

Detection of Red Dye in Diesel Oil

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ABSTRACT

Developing a sensitive and effective instrument for detecting the presence of red dye in diesel fuel is very advantageous for governments in preventing tax loss by controlling illegal use of the diesel fuel.

The objective of this work has been to investigate and develop an instrument to detect red dye in diesel, based on the principle of absorption. The peaks of absorption in red and pure diesel fuel were measured with the help of UV-spectrometer (Lambda 6/ PECSS). Optical interference filters of wavelengths 405 nm and 616 nm were used to modify the spectral transmittance of an optical system with appropriate spectral absorption characteristics. Two simultaneous light beams of two different colors were sent into the diesel fuel and the transmitted light from the fuel censored by a silicon photo detector. The signal from the detector was then amplified with the help of three operational amplifiers (OP-177) and sent to an analog device (AD 538) which can perform division operation.

The voltage produced when the violet light passes through the medium was divided when the red light passes through the medium in the one quadrant division unit (AD 538). The output voltage from the analog device was measured with the help of a digital multi-meter. The results show that the output voltages decreases with the increase in percentage of red dye in diesel fuel.

1. INTRODUCTION

In daily life, diesel oil is one of the most used fuel oils in the world. Diesel oil is comparatively cheaper than other oils. In the past, there was only one type of diesel oil present on the Norwegian market and diesel oil had only one common price. But the owners of diesel motor vehicles had to pay a certain amount of money per kilometer to the state. Two years back (in 1993) the Norwegian government changed their policy on the taxation of diesel oil and instead of paying money per kilometer by vehicle owners, they decided to classify diesel in two categories.

At the moment of this experiment, there were two types of diesel oil present on the Norwegian oil market and they were; Pure (Common) diesel oil and Red diesel oil. Pure diesel oil is one without any added color and it is meant for the purpose of ordinary motor vehicles. The second one is a diesel oil with red dye in it. A red color is obtained by adding 0.005 gram red and 0.005 gram yellow solvent to one liter of the pure diesel oil. This red diesel is cheap compared to pure diesel oil because there is no tax on it. The red colored diesel oil is meant for farmers to run their tractors, motor boats, excavators, .etc. and for other industrial purposes as a subsidy from the government to assist an enterprise deemed

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advantageous to the public. Therefore, it is illegal to use the red colored diesel in ordinary motor vehicles.

Currently, there is no commercially available device for controlling the type of diesel oil used in ordinary motor vehicles. Now, in order to check the illegal use of red diesel oil in ordinary vehicles, the authorities have to collect some sample diesel oil in a transparent vessel from the diesel tank of the motor vehicle and identify with their eyes whether any trace of red color is present in the diesel oil or not. This method of detecting the presence of red color in diesel oil is not very safe and correct unless it is taken to a laboratory analysis and it is a time consuming method. Moreover, another disadvantage with this method is that it is impossible to detect, in the field, the presence of a very small percentage of red dye in diesel. Therefore, a particular device, which is more safe and correct, has to be developed for the purpose of detecting the presence of red dye in diesel oil without taking the sample diesel out from the diesel oil tank of the vehicle. An experimental setup for detecting red dye in diesel oil is presented here.

2. THEORY

The color determination (whether the red dye is present or not) in the diesel oil is based on a principle of absorption as illustrated in Figure 1 [1]. In this, light beams of two different colors are sent into the diesel oil and the transmitted light from oil is censored by a silicon photo detector. The signal from the detector is then amplified and sent to a division unit. The output from the division unit is a voltage. It is also possible to determine the presence of color by using the principle of reflection except that the reflection principle needs higher light intensity for same sensitivity [2].

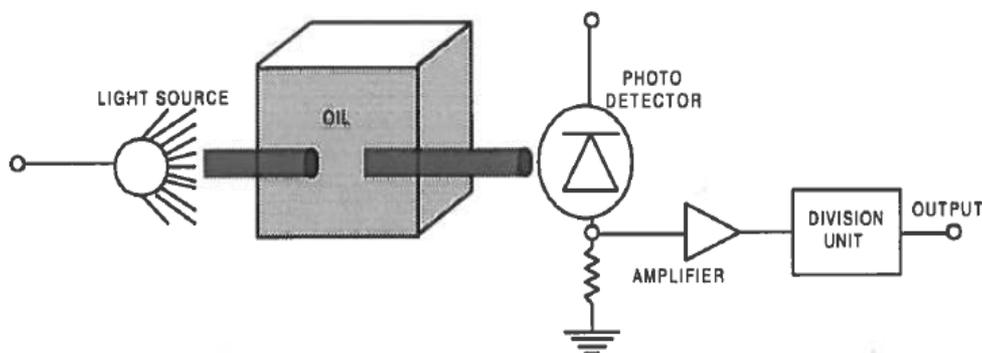


Figure 1: The Principle of Color Detection of Diesel Oil

2.1. Absorbance

The quantity expressing the absorption of radiation by a solution at a specified wavelength is given by Beer's law as shown in Equation (1),

$$A = \ln \left(\frac{1}{T} \right) = -\ln (T) = \epsilon lc \quad (1)$$

where the absorbance (A) is natural logarithmic inverse of transmittance (T) and linearly related to the path length (l), concentration (c) and absorptivity (ϵ) of the solution.

2.2. Spectrometric Analysis of Diesel Oil

The UV-spectrometer experiment was performed at the Department of Chemistry, University of Bergen by initially measuring the absorbance of pure diesel oil. The sample of pure diesel oil was taken in a clean dry cell and kept in sample holder of the spectrometer. We used air as reference medium. The absorbance (A) defined by Equation (1) is recorded directly by all modern double-beam instruments [3].

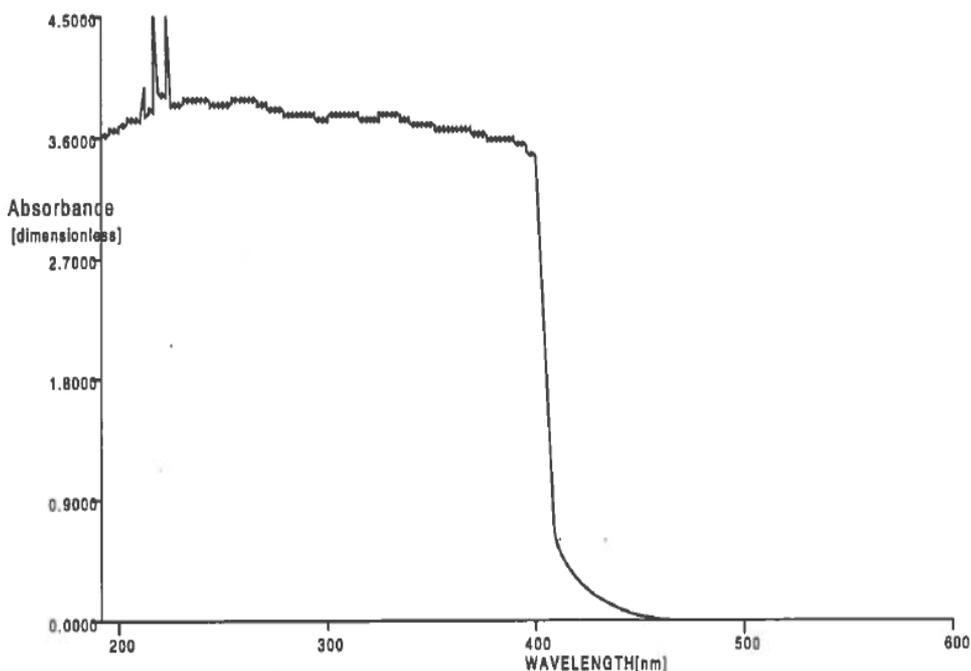


Figure 2: The Spectrum of Pure Diesel Oil

As it can be observed from Figure 2, the spectrum of pure diesel oil with air as reference has strong absorption in ultraviolet region (from 400nm and lower) and very little absorption in visible region (400nm-800nm) [4].

Next step was to find a similar spectrum of red diesel oil with reference air. For that purpose, we replaced the sample of pure diesel with a sample of red diesel in clean cell.

As Figure 3 illustrates, the spectrum of red diesel oil with reference air has higher absorption in both ultraviolet and visible region compared to pure diesel oil.

Finally, we tested the absorption spectrum of red diesel oil compared to pure diesel oil. It was done by placing a second "reference" cell containing pure diesel oil in the reference holder and a cell containing red diesel in the sample holder of the spectrometer [5]. The purpose of this reference cell with pure diesel in it is to compensate for the absorption of

the sample cell with red diesel. The resulting spectrum of red diesel is an absorption spectrum of red diesel subtracted from the absorption of pure diesel.

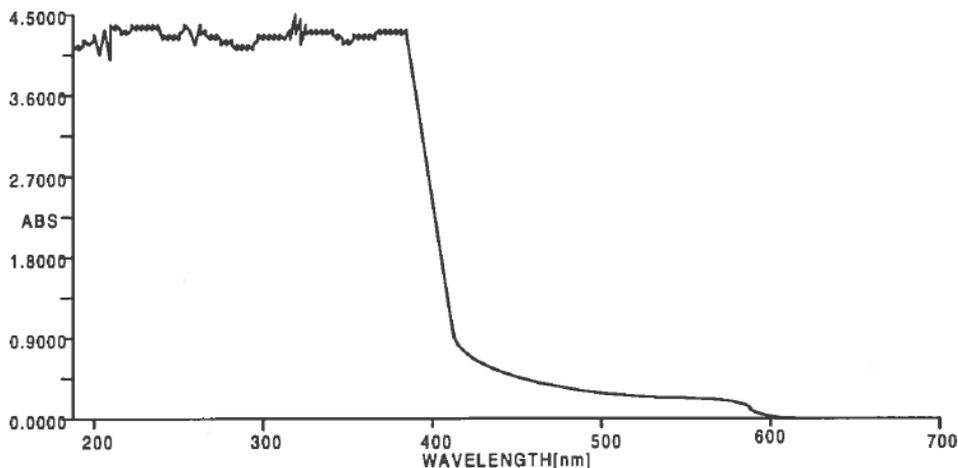


Figure 3: The Spectrum of Red Diesel Oil

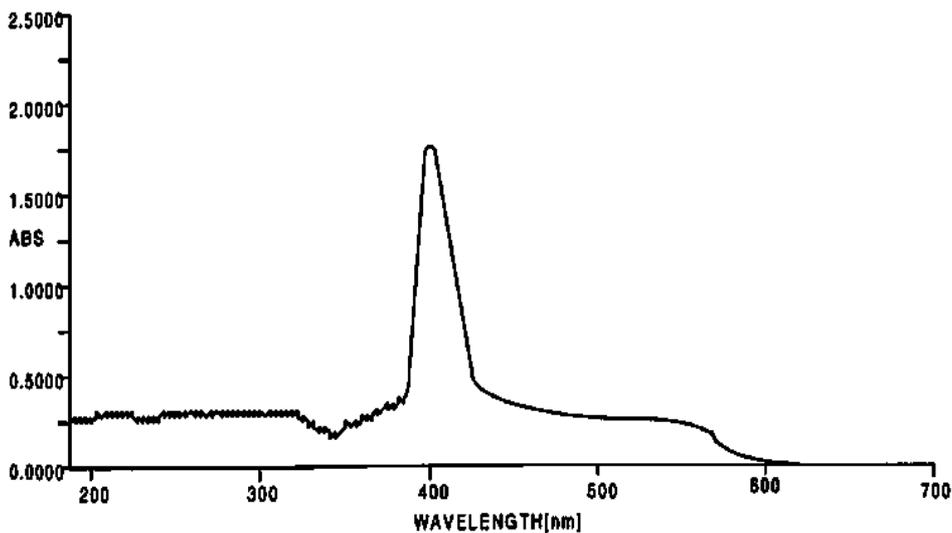


Figure 4: The Spectrum of Red Diesel with Reference to Pure Diesel Oil

Figure 4 shows that the relative absorption of red diesel is very high around the wavelength of 400nm (violet). Since the red diesel has its peak absorption on 400nm, we came to the conclusion that one of the lights which we can send through the oil for its color detection must be a light source with wavelength around 400nm and the second one is a source with wavelength at about 600nm.

3. SETUP AND RESULTS

3.1. Construction of Instrument

According to the spectrometric analysis of diesel oil and the results discussed in the theory section, we found that, at the time, the lack of small, rugged violet light source with wavelength around 400nm was a great problem, and complicated the setup of the experiment. The setup was further divided into two main parts; Optical part and Electrical part.

3.1.1. Optical Part

The first construction step in optics was so construct a light source that could send violet (about 400nm) and red (about 600nm) lights alternately through the measurement cell. As shown in figure 5, an incandescent lamp and two optical spectral filters passing wavelengths 405nm and 616nm. The optical filters with wavelength 405nm and 616nm are placed on a black metal disk with two square holes. Then the metal disk with filters was fixed to the output shaft of a gearbox mounted on an AC motor. The gear shaft rotated at 120 RPM and the motor was supplied with 6V [6].

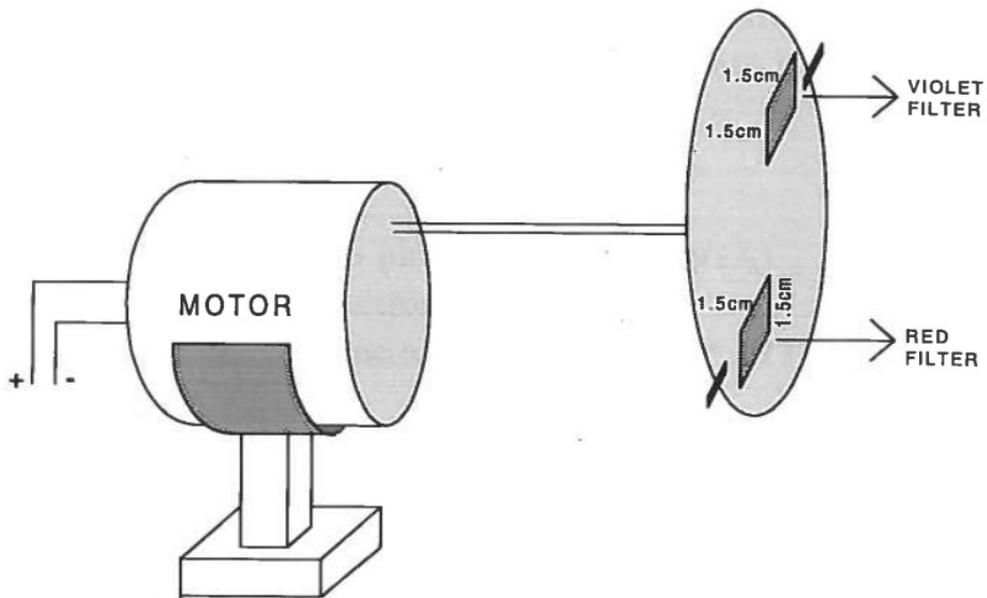


Figure 5: Schematic of the optical part

We would thus get an alternative sending of violet and red light to the diesel oil two times per second. Two metal vanes are attached to the metal disk from the center of the filters. When these metal vanes pass through the gap between the sensor and the magnet on the Hall Effect switch, it gives information to our electronic circuit about which light was sent through the sensor head at that moment [7].

3.1.2 Electronic Part

The electrical schematic is shown in the Figure 6. A notation for the symbols are given in table 1:

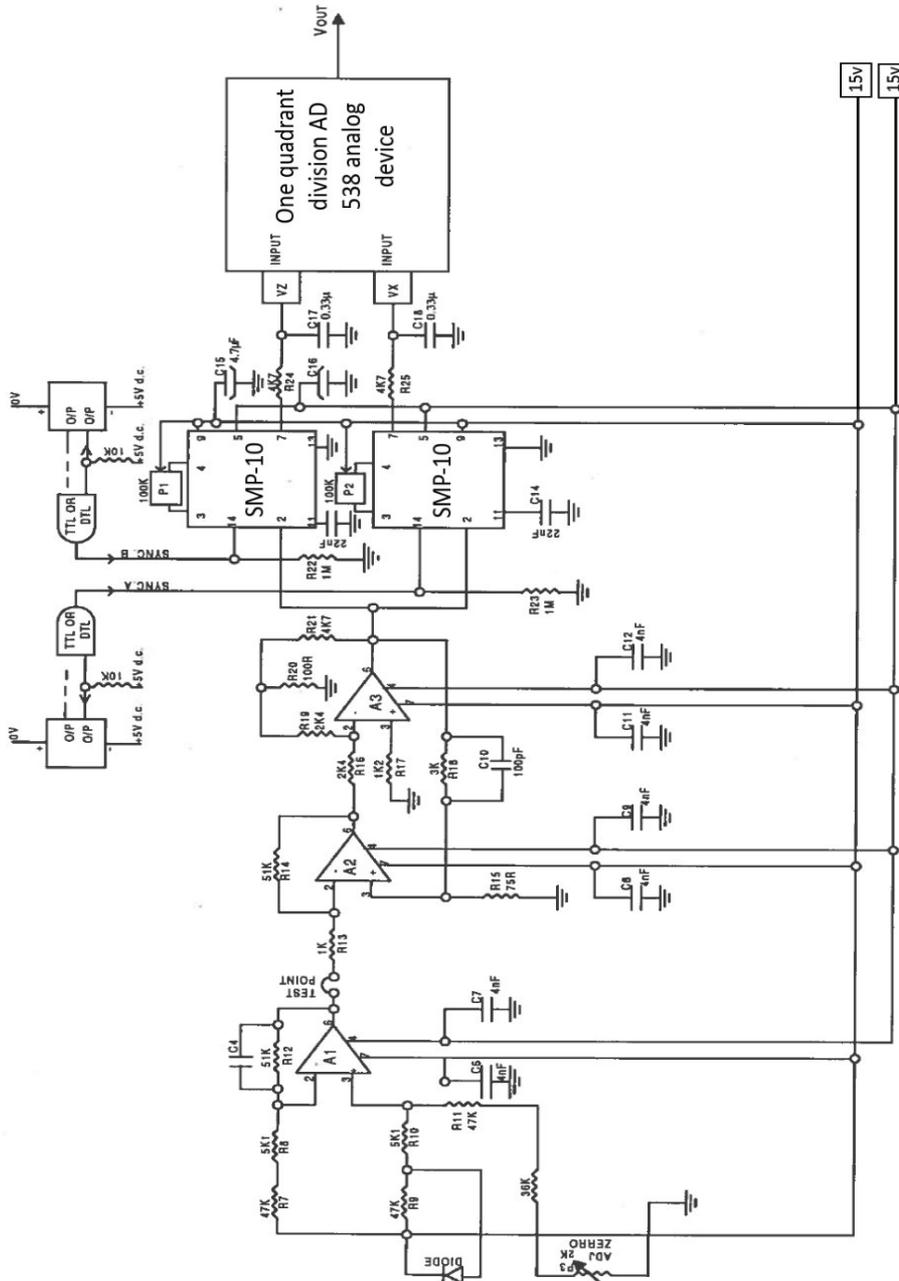


Figure 6: Schematic of the electronic part

Table 1: Description of notation used in Electronic circuit [8]

Components	Symbols
One silicon photodiode[AE-9891A]	D
Three potentiometers	P1, P2, P3
Three operational amplifiers[OP-177]	A1, A2, A3
Two Sample and Hold devices	SMP-10
One Analog Device	AD538
Resistances	R
Capacitors	C

3.2. Experimental Setup

The complete experimental setup used for this work is illustrated in Figure 7. It contains both the optical and the electronic parts as mentioned earlier [9].

The tests were further conducted in a room with as little light as possible as light rays other than those from our main light source could affect our final results [10]. The main light source itself had to be adjusted to get a parallel beam of rays or else the intensity of light that reaches the optical filters would be very low.

Rays from the main light source must be focused to a point on the optical filters and the rays transmitted from these filters must be focused to get enough intensity of light through the optical fibers which send alternate lights to the measurement cell. For this purpose, we used two optical lenses with focal length 25mm and 20mm. A lens with focal length 25mm was fixed between the main light source and the optical filters. The second one with focal length 20mm was placed in a round metal tube. Inside that tube, we had a metal ring, which was able to rotate, so that we could adjust the position of the lens between the fiber and the filter [11, 12].

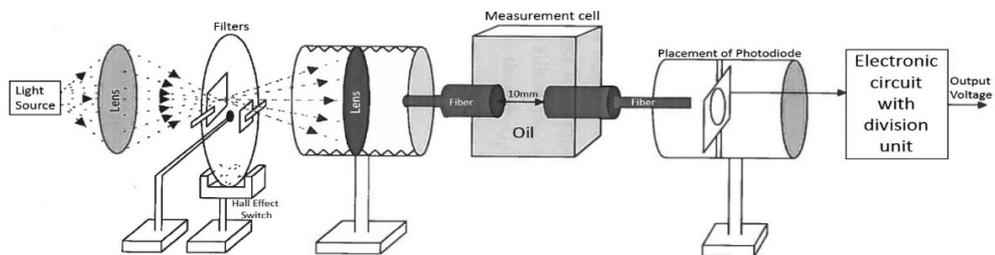


Figure 7: Experimental setup of the proposed instrument for the detection of red dye in diesel oil

4. RESULTS

The intensity of light, which was transmitted through the different media, was detected by the silicon photodiode. The output voltages are found by two different methods:

By calculation: Divide the measured voltages (Table 1) from the two Sample and Hold devices by using the Equation (2),

$$\text{The output voltage, } V_o = 10 \cdot \frac{V_{vio}}{V_{red}} \quad (2)$$

where V_{vio} is voltage when violet light passes through the medium and V_{red} is the voltage when red light passes through the medium.

By measuring the minimum and maximum output voltages from the division unit using digital multimeter (Table 2) and their mean values was taken as the mean output voltage.

Figure 8 is a graph showing the measured output voltages, V , as a function of different concentrations of red diesel oil.

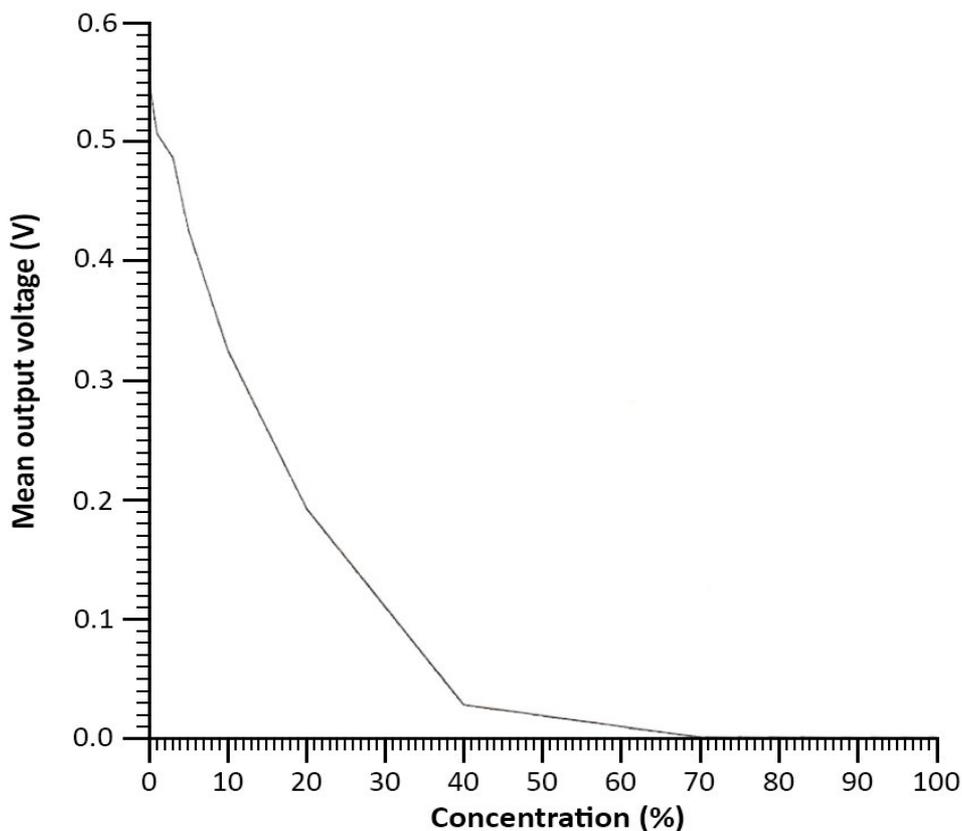


Figure 8: Mean Output Voltage as a Function of Concentration of Red Diesel

Accuracy of results depended on several key points, standards that we tried to meet. Cleaning the diesel oil tank was important as we had to use the same test tank to test the different samples of different concentrations of red diesel oil. It was necessary to clean the oil tank to avoid remainders of the previous sample from contaminating the present measurement. We cleaned out oil tank and the ends of the optical fibers protruding into the oil tank. We used Acetone to clean the diesel oil tank as Acetone does not react with the PVC in the tank walls.

However, it would be harmful to the ends of the optical fiber, so we removed the fibers from the tank before cleaning the tank and cleaned then with dry cloths.

Variation in voltage could have led to errors. So we tried to keep the supply voltage at exactly $\pm 15V$. It was important to adjust the main supply voltage to the electronic circuit before starting our experiment. Components like the silicon photo diode, the sample and hold device and the division unit were very sensitive; they are easily destroyed by supply voltages exceeding their nominal values.

The relative errors of small concentrations of red diesel oil in diesel oil were also calculated. These errors were estimated to 0.05 for small concentrations used in our experiment. However, it is likely that the relative error would increase with decreasing concentrations [13].

Table 2: Output Voltage measurement of the Proposed Instrument for the Detection of Red Dye in Diesel Oil: Voltage after SMP 10 and Calculated Voltage.

Medium	Red	Violet	Calculated Voltage (V_0)
Air	10.81	0.83	0.7678
Pure Diesel	10.81	0.58	0.5365
1% Red Diesel	10.81	0.55	0.5088
3% Red Diesel	10.83	0.52	0.480
5% Red Diesel	10.82	0.47	0.434
10% Red Diesel	10.82	0.35	0.3235
20% Red Diesel	10.79	0.21	0.1946
40% Red Diesel	10.80	0.033	0.0305
70% Red Diesel	10.80	0.0019	0.0018
100% Red Diesel	10.81	0.00122	0.0011

Table 3: Output Voltage measurement of the Proposed Instrument for the Detection of Red Dye in Diesel Oil: Output after Division V plotted in Figure 8.

Medium	Min	Max	Measured Voltage (V)
Air	0.759	0.795	0.777
Pure Diesel	0.537	0.564	0.551
1% Red Diesel	0.498	0.516	0.507
3% Red Diesel	0.476	0.499	0.487
5% Red Diesel	0.418	0.433	0.426
10% Red Diesel	0.313	0.337	0.325
20% Red Diesel	0.185	0.2010	0.193
40% Red Diesel	0.025	0.032	0.029
70% Red Diesel	0.0017	0.0018	0.0018
100% Red Diesel	0.0012	0.0012	0.0012

4. CONCLUSION

Although we were not able to develop a prototype instrument for field use at the time, we were able to put the proposed model to test. The experiment results showed that the proposed instrument could detect the presence of red dye in diesel oil, and it seemed like it was more sensitive to very low concentrations of red dye than to higher concentrations. Even concentrations as low as 1% of red diesel oil in diesel oil could be detected by our system according to our calculations.

If all possible errors are taken into account, the conclusion that can be drawn from this work is that the proposed instrument can be used to detect the presence of red dye in the diesel oil in the concentrations of interest for controlling illegal use in ordinary motor vehicles.

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