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Modeling Magnetic Configurations for Improved Separations of Magnetic and Non-Magnetic Materials

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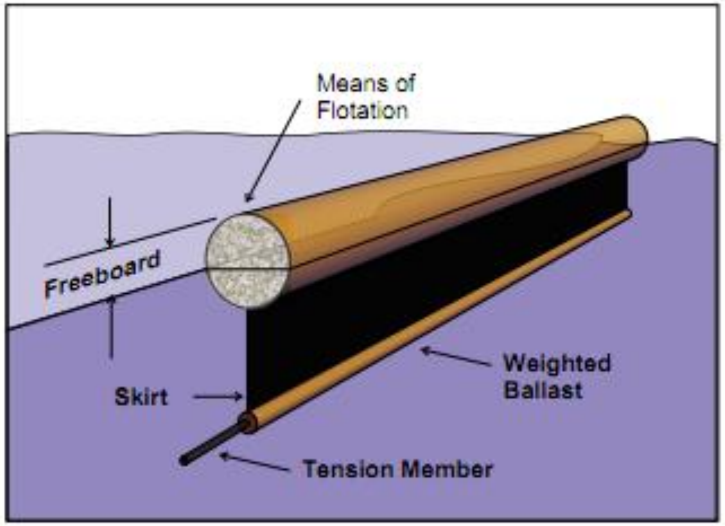
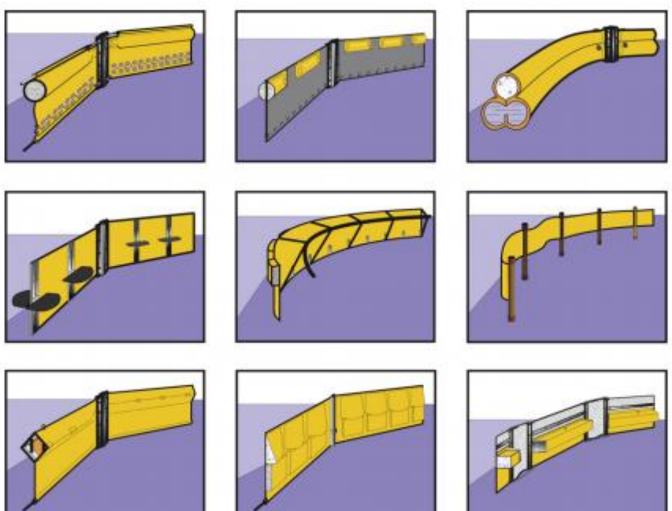
Excerpt from the Proceedings of the 2012 COMSOL Conference in Boston

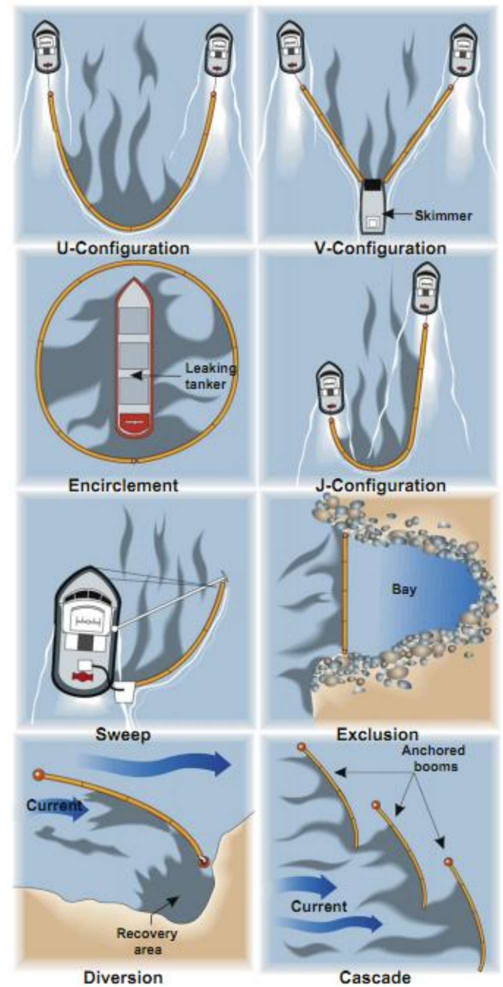
Motivation

http://www.telegraph.co.uk/finance/newsbysector/energy/oilandgas/9107069/BP-Gulf-of-Mexico-oil-spill-trial-postponed-at-the-eleventh-hour.html

Current Oil Spill Technologies - Booms

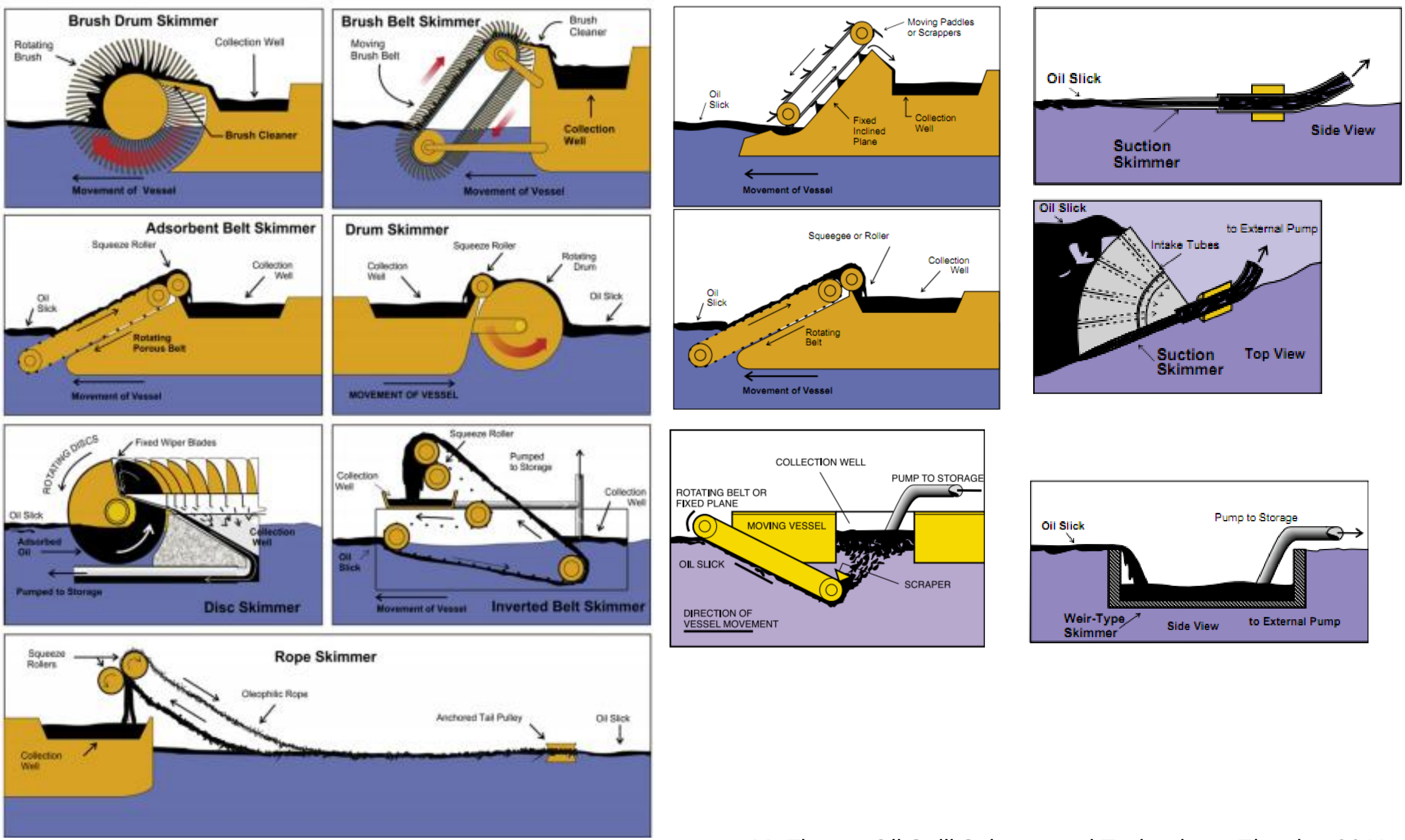






M. Fingas, Oil Spill Science and Technology: Elsevier, 2011.
M. Fingas, The Basics of Oil Spill Cleanup, Second Edition: CRC Press, 2001.

Current Oil Spill Technologies - Skimmers



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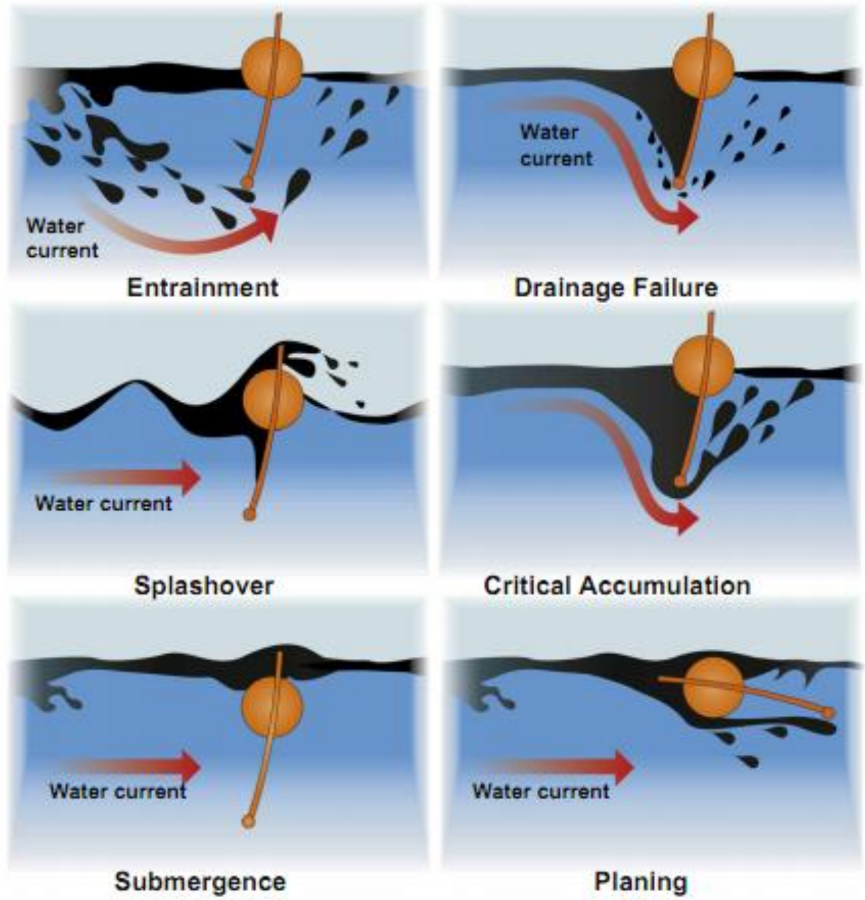
Current Performance

Skimmer Type	Recovery Rate (m^3/hr) for given oil type*				
	Diesel	Light Crude	Heavy Crude	Bunker C	Percent Oil**
Oleophilic Skimmers					
small disc	0.4 to 1	0.2 to 2			80 to 95
large disc		10 to 20	10 to 50		80 to 95
brush	0.2 to 0.8	0.5 to 20	0.5 to 2	0.5 to 2	80 to 95
large drum		10 to 30			80 to 95
small drum	0.5 to 5	0.5 to 5			80 to 95
large belt	1 to 5	1 to 20	3 to 20	3 to 10	75 to 95
inverted belt		10 to 30			85 to 95
rope		2 to 20	2 to 10		
Weir Skimmers					
small weir	0.2 to 10	0.5 to 5	2 to 20		20 to 80
large weir		30 to 100	5 to 10	3 to 5	50 to 90
advancing weir	1 to 10	5 to 30	5 to 25		30 to 70
Elevating Skimmers					
paddle conveyer		1 to 10	1 to 20	1 to 5	10 to 40
Submersion Skimmers					
large	0.5 to 1	1 to 80	1 to 20		70 to 95
Suction Skimmers					
small	0.3 to 1	0.3 to 2			3 to 10
large trawl unit		2 to 40			20 to 90
large vacuum unit		3 to 20	3 to 10		10 to 80
Vortex/Centrifugal Skimmers					
centrifugal unit	0.2 to 0.8	0.2 to 10			2 to 20

**Recovery rate depends very much on the thickness of the oil, type of oil, sea state, and many other factors*
***This is the percentage of oil in the recovered product. The higher the value, the less the amount of water and thus the better the skimmers' performance*



As low as 2%, higher percentages assume calm waters

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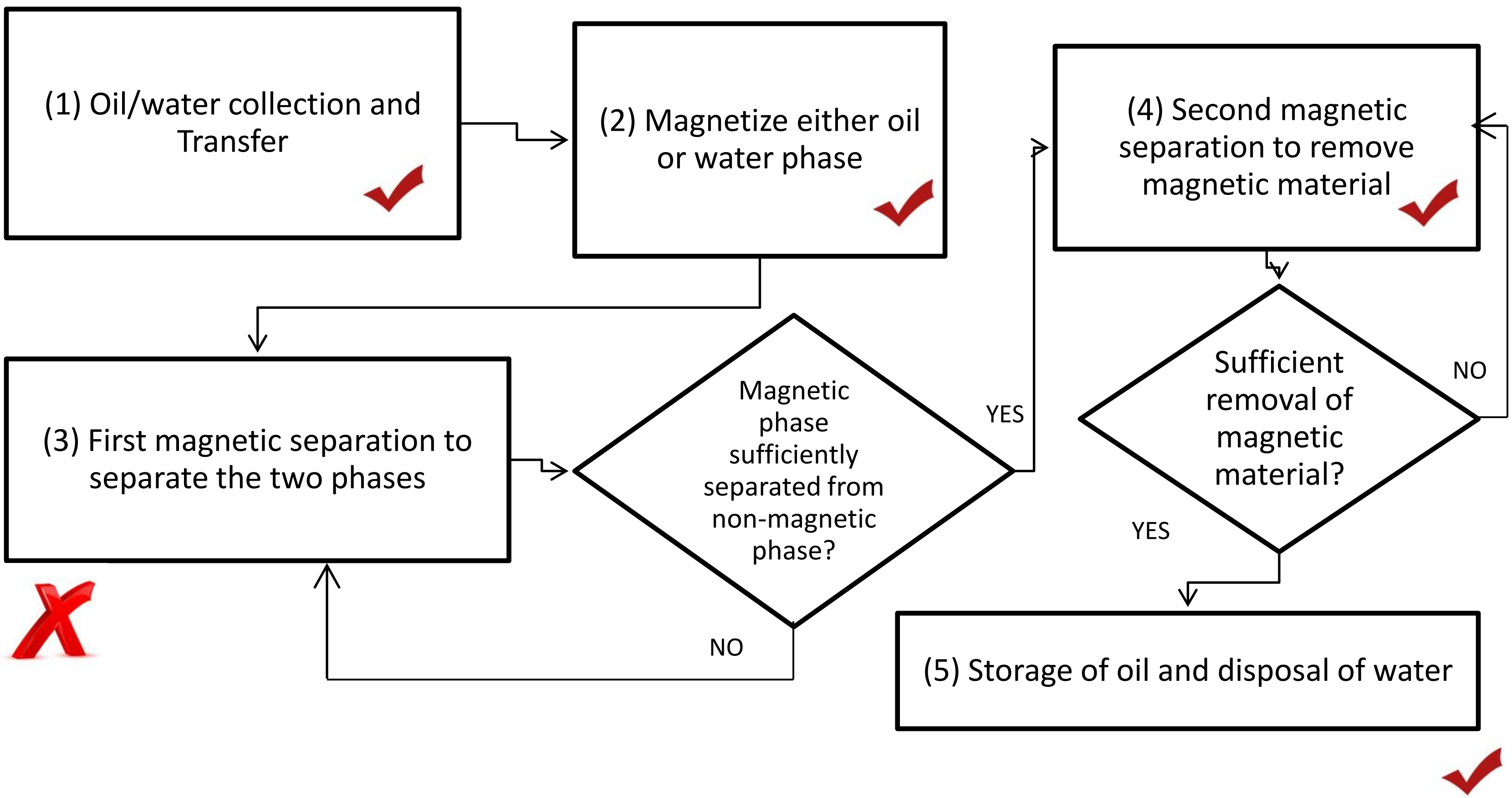
M. Fingas, The Basics of Oil Spill Cleanup, Second Edition: CRC Press, 2001.

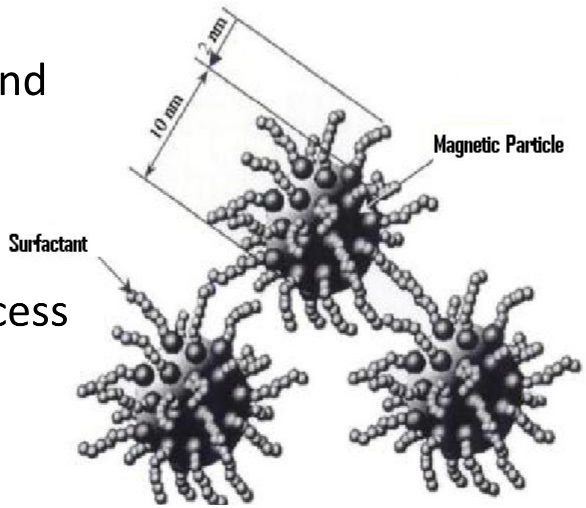
Magnetic Separation Method



M. Zahn, *et al.*, "Magnetic Colloid Petroleum Oil Spill Clean-up of Ocean Surface, Depth and Shore Regions," USA Patent Application No. #13/369,338, 2011.

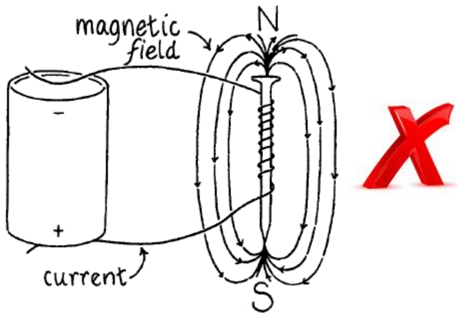
Requirements

1) Methodology and materials used should be reusable and environmentally safe



2) Methodology should be a continuous, sustainable process that recycles materials

3) Methodology should be robust for marine environment



4) Methodology should use none/very little energy

5) Methodology should work when there is a variable amount of oil and water in the mixture

Magnetoviscous Effects in Ferrofluids – S. Odenbach

Governing Equations and Modules Used

$$F_m = \mu_0 (M \cdot \nabla) H$$

Magnetic Force Density (N/m^3)

$$W_m = \int_0^B H \cdot dB$$

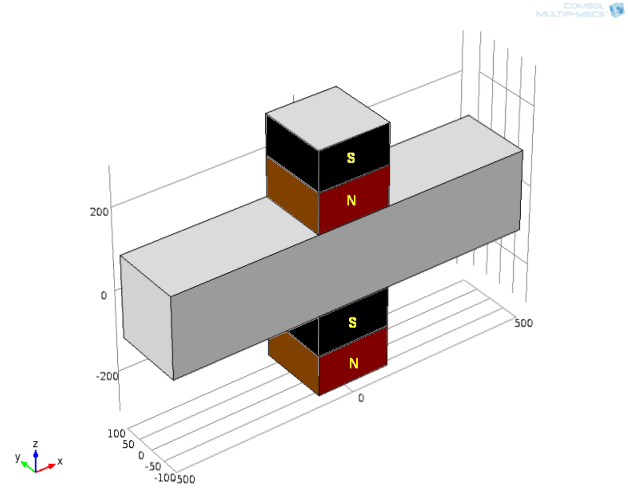
Magnetic Energy Density (J/m^3)

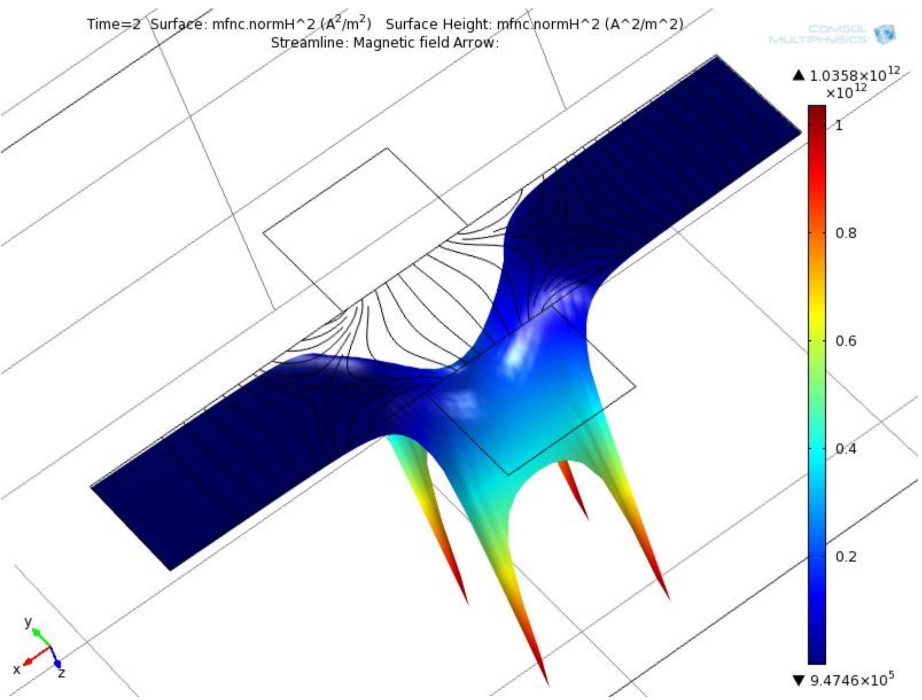
$$F_m = -\nabla W_m$$

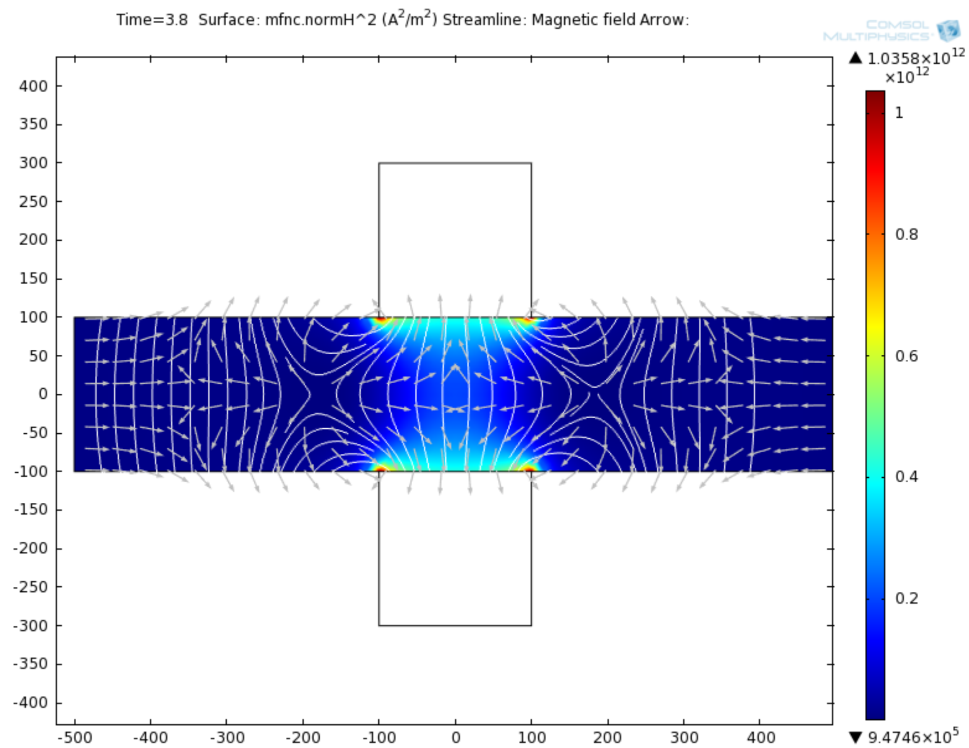
Magnetostatics (AC/DC Module)
Laminar Two Phase Flow (CFD Module)

Think in terms of Magnetic Energy Density?

Two Attracting magnets



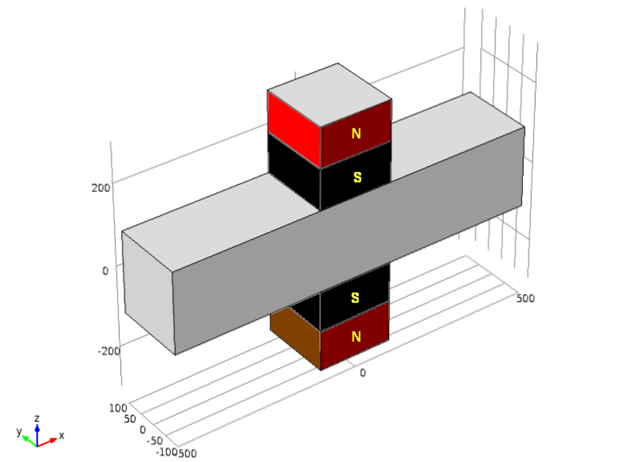


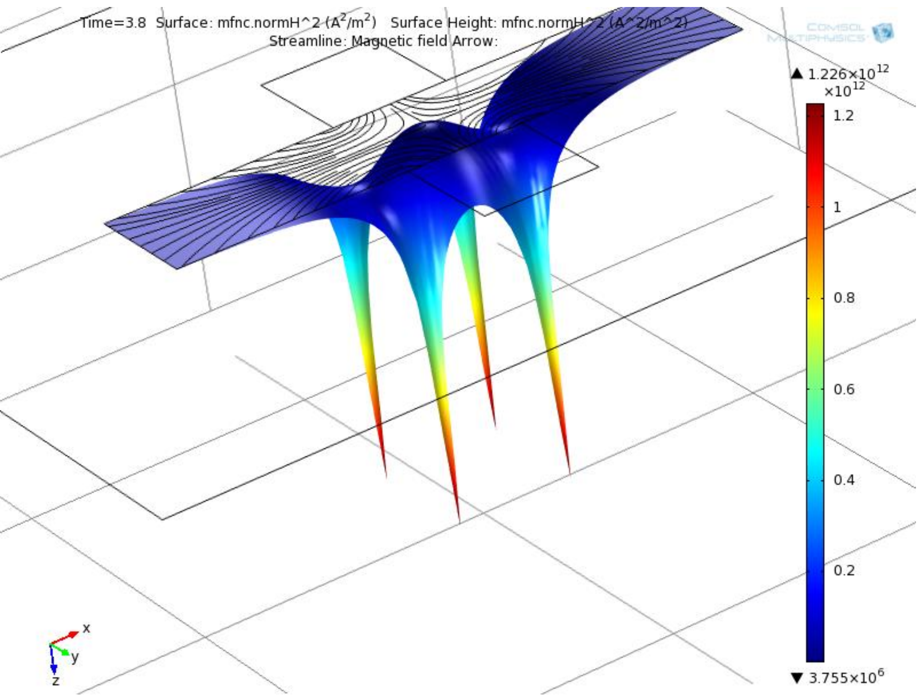


Magnetic Energy Surface Plot *(with Height)*

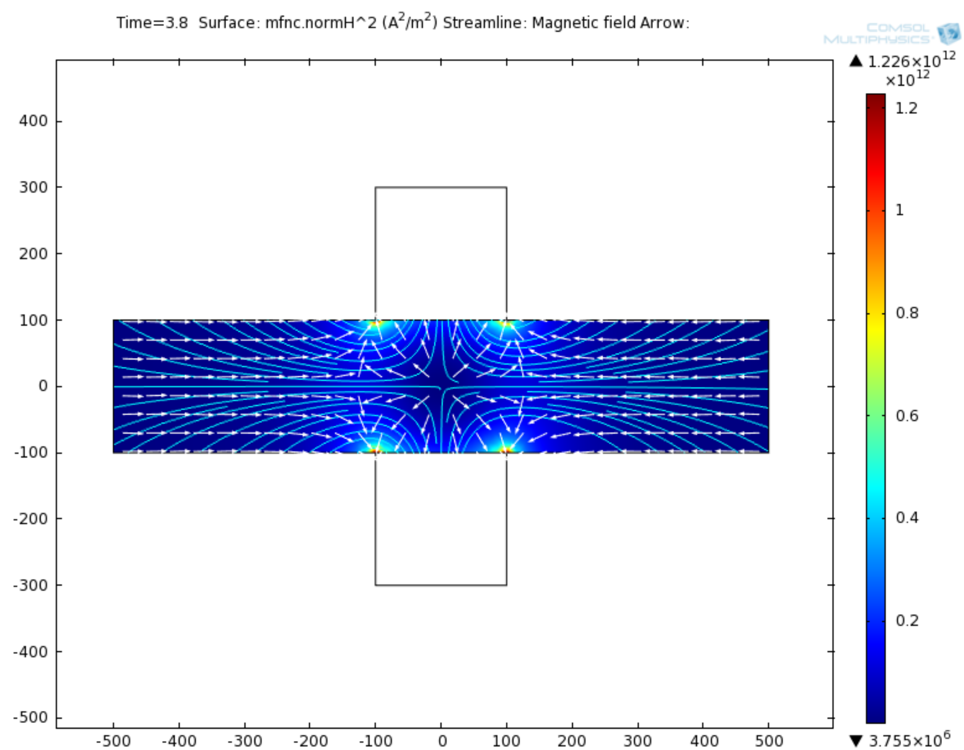
Magnetic Force Density Arrow Plot

Two Repelling magnets



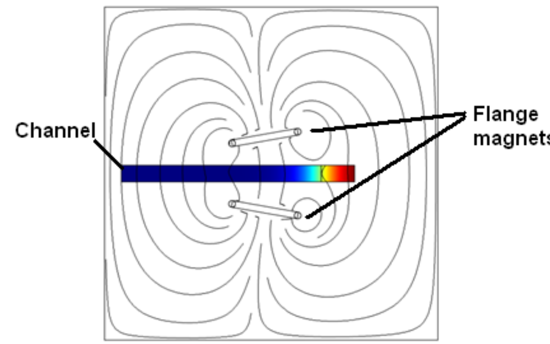


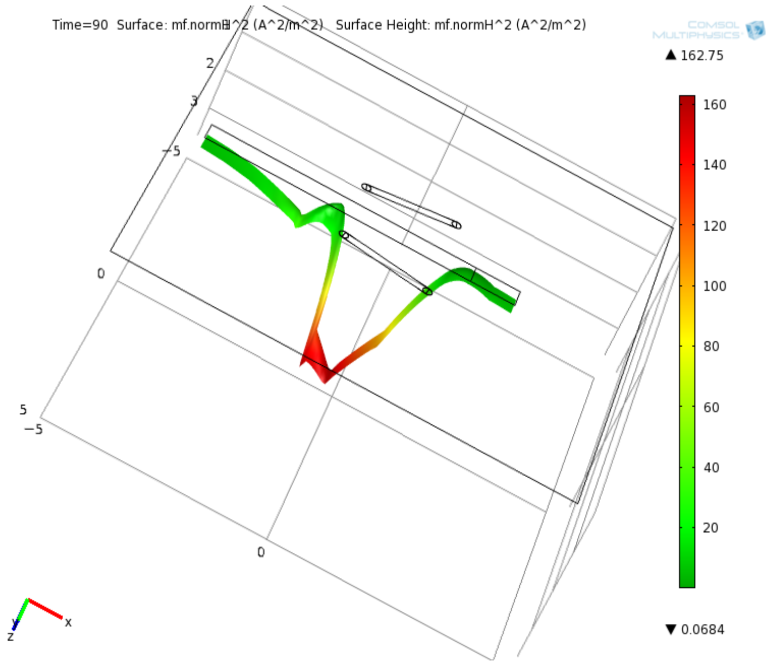
Magnetic Energy Density Surface Plot
(with Height)



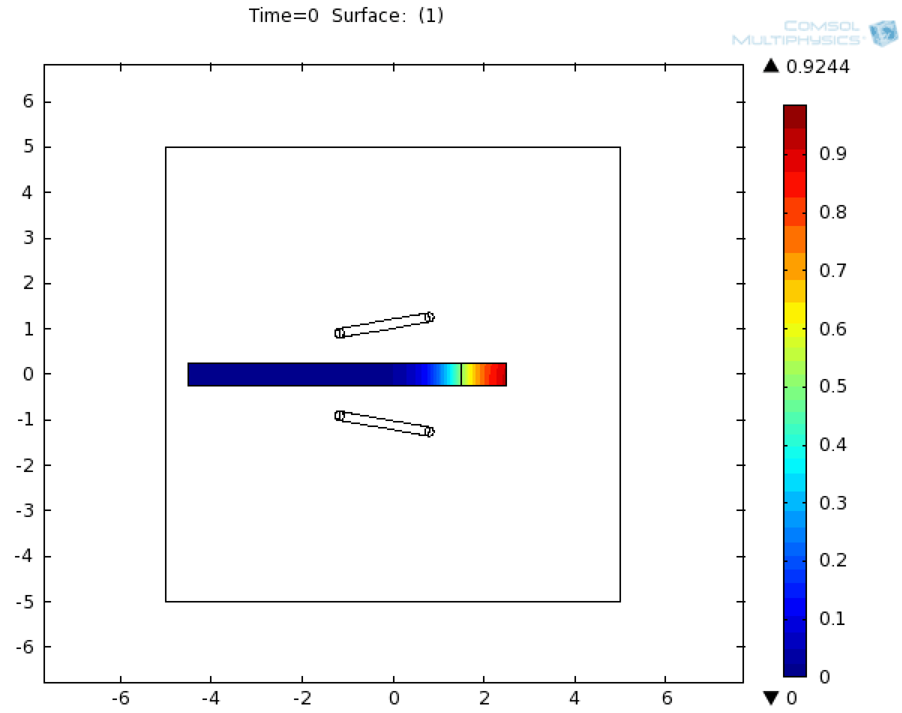
Magnetic Force Density Arrow Plot

Flows with no Magnet Edges

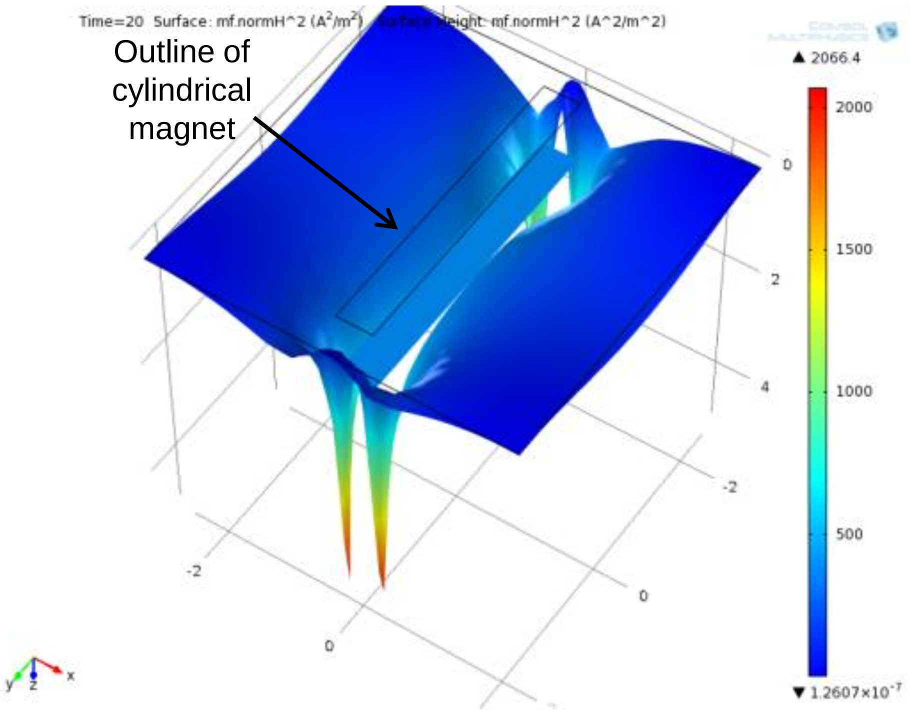




Magnetic Energy Density Surface Plot
(with Height)

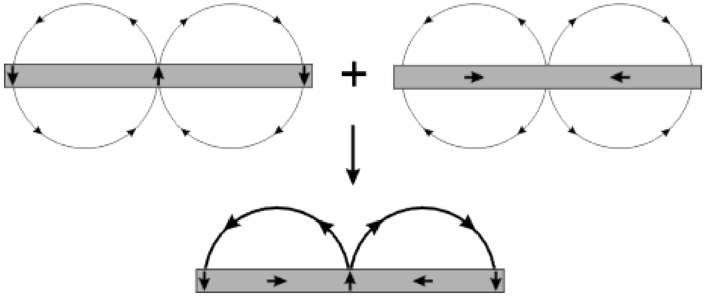


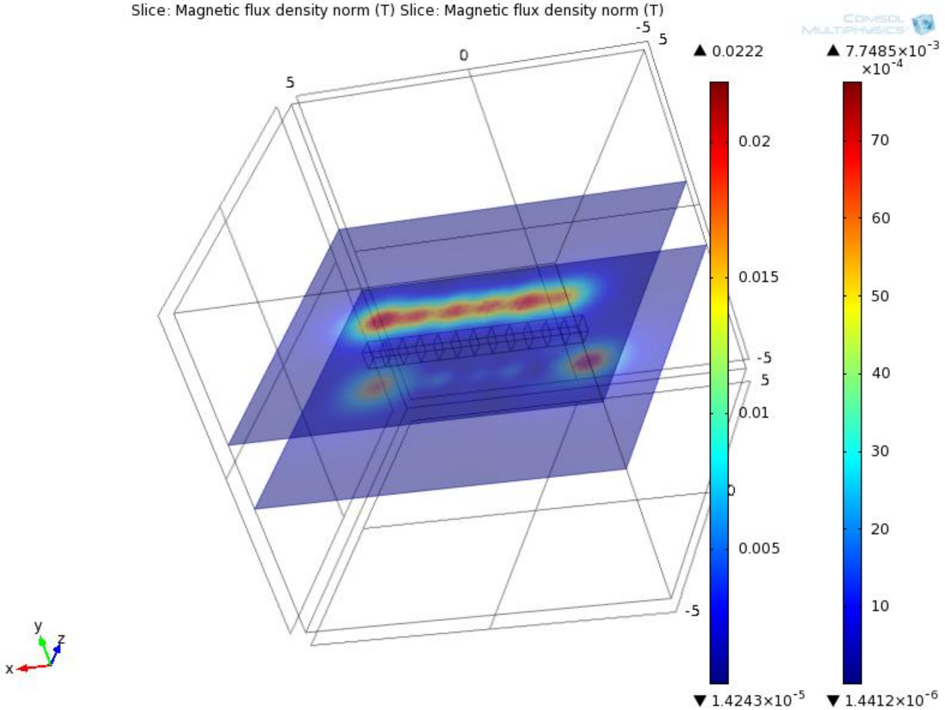
Using Edges

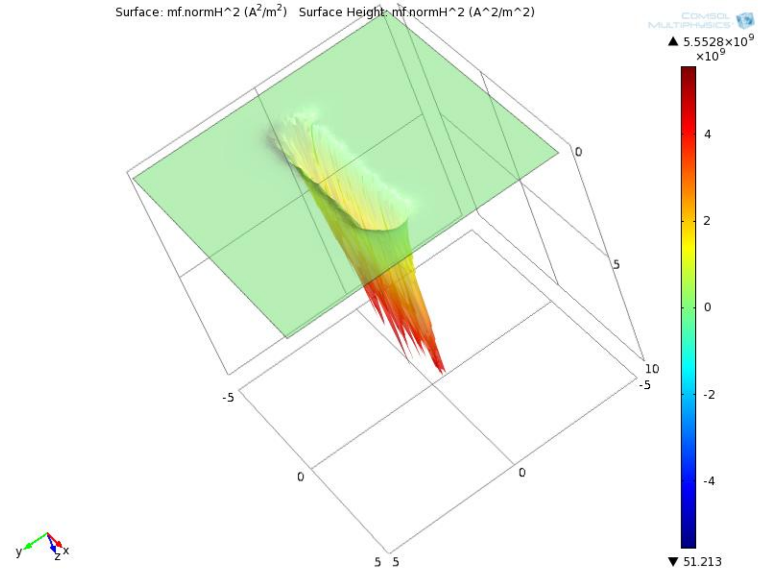


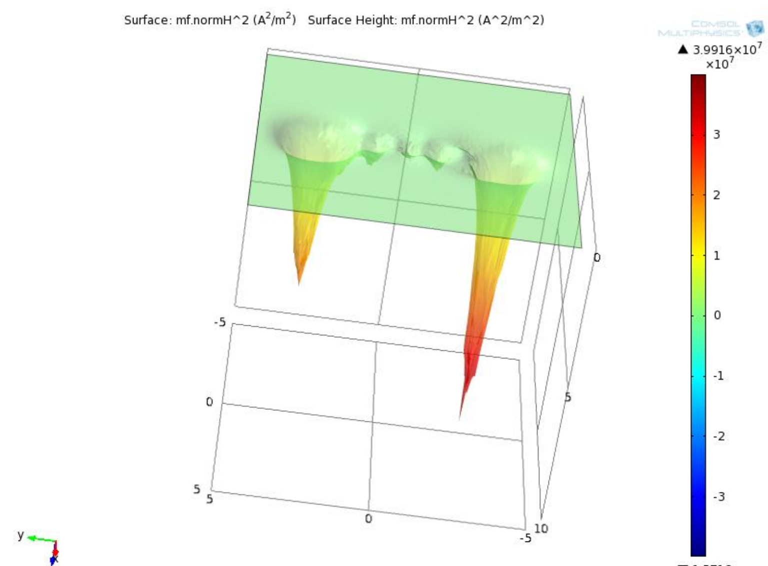
Magnetic Energy Density Surface Plot
(with Height)

Using Halbach Array









Magnetic Energy Density Surface Plot
(with Height)

New Magnetic Separation Technique