SPS Chapter Research Award Final Report

Project Title	**Oil Spill Detection through Multispectral Technology**
Name of School	Saint Peter's University
SPS Chapter Number	6626
Total Amount Awarded	1550/-
Total Amount Expended	1465/-
Project Leader	Prajwal Niraula

Abstract

An oil spill is a major environmental disaster, which is good prevented, best stopped. Infrared Radiation (IR) Technology is a new promising technology rising in this field. IR has advantages over traditional methods because of the distinct thermal contrast between oil and water. While IR has been successfully employed at various instances including the Deep Water Horizon Crisis, the technology has not still fully matured. At Saint Peter's, we intended to study in detail the thermal properties of oil, particularly the dependence of emissivity of oil on the thickness of the oil, which will allow us to make a quantitative estimation of the oil. In addition, we planned to employ fluorescence to investigate the spectral response of different oil samples. Numerical simulation would be done in addition to supplement the experimental finding.

Statement of Activity

Introduction:

Every object above absolute zero emits radiation. For the body at the room temperature which is around 300 K, the major part of the radiation falls in infrared region. Thus, IR due to its ubiquity is a very handy technology in detecting objects. In oil spill detection, the thermal contrast of oil and water [1] allows us to localize the boundary of the oil. Even though the water and oil are about the same temperature, an IR camera registers different temperatures owing to the different emissivity of oil and water as shown in the image below. We intended to measure the dependence of emissivity of oil on thickness. Previous investigation has been directed at studying varieties of oils and their properties. We will be particularly focusing on using crude oil, which has not been studied as extensively.

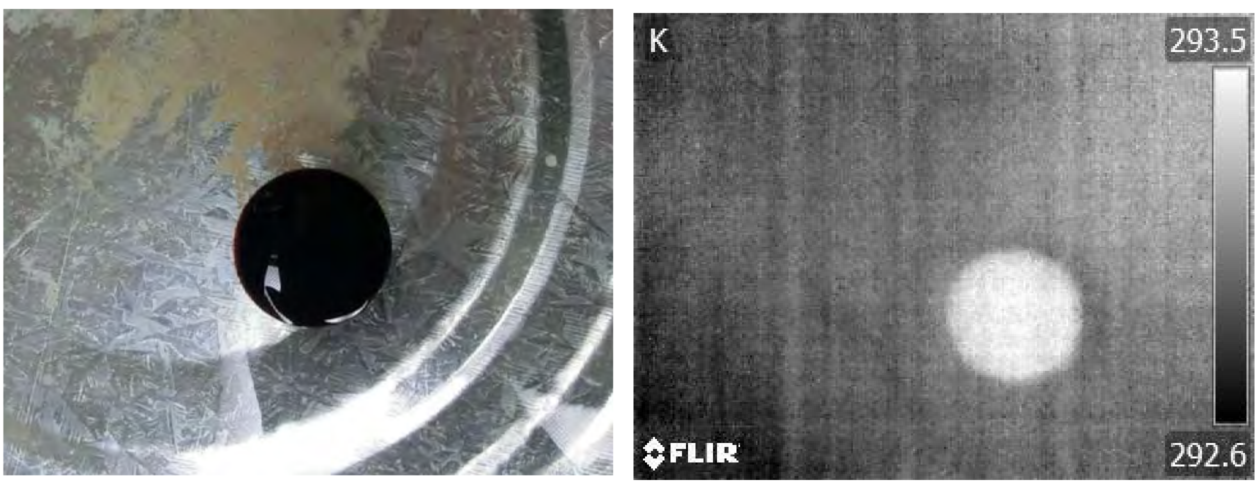


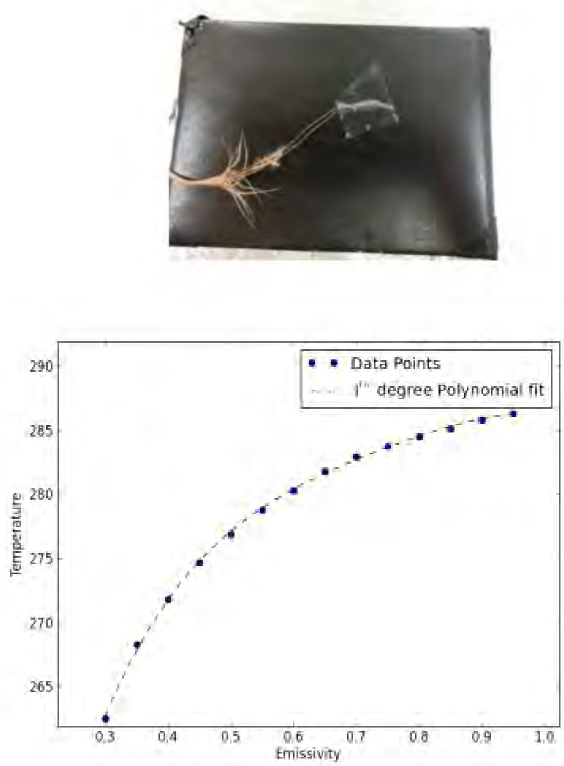
Fig 1. An optical Image (left) and infrared image (right) of oil drop of a crude oil taken at room temperature.

Procedure:

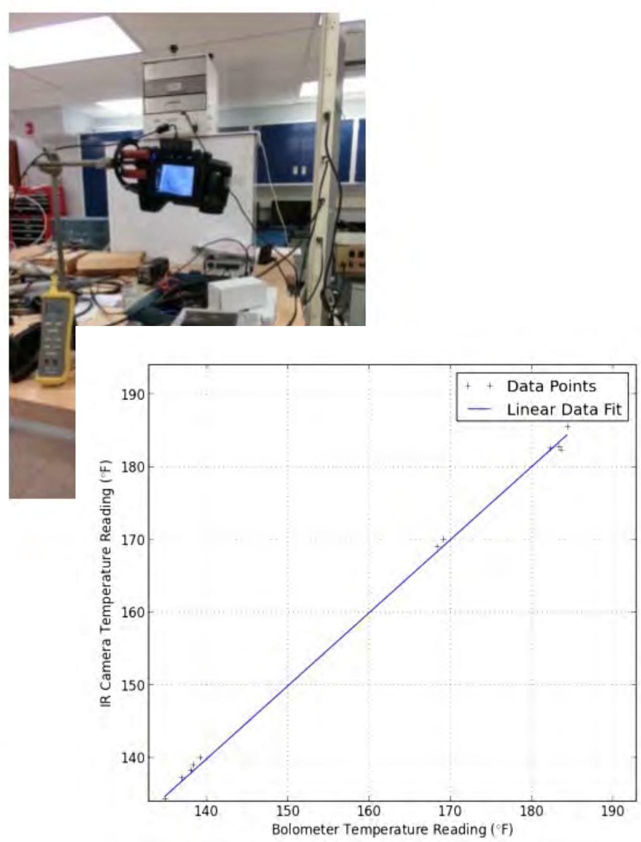
For our experiment we used a Camera FLIR® 420 Series. We used three different types of oil, although we focused primarily on the crude oil. Before starting the experiment we calibrated the camera against a standard bolometer available in the lab. Then, we took a water and oil mixture, and with the help of IR camera we tried to see if there was any relation between thickness and emissivity. This was tried in two ways: first, allowing the surface area for a given volume of oil on the surface of water to increase, and second, having a small boundary within the bigger container so as to contain the surface of oil itself and change thickness with volume. Previous research has shown that for crude oils the emissivity contrast between oil and water is supposed to transition from positive to negative at about 50 µm and 150 µm [2,3], and we tested if this could also be seen with our crude oil sample. Also we had gained the tunable laser from the funds provided by SPS to perform experiments related to laser heating, and fluorescence.

Finding:

We began our research by calibrating the IR camera. The error percentage of the camera as mentioned in the manual is +/- 2°C. When tested against a thermocouple with tolerance of 0.2 °C, we were able to verify this claim.

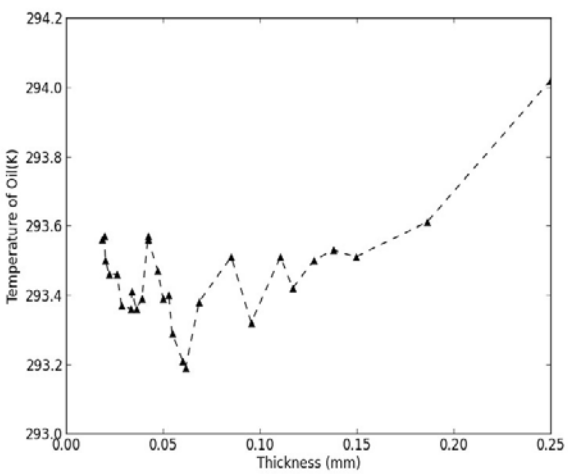


Temperature reading response of Camera on emissivity feed

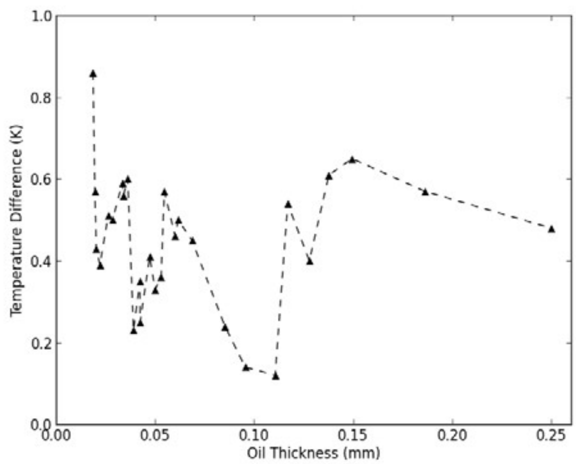


Temperature Calibration of Infrared Camera with Bolometer

For this we used a blackbody to calibrate the camera as shown in the figure above, which simply consisted of an aluminum plate covered with a black sheet of paper. Since a heater was used which had preset temperature steps, we were able to calibrate only over the certain temperature range. We were also interested to study the role of emissivity feed in the camera and its temperature response. As shown in the graph above, we were able to get a good fit with a fourth degree polynomial fit for the data. From the data we could also see that the range of 0.9 – 1, where most of the emissivity coefficients fall, is not very sensitive region to work with. When we conducted the experiment, we were not able to find a clear cut signal for the oil detection in order to determine the thickness. Also as seen in the diagram below, while the relative temperature difference between oil and water is detectable, the difference lied within the error range of camera +/- 2K, which made us conclude that our IR camera is not effective to measure the relation between emissivity and thickness. [The initial difference is primarily because the oil has yet to thermalize with the water.]

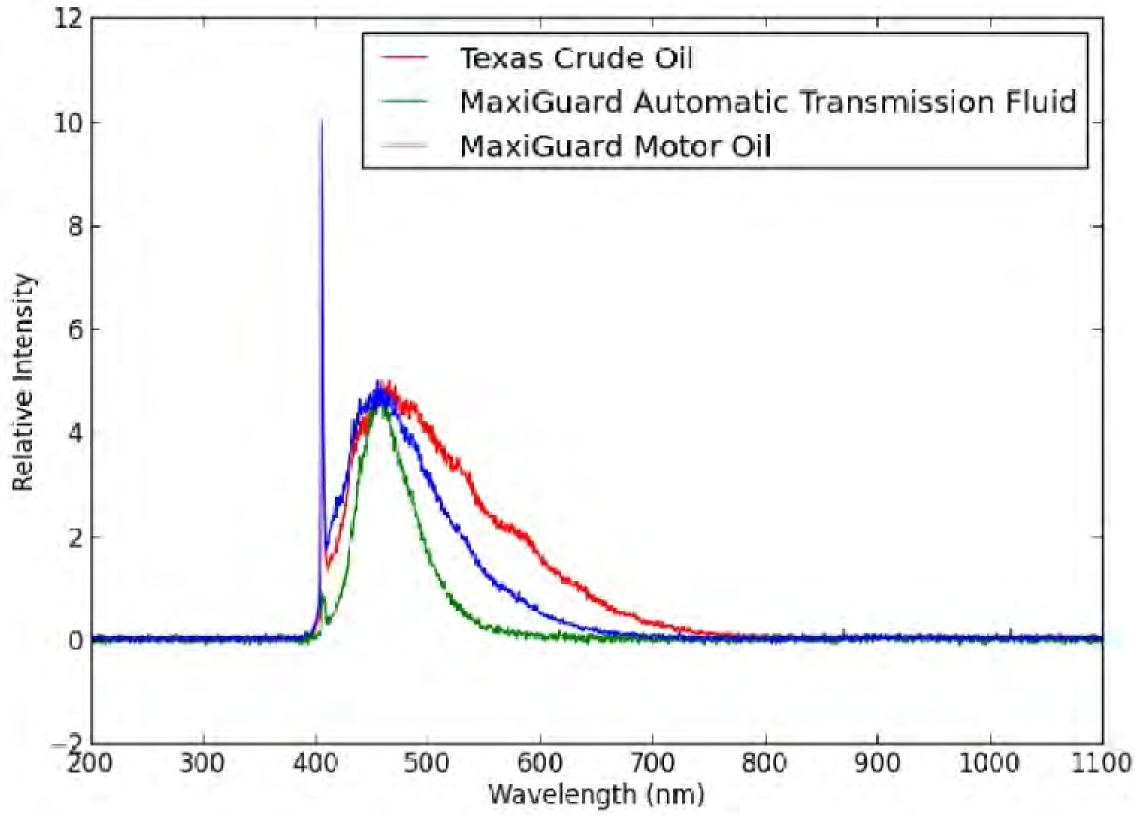


Temperature Variation with thickness of oil

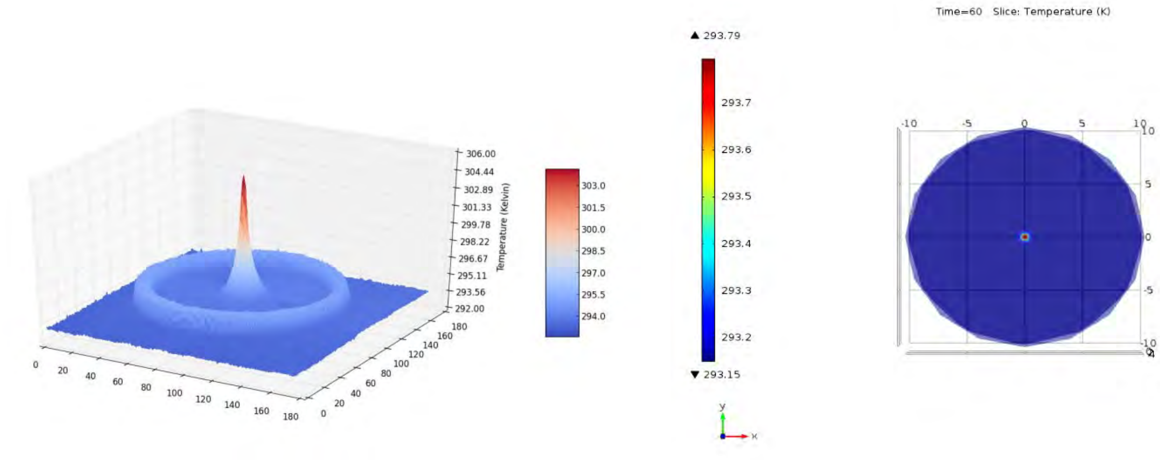


Temperature Difference between Oil and water variation with thickness

Then we went onto measure the fluorescence. The three major oil samples used in the research are Maxi guard Automatic Transmission Fluid, Maxi guard Motor Oil and Texas Crude Oil. While these oils are physically distinguishable through the color, they also produced three distinguishable fluorescence spectra, which were recorded and studied. We have been able to distinguish the three oil samples from their respective fluorescence spectrum. This technique would be particularly helpful when dealing with more species of oil, and in fact is already performed in industry through flouro-spectrometry.



In addition to that, we performed laser simulation with the new laser we acquired. It was clear that we can potentially differentiate between the oil surface and water surface, as oil absorbs the laser power more readily than the water for the lasers in visible spectrum, which would correspond to a higher rise in temperature. When oil is present we see a rise of temperature as high as 15K from the background temperature in steady conditions, which is easily detectable by the infrared camera. A more accurate temperature measurement would also allow us to infer the thickness of the oil sample. However, this value is would depend on the environmental factors such as environmental temperature and would require more extensive research. Since we lacked instruments to accurately calibrate the laser, we could not match our simulation with the experimental finding for laser heating. With the table top laser we bought with SPS funding we were not able to obtain significantly better results primarily due to the absence of a radiometer that would allow us to calibrate the laser power.



Experimental and simulation of laser heat profiling of a crude oil sample.

Conclusion:

From the experiments we performed we came to the conclusion that while Infrared Technology is helpful in determining the surface area of the oil, using it to measure the thickness is not viable, as more precise measurement would be needed. On the other hand spectroscopy and laser stimulation show more promising avenues in determining the thickness of the oil sample.

Bibliography

1. Shih, Wei-Chuan and A. Ballard Andrews. *Modeling of thickness dependent infrared radiance contrast of native and crude oil covered water surfaces*. Optical Society of America. 2008.
2. Goodman, R.H., *The remote sensing of oil slicks*. 1989, Chichester, UK: John Wiley and Sons. p. 39-65.
3. Hus, L., *Remote Sensing Of Oil Spills In Thermal Infrared - Contour Line Effect* IEEE International Geoscience and Remote Sensing Symposium (IGARSS), 1991. **3**: p. 1315 - 1317.

Impact Assessment:

At our college, the research is primarily done in the field of plasma. However, recently the scope of research has expanded with the joining of Dr. Debing Zeng. This project helped to entrench the options of research available for Saint Peter's Students as we now have more facilities to do better research. With regard to this specific project, students from different departments came together to discuss their ideas, and while physics students took the lead, we all learned to solve problems as a group. Everyone involve enjoyed the experience, and took back some meaningful skills that will be helpful in the future.

Key Metrics and Reflection

How many students from your SPS chapter were involved in the research, and in what capacity?	6
Was the amount of money you received from SPS sufficient to carry out the activities outlined in your proposal? **Could you have used additional funding? If yes, how much would you have liked? How would the additional funding have augmented your activity?**	Yes.
Do you anticipate continuing or expanding on this research project in the future? If yes, please explain.	Yes. Our friend Joseph Ghobriel is taking on the experiment, and he will probably expand the result. Also Dr. Zeng told us about a collaboration with some colleagues in China. Hence we should have more interesting results in the future.
If you were to do your project again, what would you do differently?	Not much, though, we would have probably involved more people.

Press Coverage

Spotting and Measuring Oil Spills" in SPS Observer. Spring 2015. URL:
http://www.spsobserver.org/2015/spring-building-blocks.pdf

Expenditures

Expenditure Table

Item	Please explain how this expense relates to your project as outlined in your proposal.	Cost
Laser	This was the most important part of the research that we carried out.	1065/-
Gloves	In order for crude oil handing	$91.75/-
Punch Die Set	To create optimum diameter holes in metal to contain the oil	$ 314.69/-
	Total of Expenses Covered by SPS Funding	**1472/-**

Activity Photos

Unfortunately we did not take any photos during the activity.