control of the vessel. During the docking manoeuvre the vessel usually enters the dock bow first and the stern of the vessel is controlled by tugs. The four-winch system employs two winches at the head and two at the entrance, each with one trolley. Some systems, and the four-winch system in particular, require other refinements, such as the ability to hold or lock trolleys at defined positions so that the ship can be accurately located over the blocks.

NOTE 3 Usually, the tractive force to tow the ship out of the dock is provided by tugs, the trolleys at the bow being used to hold the ship on the dock centre line (rendering).

Particular attention should be paid to the very high loads that can be induced if the trolleys are intended to be locked in position.

NOTE 4 In this case the loads in the ropes controlling the vessel are no longer related to the slipping load of the winch. In consequence very large loads can be induced.

In some systems the winches at the entrance are used to control the ship as it is towed in by the winches at the head. This can cause a sudden application of loads, which should be allowed for in the design.

Another alternative which should be evaluated is that of designing the winches at the entrance to operate through fixed fairleads located on the cope without the use of trolleys.

NOTE 5 Control of the forward winches is often performed by one operator situated in a cabin on the dock centre line at the dock head. Control of both of the entrance winches is normally done at a single point at one side of the entrance.

To assist the winch operators in controlling the alignment of the vessel, distance markers on the side of the dock should be provided so that the position of each hauling in trolley can be judged more easily.

NOTE 6 There are other types of ship hauling systems such as the use of a ship leading girder, which spans the dock and is attached to the ship's bow. Hinged rigid arms on tracks at the copes with suction pads to connect to the side of the ship have also been used.

The system to be used should be selected as early as possible in a new project, to enable the dock designers to incorporate a suitable track at the dock cope, and to integrate it with the other installations.

5.4.3 Typical cranage arrangements

Shipbuilding docks generally benefit from being provided with goliath-type gantry cranes. The spans of the goliath cranes should be arranged to be greater than the width of the dock to enable them to pick up prefabricated units of ships, which are delivered to the dockside by multi-wheeled road transporters.

NOTE 1 No detailed indication of crane loading can be given, since the capacities vary greatly depending on the size of shipyard and the type and size of the ships to be built. Goliath cranes can range up to 3 000 t capacity with heights of lift above the cope up to 115 m.

Shipbuilding docks should also be equipped with jib cranes, which are usually arranged to operate independently of the goliath cranes and thus require separate tracks with adequate clearances to permit the cranes to pass each other. The maximum lift of the jib cranes should be arranged to be at a radius extending at least to the dock centre line, with an ancillary lift radius to the far side of the widest planned ship.

Ship repair docks should be equipped with level luffing jib cranes, the capacities of which can range between 5 t and 100 t depending upon the size of the dock and the type of work undertaken by the shipyard. The maximum lift of a jib crane should be arranged to extend at least to the dock centre line with auxiliary lifts at greater radii. In general, one crane should be provided which is able to plumb the dock centre line and to lift the largest unit in the vessels that can use the dock.

NOTE 2 The unit may be a propeller, rudder or prefabricated element of structure, and lifts of 80 t or more can be required. The installation of dock arms can effectively reduce the work requirements of light dockside cranes by the elimination of staging, etc.

Delivery to the dockside should be made to the required longitudinal position on the ships under construction, in order to keep to a minimum the relatively slow longitudinal movement of the crane carrying the unit.

Owing to the size of the cranes and the type of electrical equipment inside, an assessment of the fire prevention/detection and extinguishing requirements should be undertaken.

5.4.4 Access towers

Ship repair docks and, less commonly, shipbuilding docks should be supplied with towers arranged at strategic locations along the sides of the dock copes to enable safe and convenient access of personnel between the ship and dock cope. Allowance should be made for the towers to be moved to or located at alternative locations along the side of the dock.

Gangways spanning from the tower to the ship should be provided and these should either be detachable and lifted into position by crane, or be permanently attached to the towers and controlled by hydraulic and/or electrical equipment. Where permanently attached, gangways should be capable of being:

- slewed horizontally;
- luffed;
- raised/lowered vertically up the tower.

Means to prevent the gangway from moving into an unsafe position/orientation should be provided. The control system should warn and prevent overloading. In the event of a failure of the control system a fixed mechanical stop should be provided.

5.4.5 Propeller winches

NOTE 1 Propeller winches utilize an arrangement of pulleys and sheaves to allow the axial extraction of the propeller from its shaft, reorientation and then lowering for cleaning, maintenance or replacement.

Propeller winches should either be sited permanently on the cope at the dock gate end of the dock on one side, or on a mobile winch skid anchored to the dock floor.

NOTE 2 The mobile systems might be difficult to site at the dock floor and therefore can sometimes not achieve the hoisting angles required.

Where propeller winches are permanently installed at high level on the dock cope, the hoisting system should be able to achieve a range of inclined angles down to the dock floor/propeller shaft.

NOTE 3 Typically a propeller winch has a load capacity of between 5 t and 10 t. With a combination of fixed swivel type sheaves and temporary block and tackle assemblies, it provides sufficient forces at varying positions to suit a range of vessel types and sizes.

The winch should be able to render out sufficient rope length to reach the opposite side of the dock at floor level and therefore is likely to be a multi-layered winch.

NOTE 4 For the permanently mounted swivel sheaves positioned adjacent to the winch, snatch block type sheaves are preferred to allow easy threading with large ropes.

Winch drive motors are usually electrically powered. Inching control of the winch should be provided to enable accurate assembly and disassembly of the propeller components.

NOTE 5 The winches can be driven by fixed speed, multiple speed or variable speed motors; control over a range of speeds or variable speed control is more convenient as it allows operations to be carried out more quickly.

The position of the control panel for the winch should provide visibility of the dock area and should provide a safe working area for the operator away from the loaded rope.

A decision on the type and location of the winch should be made by the designer at an early stage, as the installation, wire rope route and electrical supply can cause a hindrance to other dock operations.

5.4.6 Capstans

Capstans should be provided to assist the mooring of vessels and floating structures in the dock. Each capstan should have reversible, multiple speeds and inching capability, being driven electronically, pneumatically or hydraulically.

The barrel of the capstan should be of sufficient girth to allow at least three turns of the mooring lines to be wound on, to establish the necessary friction forces to hold the line to the capstan when rotating. A ribbed capstan should be provided to assist with the gripping of large diameter mooring lines, and in some cases can be applied in securing of chains.

As space on the dock cope is usually at a premium, the drive and associated gearbox of the capstan should be mounted beneath the barrel in a recess below cope level so that only the barrel is exposed.

Controls should be sited a safe distance away from the capstan and can be pedestal-mounted or foot pedal-operated (or provided with both).

NOTE Foot pedal controls provide the means for the operator to handle the ropes and simultaneously operate the capstan to establish the line tension and to feed or pay out the line to control the movement of the vessel/floating structure.

Capstans should be provided on both sides of the dock at the dock entrance, mid-way along the dock, and at the head of the dock.

5.4.7 Fairleads

Roller type fairleads should be provided along the dock copes for use with the capstans during docking or undocking operations.

5.4.8 Fendering

Rubber arch rubbing fenders should be provided along the face of the top of the dock side walls to provide some nominal protection to the concrete structure during docking or undocking of a ship.

NOTE 1 It is normal to provide 2 m long rubbing fenders with a projection of 200 mm or 250 mm at 10 m centres along the dock.

A highly energy-absorbent wheel fender, preferably with a sliding axle, should be provided at each side of the entrance to the dry dock to protect against ship impact and to aid docking or undocking.

Fendering on lead-in structures (see **5.2.2**) should be provided and should be arranged to allow straight alignment of vessels for entering and exiting the dry dock.

NOTE 2 The sizing of fendering on lead-in structures might need to be designed for larger or deeper draught vessels as they might be de-ballasted at the lead-in berth after berthing, but before entry into the dock.

Fendering should be designed in accordance with BS 6349-4.

5.4.9 Bollards

Bollards should be provided at regular intervals (normally 20 m or 25 m) along the dock copes to aid with the docking or undocking of a ship.

The capacity of bollards should be assessed from a suitable mooring analysis, taking into account any limiting dry dock operational conditions. The assessment should take into account the recommendations in BS 6349-4.

5.4.10 Dry dock pumps

*COMMENTARY ON **5.4.10***

A number of pumps or sets of pumps are usually located within the dry dock pumphouse, including:

a) main dewatering pumps;

b) dock drainage pumps;

c) underfloor drainage pumps;

d) contaminated water pumps;

e) house drainage pumps.

As the dry dock pumphouse is usually located next to the sea it might also be a convenient location to locate the following sea water system pumps:

1) ballast water pumps;

2) fire pumps;

3) cooling water pumps (cooling water systems can also be fresh water systems).

5.4.10.1 General considerations for pump selection

Rotodynamic pumps (i.e. centrifugal, mixed flow or axial flow types) should be used as these are expected to be adequate for the duty (flow and head) and can efficiently handle the suspended solids. The particular pumps selected should be suitable for handling the type of debris that is likely to be drawn into them, taking into account the type of screens to be adopted.

In the selection of pumps the following factors should be taken into account.

- Either horizontal or vertical lineshaft orientation pumps can be used. There are advantages and disadvantages with each type.
- Horizontal design pumps can be easier to install, inspect, maintain and service because their rotors and internals are more easily accessible. They can be coupled directly to a variety of drivers including electric motors and diesel engines. They can be supplied in either overhung design for low suction pressure service, or in between-bearing design for high suction pressure service. Various nozzle configurations are available to suit the external site piping. They require less headroom but can be more difficult to crane in through a roof hatch than a vertical design pump.
- The disadvantages of horizontal design pumps are that they are required to be located at a deeper level (which incurs addition civil engineering construction for the pumphouse); their maximum allowable operating temperature and working pressures are often lower than that of the vertical design; and they require a larger footprint.
- Vertical design pumps require a smaller footprint and are suitable for installations where the floor area is limited. With a vertical lineshaft pump the impeller setting below the ground can be lowered to increase the site net positive suction head available. They can be suitable for higher temperature service. Due to their radial-split case design, they can be centre line-mounted providing even thermal expansion. They can be suitable for higher pressure service because of their simplified bolting and confined-gasket design.
- The disadvantages of vertical design pumps are that they require more headroom for installation, servicing, and maintenance. They are suitable for direct coupling to electric motors but using other type of drivers, such as engines, requires a right angle gear drive and, possibly, a universal shaft joint and a clutch. Being of an overhang design, their hydraulic axial thrust is more difficult to balance in high suction pressure service.

An assessment should be undertaken to determine the consequences of a full or partial loss of pumping capacity/availability of the system in question. Where a full or partial failure would have significant safety, environmental or commercial consequences, measures to mitigate these consequences should be provided.

NOTE 1 The measures can range from elimination of the resulting hazard through design, through to providing redundancy (by provision of additional pumps, power supplies, etc.) in the pumping system. More than one pump is usually provided in each pumping system, either in a duty-duty or a duty-standby type arrangement. Where very large flows are required, e.g. in large dewatering systems, multiple pumps are often necessary to meet the capacity.

Standby pumps should usually be installed units, although non-installed spare units might be acceptable. The same pump model should be used for different applications where practicable, to reduce the number of different spares which are held.

Liaison with pump suppliers should take place early in the design process, particularly for the larger dewatering pumps, where there are likely to be fewer commercially available solutions available due to the large capacity of the pumps.

It is common for equipment installed in the pumphouse to be subject to humid conditions; the best means of protection from corrosion should be determined.

NOTE 2 This can be achieved through surface protection finishes (paint or metal plating), ventilation, air conditioning, equipment heaters, the use of corrosion-resistant materials or very often a combination of two or more of these measures.

NOTE 3 Where pumps are expected to be stationary in a dry state for long periods, there might be a requirement to provide additional lubrication for the shaft seals and shaft bearings.

5.4.10.2 Main dewatering pumps

The main dewatering pumps usually constitute the largest pieces of equipment located in the pumphouse. When selecting the pumps, factors which should be assessed to determine the optimum solution include:

- ideal head range required for dock and culvert;
- dewatering time required (flow changes with head);
- capacities of commercially available pumps;
- dimensions and weight of the pumps;
- advantages and disadvantages of horizontal versus vertical pumps;
- effects on civil engineering design aspects of pumphouse and culverts;
- pumping efficiency over the head range;
- effect of starting and stopping on the electrical system;
- level of engineering support provided by the manufacturer/supplier;
- maintenance requirements;
- energy consumption (affected by efficiency of pumping system and electricity costs).

Generally, at least two pumps should be used and they should preferably be identical. Each pump should be able to generate the additional head necessary to prime the siphon (where siphons are used) under all conditions (including starting up with the dock level close to the lowest level at which the main dewatering pumps are required to operate).

5.4.10.3 Dry dock drainage pumps

Drainage pumps should have their suctions in a sump connected to the main dewatering pump's sump.

NOTE Drainage pumps remove the remaining water left in the main dewatering pump's sump and culvert when the main dewatering pumps are stopped. They are also used to pump out any other water which enters the sump such as ballast water, rainfall into the dock body, and leakage through the dock floor, walls and gate. If underfloor drainage pumps are not provided then they are also required to deal with the flow from the underfloor pressure relief system.

5.4.10.4 Underfloor drainage pumps

A dock which incorporates an underfloor pressure relief system should be provided with a set of drainage pumps connected to the underfloor drainage culverts.

NOTE The maximum required flow rate for these pumps cannot easily be established until after construction of the dock, when observations of percolation water can be made. If initial estimates prove to be too low, as an interim measure, it might be possible to install portable submersible pumps (i.e. vertical shaft pumps with sealed electric motors) until any deficit in the pumping system is rectified by the installation of additional pumps.

5.4.10.5 Contaminated water pumps

*COMMENTARY ON **5.4.10.5***

When the dock is dewatered and in use, the contaminated water system collects any water from the dock floor. This includes the contaminated water used in blasting and cleaning as well as spillages.

If ballast water from the vessel is to be discharged into the contaminated water system, there might be a requirement to treat this water to prevent the spread of marine organisms.

Contaminated water systems are usually required for ship repair facilities and might also be required for construction facilities.

Pumps should be protected from large debris by the use of screens. Settling pits should be used to collect the majority of the smaller sized debris and the pumps should be capable of handling the remaining grit and debris.

Pump controls should be automatic, on/off, by float switches or similar.

5.4.10.6 House drainage pumps

House drainage pumps should be provided in the pumphouse dry rooms to deal with leakage from pumps or pipework.

Flood alarms should be provided if the rooms are generally unoccupied. Fault detection of pumps should also be monitored at the control room.

5.4.10.7 Ballast pumps

*COMMENTARY ON **5.4.10.7***

Ballast pumps supply ballast water (seawater) to ships in dock through a ballast main. The ballast water system can also serve other areas of the shipyard.

In some shipyards, the ballast main is used to supply auxiliary equipment such as ship cleaning equipment, shipboard coolers, or shipboard air-conditioning plant, at flow rates that are low relative to the ballast pumping duty. If this situation is likely, the pump models/capacities selected might need to be different to cover a range of requirements. Higher pressures, finer filtered water or fresh water might be required for some equipment and processes, which might mean that the use of an additional dedicated system is necessary instead.

During ballasting operations, the flow of water is often throttled by adjusting or closing valves on the vessel. The pump system should therefore be capable of operating with the main shut off for extended periods. Means to accommodate this scenario and prevent overheating should be provided, e.g. by using a relief valve system or by variable speed control of the pump motor.

5.4.10.8 Fire pumps

*COMMENTARY ON **5.4.10.8***

Fire systems are covered by many national and international codes. For preliminary design purposes, the suite of codes and standards published by the National Fire Protection Association and listed on the NFPA website [1] are a suitable minimum standard to adopt. In some countries legislation might dictate which codes are to be followed. Additional requirements might be imposed by local bye-laws or by specific policy of the client or by insurers.

The fire-fighting system should be a dedicated system which is normally maintained in a permanent state of readiness. The main pumps should be either electrically or diesel powered.

NOTE To comply with the high reliability levels required, a combination of the two types of prime movers powering pumps in a duty/standby configuration is common (but not always essential).

The fire-fighting system should not be designed to be used for any other purposes.

Due to the proximity of a plentiful supply, seawater is usually the medium used for fire-fighting; however, to reduce corrosion, the systems should be primed with fresh water where practicable.

The fire main should be kept permanently pressurized using small capacity jockey pumps sized to meet the estimated maximum system leakage (through joints etc.). The starting of the main fire pumps should be automatically initiated by the detection of a significant pressure drop in the system, e.g. caused by opening of a hydrant. The fire pumps should be stopped manually. A means of preventing overheating of the pumps should be provided in case all the hydrants and monitors are closed and the pumps are left running.

The jockey pumps should be under on/off automatic control signalled by low and high pressure switches on the fire main. An air vessel connected to the fire main should be installed to minimize the frequency of jockey pumps starts that are required to maintain the system pressure if small leaks are present.

The materials selected for the fire pumps should be listed as suitable for fire protection duties in accordance with the code which has been selected as the design specification.

The pump capacity should be determined by the requirements of the hydrant system for fighting a worst credible fire envisaged in the fire-fighting strategy. The pump and fire main should be sized to provide the specified pressure at the most remote hydrant/monitor of the system whilst the pumps are delivering maximum flow.

5.4.10.9 Cooling water pumps

*COMMENTARY ON **5.4.10.9***

A system might be required to provide cooling water to equipment on vessels in the dry dock. It might also be required to service other vessels moored around the shipyard and fixed equipment such as compressors located in shoreside compressor houses.

If seawater is used, the dry dock pumphouse might be a convenient location to locate the pumps.

The system and its supply should be designed such that it cannot be starved of water by other systems, as this could lead to overheating of equipment.

5.4.10.10 Pump controls

Pump controls should meet the general recommendations for control systems given in Clause **14**.

Pump protection should be provided by the control system.

NOTE Depending on the pumping application, type of pumps selected and manufacturer, additional protection features could include:

- *motor overload (from motor starter);*
- *vibration;*
- *high temperature (winding and bearing);*
- *low water suction level or pressure;*
- *lubrication system failure;*
- *moisture detected (if submersible pump type).*

The pump control console should provide the operator with the means to control the pumps safely. It should typically include:

- emergency stop pushbutton;
- reset pushbutton;
- start/stop pushbuttons;
- suction and discharge pressures;
- suction and discharge water levels;
- system alarms;
- pump and isolation valve status.

The pumps should also be protected from operating outside their designed operating head range through the implementation of suction level sensors and low level switches.

5.4.11 Keel and bilge blocks for dry docks

*COMMENTARY ON **5.4.11***

The method of supporting ships in a dry dock has undergone various changes over the years. In the past, ships were set down either on a cradle of blocks preset to accommodate the particular shape of the ship or on a line of keel blocks, and then supported by horizontal struts fitted between the side of the ship and the steps or altars of the dock wall. These struts were adjusted as the water level was reduced and then additional blocks were inserted under the bilges after the dock was pumped out.

Various attempts have been made to overcome the nuisance of the horizontal struts and designs of adjustable bilge blocks have been introduced with only limited success, the difficulties being due mainly to maintenance problems.

The majority of ships now have flat-bottomed hulls. For these ships, keel and bilge blocks can be set out in one plane with no requirement for adjustability.

Designs of keel and bilge blocks are various and can involve a wide range of materials, including combinations of hardwood, fabricated steel, concrete, softwood and rubber.

5.4.11.1 Timber blocks

Blocks made wholly of timber should be fully tied down to the floor to prevent flotation.

NOTE Hardwood timber blocks, typically greenheart, oak or elm, have been widely used in many docks in conjunction with expendable softwood capping pieces.

5.4.11.2 Fabricated steel blocks

Fabricated steel blocks can be used, but precautions should be taken against corrosion. The regular immersion in sea water and the high humidity conditions under a ship in dock are extremely conducive to corrosion and continuous maintenance by painting is not easy. Therefore, either a generous corrosion allowance or galvanizing should be provided.

NOTE Fabricated steel has the advantage that it can easily be cut if a block has to be removed under load, and some blocks have been designed with this procedure in mind.

5.4.11.3 Concrete blocks

Concrete has been used extensively for blocks, since it is usually easily obtainable and readily transmits the ship load uniformly to the dock floor. Both hardwood and softwood packing should be used in combination with the concrete to reduce high concentrations of loading which can damage the blocks.

Reinforcement is normally introduced to prevent damage by eccentric loading, but the quality of the concrete and the cover to the reinforcement should be controlled to prevent corrosion of the reinforcement.

5.4.11.4 Capping pieces on blocks

Softwood or rubber cappings should be used on top of blocks as make-up pieces to produce a level plane and to eliminate very high intensities of load, which can otherwise occur if there is an irregularity on the underside of the ship.

The material selection should be made after evaluating the relative advantages and disadvantages.

NOTE Timber is generally selected owing to ease of replacement and modification.

5.4.11.5 Removal of blocks under load

Provision should be made to remove individual keel and bilge blocks so that repair to the ship's plating at that point can be undertaken.

Precautions should be taken to avoid difficulty in the removal of blocks, under load, in the design of the blocks by any of the following means.

a) The blocks can be constructed in the form of folding wedges which can be loosened by driving out the wedge by hammer or jack. This method is particularly applicable to cast iron blocks or other materials on which smooth sliding faces can be formed.

b) Sand boxes can be introduced into the design of the blocks. The blocks can then be lowered by the removal of sand by water jetting. The replacement of the block to its previous position is not possible under load, but it is easily replaced and levelled with the dock dry.

c) The blocks can be removed by jacking combined with the removal of pre-laid packing under the blocks.

d) The blocks can be removed by partial destruction as in the case of fabricated steel blocks, which can be cut and then repaired before re-use.

5.4.11.6 Methods of adjusting bilge blocks

5.4.11.6.1 General

In dry docks in which ships with other than flat bottoms are likely to be accommodated, bilge blocks should be adjustable.

NOTE Adjustment can be achieved by:

a) adjusting the vertical height of the blocks to suit the transverse slope of the dock floor and the rise in the ship's hull; and

b) adjusting the position of the blocks transversely relative to the centre line of the dock so that the blocks are positioned under longitudinal stiffening in the ship's hull.

5.4.11.6.2 Vertical adjustability

Vertical adjustability of bilge blocks should be provided by one of the following means:

a) a wedged shape upper section of the block sliding on an inclined base of the block under the action of a ram or chain;

b) a motorized screw jack (compressed air motor or electric motor). The screw is arranged to take the full load of the block and be self-sustaining. Such systems require a high level of maintenance and some have fallen into disuse for this reason;

c) a direct hydraulic jack, where the load is taken on the hydraulic fluid, incorporating some form of locking device to take the full load in the event of fluid pressure loss.

5.4.11.6.3 Transverse adjustability

Remotely controlled transverse movement of the blocks can be arranged by chains operated by any suitable form of motor from the dock walls or by underwater air or electric motors operated from the dock floor. Some positive method of checking the position of the blocks at all stages of the operation should be introduced.

NOTE The difficulty of maintenance of underwater equipment is considerable and some shipyards have made alternative arrangements by positioning the blocks laterally when the dock is dry. One method involves the use of two sets of blocks, each set being positioned and used for alternate ships. As one ship leaves the dock, its blocks are lowered by remote control and the other set raised to the appropriate height for the next ship.

5.4.11.7 Loads on keel and bilge blocks

The design should take into account that the maximum acceptable load on keel and bilge blocks is related, in many cases, to the maximum load that can be applied to the ship's plating.

NOTE 1 The distribution of load between the keel and bilge blocks is a function of the stiffness of the ship's hull as well as the stiffness of the dock floor and the blocks themselves.

Blocks should be proportioned such that the nominal contact pressure between hull and block does not exceed 2 400 kN/m^2 (240 t/m^2).

NOTE 2 Actual contact pressures can exceed this value by a considerable margin.

NOTE 3 By adjusting the height of the bilge blocks during the dewatering process, it is possible to arrange for virtually all of the weight to impinge on the keel blocks, assuming that the ship has adequate strength and stiffness transversely. Conversely, if the bilge blocks are inadvertently left too high in relation to the keel, the full load from the ship can be distributed to the bilges and hulls have been accidentally damaged in this way. The use of rubber capping pieces with high compressibility can make this occurrence less likely.

6 Shipyard quays, piers and dolphins

6.1 Operational parameters of shipyard quays, piers and dolphins

6.1.1 Ship characteristics

The basis of design for quays, piers and dolphins should define:

- range of ship sizes and types to be accommodated, including the particular constraints of ships such as belting, need for low pressure fenders, hazardous cargo, under-keel protrusions;
- operations to be carried out on ships whilst berthed, including personnel access, crane coverage and lift capacity, mechanical piped services, electrical supplies.

6.1.2 Arrangement at pier and quay copes

The arrangement of various installations and details at the cope of a pier or quay is a major design task involving many competing requirements. Account should be taken of the following items to achieve the optimum cope arrangement:

- ducts and subways for electrical and piped services;
- connections of services to the ship;
- dockside crane tracks, including storm anchors, jacking points, cable turnover pits and crane stops;
- bollards;
- capstans;
- fairleads;
- ladders;
- access towers to ships' decks;
- fendering;
- piped services take-off pits;
- electrical services take-off pits;
- substations;
- lighting towers;
- navigation aids.

6.2 Siting of shipyard quays, piers and dolphins

The siting of quays, piers and dolphins should be determined from a review of the physical site conditions in conjunction with the marine access and operational use of the facility.

6.3 Elements of shipyard quays, piers and dolphins

The structural elements of shipyard quays, piers and dolphins should be designed in accordance with BS 6349-2.

6.4 Equipment for shipyard quays, piers and dolphins

Equipment for shipyard quays, piers and dolphins is similar to that for dry docks, and should meet the recommendations in **5.4**.

7 Slipways and shipbuilding berths

*COMMENTARY ON CLAUSE **7***

This clause covers the design of fixed inclined structures which facilitate ships being moved up or down between dry and buoyant conditions. The principal difference between a slipway and a shipbuilding berth is that slipways incorporate a mechanism for hauling ships out of the water up the incline with subsequent relaunch by downhauling, whilst a shipbuilding berth is a fixed inclined structure down which ships can be dynamically launched.

A marine railway is a type of slipway where a ship is docked on a horizontal platform which is then hauled up or down a fixed inclined structure.

7.1 Operational parameters of slipways and shipbuilding berths

7.1.1 Reliability and operational dependency on slipways

The design of slipways should take into account the reliance of the shipyard operations on the availability of the slipways to retrieve and re-launch ships. A failure of any part of the system to perform correctly could lead to the shipyard being unable to deliver ships to owners after building or repair. The design life and maintenance programme should be specified to maximize the reliability of the slipways with due regard to efficient scale of construction and whole life maintenance requirements.

Slipways should be designed in pairs to provide redundancy.

7.1.2 Operational purposes

7.1.2.1 Slipways

Slipways should be provided where ships are to be retrieved for repair and subsequently relaunched in a controlled manner on wheeled carriages mounted on inclined rails which extend below water level. They can also be used for launching new ships.

7.1.2.2 Shipbuilding berths

Shipbuilding berths should be provided for the construction of ships on the land prior to dynamic launching on sliding ways or pneumatic tubes.

7.1.3 Ship size capacities

7.1.3.1 Slipways

The required capacity of slipways should be clearly defined in terms of the following parameters:

- maximum ship dimensions (length, beam, slipping draught);
- displacement of the maximum sized ship which can be slipped;
- maximum hauling capacity (uphaul and downhaul).

These parameters should be determined from the throughput mix of ships for which the slipways and shipbuilding berths are intended. The design of slipways and shipbuilding berths should be able to accommodate the maximum width of ship to be safely manoeuvred into position for slipping. The design should include sufficient space for rope handling and equipment to haul and then maintain the ship at the dry location.

Slipways are typically suitable for slipping vessels ranging up to 5 000 t lightship displacement and 150 m length, and these values should be adopted as an upper limit for planning purposes.

The docking draught should be taken as the depth of water over the keel blocks on the carriage at the sue point. The docking draught varies with the tide. The longest vessels should have a restricted operating window over the top of the tide cycle.

The design should enable deeper draught ships to be slipped which are significantly shorter than the maximum design ship length.

7.1.3.2 Shipbuilding berths

The shipbuilding berth should be designed for the range of ships identified in the throughput for this facility. For planning purposes, the range of ships should be adopted as up to 250 m overall length. The limitations of draught, beam and launch weight should be determined from the site constraints.

The operational use of the berth should be designed as an integrated part of the shipbuilding process, similar to a shipbuilding dry dock.

7.2 Siting of slipways and shipbuilding berths

7.2.1 Slipways

7.2.1.1 Location and orientation

The design optimization should take into account at least the following factors:

- good marine access water depth;
- tranquil wave climate;
- low velocity currents and tidal streams;
- slipway centre line parallel to prevailing wind;
- good onshore access to dry berths and working space;
- proximity to onshore workshops;
- elapsed time to recover a ship;
- sufficient area of land for control room, winch house, dry berths and transfer area (if required).

7.2.1.2 Length

The length of slipways should be determined using the maximum length of ship, docking draught, height from rail level to top of keel blocks, profile of slipway, and length of dry berths.

The design length should be not less than 2.5 times the length of the largest ship to be accommodated.

NOTE The actual length is usually the sum of the dry berth length required above high water level plus the length below high water needed to dock the ship, which depends on the draught and the vertical profile of the slipway. Where the profile is a vertical curve, the length below water level is less than for a constant gradient.

7.2.1.3 Control room and winch house

The control room should be situated such that the operator has a clear view of the ship for recovery and launching. This should ideally be at the head of the slipway.

7.2.1.4 Ground conditions

The ground conditions should be assessed as part of the study optimizing the location of the slipway.

The underwater length of the slipway should be constructed in dry conditions to achieve the required construction tolerances and quality. The ground conditions should be assessed to determine whether construction of a temporary cofferdam and associated dewatering works is viable.

7.2.1.5 Water depths

The slipway should ideally be located in an area of natural deep water to preclude capital dredging and possibly maintenance dredging.

Provision should be made for sufficient depth of water at the end of a launchway to give clearance under the ship during the launch. The depth should be as specified by the ship designer.

7.2.1.6 Dry berths

Dry berths comprising concrete slab structures should be provided at the landward end of the slipway above highest water level, to allow shipbuilding and ship repair to be carried out in dry conditions. The plan area of the dry berths should be determined by the maximum size of ship. Sufficient space should be provided to allow for piped and electrical services take-off points, temporary staging, scaffolding, mobile plant and crane access as required.

Anchorages should be provided at the dry berths to restrain the ship when recovered and prevent it from running back down the slipway. The hauling winch should not be used to restrain the ship in the permanent situation.

A ship transfer system should be provided where the required throughput demands a greater number of dry berths to be accessed by ships than are provided at the top of slipway rails.

Space should be provided for the storage of spare carriages when not in use.

A system of drains and bunds should be provided to allow for the collection and disposal of contaminated water and waste material.

7.2.1.7 Lead-in structures

To enable ships to be controlled either when being manoeuvred over the carriages for retrieval or after being refloated at relaunch, a lead-in structure should be provided. This should be on at least one side of the slipway, in exposed locations, it should be on both sides.

7.2.2 Shipbuilding berths

7.2.2.1 Dry berth above MHWN

The inclined dry shipbuilding berth should be located such that operations on the berth can be undertaken without significant disruption from high water levels.

7.2.2.2 Berth below MHWN

The inclined berth structure should extend to a level below MHWN and for the economy of construction should terminate no lower than mean low water springs (MLWS).

7.2.2.3 Water depth

An area of water of sufficient depth should be provided beyond the lower end of the inclined berth such that:

- the water depth immediately adjacent to the inclined berth permits the upper end of the ship (usually the bow) to submerge dynamically until sufficient buoyancy counteracts the associated energy;
- the water depth for the lower end of the ship (usually the stern) provides buoyancy lift (stern lift);
- the ship can be brought to a stationary buoyant condition safely.

7.2.2.4 Gated berths

Where the site constraints, in particular small tide variation, make it impractical to provide the water depths for a simple dynamic launch, a gated berth should enable the lower end of the berth to be flooded prior to launch.

The design of the area of the gated berth which is below highest astronomical tide (HAT) should be in accordance with Clause **5**.

7.3 Elements of slipways and shipbuilding berths

7.3.1 Slipways

7.3.1.1 Components

The design of a slipway should include the following components:

- lead-in structures;
- civil works foundations and support structures;
- rail system;
- carriages;
- hauling system;
- control system;
- dry berths;
- piped and electrical services.

Where appropriate, a transfer system should be included.

7.3.1.2 Loads

The slipway loads should be expressed as a set of wheel loads acting on the rails.

The position of maximum load and the load distribution varies with the draught of the ship and the state of the tide. The width of the carriages and the number and gauge of the rails should be determined from the beam and displacement of the maximum sized ship. For a two-rail system, the load should be shared equally between the tracks. For a larger installation with more than two rails, the transverse load distribution across the tracks should be calculated by a naval architect or using accepted empirical formulae.

The loads on the dry berths should be provided by the shipyard operator.

The maximum load imposed on the fore end block should be calculated as the point at which the ship is being uphauled but the lower end is still supported by the water. When the ship is in contact over the length of the keel and above water level, the design load distribution should be taken as being the same as in its drydocking condition.

NOTE From the moment of first contact of the ship with the shore end keel blocks of the carriage, load is applied to the rails in proportion to the lost buoyancy of the ship as it is drawn out of the water. At the time of first contact the ship is in floating trim, but as the carriage is uphauled the angle between the ship and the blocks reduces. Just before the keel becomes parallel with the blocks, the maximum load is imposed on the fore end block. This is the point of full sue load.

7.3.2 Shipbuilding berths

7.3.2.1 Components

The design of a shipbuilding berth should comprise the following components:

- inclined berth structure;
- dynamic launching interface between ship and berth;
- ship launch release system;
- ship dynamic launch energy dissipation system.

The launching system and loads applied to the berth structure during both shipbuilding and dynamic launching should be as specified by the ship designer.

7.3.2.2 Dynamic loading during launching

The point loads ascertained by static calculations of launching conditions should be increased by 25% to take account of dynamic forces.

7.3.3 Seismic effects

In locations at risk of seismic activity, the launchways, carriages and supporting structures should be such that a ship will not become unstable on the launchway or carriages, and any part of the supporting structure will not fail leading to the collapse of the ship on the launchway or carriages. For the design of other structures where ships are likely to be located for periods, such as dry berths, these structures should be able to accommodate seismic events without damage to ships through either instability or excessive permanent deflection.

7.4 Equipment in slipways and shipbuilding berths

7.4.1 Slipways

7.4.1.1 Carriages

NOTE Simple slipway carriages are usually constructed of steel with timber keel and bilge blocks, and are of modular form whereby a number of unit lengths can be joined together to suit the length of ship being slipped.

Carriages should be of the rigid, semi-rigid or telescopic types of design, and should be chosen according to the particular operational requirements, taking into account the following factors.

- Rigid cradles are simpler to operate.
- Telescopic carriages are collapsible and result in a shorter length of slipway under water.

The structure of the carriage for a marine railway should be a single unit, since telescoping is not possible. At the seaward end the structure can be of considerable height, and bracing should be provided to maintain stability.

The carriages should be designed so that the keel and bilge block loads can be transferred to the wheels and rails without overstress, with due attention being paid to the heavy point load under the bow during the suing process.

The maximum intensity of the wheel loading allowed on the carriages is a function of the number of wheels, size of wheels, etc. but should be ascertained before the final design of the slipway is undertaken. The maximum wheel load should preferably be restricted to 30 t with an upper limit of 40 t.

The wheel diameter should be the minimum compatible with the overall stability of the carriage, the berthing characteristics, and the chosen rail section.

The rail section should be chosen on the basis of the cradle and track design, the berthing characteristics, the client's preferences, and the availability of materials.

It should be assumed that the full displacement of the ship can ultimately be carried on the keel blocks, but that 25% of the displacement might impinge on each line of the bilge blocks. An out-of-balance factor of 1.33 should be used in determining the loads on the cradle and rails, on the basis that a ship is generally heavier at the stern.

The concentrated point load under the bow during the suing process should be distributed in the design by the use of flexible blocking with rubber sections fixed to the top of the timber keel blocks at the leading carriage(s).

Slipways may be fitted with single or double flanged wheels running on rails of crane or railway section, or with rollers running on a plated track with lipped guides. Sealed roller bearings should be provided to reduce friction, but provision of access for maintenance should be made, since the equipment might be immersed in sea water for prolonged periods.

A corrosion protection system should be provided to the carriages and rails or plates.

As a safety measure, a rack and pawl system, consisting of a rack laid on the slipway base structure and a pawl or series of pawls attached to the slipway carriage at intervals, should be provided.

7.4.1.2 Hauling winches

The winch may be either fully electric or electro-hydraulic, depending upon the make and design to be used. Where two winches are required to work together, they should be synchronous or otherwise controlled in such a way that the speed of the different winches remains equal, in order to try to limit fluctuations of the load for each of the winches during the winching process.

The design of the haulage system should be simple and robust and with adequate capacity to deal with unexpected or deteriorating conditions that can occur during ship repair operations.

In determining the capacity of the winch, an allowance for the cumulative effect of carriage wheel friction, sheave friction and the wire rope stiffness should be included, assuming 2% of wheel load for ball or roller bearings, and 5% of wheel load for plain or bushed bearings.

7.4.1.3 Rope system

The rope system should be designed for the specific geometry and loads expected from the ships to be accommodated.

The rope system should minimize the risk to personal safety posed by rope breakage.

Rollers or low friction blocks should be provided to prevent the rope dragging on the ground and becoming damaged. Where necessary, rope guides should be provided on the sheaves.

The safety factor for wire ropes used in the haulage system should be not less than 3, based on the certified breaking strength of the rope divided by the maximum rope tension. The maximum rope tension should be calculated as the greater of the following two cases:

- rated capacity of the winch;
- maximum force during operations, including but not limited to the forces due to accelerations, sheave frictions and dead loads.

Sheave and winch drum diameters should be not less than those recommended in BS EN 13001 and by the rope manufacturers for the type of rope under consideration. In general, sheave and drum diameters should be not less than 24 times the rope diameter.

7.4.1.4 Control system

The control system should be designed such that when the uphaul winch is operating, the downhaul winch is paying out to ensure the downhaul rope does not become slack or impose additional load on the uphaul winch. When the downhaul winch is operating, the uphaul rope should be similarly controlled. With a multi-part hauling system, the uphaul and downhaul ropes travel at different speeds, and this should be taken into account in the design.

Provision should be made for acceleration and deceleration during the start-up and stopping of the winch.

The operational positions for all automatic changes of speed and automatic stopping should be fully adjustable after installation to suit the actual operational conditions. Control provisions such as limit switches should be provided such that the automatic changes of speed can be implemented.

In the event of an overload condition, the winch should automatically release/pay out the rope in a controlled manner until the excess load in the rope is removed/alleviated, and should then sustain the stalled load. An overload alarm should be initiated.

7.4.1.5 Dry berths

The dry berths at the top of the slipway should be designed in accordance with the recommendations for shiplift dry berths given in Clause **8** for:

- transfer system;
- piped and electrical services.

7.4.2 Shipbuilding berths

The equipment related to shipbuilding berths is principally cranes associated with the shipbuilding process, which should be in accordance with **5.4.3**.

8 Shiplift facilities

8.1 Operational parameters of shiplifts

8.1.1 Shiplift facility reliability

The design of a shiplift facility should take into account the reliance of the shipyard operations on the availability of the shiplift to retrieve and launch ships. A failure of any part of the system to perform correctly could lead to the shipyard being unable to deliver ships to owners after building or repair. The design life and maintenance programme should be specified to maximize the reliability of the shiplift facility with due regard to efficiency of construction.

8.1.2 Nomenclature for shiplift facility components in documentation

To avoid misunderstanding of the scope intended when using the term "shiplift", the term should not be used on its own in documentation throughout the design process.

The principal shiplift facility components should be referred to in all documentation preceded by the word "shiplift", for example:

- shiplift hoist;
- shiplift control system;
- shiplift electrical system;
- shiplift platform;
- shiplift transfer system;
- shiplift pier;
- shiplift transfer area;
- shiplift dry berth.

8.1.3 Shiplift facility capacity

The required capacity of the shiplift facility should be clearly defined in terms of the following parameters:

- platform dimensions (length and width in metres);
- maximum distributed load (tonnes per metre);
- maximum lift capacity (tonnes);
- nominal lifting capacity (displacement in tonnes of the maximum sized typical ship which can be lifted).

These parameters should be determined from the throughput mix of ships for which the shiplift facility is intended.

NOTE The capacity of a shiplift to lift a specific vessel of a specific docking displacement and load distribution is independent of the form of articulation of the platform.

8.1.4 Platform dimensions

The platform length should be taken as the distance between the extremities of the cantilevers at each end of the platform. The platform width should be taken as the usable deck width excluding the clearances between the deck and the hoist support structures.

8.1.5 Ship maximum length

The length of the platform should be designed for the maximum length of ship to be accommodated, taking into account the loading imposed by the stern and bow areas of the ship and the potential for overhanging the ends of the platform.

NOTE For side transfer only shiplifts, there is usually no physical restriction on the extent of overhang. For end transfer, the landward end fixed structure is a physical constraint.

8.1.6 Ship maximum width

The design of the facility should be able to accommodate the maximum width of ship to be safely manoeuvred into position between the shiplift piers which support the hoists.

The design should include sufficient space for rope handling and equipment to haul in and then maintain the ship in the correct position over the submerged platform.

8.1.7 Docking depth

The docking depth provided should be taken as the depth of water at MHWN over the centre line of the transfer carriage or cradle blocks when the platform is at its lowest level.

The docking depth should include a suitable allowance for under keel clearance over the carriage or cradle blocks. The design clearance should be at least 0.5 m.

8.1.8 Maximum distributed load (MDL)

The maximum distributed load (MDL) should be used as the principal measure of the lift capacity of a shiplift.

The MDL should be expressed in tonnes per metre length of platform which the platform is designed to lift. It should be calculated as the capacity in tonnes of one pair of hoists minus the weight of the length of platform associated with this pair of hoists, divided by the hoist spacing in metres.

The design concept should include the potential for adopting a dual MDL, where part of the length of the platform accommodates the highest expected intensity of loading imposed by a ship and the remaining length accommodates a lower value of MDL.

NOTE Where transfer from the platform is at the end, the higher MDL is nearer the land.

8.1.9 Maximum lifting capacity

The maximum lifting capacity should be calculated as the sum of:

a) maximum value of MDL multiplied by the effective length of the platform for which it is designed; and, where applicable;

b) lower value of MDL multiplied by the effective length of the platform for which it is designed.

The effective platform length should be calculated to include the length of each end cantilever, which should be not greater than 0.4 times the adjacent hoist spacing.

8.1.10 Nominal lifting capacity

NOTE The nominal lifting capacity takes account of the realistic applied load distribution from a typical ship in conjunction with the platform response to a varying distributed load. Hence the nominal lifting capacity represents the maximum displacement in tonnes of a typical ship which can be lifted without exceeding the MDL.

The nominal lifting capacity should be calculated as the maximum lifting capacity multiplied by the distribution factor.

The distribution factor includes an allowance for dynamic effects and is intended to limit the load applied to the platform such that the MDL of the platform is not exceeded. It should be taken as:

- 0.67 for articulated platforms which do not distribute load longitudinally between adjacent hoists through longitudinal structural bending continuity; or

- a higher value where it can be justified by calculation for the following instances:
  - articulated platforms in combination with either longitudinal load-spreading cradles, such as those incorporating hydraulically linked systems, or arrangements where the hoist spacing is an integer multiple of the cradle spacing; or
  - rigid platforms in combination with either simple or load-spreading cradles.

Under all circumstances the value of the distribution factor should be not more than 0.83.

8.1.11 Use of platform for ship repair

The repair of a ship whilst drydocked on the platform should be only an emergency design case and not part of normal planned operations, unless the platform is specifically designed as a repair berth.

NOTE The reasons for this include the following.

- *The platform decking is typically of lightweight construction and generally not designed as a working area.*
- *Waste material tends to fall or be washed down into the shiplift platform dredged pit, increasing subsequent maintenance and increasing seawater contamination.*
- *Other ships are prevented from being retrieved or launched by the facility.*

8.1.12 Anchorages and afloat berths

Provision should be made in the design for ships which are waiting to access the shiplift facility and others which have been re-launched prior to redelivery.

NOTE Where the shiplift piers protrude from the waterfront, they can serve as afloat waiting berths if they are designed appropriately. Access to the afloat berths can also function as the access route for small land-based cranes to maintain the hoists.

8.1.13 Shiplift transfer area with rails

The provision of a transfer area should be made for the movement of ships from platform to dry berth or vice versa.

The transfer area size and level should be determined according to the type of transfer system adopted, of which the options are:

- a two-level transfer system, which incorporates a dedicated transfer carriage mounted on rails within a transfer pit below the platform and dry berth level;
- a single level transfer system, which has all the rails at the same level and carriages which are capable of changing the direction of transfer, generally rotating the wheels through 90° on plan.

In selecting the transfer system, the designer should take into account the respective merits of each system, which are principally:

- a two-level system typically has shorter overall transfer time particularly for smaller ships;
- a single level system obviates the need for a large operationally sterile transfer pit area.

8.2 Siting of shiplifts

8.2.1 Topography

The shiplift facility usually incorporates a level rail system over an extensive area, thus facilities should be sited where there is a large area of flat land available, either natural or formed.

8.2.2 Location and orientation

Most shiplift facilities incorporate transfer systems which restrict ship movement to a rectilinear routing with all rails either parallel or at 90 degrees to the platform centre line. When determining the location and orientation of shiplift facilities, the following factors should be optimized:

- good marine access water depth;
- tranquil wave climate;
- low velocity currents and tidal streams;
- platform centre line parallel with prevailing wind;
- good onshore access to dry berths and working space;
- proximity to onshore workshops;
- elapsed time to transfer a ship from platform to dry berth.

8.2.3 Dry berths and transfer layout

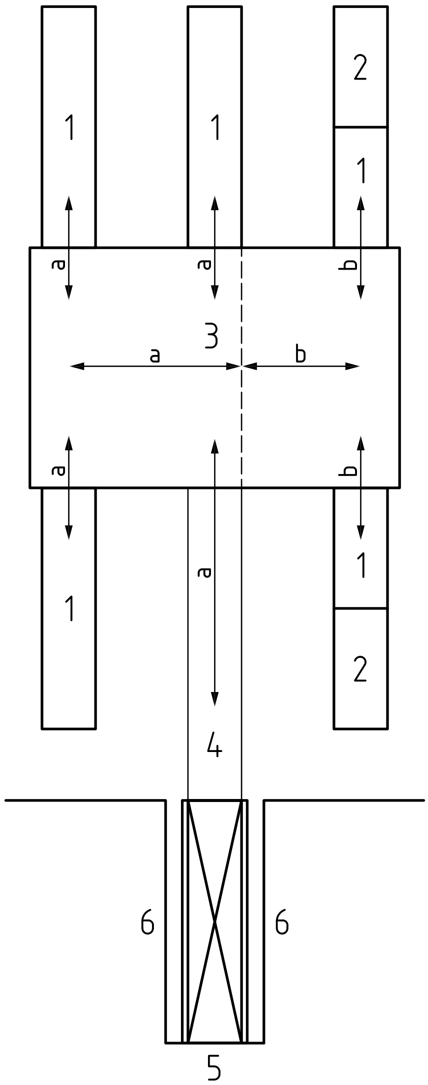
The layout of the transfer area should be designed to minimize the area which will be subjected to the MDL as the ship is transferred from the platform to the dry berth. The design throughput mix of ships determines the number, size and load capacity of the dry berths. Dry berths should be classified as either:

- primary berths with direct access to the platform via a transfer area; or
- secondary berths for longer term repair or building purposes which have a primary berth between them and the transfer area.

The design should optimize the need for the full MDL capacity dry berths and lower capacity dry berths. The design of the whole transfer area and dry berths for the full MDL, particularly for larger load capacity shiplift facilities, should be avoided. The optimization assessment of the transfer arrangement should include a suitable transfer arrangement, of which the principal types are:

- end transfer only to side transfer area with capacity to support full MDL to either:
  - all dry berths; or
  - some dry berths with lower load transfer capacity to other berths (see Figure 13);
- mixed arrangement comprising end transfer to dry berths with capacity to support full MDL and side transfer to dry berths designed to support a lower value of distributed load (see Figure 14);
- side transfer only to side transfer area with capacity to support full MDL to either:
  - all dry berths; or
  - some dry berths with lower load transfer capacity to other berths (see Figure 15).

Figure 13 **Typical end transfer only arrangement** *(1 of 2)*

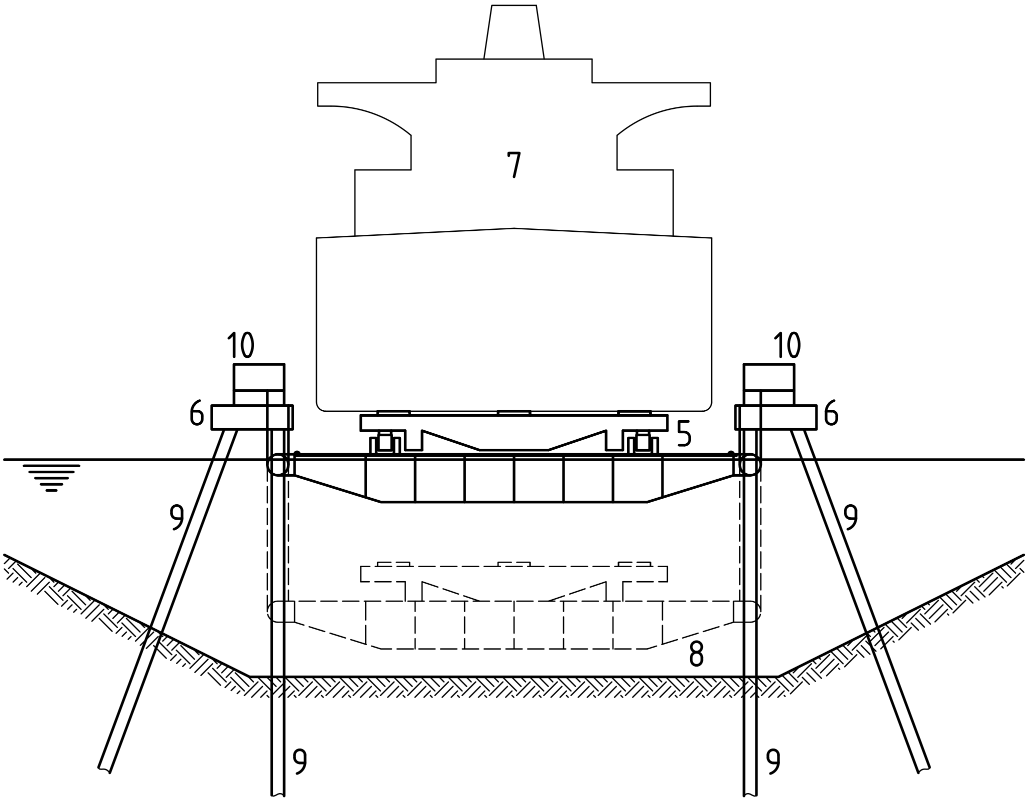


Key

1 Primary berth
2 Secondary berth
3 Transfer area
4 End transfer
5 Shiplift platform
6 Shiplift pier
a Full MDL
b Reduced MDL

a) Plan of shiplift platform

Figure 13 **Typical end transfer only arrangement** *(2 of 2)*



b) Section through shiplift platform

Key

5 Shiplift platform

6 Shiplift pier

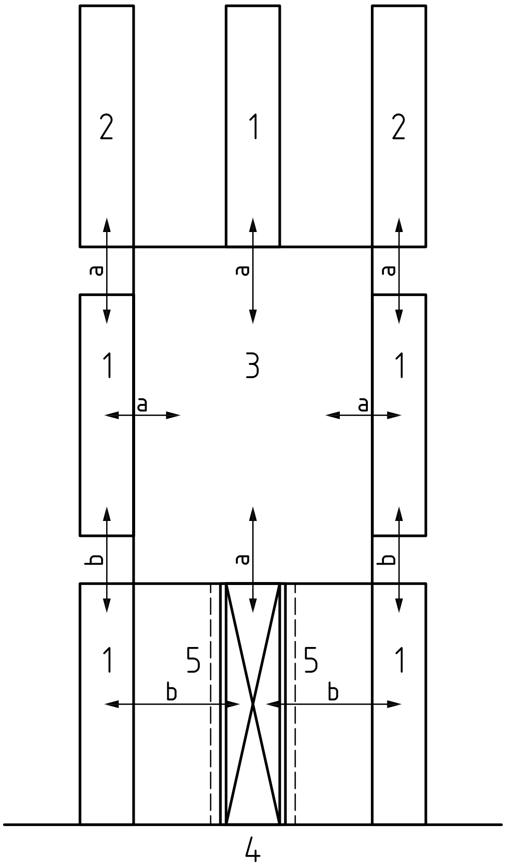
7 Ship

8 Platform pit

9 Piles

10 Hoist

Figure 14 **Typical mixed side and end transfer arrangement**



Key

1 Primary berth

2 Secondary berth

3 Transfer area

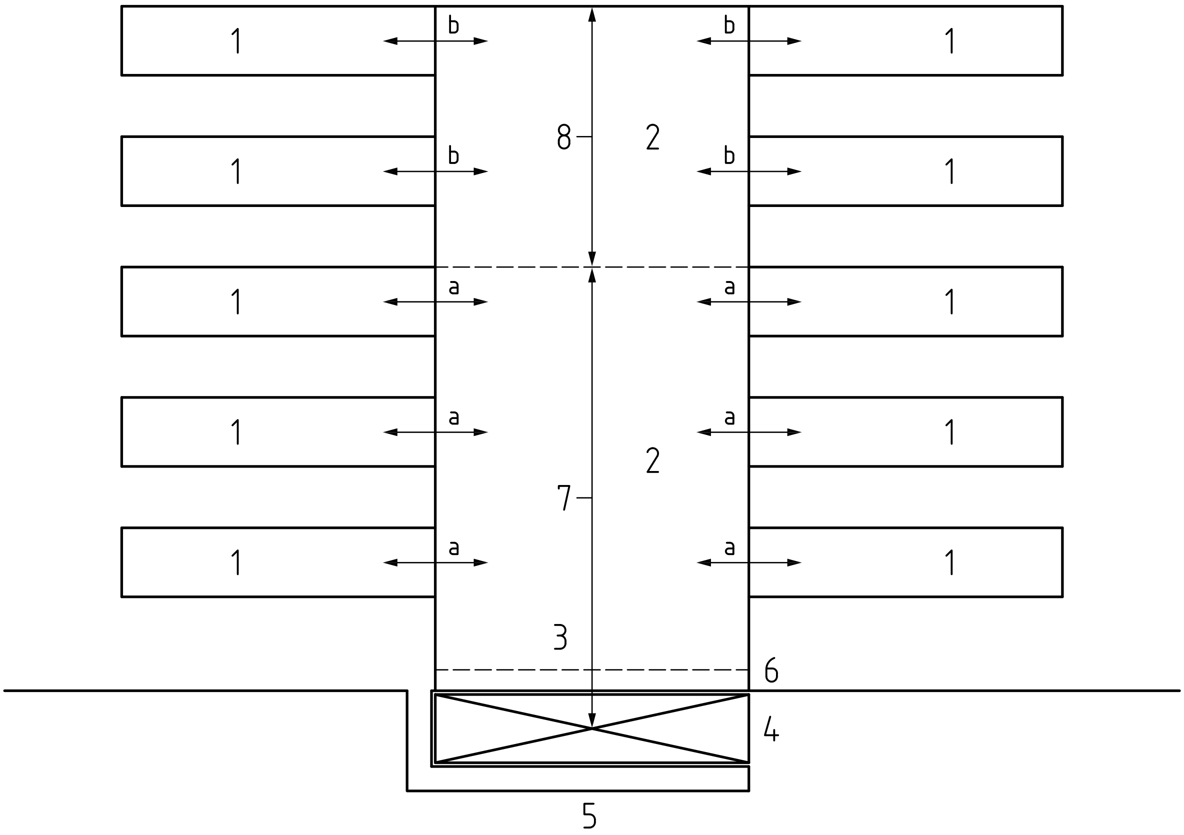
4 Shiplift platform

5 Hoist supports

a Full MDL

b Reduced MDL

Figure 15 **Typical side transfer only arrangement**



Key

1 Primary berth
2 Transfer area
3 Side transfer from platform
4 Shiplift platform
5 Shiplift pier
6 Hoist supports
7 Side transfer full MDL
8 Side transfer reduced MDL
a End transfer to dry berth full MDL
b End transfer to dry berth reduced MDL

8.2.4 Transfer systems

In determining the optimum transfer and dry berths layout, a suitable transfer system with the appropriate directional flexibility should be selected, of which the three most common are:

- rail-mounted carriages restricted to rectilinear movement;
- cradles on multi-wheeled rubber tyred trailers providing flexible direction of transfer;
- rail-mounted carriages with a directional changer on a turntable.

8.2.5 Operator control panel

The operator control panel should be sited such that the operator has a clear view of the shiplift platform. The siting of the electrical facilities should also be suitable for efficient power and cable routing to the hoists.

8.2.6 Ground conditions

The ground conditions should be assessed as part of the siting optimization.

The design of the foundations for shiplift transfer systems which incorporate rails should limit the operational settlements to within level tolerances, enabling ships to be moved with an efficient traction system.

The shiplift platform pit should ideally be located in an area of natural deep water to avoid the need for capital dredging and onerous maintenance dredging. The platform pit creates the need for the construction of either a significant high retaining wall to retain the land adjacent to the platform, or a piled deck structure over a revetted slope from pit level to ground level, depending on the ground conditions.

8.3 Elements of shiplifts

8.3.1 Shiplift platform

8.3.1.1 Platform function

The platform is usually designed for the sole purpose of lifting the ship and its cradles to a suitable level for transfer ashore or vice versa. Where practicable, the vertical travel should be designed such that the platform steelwork is parked at a height clear of mean high water springs (MHWS), to facilitate access for maintenance, particularly in adverse weather conditions. The weight of the platform should be kept to a minimum as it directly impacts on the available lift capacity of the shiplift facility.

The principal loading on the platform is from the transfer carriage wheels. The arrangement of the transfer rails on the platform should be determined by the design of the transfer system. The rails should be supported directly on steel beams.

The design loading on the platform deck area should be at least:

- uniform distributed load of 5 kN/m^2; and
- single point load of 10 kN at any point applied over an area 0.3 m × 0.3 m.

Where specific vehicular access is required, such as for mobile cranes or multi-wheel trailers, the docking and support structure should be designed for the intended vehicles.

8.3.1.2 Articulated and rigid platform design

The relative merits of articulated and rigid platforms should be assessed as an integral part of the whole lifting and support design, taking into account the following factors.

- The rigid platform can prove to be a lighter weight than the articulated platform, with the benefit of lower cost of steelwork fabrication and less weight to be lifted by the hoists.
- The principal advantages of the articulated platform are:
  - structural determinacy in the design of the platform steelwork;
  - the imposed platform loads transmitted to the hoists are limited to the MDL without any elastic redistribution effects;
  - concentrated loads do not result in uplift forces;
  - the articulation means that it adopts the shape of the ship keel and hence does not impose bending in the hull;
  - modular construction facilitates quality control during fabrication and installation.

8.3.1.3 End transfer from platform

The loading during end transfer from the platform should be taken as a symmetrical load about the centre line on the platform structure, which is also therefore symmetrical on the platform steelwork. To improve the efficiency of the platform and hoists a longitudinal locking pin can be included in the design. However, as this introduces an additional electromechanical feature below platform level on which the full operation of the facility relies, the potential operational downtime risks should be assessed.

8.3.1.4 Side transfer from platform

Side transfer from the platform results in the ship load being imposed asymmetrically as it moves towards the hoists. The design should therefore allow for the increased shear forces at the transfer side of the platform.

A side transfer locking device should be included in the design to eliminate higher loads on the hoists and ropes during transfer than occur during lifting operations.

NOTE This locking system can be relatively simple and manually operated being located above platform level at the hoists and where its correct operation can be visually checked.

8.3.1.5 Horizontal loading on platform

The platform and supporting structure should be capable of resisting horizontal forces from transfer operations and wind loading as follows.

- During transfer operations:
  - the design wind load applied to the projected area of the docked ship and structure should be appropriate to the expected operational and environmental conditions. The requirements of classification authorities should be allowed for but a minimum value of 0.20 kN/m^2 should be adopted in the absence of other guidance or in exceptionally benign locations;
  - traction forces should be derived for self-driven transfer systems such as multi-wheel cradles;
  - friction in the transfer system should be calculated from:
    - 2% of wheel loads for wheels with roller bearings;
    - 4% of wheel loads for wheels with plain or bushed bearings.
- Where ships are docked without transfer, the wind load on the projected area of the ship and structure should be taken as 1.5 kN/m^2. In areas of exceptional events subject to typhoons, higher values should be calculated in accordance with BS EN 1991-1-4.

8.3.2 Hoist support structures

8.3.2.1 Shiplift piers

Where the hoists are in front of the quay line on piers, the structures should be designed in accordance with BS 6349-2. In addition to the recommendations given in BS 6349-2, particular attention should be given to the vertical and horizontal deflection performance of the structures to ensure that they are within the requirements of the transfer system and the shiplift control system, which are generally more onerous than in the design of general piers.

NOTE The form of construction of the pier is generally open piled with a reinforced concrete deck. Reinforced concrete caissons can be used to form piers with the advantage that they can create a more tranquil environment for docking the ships.

8.3.2.2 Hoists support at quay edges for side transfer

Where the ship transfers across a quay edge, the hoists should be recessed into the pier to provide clearance between the carriages and the tops of the hoists. The quays should be designed for the full load of the ship and carriages which are intended to be transferred.

8.3.3 Shiplift platform pit

The platform pit should be designed as a geotechnical structure with long-term side-slope stability. The pit is often the deepest dredged area within a shipyard and the influence on adjacent structures should be fully incorporated in the overall facility design.

The design of the pit depth should take account of the rate of siltation, both natural and from the shipyard operations. The planned maintenance of the pit should be allowed for in the design, as this is a difficult operation requiring either removal of the platform or dredging to the sides or through openings in it. Where the ground conditions are such that over-dredging could prejudice the integrity of adjacent structures, the construction of a pit protection layer comprising rock or concrete should be included in the design.

8.3.4 Transfer area

The design of the transfer area should be carried out in conjunction with the design of the transfer carriages to achieve overall maximum efficiency. The design should facilitate using the carriage structure to spread the ship load.

The deflection performance of the transfer area structure should be adequate to enable the transfer system to operate. In the case of rail-mounted transfer systems, the structural design should incorporate the deflection criteria to ensure that the rail alignment and gradients are within the required tolerances for the wheels, steelwork and traction systems.

8.3.5 Dry berths

The design of the dry berth structures should be carried out in conjunction with the design of both the transfer carriages and ship cradles to achieve overall maximum efficiency.

The ships are typically transferred to the dry berths by wheeled carriages which then transfer the support of the ship to either blocks or cradles. The design of the dry berths should accommodate the two load application arrangements via the wheels and then via the cradles. The load distribution from the cradles depends on the precise relative levels of the finished berth surface. The tolerance of the finished berth surface should be similar to that for dry dock floor keel strips.

8.3.6 Seismic effects

In locations at risk of seismic events, the design of the platform and the supporting structures should be designed such that in the event of the identified design case seismic activity:

- a ship does not become unstable on the platform;
- no part of the supporting structures fails leading to the collapse of the ship and platform.

For the design of other structures where ships are likely be located for long periods, such as dry berths, these structures should be able to accommodate seismic events without damage to the ships through either instability or excessive permanent deflection.

8.4 Equipment for shiplifts

8.4.1 Hoists

The type of hoist incorporated in the design should be reliable, easily maintainable, simple and safe to operate.

NOTE The majority of shiplift hoists installed are driven by electric motors with wire ropes which pass around lower sheaves at the ends of the platform main transverse beams and upper sheaves at the hoist. There are some installations which use hydraulic hoists and chains, which are usually slower to operate.

The type of drive unit should be selected in conjunction with the control system, and should be either:

- synchronous motors which operate at the same speed regardless of load and hence act as though they are linked; or
- asynchronous motors which rely on the control systems, through feedback, to control individual motor speed.

8.4.2 Control system

The control system should be able to control the operation of all hoists simultaneously in order to lift and lower the platform in a level condition.

In the event that one or more hoists develop a fault, the control system should stop all hoists automatically to prevent distortion of the platform and potential damage to a ship on the platform. In addition, in the event that one hoist is subjected to a load greater than the specified maximum, then the control system should stop all hoists.

The hoist load of each individual hoist should be continuously monitored, either directly through load cells incorporated in the lifting mechanism, or alternatively by monitoring the current requirements of each motor.

The system should be designed with a fail-safe mechanical brake system for use in the event of power failure.

8.4.3 Wire rope factor of safety

The safety factor for wire ropes used to raise and lower shiplift platforms should be not less than 3, based on the certified breaking strength of the rope divided by the maximum rope tension. The maximum rope tension should be calculated as the greater of the following two cases:

- rated capacity of the hoist;
- maximum force during operations, including but not limited to the forces due to accelerations, sheave frictions and dead loads.

The cumulative effect of sheave friction and the wire rope stiffness should be calculated from:

- 2% for ball or roller bearings;
- 5% for plain or bushed bearings.

8.4.4 Transfer equipment

8.4.4.1 Rail-mounted

The design and specification of the transfer equipment should be made as an integral part of the whole shiplift facility design. The interaction between the transfer equipment design and the structures which support it should be optimized.

Suitable transfer equipment, comprising carriages and cradles, should be selected, of which the most common are:

- rail-mounted carriages or cradles with wheels fixed in one orientation which can only move linearly. Transfer sideways on a separate carriage mounted on rails within a transfer pit;
- rail-mounted carriages or cradles with wheels that can be rotated on plan through 90° by jacking up the carriage or cradle. Transfer on a second set of rails which are at the same level as the first rails, thus inherently obviating the need for a separate transverse carriage within a transfer pit;
- fluid bed carriages which support the ship via cradles on sets of hydraulically linked rams and which uniformly distribute the loads between the linked rams. These systems usually incorporate the facility to rotate the wheels on plan through 90°, thus inherently obviating the need for a separate transverse carriage within a transfer pit.

A suitable traction option for the transfer system should be selected, of which the most common are:

- wire ropes and winches or capstans through an arrangement of pulleys, fairleads and snatch blocks;
- heavy land vehicles towing or pushing the carriage;
- self-driven motorized carriages sometimes incorporating rack and pinion mechanisms;
- self-driven carriages using hydraulic motors within the bogie assemblies.

8.4.4.2 Rubber tyred trailers

The specification of proprietary multi-wheeled rubber tyred trailers should be within the adopted design parameters of the supporting structures. A means of constraining the route of the trailers to that designed to support them should be adopted.

8.4.5 Piped and electrical services

8.4.5.1 Platform operation

The shiplift hoists should be provided with a reliable power supply. Where back-up emergency power generation is provided within the shipyard, it should be sized such that the shiplift platform can be safely operated. The area of the shiplift piers should be supplied with sufficient services to enable operations to be carried out safely, which as a minimum should include lighting and fire-fighting.

8.4.5.2 Production process at dry berths

The provision of a range of piped and electrical services should be designed at dry berths to accommodate the full range of production process operations for which the shiplift facility is intended. The services which should be specified by the operator of the dry berth are likely to include:

- power at 50 Hz and/or 60 Hz;
- compressed air;
- ballast water;
- potable water;
- fire-fighting;
- lighting;

- cooling water;
- industrial gases.

8.4.6 Drainage and dry berth waste collection

The collection of contaminated water and other waste materials at the dry berths should be incorporated in the design. Surface water drainage design should take account of the limitation for surface falls imposed by the level rail layout over the areas.

9 Floating docks

9.1 Operational parameters of floating docks

9.1.1 Floating dock design

The floating dock structure and on-board systems should be designed by a specialist naval architect.

NOTE The design of these floating structures and systems is outside the scope of the BS 6349 series.

The size and load capacity of the floating dock should be derived from the target throughput of ships that has been identified (see Clause **4**).

9.1.2 Floating dock specific parameters

The maritime works designer should have a good understanding of floating dock operations and the limitations pertaining to a specific floating dock. Floating docks vary in construction material, structure and capacity. The specification of a new floating dock should maximize the operational efficiency of the combined floating dock and support facilities.

The design of a floating dock is often already defined, and the operational requirements of a specific floating dock should be obtained as they can impose significant constraints on the maritime works.

When a floating dock is relocated, a check should be made that the design parameters of the floating dock structure itself are applicable to the new geographical location.

When planning a floating dock facility, the designer should check that a potential floating dock which is to be relocated is capable of undergoing towage.

9.1.3 Floating dock types of construction

An appropriate type of floating dock should be selected to match the shipyard location constraints.

NOTE The most common type of floating dock comprises a single steel pontoon with continuous steel walls on two sides. Some floating docks have a reinforced concrete structure. Others are a hybrid with a reinforced concrete pontoon and steel walls.

9.1.4 Lift capacity

The lift capacity should be calculated as the displacement of the dock at normal operational draft, minus the weight of dock, weight of compensating ballast water, weight of residual ballast water and weight of shore services (gangways, utility piping) and moorings. Data should be obtained from the dock designer on the allowable ship load distribution associated with this lift capacity.

NOTE Each floating dock has its own limiting pontoon strength criteria for distributing load along its length and hence the capacity to accommodate ships with large variation in keel loading intensity.

The lift capacity should not be quoted in terms of deadweight tonnage for design purposes as it can be misleading.

For clarity the designer should adopt the following definitions.

- Residual ballast water is the ballast water that cannot be removed by the dock's dewatering pumps.
- Compensating ballast water is the ballast water available for control of the dock and is the total ballast water at a given draft minus the residual ballast water.
- Pontoon freeboard is the height of the pontoon deck above the waterline on the dock centre line. This should be not less than 300 mm, and it should be increased if necessary to accommodate trim effects due to travelling portal cranes on the dock sidewall or where the wave height, H_s, will result in significant overtopping onto the pontoon deck. The trim effects due to cranes should not result in any part of the pontoon deck being submerged.

9.1.5 Ship dimensions and types

When calculating the maximum ship beam that can be accommodated, an allowance of 1.5 m working space on both sides of the ship should be made between the inner sidewalls and the vessel hull side. Where dock arms are provided on the floating dock, the working space allowance should be increased to 3 m each side.

Floating docks are usually provided with fendering over the length of the sidewall at top deck level and extending into the dockwell to prevent damage to the dock wall and any service pipes on the outside of the wall. The minimum clearance between these fenders and ship hull or fenders at the dock entrance, e.g. roller fenders, should be not less than 0.60 m on both sides.

The maximum ship keel length should be not greater than the pontoon length.

To provide working access around the stern and bow, the floor of the floating dock should be extended by a non-buoyant cantilever structure at each end.

NOTE This is commonly known as an apron.

9.1.6 Floating dock maintenance

The maintenance requirements of the floating dock and its support facilities should be allowed for in the design.

NOTE Most floating docks have a continuous monolithic pontoon structure. Maintenance of these monolithic floating docks requires another larger dock for complete dry maintenance. For maintenance purposes, some have a discontinuous pontoon subdivided along the length of the floating dock such that each unit of the pontoon can in turn be disconnected from the walls and subsequently positioned within the floating dock in the dry for maintenance. These are known as self-docking.

9.1.7 Mooring systems and forces

The mooring forces for which a floating dock has been designed should be fully understood, as the mooring point capacities and positions on the floating dock can be a constraint on the mooring system concept.

The most suitable type of mooring system should be selected from:

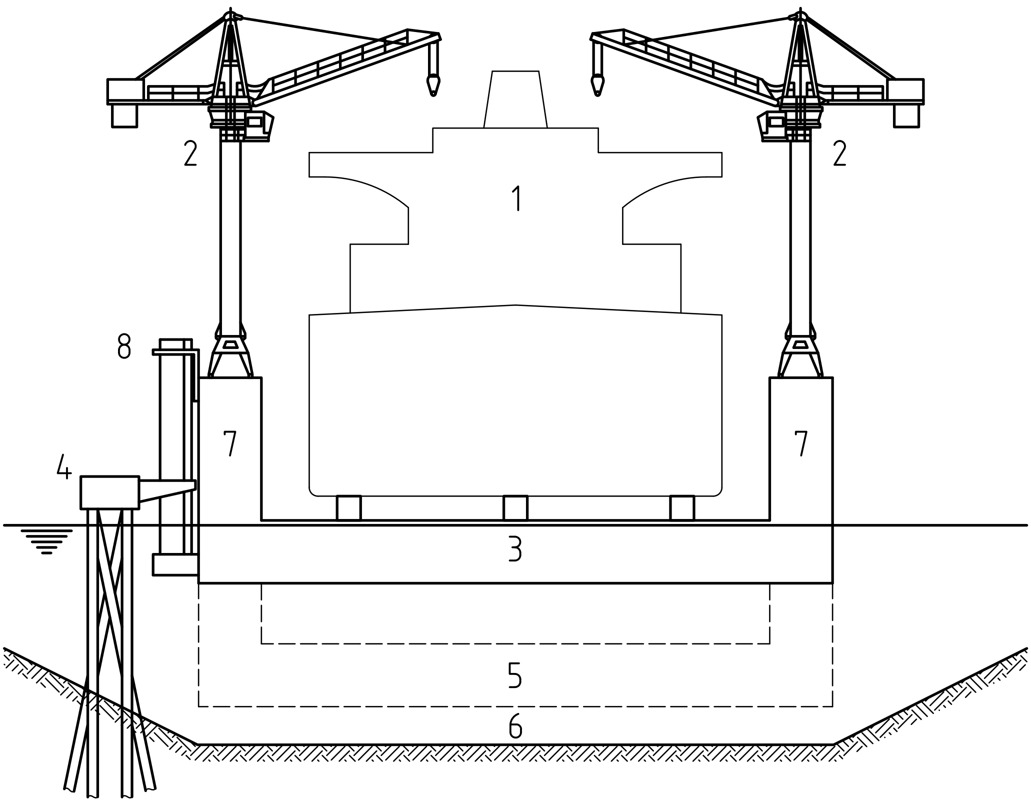
a) **vertical mooring tubes**, which pass through a mooring collar to allow free vertical movement but very limited horizontal movement (see Figure 16).

The tube can be mounted on the floating dock with the collar fixed to a mooring structure. Alternatively the mooring collar is located on the floating dock and the tube is fixed either by a mooring structure or a cantilever pile. The locations of the mooring tubes or collars, usually at two points on one side of the floating dock, should be checked against the floating dock design specification. The principal advantage of vertical mooring tubes is that they maintain the floating dock in its plan position, occupying the minimum area of water front;

b) **chain moorings**, which anchor the floating dock to the sea bed inherently allow significant movement of the floating dock on plan (see Figure 17 and Figure 18). The implications of this type of mooring should be determined, particularly in locations of the exposure to significant wind and currents. The water front area required for a chain mooring system can be significantly greater than the plan area of the floating dock alone;

c) **arm moorings**, which restrain the floating dock by acting as hinged struts and ties attached to fixed structures.

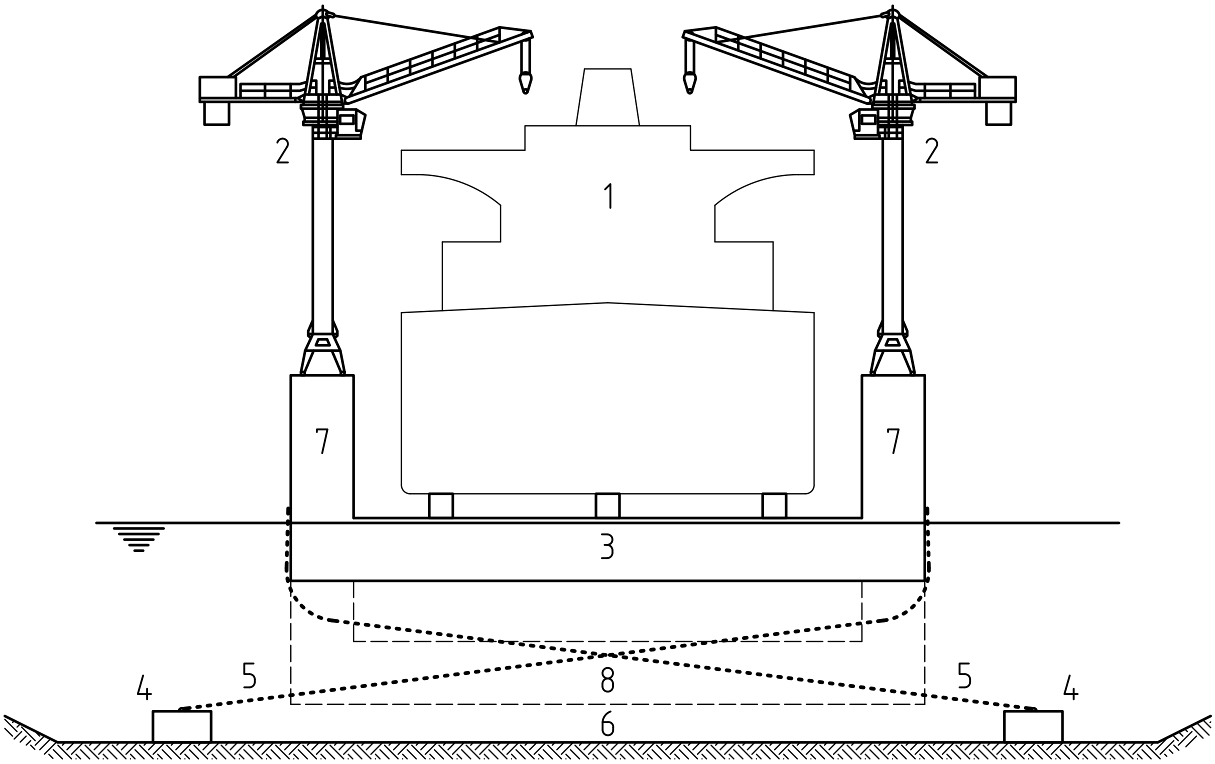
Figure 16 – Section through typical vertical mooring tube arrangement



Key

1 Ship
2 Crane
3 Floating dock pontoon
4 Mooring dolphin
5 Floating dock submerged
6 Floating dock pit
7 Floating dock wall
8 Vertical mooring tube

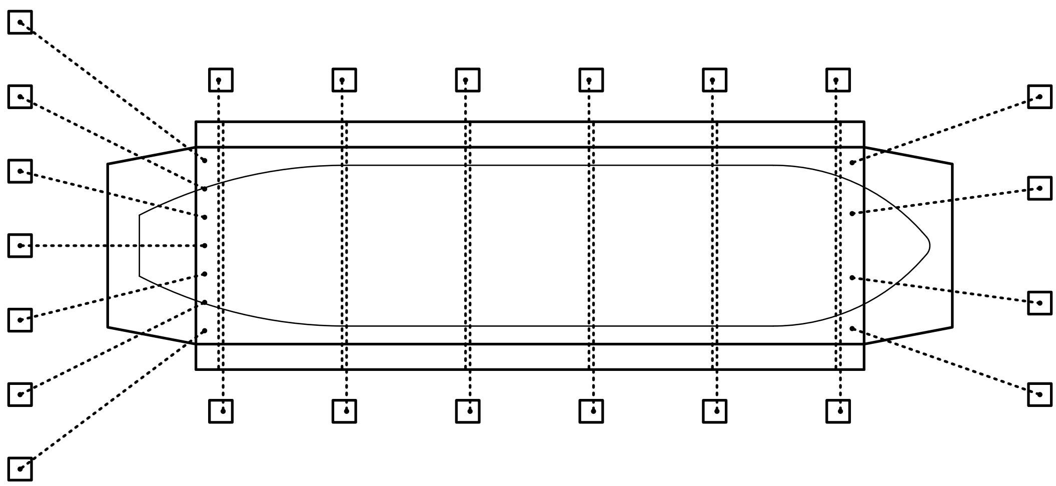
Figure 17 **Section through typical chain mooring arrangement**



Key

1 Ship
2 Crane
3 Floating dock pontoon
4 Sinker block
5 Chains
6 Floating dock pit
7 Floating dock wall
8 Floating dock submerged

Figure 18 **Plan on typical chain mooring arrangement for floating dock**



9.1.8 Docking ships

NOTE The procedure for docking ships in floating docks is similar to that for dry docks. Floating docks are often equipped with similar equipment including hauling-in systems. Tugs are required to manoeuvre the ships at the entrance.

Owing to the importance of maintaining stability for floating docks, pumping arrangements should be designed such that the duty of a failed pump can be carried out by another pump. The floating dock ballast system should be arranged such that in the event of loss of power during raising or submerging, the dock can be quickly brought to a safe condition. This should be by means including fail-safe valves (quick closing), manual operation, and uninterrupted power supply for the dock control system.

The floating dock should be provided with means to prevent accidental oversinking of the dock when submerging. This should be by such means as an air cushion in the tanks, draught alarms, and limited water depth in the case of soft bottoms.

The design parameters of the floating dock should take into account the dock operating instructions, which should include:

- maximum allowable parameters for weight of ship;
- load distribution;
- keel block load;
- bilge block load;
- vertical centre of gravity of ship;
- submergence draft;
- operating freeboard;
- allowable longitudinal deflection;
- differential levels of ballast between adjacent tanks and differential ballast levels between tanks and the dock waterline;
- trim and heel.

9.1.9 Stability

From the moment a ship sues, the floating dock and ship should be assumed to be a single unit for the purpose of the design calculations.

The design should take into account that the minimum stability of a dock normally occurs during raising and lowering the dock, when the waterline is between the top of the blocks and the top of the pontoon, and that the stability increases significantly when the dock is raised.

The minimum allowable transverse metacentric height during raising or lowering varies according to specialist codes but should be not less than 1.0 m. The value should be increased as necessary for vessels where the centre of gravity is not accurately known or where the vessel might have a large lateral wind profile, e.g. cruise ships. The vertical centre of gravity of the ship should be corrected for the ship's free surface effects.

The floating dock should be supplied complete with operating instructions that provide a curve of docking weight against allowable vertical centre of gravity for the ship. The design should make sure that all forces imposed by the operational support facilities and moorings do not compromise the stability of the floating dock.

NOTE Vessels such as cruise ships with a high centre of gravity are often not deemed to be suitable for many floating docks.

The floating dock master should be kept advised of any significant weight distribution changes to the ship during repair in order that the dock ballasting can be adjusted, if necessary, to compensate for effects on strength, stability, trim and heel. The final weight distribution is required to assess the undocking condition of the vessel.

9.1.10 Wave climate

The operational wave climate limits which induce pitching, heeling, and yawing of the floating dock should be obtained from the floating dock supplier. A tranquil wave climate should be targeted with wave height less than 0.5 m for a high percentage of the time to avoid operational downtime of the floating dock.

NOTE Long period waves can be dynamically onerous even at low values of significant wave heights. Higher values of significant wave height can usually be accommodated for short wave lengths. The floating dock's limiting wave heights and wave lengths are necessary parameters for the harbour design.

In locations where extreme climatic events can occur, such as typhoons, which are limited in duration and can be forecast, planned floating docks submergence should be allowed for in the design.

The designer should check that the floating dock will only be subject to acceptable longitudinal and transverse wave bending moments defined by the floating dock designer.

9.1.11 Mooring of ships to walls

The common practice of mooring ships to the outside walls of floating docks should be allowed for in the design, or explicit signage should be specified on the outside of the walls to warn against this practice. In the absence of information to the contrary, the default assumption should be that the design should allow for the operational eventuality of ships moored to the outside of walls.

9.1.12 Vertical submergence

Floating docks require sufficient depth of water to allow them to submerge by ballasting the pontoon to enable the maximum design draft ships to dock and undock. The design should normally provide this depth at the floating dock location when submergence is a frequent event. When the submergence is infrequent, such as for launching of new ships, the design process should assess the option of releasing the floating dock and towing to an area of deep water.

The floating dock should provide a clearance between the top of the blocks and the underside of the ship's keel of not less than 0.50 m. Clearance between the underside of the dock pontoon and the seabed should be not less than 1.0 m for soft seabeds (e.g. mud, sand) or 1.5 m for hard seabeds (e.g. rock).

9.1.13 Floating dock pit maintenance

The maintenance dredging of the area beneath the floating dock, which is often a special dredged pit, should be planned, and the necessary measures, including temporarily moving the floating dock, included in the design parameters. The frequency of maintenance dredging should be estimated, with chain mooring systems being more disruptive than other types of mooring due to the presence of the chains and the length of time taken to disconnect and then reconnect the mooring chains.

9.1.14 Floating dock mechanical and electrical supplies

The extent to which a floating dock has been designed to be self-sufficient in mechanical and electrical services should be ascertained, as the need for external service supplies can vary widely. Many are almost fully self-sufficient in power generation, whilst others require significant shore supplies, principally power and fresh water.

9.1.15 Crane capacity

The operational crane capacity requirements should be taken into account in the design of the whole waterfront operations. Floating dock cranes mounted on the walls are normally sufficient for routine ship repair. The design of the floating dock cranes should include the calculated heel and trim that might occur during dock operation. The operational need for heavy lifts to augment the wall-mounted cranes, through either land-based cranes or floating cranes, should be established.

9.1.16 Access

The operational needs for access to the floating dock location and the pontoon deck should be established.

Pedestrian access should be provided to the top of one dock wall at all states of submergence. The pedestrian access to the remote dock wall should be provided by swing bridges or flying gangways between the ends of the dock walls.

Vehicular access to the pontoon deck when the floating dock is raised should be provided where rapid mobilization and demobilization of equipment and materials to the dock floor is required.

9.1.17 Pontoon deck waste collection

Measures should be specified to limit the waste material from the work on a ship being washed into the sea, to reduce the frequency of maintenance dredging beneath the floating dock and minimize contamination of the sea. A drainage arrangement should be designed for collecting contaminated water on the pontoon deck for subsequent treatment. The criteria for limiting contamination of the sea should be established in an environmental impact assessment.

9.1.18 Shipbuilding

When a floating dock forms part of the launching system for shipbuilding operations, the mooring systems should be designed for the vertical loads, which are usually specified to maintain level alignment of the pontoon deck with the launching quay. The design of the moorings should also take account of the relatively infrequent use of the floating dock for this purpose, in conjunction with the possible need to avoid operations during extreme weather events.

9.2 Siting of floating docks

9.2.1 Optimum location

The optimum location and orientation of a floating dock should be determined by an analysis of the competing parameters, taking into account the impact of the floating dock facilities on the other elements of the shipyard.

9.2.2 Location parameters

The parameters which should be included in the assessment of the location, in typical order of importance, are:

- tranquil wave climate with principal wave direction parallel to floating dock centre line;
- prevailing wind direction parallel to floating dock centre line for ease of docking/undocking of ships and minimizing wind loading;
- tidal or river currents parallel to floating dock centre line for ease of docking/undocking of ships and minimizing loading;
- proximity of floating dock pit to waterfront structures;
- entrances of adjacent floating docks in line to enable tugs to control ships on both sides;
- minimum capital and maintenance dredging for adequate ship access water depth;
- minimum capital and maintenance dredging for floating dock submergence;
- ground conditions for moorings;
- proximity to operational support area, workshops, etc.

9.3 Elements of floating docks

9.3.1 Risk to floating dock stability

The design of all elements in floating dock facilities should be designed so as to minimize the risk of imposing a force on the floating dock which could prejudice its stability and result in a catastrophic event.

9.3.2 Moorings

9.3.2.1 Vertical tube moorings

Mooring systems with vertical mooring tubes directly transmit the actions applied from floating dock to the mooring structure. The design mooring forces should be the most onerous combination of actions on the floating dock. The calculation of actions should include the presence of the largest ship which can reasonably be accommodated in the floating dock.

In the case of wind action parallel to the centre line of the floating dock, the area subject to wind should be determined using the external width of the floating dock to take account of the practice of sheeting across the ends of ships being repaired. Appropriate allowance should be made for dock wall-mounted equipment such as cranes and the ship superstructures.

The distribution of mooring forces between the mooring tubes should take account of the interface between the mooring collar and the tube. Typically the interface is a hard resilient material which should wear preferentially to the steel tube. In this case, the longitudinal mooring total force should be applied to each of the mooring points as this scenario could arise in practice due to differential wear. The distribution of transverse forces should be calculated according to the centroid of the applied loads on the floating dock plus ship and the locations of the mooring tubes along the side of the floating dock.

The extreme operational levels of the floating dock relative to the fixed mooring collar of the tube upper and lower restraints should be calculated, and sufficient clearance allowed to ensure that the fixed mooring structure cannot interact vertically with the floating dock.

Systems other than cantilever tubes include an isolated dolphin or strongpoint incorporated in a pier structure. These structures should be designed in accordance with BS 6349-4.

9.3.2.2 Chain moorings

Chain mooring systems should be designed using dynamic analysis methods.

9.3.3 Floating dock pit

The floating dock pit should be treated as a significant part of the facilities as it is fundamental to the continued operation of the facility. The pit should be treated as a significant geotechnical structure as it will probably be the deepest area in the shipyard, influencing the design and proximity of other structures. The practicality of capital dredging and the long term side slope stability should be assessed. The alignment of the facility should be arranged where possible to minimize the rate of siltation in the pit.

9.3.4 Access bridges

The vehicular and pedestrian access bridges are usually constructed in steel and should enable the floating dock to be removed for maintenance purposes. Due account should be taken of shipyard vehicles that are more onerous than normal highway vehicles.

Vehicular access bridges should have articulated bearings to allow for the vertical tidal movement. The upper end should be supported by a fixed structure. The lower end may be supported by a service pontoon which is moored adjacent to the floating dock apron, or supported directly by the floating dock pontoon when it is raised. During floating dock submergence, the lower end should be supported by a fixed frame or buoyancy tank.

The vehicle access bridge should be positioned outside any swing bridges connecting the ends of each sidewall top deck in plan, to avoid any collision during submergence of the dock.

NOTE This can be accomplished by ensuring that any apron supporting the vehicle access bridge extends sufficiently beyond the swing bridges.

Pedestrian access bridges should be fixed to the top of the sidewalls to allow vertical and horizontal rotation. Roller bearings should be provided at the shore end of the access bridge to allow for horizontal movement during submergence and raising of the floating dock.

9.3.5 Docking blocks

Docking blocks are normally only placed above primary strength members in the pontoon, e.g. centre line bulkhead, longitudinal bulkheads or girders, transverse bulkheads. Floating docks are normally provided with a standard quantity of blocks. Where additional blocks are provided for undertaking a docking, they should be added to the weight of the vessel.

9.3.6 Services supports

The arrangements for maintaining service supplies to the floating dock should be designed for all operational levels, submergence and mooring variations in plan position.

NOTE These might include catenary mast towers and bridges.

9.4 Equipment for floating docks

The design should take account of the compatibility of the equipment on the floating docks and the services they require, such as power frequency, in addition to their capacity to supply ships during repair.

NOTE Power can be augmented by the addition of generation sets temporarily located on the dock walls.

The floating dock should be provided with means of ensuring that there is no electrical potential between the dock and shore. A steel floating dock does not have to be earthed against lightning, but docked ships should be electrically bonded to the dock to protect against lightning and to ensure that the ship and floating dock are at the same electrical potential.

Holding tanks, piping and pumps should be provided to remove contaminated water from the floating dock to the main shipyard treatment facility.

10 Sea locks

10.1 Operational parameters of sea locks

10.1.1 General

Sea locks can be provided where impounded areas such as wet docks or canals are required to connect to tidal areas and have a maintained water level within defined tolerances. The lock should enable ships to enter the wet dock or basin from a tidal area and be raised (or sometimes lowered) to the impounded level.

Sea locks which are required to provide a high level of security or minimum risk of accidental water level lowering outside the tolerances should be designed with at least three gates.

10.1.2 Capacity

The size of a lock should be defined by its usable length, breadth and depth, having regard to clearances required for opening gates and handling ships in the lock. The dimensions of the lock should be chosen to suit the expected maximum dimension of ship which will use the impounded area it serves.

Canal locks should allow for situations where several ships will use the lock simultaneously.

10.1.3 Depth

The depth of a lock should be defined as the depth of water over the sill at the appropriate tide level, or the depth of normal impounded dock water over the sill at the landward end of the lock, whichever is the smaller. The appropriate tide level can range between MHWN if tidal constraints on access are acceptable (e.g. for a shipyard), and lowest astronomical tide (LAT) if no tidal constraints can be accepted (e.g. for a canal). Care should be taken to check the depths to keel blocks if the lock is also used as a dry dock. Account should be taken of the effect of siltation on the lock and the impounded area.

10.1.4 Width

The defined width of a lock should be the minimum width available for navigation, through the entrances, gates and lock chamber.

10.1.5 Length

The useable length of a lock should be measured on the centre line of the lock and should be the minimum horizontal distance between the furthest projecting part or fenders of the lock gates. Allowance should be made for the operating equipment of the lock gates, which can restrict the length of ship that can be accommodated depending on the profile of the ship’s hull. In some designs, the presence of a gate sill can reduce the useful length of the lock, so this should also be taken into account.

10.1.6 Clearances between ship and lock

The horizontal and vertical clearances between the ship and the lock should be sufficient to allow the ship to manoeuvre into and out of the lock without excessive hydraulic resistance.

10.1.7 Height of lock cope

The choice of height of cope should take into account:

a) the highest water level likely to be attained outside the lock entrance, having regard to wave swell and surge;

b) the highest water level to be impounded (this is unlikely to be above the highest sea level);

c) the general level of the ground surrounding the lock and dock and the advantage of maintaining the cope at a similar level.

10.1.8 Maximum variation in water level

At a very early stage in the design the following should be established:

a) maximum and minimum sea water levels with and without allowance for wave and clapotis effect;

b) maximum and minimum water levels in the impounded area served by the lock;

c) minimum and maximum sea water levels at which the lock will be used;

d) whether provision is to be made in the design for the lock to be dried out in the future for maintenance.

NOTE This decision affects wall and floor design. It also requires special arrangements for the entrance gate and a stronger dockside gate, unless stop beams are provided or temporary cofferdams are to be constructed.

Provision for drying out the lock, as described in item d), should be made if circumstances permit.

10.1.9 Intermediate gate

The operational benefits of an intermediate gate should be assessed to determine whether an intermediate gate should be incorporated in the design of a sea lock.

NOTE The use of intermediate gates means that only a portion of the lock need be utilized when small ships use it. It also conserves water in the wet docks and gives speedier operation.

Where an intermediate gate is used, it should, where possible, be able to act as a substitute when one of the main gates is removed for maintenance or suffers damage.

If no intermediate gate is fitted, and where operational reliability and water loss security are critical, the provision of double lock gates, a spare gate, or means of protecting lock gates from ship impact should be assessed as risk mitigation.

10.1.10 Operating times

The design should meet the two key parameters of transit time (i.e. the time required for a vessel to pass through the lock system) and number of ships per day.

NOTE The time for a vessel to pass through the lock system, and the number of vessels per day, depend on the time required for each of the following operations:

- *mooring to approach structure (if required);*

- *entering lock;*
- *gate closing;*
- *filling or emptying ("levelling");*
- *leaving lock;*
- *preparing the lock for the next vessel.*

The design should take into account the operational and economic priorities for lock operations while achieving safe conditions at all times for ship manoeuvres and while moored in the lock during levelling.

10.1.11 Hydraulic parameters

The hydraulic parameters for sea locks can vary greatly according to the location and should be determined early in the design process to include requirements for:

- limits for saline penetration;
- navigational effects from density currents.

NOTE The analysis and design of the hydraulic effects in sea locks is outside the scope of the BS 6349 series. Guidance is given in PIANC Report No. 106 [2] and Final report of the international commission for the study of locks *[3].*

10.2 Siting of sea locks

10.2.1 Navigational approach

The location should provide safe navigational approaches to the lock.

The lock should be provided with adequate lead-in structures to assist entry and to protect the entrance works and gates from waves and currents where necessary.

At the inner entrance to a wet dock, a turning dolphin should be provided if necessary to facilitate the manoeuvring of vessels to those parts of the dock adjacent to the entrance.

10.2.2 Sheltered anchorage

Sheltered anchorage should be provided for ships waiting to enter the lock.

NOTE This could be provided by the outer harbour breakwaters, the approach structures, or by anchoring in a deep channel of a river or estuary.

10.2.3 Position with respect to subsoil conditions

The location of the lock structure should take into account local variations in subsoil conditions, which can greatly influence the design and scale of construction required for the lock structure.

10.2.4 Scour

Particular attention should be given in the design to the potential for propeller scour effects in areas of weak or loose subsoil conditions, as ships enter and leave the sea lock under their own power.

10.2.5 Prevailing wind

The orientation of a sea lock should take into account the direction of prevailing winds.

10.2.6 Position with respect to waves, currents and tidal streams

The lock should be protected from the effects of waves, currents and tidal streams sufficiently to allow navigation at suitable stages of the tide (or all tidal conditions if operational requirements so demand). This protection can be provided by outer harbour breakwaters, although suitable lead-in facilities should also be provided if necessary.

The possibility of siltation in the lock entrance and approach should be taken into account in these circumstances. Numerical and physical modelling should be used if necessary to optimize the configuration at the entrance in order to reduce or eliminate siltation.

Density currents can occur where there is fresh water upstream of the lock discharging into sea water downstream. Such currents can have a significant effect on navigation, particularly if they are not symmetrical along the lock alignment, and the design should take this into account.

10.3 Elements of sea locks

10.3.1 Sea lock structures

10.3.1.1 Floor

Where durable competent rock or other hard material exists at floor level, a concrete floor can be dispensed with unless the lock is to be used as a dry dock. Where softer or granular material exists at floor level, a concrete cover slab should be provided to protect the surface from disturbance from ships' propeller action and during sluicing. Where appropriate, the floor should be designed to give stability to the lock walls, e.g. by incorporating concrete struts, sometimes in horizontal lattice girder form, set into the floor.

The floor should be able to cater for any uplift pressure that might develop at its underside when there is a low water level in the lock, including the case when the lock is drained for maintenance (if this is required). This should be achieved by providing either:

a) a gravity floor, i.e. a floor of sufficient weight to withstand all uplift pressures; or

b) a drained floor, where typically a suitable sub-floor drainage layer (e.g. of gravel or no-fines concrete) is provided to allow ground water under excess pressure to discharge through holes in the floor into the lock chamber.

NOTE 1 If the floor and walls of a lock are an integrated structure, then the total weight of the structure can be used to resist possible uplift forces.

NOTE 2 If the lock is built in or above permeable material, a cut-off in concrete, steel sheet piling or bentonite might be required in order to limit the ground water flow through the floor even when the lock is not dry.

Sumps should be provided in the floor to facilitate pumping the chamber dry.

10.3.1.2 Walls

Lock walls should be able to carry safely all loads to which they are subjected, including those from earth and ground water pressures, bollards, fairleads, capstans and other hauling-in arrangements. They should normally be built vertically for maximum clearance at all water levels and be capable of supporting fendering suitable for all types of ships likely to use the lock and for all states of water level.

Particular care should be taken to ensure that small vessels cannot become trapped under the fender system as the water level rises.

10.3.2 Filling and emptying systems for locks

10.3.2.1 Filling and emptying system layout

Filling and emptying systems should be arranged so that the flow of water does not cause disturbance to the ship in the lock creating a risk of damage to the ship or lock.

NOTE 1 There are many possible arrangements of filling/emptying systems for locks, and these are outside the scope of the BS 6349 series.

NOTE 2 Location of the intakes near the lock head (i.e. near the impounded area) presents a simple solution but can lead to unacceptable hydraulic forces on vessels moored in the lock, unless filling times are extended to mitigate this. For canal locks with continuous traffic, faster filling and emptying times can be achieved with the use of culverts arranged longitudinally along the chamber walls or under the lock floor, to produce a smoother flow into the lock.

Numerical and physical model studies should be undertaken to optimize and check the design of the filling/emptying system.

10.3.2.2 Types of lock valves and sluices

In a large maritime lock, all valves and sluices should be actuated via control systems, for speed of operation, operated from a central control position. The design of the control systems should include adequate back-up systems and redundancy to allow the safe use of the lock during both operation and maintenance with limited downtime.

The flow rates and changes in flow rates should be designed to minimize hydraulic forces on ships and minimize the risk of excessive pressures in culverts. Cavitation and aeration should also be taken into account in the design of hydraulic systems.

10.3.2.3 Water saving systems

Where water saving is necessary, the design should incorporate a suitable water saving system, which could include:

- arranging locks in a ladder of two or more locks instead of a single high-lift lock;
- provision of water saving basins;
- cross-linking parallel locks to act as water saving basins;
- operational practices such as reducing the number of locking operations by working to a timetable or by waiting until the locks are full of vessels.

NOTE The design of water saving systems is outside the scope of the BS 6349 series.

10.4 Equipment for sea locks

Equipment designed for sea locks should meet the recommendations for dry docks given in **5.4**.

NOTE Additional guidance on the requirements for equipment for sea locks is given in PIANC Report No. 106 [2] and Final report of the international commission for the study of locks *[3].*

11 Hydrolifts

*COMMENTARY ON CLAUSE **11***

A hydrolift is a system whereby a ship or floating structure is lifted from sea level up to ground level by water, or vice versa. The hydrolift process works in a similar manner to a lock via the flooding of an impounded basin, as follows:

- *the ship enters an enclosed basin and the entrance gate is closed;*
- *water is pumped into the basin to lift the ship above ground level;*
- *the ship is floated across the enclosed basin into a dock or over a support platform;*
- *the basin is then drained so that the ship or floating structure is lowered onto the dock floor/support platform, where it can be repaired in the dry.*

The process works in reverse with respect to the launching of new build vessels.

*Many of the operational and design parameters covered by other clauses in this part of BS 6349, in particular Clause **5** for dry dock facilities, are equally applicable to hydrolifts. The fundamental design hydrostatic difference between hydrolifts and dry docks is:*

- *hydrolifts raise ships to an area where they will be in a dry condition above high water level when the water which has raised them is removed, hence hydrolifts are an impounding system;*
- *dry docks lower ships onto an area which is not normally dry and has to be artificially kept dry.*

11.1 Operational parameters of hydrolifts

The operational parameters for a hydrolift should be defined by the designer based on a thorough understanding of this infrequent type of facility.

11.2 Siting of hydrolifts

11.2.1 General

The siting of hydrolifts should be in accordance with the recommendations for dry docks given in **5.2**.

11.2.2 Ground conditions

Hydrolifts should be sited in locations where an impounding system for water retention can be efficiently constructed.

11.3 Elements of hydrolifts

11.3.1 Design of entrance gate

The entrance gate should be in accordance with the recommendations given in **12.3**. The following factors should also be taken into account.

a) The entrance gate should be an impounding gate design to retain water within the basin.

b) The operation of the gate is critical to its design, as it should open clear of the entrance to allow vessels to pass through, and should be of sufficient height above sea level to retain the impounded water.

11.3.2 Design of entrance gate abutments and sill

The entrance abutments and sill should be able to carry safely all loads to which they are subjected. The principal loadings which should be accommodated include:

a) entrance gate loading;

b) earth pressures including surcharge effects;

c) ground water pressures;

d) water pressure from impounded water.

The pumping arrangements should be incorporated in one of the abutment structures. A simple arrangement should be adopted using submersible mixed flow pumps discharging into the basin through a siphon. Pumps and siphons should be in accordance with the recommendations for dry docks given in **5.4.10**.

11.3.3 Design of impounding basin walls and floor

Hydrolift walls should be in accordance with the recommendations for dry docks given in **5.3.2**.

The impounding walls of the retaining structure above ground level are generally of slim construction, so the risk of vessel impacts should be assessed and incorporated into the design.

Particular attention should be paid to the provision of ample working space along the copes for rope handling.

The retaining walls around the deeper sections of the impounding basin should be able to support safely loads to which they are subjected. The principal loadings which should be accommodated include:

a) earth pressure including surcharge effects;

b) impounded water pressures (which can cause retaining walls to bend in the opposite direction to more normal conditions);

c) mooring forces;

d) berthing forces.

The walls should be designed as water-retaining structures that minimize leakage of impounded water through construction joints and seapage paths beneath the wall. A leakage collection and drainage system should be provided if leakage is likely to be a problem.

11.3.4 Design of impounding basin floor

The impounding basin floor should be formed at two separate levels. The seaward side of the basin should be at lower level that provides sufficient under keel clearance for vessels entering and leaving the facility at lowest design water level.

The landward or berth side floor of the basin should be at a higher level, and a minimum vertical clearance to either the floor level or that of the keel blocks should be provided. Generally a minimum under keel clearance of approx. 0.5 m should be provided although this will depend on the operation requirements.

The landward or berth side floor should have a watertight connection to the impounding walls to minimize leakage during impounding operations.

The berth side floor structure should be designed similarly to a dry dock floor and hence in accordance with the recommendations for dry docks given in **5.3.1**.

11.3.5 Design of skidding system

For shipbuilding operations, a skidding system should be provided in the hydrolift facilities to allow vessels to be transferred in or out of the impounding basin.

11.3.6 Design of landward/intermediate gate

In shipbuilding facilities, a landward or intermediate gate should be in accordance with the recommendations given in Clause **12**. The sealing of the gate over and against the skidding system and civil works support structure should prevent leakage.

11.3.7 Design of land transfer system

Land transfer systems should be in accordance with the recommendations for shiplifts given in **8.2.4**.

11.4 Equipment for hydrolifts

Equipment for hydrolifts should meet the recommendations for dry docks given in **5.4**.

12 Dock and lock gates

12.1 Operational parameters of dock and lock gates

12.1.1 Dock and lock gate design

The dock and lock gates design parameters should be determined as an integral part of the dock or lock structure design to achieve combined design and operational efficiency.

NOTE The principal interactions between the gate and the dock or lock structure are:

- *suitability of the dock or lock structure to accommodate the actions from the gate;*
- *space required by the gate when closed in service and when open;*
- *space required by the gate and any maintenance arrangements when being maintained in situ;*
- *clearances required by the gate when moving for opening, closing, installation and removal;*
- *operating equipment (winches, hydraulic cylinders, etc.) and their associated power supply and controls.*

12.1.2 Gate parameters

The operational parameters for the gate design should be established so that an appropriate type can be selected.

The operational requirements of the gate should be defined for the following parameters where applicable:

- speed of operation;
- maximum retained head of water – maximum water level with corresponding minimum water level on reverse side;
- maximum reverse head of water – maximum water level on reverse side with corresponding minimum level on opposite side;

- maximum and minimum water level differences at which the gate can be opened and closed (i.e. ability to open against a retained head of water);
- potential ship impact loads and dropped loads, including identification of critical systems such as ballast tanks that might need to be protected;
- gate location when opened;
- sluicing capability (if required);
- maintenance planned downtime (of dry dock/lock) limit in days per year;
- scope for maintenance without stopping dock or lock operations;
- design life;
- protection against corrosion;
- power supply availability;
- available labour force for operation and maintenance;
- controls for gate operation;
- operation and control requirements;
- level of automation;
- level of safety;
- stability;
- naval architecture requirements (if required);
- tug boat availability for manoeuvring gate (if required);
- crane coverage capacity (if required);
- pedestrian/vehicular access route over gate.

The following site parameters of the gate location should be determined:

- width of dock or lock;
- sill and cope height;
- support capability of dock or lock structure;
- tidal range;
- wave climate;
- sedimentation;
- seismicity;
- availability of any dockside services which might be required by the gate.

The following parameters or limitations for commissioning, maintenance and decommissioning should be determined;

- initial installation (stepping), possibly behind a cofferdam or similar;
- typical stepping and unstepping;
- test and commissioning requirements;
- maintenance strategy;
- mode of fabrication;
- location of gate fabrication;
- method of transportation, where relevant.

12.1.3 Gate type selection

The gate parameters should be prioritized so that an appropriate type of gate can be selected, of which the principal types are:

a) entrance gates:

- flap gate (see Figure 19) – rotates about hinges aligned horizontally in the sill structure to the open position below sill level. Typically operated using, singly or in combination: winch(es) and wire rope, hydraulic rams, compressed air. Types include:
  - spanning box flap gate;
  - strutted flap gate;
  - cantilever flap gate;
- floating (or ship type) caisson gate (see Figure 20) – floats out of position when deballasted and is manoeuvred to an alternative location clear of vessels entering or leaving the dock/lock. Types include:
  - free floating – manoeuvring with tug assistance and handling ropes;
  - hinged floating gate – controlled rotation on plan with a loose hinge on one side and tug assistance or winch system at the free end;
- sliding or rolling caisson gate (see Figure 21) – moves into recess or camber housing parallel to sill. Typically operated using winches and wire rope, or chains and sprockets driven by machinery contained within the camber;

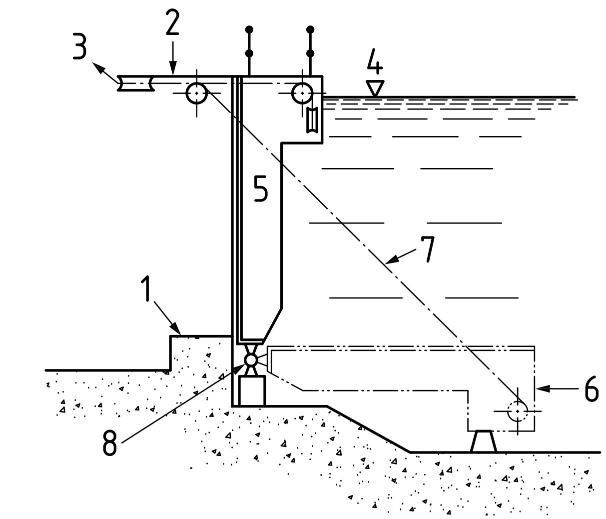
  NOTE 1 The installation of sliding or rolling caisson gates requires particular attention to clearances when being floated into place. The clearances can be increased when necessary by inclining the dock walls.
- mitre gates (see Figure 22) – pair of gates each rotating about a vertical hinge into a recess at the side, typically operated with chains or hydraulic rams;
- sector gates (see Figure 23) – single or in pairs, each rotating about vertical hinges into a recess at the side, typically operated with hydraulic rams;
- lift gates – lifted out of position on static towers via winches and wire rope or hydraulic cylinders, allowing the vessel to pass beneath the elevated gate;

b) intermediate gates:

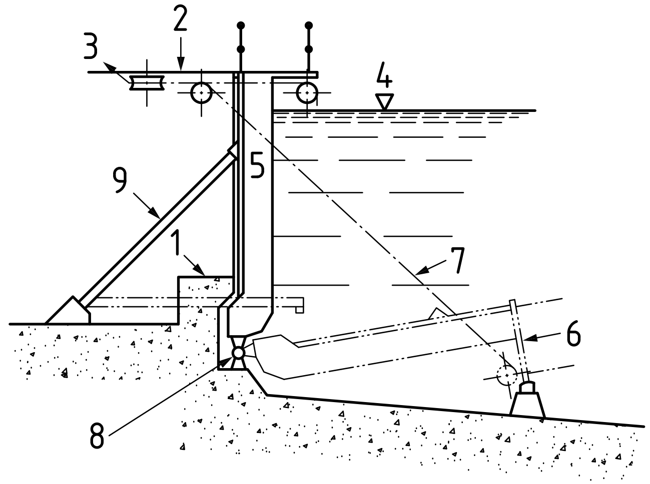
- gate types listed in a) above;
- modular units installed by crane (only used in a dry dock) (see Figure 24):
  - inverted "Y";
  - lamda "λ";
  - stop logs (or stop beams).

NOTE 2 Table 1 shows typical gate types and parameters.

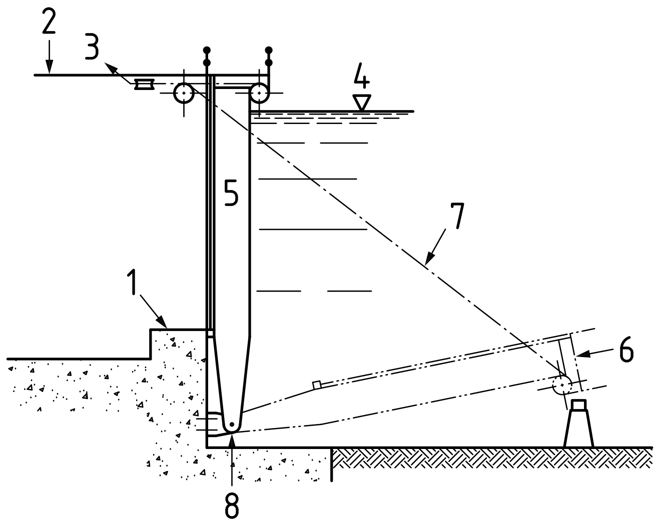
Figure 19 **Examples of entrance gates: flap gates**



a) Spanning box (cross-section)



b) Strutted flap (cross-section)

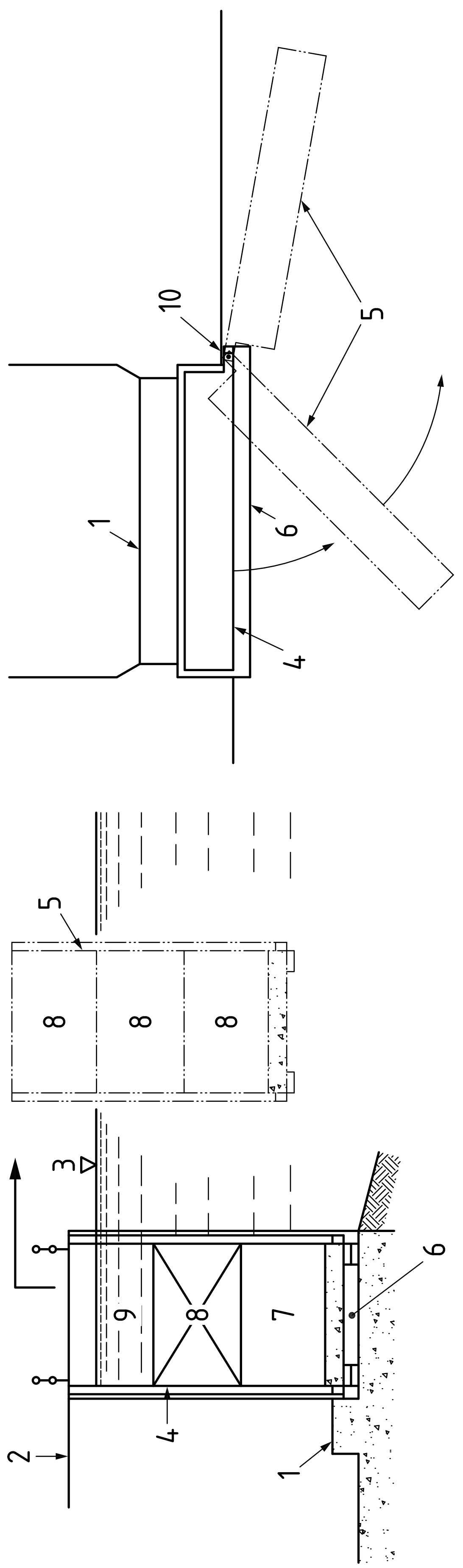


c) Cantilever (cross-section)

Key

1 Dock sill
2 Dock cope
3 To winch
4 Sea water level
5 Gate in closed position
6 Gate in open position
7 Wire rope
8 Hinge
9 Strut

Figure 20 **Examples of entrance gates: floating caisson gates**



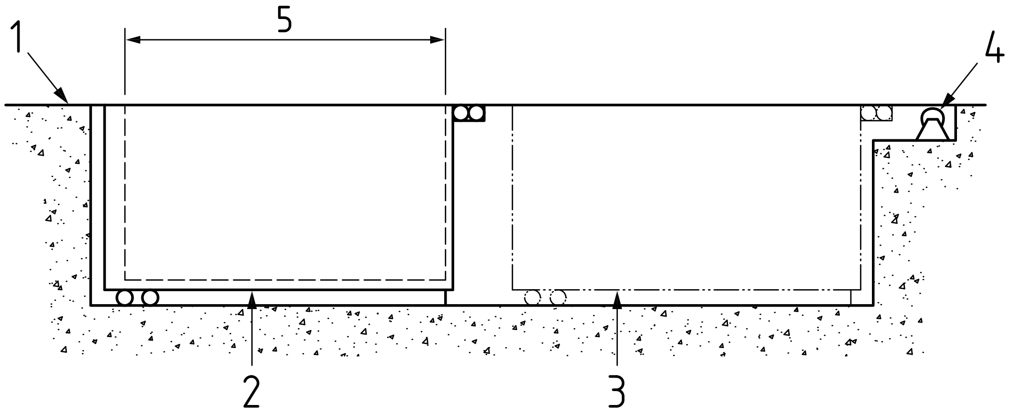
a) Free floating (cross-section)

b) Hinged (plan)

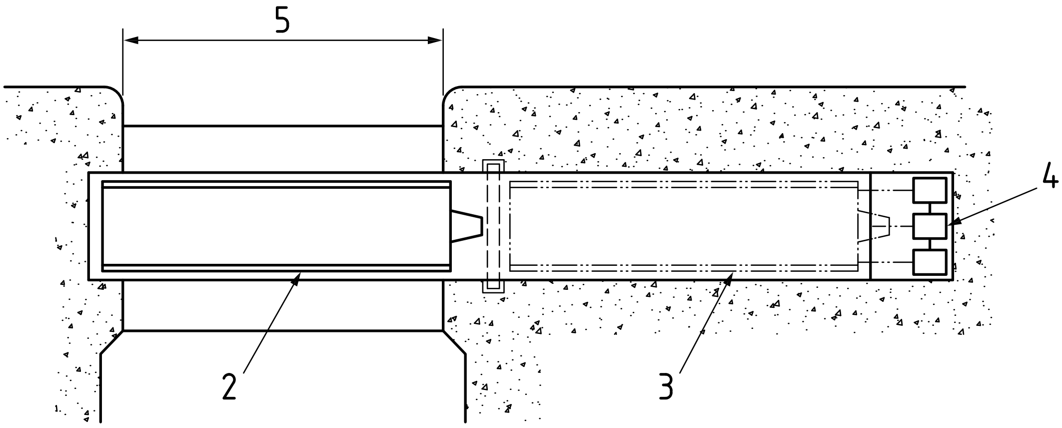
Key

1 Dock sill
2 Dock cope
3 Sea water level
4 Gate in closed position
5 Gate in open position
6 Apron
7 Ballast
8 Air
9 Free-flooding
10 Hinge

Figure 21 **Examples of entrance gates: sliding/rolling caisson gates**



a) Sliding/rolling caisson (cross-section)



b) Sliding/rolling caisson (plan)

Key

1 Dock cope

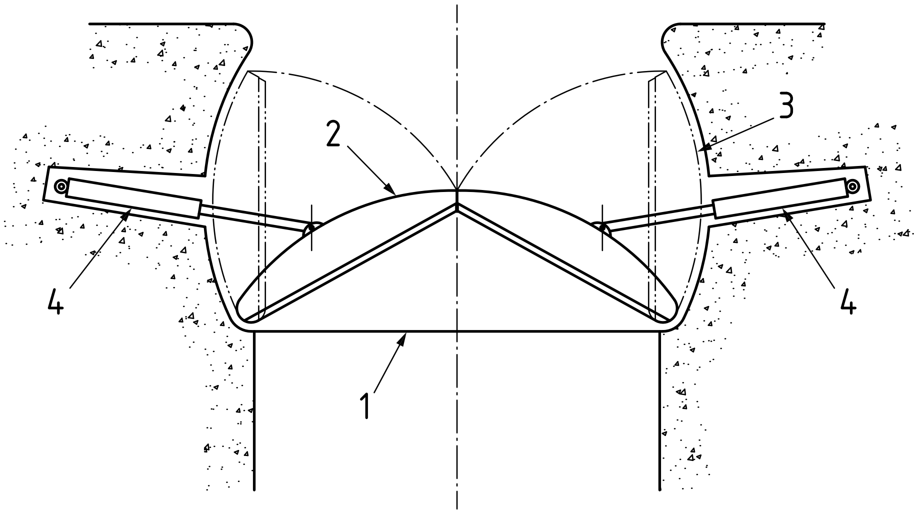
2 Gate in closed position

3 Gate in open position in camber recess

4 Winch

5 Dock or lock entrance

Figure 22 **Examples of entrance gates: mitre gates**



Key

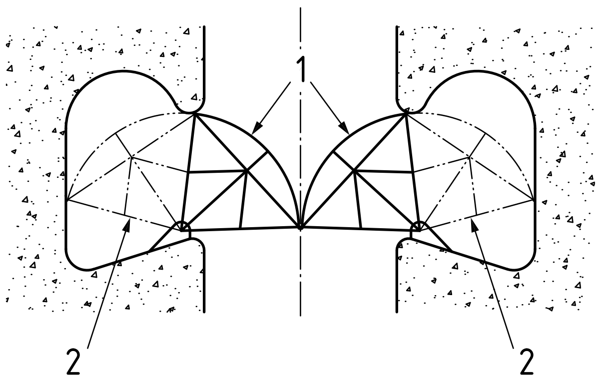
1 Dock sill

2 Gate in closed position

3 Gate in open position in recess

4 Hydraulic cylinder

Figure 23 **Examples of entrance gates: sector gates**

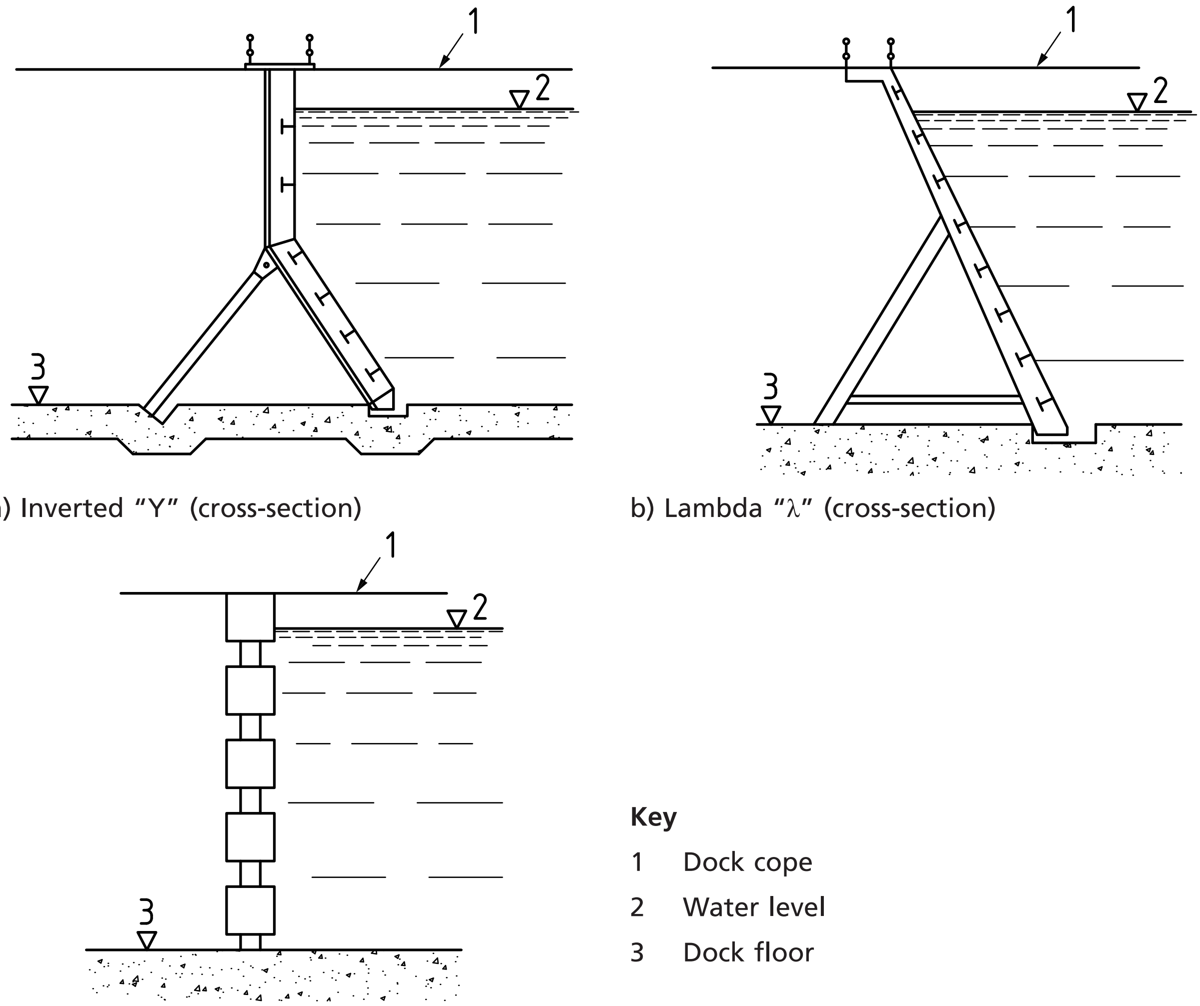


Key

1 Gate in closed position

2 Gate in open position in recess

Figure 24 **Examples of intermediate dock gates**



a) Inverted "Y" (cross-section)

b) Lambda "λ" (cross-section)

c) Stop logs (cross-section)

Key

1 Dock cope

2 Water level

3 Dock floor

Table 1 **Typical gate types and parameters** *(1 of 2)*

Type of gate	Structural form	Speed of operation	Reverse head capability	Method of operation	Ease of maintenance	Gate location when open	Main support requirements
Entrance							
Flap gate	Spanning	Fast (10 min)	In special circumstances	One person with winch operation	Unstepped and floated to dry berth	Fully recessed below sill level	Quoins and sill
Flap gate	Strutted	Fast (10 min)	No	One person with winch operation	Unstepping (very difficult) and floated to dry berth	Fully recessed below sill level	Sill and dock floor
Flap gate	Cantilever	Fast (10 min)	In special circumstances	One person with winch operation	Unstepping (very difficult) and floated to dry berth	Fully recessed below sill level	Sill
Floating caisson	Free floating and spanning	Slow (1 h to 5 h)	Yes	>4 person team plus tugs	Can be reversible and majority of exposed structure is maintainable when closed	Moored at berth while floating	Quoins and sill
Floating caisson	Free floating and gravity	Slow (2 h to 6 h)	No	>4 person team plus tugs	Can be reversible and majority of exposed structure is maintainable when closed	Moored at berth while floating	Sill
Floating caisson	Hinged floating	Slow (1 h to 2 h)	Yes	Two persons	Can be reversible and majority of exposed structure is maintainable when closed	Moored at berth while floating	Quoins and sill
Sliding or rolling caisson	Spanning	10 min with no deballasting, 1 h to 2 h with deballasting	Yes	1 to 2 persons with winch operation	Can be maintained behind stop logs inside recess	Fully recessed in large camber in dock or lock wall	Quoins and sill
Mitre	Three pin arch	Fast (10 min)	No	One person with hydraulic ram operation	Unstepped and floated to dry berth	Small recesses each side of entrance	Quoins
Sector	Truss	Fast (10 min)	Yes	One person with hydraulic ram operation	Removal by crane needed	Large recesses each side of entrance	Via vertical hinges

Table 1 **Typical gate types and parameters** *(2 of 2)*

Type of gate	Structural form	Speed of operation	Reverse head capability	Method of operation	Ease of maintenance	Gate location when open	Main support requirements
Intermediate – Entrance as listed above and Modular as listed below							
Modular	Inverted "Y"	Up to 1 day	No	5 to 10 person team with crane	Easily maintainable when not in use	Stored near dock cope	Dock floor
Modular	Lambda "λ"	Up to 1 day	No	5 to 10 person team plus crane	Easily maintainable when not in use	Flat on dock floor or stored near dock cope	Dock floor
Modular	Stop log	Up to 0.5 day	Yes	3 to 4 person team plus crane	Easily maintainable when not in use	Stored near dock cope	Dock wall quoins

NOTE For seals at quoins or sills, a small force is imposed on the supporting structure to create the seal effect.

12.1.4 Materials for gate construction

The most efficient material should be used for the construction of the gate structure, bearing in mind the implications of whole life costs.

NOTE This is generally found to be steel, but reinforced concrete can be more economic for very large gravity caisson type gates. For small gates (mitre, stop-log, etc.), timber might be a suitable alternative.

12.2 Siting of dock and lock gates

12.2.1 Siting of facility

The general siting of dock and lock gates should be determined as part of the dry dock or lock facility site selection. The siting should be suitable for an entrance gate throughout its operation when in the closed position, when in the open position, and when being opened and closed. Particular criteria that should be taken into account when siting dock or lock gates include:

- exposure to waves;
- space requirements;
- risk of accidental collision.

12.2.2 Space required for gate

The space should be calculated as that required, within the dock or lock and its entrance area, for the gate itself plus clearances required both for safety purposes during normal dock or lock usage and when the gate is being opened and closed. Dimensional allowances should be made for dock furniture, such as fenders, bollards, etc., which could cause obstructions to the gate and handling ropes, etc. when being opened and closed.

The space required for the initial installation should be assessed as part of the dock or lock construction sequence. This could be from within a cofferdam, or other temporary structure, in which case there might be limited availability of space to enable the gate to be manoeuvred into position. Space required for any maintenance operations should be allowed for, either to allow in situ maintenance to be carried out, or in preparation and delivery or removal or re-instatement of the gate or its components.

12.3 Elements of dock and lock gates

12.3.1 Gate design analysis

A gate should be sufficiently robust to ensure that it provides long-term service with relatively low maintenance.

The analysis of the gate design should take into account the need for:

- optimization of gate operations, including tidal windows and speeds of operation;
- efficiency of design to minimize the materials used and ballasting requirements (when necessary);
- durability of the gate against the environment and any operational wear and tear;
- optimization of the gate’s ability to form an effective seal to hydrostatic pressures;
- ease of maintenance;

- potential load cases induced by the mode of transportation from the fabrication yard;
- ease of installation and possible removal for maintenance.

The analysis of the gate structure should be carried out using methods which can accurately determine the deflected shape of the gate under all likely combinations of actions which can reasonably be expected to occur during the operational life of the gate.

NOTE This is necessary to be able to achieve the defined seal performance.

12.3.2 Design actions

12.3.2.1 Hydrostatic

The actions which are applicable should be defined for the type of gate selected and the operational parameters. Hydrostatic actions should be based on the actual density of water for the location, or, in the absence of local data, the value of 1.025 kg/m^3 should be adopted. Hydrostatic actions should be based on minimum, maximum operating (highest tide) and maximum credible (top of structure) water levels together with the application of the appropriate factors of safety.

The hydrostatic load acting on the gate when opened and closed should also be taken into account. In addition, the design should include the areas of the gate which might have increased hydrostatic action acting during non-normal working conditions, such as when being installed (ballast tanks might become buoyancy tanks and vice-versa).

12.3.2.2 Waves

The design should incorporate the increase in hydrostatic actions arising from waves by adding the height of the design wave to the maximum operating static water level. The effects of fatigue arising from continuous wave action should be incorporated in the design.

12.3.2.3 Reverse head

The potential effects of a small reverse head should be checked for all gates, as this can generate a large reverse force which is unlikely to produce an overstress in the structure but can lead to instability for gates with a meeting face on one side only.

12.3.2.4 Compressed air

Compressed air can be used to expel water from tanks in gates, which should be capable of withstanding a pressure in excess of the maximum hydrostatic pressure at the depth of the tank.

Some gates require tanks to be temporarily flooded with water during installation and removal operations which might then be displaced with compressed air. These tanks should be capable of withstanding a pressure in excess of the anticipated hydrostatic pressure at the depth of the tank.

During fabrication it is common for fabricators to use compressed air to test tanks for leaks. The designer should either specify what pressure the fabricator should use, or obtain details from the fabricator of the test pressure to be used.

Where compressed air is supplied by a pump system, a pressure regulator should be provided to prevent unexpected overpressure.

12.3.2.5 Roadways and pedestrian walkways

The loading on the top road deck should be determined from the vehicles that are likely to use the route across the gate. The minimum design load adopted should be 10 kN/m^2 or a concentrated load of 20 kN applied to a square area 300 mm by 300 mm for a roadway.

A pedestrian walkway over gates should be designed for 5kN/m^2.

12.3.2.6 Collision

A risk assessment should be made of the vulnerability of the gate to accidental collision, including glancing blows as a vessel passes a gate, the function of the element at the potential point of impact and the overall consequence of the failure of an element at risk of collision. Where possible, risks should be mitigated through the protection of elements by fendering, protected booms or a precautionary factor of safety.

12.3.2.7 Seismic effects

Where required, the gate should be capable of withstanding seismic actions due to the simultaneous accelerations in all three orthogonal axes, including vertical accelerations induced within the water column itself. Inertial forces from the total likely structural mass and any trapped water within it, and any added hydrodynamic mass effects, should be incorporated into the design. Seismic design is complex, and specialist advice should be sought.

At all times before during and after a seismic event, the gate should remain stable and the integrity of the gate should be maintained such that no significant leakage occurs, lives will not be endangered and the dock/lock remains operational with only minor repairs being required.

12.3.2.8 Factors of safety

The guidance given in BS 6349-2 should be used, in conjunction with the following recommendations.

- Hydrostatic: Characteristic water levels [i.e. maximum operating static water level up to extreme high water level (EHWL), which might include future sea level rises] should be treated as permanent actions, with a minimum partial factor of 1.1. When an increased water level up to a maximum credible water level plus the effects of waves (e.g. maximum possible retained height of water) is applied then a reduced partial factor, no less than 1.0, may be used.
- Collision: The event of a collision, including dropped loads, should be treated as an accidental load.

12.3.3 Stability

The overturning seated stability of gates that rely on gravity for their stability should be checked by analysis of the overturning and restoring moments.

NOTE The factor of safety for overturning might be different while the dock or lock is being dewatered.

If the gate is a floating caisson type gate then the floating stability should be determined. The metacentric height of the gate should be maximized to provide a sufficiently stable structure during manoeuvring operations in its normal floating condition (i.e. floating sufficiently that it can be moved with tugs, or similar) and in wind conditions consistent with its normal operational state. The metacentric height should be not less than 0.30 m. Stepping and unstepping operations should be treated as a temporary condition. In this temporary condition the metacentric height value may be reduced, but it should always remain above 0.05 m. Stability is complex, and specialist advice on naval architecture should be sought.

Some alternative gate types might float during installation and removal. These gate types should be checked to ensure they will remain stable whilst afloat in this temporary condition.

12.3.4 Preponderance

The net downward force (preponderance) of any caisson or similar buoyant gate when in its closed position and normal fully ballasted condition should typically be a minimum specified value, regardless of the external water levels.

NOTE Large gates typically have a value of 50 t.

12.3.5 Steelwork corrosion

The design should include sacrificial allowances for corrosion of steel surfaces as determined by a corrosion risk analysis or as follows, as a minimum:

- wetted surfaces that are fully exposed should have an allowance of 1 mm in addition to a maintained coating system;
- dry surfaces inside permanently dry and sealed air tanks need have no allowance;
- surfaces inside general ballast chambers should have 1 mm allowances;
- surfaces inside sealed ballast chambers filled with treated water need have no allowance.

The use of sacrificial anodes should be incorporated in the design for steelwork corrosion protection in particularly aggressive marine environments or where frequent planned maintenance is not practical.

12.3.6 Seals and meeting faces

The seals and meeting faces (both gate and dock or lock structure) should be designed and specified to tight tolerances to avoid high local stresses and maximize the sealing capability of the gate. A flexible seal should be used to help achieve a watertight seal.

The meeting face material should be capable of transmitting the load from the gate without significant elastic deflection. The material should be selected from timber, rubber or plastic, although in circumstances of high compressive loads, alternatives such as steel should be used.

The meeting faces on sill and quoins should be formed from one of the following:

- high class concrete units which have been precast against a machined steel shutter to produce an accurate finish within the tolerances below;
- continuous stainless steel meeting face plates;
- dressed granite blocks.

The specification for accuracy should be given in three parts:

- a maximum deviation at any point on the meeting face from a defined plane;
- a maximum deviation from a straightedge of defined length laid at any position on the meeting face;
- a maximum step in the face at joints of precast units or deformations of a shutter.

The civil works and gate meeting face tolerances for gates with rubber seals should be:

- ±3.0 mm deviation from the plane;
- ±0.5 mm from a straightedge 2.0 m long;
- 0.5 mm step.

Meeting faces should be protected from damage by the provision of fenders at dock and lock entrances. Where possible, the cope in front of the entrance should be cantilevered over the entrance pier wall such that it is at least flush with the side face of the quoin, thus presenting a smooth entry for ships into the dock or lock. Flap gates should be fitted with hinged plates to cover the gap between the sill and the base of the gate when the gate is open to protect the meeting face from falling debris. The meeting faces and adjacent structure for caisson gates should be designed to minimize the risk of debris preventing the gate from being installed in its correct position. The means for checking and clearing debris should be allowed for in the design.

12.4 Equipment for dock and lock gates

12.4.1 Operating equipment

12.4.1.1 General

The operating equipment for dock and lock gates should be of robust construction to withstand the onerous conditions in shipyards and locks. Good reliability is essential and maintenance should be as simple as possible. Protection against corrosion should be provided to a high standard owing to the aggressive environment in which gates are located.

12.4.1.2 Wire ropes

Wire ropes should be manufactured from zinc coated steel wire. The breaking load of the rope should be at least three times the maximum rope tension. The maximum rope tension should be calculated as the greater of the following two cases:

- rated capacity of the winch;
- maximum force during operations, including but not limited to the forces due to accelerations, sheave frictions and dead loads.

12.4.1.3 Winches

The winches specified for flap gate operation should be reliable, of robust construction and without complex controls. The winch drum should be a size which is compatible with the wire rope used.

The winch should be capable of operating at two speeds and should be reversible; normal speed should be used for the majority of the run and slow speed used at the initial opening and final closing stages. An inching facility should also be provided. A rope guide for control of spooling should be fitted when necessary. Control sensors should be incorporated as follows:

- sensor to stop the winch before final closure so that the final movement can be performed by inching;
- slack rope sensor to prevent the winch paying out when continuous opening travel of the gate is impeded by an obstruction or wind or wave conditions. This sensor should also stop the winch when the gate is fully open.

The winch controls should be located in the dock or lock control room with good visibility for the operator of the gate.

Friction forces in the sheaves should be included in determining the capacity of the winch.

12.4.1.4 Capstans and bollards

Capstans and bollards should be provided for the control of floating caisson gates.

12.4.1.5 Pumps

Caisson gates can be fitted with pumps for controlled ballasting and de-ballasting operations. These should be sized to ensure that the gate can be operated within the necessary time.

12.4.1.6 Valves

Where gates are fitted with actuated valves to enable ballast tanks to be flooded or emptied, the design should be able to accommodate safely the event of a power failure during ballasting or un-ballasting operations.

12.4.1.7 Hydraulic rams

Hydraulic rams are typically used on mitre, sector and small flap gates. The ram should be sized so that there is sufficient capacity to operate the gate against a head of water, plus wind and current loads. Friction forces should also be taken into account.

12.4.1.8 Ventilation equipment

Tanks in gates that require regular access (e.g. control/equipment rooms) might need to be classified as a confined space and should have permanently fitted forced ventilation equipment.

Tanks which will only be accessed during infrequent maintenance periods should be capable of being ventilated via temporary mobile ventilation.

12.4.2 Operating equipment maintenance and failure

Systems should be specified which facilitate maintenance and repair or replacement over the full design life of the gate.

An alternative means of operating the dock or lock gate as a whole, or any filling/emptying equipment within it, should be planned to provide a back-up in the event of failure of a critical item of operating equipment.

NOTE This can be by using alternative methods of operating the gate or with the use of spare equipment on standby.

13 Piped services and electrical distribution systems

13.1 Operational parameters of piped services and electrical systems

13.1.1 General

The piped services and electrical systems form a critical part of the shipyard operational infrastructure and should be planned, coordinated and designed in conjunction with the rest of the infrastructure, structures, buildings, plant and equipment that form part of the facility.

13.1.2 Concept design considerations

13.1.2.1 Capacity expansion

Piped services and electrical systems should incorporate sufficient spare system capacities within the initial design to take account of known future development, expansions and phasing of the facility in respect of each of the piped services and electrical systems. Where future increase in capacity is not quantifiable, the designer should allow for:

- free space adjacent to the existing services to increase the service capacity;
- free space adjacent to the existing services to increase the number of services;
- additional reserved service corridors;
- additional connection or tap off points;

so that additional piped and electrical services can be incorporated with minimum disruption to existing services and operations.

13.1.2.2 Stakeholders

During the conceptual design of the piped services and electrical distribution systems, external stakeholders such as the authority having jurisdiction, fire-fighting officers, insurance companies and utility supply companies should be consulted by the shipyard operator and designers, as their requirements can have a substantial impact on the conceptual design. Requirements related to water, power and sewage from external utility authorities can take several years in the planning, implementation and construction following the initial enquiry, so early consultation and involvement of the utility supplier is essential.

13.1.2.3 Proximity

The conceptual design should include segregation and separation assessments for the proximity of:

- individual services to each other;
- hazardous materials, liquids and gases to operational areas for:
  - the safety risk to personnel and other facilities;
  - the risk of hazardous items being affected by operations, including potential ignition sources, vehicle movements, shipyard operations, personnel, etc.

13.1.3 Range of piped and electrical systems

The planning of the piped services and electrical systems for shipyard facilities should be carried out based on a clear and early definition of:

- the type of work which is envisaged to be undertaken; and
- the services to be provided.

During the concept design, the appropriate services should be determined for the required type of piped service for each shipyard work activity. If the operator of the shipyard has been identified, they should be involved in the determination of each service.

When vessels are drydocked, the ship's power generation and other services might not be fully operational. Provision for supplies from the shore should be incorporated within the design and facilities that can be made available to vessel owners. The determination of services supplied to the vessel should be based on the service requirements for the range of vessels likely to be docking in the shipyard. If ballast water is received from vessels, it should be treated as contaminated water.

The types of services should be grouped under the following headings which cover the common services in shipyards:

a) services to ships, which vary according to the throughput types of ships:
    - ballast water replenishment;
    - cooling water supply for cooling of ships' systems;
    - fire-fighting water supply;
    - potable water supply;
    - electrical power supply;
    - telecommunications and data networks;
    - fire alarm, detection, warning and communications system;
b) shore services, systems and service points, which are dependent on the planned shipyard process activities:
    - fire-fighting;
    - fuel supply and distribution;
    - welding and cutting gases:
        - acetylene;
        - compressed natural gas (CNG);
        - liquid petroleum gas (LPG);
        - oxygen;
        - carbon dioxide;
        - argon;
        - nitrogen;
    - potable water;
    - industrial water;
    - high voltage electrical distribution systems;
    - low voltage electrical distribution systems;
    - control and monitoring:
        - telecommunications;
        - CCTV;
        - supervisory control and data acquisition (SCADA);
        - public address systems;
    - lighting:
        - general area lighting;
        - access and working lighting;
        - task lighting;

    - security and perimeter lighting;
    - permanent and temporary lighting systems;
    - dock floor lighting systems;
  - distribution service units (equipment supplies);
  - portable equipment plug units;
  - vessel supplies units (electrical supplies and communications systems);
  - fire detection, alarms, warning and communications systems;
  - dock arm power rail system;
  - dock floor, personnel, fire and safety system audible and visual warning alarms;
  - cable ways, support systems, ducting and draw pits;
  - earthing networks and grids;
  - earthing, bonding and lightning protection;

c) collection of waste flows:
  - contaminated water;
  - foul water;
  - surface water;
  - wash-down water.

13.1.4 Requirements of piped services

The design of piped services should be based on the estimated consumption levels. The requirements should be identified for each work activity and each service point, and should include such parameters as flow rate, pressure, temperature and composition/cleanliness, according to the service.

The estimate of the consumption and the requirements of each service should be carried out in close cooperation with the operator of the shipyard.

The peak and average consumption levels should be estimated, taking diversity into account, in order to design the generation, storage and distribution facilities and equipment. The location, level of storage and buffering of supplies should allow for the variances in supply and the large fluctuations in demand typical for different work activities in shipyards. The locations where each service point is required should be identified.

13.1.5 Requirements of electrical systems

13.1.5.1 Shore services

The amount of connected electrical power using equipment in the shipyard should be calculated. Not all of the equipment or facilities will require electrical power at the same time, and therefore the diversity between connected electrical power and actual electrical power usage should be derived. It should be a safe and secure electrical distribution arrangement, capable of enabling flexibility in the event of planned and unplanned disruptions in sections of the network, to maintain operations.

The electrical capacity of the shipyard should be sufficient to provide the calculated peak demands of the shipyard operational requirements and incorporate sufficient spare capacity to accommodate anticipated future planned development, expansion or growth.

The electrical system design should include the peak demand for each consumption area and the average operational demands of the facility, such that the electrical system can provide the necessary electrical capacity at the desired area to provide calculated demands. The fault level contributions from dynamic systems such as large pump motors, drives, winches and cranes, and the affects upon the electrical network design and arrangement, should be incorporated in the design.

The voltage of the system should be selected relative to the system power requirements, network arrangement and capacity requirement for an efficient, secure and reliable electrical network, allowing for system flexibility in relation to operational demands, maintenance requirements and unplanned electrical system disruptions.

The provision of electrical power to ships within the shipyard should be designed for ship systems, maintenance and testing. These services to ships should be incorporated into the electrical system network design and arrangement, depending upon the number, size and electrical capacity requirements of the ships.

13.1.5.2 Supplies to ships

Depending upon the shipyard system voltage and frequency, additional voltage (high and low voltage) and frequencies (50 Hz and 60 Hz) should be provided, either generated or converted, to provide the required power, voltage, frequency and earthing arrangements for the supplies to the vessel. The services to ships should be coordinated with the docking and berthing arrangements relevant to the vessel electrical system switchroom and switchgear.

The design should allow for the supplies to the vessel (high voltage or low voltage) without a permanent connection to the earth of the vessel itself.

13.1.6 Supply of services to the shipyard site

The supply arrangements for industrial gases should be planned according to the characteristics of the gas and the supply method of the local gas suppliers: it can be bottled, pressurized or cryogenic. The design of the industrial gas reception system and storage system consequently should depend on the foreseen supply method.

Potable water should be planned to be either supplied by a water utility company or produced at the site from seawater via a reversed osmosis plant or from a water treatment plant.

The supply of power to a shipyard should be provided from a reliable, robust and secure electrical supply such as a public/national utility company, and/or internally generated at the site. Where the public/national utility electrical supply is unreliable then standby emergency generation should be provided at the site to minimize disruption of operations and ensure continuation of the facility's functions. Sufficient electrical supply capacity should be provided to serve the peak demands of the shipyard, future demand and expansion.

NOTE The design of industrial gas reception facilities, gas storage systems, water treatment plants and power generator sets is outside the scope of the BS 6349 series.

13.1.7 Disposal or treatment of waste water

For services that produce waste water, a suitable means of disposal should be determined, e.g. treatment for contaminated water.

NOTE The design of sewage, contaminated or waste water treatment facilities in a shipyard is outside the scope of the BS 6349 series.

13.2 Siting of piped services and electrical systems

13.2.1 General

Siting and routing of piped services and electrical systems should be included as an integral part of the shipyard design and development owing to the space required, range, hazardous materials and gases, operational and capacity requirements of the shipyard's services.

Designated locations of services, routing and system compounds or storage facilities should be coordinated with all other facilities, operational requirements, workshops, buildings and services intake points, segregation, zoning, safety and safety distance, hazard controls and mitigations.

The location of services both above ground and below ground should be determined in the context of:

- type of service;
- operational need and function, criticality, robustness, access and maintenance requirements;
- capacity;
- impact of, and susceptibility to, environmental conditions (both ground and atmospheric), other external influences and susceptibility to damage;
- proximity to other systems and services.

Shipyards can include very congested facilities, with sometimes limited available space for the services, and therefore the design should be planned to incorporate the piped services and electrical systems within the maritime structures. The services should be located in designated service corridors and routes where possible. Sizing of trenches and pipe racks should allow for the crossings, changes in direction and level, pipe take-offs, connection points and future maintenance access to pipe flanges, valves, supports, indicators, bends and elbows.

Shipyard activities typically include transport of structures and components on transporters with heavy wheel loads. The services should be at sufficient depth, with suitable protection from the expected ground loads. Where trench covers are installed they should be designed to allow for heavy wheel loads.

Piers and quays are heavily utilized operational areas, requiring regular and demanding access with often limited space for services. The services should be sited and coordinated within the structures to minimize their susceptibility to damage but allow the appropriate access for operational and maintenance requirements.

The routing of services which rely on gravity to operate (such as surface water drainage and sewers) should be planned to take into account the necessary depth, gradient and changes of direction. The routing of these services should take priority over that of services which do not rely on gravity, but should be coordinated with those services.

The siting of piped services and electrical systems should not hinder or be susceptible to damage from mooring, docking and berthing operations, maintenance, repair, construction or fitting out of vessels.

13.2.2 Piped services

Piped services originate from one or more sources of supply and are distributed around the site either in a ring main or branch line or a combination. A ring main should be adopted where:

- reliability and redundancy of supply is required; and/or
- there are heavy fluctuations in demand, potentially resulting in local pressure drops.

Routing of the ring mains should be such that major consumers are connected to the ring. Separate sub-rings should be provided inside the buildings.

NOTE Piped services are usually buried directly in the ground, contained in open or closed trenches/troughs//galleries, run overhead or a combination of these to facilitate access for operations, inspections and maintenance.

Piping of acetylene should be separated from oxygen piping and electrical cabling. Piping of flammable gases should be positioned as much as possible in open trenches and galleries. Wherever possible, piping of dangerous gases should not be located in enclosed spaces where the gases could accumulate. If such location is unavoidable, measures should be taken to minimize the possibility of leakage and to deal with any leakages that might occur.

13.2.3 Electrical services

The locations of substations and electrical equipment should be coordinated with the structures and facilities to minimize the physical space in the operational areas and to alleviate hindrance or obstructions to operations and to docking, berthing or mooring facilities.

The electrical services should distribute the electrical power in the most practical, reliable, robust and efficient way for the operational facilities of the shipyard.

NOTE 1 The shipyard is likely to incorporate or require an intake substation with the incoming supply provided at high voltage, which serves as the main substation and feeds other strategically located secondary substations, serving buildings, plant, equipment and the main load centres of the shipyard, before in turn serving other facilities or being transformed down to other voltages.

The main intake substation should be located within the shipyard at or near the boundary.

NOTE 2 Cabled services can originate from one or more sources of supply (e.g. a backup generator) and are then distributed around the site interconnecting the secondary substations, buildings and facilities, in a ring or radial electrical network arrangement or a combination of these. The system voltage depends upon the national or regional standard network voltage appropriate to the power requirements and electrical capacities determined for the shipyard. To facilitate an efficient design and electrical system arrangement, it is usually at high voltage (typically in the range of 10 kV to 20 kV).

The electrical network and cabling system should be suitably designed and configured to minimize potential disruptions of the shipyard facility and operations in the event of maintenance and network interruptions (planned or unplanned). Each section of the electrical network should be designed, configured and installed to carry the maximum power demand in each section of the network, including any system network reconfigurations for maintenance and interruptions, with allowance for future developments or electrical power requirements.

Where plant, equipment or facilities (such as large dewatering pumps, compressor houses, shiplifts, cranes, construction halls, machines and workshops, blast and paint shops) have a large or distant high power demand, dedicated substations should be provided to serve that facility. The electrical network should be suitably configured to provide alternative network arrangements for the provision of electrical power to substations.

13.3 Elements of piped services and electrical systems

13.3.1 Piped services

The piped services design should comprise:

- pipes for containment of the fluid;
- valves for control and isolation;
- protection systems to minimize risk of damage and, where applicable, corrosion;
- access points for maintenance and inspection;
- connections for equipment at the point of demand.

13.3.2 Electrical systems

13.3.2.1 Electrical systems cable containment

The interconnecting cabling network between substations, switchgear and equipment should, where possible, be routed around the shipyard by one of the following methods:

- underground electrical cable ducting with cable draw pits at appropriate spacing and at changes in direction;
- electrical services galleries complete with cable support systems;
- electrical services trenches complete with cable support systems and trench covers;
- above ground cable ladder/tray systems and overhead gantries (although this should be avoided where possible in main traffic, plant, equipment movement and construction areas).

Where cables are incorporated in underground cable ducting systems then the cable route should be clearly identified. Cable markers should be placed at the finished ground level at regular intervals and at every change in direction, clearly identifying the cable system voltage, cable direction and depth of laying. The cable marker should be a robust embossed tile and/or post suitable to the location and area through which the cables are routed.

All cable runs should be in one complete length, with cable joints in between switchgear and distribution equipment kept to a minimum. Where cable joints are necessary, the positions of the cable joints should be clearly identified at finished ground level.

For cables installed in service galleries, trenches or on cable ladder/tray systems or overhead gantries, the cables' system voltages should be clearly identified.

All cable routing and facilities should enable the installation of the cables without compromising the cable manufacturer's minimum bending radii. In the absence of any specific requirements, the following recommendations should be met:

- high voltage cables should have a minimum bending radius of 15 times the overall outer diameter of the cable;

- low voltage cables should have a minimum bending radius of 10 times the overall outer diameter of the cable.

13.3.2.2 Means of control and isolation

All electrical circuits and cable systems should be suitably separated and/or sectioned to minimize disruption to the electrical system and operations of the shipyard.

Each circuit or distribution network should be provided with a means of automatic disconnection of the electrical supply, and means of isolation or disconnection for maintenance, functional switching and emergency switching to remove any fault or danger as quickly as possible for any unexpected event.

Automatic reinstatement of electrical supplies which could cause a danger to people or operations should be avoided.

13.3.2.3 Identification and protection from damage

Cable systems of different voltages should incorporate different coloured outer cable sheaths, following international or national/local conventions as appropriate, to assist with cable system voltage identification.

All cables should be clearly and uniquely identified at each end of the cable and at strategically located points along the cable route to assist with future identification of the cable.

The unique cable identification system should clearly identify the cable system voltage, supply source, system or equipment type (e.g. high voltage distribution, low voltage distribution, high voltage supply, low voltage supply, lighting, power or control circuit, etc.) and incorporate a unique number for each cable.

Cabling systems of differing voltages should be suitably segregated, particularly where they might interfere and/or be likely to induce voltages on the other cables.

Where cables are exposed above ground then they should be mechanically protected from inadvertent damage and ultraviolet light.

Where possible, cables should not be routed through or near designated hazardous areas and zones. Segregation and separation zones should be provided to minimize the introduction of potential hazards.

Equipment, functional and structural earthing points should be clearly identified with permanent labels.

Coordination with, and physical clearance from, cranes, winches, plant and equipment should be an integral part of the design.

13.3.2.4 Access for inspection and control

Depending upon the method of cable installation, electrical system and maintenance requirements of equipment, access should be provided at specific locations along the cable route and/or at the termination points at each end of the cable for future inspection and testing.

Equipment, functional and structural earthing points should be clearly identified with permanent labels for future reference, inspection, maintenance and testing purposes.

Access to equipment and systems should be provided with the necessary space for the inspection and maintenance team to carry out their duties safely and correctly. Areas in front of and around equipment should be provided with suitable safety barriers.

13.3.2.5 Connections/equipment at point of demand

Electrical equipment at the point of demand or near the entrance to a building should be provided with suitable means of isolation, circuit protection devices and means of disconnection of the electrical supply.

Each connection point and item of equipment should be clearly identified in respect of its function.

Each connection point and item of equipment should be suitably protected from access or interference by non-authorized personnel.

Access to electrical equipment should be achievable only by the use of special tools.

13.4 Equipment for piped services and electrical distribution

13.4.1 Equipment for piped service systems

13.4.1.1 Piping

A system of pipes and fittings (elbows, bends, tees valves, etc.) should be employed to distribute the particular liquid or gas around the site to the points of demand. The materials selected should be appropriate for the specific service and the prevailing climatic conditions.

NOTE The most common materials include carbon steels, stainless steels, non-ferrous metals, plastics and composites.

13.4.1.2 Isolation and control

Piping networks should include means to isolate the flow of liquid or gas for emergency use, operational purposes and maintenance.

Equipment located at the waterfront should be limited to isolation valves. Valves can be located above or below the ground, and suitable arrangements for their support and access for manual operation should be provided where required.

Isolation and control valves should be sited so as to be readily accessible and with safe access for the operator.

NOTE Potential hazards include vehicular traffic, moving equipment, falls from height/into pits and, in emergency conditions, exposure to fire or explosion.

13.4.1.3 Pipe bridges

Pipe bridges are sometimes required to facilitate the crossing of a road or other services. The location and vehicle headroom clearance height should be defined at an early stage, as this can affect the movement of large vehicles and site cranes.

13.4.1.4 Connections/equipment at point of demand

Within the waterfront area, the need for connections to other systems, items of equipment or termination points (usually at isolation valves) should be determined. The following should be provided as applicable.

- For welding and cutting gases and compressed air, offtake manifolds should be provided to allow connection of the hoses to the torches or pneumatic devices.
- Fire-fighting systems are connected to fire hydrants, fire monitors or sprinkler systems. Where the service is provided for ships, an isolation valve should be provided.
- Other water systems usually terminate with hydrants or isolation valves. Discharge points to the sea should be provided if required.

If the piping is to enter a building, an isolation valve outside the building should be provided.

13.4.2 Equipment for electrical systems

*COMMENTARY ON **13.4.2***

The equipment required for the electrical system's distribution varies depending upon the physical size and operations of the shipyard and required facilities.

This subclause describes the facilities that need to be provided to assist with the interconnecting cable distribution and electrical equipment of the shipyard.

13.4.2.1 Electrical cabling distribution systems

Electrical cable distribution systems require the physical routing of cables such that they are protected from harm or damage. The cable systems should be provided with means of disconnection, isolation and protection devices to protect the cables from overcurrent and fault current at the source end.

Cable systems should be provided with the correct means of mechanical and physical protection and support throughout their entire length, below and above ground.

Cables should be provided with correct space, arrangements, routing and termination glands for the environment.

13.4.2.2 Substations and distribution points

Substations, switchgear rooms, distribution points and feeder pillars should be provided at appropriate locations throughout the shipyard, to facilitate the electrical distribution to the areas and equipment to be served, and to provide means for segregation of the electrical circuits to minimize disruption to the electrical systems, plant, equipment and buildings.

The substations, switchgear rooms, distribution points or feeder pillars should house and incorporate all the circuit protection devices and means of isolation of the respective feeder circuits. These facilities should be suitably protected from access by non-authorized personnel.

Distribution service points, known as dock side service units, should be provided at designated spacings and positions in the operational areas such as dry docks, quays, piers, construction areas, laydown areas and fabrication areas, to facilitate the provision of electrical supplies for equipment.

13.4.2.3 Cranes

Electrically powered cranes should be provided with electrical supplies at designated points in dry docks, piers, quays, construction areas, and laydown and fabrication areas.

Cranes with trailing cables should be provided with cable turnover pits, cable anchor drums and crane cable slots, which should be constructed and coordinated within the marine structures to protect and minimize damage to the cable systems.

13.4.2.4 Dock arms

Electrically powered dock arms should be provided with cable reeling systems or power rail systems located adjacent to pipe services on the dry dock. These electrical power systems should be suitably segregated and separated from the hazardous and flammable gases likely to be present within a shipyard.

13.4.2.5 Electrical equipment protection

All electrical equipment installed above ground should be suitably protected from damage through the installation of barriers and/or be suitably located, identified and protected by suitable structures.

Barriers should also be provided in and around the required access points of electrical equipment, to provide protection for the operations and maintenance personnel.

Area lighting columns should be provided with suitable protection barriers or posts.

13.4.2.6 Temporary equipment

Some equipment or plant will have several designated or temporary locations to suit flexible operational requirements. Permanent provisions within the marine structures should be provided for the electrical infrastructure to serve the various temporary locations of equipment and plant such as vessel access towers and gangways.

14 Control systems

14.1 Operational parameters of control systems

14.1.1 Operational benefits

The design of the shipyard should incorporate control systems that can:

- reduce the health and safety risks during operation of the facilities;
- increase operational reliability and speed up some operations;
- reduce the consumption of power and other utilities, thereby improving the environmental performance of the shipyard.

14.1.2 Definition of a control system

Instrumented control systems within the shipyard design comprise electrical, electronic or programmable electronic systems, and should include some or all of the following functions:

- monitoring, recording and logging of equipment status and system parameters;
- provision of operator information regarding equipment status and system parameters;
- provision of operator controls to effect changes to the equipment status;
- automatic process control/sequence control during start-up, normal operation, shutdown and disturbance, i.e. control within normal operating limits;
- detection of onset of hazard and automatic hazard termination (i.e. control within safe operating limits) or mitigation;
- prevention of automatic or manual control actions which might initiate a hazard.

These functions should be provided by a suitable combination of alarms, protection through trips, interlocks and emergency shutdown, and process control systems.

The control systems can be independent, or may share elements such as human interface, equipment interface, logic, utilities, environment and management systems.

The human interface should comprise a number of input and output components, such as control consoles consisting of discrete pushbuttons and lamps, keyboard/mouse, indicators, annunciators, graphic terminals, mimics, audible alarms and charts.

The equipment interface should comprise inputs (sensors), outputs (actuators), and communications (wiring, fibre optic, analogue/digital signals, pneumatics, fieldbus, signal conditioning, barriers, and trip amplifiers).

The logic elements should be distributed, and linked by communications, or marshalled together. They should be in the form of relays, discrete controllers or logic elements (electronic, programmable or pneumatic), distributed control systems (DCS), supervisory control and data acquisition (SCADA), computers (including PCs), or programmable logic controllers (PLC). The logic elements should perform continuous control functions, or batch or change of state (e.g. start-up/shut-down) sequences. Logic functions should be undertaken within smart sensors or actuators.

Control systems used in shipyards should encompass SCADA systems, DCS, and other smaller control system configurations such as skid-mounted PLC often found in the industrial sectors and critical infrastructures.

14.1.3 Operational design of control systems

At the concept stage of the shipyard development, the high level requirements for the control systems for the electro-mechanical plant and equipment should be defined and agreed in order to achieve the safe and efficient operation of the shipyard. This conceptual information should be fed into the recommended risk identification process undertaken at the shipyard conceptual layout stage.

Following the completion of the conceptual layout and the associated hazard identification, the control system engineers, in close cooperation with other disciplines (including, but not limited to, civil, electrical and mechanical), should develop detailed operational and control philosophies for the respective equipment. The shipyard operator’s key operational and maintenance staff should be consulted in order to incorporate their requirements and experience.

Detailed risk assessments should be undertaken for each piece of equipment or plant. This may be in the form of machinery risk assessments where the identified hazards are local to the machinery and are relatively easy to contain by guarding or access control. A hazard and operability (HAZOP) study should be undertaken:

- where hazards associated with a machine are present over a wide area;
- where hazards are caused by the interaction of the new facilities with existing facilities;
- in the case of complex multidisciplinary projects.

The HAZOP study should include all the required design disciplines and operation and maintenance personnel.

The design of the control system should be undertaken by competent persons in line with all applicable local and international standards and good practice. Adequate resource should be given to the validation and verification of the design of the control system, and in particular to any control system safety functions identified.

All equipment and plant should be subjected to a methodical and detailed factory acceptance test (FAT) and, when installed, to a rigorous site acceptance test (SAT).

Comprehensive technical files and installation, operation and maintenance manuals should be produced by a competent technical author. “As built” drawings should also be produced.

The control philosophy for each system should as a minimum include a description of the requirements of the equipment under machinery or plant control, and should define:

- level of automation;
- control equipment location and number of control locations;
- level of redundancy;
- level of reliability;
- level of availability;
- level of safety.

14.2 Siting of control systems

14.2.1 General

Locations should be established for control panels, motor starters and control consoles, and space should be allocated accordingly.

The location of the control panels should take into account the following factors:

- control requirements (setting-up, maintenance and operation);
- line of sight of equipment and shipyard operations;
- protection of the equipment and personnel from rain, humidity, dust, wind, sun and flooding;
- protection of the operator(s) against hazards (e.g. equipment failure/site traffic);
- proximity of other services;
- adequacy of space and suitability of access for installation, inspection, maintenance and operation;
- human factor and ergonomic features such as console height/palm push-buttons or solar glare.

14.2.2 Environmental considerations

The control equipment should be selected to take into account the environmental constraints associated with its location. The temperature range and tolerance to other environmental factors should be incorporated in the design of electronic and electro-mechanical components of control systems. Where necessary, control panels and equipment should be located in an environmentally controlled room. All control system interlocks and safety functions to prevent dangerous operational states should be implemented within the equipment control panels.

14.2.3 Physical considerations

At least one of the following control locations should be selected:

- local control;
- remote control;
- centralized control.

A local control point, with limited functionality, directly adjacent to the equipment should be provided to facilitate fault finding, setting up and maintenance. Suitable responsibility for functionality should be allocated to the person controlling the equipment to ensure that the equipment is controlled safely.

Where required, a remote control point (in addition to a local control) should be provided. The remote control point should be provided where good overall visibility is required, to allow the operator a better viewing vantage point from which to achieve safe equipment operation. Where necessary, CCTV should be provided to supplement the operators' views of the equipment and other peripheral area hazards. This control point should generally provide fully automated or semi-automated sequence control, with trips, interlocks and emergency shutdowns to prevent dangerous operational states.

For complex operations with multiple equipment, a centralized control point, in addition to limited local and remote control points, should be provided. The central control point should be provided in a fully air-conditioned room which may also be used to control other site-wide equipment and processes. This control point should generally provide fully automated sequence control using the principles of SCADA. All control system interlocks and safety functions to prevent dangerous operational states should be implemented within the equipment control panels.

The correct selection and installation of the control system instrumentation is of fundamental importance to the operational reliability of machinery or plant under control. The type of instrumentation and installation requirements should be determined early in the design process to ensure that adequate provision is made within the civil engineering structures and mechanical equipment.

14.3 Elements of control systems

14.3.1 Level of automation

One of the following levels of automation should be selected, as appropriate to the required operational needs of the shipyard:

- automatic operation;
- semi-automatic operation;
- manual operation.

NOTE Some continuous processes such as a water treatment plant and desalination plant are often completely automated and monitored from a central control room. The operation of other equipment such as dock gates is often controlled in a semi-automatic manner as their operation is relatively seldom and a control pedestal can often be located in a position which provides good views.

Irrespective of the automation level, following the risk assessment, safety functions (trips, interlocks and emergency shutdowns) to prevent dangerous states should be applied.

14.3.2 Level of redundancy

The design should incorporate a level of redundancy appropriate to the required operational needs of the shipyard.

NOTE Redundancy is the provision of duplication of critical equipment or components in order to increase the reliability or availability of a system. The purpose of providing redundancy of equipment in a shipyard or similar environment is to ensure that a system's function can be maintained in the event of an equipment failure.

The level of redundancy provided should be determined by the adverse impact that failure of a system might have on the safety or operation of the shipyard. All identified strategically essential systems should be subjected to a systematic redundancy study.

The provision of redundant equipment should be made for the mechanical equipment or plant under control as well as the associated control system, motor starting equipment and instrumentation.

14.3.3 Level of reliability

The design should ensure that the required operational needs of the shipyard are met in terms of reliability.

NOTE The reliability of a system is the measure of the time that system is supposed to perform its function under the required conditions excluding scheduled down time or maintenance. The reliability of a system can be increased through good design and selection of higher reliability components or equipment, and/or by application of redundant components or equipment, and can be improved by increasing the frequency of appropriate maintenance.

14.3.4 Level of availability

The design should ensure that the required operational needs of the shipyard are met in terms of availability.

14.3.5 Level of safety

The design should ensure that the required operational needs of the shipyard are met in terms of safety.

The required performance level of the associated control system functions (i.e. trips, interlocks and emergency shutdowns) should be determined according to the level of risks identified and which are to be mitigated through the control system (i.e. risks that cannot be designed out).

14.4 Equipment for control systems

The design should incorporate the equipment for the control system, which typically comprises the following main components:

- control panels;
- control consoles;
- cabling distribution systems;
- field and equipment sensors.

NOTE The design of the components is outside the scope of the BS 6349 series.

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