

	MARINE TERMINAL CONTAINMENT AND DRAINAGE OF CARGO TRANSFER AREAS PROPRIETARY INFORMATION - For Authorized Company Use Only		DESIGN PRACTICES	
			Section XXXI-K	Page 1 of 17
			Date December, 1999	

CONTENTS

Section	Page
SCOPE	2
REFERENCES	2
DESIGN PRACTICES	2
INTERNATIONAL PRACTICES	2
OTHER REFERENCES	2
INTRODUCTION	2
DEFINITIONS	2
Catch Basin	2
Drains	2
Seals	2
Time of Concentration	2
Toe Walls	2
Vents	2
SYSTEM DESCRIPTION	3
DESIGN CONSIDERATIONS	3
MARINE TERMINAL GROUP CLASSIFICATION	3
DESIGN FLOW RATE AND CAPACITY	4
Sizing Gravity Flow Drainage Lines	4
Design Capacity	6
CONSTRUCTION DETAILS	6
Sealing a Closed Sump System	6
Precast Concrete Construction	6
NOMENCLATURE	7
APPENDIX A EXAMPLE PROBLEM 1	14
FIGURES	
Figure 1 Drainage and Containment System for Group I & II Terminals	8
Figure 2 Hydraulic Radius for Circular Pipes	9
Figure 3 Ratios of Hydraulic Elements for Circular Conduits Flowing Part Full	10
Figure 4 Solution of The Manning Equation	11
Figure 5 Example Sealing Details	12
Figure 6 Example Precast Concrete Sump	13

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DESIGN PRACTICES		MARINE TERMINAL CONTAINMENT AND DRAINAGE OF CARGO TRANSFER AREAS PROPRIETARY INFORMATION - For Authorized Company Use Only	EXXON EXXON ENGINEERING
Section XXXI-K	Page 2 of 17		
Date December, 1999			

SCOPE

This section covers the containment and drainage of cargo transfer areas around hoses, loading arms and manifold valves at conventional marine pier and sea island facilities.

REFERENCES

DESIGN PRACTICES

- DP XXIII-A Basic Loading Systems
- DP XXIX-C Drainage Systems
- DP XXXI-I Safety Considerations for the Design of Marine Terminals

INTERNATIONAL PRACTICES

- [IP 3-2-1](#) Sewer Systems

OTHER REFERENCES

1. Oil Companies International Marine Forum, *Guide on Marine Terminal Fire Protection and Emergency Evacuation*, 1987.
2. International Chamber of Shipping, Oil Companies International Marine Forum, International Association of Ports and Harbours, *International Safety Guide for Oil Tankers & Terminals (ISGOTT)*, Fourth Edition, 1996.

INTRODUCTION

Surface drainage control facilities at the cargo transfer areas of marine terminals are an important aspect of containing possible spills and controlling pollution. Effective containment prevents inadvertent spills and leakage resulting from the draining, stripping or purging of loading equipment and piping from entering the local body of water. The objective of this subsection is to provide the appropriate guidelines and criteria for the design of such facilities.

DEFINITIONS

Catch Basin

An enclosed volume used to collect surface drainage and process wastes in individual drainage areas and to trap sediment at the point nearest the source.

Drains

Small inlets / connections (such as an open end pipe or fitting) discharging through a sealed connection to the drainage system from discrete sources such as equipment drips, but not from outside surface drainage.

Seals

Used to prevent vapor emission out of inlets, and to isolate the various parts of the drainage system, preventing vapor travel and spread of fire or explosion.

Time of Concentration

The time, usually in minutes, that it would take water from the hydraulically most remote location in the catchment area to arrive at the point of interest.

Toe Walls

Raised curbs which control spillage and drainage of storm, process and firewater.

Vents

Pipes open to the atmosphere to prevent blowing of seals by pressure buildup.

EXXON EXXON ENGINEERING	MARINE TERMINAL CONTAINMENT AND DRAINAGE OF CARGO TRANSFER AREAS PROPRIETARY INFORMATION - For Authorized Company Use Only	DESIGN PRACTICES	
		Section XXXI-K	Page 3 of 17
		Date December, 1999	

SYSTEM DESCRIPTION

On a dock or pier structure, the cargo transfer (manifold) area containment and drainage system consists of toe walls or curbs; catch basin(s); drain(s); underdeck piping; an underdeck sump tank and discharge pumps. The toe walls (curbs) keep the potentially contaminated stormwater runoff from the cargo transfer area separated from the clean stormwater runoff of adjacent areas.

Any spilled product and all stormwater from the manifold area is then collected in catch basins and drains that flow by gravity to a closed sump tank which is located below the deck level. As the sump tank fills, it is periodically pumped out for treatment. Elements of a containment and drainage system are shown in **Figure 1**.

DESIGN CONSIDERATIONS

The design of the containment and drainage system should include consideration of the following factors:

- Group classification criteria for the marine terminal
- Magnitude of the rainfall intensity for the design storm
- Draining / purging procedures of cargo transfer equipment
- Size of potential spill
- Wastewater segregation requirements to facilitate treatment
- Terminal layout
- Local environmental control regulations

S MARINE TERMINAL GROUP CLASSIFICATION

For purposes of pollution prevention measures and other safety systems, all marine terminals should be classified in Groups based on the importance of the terminal's operations to the business interest of the company. The classification is determined based on the criteria per **DP XXXI-I**.

For the containment and drainage system, the Group classification establishes the basis for design of the sump tank equipment and pumpout facilities. The specific safety consideration, which are provided in **DP XXXI-I**, are summarized according to Group classification as follows:

TERMINAL GROUP	DRAINAGE REQUIREMENTS
I or II	• Closed sump system with a pressure / vacuum controlled vent • Sump tank fitted with automatic pumps for discharging sump contents to shore. Automatic high and low level pump cut in / cut out required. Sump also fitted with high level alarm in event of pump failure. • Cargo transfer system stripping pumps or purging systems which empty directly into the appropriate shore piping can be used in lieu of a below deck sump tank.
III	• May be fitted with either a closed system or cargo transfer stripping or purging system. • Sump tank fitted with mechanical level gauge and a pressure / vacuum vent. • Automatic pump out not required; may be fitted with a sealed manhole cover to allow pumping out by a tanker truck as required.
I, II and III (LPG or Toxic Chemicals)	• Fitted with purging systems which empty the cargo transfer systems into the appropriate shore piping or tanks. • When approved by affiliate management, LPG systems may be vented to atmosphere after shutdown or cargo transfer via a minimum 32.8 ft (10 m) elevated vent located outside of the berth electrical classification area.



DESIGN PRACTICES		MARINE TERMINAL CONTAINMENT AND DRAINAGE OF CARGO TRANSFER AREAS PROPRIETARY INFORMATION - For Authorized Company Use Only	EXXON EXXON ENGINEERING
Section XXXI-K	Page 4 of 17		
Date December, 1999			

DESIGN CONSIDERATIONS (Cont)

DESIGN FLOW RATE AND CAPACITY

The stormwater design flow rate for the manifold area depends on the precipitation (rainfall) characteristics at the terminal location. Stormwater flow rates are a function of rainfall intensity, the runoff area and the surface characteristics of the area.

$$Q = c i A_d \quad \text{Eq. (1)}$$

where: Q = Peak runoff from a given area in cfs (m³/min)
c = Runoff coefficient, dimensionless
i = Average rainfall intensity in in./hr (mm/h)
A_d = Drainage area in acres (Km² x 17)

The runoff coefficient is dependent on the terrain and the surface characteristics of the drainage area. Since berth manifolding areas should always be constructed over a solid steel or concrete deck structure, c = 1.0 should be used.

The rainfall intensity is based on the storm duration and the time of concentration. As shown in the example intensity duration frequency curve (IDF) in [Figure 3-A of DP XXIX-C](#), the rainfall intensity decreases exponentially as the time of concentration increases. The intensity used in the Rational Method should be based on a storm duration equal to the time of concentration for the drainage area or one hour, whichever is greater. However, in most cases the intensity corresponding to a one hour storm with a ten year occurrence frequency should be used unless local environmental agencies require a more stringent basis.

If the rainfall intensity is based on the actual time of concentration for a small site, it may be higher than the intensity of a one hour storm. In the example IDF curve, a design hourly rainfall intensity of 2 in./hr (50 mm/hr) and concentration time of 10 minutes yields an actual rainfall intensity of 5 in./hr (127 mm/hr). Therefore, the design intensity for a storm duration of one hour will be exceeded more frequently than once in ten years on average. However, it is not economical to design the drainage system for the greatest actual rainfall intensity that will occur for a short time of concentration.

When the design rainfall intensity is exceeded by the actual intensity some ponding or flooding may be expected. The duration of any ponding or flooding will be brief since the system design is based on a one hour duration rainfall intensity. The following factors also lessen the consequences of rainwater flow exceeding design rates for brief periods and reduce its frequency of occurrence.

- Drain lines from catch basins are designed for open channel flow at a depth of 70% of their diameter. Therefore, they have a reserve capacity in that they can run full and function as pressure systems when greater than design rainfall causes water to accumulate in catch basins and curbed areas.
- Drainage line sizes are often larger than required because of limited available sizes.

Rainfall intensity, duration and frequency curves for selected stations in the U.S. and Puerto Rico have been published by the U.S. Weather Bureau. They may be used to select appropriate rainfall intensities for use with the Rational Method. For locations not covered by Weather Bureau data, a study of climatological data must be made to select appropriate rainfall intensity values.

For a more comprehensive discussion of basic runoff hydrology see [DP XXIX-C](#).

Sizing Gravity Flow Drainage Lines

After the layout of a containment drainage system has been established and the required flow capacity determined for the curbed areas, the gravity flow drainage lines must be sized. The following discussion of procedures for calculating flow velocity and discharge rate apply to gravity flow lines of uniform cross-section and uniform slope, which characterize most drainage systems. For more complex situations, other factors must be considered, as explained in other textbooks and engineering manuals.

Drainage lines should be designed for the estimated maximum flow at 70% of depth. This basis provides some reserve capacity to handle unanticipated flow without modification of the drainage system. Winterization should be provided where necessary. A minimum line size of NPS 4 (100 mm) should be used for gravity lines extending off the berth.

The relationship between flow rate and velocity is:

$$Q = A V \quad \text{Eq. (2)}$$

where: in consistent units:
Q = Volumetric flow rate
A = Area of wetted cross-section of the pipe
V = Velocity

EXXON EXXON ENGINEERING	MARINE TERMINAL CONTAINMENT AND DRAINAGE OF CARGO TRANSFER AREAS PROPRIETARY INFORMATION - For Authorized Company Use Only	DESIGN PRACTICES	
		Section XXXI-K	Page 5 of 17
		Date December, 1999	

DESIGN CONSIDERATIONS (Cont)

Several procedures have been developed for calculating flow velocity in conduits, the most convenient being the Manning Formula:

$$V = \frac{1.486}{n} R^{2/3} S^{1/2} \quad \text{for R in ft} \quad \text{Eq. (3)}$$

$$V = \frac{R^{2/3} S^{1/2}}{n} \quad \text{for R in meters} \quad \text{Eq. (3)M}$$

where: V = Mean flow velocity, ft/s (m/s)
R = Mean hydraulic radius, ft (m)
S = Slope of pipe, in decimal form (e.g., 1.5% slope is S = 0.015)
n = Roughness coefficient

The flow velocity in the drain lines are designed for a maximum of 10.0 ft/s (3 m/s) flowrate at the design storm flow. This requirement is generally consistent with industry practice. It is intended to prevent high velocities that could lead to rapid abrasion of the pipe.

The roughness coefficient, n, describes the type and condition of pipe. Selection of a n-value for use in design requires consideration of many factors, such as the anticipated change in the condition of the pipe due to deterioration through its service life. Typical values of the roughness coefficient for different types of conduits are provided in [Table 4 of DP XXIX-C](#). For carbon steel use n = 0.013.

The mean hydraulic radius (R) of the conduit, applicable to any cross section, is calculated as follows:

$$R = \frac{\text{area of wetted cross-section}}{\text{wetted perimeter}} = \frac{A}{P} \quad \text{Eq. (4)}$$

The hydraulic radius of a circular pipe is dependent on the depth of the water in the pipe. For the special cases of a pipe flowing full or half full (d/D = 0.5, 1.0) the hydraulic radius can be calculated as:

$$R = \frac{\text{diameter}}{4} = \frac{D}{4} \quad \text{Eq. (5)}$$

To calculate the hydraulic radius for other depths, use the equations shown in [Figure 2](#).

The Slope, S, is a measure of the change in height per unit of length. The slope can be represented as a percentage or a decimal number. Typical values of slope for drainage systems are 10 – 20 in. per 100 ft (S = 0.008 – 0.016). The depth of the water table at the site may limit the maximum slope which can be used.

Solving for the flow velocity, slope and line size according to Eqs. 2 and 3, requires an iterative procedure. The volumetric flow rate and line size must correlate with the Manning velocity. The general design procedure is as follows:

1. Select an appropriate rainfall intensity (10 year storm with an hour duration).
2. Calculate the design flow rate for the rainwater runoff from [Eq. 1](#).
3. Determine an initial line size. Calculate the area required at 70% depth from [Eq. 2](#). Use the design flow rate from step 2 and a maximum design velocity of 10 ft/s (3 m/s). From this area calculate the required diameter. Round this diameter to the next largest available line size.
4. Determine the actual velocity of the water at a 70% depth from [Eq. 2](#). Using this velocity, calculate the line slope required according to [Eq. 3](#). A value of R must be calculated and a value of n selected from [Table 4 of DP XXIX-C](#).
5. If the required slope calculated in Step 4 is too great, repeat Steps 3 and 4 for the next largest available line size.

The hydraulic elements graph shown in [Figure 3](#) is a useful tool to determine velocity and volumetric flow rate for circular pipes flowing partially full.

The Manning Formula is applicable to open-channel flow in pipes and conduits of all shapes including rectangular culverts, trapezoidal and triangular ditches. Various texts and handbooks give graphical solutions for the Manning Formula for a range of cases of **circular pipes flowing full**, but not under pressure. The nomograph shown in [Figure 4](#) is an example of this; it relates flow rate, pipe diameter, velocity, slope and Manning's roughness coefficient in an easy to use format.

DESIGN PRACTICES		MARINE TERMINAL CONTAINMENT AND DRAINAGE OF CARGO TRANSFER AREAS PROPRIETARY INFORMATION - For Authorized Company Use Only	EXXON EXXON ENGINEERING
Section XXXI-K	Page 6 of 17		
Date December, 1999			

DESIGN CONSIDERATIONS (Cont)

Design Capacity

Unless cargo transfer system stripping pumps or a purging system are used, the volume of the sump plus the containment area inside the curb should be greater than the larger of the volume of the product contained within the cargo transfer equipment or stormwater loading. Where there are multiple pieces of equipment within the containment area, the volume of the sump plus containment area should be greater than the volume of the largest piece of equipment, allowing for the displacement of the other equipment. Where cargo transfer stripping pumps or a purging system are used, the containment capacity should be based only on the stormwater loading. In some cases where a separate cargo transfer drainage / stripping system is provided, it may be possible that a sump tank is not necessary. In this situation, the height of the 6 in. (150 mm) toe wall would need to contain the rainfall at the affiliate site for a sufficient period of time (minimum of one hour design rainfall). For a discussion on the design of loading arm stripping systems see [DP XXIII-A](#).

When designing for stormwater loading, the sump is sized that such it has the capacity to contain a minimum of one-half the volume of the stormwater flow. This is equivalent to one-half the volume of rainfall generated by the one-hour intensity storm (i.e., rainfall intensity lasts for 30 minutes).

CONSTRUCTION DETAILS

S Sealing a Closed Sump System

Covers on sumps may be concrete or solid steel plate if it is properly gasketed to the concrete walls of the sump. All penetrations into the sump must also be properly sealed to prevent flammable vapors from escaping and ultimately igniting at or near the sump. This includes having the drainage area within the curbing be collected into a catch basin or drain whose outlet pipe is then routed to the sump where it is submerged under the low level mark so that it is hydraulically sealed.

Example details for sealing the cover on and penetrations into a sump are shown in [Figure 5](#).

The consequence of not sealing the sump properly is that it may impact the electrical area classification. If the vapors from the sump are not confined, then the electrical classification would need to be the equivalent of Class I, Division 1, per the National Electric Code (NEC) and API 500A, instead of Class I, Division 2. Electrical equipment in Class I, Division 1 areas must not constitute a source of ignition either by sparking during normal operation or failure, whereas electrical equipment in Class I, Division 2 areas must only not constitute a source of ignition during normal operation. For a more in depth discussion of Electrical Classification at Marine Terminals see [DP XXXI-I](#).

Precast Concrete Construction

Sumps for some affiliate marine terminals have been of precast concrete. Sumps that are precast can generally be made superior in quality compared to those that are constructed in-situ. They also can be used to decrease field installation time since all construction is performed off site in a more controlled environment. This can be especially advantageous in eliminating the difficult construction for work over water. With precast sumps all penetration connections are cast directly into the sump during construction. An example precast concrete sump with typical details is shown in [Figure 6](#).