

# Get the Most out of API Separators

The keys to maximizing performance include a realistic, educated awareness of the separator's capabilities, an understanding of how the device functions, and an appreciation of what it should have in the way of support equipment



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**FIGURE 1.** API separators have long been workhorse devices for refiners and petrochemicals manufacturers

**M**any chemical process plants, particularly petroleum refineries and petrochemical plants, employ API separators as their first, and arguably the most important, wastewater treatment step for primary oil/solids separation (Figure 1). Employing gravity-driven settling, the separators remove gross quantities of oil and suspended solids from plant wastewater prior to subsequent downstream wastewater-treatment processes, the latter normally consisting of a second oil/water-separator polishing step plus some form of advanced (usually biological) treatment for removing dissolved organic compounds. An understanding of the design, the operating principles and the available options for these devices can maximize the value derived from them by process plants

Jointly developed more than 70 years ago by the American Petroleum Institute (API) and Rex Chain Belt Co. (now USFilter Envirex Products), the first API separator was installed in 1933, at Atlantic Refining's Philadelphia refinery. Since then, hundreds of refineries around the world have installed these separators in their wastewater treatment plants (WWTPs).

The API separator works on the principle of Stokes' Law. The technology, which allows oil to rise to the surface of the device, is based on the difference between the specific gravity of the oil to be separated and that of the wastewater. This difference is typically much less than the difference between the total suspended solids (TSS) and wastewater, so the majority of TSS will settle in the unit. Thus, the oil and TSS phases alike are removed in the API separator.

## Design standards and features

The typical API separator is basically a long, narrow and shallow tank. A further description can be deduced from its design standards, the most current version being set out in API Publication 421, "Management of Water Discharges: Design and Operation of Oil Water Separator." Among the most important design criteria are the following:

- The minimum length-to-width ratio is 5:1, to ensure that the operating conditions are as close to plug flow as possible, and to minimize the potential for short-circuiting in the unit
- The minimum depth-to-width ratio is 0.3:0.5, to ensure that the separation units are not excessively

deep. This provision minimizes the amount of time needed for oil particles to rise to the surface

- The maximum channel width is 20 ft; the maximum depth, 8 ft
- The horizontal velocity is no more than 3 ft/sec, to minimize turbulence and consequent interference with oil/wastewater separation
- Reaction jet baffles are recommended, to diffuse influent flows across the width and depth of the API separator. The baffles help minimize the effect of high wastewater inlet velocities, as well as the possible short-circuiting and decreased oil-removal efficiency associated with such velocities
- API separators can remove oil particles of 150-micron size or larger. Unless sizing adjustments are made to compensate for removal of smaller oil droplets, particles smaller than 150 microns will normally exit the separator with the wastewater, and will need to be removed by downstream treatment.

Employment of numerous design features can ensure efficient treatment, environmental compliance and minimal need for operator attention:

- There should be single scraper/skimmer system in the tank to remove



**FIGURE 2.** For wastewaters containing substances that are toxic or otherwise hazardous, it is prudent to specify steel tanks that are above-ground. This approach also facilitates maintenance and inspection

the settled solids and floating oil. This provision prevents solids and oil from accumulating in the vessel and thus reducing separator capacity. A four-shaft system employing a chain and a flight collector can convey settled solids to a sludge hopper at the inlet end and floating oil to a skimmer (see next phrase) at the effluent end

- A rotating oil-skimmer pipe, or oil roll skimmer, should be provided to remove accumulated oil from the surface of the fluid in the separator. The design may also include an electronic or manual means of monitoring the tank's oil level
- A sludge pumping system and related equipment should be included, to intermittently or continuously remove accumulated sludge from the separator
- Abovegrade separators should be equipped with a pumping mechanism to deliver the wastewater to the units
- The separator requires a system to distribute and disperse the wastewater at the inlet
- Airtight covers can be provided to contain VOCs and other vapors, usually with some type of inert-gas blanketing system for safety
- Aboveground steel tanks should

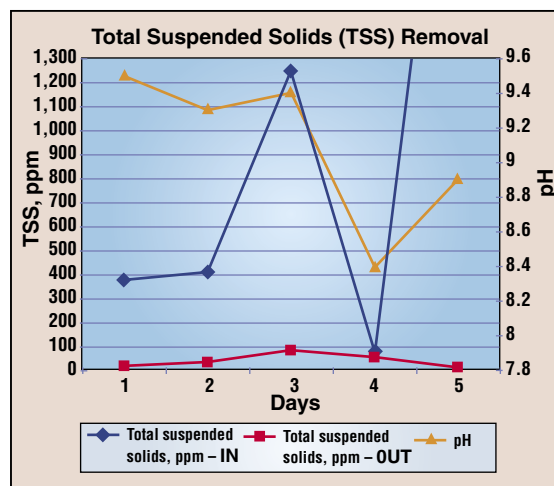
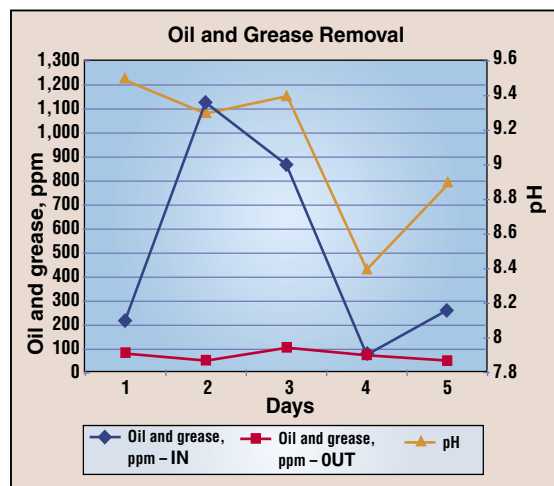
be provided to contain potentially hazardous wastes and wastewaters, as shown in Figure 2.

### Myth vs fact

An engineer who has picked up some information about API separators and is considering the use of one should become aware that there are at least two basic fallacies about their performance.

One fallacy is that separators invariably remove a certain percentage of oil plus TSS from wastewater. In truth, because every application is different, the amount, size distribution and specific gravity of the oil particles and TSS particles in the wastewater can differ significantly. The removal efficiency of these constituents will also vary accordingly. Operational variables, such as ones concerning the pumping the wastewater to the separators, can shear oil particles into smaller ones and therefore hinder separation. In short, the removal efficiency of oil and TSS must be evaluated on a case-by-case basis.

Another fallacy is that API separators should always be able to achieve the effluent quality desired by its user,



**FIGURES 3 (top) and 4.** Although the influent streams to API separators can vary significantly with respect to their content of oil, grease and total suspended solids, as well as pH, the quality of the effluent from a well-designed separator should prove to be not only acceptable but also consistent

regardless of influent oil and TSS concentrations. In fact, site-specific issues can have a significant impact on effluent quality. On the other hand, it is accurate to state that a well-designed API separator should achieve effluent oil and TSS concentrations of down to 50 to 200 mg/L in the water phase leaving the device, independent of influent concentration. In this context, Figures 3 and 4 show how a properly designed separator can be expected to operate in a petroleum refinery. Note that the separator performance depicted in the graph does lead to fairly consistent effluent quality, despite the influent quality being highly variable.

### The support equipment

The specifying and designing of an API separator to operate properly requires more than just running a siz-

ing calculation; the supporting equipment must also be properly designed. This includes the subsystems for: raw wastewater pumping (if used); sludge pumping and removal; sludge collection; VOC and vapor containment; and oil collection and removal

**Raw wastewater pumping:** Many new API separators are housed in above-grade steel tanks, making them easier to maintain and inspect. With this type of tank, raw wastewater cannot flow by gravity to the separator, but rather must be pumped to the tank. The pumping action, however, can shear and emulsify oil droplets, which not only hinders oil removal in the separator but also lowers the performance of downstream wastewater treatment processes.

So, it is wise to specify a pump that induces low shear and low turbulence. An Archimedes screw pump is ideal for this application (Figure 5). Low-shear centrifugal pumps have also been used, although they are not as effective at reducing pumping shear forces.

**Sludge pumping and removal:** Ineffective sludge removal is the most common cause of API separators not operating properly. For this reason, sludge pumping and removal systems are perhaps the most important support equipment in the API separator design. These systems remove accumulated oily sludge from the separator, and prevent overloading the components of internal chain and flight collector systems with excessive sludge.

When one is specifying or designing a separator sludge-removal system, the following points should be kept in mind:

- The sludge that develops in API separators is heavy, viscous and sticky. In sludge hoppers, it can quickly bridge, plugging sludge withdrawal points. To ensure continued removal from the separator, it is essential to fluidize and break up this compacted sludge. Water or steam fluidization nozzles within the sludge hoppers can alleviate this situation
- Oily sludge also tends to adhere to sludge-withdrawal piping. As a result, cleanout and flushing connections must be provided, to prevent the material from accumulating and

eventually plugging the piping

- Sludge pump selection is critical. Conventional centrifugal pumps often have difficulty moving the thick solids in API bottoms. Positive-displacement diaphragm pumps and, to a degree, centrifugal trash pumps are acceptable in such applications
- Whenever possible, sludge pumps should be located close to and at the same elevation as the sludge hoppers, to provide flooded suction to the pumps and to minimize plugging the sludge suction piping. Due to the sludge's viscous nature, it is not advisable to locate the sludge pumps above the separator's water surface

### **Sludge collector systems:**

An API separator's chain-and-flight-collector system skims the floating oil to a common collection point and scrapes settled oil solids (the sludge) to a common withdrawal point. If floating oil and settled solids are allowed to accumulate, the separator's effective volume will eventually decrease. This accumulation will also affect oil- and solids-removal efficiency, lead to increased oil and TSS concentrations in the exiting effluent, and adversely affect downstream treatment processes. A well-designed sludge collector system will prevent this from occurring.

In particular, the chain and flight collector components must be specified to accommodate heavy-duty service. Although numerous styles are available, they are not all ideal for use in API separators.

Metallic chains have traditionally been used in API separators, with varying degrees of success. Consisting of cast iron, cast steel or stainless steel, metallic chain is much heavier than non-metallic chain. Metallic chains' weight can be a major disadvantage during installation. Cast iron and steel components may deteriorate over time due to API separators' somewhat corrosive wastewater and, as a



**FIGURE 5.** Archimedes screw pumps are good choices for delivering raw wastewater to API separators' aboveground tanks

result, they may require periodic replacement. While not as susceptible to corrosion, stainless steel components are significantly more expensive than their cast iron or steel counterparts.

Nonmetallic components are a more recent introduction in collector chain technology. Many types and styles have been used in API separators, their success depending mainly on their material composition. Certain nonmetallic chains are prone to attack from organic compounds in the wastewater. Other types can expand unduly in the presence of high wastewater temperatures; this elongation may cause the chains to disengage from the sprockets and may also result in the collector system failing prematurely. Aside from the material-composition issue, abrasive grit in the wastewater can also cause excessive wear and premature failure on improperly designed chain connector pins. On the other hand, with proper selection of chain materials and design, the nonmetallic chains can offer suitable resistance to chemicals and abrasion, mechanical strength matching that of their metallic counterparts, and significantly



**FIGURE 6.** In many cases, the components for modern chain and flight collectors employ fiberglass as a material of construction



**FIGURE 7.** To prevent emissions of volatile organic compounds, many API separators are outfitted with covers

lower material costs and installation labor charges.

Metallic and nonmetallic collector sprockets alike are available. They have the same advantages and disadvantages as nonmetallic chains, with one exception: Motor-driven sprockets, and ones for collector head shafts, operate under a lot of torque, and some nonmetallic sprockets acceptable for use on idler shafts may not be suitable for these high-torque applications because of material strength.

Collector flights were formerly made of expensive redwood, whereas fiberglass material has become popular for this role today (Figure 6). However, fiberglass flights' suitability depends on the type of resin used to make them. The organic compounds found in refinery and petrochemical-plant wastewater cause many resins to deteriorate, and the flights to rapidly delaminate.

The strength and stiffness of the flight also depend on the modulus of elasticity of the material, as well as the moment of inertia of the flight itself. Weak flights may bend or break due to heavy sludge loads.

A typical chain-and-flight collector system has wear shoes: usually of steel for metallic collectors, or of polyethylene for nonmetallic ones. The wear shoes ride on wear strips that are attached to floor rails in the bottom of the API separator as well as to carrying tracks at the top of the unit. Mostly, stainless steel is employed for wear strips, because nonmetallic wear strips could expand under heated conditions and carbon steel wear strips could corrode.

**VOC and vapor control systems:** In many refinery or petrochemical-plant installations, API separators require either floating or fixed covers for containment and control of volatile organic compounds (VOCs), as shown in Figure 7. Floating covers float directly on the liquid surface in the separator, whereas fixed covers are set above the surface. Fixed covers are more commonly used on new API-separator installations, and floating covers on existing ones that must become covered for VOC control.

In evaluating the best cover selection for a given situation, consider the following:

- Oil skimming efficiency (will interference be a problem?)
- Ease-of-access to, and maintenance of, collector components
- Safe operation
- Capital and operating costs
- Regulatory compliance
- Maintenance requirements

Floating covers can sometimes interfere with oil skimming devices that extend above the water surface at the effluent end of the separator. In such instances, a fixed cover must be used over that portion of the separator, even if a floating cover is used for the rest of it.

It is difficult if not impossible to see into a covered separator to determine the oil levels and the skimming needs. This drawback results in oil either not being removed often enough (causing oil carryover to downstream treatment processes) or being skimmed too often (resulting in significant amounts of water being skimmed with the oil).

Windows installed in the covers have been tried to alleviate this problem. But they usually become fouled with oil and with water condensation, rendering them useless. More-successful solutions include installing electronic probes in the separator covers to monitor oil concentrations at various depths in the units, or installing sample taps on the side of an above-grade separator to manually monitor oil depth.

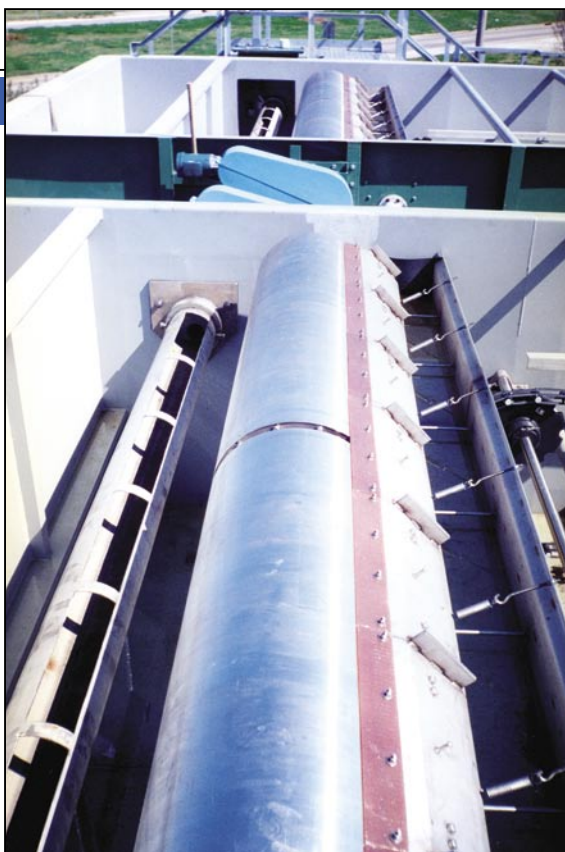
**Oil collection and removal systems:** Efficiency in removing oil from the separator ensures that the oil (which has economic value) will be collected, recovered and reprocessed, instead of either accumulating at the separator unit or entering downstream treatment processes.

As already mentioned, the chain and flight collector skims oil from the influent end to the effluent end of the separator. There, a skimmer pipe typically serves to remove the oil. This slotted pipe extends partially into the surface of the API separator, and is rotated so that the slotted section is on the oil surface. When the skimmer pipe's slots are fully up, the skimming temporarily ceases.

To help ensure that the skimmed oil does not contain excessive water, many API separators also include an oil roll skimmer. This device is an externally rotated drum, normally made of metal (in many cases, stainless steel), that extends across the width of the separator and is partially submerged in the wastewater surface. As the drum rotates, free oil adheres to the drum's specially prepared surface.

Accumulated oil is removed by a doctor blade, then flows into a collection trough and out of the unit. The oil collected by an oil roll skimmer is usually 95% pure and is easily reprocessed.

The skimmer pipe will not remove floating debris or paraffins that may be present. It also has a limited capacity and can become quickly overloaded by refinery or petrochemical upsets. For this reason, an oil skimmer pipe is almost always used as a backup oil removal device. Oil may be skimmed using solely an oil roll skimmer, but such operation is difficult due to the large skimming area, the water elevation changes in the separator, and inaccuracies associated with rotating the skimmer pipe.



**FIGURE 8.** Oil removal is vital for API separators

caustic should be added to the wastewater downstream of oil/water separation equipment, or should be disposed of by some other means, such as separate on-site treatment or off-site disposal.

### In summary

The API separator represents one of the most important wastewater treatment steps for refineries and petrochemical plants. Proper design and selection of support equipment are crucial to proper operation. Plant operational activities, such as changes in crude oil slates or introduction of spent caustic into the separators may also affect the separator's operation. By considering the tips presented in this article, operators can improve the operation of existing API separators and ensure that

new API separators meet performance expectations. ■

*Edited by Nicholas P. Chopey*

### Operational issues

Many API separators in use today at petroleum refineries were designed and installed several decades ago, when much lighter crude oils were being processed. As crude slates have become heavier, so too has the oil contained in the wastewater that enters separators. This oil is closer to the specific gravity of water, and therefore takes longer to separate by gravity. As a result, the separator's efficiency may decrease significantly. To offset this complication, some refineries have greatly reduced wastewater generation at their facilities through water conservation measures. In either case, because of changing operating conditions over the years, separators installed 20 to 40 years ago should be reviewed to ensure adequate protection of downstream treatment equipment.

Oil emulsions in wastewater pose a major problem to existing API separators. As gravity separation devices, API separators are typically designed to remove free oil particles larger than 150 microns. Anything that increases the percentage of sub-150-micron oil particles can significantly impact the separators' efficiency. Desalter brine water and spent caustic are two common op-

erational issues that can affect the size of oil particles and cause oil emulsions.

The increased processing of heavier crude oils all too often results in poorer oil/water separation in the crude-oil desalter, and consequent emulsion formation. Significant amounts of oil and oil emulsions that can quickly overwhelm API separators, as well as other oil/water-separation equipment in downstream wastewater-treatment units. To deal with such situations, a dedicated oil-water-separation step may be used for just the desalter brine water, to break any oil emulsions and remove the majority of free oil before sending the brine water to the sewer. This can prevent overloading the WWTP separators with oil and consequently affecting downstream treatment processes.

Spent caustic is less likely to cause problems in most refineries and petrochemical plants. If sent to sewer systems upstream of oil/water separators, however, spent caustic can raise the wastewater's pH and cause oil emulsification, especially when turbulence (such as that due to wastewater pumping) occurs.

To avoid these situations, spent

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