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# Replacing or Retrofitting Oil/Water Separators
# A Case Study at Fort Lee, Virginia

July 1998
Contract No. DACA31-96-D-0082
Delivery Order No. 0001

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The U.S. Army Major Commands (MACOMs) and installations have programmed over 1,000 environmental projects to upgrade OWS/washracks. Many of these projects involve installing or replacing existing OWS with commercial off-the-shelf (COTS) oil/water separators. If retrofitting with treatment-enhancing technology can adequately improve the performance of certain units, there is a potential for significant cost savings over replacement. This study examines one installation's approach to retrofitting OWS and identifies lessons learned from their experience.

Although a complete characterization of the project's background was not possible, a number of important conclusions are derived based on the available information. The observations and performance test results highlighted the critical importance of effective maintenance programs, especially with the coalescing tube technology, and of proper OWS chamber design to control water levels and solid materials.

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## EXECUTIVE SUMMARY

The U.S. Army currently operates over 5,000 oil/water separators (OWS) at various installation washracks worldwide. During the past couple years, many of these OWS have failed to meet current performance requirements because of either changes in existing operating conditions or design parameters, worn or deteriorated units, or inadequate maintenance. Consequently, the U.S. Army Major Commands (MACOMs) and installations have programmed over 1,000 environmental projects to upgrade OWS/washracks. Many of these projects involve installing or replacing existing OWS with commercial off-the-shelf (COTS) oil/water separators. If retrofitting with treatment-enhancing technology can adequately improve the performance of certain units, there is a potential for significant cost savings over replacement.

The U.S. Army Environmental Center (AEC) Pollution Prevention & Environmental Technology Division, in conjunction with the U.S. Army Aberdeen Test Center (ATC), the U.S. Army Corps of Engineers' Construction Engineering Research Laboratory (USACE/CERL), and Platinum International, Inc. (PII), is evaluating the performance of OWS retrofitted with COTS coalescing tube packs in order to determine the technology's feasibility and benefits for OWS retrofit.

As part of the overall evaluation, PII was tasked to prepare a case study that identifies one installation's approach to retrofitting OWS and the lessons learned resulting from it. The case study's approach has two primary components. The first is a review and discussion of background information available on the retrofitted units, and the second is a summary of performance test information, conducted by the USACE/CERL at the subject installation as part of another component of the overall study, that is included herein because of its direct relevance to the specific OWS.

Very limited background information was available because the project file documents had been placed in storage and were no longer available. File documents that were retrieved from another source were incomplete. Also, the primary persons who originally were involved with the project had relocated and were not able to be contacted. As a result, it was not possible to fully determine and evaluate the original factors, circumstances, and criteria that led to the decision to replace and retrofit the OWS at Fort Lee. In addition, the OWS selected for this study related to general motor pool and civilian vehicle washracks. Therefore, the study can not reliably predict OWS technology performance for typical tactical vehicle washracks.

Although a complete characterization of the project's background is not possible, a number of important recommendations can be derived based on the available information, performance test results, and observations on site. Basically, a number of variables (that were not evaluated here) can affect the treatment effectiveness of the technology and need to be further evaluated.

The observations and performance test results clearly highlight the critical importance of effective maintenance programs, especially when the coalescing tube technology is present, and of proper OWS chamber design to control water levels and solid materials. Without proper design and maintenance regimes, vendor claims for performance of OWS technologies cannot be verified.

In general, the site conditions and OWS, which were used for the study, were not the best for the desired performance test objectives. The test results show that the OWS retrofitted with AFL Industries' coalescing tube packs demonstrated no significant improvements in performance. However, it should be noted that this study was very limited in its scope, and that the retrofitted OWS were not maintained according to manufacturer recommendations. It is recommended that a more comprehensive evaluation be performed to evaluate OWS having coalescing tube packs under a variety of field conditions.

**Replacing or Retrofitting Oil/Water Separators at Fort Lee, Virginia**

## Table of Contents

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**1.0 Introduction.** This case study report discusses the rational and performance of retrofitted oil/water separators (OWS) at the U.S. Army's Fort Lee near Hopewell, VA.

The U.S. Army currently operates over 5,000 oil/water separators (OWS) at various installation washracks worldwide. [1] During the past couple years, many of these OWS have failed to meet current performance requirements because of either changes in existing operating conditions or design parameters, worn or deteriorated units, or inadequate maintenance. Consequently, the U.S. Army Major Commands (MACOMs) and installations have programmed over 1,000 environmental projects to upgrade OWS/washracks. Many of these projects involve installing or replacing existing OWS with commercial off-the-shelf (COTS) oil/water separators. If retrofitting with treatment-enhancing technology can adequately improve the performance of certain units, there is a potential for significant cost savings over replacement.

Different techniques have been used in OWS operations. The American Petroleum Institute's (API) standard gravity–type OWS are the simplest and the most commonly used. API- OWS performance is based on the relatively low solubility of oil in water and the specific gravity difference between water and oil. The gravity-type OWS are effective in removing large droplets of oil, which quickly float to the surface of wastewater. Fine droplets of oil, or oil-water emulsions, do not separate as readily and require longer retention time (a.k.a. travel time).

OWS with coalescers are used to enhance separation by using a solid surface to facilitate the consolidation of fine oil droplets into larger, and therefore, more buoyant ones. This effect enhances gravity segregation, allowing the oil droplets to rise to the surface much faster. Many coalescing OWS use inclined plates to increase retention time and to reduce the distance to the surface that the oil droplets have to travel. Other OWS employ a coalescing feature that uses oleophilic vertical tubes as seen in Photo 1-1. The fine droplets are removed from the flow by adhering to the surface of the tubes. As more droplets adhere, they coalesce and get larger, becoming buoyant enough to detach from the tubes and rise to the surface.

In recent years, findings have shown that some standard gravity-type OWS at Army installations are not consistently meeting their design performance specifications.[1] As described in Public Works Technical (PWT) Bulletin 200-1-5, there are many possible reasons for this problem. For instance, land use changes cause greater surface area accumulation and storm flow of rainwater than the OWS were designed to handle, the use of soaps, detergents, and steam cleaners emulsify the oil and prevent it from achieving effective separation, use of synthetic oil, and ineffective maintenance practices that allow oily sludge build-up within the system and sloughing of oil through the effluent lines. In general, when performance problems occur that can be attributed to design deficiencies, installations have five general options:

1. Replace the existing gravity separator with a larger unit to increase wastewater retention time in the separator;
2. Replace the existing gravity separator with a coalescing tube or plate unit;
3. Retrofit the existing gravity separator with coalescing plates or tubes;
4. Update and modify the design parameters and maintenance regime; or,
5. Add a polishing oil/water separator to enhance effluent quality.

## 2.0 Technical Approach.

The U.S. Army Environmental Center (AEC), in conjunction with the U.S. Army Aberdeen Test Center (ATC), the U.S. Army Corps of Engineers' Construction Engineering Research Laboratory (CERL), and Platinum International, Inc. (PII), is evaluating the performance of OWS retrofitted with the coalescing tube packs in order to evaluate the feasibility and benefits of retrofit versus replacement of OWS.

Several Army installations were identified that either installed OWS with coalescing tube packs manufactured by AFL Industries, Inc. (AFL) or had retrofitted existing OWS with the AFL tube pack assemblies. A site visit and reconnaissance of three installations was conducted to evaluate the feasibility and applicability of each installation's OWS for further testing. Fort Lee was found to have the greatest variety of situations and ready access to OWS. A research study was developed to determine Fort Lee's experience with retrofitted units, and at the same time, to measure the OWS performance with and without the coalescing tube pack assembly in place to determine the effectiveness of the retrofitted coalescing OWS under normal operating conditions.

## 2.1 Fort Lee Project Background

Between 1994 – 1996, the Fort Lee environmental staff, in conjunction with the U.S. Army Corps of Engineers, Norfolk District, undertook a series of projects to improve OWS performance in order to ensure compliance with state water quality and permissible discharge regulations. During the original project scoping phase and development of construction design specifications, the wastewater influent for the OWS at Fort Lee was characterized as follows: (2)

| Oil/Water Mixture | Minimum | | Maximum |
|---|---|---|---|
| Total Suspended Solid (TSS) | 0 | to | 500 ppm* |
| Total Oil & Grease (O&G) | 0 | to | 1,000 ppm |
| Total Petroleum Hydrocarbon (TPH) | 0 | to | 1,000 ppm |
| Detergent Content | 0 | to | 50 ppm |
| pH | 6 | to | 9 |
| Water Temperature | 40 | to | 60 ° F |
| Ambient Temperature | 0 | to | 100 ° F |
| Specific Gravity of Oil | 0.70 | to | 0.95 |
| Specific Gravity of Water | 1.0 | to | 1.03 |

* ppm means parts per million

These assumptions of the influent characteristics used for the OWS design were felt to be conservative. The design specifications also assumed the following parameters for discharge limitations to a sanitary sewer system:

| Contaminants | Limitation |
|---|---|
| Total Oil & Grease (O&G), 30-day average | 10 ppm |
| Total Petroleum Hydrocarbon (TPH), 30-day average | 10 ppm |

[Note: Virginia State regulations have since changed to cover different situations or discharges. Effective from February 24, 1998, General Virginia Pollutant Discharge Elimination System (VPDES) Permit Regulation requires that the maximum discharge limit of TPH or O&G to Virginia State surface water is 15 ppm. [3] [4] However, discharge limits to the sewer system would be determined by the water treatment facilities.]

Furthermore, the oil droplet size distribution in the influent was described as follows: [2]

| | |
|---|---|
| Greater than 150 microns | 30 percent (by weight) |
| Greater than 100 microns | 60 percent (by weight) |
| Greater than 50 microns | 90 percent (by weight) |
| Greater than 20 microns | 100 percent (by weight) |

[Note: This distribution was estimated by Ft. Lee personnel in order to determine the minimum droplet size that would have to be removed. However, there is no known or recognized testing or analytical procedure that will provide the above distribution.[5] Readers should pay attention on performance claims related to this kind of size distribution. Further guidance is available in reference (5).]

In order to meet the prescribed discharge parameter (10 ppm O&G/TPH in the effluent) under the worst possible loading condition (1,000 ppm O&G/TPH in the influent), OWS would need to remove 99 percent of the oil from wastewater. Therefore, it would be necessary to virtually remove all oil droplets greater than 20 microns.

The OWS were designed to retain surge flows a long enough period of time to separate oil droplets at the 20-micron size. This design parameter was not a concentration dependent variable. In other words, 20-micron bubbles exist in low concentrations of oil and water mixtures as well as high concentrations

According to Stokes' Law, a 20-micron oil droplet would have a rise rate of about 6 inches per hour (assuming specific gravity of 0.8 for oil). This would require a very long retention time for wastewater or a large volume OWS chamber. For example, to remove 20-micron oil droplets from wastewater in a worst case scenario having a flow rate of 1000 GPM, a traditional API gravity OWS would need a surface area of more than 15,000 square feet to provide the retention or travel time needed, which was not deemed feasible. For situations more applicable to small washracks, a flow rate of 100 GPM would require an OWS with a surface area of 1,500 square feet – still not practical for most installations.

An alternative was to increase the retention or travel time by using the coalescing media to enhance the separation of oil in water. A specially designed, polypropylene coalescing tube technology manufactured by AFL Industries, Inc. was used for the Fort Lee OWS project. The coalescing tubes come in various size packs and are oleophilic in nature to enhance oil droplet separation and migration. Manufacturer claims indicate the coalescing tube packs are capable of removing oil droplets down to 20 microns, which would thereby reduce effluent oil concentration to less than 10 ppm.

Consequently, Fort Lee installed six new, pre-constructed OWS with vertical tube coalescers and retrofitted four existing API-OWS with vertical tube packs. All of the retrofitted OWS that were equipped with the vertical coalescing tube packs were encased in metal frame assemblies for ease of installation and removal.

## 2.2 Performance Test of Retrofitted OWS

Among the four retrofitted OWS at Fort Lee, two separators experienced minimal or no use during the test period (March,1998). As a result, the remaining two separators were chosen for this study due to their accessibility and likelihood for actual field condition use during the test period.

The two OWS chosen were at the following locations:

Building #1617 - Post Transportation Motor Pool (TMP) Washrack – 200 GPM unit
Building #9035 - Auto Hobby Shop/POV Washrack #1 – 120 GPM unit

The study was designed to sample the OWS under actual use conditions, with the tube packs in place and removed. The detailed working condition of the tube pack assemblies (as described in Section 3.0 under Operation & Maintenance) was not known at the time the study design was developed. It was assumed that these tube pack assemblies were clear and operating under normal working conditions.

Samples of the influent and effluent flows were taken at both sites with the tube packs installed. The coalescing tube pack assembly in the OWS at the TMP site was later removed and samples of the influent and effluent flows were taken again. The coalescing tube pack at the POV site was not removed. It is important to realize that while influent samples might closely represent the composition of wastewater during vehicle washing, effluent samples can only show the general performance due to the long retention time and mixing of wastewater in OWS. Instantaneous change at the influent side may not affect the effluent concentration. Oil removal efficiencies based on the average influent and effluent concentrations only provide an approximate indication of the overall OWS performance.

All water samples were taken when vehicle wash activities took place. This was the primary use of these washracks. Each wastewater sample was subsequently analyzed by EPA Standard Methods for its chemical oxygen demand (COD), oil and grease (O&G) content, total suspended solids (TSS), and volatile suspended solids (VSS).

<u>TMP Washrack Data</u>

Samples of influent and effluent flow were taken at the TMP washrack where routine vehicle washing was performed. Test results are listed in Table 2-1 and Table 2-2 for measurements with and without the coalescing tube pack assembly respectively.

With the coalescing tube pack in place, TSS and O&G averaged 259 mg/l and 480 mg/l in the influent, 48 mg/l and 20 mg/l in the effluent, respectively. Overall removal efficiency for TSS was 81% and for O&G was 96%. One influent O&G measurement of 1418 mg/l was significantly higher than all other influent measurements. However, this high O&G measurement was not supported by the corresponding COD measurement for the same sample. This suggests that the anomaly measurement was probably due to (a) slugs of oil caught in the sample, or (b) measuring error during sample analysis.

With the coalescing tube pack removed, TSS averaged 160 mg/l in the influent and 27 mg/l in the effluent. Overall removal efficiency for TSS was 83%. The O&G averaged less than 10 mg/l in both influent and effluent indicating that little or no oil was going into the OWS during the sampling period.

**TABLE 2-1: Ft. Lee TMP Washrack Separator Treatment Performance Data [Coalescing Tube Pack in Place] (6)**

| SOURCE OF SAMPLE | COD (ppm) | TSS (ppm) | VSS (ppm) | O & G (ppm) |
|---|---|---|---|---|
| INFLUENT | 116 | 261 | 54 | 10 |
| INFLUENT | 69 | 376 | 52 | 1418 |
| INFLUENT | 72 | 287 | 68 | 2 |
| INFLUENT | 34 | 111 | 0 | 8 |
| EFFLUENT | 55 | 48 | 6 | 11 |
| EFFLUENT | 44 | 48 | 6 | 26 |
| EFFLUENT | 44 | 47 | 8 | 23 |
| EFFLUENT | 35 | 48 | 6 | 20 |

**TABLE 2-2: Ft. Lee TMP Washrack Separator Treatment Performance Data [Coalescing Tube Pack Assembly Removed] (6)**

| SOURCE OF SAMPLE | COD (ppm) | TSS (ppm) | VSS (ppm) | O & G (ppm) |
|---|---|---|---|---|
| INFLUENT | 42 | 416 | 8 | 5 |
| INFLUENT | 54 | 190 | 20 | 0 |
| INFLUENT | 64 | 70 | 8 | 0 |
| INFLUENT | 10 | 18 | 0 | 2 |
| INFLUENT | 32 | 36 | 2 | 2 |
| INFLUENT | 120 | 228 | 42 | 2 |
| EFFLUENT | 20 | 26 | 1 | 3 |
| EFFLUENT | 15 | 15 | 0 | 2 |
| EFFLUENT | -- | -- | -- | 14 |
| EFFLUENT | 31 | 22 | 0 | 1 |
| EFFLUENT | 45 | 45 | 0 | 10 |

POV Washrack Data

The POV washrack was not heavily used during this study period due to inclement weather. Consequently, the tube pack assembly was not removed for subsequent testing. Results of the sample analysis are listed in Table 2-3.

TSS in the POV separator influent averaged 390 mg/l, and O&G averaged 147 mg/l. TSS and O&G in the effluent averaged 15 mg/l and 132 mg/l respectively. Removal efficiency for TSS was 96% and for O&G was 10%.

It was noticed that a couple of effluent samples showed exceptionally high concentrations of O&G. These analytical results were inconsistent with other effluent samples. This was probably due to sloughing of oil and other organic material from the separator system. Since the washrack was lightly used, no water flowed into the OWS most of time. Oil and other organic material could settle inside the separator as well as the connection pipes. When water occasionally flowed as a result of vehicle washing, oil and other organic material could be sloughed off the system, causing the high reading of effluent O&G concentrations.

**TABLE 2-3: Ft. Lee POV Washrack Separator Treatment Performance Data [With Coalescing Tube Pack in Place, but Submerged] (6)**

| SOURCE OF SAMPLE | COD (ppm) | TSS (ppm) | VSS (ppm) | O & G (ppm) |
|---|---|---|---|---|
| INFLUENT | 304 | 243 | 35 | 20 |
| INFLUENT | 1908 | 436 | 166 | -- |
| INFLUENT | 996 | 1074 | 237 | 140 |
| INFLUENT | 1093 | 727 | 174 | 896 |
| INFLUENT | 556 | 838 | 146 | 27 |
| INFLUENT | 124 | 71 | 17 | 8 |
| INFLUENT | 66 | 20 | 8 | 11 |
| INFLUENT | 270 | 28 | 10 | 16 |
| INFLUENT | 1033 | 52 | 27 | 55 |
| | | | | |
| EFFLUENT | 91 | 22 | 5 | 23 |
| EFFLUENT | 100 | 14 | 5 | 21 |
| EFFLUENT | 99 | 14 | 3 | 1 |
| EFFLUENT | 104 | 15 | 3 | 1 |
| EFFLUENT | 85 | 15 | 3 | 16 |
| EFFLUENT | 84 | 10 | 4 | 494 |
| EFFLUENT | 107 | 13 | 4 | 371 |

## 3.0 Observations.

During the site visit, review of background records, and field sampling at Ft. Lee, several key observations were made and are outlined in the following paragraphs.

Selection, Design and Retrofit Considerations

The study team observed that each of the new OWS with coalescing tube packs at Ft. Lee, were designed and equipped with small (1ft x 2ft) manways (hatches) on top for access to the internal chamber (see Photo 3-1). Because of the relatively small size of these hatches, it was virtually impossible to adequately access the central chamber and to pull out the coalescing tube packs from these OWS either for study or routine purposes. On the other hand, as indicated in Photo 3-2, the TMP's retrofitted OWS had large metal door panels, allowing easy access into the central chamber for installation and removal of the coalescing tube pack assemblies.

Wastewater flow to the TMP separator was intermittent. The maximum water flow rate to the separator was estimated at 5 GPM during the peak usage. The total volume of water in the separator was about 2000 gallons. The mean retention time of wastewater in this separator was about 400 minutes. This separator far exceeded the design criteria for gravity separators established in the Corps of Engineers Technical Letter 1110-3-466 "Selection and Design of Oil/Water Separators at Army Facilities".[(5)]

The coalescing tube pack assemblies appeared to be installed differently in the two separators chosen for this study. Figure 3-1 shows the intended design of the retrofitted OWS. In the POV washrack separator, the top of the tube pack was about 4 inches below the water surface, allowing wastewater flowing directly from the influent pipe to travel over the pack rather than through it. That by-pass flow negated the purpose of the retrofit. In the TMP separator, the top of the tube pack was about 4 inches above the water surface, resulting in trapped oil and debris inside and between the coalescing tubes.

Construction & Materials

The structural design of the coalescing tube pack assembly in the retrofitted OWS appears to lend itself to ease of removal as a unit, assuming effective maintenance is performed. Vertical polypropylene tubes, in one-foot square bundles and 4 feet in length, were welded together and securely fastened within a steel or angle-iron frame. This entire assembly is held in place by steel channels bolted to the sides of the concrete separator. No corrosion was observed anywhere on the steel in the chamber or on the assembly. Flexible seals hold the assembly in place and prevent short-circuiting of wastewater around the corner edges. The assembly is removed by lifting the attached assembly cables with a piece of equipment such as a forklift, front-end loader, or backhoe. No other bolts or fasteners needed to be removed.

## Operations & Maintenance

Vehicles washed at the TMP and POV washracks were typical administrative vehicles (sedans, vans, and buses). Most of these vehicles were relatively new and well maintained. As expected, low levels of suspended solids and oil and grease were confirmed by the sample analysis. Results of this evaluation were within such a low range that they are probably unreliable to predict treatment performance at tactical vehicle washrack separators.

The use of various soaps and detergent solutions was observed at one washrack and was known to occur at the other. Soaps tend to emulsify the oil in water, thereby hindering the separation process and requiring much longer retention time. The presence of soaps and detergents could have contributed to the inconsistent results. Further analysis of this parameter and its potential affect on coalescing tube performance is needed.

As is evident in Photo 3-3 through Photo 3-5, the coalescing tube pack assembly removed from the TMP separator was, to a large extent, plugged with oil/sand sludge and debris (mainly grass and leaves). Although the OWS had been routinely maintained for waste oil disposal, the coalescing tube pack assembly had not been removed for cleaning since it was installed two years ago. The most severe plugging occurred at the top of the tube pack, near and just below the water surface, as a result of the coating of trapped oil and suspended solids mixture.

The sediment/sludge deposition in the bottom of the TMP OWS was also heavy. The depth of this sedimentation layer was measured at 9 inches. Ft. Lee personnel reported that this sedimentation impaired the ability to remove the tube pack assembly, requiring the use of a front-end loader to break the sediment seal and lift the assembly out of the chamber. Although a sludge removal manifold was present in the chamber, its use could not be verified with Ft. Lee records or personnel.

## 4.0 Conclusions.

The study on the two retrofitted OWS in Ft. Lee was preliminary and limited. Problems and suggested preventative or corrective actions identified during this study are summarized below.

Selection, Design & Retrofit

Test results of the samples taken during this study showed that the OWS retrofitted with AFL coalescing tube packs didn't show significant improvements on performance. Mainly because the O&G and TSS concentrations were very low in the influent, and wastewater retention time in the separator was long. Under similar conditions, coalescing tube pack retrofitting may not be necessary or beneficial. Additional testing is necessary to evaluate the coalescing tube performance with higher O&G concentrations.

The structural design of the coalescing tube pack assembly appeared to be effective for these non-tactical vehicle washracks. However, observations of the water level above and below the top of the coalescing tube pack suggests that the chamber design of OWS must carefully be evaluated (especially for retrofit units) to ensure proper placement and depth of the tube pack assemblies below the effluent water level. For example, the water level in the OWS is controlled by the effluent outlet elevation, which should be slightly lower than the influent elevation. The tube pack should be placed so that its top is at least a couple of inches below the water surface. This way, waste oil can float to the surface above the tube pack and be removed by a skimmer, instead of being trapped in the coalescing tube pack.

Further, in order to eliminate the problem of by-pass flow over the tube pack, a baffle or skimmer could be placed along the top of the front edge of the tube pack (facing influent pipe). Figure 4.1 depicts these recommendations.

The depth of the sedimentation at the bottom of the OWS and the degree of plugging by grass and leaves on the coalescing tube assembly suggested that a better designed grit chamber upstream of the coalescing tube pack is needed to remove sediment and debris. Reducing the plugging by sand and debris of the coalescing tube surface will help maintain the optimum performance of coalescing tube packs. For applications with higher suspended particulates, such as tactical vehicle washracks, coalescing tube technology may better be suited for use as a "polishing" unit.

Construction & Materials

Construction of OWS with coalescing media must include large enough openings to allow for complete access to and removal of the coalescing media assembly or components. The 1'x 2' manways are not adequate for this purpose.

Tube pack assemblies should be outfitted with lifting harnesses or some other strong, reliable method that enables complete removal of the assembly from the OWS chamber for maintenance.

## Operations & Maintenance

Although coalescing type OWS can improve separator performance, they will also require greater maintenance demands upon the installation. Proper maintenance is critical to ensure the OWS performance meets its design parameters. Coalescing tube pack assemblies should be pulled out and cleaned on a timely basis, depending upon local influent loading. Tubes need to be cleaned regularly to permit the unimpeded movement of oil to the surface. A coalescing tube pack in a tactical vehicle washrack separator would certainly require more frequent maintenance due to greater oil concentrations and solids.

Routine maintenance of the tube pack assemblies should be included as part of existing waste oil, debris and sediment removal/maintenance regimes. Maintenance plans should include the degree, type, and frequency of cleaning; access routes; how the tubes are to be removed and cleaned; how frequently the tubes should be replaced; oil/sludge/sediment pump-out capabilities and schedule; training materials for installation staff and contractors; and, design specs and drawings for each of the OWS at an installation.

The manufacturer of these coalescing tube packs (AFL Industries, Inc.) stated that a maximum of six-month maintenance intervals are recommended, and that the tube pack assemblies should be removed and cleaned with a high-pressure water hose. Steam-cleaning should not be used because it destroys the oleophilic properties of the tubes. Consequently, this technology may not be suitable for tactical washrack OWS that commonly us steam-cleaning technology.

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## Photographs

**Photo 1-1.** New polypropylene coalescing tube packs manufactured by AFL Industries, Inc. were used in both new and retrofitted oil/water separators in Ft. Lee, Virginia. The goal of using coalescing tube technology was to remove all the oil droplets larger than 20 microns from waste streams so that the total oil/grease concentration of the effluent would not exceed the target limit of 10 ppm.

**Photo 3-1.** Pre-constructed OWS installed at a new motor pool washrack location. All the new OWS were equipped with small manways, inhibiting access to the internal chamber and removal of the coalescing tube packs.

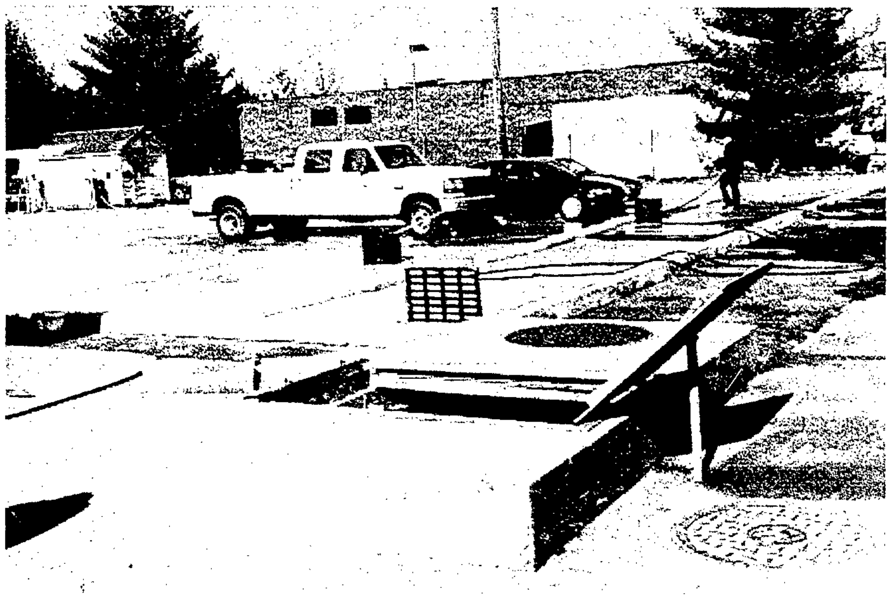

**Photo 3-2.** OWS at TMP site with its door panels open. All the retrofitted OWS were equipped with similar door panels, allowing easy access to the coalescing tube packs.

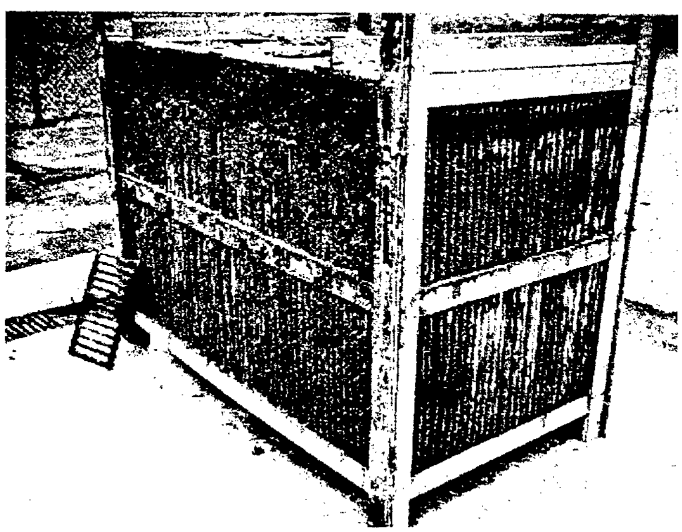

**Photo 3-3.** Front (left side facing influent) and side of the AFL coalescing tube pack after two years service in Ft. Lee TMP washrack

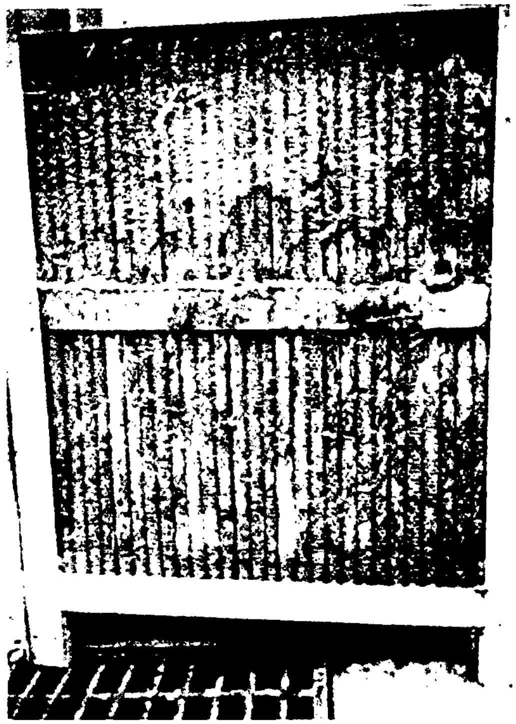

**Photo 3-4.** Side view of the AFL coalescing tube pack after two years service in Ft. Lee TMP washrack. About 15 inches of the coalescing tubes at the top were basically covered with sludge.

**Photo 3-5.** Close-up section view of the front side (facing influent) of the coalescing tube pack after two years service in Ft. Lee TMP washrack. Heavy deposit of sludge and debris could be seen at the top of the coalescing tube pack.

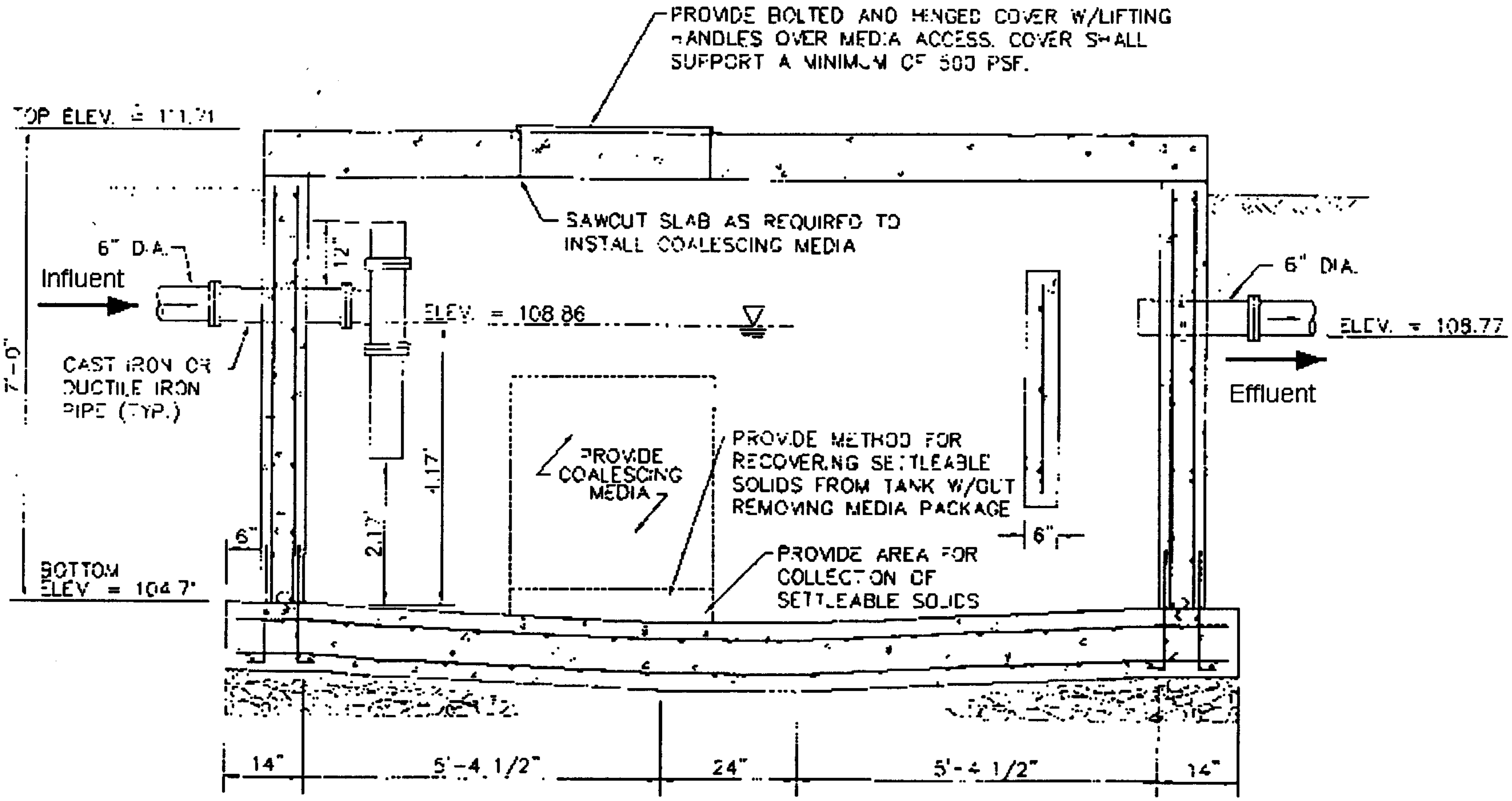


**Figure 3-1.** Schematic of the OWS retrofitted with AFL coalescing tube pack at the POV site. The water level was found to be 4 inches higher than the top of the tube pack.

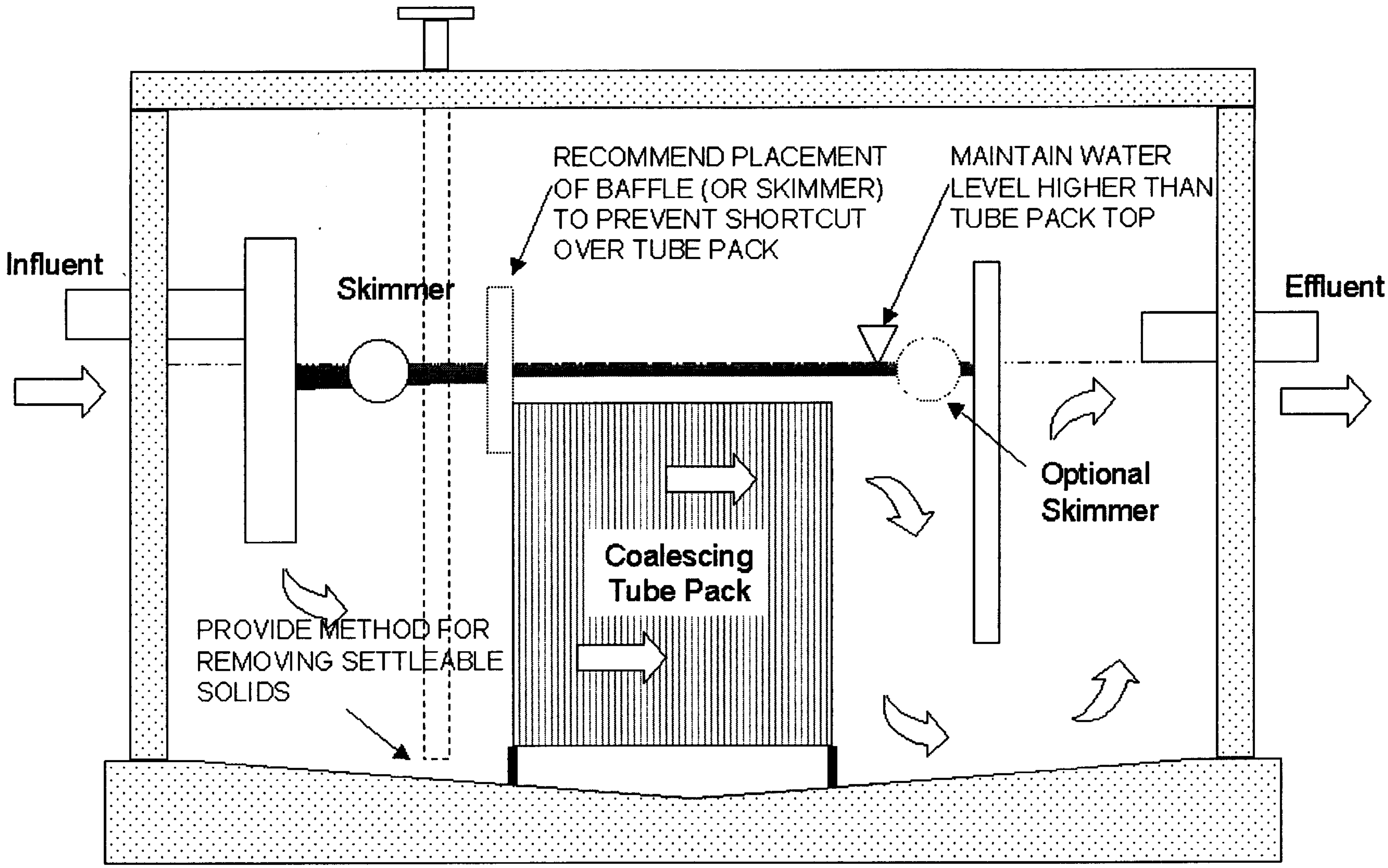


**Figure 4-1.** Schematic of the retrofitted OWS with recommended modifications.