**Group Project 3**

**Group Members: William Olson, Chris O'Brien, Ian Macfarlane, and Gamal Elbialy**

**Flow Visualization**

## Purpose:

The purpose of this experiment was to work with groups to capture a beautiful and visually appealing image of ferrofluid. We were lucky enough to have been able to check out a bottle of ferrofluid that the professor had. We then tried many different containers and magnet formations and locations to see what would create the most interesting image. I ended up deciding to use two magnets and cover them with ferrofluid in a ceramic bowl with magnets on the bottom. This arrangement showed a very interesting bridge like formation of the ferrofluid. Chris O'Brien, Ian Macfarlane, Gamal Elbialy, and myself collaboratively created this image and report.

## Flow Set Up

For the setup of this image a ceramic bowl, disk magnets, ferrofluid, and a few lights were used. Approximately one teaspoon of ferrofluid was added to the 6 in. diameter bowl before any magnetic forces were applied. Once the ferrofluid had settled in the bowl, two disk magnets attached together were dropped into the bowl with the fluid. The bowl was placed underneath two lamplights to help illuminate the fluid and give it a crisper appearance. These two magnets were then forced sideways by two sets of bigger magnets held underneath the bowl (not touching the fluid). Using this setup, which can be seen in figure 1below, I was able to create my final image.

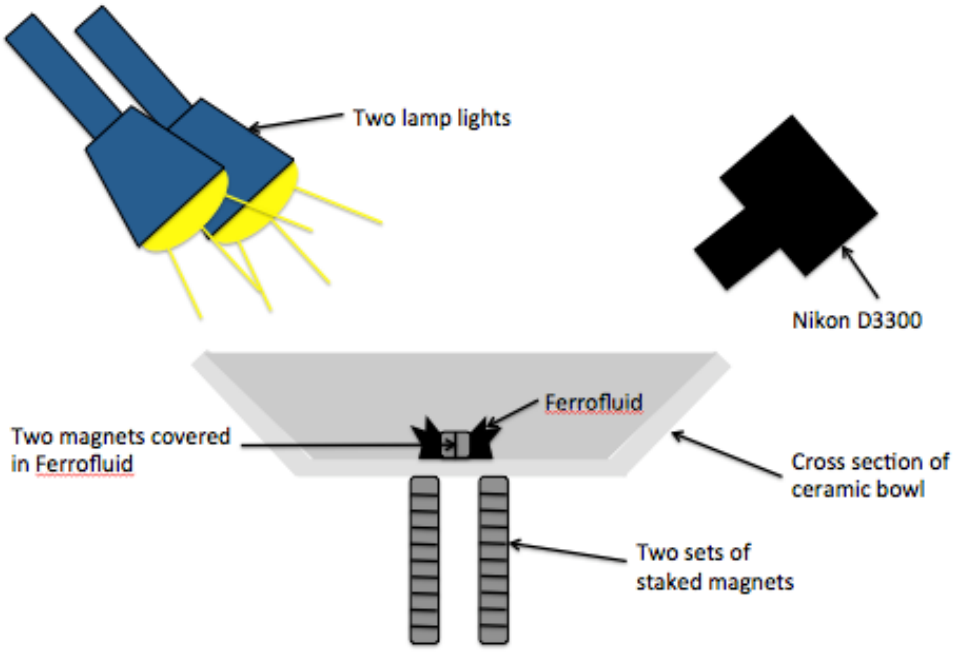


Figure 1: Experimental Set Up

## Visualization Technique

With using ferrofluid we were able to visualize the physics involved in magnetic fluid. Ferrofluid is a liquid that becomes magnetized in the presence of a magnetic field. It is made up of many tiny insoluble particles within a carrier fluid. [1] The fluid we used was manufacture by FerroTec. The physical properties of this fluid can be seen in the appendix. The MSDS for this ferrofluid can also be seen in the appendix. As seen in the images within the ferrofluid there are spikes formed throughout the liquid at some of the edges. The Normal-Field Instability can describe these peaks and valleys that are created.[2] The magnetic field concentrates at certain points then due to the fact that the fluid is more easily magnetized then the air the fluid gets pulled out creating the spikes. This occurs until there is a force balance between the forces of the magnetic field and the forces of gravity and surface tension. [1] It takes energy to suspend the fluid against gravity as well as increase the surface tension so the stronger the magnetic field lines the greater the spikes will be. By placing magnets within the fluid along with underneath the fluid, being separated by a ceramic layer, the ferrofluid gathered at the ends of the magnets within the fluid and created spikes around this pole.

## Photographic Technique

The following settings were used when taking this photo:

- Exposure Time: 1/125 sec.
- Aperture: f/5.6
- Focal Length: 55 mm
- ISOS: 800
- Resolution: 300x300 inches
- Original image dimensions: 6000x4000 pixels
- Cropped image dimensions: 5720x3072 pixels

After the picture was taken I used Adobe Photoshop to help develop my final image. I first cropped out the reflections of the lamplights on the top of the bowl. I then played with the curves of the image. There is an auto function of the curves menu, which I used. I automatically changed the reds, blues, and greens of the image. This really brought out the darkness of the ferrofluid. It also made the combination of the white surface of the ceramic bowl and the thin layer of ferrofluid much brighter and almost more orange. You can see the differences between the original photo (figure 2) and the final image (figure 3).

Figure 2: Original Image

Figure 3: Final Image

**Conclusion:**

The image reveals the beautiful physical properties of the ferrofluid. What I like about the image is the unique formation of the ferrofluid that I achieved using the magnets. I almost looks like a bridge formation. I also liked how the surface of the ceramic bowl and the thin layer of ferrofluid turned out almost orange which made it contrast well with the darker ferrofluid. I believe I achieved my goal of this experiment but there are a few things I could improve on. One would be to use more powerful mahnets to create more destict spikes in the ferrofluid. I like how mine turned out but it would be even better with the larger spikes.

**Sources:**

**[1]** https://en.wikipedia.org/wiki/Ferrofluid

**[2]** http://www.physicscentral.com/explore/action/ferrofluids.cfm

**Appendix:**

FerroTec

# Technical Data Sheet

## Ferrofluid Type: EFH1

### Physical Properties

| | |
|---|---|
| Appearance | black-brown fluid |
| Carrier Liquid | light mineral oil |
| Saturation Magnetization | 440 Gauss (44 mT) |
| Viscosity @ 27°C | 6 cp (6 mPa-s) |
| Nominal Particle Diameter | 10 nm |
| Initial Magnetic Susceptibility | 2.58 Gauss/Oe (0.17 emu/g / Oe) |
| Relative Magnetic Permeability @ 20 Oe | 2.6 |
| Density | 1.21 g/ml ($1.21 \times 10^3$ kg/m$^3$) |
| Magnetic Particle Concentration | 7.9% by Volume |
| Flash Point | 92°C |
| Pour Point | -94°C |
| Surface Tension | 29 dynes/cm (29 mN/m) |
| Volatility (1 hr @ 50°C) | 9 % |

**For further technical data, please contact your local Ferrotec office:**


| | | |
|---|---|---|
| Ferrotec (USA) Corporation, USA | (603) 472-6800 | info@ferrotec.com |
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March 18, 2009

# MATERIAL SAFETY DATA SHEET

## SECTION I: PRODUCT IDENTIFICATION

| | |
|---|---|
| MANUFACTURER'S NAME: | Ferrotec (USA) Corporation |
| ADDRESS: | 33 Constitution Drive<br>Bedford, N.H. 03110 |
| TELEPHONE: | (603) 472-6800 |
| EMERGENCY ONLY TELEPHONE: | (800) 424-9300 (Domestic)<br>(703) 527-3887 (For International) |
| CHEMICAL NAME: | Proprietary Product |
| TRADE NAME & SYNONYMS: | EFH Series |
| CHEMICAL FAMILY: | Colloidal Dispersion |
| FORMULA: | Mixture |

## SECTION II: COMPONENTS

The precise composition of this mixture is proprietary information. A more complete disclosure will be provided to a physician or nurse in the event of a medical emergency.

| | |
|---|---|
| Magnetite: | 3-15 % by volume |
| Oil Soluble Dispersant: | 6-30 % by volume |
| Carrier Liquid: | 55-91 % by volume |

## SECTION III: CHEMICAL AND PHYSICAL PROPERTIES

| | |
|---|---|
| Boiling Point (°F): | 401-491 |
| Specific Gravity: | 0.92 to 1.47 |
| Vapor Pressure (mm Hg.): | 1 at 100°F |
| Percent Volatile by Volume: | 55-91 % |
| Vapor Density (AIR = 1): | 6.4 |
| Solubility in Water: | Negligible |
| Evaporation Rate at: | <0.1 |
| Appearance & Odor: | Black liquid, mild odor |