Research Article

An Innovative Approach for Determination of Fuel Type Using Gasoline and Diesel Vapor - SNIFFEX

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Abstract

It is known that the methods that have been used for many years to prevent large amounts of vehicle equipment consumption and environmental damage caused by incorrect fuel fillings (cross-fillings) do not work accurately.
In order to further minimize the damages incurred, it is aimed to develop a sensor device with a multi-disciplinary structure covering chemistry, physics and electronic methods.

Keywords: *Fuel type, membrane, sensor*

1. Introduction

Cross-fillings in the fuel distribution sector cause great losses on the subjects of time, effort, money for citizens and countries. In addition to damaging many components of the vehicles, re-using or separating the mixture formed as a result of cross-filling is impossible, and the damage caused to the environment during the disposal of this mixture is also great.

Cross-filling of vehicles and underground storage tanks causes loss of time, effort and money. There are several methods developed and used for years to prevent these losses. However, 100% accuracy could be achieved with none of these methods.

Especially in countries where self-service fuel filling is common, the consequences of such cross-filling are much more severe.

In order to prevent these pecuniary losses (more than 3 Billion USD/year all over the world), it is aimed to develop a solution that can work with 100% accuracy.

2. Materials and Methods

Within the scope of this project; a multidisciplinary structure consisting of chemistry, physics and electronics was used.

The main method used in the development of this sensor device, which is planned to be used by attaching it to the nozzle in the dispenser, is based on analyzing the fuel vapor using a synthesized membrane, electronic sensors and an electronic circuit. As a result of analyzing the hydrocarbons in fuel vapor, it is aimed to determine the fuel type in the target location.

Precast polyethersulfone (PES) membrane (0.45μm) and polyvinyl alcohol (Aldrich, 31,000-50,000, 99% hydrolyzed) were used as the polymeric precursors for membrane synthesis. Sepiolite (Eskişehir) and silica were used as filler materials. Glutaraldehyde (GA, Merck, 50% wt) was utilized as the crosslinker. Analytical grade ethanol, acetone, dimethyl sulfoxide, sulphuric acid and acetic acid (Merck) were used as solvents or reaction media when necessary.

2.1. Membrane Synthesis

Sepiolite (SEP) was ground in a mortar and washed successively in hot water to remove soluble impurities. Acid treatment was applied using concentrated H_2SO_4 solution to enhance surface area and porosity. Polyvinyl alcohol solution (10% w.) was doped with acid treated and dried SEP particles at various ratios (0.5-5% w.). SEP-PVA solution was either casted by film applicator or coated using a spin coater on PES membrane to produce double layer composite membranes of varying thickness (135-250 μm). Dried membranes were cut in 1 cm diameter and stored in a desiccator until use.

2.2. Membrane Testing

An experimental setup as shown in Figure 1 was used for testing gas diffusion through the synthesized membranes.

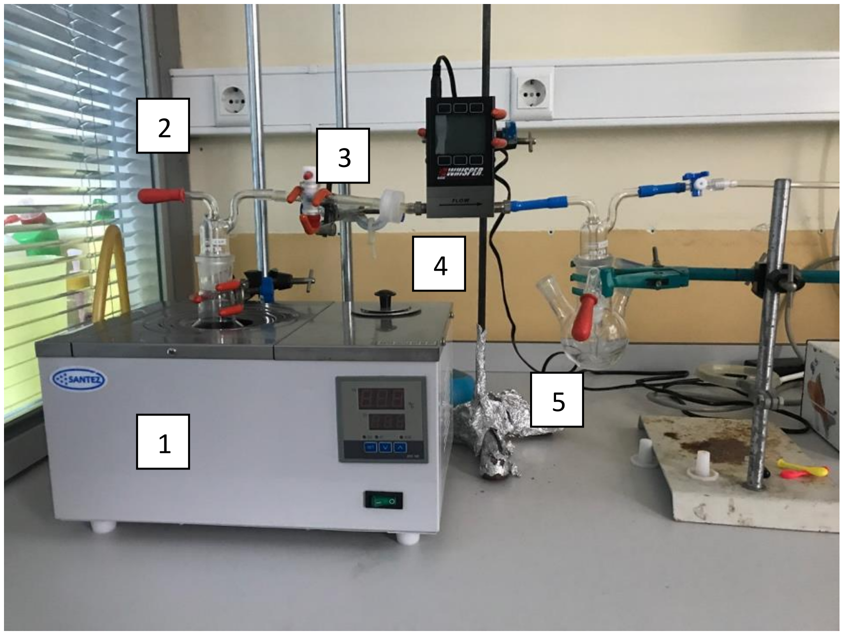

Figure 1: The experimental setup for measuring the flow of gasoline or diesel vapors from the membranes. 1) Heater; 2) Storage tank for gasoline or diesel; 3) Membrane holder; 4) Flowmeter; 5) Vapor tank; 6) Computer (not shown).

In a typical experiment, 50 mL gasoline or diesel was transferred to the storage tank. Vaporization was achieved in the heating bath which was maintained at a predetermined constant temperature. Gate valves were opened and the gas flow through the membrane was measured by the flowmeter. The integrated computer system recorded the instantaneous and cumulative gas flow through the membrane. Each test was continued for three to five minutes. At the end of the period, the oil tank was refilled, and the membrane was replaced with a fresh one. The mean results of five experiments for each type of membrane were reported.

2.3. Sensors

Two Combustible Gas Sensors were used to detect whether the fuel vapor belonged to gasoline or diesel. Basic Measurement Circuit for this Sensor and the Sensitivity Characteristic of Sensor are shown in Figure 2 and Figure 3 respectively.

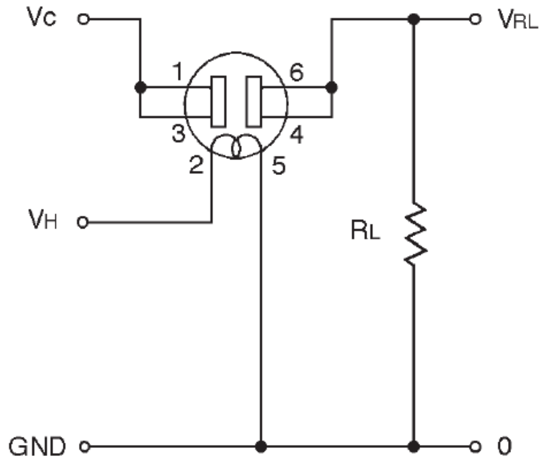

Figure 2: *Basic Measurement Circuit*

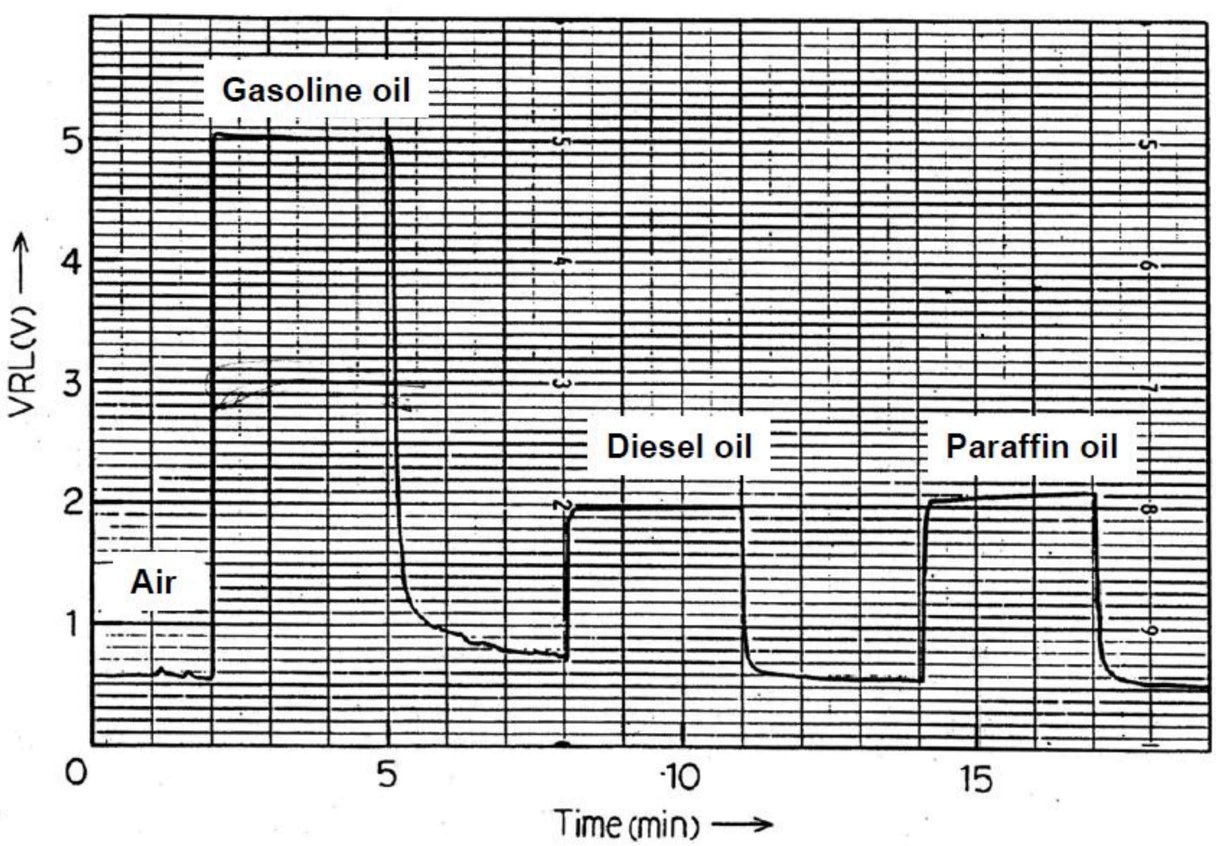

Figure 3: *Sensitivity Characteristic of Sensor*

As can be seen from Figure 3, the sensor's speed of detecting the fuel type is quite low and it was evaluated as convenient and used within the scope of this project.

These sensors were placed in chambers that are separated by membrane. The first chamber is the one at the entrance of Sensor Device and where all the vapors enters into. The second chamber was positioned on the other side of membrane. Sensor-1 and Sensor-2 were placed into Chamber-1 and Chamber-2 respectively.

2.4. Electronic Control Unit (ECU)

A new ECU was designed to detect fuel type of vapor and communicate with other systems. The block diagram of ECU is shown in Figure 4.

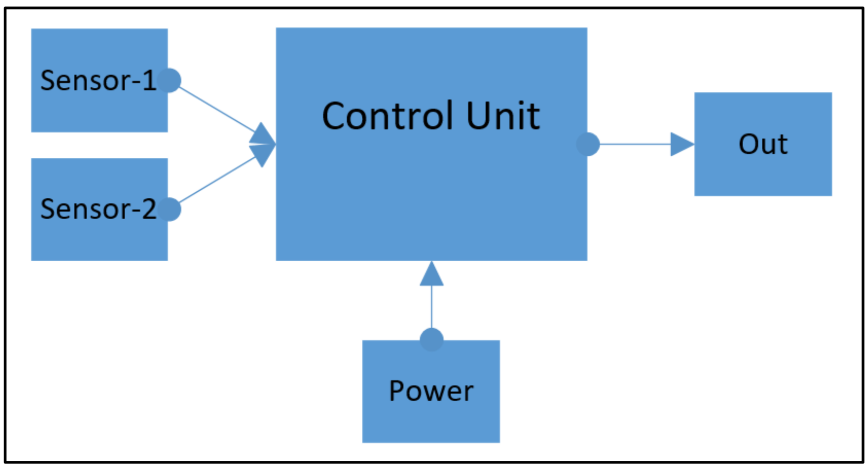

Figure 4: *Block Diagram of Electronic Control Unit (ECU)*

This ECU consists of two Sensors, Control Unit, Power and Out.

Th datas retrieved from two sensors are processed by Control Unit and then compared to each other's value. After comparision, there are two options:

1. If the Sensor-1 and the Sensor-2 indicates gasoline, the vapor entered into Sensor Device is absolutely GASOLINE.

2. If the Sensor-1 indicates diesel and the Sensor-2 indicates gasoline or none, the vapor entered into Sensor Device is absolutely DIESEL.

There are no other options because the membrane was designed so that diesel hydrocarbons cannot pass to the other side of the membrane.

This output can be transferred to the other systems that were integrated to SNIFFEX as wired or wirelesss.

2.5. Pipe & Fan

Once the fuel nozzle entered the vehicle tank, a thin pipe and a fan had to be used to transfer the fuel vapor coming out of the vehicle tank to the sensor device. The used Pipe on Nozzle is shown in Figure 5.

A fan - with the airflow direction inwards - placed at the inlet of the sensor device, was operated and fuel vapor was allowed to enter with the help of the thin pipe. This vapor taken into the Sensor Device is analyzed by the ECU and the result is obtained.

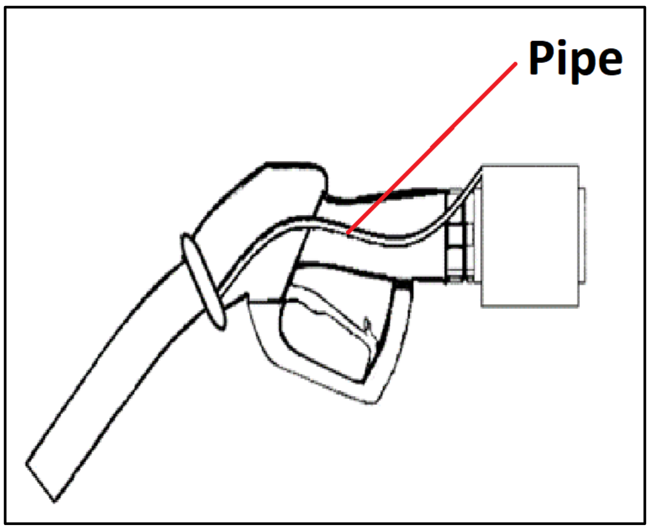

Figure 5: *Pipe on Nozzle*

2.6. Sensor device

By using Membrane, Sensors, ECU, Pipe & Fan, a Sensor Device (SD) is developed.

The SD device, which allows fuel vapor to be taken in with the help of a thin pipe and fan, to analyze this vapor, to decide on the fuel type, and to transfer the resulting output to external environments as wired/wireless, is mounted on the nozzle in a compact structure.

The battery-powered SD has been developed as a device that can detect fuel type only with the gaseous form of the fuel, without the need for the liquid form of the fuel.

3. Results

A number of membranes with different chemical compositions and physical properties were synthesized and tested for selective permeation of diesel and gasoline vapors. Accordingly, composite membranes of PES, PVA and acidified SEP allowed the controlled permeation of gasoline and diesel vapors. The composition, thickness and the cross-linking degree affected the gas flow through the membrane significantly.
Figure 6 shows the difference between the measured flow rates of gasoline and diesel vapors through the optimized composite membrane, clearly.

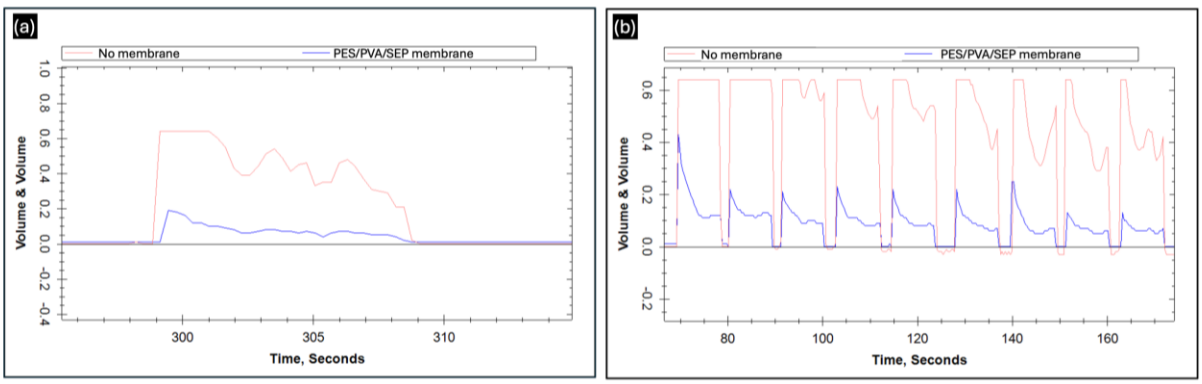

Figure 6: *The flow of (a) diesel and (b) gasoline vapors from the membranes.*

The known studies carried out so far to determine the fuel type use the liquid form of the fuel and the type determination time is very long. Within the scope of this project, an SD was developed that detects the type of fuel by using only its vapor in a short time.

The outputs of each sensor (Sensor-1 & Sensor-2) are shown in below figures. The RED lines indicates the output for Sensor-1 and the BLUE lines indicates the output for Sensor-2.

The sensor outputs for DIESEL are shown in Figure 7. The differences between Sensor-1 and Sensor-2 (Chamber-1 and Chamber-2) indicates that this vapor belongs to DIESEL because diesel hydrocarbon molecules can't (or minimum) pass from membrane to second chamber.

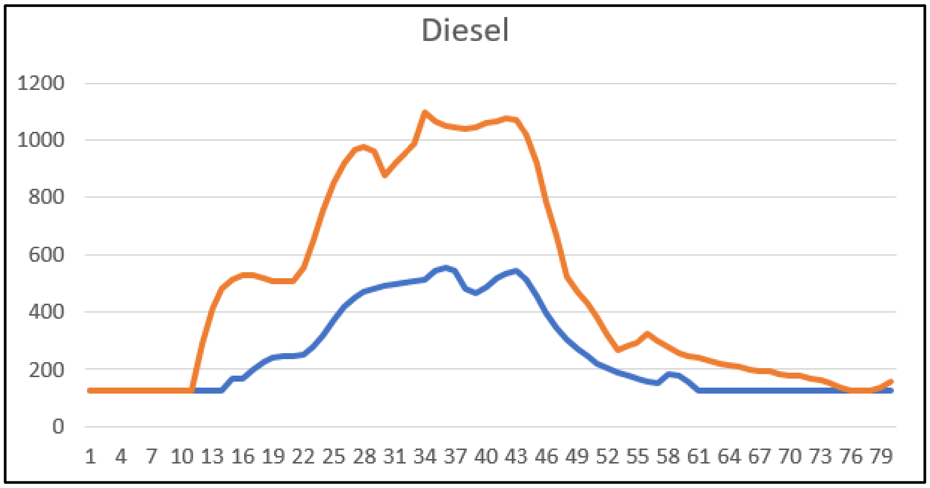

Figure 7: *Diesel Detection*

Example values of Sensor-1 and Sensor-2 for DIESEL vapor are shown in Table 1.

Table 1: *Reading values of Sensor-1 and Sensor-2 for DIESEL vapor*

DIESEL					
READING #	SENSOR-1 (ppm)	SENSOR-2 (ppm)	READING #	SENSOR-1 (ppm)	SENSOR-2 (ppm)
1	216	125	49	1133	496
2	214	125	50	1131	498
3	211	125	51	1098	497
4	208	125	52	1010	488
5	201	125	53	905	474
6	189	125	54	774	454
7	188	125	55	680	427
8	194	125	56	679	393
9	248	125	57	600	356
10	409	125	58	536	342
11	703	154	59	492	310
12	872	231	60	458	265
13	962	318	61	435	201
14	1004	314	62	416	176
15	1023	356	63	400	172
16	1021	394	64	385	168
17	1005	419	65	370	166

18	1008	430	66	358	163
19	1016	439	67	349	162
20	1027	448	68	340	157
21	1029	451	69	332	154
22	1032	451	70	326	151
23	1035	450	71	316	150
24	1032	450	72	309	146
25	1029	447	73	299	142
26	1020	445	74	285	139
27	1008	443	75	263	138
28	981	439	76	224	135
29	914	433	77	231	133
30	897	428	78	245	130
31	887	424	79	273	128
32	906	423	80	262	126
33	977	425	81	254	136
34	989	446	82	247	138
35	1005	457	83	241	136
36	1023	457	84	236	125
37	1037	440	85	230	125
38	1057	435	86	228	125
39	1070	442	87	225	125
40	1079	449	88	222	125
41	1086	457	89	220	125
42	1100	464	90	218	125
43	1106	470	91	217	125
44	1111	475	92	215	125
45	1117	480	93	214	125
46	1121	485	94	211	125
47	1127	489	95	209	125
48	1130	493	96	204	125

The sensor outputs for GASOLINE are shown in Figure 8. The differences between Sensor-1 and Sensor-2 (Chamber-1 and Chamber-2) indicates that this vapor belongs to GASOLINE because gasoline hydrocarbon molecules can easily pass from membrane to second chamber.

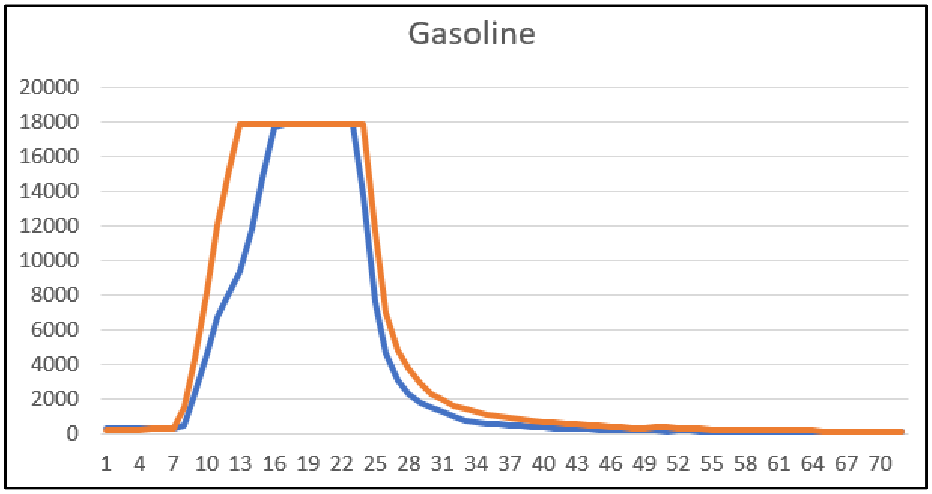

Figure 8: *Gasoline Detection*

Example values of Sensor-1 and Sensor-2 for GASOLINE vapor are shown in Table 2.

Table 2: *Reading values of Sensor-1 and Sensor-2 for GASOLINE vapor*

GASOLINE					
READING #	SENSOR-1 (ppm)	SENSOR-2 (ppm)	READING #	SENSOR-1 (ppm)	SENSOR-2 (ppm)
1	125	138	49	193	476
2	125	138	50	192	462
3	125	138	51	194	446
4	125	138	52	195	433
5	125	138	53	193	422
6	125	138	54	189	410
7	125	276	55	187	401
8	205	2078	56	181	390
9	1840	6367	57	176	381
10	5763	14599	58	172	369
11	12578	17898	59	168	357
12	17898	17898	60	164	348
13	17898	17898	61	159	332
14	17898	17898	62	155	311
15	17898	17898	63	152	267
16	17898	17898	64	148	275
17	17898	17898	65	144	290
18	14391	17898	66	142	321
19	7565	13536	67	138	304
20	4956	8576	68	150	290

21	3600	6395		69	152	282
22	2717	4927		70	148	275
23	2086	3915		71	129	268
24	1540	3193		72	125	259
25	1281	2681		73	125	254
26	1110	2306		74	125	252
27	979	2022		75	125	248
28	872	1804		76	125	247
29	787	1469		77	125	242
30	711	1344		78	125	240
31	645	1240		79	125	238
32	593	1150		80	125	235
33	548	1065		81	125	231
34	507	995		82	125	228
35	477	929		83	125	223
36	444	863		84	125	215
37	414	797		85	125	203
38	390	713		86	125	180
39	364	594		87	125	182
40	344	611		88	125	186
41	327	614		89	125	196
42	312	628		90	125	218
43	299	676		91	125	211
44	321	615		92	125	206
45	332	574		93	125	203
46	307	542		94	125	200
47	278	515		95	125	197
48	211	494		96	125	195

The average fuel type detection time was determined as 3,4 seconds as a result of 8.500 tests.

4. Discussion and Conclusion

In SD solution, as a result of approximately 8.500 tests, it was concluded that the success rate in fuel type determination was 100%.

From now on, studies should be carried out to extend the battery life of SD solution, to reduce the fuel type detection time, to extend the life of the membrane, to increase membrane's physical and chemical strengths, to reduce the size of the SD device.

5. Acknowledge

In the scope of this paper, we would like to extend our gratitude to R&D Center of ASIS Automation and Fueling System Inc., and Chemical Engineering Department, Marmara University for their contributions to the research.