C.I.Agent® Hydrocarbon Flow Filter Validation Study

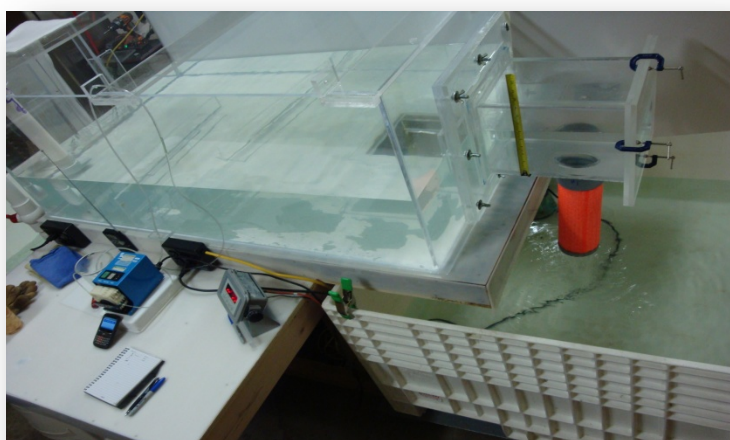
August 11, 2013

FILTER DESCRIPTION

C.I.Agent® Hydrocarbon Flow Filter (HFF) is a versatile device that reduces both semi-volatile and volatile petroleum hydrocarbons from water to non-detected levels while meeting federal SPCC mandates.

The C.I.Agent HFF allows water to freely flow through its proprietary blend of C.I.Agent® oil adsorbing polymers and adsorbing geotextiles. The C.I.Agent HFF will remove low level chronic hydrocarbons in the water as well as prevent a major release. Breakthrough of the hydrocarbons is always prevented as the polymers upon saturation will act as a chemical valve shutting off all liquid flow through the filter. This provides a cost-effective and environmentally friendly solution for secondary containment needs.

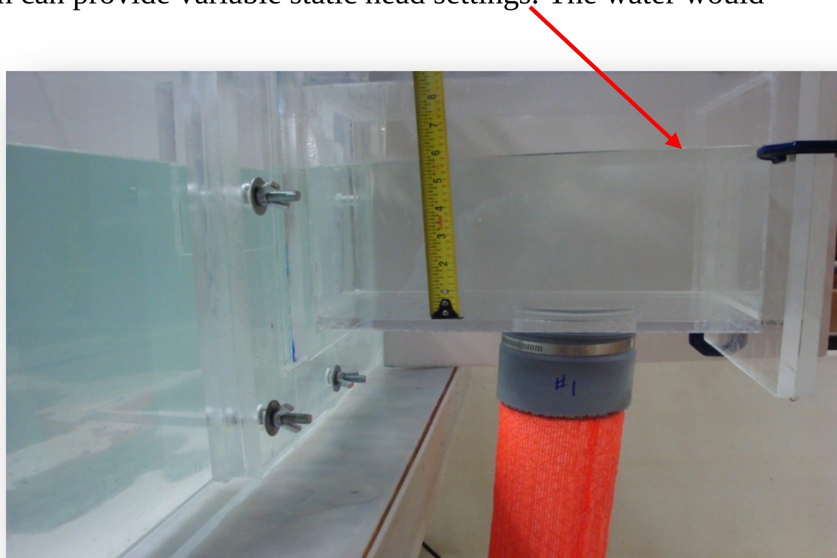
Intent and Design of Testing: It is the purpose of this study to validate the claim that water will pass freely through the HFF removing hydrocarbons and yet prevent any hydrocarbon release upon being fully saturated. The physical flow data and the samples generated for evaluation will be generated in a full scale controlled test chamber shown in the photo to right:



The testing will be in five sections:

1. **Flow rate vs. steady state head of water**
2. **Flow rate vs. oil uptake allowing 10 min draining cycles forcing oil into the filter**
3. **Sample generation and laboratory analysis of influent and effluent water after complete oil saturation.**
4. **Analysis and evaluation of laboratory data comparing efficacy for TPH, PAH's, EPH and VPH.**
5. **Summary and conclusions.**

Flow Rate vs. Steady State Head of Water: The flow rate was determined using a tank and pumping overflow system which can provide variable static head settings. The water would flow down vertically through the HFF as it would be deployed, and spill into a 300 gallon storage container. The container rested on a 5000 lb. capacity digital floor scale for measurement of continuous weight of water spilled into it. Knowing the weight of water per unit times the flow rate was calculated to GPM (see photo).

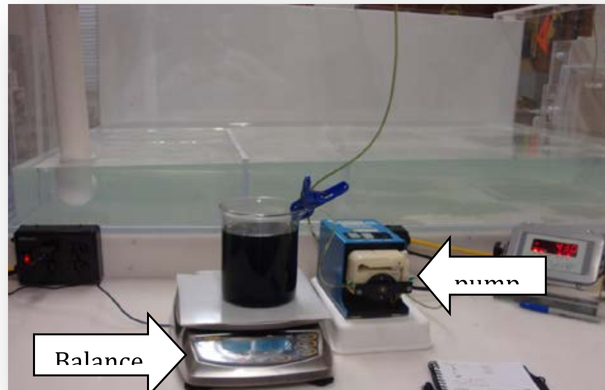


A steady head on a HFF was held at 2", 4", 6", 8", and 12" for 10 minutes at each level, repeated three times and averaged. The total weight per unit time was obtain and converted to gallons per minute. The flow results are charted below:

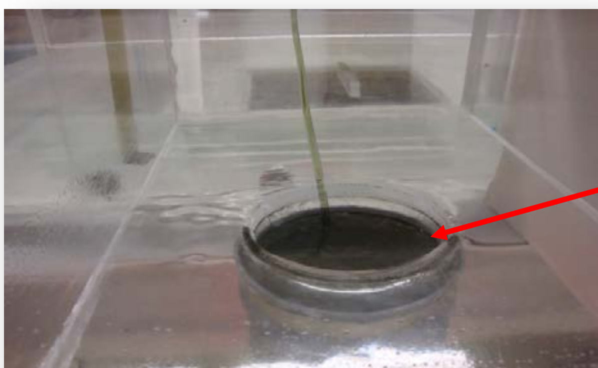
Steady State Flow Rates Product tested C.I.Agent® HFF 4" x 12"					
!0 min flow tests	2 inch	4 inch	6 inch	8 inch	12 inch
Test #1 GPM	6.1	7.6	8.8	9.8	11.9
Test #2 GPM	6.6	7.5	8.9	9.4	11.5
Test#3 GPM	6.3	7.8	9.2	9.7	11.8
Ave. GPM	6.3	7.6	9.0	9.6	11.4

Flow Rate vs. Oil Uptake: Because of the hydrophobic nature of oil, designing an effective testing apparatus which will deliver a known mg/l of oil/water to the test HFF Filter influent surface, while keeping the oil contained there during a constant water inflow, is the challenge. If the oil is added to the large tank directly it will float to the surface and adhere to the walls, not ever reaching the filter at a known concentration for efficacy studies. A testing chamber was used which delivered a known amount of blended oil; 33% diesel, 33% mineral oil and 33% bunker oil into the HFF filter mounted vertically, and maintained a known steady state water level just below the HFF's inlet lip. 10 minute draining cycles were employed to recreate field conditions and insure that all areas of the filter contacted the oil. Flow rates verses oil uptake was measured and initial and final samples were taken.

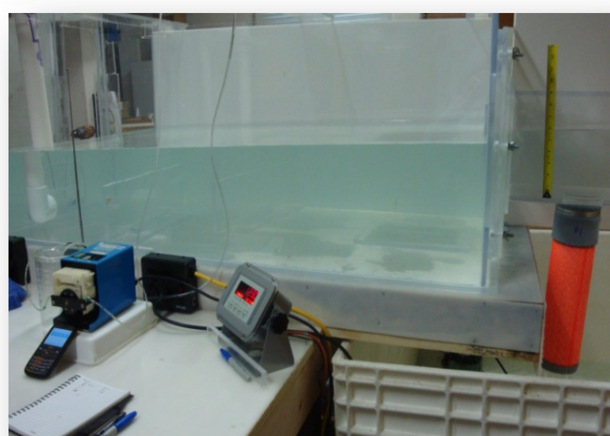
Apparatus: The testing tank used for the flow rate determination was also used for the oil removal efficacy study. The following additions were incorporated into the tank to allow it to contain, deliver and measure known amounts of oil/water concentrations added and removed.



1. Analytical peristaltic pump delivering oil into the HFF influent flow with 1/8" tubing.
2. Analytical balance continuously monitoring the amount of oil delivered in grams/unit time.
3. Mixing containment area which allows oil contact within the HFF not allowing it to float free to the surface.



Water influent level maintained just below inlet lip.



4. Tank and pumping overflow system providing a steady head of water for the vertical mounted HFF, while providing a constant water effluent flow maintained just below the inlet lip.

5. Digital floor scale weighing effluent container.

Sample and Data Generation: A steady state of water was established through the HFF maintaining the level at just below the inlet lip. At this point the HFF filter was removed, the constant flow peristaltic pump activated and oil and water influent samples were funneled into one liter and volatile bottles for analysis, these samples represented the before filtration influent water stream. The HFF was then replaced and the oil and water flow resumed. The volume of water was monitored vs. the weight of oil delivered to the HFF for ten minute intervals. After each 10 minute run, the flow was stopped and the filter was allowed to drain and settle for 10 minutes. This cycle was repeated 6 times until that point where the flow rate had almost subsided. At this point the final effluent samples were taken where the HFF was fully saturated. After 12 hours settling time the free oil within the filter was obtained and the amount solidified by the filter calculated by differed from oil delivered. The results and tables are shown below.

Minutes	Oil wt./grams	Water Vol./Liters	Conc. Oil in Water mg/l	Flow L/min.
0.0	0.0	0.0	0.0	0.0
1.0	20	20	1000	20
5.0	99.6	90	1107	18
10.0	204	180	1133	18

10 minute Drain

Minutes	Oil wt./grams	Water Vol./Liters	Conc. Oil in Water mg/l	Flow L/min.
0.0	0.0	0.0	0.0	0.0
1.0	22	15	1466	15
5.0	118	65	1815	13
10.0	204	120	1700	12

10 Minute Drain

Minutes	Oil wt./grams	Water Vol./Liters	Conc. Oil in Water mg/l	Flow L/min.
0.0	0.0	0.0	0.0	0.0
1.0	22	7.0	3142	7.0
5.0	96	27	3556	5.4
10.0	194	54	3593	5.4

10 Minute Drain

Minutes	Oil wt./grams	Water Vol./Liters	Conc. Oil in Water mg/l	Flow L/min.
0.0	0.0	0.0	0.0	0.0
1.0	22	2.3	9565	2.3
5.0	118	8.5	13882	1.7
10.0	204	11.5	17739	1.2

10 Minute Drain

Minutes	Oil wt./grams	Water Vol./Liters	Conc. Oil in Water mg/l	Flow L/min.
0.0	0.0	0.0	0.0	0.0
1.0	21	1.5	14000	0.15
5.0	110	7.0	15714	0.14
10.0	202	9.0	22444	0.09

10 Minute Drain

Minutes	Oil wt./grams	Water Vol./Liters	Conc. Oil in Water mg/l	Flow L/min.
0.0	0.0	0.0	0.0	0.0
1.0	20	0.4	50000	0.04
5.0	100	1.0	100000	0.02
10.0	214	2.1	101904	0.02*

***Effluent water from filter sampled at this point,**

Total oil delivered to HFF was 1,222 grams, after an additional 12 hour drain time, 766 grams of free oil remained, that was poured out of the filter and weighed. The resultant difference was solidified oil as no breakthrough was observed.

Flow Rate vs. Oil Uptake until flow shut off can be graphed using the accumulative totals as shown below:

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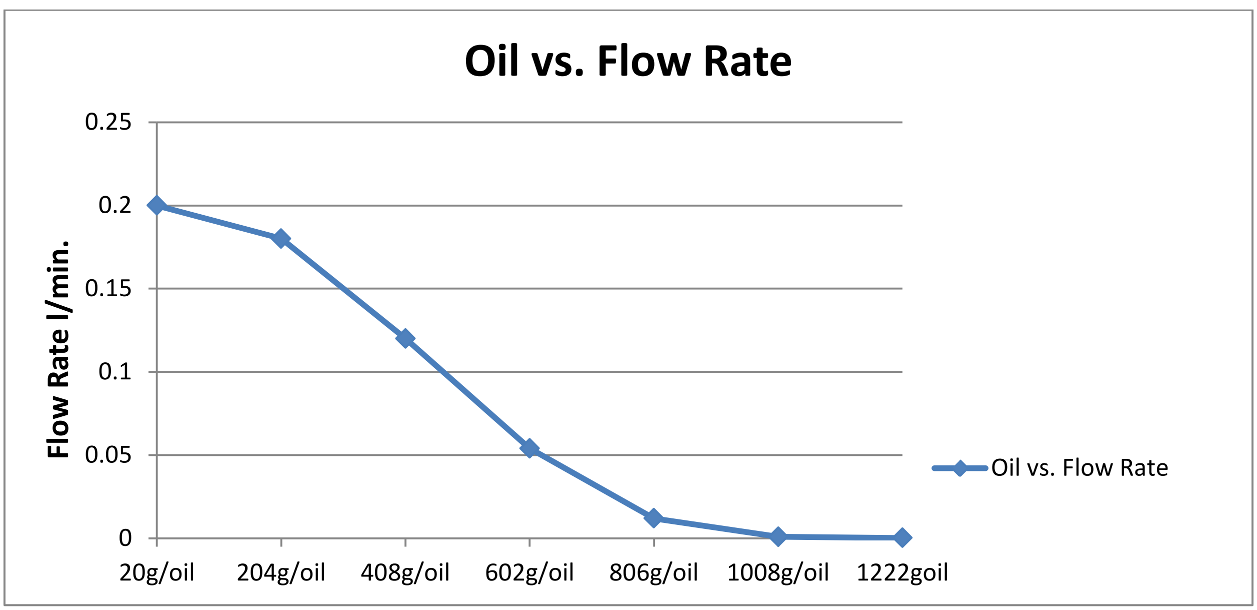

The HFF performed as intended, removing chronic levels of oil from the water and slowly restricting the flow until the C.I.Agent® polymers were completely saturated, at which time all flow was restricted preventing breakthrough. The filter had solidified 450 grams of oil but was retaining over 700 grams of free oil preventing its breakthrough into the environment. The small amount of water that was still flowing at the end of the last cycle represented the worst case scenario. This effluent stream was sampled, and submitted to Test America, a NELAC accredited laboratory, for analysis. The parameters tested for were: GC/MS Semi VOA - Method 8270C SIM for PAH's, NWTPH- Volatile Petroleum Hydrocarbons (VPH) and NWTPH Extractable Petroleum Hydrocarbons (EPH). The results are tabulated in a summary format below:

Analysis and Evaluation of Laboratory Data: The submitted samples were the initial influent sample, the final effluent sample and a trip blank for all parameters. The initial influent represented a sample that was only around 1000 mg/l, later concentrations exceeded 100,000 mg/l dependent of the water flow dilution factor. The parameter values are only to provide a relative comparison and ratios of what parameters the HFF is removing

Method: 8270C-SIM - Semivolatile Organic Compounds (GC/MS SIM)

Analyte	Influent ug/l	Effluent ug/l	Blank ug/l	RL ug/l
Naphthalene	360	0.11*	ND	0.10
2-Methylnaphthalene	730	ND	ND	0.13
1-Methylnaphthalene	520	ND	ND	0.10
Acenanaphthalene	6.5	ND	ND	0.10
Aceanaphthene	12	ND	ND	0.10
Fluorene	27	ND	ND	0.10
Phenanthrene	50	ND	ND	0.10
Anthracene	8.6	ND	ND	0.10
Fluoranthene	ND	ND	ND	0.10
Pyrene	23	ND	ND	0.10
Benzo(a)anthracene	ND	ND	ND	0.10
Chrysene	ND	ND	ND	0.10
Benzo(b)fluoroanthrene	4.3	ND	ND	0.10
Benzo(k)fluoroanthrene	4.0	ND	ND	0.10
Benzo(a)pyrene	ND	ND	ND	0.10
Indeno(1,2,3-cd)pyrene	4.3	ND	ND	0.10
Dibenz(a,h)anthracene	2.6	ND	ND	0.10
Benzo(g,h,i)perylene	6.2	ND	ND	0.10

* Naphthalene found being 0.01 ug/l above the reporting limit is essentially ND

Method: NWTPH/VPH Volatile Petroleum Hydrocarbons (GC)

Analyte	Influent ug/l	Effluent ug/l	Blank ug/l	RL ug/l
C10-C12 Aliphatics	890	ND	ND	50
C10-C12 Aromatics	2600	ND	ND	50
C12-C13 Aromatics	1200	ND	ND	50
C8-C10 Aliphatics	760	ND	ND	50
C8-C10 Aromatics	2800	ND	ND	50
C5-C6 Aliphatics	ND	ND	ND	50
C6-C8 Aliphatics	ND	ND	ND	50
Total VPH	9100	ND	ND	50

Method: NWTPH/EPH-Extractible Petroleum Hydrocarbons (GC):

Analyte	Influent ug/l	Effluent ug/l	Blank ug/l	RL ug/l
C10-C12 Aromatics	6900	ND	ND	50
C12-C16 Aromatics	17000	ND	ND	50
C16-C21Aromatics	45000	ND	ND	50
C21-C34 Aromatics	39000	64	ND	50
C10-C12 Aliphatics	77000	ND	ND	50
C12-C16Aliphatics	190000	ND	ND	50
C16-C21 Aliphatics	160000	ND	ND	50
C21-C34 Aliphatics	1100000	270	ND	50
Total EPH	1634900	334	ND	50

Method: TPH analysis per method ASTM Method D **7066. (Direct IR analysis**)

In house analysis of the TPH total from 100 ml sample of the effluent water showed ND with a >1.0 mg/l reporting limit confirming Test America's 0.334 mg/l total VPH/EPH results.

Summary and Conclusions: The HFF solidified and retained a chronic stream of influent oil contaminated water. The influent stream contained oil/water concentrations of 1000 mg/l up to 101,000 mg/l dependent on the flow dilution rate into the HFF. A total of 1222 grams of oil and 376.6 liters of water were delivered into the HFF. The filter solidified 456 grams of oil and retained 766 grams of free oil after 12 hours without observing breakthrough. The resultant effluent water contained no PAH's at detectable levels; no VPH detectable values for either the aliphatic or aromatic fractions. The aromatic and aliphatic fractions of the EPH analysis showed 334 ppb or 0.34 mg/l of extractible hydrocarbons which equates to a 99.98% removal rate. This value correlated with our TPH in house analysis of >1.0 mg/l result.

In conclusion, C.I.Agent® Hydrocarbon Flow Filter (HFF), has been shown in this study to provide an adequate water filtration system which solidifies and retains oil, aliphatics, aromatics and PAH's in either a chronic or episodic event, providing a chemical valve preventing oil breakthrough while purifying the effluent water.

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