# A New Absorbent Filter System for Treating Small Water Flows to Remove Hydrocarbon VOCs and Meet Environmental Requirements

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**Abstract:**

The paper describes a new and simple filter system designed to remove hydrocarbons from wastewater streams. The system utilizes a specially designed multi-stage filter cartridge that exhibits virtually 100% removal of hydrocarbons and has a high capacity so the filters do not need frequent changing. The system cartridges can be installed in inexpensive, readily available commercial plastic filter housings and can be used either singly or in series. Series use is recommended because the first cartridge in series can be completely expended and then discarded. The second cartridge is then moved to the first position and a new cartridge installed in the second position. This ensures against inadvertent release of hydrocarbons. When expended, the used filter cartridges can be incinerated, depending on local regulations.

## Introduction

In many industrial and marine facilities, small water streams are present containing very small but still significant amounts of hydrocarbons. These may be small wastewater streams from groundwater inflows, waste water from chemical treatment baths such as are found in metal cleaning applications, and bilge water from small and medium size boats. The Clean Water Act does not discriminate for size of flows, it only notes that there may be “no sheen” on the effluent water(Findley and Farber 1992). Sometimes small streams may be directed to sanitary sewers (or in the case of marine systems, overboard), but often the hydrocarbons must be removed from water before disposal.

Oil-water separators can be used economically for larger streams, but for smaller streams absorbents and absorbent filter cartridges have been used to treat the water flows for removal of hydrocarbons. Many users have complained of short absorbent life before breakthrough of hydrocarbons is experienced, and it is postulated that this may occur because of internal bypassing within the absorbent filter cartridges, many of which are filled with loose granular or pellet absorbent materials. Because there seemed to be a need for improved treatment of these small hydrocarbon-containing water streams and the commercially available filters seemed inadequate, a new type filter cartridge was developed to address these needs, which has a unique internal structure that prevents the possibility of internal bypass.

**History:**

Natural hydrocarbons have been seeping into water for millennia. The Greek historian Herodotus reported petroleum and tar as early as 450 BC (Nelson 1969). Laws (Laws 1981) noted that natural gas from the Kirkuk oil field in Iraq has been burning since biblical days, and that reports of oil seeps in the ocean off Coal Oil Point in California were noted as early as 1629.

Kerosene distilled from coal was patented in the US in 1854 as an inexpensive alternative to whale oil (Scientific American 1854), and it was subsequently found that it could more easily be refined from crude oil. Hydrocarbons in the environment did not present much of a problem until the advent of the automobile as a major mode of transportation because petroleum was of little use except as a lubricant and a replacement for whale oil in oil lamps. Eventually, kerosene, lubricating oils, and gasoline from petroleum became major industrial products and subsequently began entering the environment in larger quantities. Today, many freshwater systems are polluted with hydrocarbons.

**What is Oil?**

“Oil” is a generic term used in the context of this paper to mean hydrocarbons of miscellaneous nature, primarily fuels and lubricating oils.

Fuels and lubricating oils are derived from crude oil, which is a variety of complex hydrocarbon substances composed of thousands of different kinds of molecules. Gasoline, kerosene, diesel fuel and jet fuels are composed mainly of aliphatic and aromatic hydrocarbons (Nelson 1969).

## Industrial Sources of Oil in Water:

Industrial continuous sources are generally "point sources", have generally constant flow and constant oil content. These sources, such as refinery water outfalls, are often large sources of hydrocarbons, but many streams are small and the oil content may vary from almost zero to substantial amounts. Large point sources can be dealt with either by installation of oil-water separators or by elimination of individual sources of oil within the refinery or other industrial plant. Small point sources, which tend to vary more in hydrocarbon content and flows, can be dealt with using a variety of methods including the use of absorbents.

From a regulatory standpoint, "oil and grease" content of these sources is regulated in the US under the National Pollutant Discharge Elimination System (NPDES) program.

Because there are differing engineering and legal opinions about the effects of oil in the environment, substantially different legal requirements have been enacted in different countries. Local conditions and environmental conditions can also have an effect on legal requirements within countries. A few of these requirements are discussed below. Virtually the only international agreement concerning oil pollution in water is among the members of the International Marine Organization (IMO),

## Laws And Regulations

*United States:*

Oil in water discharges from industrial and other facilities are governed by a variety of federal, state and local laws. Most important are the Clean Water Act (CWA) and its amendments (Findley and Farber 1992). It was originally enacted as the Federal Water Pollution Control Act of 1972, but was amended extensively in 1977. The 1977 amendments, in conjunction with the earlier legislation, became known as the Clean Water Act. Under the terms of this Act, amended Section 402 created the National Pollutant Discharge Elimination System (NPDES) permit system. Permits for point sources under this system are granted by the United States Environmental Protection Agency (EPA) or by states with EPA approved programs. Any discharges other than those allowed by permit are illegal.

Although the Clean Water Act was enacted primarily to control discharges from Publicly Owned Treatment Works (POTWs) and toxic discharges from industrial plants, it also controls most discharges of petroleum and other hydrocarbons into the waters of the United States (other than those specifically exempted by law, including effluent from oil and gas production).

Most states and localities require discharges to contain 15 mg/l or less oil and grease, as measured by the EPA 1664 analytical method or other test method, and based on a 24 hour composite sample. This requirement is based on the CWA requirement for “no sheen” and an EPA study defining sheen (Horenstein 1972). Some localities have established lower discharge limits. King County, Washington, which includes the Seattle area, requires discharges to be less than 10 mg/l (Romano 1990).

Small sources appear to gain in importance as discharges of large industrial process wastewater and municipal sewage plants come under increased control.

*Canadian Regulations*

Canadian marine regulations are similar to other countries for ocean-going ships, requiring the discharges to meet the IMO 15 mg/L or less regulation. For inland waters of Canada, however, the discharges must meet 5 mg/L or less(Government of Canada 1993).

*INTERNATIONAL MARINE LAW – the International Marine Organization*

The International Marine Organization (IMO) regulations govern the discharge of bilge water from ships in international waters. These regulations require all ships over 400 tons gross tonnage to be equipped with a bilge water separator that has passed the IMO mandated performance test and approved by one or more of the world’s regulatory authorities(International Marine Organization 1993). In many countries including the US and Canada the regulatory body is the Coast Guard. In other countries it may be the maritime administration or Navy.

The IMO performance test is detailed in IMO Resolution MEPC.60(33), adopted in 1992(International Marine Organization 1993). The test must be witnessed by an independent certifying body. The US Coast Guard issues Certificates of Approval based on the test results.

## Treating Small Water Streams

Many industrial facilities have one or more small wastewater streams that may contain hydrocarbons. These flows may result from groundwater inflows, waste water from chemical treatment baths such as are found in metal cleaning applications, compressor blowdown, machine washing, and other activities. Such streams can also arise from bilge water from small and medium size boats.

Many types of treatment systems are available for large streams, and it may even be possible to economically recover the oil for reuse or recycling. For small streams that may contain sporadic traces of hydrocarbons, economic solutions remain less common. Oil-water separators can be installed, or the wastewater can be trucked to disposal facilities. Some industrial facilities may be allowed to dump small quantities of hydrocarbon-containing water to sanitary sewer systems, but this is becoming less common because of volatile organic carbon (VOC) regulations on sanitary sewer facility outfall streams and sometimes the hydrocarbons must be removed before the water is introduced into the sewer system. These solutions are often bulky and expensive for treating small flows, and positive assurance against environmental problems may be absent.

Some systems are available that can treat small streams economically, including small oil-water separators and absorbent systems. The separators tend to be bulky for the size of flows, and since small flows are often present in small facilities with small spaces, this is often inconvenient. Absorbents of various types have been used with mixed success. Included among common absorbents are:

- Absorbent pads – often of polypropylene fibers
- Peat filter cartridges
- Activated carbon filter cartridges
- Linseed oil based filter cartridges
- Other absorbent filter cartridges

Absorbent pads are most often used as floor type absorbents, although they can also be placed on the water surface of a tank of oily water to absorb the oil that rises to the surface. This oil is absorbed by capillary action and not chemically combined with or permanently attached to the absorbent.

Peat filter cartridges are sometimes used in treating stormwater flows, but they have limited capacity and are bulky. In one California location, several peat-based stormwater treatment systems were abandoned by the owner (the local turnpike authority) because of excessive maintenance cost (Hanley 2001).

Activated carbon cartridges have been used extensively, but capacity is limited and therefore maintenance costs can be excessive. Linseed oil based filter cartridges are produced by at least one manufacturer.

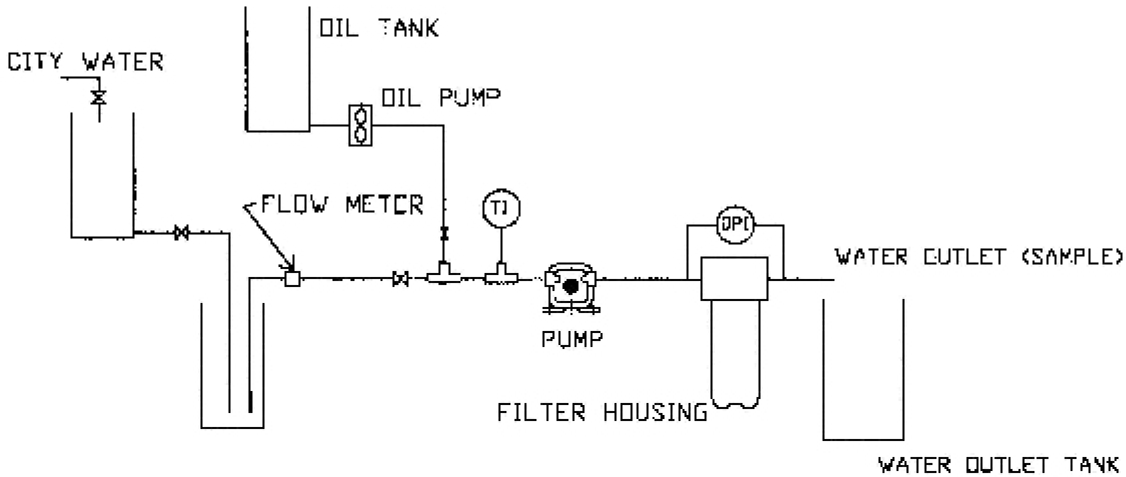
**Development of the new style filter cartridges:**

Several commercially available systems were examined, and it was found that loosely packed absorbent or incompletely treated media could be allowing bypassing of water through passages within the filter media. It was therefore necessary to design a system with the high absorbent capacity of the loosely packed media with a system to ensure against bypassing. This was done by the use of a multi-stage filter cartridge design utilizing an inner media barrier against bypassing. Patent considerations preclude further discussion of the design in this paper.

Testing of some of the currently available filter cartridges as well as the new style cartridge are discussed below.

## Laboratory testing:

Laboratory testing was conducted using a system designed to measure both inlet water flow and inlet hydrocarbon flow using a flow meter for the water and a calibrated-flow oil injection pump for oil injection. A schematic of the test system is shown below:




SCHEMATIC OF FLOWS DURING TESTING

City water was used as the test medium at a nominal flow rate of 1.6 US gpm (maximum flow of the test pump). The oil utilized for testing was 0.85 specific gravity commercial diesel fuel. Water flow, temperature, and differential pressure across the filter housing were closely monitored. Oil injection was by calibrated pump at a flow rate equivalent to 1620 mg/l. Water temperature was maintained at about 70 degrees F. by use of an upstream heater.

Results of Laboratory Testing:

Three types of absorbent filter cartridges were tested, discussed below as System "A", System "B" and System "C". System "C" is the newly developed Parker Hannifin cartridge system.

A cartridge of System "A" was installed in the test housing and water flow was established. Temperature was about 74 degrees F. and the water flow rate was 1.61 US gpm. The flow was maintained with water only for 5 minutes. A sample was taken and inspected for oil droplets. A small amount of oil was observed in the effluent and a smell test indicated that the oil in the sample was probably some of the linseed oil absorbent and not diesel fuel. At this time oil injection was started at a rate of 9.8 ml/minute. A sample was taken at about 3 minutes after the start of injection and inspected for oil droplets. A substantial amount of oil (much more than the previous sample) was observed in the effluent and a smell test indicated that the oil present was diesel fuel. A liter bottle sample was taken to be analyzed and the cartridge removed to determine if it had sealed against the knife-edge of the filter housing or if bypassing had occurred. The inspection of the cartridge indicated that there was a good seal against the filter housing and bypassing around the end of the cartridge had therefore not taken place. Subsequent analysis of the liter bottle sample showed a diesel fuel content of much greater than 250 mg/l. This high initial oil content indicates that the cartridge absorbed little, if any of the diesel fuel challenge. Dissection of the cartridge indicated no obvious structural damage or visible channeling.

A cartridge of System “B” was installed in the test vessel with conditions the same as noted for System “A” above. Water flow was started and maintained for approximately 10 minutes. A sample was taken of the effluent flow and there was no visible sheen or any smell to indicate the presence of hydrocarbons in the effluent sample. At this time the oil injection was started. A sample of the effluent flow was taken at three minutes and there was no evidence of a visible sheen or smell to indicate the presence of diesel fuel. A second sample was taken at 12 minutes and the gross evidence of a heavy layer of diesel fuel on the surface of the water sample made testing for the level of hydrocarbon irrelevant. Dissection of the cartridge indicated the possibility of internal bypass due to channeling through the granular absorbent.

A cartridge of System “C” was installed in the test vessel with conditions the same as noted for System “A” above. Only one vessel and cartridge was used for testing, to establish the capability of a single cartridge, even though it is anticipated that the system will usually be installed with two cartridges in series. Water flow was started and maintained for approximately 10 minutes. A sample was taken of the effluent flow and there was no visible sheen or any smell to indicate the presence of hydrocarbons in the effluent sample. At this time the oil injection was started. Samples of the effluent flow was taken periodically and there was no evidence of a visible sheen or smell to indicate the presence of diesel fuel. An analysis sample was taken at 42 minutes and was found to contain less than 2 mg/l of oil, the lower limit of the test. The differential pressure across the cartridge at this time was 5.8 psig. Subsequent samples were taken at 52 minutes, which exhibited 11 mg/l of oil (differential pressure of 16.8 psig) and after breakthrough at 57 minutes, where more than 250 mg/l of oil were found (differential pressure of 26 psig).

The cartridge should be replaced at a differential pressure of 15 psig, so if it is replaced in a timely manner the effluent oil content should not exceed that which would cause a violation of the Clean Water Act requirement for “no sheen” on the outlet water. At the injection rate of 9.8 ml/minute, the filter cartridge absorbed over half a liter of pure diesel fuel before breakthrough. This would mean that a single cartridge would be capable of processing 4030 gallons of water at an inlet concentration of 30 mg/l (twice the allowable oil content) to an oil content of nearly zero.

Dissection of the spent cartridge indicated the absorbent was utilized relatively evenly and there was little or no channeling through the absorbent.

Commercial testing has begun or is projected at several locations in varying applications. Two of these are:

A system consisting of two cartridge housings in series is being installed downstream of an oil-water separator in a groundwater cleanup system. The overall system is designed to remove oil from a small groundwater leakage that enters the pit of an automotive maintenance facility during periods of high water table. The water becomes contaminated with lubricating oil in the pit and must be treated before being pumped to the sanitary sewer system. To satisfy local regulators, a previous system with a single housing and a differing cartridge had been installed downstream of the oil-water separator. The new system constitutes a voluntary upgrade of protection against hydrocarbons entering the sewers. It is planned that when the first cartridge is spent and the pressure drop has risen to the design 15 psig, the second cartridge will be moved to the first position and a new second cartridge installed. In this way the redundant second cartridge will serve as a final barrier to environmental contamination and promoting the partially used cartridge from the second to the first position will ensure full usage of all of the cartridge capacity for oil removal.

A system similar to the one at the groundwater cleanup site has been installed at a facility where large quantities of jet fuel are kept and handled and some of the water becomes contaminated with jet fuel. Two filter housings with cartridges in series have been installed to ensure meeting the local requirements before the water is directed to the municipal disposal system. This system is also designed with a first or operating cartridge and a second or redundant housing.

## Conclusions

There is a need for a compact and inexpensive filter-type system to treat small water streams for removal of hydrocarbons in many industrial, marine, and other facilities. Existing commercially available systems exhibit problems including short cartridge life and media bypassing, leading to high costs and unreliable treatment efficiency. The new system eliminates the problem of flow bypassing the absorbent and ensures that substantially all of the absorbent media is utilized for hydrocarbon removal. It is expected that commercial testing will show the effectiveness of this improved system in many facilities for removal of many sorts of hydrocarbons.

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