CNH INDUSTRIAL	**TESTING REPORT** R U / 0 8 1 / 1 9 CONFIDENTIAL (Y/N):	IVECO Issue date: 25/07/19 Pag. 1 / 6 Encl.

Project / Activity: Future LNG tank		**Customer:**	**Cost Center / WBS:** P0-19036-47T4-DE-PRV-001
Test Type: Basic function test		**Ref. Standard(s) / Edition:**	**Execution Lab.:**
Test Scope:	Pre-test: **x** Release (Y/N): Homologation: Other (specify):		**Work period:** From: 23/04/19 To: 19/07/19
Test sample description (Detailed):	Chart LNG-tank with an electronic pressure control		**Serial number(s):** - Prototype

To avoid problems caused by the use of economizers controlling the pressure of LNG-tanks, a LNG-tank with an electronic pressure control was successfully tested.

Two electronic valves controlled by a Datalogger GL2000, which gets information about the pressure in the LNG-tank from a pressure sensor, regulate the pressure of the tank.
If the engine is running on vapor or on liquid depends on the voltage of the pressure sensor, which correspondents to the pressure of the tank, transmitted to the Datalogger.

Different driving situations have been successfully tested on the test track.

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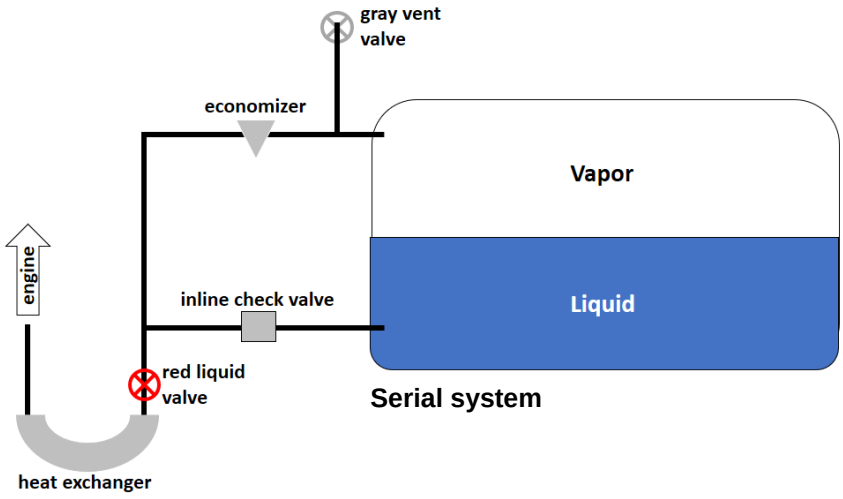
1 Target

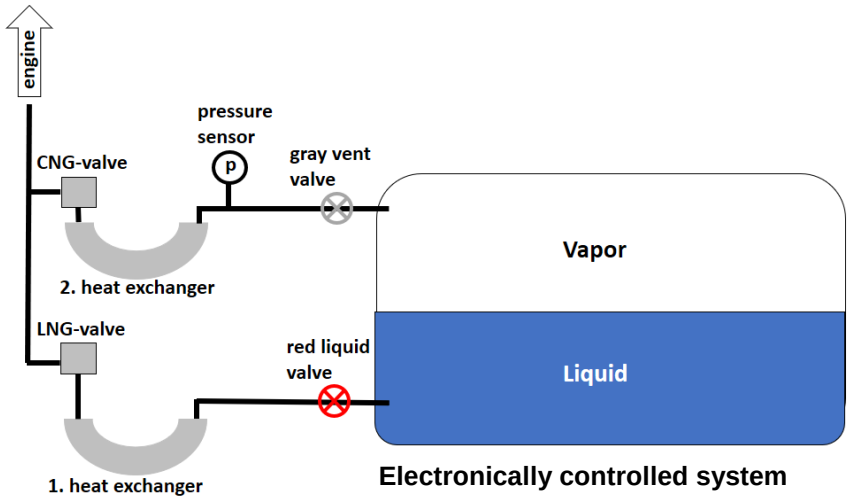
In the past there have been several problems with the economizer being responsible for the pressure control of the LNG-tank.
The goal was to build up a LNG-tank with an electronic pressure control instead of an economizer.

2 Mechanical implementation

In the serial system the pressure of the tank is controlled by the economizer and the inline check valve.
An electrically controlled valve, a second heat exchanger and a pressure sensor have been added to the serial tank.
The two electrically controlled valves (CNG valve + LNG valve) are replacing the economizer and the inline check valve. One electrically controlled valve is still serial as shutoff valve.
The second heat exchanger is necessary because the electronically controlled valves are not protected against freezing and it is not possible to install them between the tank and only one heat exchanger like the economizer and the inline check valve in the serial system. In a serial version a heat exchanger with two pipes could be used.
The gray vent valve is now connected with the second heat exchanger so if the engine is running on vapor and the CNG valve is opened, the vapor will take its way through the gray vent valve then through the second heat exchanger and after that through the CNG valve to the engine.
The red liquid valve is still connected to the first (regular) heat exchanger so if the engine is running on liquid and the LNG valve is opened, the liquid will go through the red liquid valve, pass the first heat exchanger and then go through the LNG valve to the engine. The pressure sensor has been installed on the vapor pipe between the gray vent valve and the second heat exchanger.



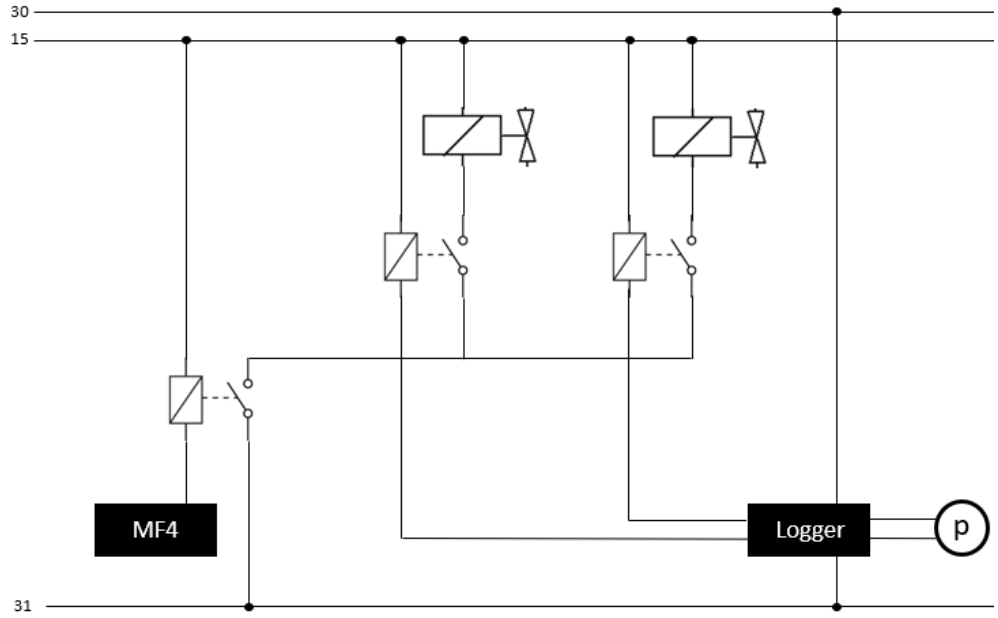
Serial system



Electronically controlled system

3 Programming

A datalogger GL2000 controls with two relays the CNG valve and the LNG valve depending on the voltage transmitted by the pressure sensor. The voltage correspondents to the in tank pressure. For safety reasons a relay activated by the MF4 has been added to ensure the CNG valve and the LNG valve just open up while the engine is running.



If the pressure is rising, at the moment the voltage of the pressure sensor reaches 3082mV (1051kPa) the CNG valve will open up. The LNG valve stays open until the voltage reaches 3107mV (1061kPa) to ensure that always one valve is open.
If the pressure is declining, at the moment the voltage drops below 3081mV (1050kPa) the LNG valve will open up and the CNG valve will be closing when the voltage drops below 3055mV (1240kPa).
To keep the system stable a hysteresis has been added.
To avoid an undefined switching, a time counter is working to allow one status change each 10s. In a serial application even a longer time is feasible.

```
const ecoLNG = 3106{mV entspricht 1060 kPa in abs}
Const ecomid = 3081{mV entspricht 1050 kPa in abs}
const ecoCNG = 3055{mV entspricht 1040 kPa in abs}


event

on cycle (1000) begin
calc
    keysig = (0) when (key = 0)
    keysig = (1) when (key = 1)
end


on cycle (10000) begin
 calc
    shcng = (1) when (Ua > ecomid)
    shlng = (0) when (Ua > ecolng)
    shcng = (0) when (Ua < ecoCNG)
    shlng = (1) when (Ua < ecomid)
end

event ON CYCLE (1000) BEGIN TRANSMIT CAN1 XDATA 0x18FF463A [UA anaIn1 anaIn2] LOG end
event ON CYCLE (1000) BEGIN TRANSMIT CAN1 XDATA 0x18FF472A [shCNG shLNG] LOG end


OUTPUT
  DigOut1 = (shcng)
  DigOut2 = (shlng)
```

4 Test

4.1 Test Vehicle

Stralis €6 LNG

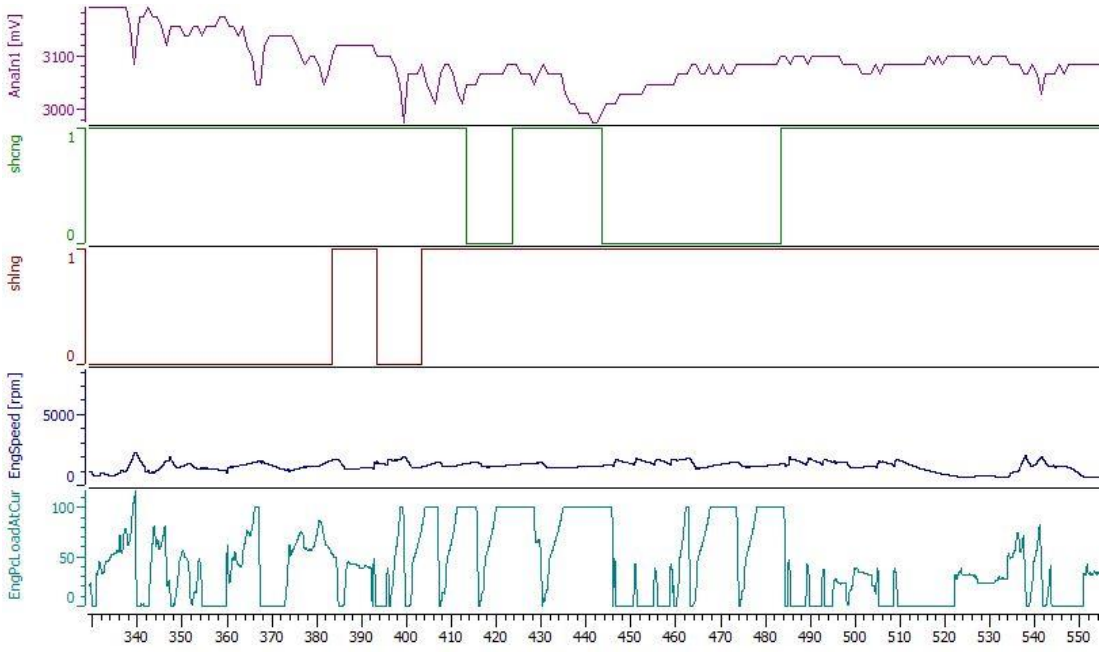
VAN		4295859
Typ		AT440S38T/P CNG
Axle configuration		4x2
VIN		WJMM1VNH60C320001
MUX		MUX
Engine	No.	F2CFE601A*B122*
	Version	CNG
Gearbox		12 AS 1931 TD
Retarder		IT3
Rear axle ratio		3.08 EVO

4.2 Test method

The supply voltage and the sensor voltage of the pressure sensor, the engine speed, the engine load, the vehicle speed and the status of the LNG valve and CNG valve were measured with CANalyzer 10.0.
In order to check if the valves are switching correctly according to the pressure of the LNG-tank the vehicle was driven on the test track with loaded semi-trailer in different driving situations.

5 Test results

During the test as well the CNG valve as the LNG valve switched properly when the corresponding pressures had been reached.
The engine has been running properly, no power losses or jerks were noticeable.
Because the pressure sensor has been installed on the vapor pipe, small pressure fluctuations were noticeable stepping on the gas.
It is worth considering mounting the pressure sensor for example on the fill pipe so accelerating will not influence the voltage of the pressure sensor.



- The purple graph shows the voltage in mV transmitted by the pressure sensor
- The green graph shows the status of the CNG valve (open: 1; closed: 0)
- The brown graph shows the status of the LNG valve (open: 1; closed: 0)
- The blue graph shows the engine speed in rpm
- The turquoise graph shows the engine load in percent
- The x-axis represents the time in seconds

Detailed measurements are in hands of vehicle validation, but this report shall only show the principle of the proposed solution.

The tests confirmed the principle concept of controlling the LNG tank pressure without an economizer.

For further actions a project must be opened.