# Chapter 16

# TERMINAL OPERATIONS

This Chapter provides information on a range of terminal operational procedures and activities that influence the safe receipt and handling of tankers. These include the assessment of limiting environmental criteria for safe operations and issues associated with the provision of a safe means of access between the tanker and shore.

Operations requiring special procedures are described, including the double banking of tankers and the loading and discharging of cargo utilising tidal increases in depth of water, called ‘over the tide’.

The Chapter also includes a brief explanation of the phenomenon of pressure surge in pipelines and discusses the manner in which it may be controlled.

The Section on pipeline flow rates provides guidance on precautions necessary to control static electricity generation in receiving tanks on board or ashore.

## 16.1 Pre-Arrival Communications

Terminals should provide tankers visiting their berths with information on all pertinent local regulations and terminal safety requirements.

Detailed information on communications at the tanker/shore interface is given in Chapter 22.

## 16.2 Mooring

Mooring equipment should be appropriate for the sizes of tanker using the berths (see Section 15.6 for tanker criteria). The equipment provided should allow the tanker’s mooring arrangements to hold the tanker securely alongside the berth in the weather and tidal conditions expected at the berth (see Chapter 23).

### 16.2.1 Mooring Equipment

The terminal should provide mooring bollards, mooring bitts or mooring hooks positioned and sized for the tankers visiting the berth.

The Safe Working Load (SWL) of each mooring point or lead should be known to the berth operating personnel or marked on each mooring point.

Where shore mooring lines are provided, the terminal should have test certificates for the lines and the berth operating personnel should be aware of their SWL. (See Chapter 23 for information on tanker’s mooring equipment.)

## 16.3 Limiting Conditions for Operations

For each berth, terminals should establish weather operating limits defining the thresholds for stopping cargo transfer, disconnecting cargo (and bunker) hose connections and removing the tanker from the berth, taking into account the SWL of the mooring system components and, if appropriate, the operating envelopes of the loading arms.

Operating limits will normally be based on ambient environmental conditions, such as:

- Wind speed and direction.
- Wave height and period.
- Speed and direction of the current.
- Swell conditions that may affect operations at the berth.
- Electrical storms.
- Environmental phenomena, for example river bores or ice movement.
- Extremes of temperature that might affect loading or unloading.

The environmental limits should define the thresholds for:

- Manoeuvring during arrival and berthing.
- Stopping loading or discharging.
- Disconnecting cargo hoses or hard arms.
- Summoning tug assistance.
- Removing the tanker from the berth.
- Manoeuvring during unberthing and departure.

Information on environmental limits should be passed to the tanker at the pre-cargo transfer conference and, where applicable, be formally recorded in the Safety Check-List (see Sections 26.3). Routine local weather forecasts received by the terminal should be passed to the tanker, and vice versa.

The terminal should, if possible, have its own locally installed anemometer for measuring wind speeds. Alternatively, other means may be used, for example wind reports from a reliable local source, such as a nearby airport or a tanker.

Equipment for the measurement of other environmental factors should be considered, as appropriate.

## 16.4 Tanker/Shore Access

### 16.4.1 General

Means of access between the tanker and shore are addressed by national and/or local regulation. Any means of access must meet these regulated standards and should be correctly rigged by the tanker or by the terminal, as appropriate.

Personnel should use only the designated means of access between the tanker and shore.

### 16.4.2 Provision of Tanker/Shore Access

Responsibility for the provision of safe tanker/shore access is jointly shared between the tanker and the terminal.

At locations that commonly handle tankers, including barges, that are unable to provide a gangway due to the physical limitations of the berth or the nature of the tanker's trade, the terminal should provide a shore based gangway or alternative arrangements to ensure safe tanker/shore access. In any case, the preferred means for access between tanker and shore is a gangway provided by the terminal.

When terminal access facilities are not available and a tanker's gangway is used, the berth must have sufficient landing area to provide the gangway with an adequate clear run in order to maintain safe, convenient access to the tanker at all states of tide and changes in freeboard.

Irrespective of whether it is provided by the terminal or the tanker, the gangway should be subject to inspection as part of the tanker/shore safety checks that are carried out at regular intervals throughout the vessel's stay at the berth (see Section 26.3).

All tanker and shore gangways should meet the following criteria:

- Clear walkway.
- Continuous handrail on both sides.
- Electrically insulated to eliminate continuity between tanker and shore.
- Adequate lighting.
- For gangways without self-levelling treads or steps, a maximum safe operating inclination should be established.
- Lifebuoys should be available with light and line on both tanker and shore.

All shore gangways should also meet the following additional criteria, as appropriate:

- Remain within deflected fender face when in the stored position.
- Provide for locking against motion in the stored position.
- Permit free movement after positioning on the tanker.
- Provide backup power or manual operation in the event of primary power failure.
- Be designed for specified operating conditions known to the berth operating personnel.

### 16.4.3 Access Equipment

#### 16.4.3.1 Shore Gangway

When provided by the terminal, a gangway should allow safe access between the shore and the tanker. This may be similar to a tanker's gangway.

At some berths, it may be necessary to provide access to small tankers from an internal stairway below the working level of the berth.

#### 16.4.3.2 Tanker's Gangway

A tanker's gangway consists of a straight, lightweight bridging structure provided with side stanchions and handrails. The walking surface has a non-slip surface or transverse bars to provide foot grips for when it is inclined. It is normally rigged perpendicular to the tanker's side and spans between the tanker's rail and the working deck of the berth.

#### 16.4.3.3 Tanker's Accommodation Ladder

Given their limited size, most inland tankers are not equipped with accommodation ladders.

An accommodation ladder consists of a straight lightweight structure fitted with side stanchions and handrails, mainly intended for access to boats from the main deck. The steps are self-levelling or formed as large radius non-slip treads. The ladder is rigged generally parallel to the tanker's side on a retractable platform fixed to the tanker's deck. The ladder is limited in its use as an access to the shore because it is fixed in its location and cannot be used if the tanker's deck is below the level of the berth working deck.

### 16.4.4 Sighting of Gangway

Means of access should be placed as close as practically possible to crew accommodation areas and as far away as practically possible from the manifold.

It should be borne in mind that the means of access also provides a means of escape. The location of any portable gangway should be carefully considered to ensure that it provides a safe access to any escape route from the jetty (see Chapter 21).

Particular attention to safe access should be given where the difference in level between the decks of the tanker and jetty becomes large. There should be special facilities at berths where the level of a tanker's deck can fall well below that of the jetty.

### 16.4.5 Safety Nets

Safety nets are not required if the gangway is fixed to the shore and provided with a permanent system of handrails made of structural members. For other types of gangway, and those fitted with rope or chain handrails or removable posts, correctly rigged safety nets are recommended

### 16.4.6 Routine Maintenance

All gangways and associated equipment are to be routinely inspected and tested. This requirement should be included within the terminal's planned maintenance programme. Mechanically deployed gangways should also be function tested. Self-adjusting gangways should be fitted with alarms that should be routinely tested.

### 16.4.7 Unauthorised Persons

Persons who have no legitimate business on board, or who do not have the tanker Master's permission, should be refused access to a tanker. The terminal, in agreement with the tanker's Master, should restrict access to the jetty or berth.

Terminal security personnel should be given a crew list and a list of authorised visitors to the tanker (see also Section 6.4).

### 16.4.8 Persons Smoking or Intoxicated

Personnel on duty on a berth or jetty, or on watch on a tanker, must ensure that no one who is smoking approaches the berth or jetty or boards a tanker. Persons apparently intoxicated should not be allowed to enter the terminal area or board a tanker unless they can be properly supervised.

## 16.5 Double Banking

'Double banking' occurs when two or more tankers are berthed at the same jetty in such a way that the presence or operations of one tanker act as a physical constraint on the other. Double banking is sometimes used as a means of conducting multiple transfers between the shore and more than one tanker at the same jetty at the same time. The outermost tanker may be moored to an inner tanker or to the shore, and hose strings led from shore, across the inner tanker, to the outermost. This causes significant complication in respect of management of the tanker/shore interface.

Double banking of tankers on a berth for cargo operations should not be conducted unless a formal engineering study and risk assessment have been carried out and a formal procedure and safety plan produced. As a minimum, before such activities are agreed, consideration and agreement must be reached by all parties concerned regarding safe arrival and departure, strength of jetty construction, mooring fittings, mooring arrangements, personnel access, management of operational safety, liability, contingency planning, fire-fighting and emergency unberthing.

## 16.6 Over the Tide Cargo Operations

This is a procedure that utilises tidal changes in water depth, either finishing loading of a tanker to its full draught as the water depth increases towards high tide, or discharging cargo to lighten a tanker before the low tidal level is reached.

Terminals with draught limitations and significant tidal variations should have procedures in place if discharging or loading over the tide operations are to be permitted. These procedures should be agreed by all parties involved, prior to the arrival of the tanker.

Procedures to control over the tide operations should be developed from a full risk assessment process with the aim of ensuring that the tanker remains safely afloat, taking underkeel clearance requirements and contingency measures into account.

The terminal should seek assurance that the tanker's equipment that is critical to the operation, for example cargo pumps and main engines, are operational prior to berthing and are kept available while the tanker is alongside at the critical stage.

### 16.6.1 Discharging Over the Tide

Where a tanker is required to use a berth when the nominated quantity of cargo will cause the tanker to arrive alongside at a draught exceeding the maximum always afloat draught for the berth, it may be possible for the tanker to berth and discharge sufficient cargo before the next low water, thus enabling her to remain afloat. This procedure may be adopted where all parties concerned accept the risk involved and agree to adopt mitigating procedures to ensure that the tanker can be discharged in good time to remain afloat, or be removed from the berth to a position where it can remain afloat.

### 16.6.2 Loading Over the Tide

This may be undertaken where a tanker cannot remain safely afloat during the final stages of loading during the low water period. The tanker should stop loading at the draught at which it can remain always afloat and should recommence loading as the tide starts rising. Loading should not recommence unless equipment critical for the departure of the tanker from the berth, main engine for example, is ready for use. The loading rate should allow the tanker to complete loading and allow time for cargo measurements, sampling, documentation, clearance formalities and unberthing, while maintaining the required underkeel clearance.

## 16.7 Operations Where the Tanker is not Always Afloat

A limited number of ports that have significant tidal ranges allow tankers to operate when they are unable always to remain afloat while alongside the cargo handling berth. This type of operation is considered exceptional and should only be permitted following a comprehensive risk assessment and the implementation of all safeguards identified to deliver a safe operation.

The type of operation that may be undertaken varies from the tanker taking the ground for a brief period during its stay at the berth, to the tanker being completely out of the water. In both cases, the following points are amongst those that need to be addressed:

- The seabed should be proved to be flat with no protuberances or high spots present that could result in local or general stresses on the hull.
- The slope of the seabed should not result in any excessive upthrust on the tanker's structure or cause any loss of stability when the tanker takes the ground.
- The tanker's hull strength should be sufficient to take the ground without excessive stress being placed on the structure. This may require the tanker's design and scantlings to be augmented to allow it to take the ground safely or dry out.
- The operation should not result in the tanker losing any of its essential services, such as cooling water for the machinery or its fire-fighting capability. This may require the incorporation of special design features into the tanker.
- As it will not be possible to remove the tanker from the berth in the event of an emergency, port operations will need to address specific emergency procedures and the provision of appropriate fire-fighting equipment.
- Contingency plans will need to address the possibility of structural failure on the tanker and the special nature and size of any resultant pollution.

## 16.8 Generation of Pressure Surges in Pipelines

### 16.8.1 Introduction

A pressure surge is generated in a pipeline system when there is an abrupt change in the rate of flow of liquid in the line. In tanker loading operations, it is most likely to occur as a result of one of the following:

- Closure of an automatic shutdown valve.
- Slamming shut of a shore non-return valve.
- Slamming shut of a butterfly type valve.
- Rapid closure of a power operated valve.

If the pressure surge in the pipeline results in pressure stresses or displacement stresses in excess of the strength of the piping or its components, there may be a rupture, leading to an extensive spill of oil.

### 16.8.2 Generation of a Pressure Surge

When a pump is used to convey liquid from a feed tank down a pipeline and through a valve into a receiving tank, the pressure at any point in the system while the liquid is flowing has three components:

- Pressure on the surface of the liquid in the feed tank. In a tank with its ullage space open to atmosphere, this pressure is that of the atmosphere.
- Hydrostatic pressure at the point in the system in question.
- Pressure generated by the pump. This is highest at the pump outlet, decreasing commensurately with friction along the line downstream of the pump and through the valve to the receiving tank.

Of these three components, the first two can be considered constant during pressure surge and need not be considered in the following description, although they are always present and have a contributory effect on the total pressure.

Rapid closure of the valve superimposes a transient pressure upon all three components, owing to the sudden conversion of the kinetic energy of the moving liquid into strain energy, by compression of the fluid and expansion of the pipe wall. To illustrate the sequence of events, the simplest hypothetical case will be considered, i.e. when the valve closure is instantaneous, there is no expansion of the pipe wall, and dissipation due to friction between the fluid and the pipe wall is ignored. This case gives rise to the highest pressures in the system.

When the valve closes, the liquid immediately upstream of the valve is brought to rest instantaneously.

This causes its pressure to rise by an amount P. In any consistent set of units:

P = *wav*

where: *w* is the mass density of the liquid
*a* is the velocity of sound in the liquid
*v* is the change in linear velocity of the liquid, i.e. from its linear flow rate before closure.

The cessation of flow of liquid is propagated back up the pipeline at the speed of sound in the fluid and, as each part of the liquid comes to rest, its pressure is increased by the amount P. Therefore, a steep pressure front of height P travels up the pipeline at the speed of sound, a disturbance known as a pressure surge.

Upstream of the surge, the liquid is still moving forward and still has the pressure distribution applied to it by the pump. Behind it, the liquid is stationary and its pressure has been increased at all points by the constant amount P. There is still a pressure gradient downstream of the surge, but a continuous series of pressure adjustments takes place in this part of the pipeline which ultimately results in a uniform pressure throughout the stationary liquid. These pressure adjustments also travel through the liquid at the speed of sound.

When the surge reaches the pump, the pressure at the pump outlet (ignoring the atmospheric and hydrostatic components) becomes the sum of the surge pressure P and the output pressure of the pump at zero throughput (assuming no reversal of flow), since flow through the pump has ceased. The process of pressure equalisation continues downstream of the pump.

Again taking the hypothetical worst case, if the pressure is not relieved in any way, the final result is a pressure wave that oscillates throughout the length of the piping system. The maximum magnitude of the pressure wave is the sum of P and the pump outlet pressure at zero throughput. The final pressure adjustment to achieve this condition leaves the pump as soon as the original surge arrives at the pump and travels down to the valve at the speed of sound. One pressure wave cycle therefore takes a time 2L/a from the instant of valve closure, where L is the length of the line and a is the speed of sound in the liquid. This time interval is known as the pipeline period.

In this simplified description, therefore, the liquid at any point in the line experiences an abrupt increase in pressure by an amount P followed by a slower, but still rapid, further increase until the pressure reaches the sum of P and the pump outlet pressure at zero throughput.

In practical circumstances, the valve closure is not instantaneous and there is then some relief of the surge pressure through the valve while it is closing. The results are that the magnitude of the pressure surge is less than in the hypothetical case and the pressure front is less steep.

At the upstream end of the line, some pressure relief may occur through the pump and this would also serve to lessen the maximum pressure reached. If the effective closure time of the valve is several times greater than the pipeline period, pressure relief through the valve and the pump is extensive and a hazardous situation is unlikely to arise.

Downstream of the valve, an analogous process is initiated when the valve closes, except that, as the liquid is brought to rest, there is a fall of pressure which travels downstream at the velocity of sound. However, the pressure drop is often relieved by gas evolution from the liquid so that serious results may not occur immediately, although the subsequent collapse of the gas bubbles may generate shock waves similar to those upstream of the valve.

## 16.9 Assessment of Pressure Surges

### 16.9.1 Effective Valve Closure Time

In order to determine whether a serious pressure surge is likely to occur in a pipeline system, the first step is to compare the time taken by the valve to close with the pipeline period.

The effective closure time, i.e. the period during which the rate of flow is in fact decreasing rapidly, is usually significantly less than the total time of movement of the valve spindle. It depends upon the design of the valve, which determines the relationship between valve port area and spindle position. Substantial flow reduction is usually achieved only during the closure of the last quarter or less of the valve port area.

If the effective valve closure time is less than, or equal to, the pipeline period, the system is liable to serious pressure surges. Surges of reduced, but still significant, magnitude can be expected when the effective valve closure time is greater than the pipeline period, but they become negligible when the effective valve closure period is several times greater than the pipeline period.

### 16.9.2 Derivation of Total Pressure in the System

In the normal type of tanker/shore system handling petroleum liquids, where the shore tank communicates to the atmosphere, the maximum pressure applied across the pipe wall at any point during a pressure surge is the sum of the hydrostatic pressure, the output pressure of the pump at zero throughput and the surge pressure. The first two of these pressures are usually known.

If the effective valve closure time is less than or equal to the pipeline period, the value of the surge pressure used in determining the total pressure during the surge should be P, derived as indicated above in Section 16.8.2. If it is somewhat greater than the pipeline period, a smaller value can be used in place of P and, as already indicated, the surge pressure becomes negligible if the effective valve closure time is several times greater than the pipeline period.

### 16.9.3 Overall System Design

In practice, the design of a more complex system may need to be taken into account. In this Section, the simple case of a single pipeline has been considered. For example, the combined effects of valves in parallel or in series may have to be examined. In some cases, the surge effect may be increased. This can occur with two lines in parallel if closure of the valve in one line increases the flow in the other line before this line, in its turn, is shut down. On the other hand, correct operation of valves in series in a line can minimise surge pressure.

Transient pressures produce forces in the piping system which can result in large piping displacements, pipe rupture, support failure, and damage to machinery and other connected equipment. Therefore, the structural response of the piping system to fluid induced loads resulting from fluid pressures and momentum must be considered in the design. In addition, restraints are usually required to avoid damage ensuing from large movements of the piping itself. An important consideration in the selection of the restraints is the fact that the piping often consists of long runs of straight pipe that will expand considerably under thermal loads. The restraints must both allow for this thermal expansion and absorb the surge forces without overstressing the pipe.

## 16.10 Reduction of Pressure Surge Hazard

### 16.10.1 General Precautions

If, as a result of the calculations summarised in Section 16.9, it is found that the potential total pressure exceeds or is close to the strength of any part of the pipeline system, it is advisable to obtain expert advice. Where manually operated valves are used, good operating procedures should avoid pressure surge problems. It is important that a valve at the end of a long pipeline should not be closed suddenly against the flow and all changes in valve settings should be made slowly.

Where motorised valves are installed, several steps can be taken to alleviate the problem:

- Reduce the linear flow rate, i.e. the rate of transfer of cargo, to a value that makes the likely surge pressure tolerable.
- Increase the effective valve closure time. In very general terms, total closure times should be of the order of 30 seconds, and preferably more. Valve closure rates should be steady and reproducible, although this may be difficult to achieve if spring return valves or actuators are needed to ensure that valves fail safe to the closed position. A more uniform reduction of flow may be achieved by careful attention to valve port design, or by the use of a valve actuator that gives a very slow rate of closure over, say, the final 15% of the port closure.
- Use a pressure relief system, surge tanks or similar devices to absorb the effects of the surge sufficiently quickly.

### 16.10.2 Limitation of Flow Rate to Avoid the Risk of a Damaging Pressure Surge

In the operational context, pipeline length and, very often, valve closure times are fixed and the only practical precaution against the consequences of an inadvertent rapid closure is correct operation of the valves and/or to limit the linear flow rate of the oil to a maximum value related to the maximum tolerable surge pressure.

## 16.11 Pipeline Flow Control as a Static Precaution

### 16.11.1 General

Safety procedures for the transfer of static accumulator cargoes require the linear flow rates of the cargo within the loading lines, both ashore and on board, to be managed to avoid the generation of static charges during the cargo transfer (see Chapter 3).

### 16.11.2 Flow Control Requirements

The generation of static is controlled by limiting the flow rate at the tank inlet at the commencement of loading to 1 metre/second. Transfer rates equivalent to flow rates of 1 metre/second through pipelines of various diameters, can be determined from Table 11.1. (See also Section 11.1.7.3.)

Once cargo has covered the tank inlet, the transfer rate can be increased to provide the maximum allowable linear flow rate as determined by the limiting pipe diameter in the tanker or shore piping, whichever is the smaller (see Section 11.1.7.8).

### 16.11.3 Controlling Loading Rates

Due to the varying loading rates that different tankers will require in order to comply with their maximum flow rate requirements, terminals should have the facility to control effectively the pumping rates to tankers loading at its berths.

Similarly, if terminals expect tankers to discharge to empty shore tanks, it may be necessary to use flow control or flow measuring equipment in order to determine that the flow rates in the shore lines and tank inlets are not exceeded, particularly in the initial phase of filling a tank.

### 16.11.4 Discharge into Shore Installations

When discharging static accumulator oils into shore tanks, the initial flow rate should be restricted to 1 metre/second unless or until the shore tank inlet is covered sufficiently to limit turbulence.

For a side entrance (horizontal entrance), the inlet is considered adequately covered if the distance between the top of the inlet and the free surface exceeds 0.6 metres. An inlet pointing downwards is considered sufficiently covered if the distance between the lower end of the pipe and the free surface exceeds twice the inlet diameter. An inlet pointing upwards may require a considerably greater distance to limit turbulence. In floating roof tanks, the low initial flow rate should be maintained until the roof is floating. Similar requirements apply to fixed roof tanks provided with inner floats.