Requirement specification

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Status

Reviewed	Karl Asklund	2023-09-15
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DOCUMENT HISTORY

Version	Date	Changes made	Sign	Reviewer
0.1	2023-09-12	First draft.	Martin Ling	Karl Asklund
1.0	2023-09-15	Final revision for BP2	Martin Ling	Karl Asklund
1.1	2023-09-27	Updated revision after BP2	Martin Ling	Jonna Jämte

1 INTRODUCTION

A ventilation system for evaporated fuel has two main functions. One is to ensure that the fuel tank does not have a vacuum nor is over-pressurized thus damaging the tank. The second function is to capture and recirculate the hydrocarbons (HC) via a charcoal canister, which improves fuel efficiency and prevents toxic gases from being released into the atmosphere. This is all managed by a control system with valves and hoses to reduce the vehicle's overall emissions.

1.1 Partners

List of all involved partners:

Partner	Name
Customer:	Aurobay, Fredrik Wemmert
Client:	Vehicular systems, Lars Eriksson
Client:	Vehicular systems, Oskar Lind Jonsson
Examiner:	Daniel Axehill
Project Group:	As stated earlier

Table 1: A table of all partners in this project

The project is done as part of the education at Linköpings University and the group consists of students at the Master's in Electrical Engineering.

1.2 Definitions

Charcoal canister: Contains active coal and its mission is to adsorb the hydrocarbon vapors so that it does not escape to the environment.

Stoichiometric combustion: Stoichiometric combustion refers to the ideal chemical reaction in which a fuel and an oxidizer (typically oxygen in the air) are mixed in precise proportions so that all the fuel is completely consumed with no excess remaining. In other words, it's the perfect balance of fuel and oxygen required for every fuel molecule to react fully with oxygen, resulting in complete combustion.

EVAP-system: Evaporative Emission Control System

1.3 Purpose and goals

The purpose of this project is to investigate the purging of a charcoal canister. This would improve the process and thus help the customer Aurobay to release a better product for their customers. Aurobay can thus stay at the forefront of market-leading technology, improving the customer's economy. The specific long-term goal is to examine and improve the purging process of the charcoal canister, which can enhance the overall emissions of the system it is installed on.

The short-term objectives for this project, therefore, are as follows in order to achieve the aforementioned long-term goals:

1. Design a regulator to control the purging cycle of the charcoal canister while maintaining flow requirements.
2. Commission laboratory equipment.
3. Model the hydrocarbon flow through the charcoal canister.
4. Regulate the EVAP flow for an arbitrary purging cycle.
5. If possible, demonstrate the EVAP system in the university's engine test cell.

1.4 Use

The goal for usage is that Aurobay can use the results from this project and implement these on their systems. Furthermore, this can then be utilized by Aurobays customers.

1.5 Background information

Due to its volatility, gasoline evaporates in the tanks of a vehicle. To prevent over-pressure in the tank and allow the evacuation of vapours during refuelling, these vapours must be vented. The hydrocarbon content in the vapours is hazardous to both health and the environment and cannot be released freely into the atmosphere. To prevent this, the EVAP system exists.

The vapors are directed to a charcoal canister where they are adsorbed. There is a limit to how many hydrocarbons the filter can adsorb before leakage occurs, so the filter must be periodically cleaned. This is done by directing a purge airflow from the surroundings through the filter and into the engine's intake manifold, where the hydrocarbons are then combusted.

To minimize emissions, the capacity of the charcoal canister should be kept large, i.e., minimizing the amount of adsorbed hydrocarbons in the canister. The purge airflow is driven by the pressure difference between the surroundings and the intake manifold, and depending on current pressure conditions, there is a limit to when the maximum purge airflow can be generated.

To meet the emission requirements, a gasoline engine has a three-way catalyst. For the three-way catalyst to function, there must be a stoichiometric combustion of gasoline in the engine. Therefore, it is important for the engine's control to correctly manage the air and fuel flow. The purge airflow through the charcoal canister will carry both ambient air and hydrocarbons, which must be accounted for in the air-fuel mixture the engine needs.

Currently, it is not possible to directly measure the exact hydrocarbon flow from the EVAP system, so it must be estimated. There is also a safety aspect in the control where the EVAP flow must not constitute too large a part of the total air and fuel flow.

2 SYSTEM OVERVIEW

The system is introduced in section 1, and figure 1 shows a simple model of the system.

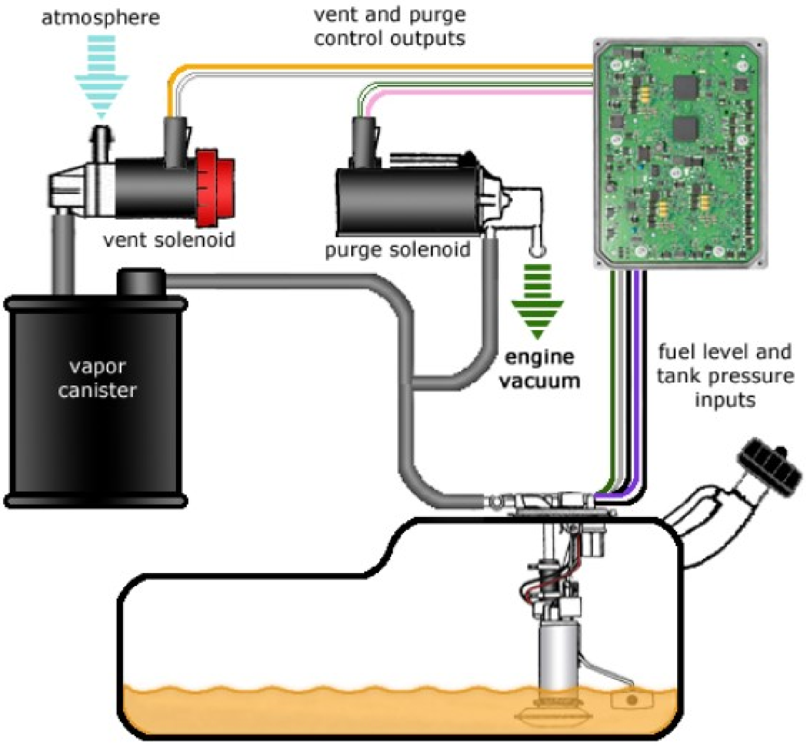

Figure 1: An overview of the system [1].

2.1 Description of the product

The charcoal canister is used to limit the emissions caused by the fuel evaporating in the fuel tank. This is done through adsorbing hydrocarbons in the activated charcoal inside the container.

The solution is aimed to improve upon the emptying of the canister by modifying the regulator controlling the purging event of the container. This is done by defining a different cleaning cycle which is based on a theoretical model of the system.

2.2 Product components

Hardware components and laboratory equipment:

- Test rig for charcoal canisters provided by Aurobay
- Charcoal canisters (EU-spec)
- Fume hood
- High-precision scale
- Mass flow regulator
- Engine test cell
- M5Stack KMeterISO
- Arduino Nano IoT
- Raspberry Pi 3B+
- Kistler 4264A-type pressure sensor
- Sensiron SFM3000-200 flow sensor

2.3 Dependency of other systems

The system model will be dependent on real-time measurement data from the test rig or simulated data to be able to perform after realistic conditions. The parameters which the model must take into consideration are as follows:

Requirement	Version	Description	Priority
1	1.0	Surrounding air temperature.	1
2	1.0	Demanded fuel amount from the engine.	1
3	1.0	Intake manifold pressure.	1

2.4 Included sub-systems

The system is divided into two sub-systems, the charcoal canister and the measurement system. These are further described below.

2.5 Limitations

This work will not do any experimentation of filling the charcoal canister, as the necessary equipment is lacking. Furthermore, the control of the intake manifold is outside of the scope, as for all components in the engine not in the EVAP system.

2.6 Design philosophy

The system provided by Aurobay will be used and further developed. The group will develop a system for collecting data from the setup, this will only use products available for consumers.

2.7 General requirements on the system

The regulator for the EVAP flow should work for an arbitrary cycle. The product should be user-friendly, easy to implement, and accessible without the need for a high-end computer.

3 SUB-SYSTEM 1 - CHARCOAL CANISTER

The charcoal canister shall be modelled as similar to the actual product as possible but without the need for too much computing power.

Figure 2: Subsystem 1

3.1 Introductory description of sub-system 1

The charcoal canister uses the active coal to bind the evaporating fuel emissions from the fuel tank. The bonded hydrocarbons from the fuel are then forced into the combustion chamber of the engine by air from the intake manifold. When this is done the canister is emptied, allowing it to absorb new hydrocarbon fumes from the fuel tank. Sub-system 1 will be the model of the canister and the filtering function of the canister.

3.2 Interfaces

The canister must be able to connect to the hoses and instruments already in the engine compartment, so this must be considered when implementing changes into the system. The size of the charcoal canister will not be altered during this project, new sensors may be added and thus the size of these must be taken into consideration.

Requirement	Version	Description	Priority
4	1.0	The canister should be able to connect to existing hoses.	1
5	1.0	The model can read data from the measurement system	1
6	1.0	The model can automatically input control signals to the control system	2

3.3 Design requirements

The design of the canister is not to be changed, and thus there are no requirements on the design of the canister.

Requirement	Version	Description	Priority
7	1.0	The design of the charcoal canister must not be altered.	1

3.4 Functional requirements

The programmed flow in and out of the canister should be measurable. The canister should have the capability to be emptied using the pressure generated by the intake manifold.

Requirement	Version	Description	Priority
8	1.0	The flow into and out from the canister should be measurable.	1
9	1.0	The canister should be able to be emptied using the pressure from the intake manifold.	1
10	1.0	The model accurately predicts the behavior of the charcoal canister.	1
11	1.0	The model should be able to run during an engine cycle.	3
12	1.0	The model can handle different engine parameters and specifications.	2

4 SUB-SYSTEM 2 - MEASUREMENT SYSTEM

The measurement system is used to collect data from the temperature sensors placed on the charcoal canister. This is done using an Arduino which sends the data to a Raspberry Pi 3B+ for logging.

4.1 External interfaces

The system will be controlled using a custom-made system where the user can input data to control the engine. At the first stage, there is no need for communication between the control system and the measurement system, this may be needed at a later stage but is not vital.

Requirement	Version	Description	Priority
13	1.0	The system should use standardized connections for the interface between sensors and microcontrollers.	2

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Requirement	Version	Description	Priority
14	1.0	Connections between sensors and controllers should not be permanent.	1
15	1.0	Both the Raspberry Pi and the Arduino must be able to communicate via Wi-Fi.	1

4.2 Design requirements

Requirement	Version	Description	Priority
16	1.0	All wires should be coloured in a way that is easy to understand and the wiring should be as simple as possible.	2

4.3 Functional requirements for subsystem 2

Requirement	Version	Description	Priority
17	1.0	The measurement software should be able to run during an engine cycle.	1
18	1.0	The measurement software should be able to save the data from the simulation on a file.	1
19	1.0	The measurement system should measure at least pressure, temperature, and flow.	1
20	1.0	Data from all sensors can be read in parallel	1

4.4 User interface

Requirement	Version	Description	Priority
21	1.0	The measurement system should be easy to use.	2
22	1.0	An easy-to-use interface to read the measured data.	3

Figure 3: Raspberry Pi [2].

5 PERFORMANCE REQUIREMENTS

Requirement	Version	Description	Priority
23	1.0	The purged air flow shall not exceed 1.5 g/s.	1
24	1.0	The hydrocarbon flow from the canister shall never exceed 30% of the total fuel flow to the engine.	1
25	1.0	The accuracy of the calculated hydrocarbon estimate shall be below 5% of the total fuel flow in one transient.	1
26	1.0	The accuracy of the calculated hydrocarbon estimate shall be no more than 1% of the total fuel flow at stationary driving conditions.	1

6 CONTINUED DEVELOPMENT REQUIREMENTS

Requirement	Version	Description	Priority
27	1.0	All code shall be well documented, follow the Google style guide [1] and be available to access through a GIT-repository.	1

1 https://google.github.io/styleguide/

7 RELIABILITY REQUIREMENTS

Requirement	Version	Description	Priority
28	1.0	All hardware shall be verified to work as intended before tests are conducted.	1
29	1.0	The results should be repeatable.	1

8 ECONOMY REQUIREMENTS

Requirement	Version	Description	Priority
30	1.0	Each member of the group shall use 240 hours of work towards the project. This shall summarize to 1440 man hours for the whole group.	1

9 SAFETY AND SECURITY REQUIREMENTS

Requirement	Version	Description	Priority
31	1.1	The group shall, in cooperation with the safety coordinator, design a risk analysis. The risk analysis shall also be approved by authorized LIU personnel.	1
32	1.0	Every group member shall read, sign, and follow safety protocols established by the safety coordinator before any tests are conducted.	1
33	1.0	All tests shall be conducted in safe environments and follow the safety protocol.	1
34	1.0	When conducting tests, there should always be at least two members of the group and one supervisor present.	1
35	1.0	No tests shall be conducted without the approval and guidance from the test-responsible group member.	1

10 TRAINING

Requirement	Version	Description	Priority
36	1.0	The solution should be simple enough to require minimal additional training, assuming someone is familiar with the system from before.	1

11 QUALITY REQUIREMENTS

Requirement	Version	Description	Priority
37	1.0	Each group member shall use the budget for the project as efficiently and productively as possible with the aim of fulfilling the requirements with great satisfaction.	1

12 MAINTAINABILITY REQUIREMENTS

Requirement	Version	Description	Priority
38	1.0	A well-organized GIT-repository with reasonable branches.	1
39	1.0	Error messages must be in English.	1

13 DOCUMENTATION OCH DELIVERY REQUIREMENTS

Table table 18 lists all documents that shall be produced in the project. The following abbreviations are used:

- PG - Project Group
- S - Supervisors
- C - Customer
- P - General public

Table 18: Documents to be produced.

Document	Language	Aim	Target	Format
Project plan	English	Structure the planning of the project.	PG, S	PDF
Requirement specification	English	Define a common ground for goals and requirements.	PG, S, C	PDF
Design specification	English	Define how the finished solution should look and work.	PG, S	PDF
Test plan	English	Conduct safe tests.	PG, S	PDF
Protocol of tests	English	Conduct repeatable tests and record results.	PG	PDF
User manual	English	Allow others to try the solutions.	C	PDF
Technical report	English	Allow others to repeat the work with similar results.	C, S	PDF
Report of final reflections	English	Reflect on the results of the project.	S	PDF
Poster	English	In a quick and simple way present the project and result.	C, P	Printed poster
Webpage	English	Present the project and the results.	C, P	Website
Presentation of project	English	Present the project and the results for other groups in the course.	S, P	Oral presentation
Demo-video	English	Attract interest for the project.	CC, P	Video
Status report	Swedish	Follow up the work.	S	Email
Time report	Swedish	Follow up the work.	S	Excel

Requirement	Version	Description	Priority
40	1.0	A specification of requirements will be delivered electronically at BP2.	1
41	1.0	A project plan including a time plan will be delivered electronically at BP2.	1
42	1.0	A presentation of the project will be delivered verbally at BP2.	1
43	1.0	A initial version of the design specification will be delivered electronically at BP2.	1
44	1.0	A final version of the design specification will be delivered electronically at BP3.	1
45	1.0	A plan for tests will be delivered electronically at BP3.	1
46	1.0	All functionality of the system will be done at BP5.	1
47	1.0	A protocol of tests will be delivered electronically at BP5.	1
48	1.0	A user manual will be delivered electronically at BP5.	1
49	1.0	A presentation verifying the requirements leading up to BP5 have been met will be delivered verbally at BP5.	1
50	1.0	A technical report will be delivered electronically at BP6.	1
51	1.0	A report on final reflections will be delivered electronically at BP6.	1
52	1.0	A poster summarizing and presenting the project will be delivered electronically at BP6.	1
53	1.0	A video presenting the project will be delivered electronically at BP6, as well as uploaded to YouTube.	1
54	1.0	Weekly reports of the status of the project will be delivered electronically each Friday during the project.	1
55	1.0	A time report for each group member and the group summarized will be delivered electronically each Friday during the project.	1
56	1.0	Any issues during the project will be documented and reported.	1

14 PROFESSIONAL SECRECY REQUIREMENTS

Requirement	Version	Description	Priority
57	2.0	~~Each member of the group shall sign an agreement of professional secrecy.~~	~~1~~
58	1.0	No models, model libraries, or communication interfaces for controlling the engine shall be shared with sources outside of the scope of the project.	1
59	2.0	~~A confidentiality agreement shall be signed by each group member regarding visits and data usage from the industry.~~	~~1~~

REFERENCES

[1] “AGCO Automotive Repair Service - Baton Rouge, LA - Detailed Auto Topics - How Vacuum EVAP Systems Work.” [Online]. Available: https://www.agcoauto.com/content/news/p2_articleid/294

[2] G. H. f. B. UK, “Raspberry Pi 3 B+ single-board computer, supplied as a press sample by the Raspberry Pi Foundation.” Mar. 2018. [Online]. Available: https://commons.wikimedia.org/wiki/File:Raspberry_Pi_3_B%2B_%2826931247748%29.png