# Monographs on Refinery Environmental Control—Management of Water Discharges

## Design and Operation of Oil-Water Separators

API PUBLICATION 421
FIRST EDITION, FEBRUARY 1990

American Petroleum Institute

**Helping You Get The Job Done Right.**SM

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# FOREWORD

The *Monographs on Refinery Environmental Control* consist of four series—*Management of Emissions to Air, Management of Water Discharges, Management of Solid Wastes,* and *Management of the Subsurface Environment.* The monograph series are ongoing projects of the Committee on Refinery Environmental Control of the API Refining Department and are intended to be used by engineers responsible for the design, construction, operation, and maintenance of disposal systems for wastes generated in refineries.

This monograph provides design guidance for gravity-type oil–water separators for use in petroleum refineries, provides practical advice on solving operating problems and improving separator performance, and presents information on performance of existing refinery separators.

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Suggested revisions are invited and should be submitted to the director of the Refining Department, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005.

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# Design and Operation of Oil–Water Separators

## SECTION 1—GENERAL

### 1.1 Introduction

The purpose of this monograph is to provide design guidance on gravity-type oil–water separators for use in petroleum refineries, to provide practical advice on solving operating problems and improving separator performance, and to present information on the performance of existing separators.

This monograph deals solely with gravity-type oil–water separators, that is, those that rely on differences in specific gravity to separate oil globules from a wastewater stream. Two types of oil–water separators are covered in this monograph:

a. The conventional, rectangular-channel unit.
b. The parallel-plate separator.

Note: Throughout this monograph, the term *conventional oil–water separator* is used in place of the term *API separator* and refers to rectangular-channel units designed in accordance with the criteria published earlier by API. The term *API separator* has become almost a generic term, sometimes used incorrectly to refer to any gravity-type oil–water separator.

Historically, the design of conventional oil–water separators was based on criteria developed from a 3-year, API-funded research study initiated in 1948 at the Engineering Experiment Station at the University of Wisconsin [1]. Since then, numerous oil–water separators based on the API-developed design criteria have been designed and put into operation throughout the petroleum industry. The criteria were developed as voluntary guidelines for designing conventional oil–water separators. Many other separators based in part on the API-developed design criteria have been adapted for a variety of other industrial wastewater treatment applications.

This monograph retains pertinent information from Chapters 5 and 6 of the 1969 edition of the *API Manual on Disposal of Refinery Wastes, Volume on Liquid Wastes*, and incorporates the recent findings of a literature review and 1985 survey of refinery separators. Data from this survey of the design and operation of oil–water separators have been incorporated in this monograph.

Although the theory of oil–water separators is briefly discussed, the emphasis of this monograph is on practical guidance for those involved in the design or operation of oil–water separators.

### 1.2 Background

A refinery wastewater stream may contain oil in three major forms: free, emulsified, and dissolved. Some pertinent features of each of these are briefly discussed below:

*Free oil* is in the form of discrete oil globules of a size sufficient so that the globules can rise as a result of buoyant forces and form an oil layer on top of the water. Under proper quiescent flow conditions, free oil can be removed by gravity separation. This removal is a function of residence time, differences in specific gravity and temperature, and the stability of the emulsion. Some coarse oily solids have a specific gravity greater than 1.0 and will settle to the bottom of a separator. Most of the oil and associated fine solids in refinery wastewater have a specific gravity of less than 1.0 and will rise to the water's surface.

*Emulsified oil* is in the form of much smaller oil droplets or globules with a diameter of less than 20 microns (mostly in the 1–10-micron range). These globules form a stable suspension in the water as a result of the predominance of interparticle forces over buoyant forces. The presence of particulates also contributes to emulsion formation. Regardless of how long a true oil–water emulsion stands under quiescent conditions, a separate oil phase will not form. Emulsified oil may be removed by chemical addition and coalescing or by flotation but not by gravity separation alone.

*Dissolved oil* is the petroleum fraction that forms a true molecular solution with water. Dissolved oil cannot be removed by gravity separation; further wastewater treatment (for example, biological treatment) is necessary if removal of dissolved oil is required.

The fraction of oil that is removable from a wastewater stream by gravity separation is affected by the type of oily material present. The method of measuring oil concentration can also affect the apparent efficiency of removal. Conventional oil–water separators remove only free oil; stable emulsions and dissolved oil require additional treatment.

### 1.3 Basic Theory

In essence, an oil–water separator is a chamber designed to provide flow conditions sufficiently quiescent so that globules of free oil rise to the water surface and coalesce into a separate oil phase, to be removed by mechanical means.

Oil–water separation theory is based on the rise rate of the oil globules (vertical velocity) and its relationship to the surface-loading rate of the separator. The rise rate is the velocity at which oil particles move toward the separator surface as a result of the differential density of the oil and the aqueous phase of the wastewater. The surface-loading rate is the flow rate to the separator divided by the surface area of the separator. In an ideal separator, any oil globule with a rise rate greater than or equal to the surface-loading rate will reach the separator surface and be removed. An ideal separator is