EACS

Engine Altitude Conditions Simulator

Technical description

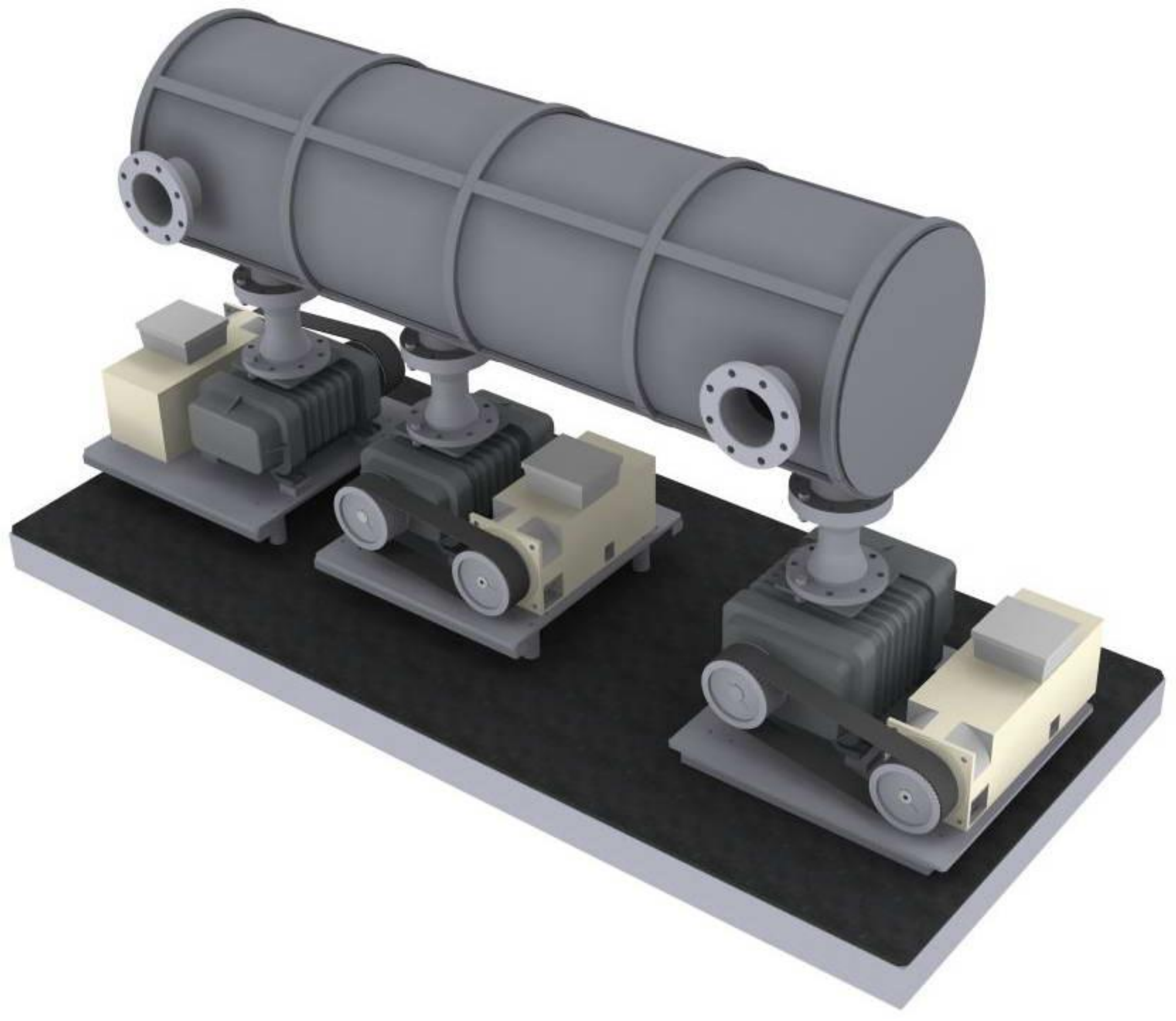
CONTROL
SISTEM

Introduction

The EACS is an innovative machine that allows to test internal combustion engines in a wide range of ambient pressure conditions, from sea level up to 5000 m altitude.

In order to test an engine in different ambient pressure, the commonly used procedure is to use a special test cell able to maintain a low pressure inside.
A test cell having this characteristic is very expensive because it needs very robust wall structure able to not collapse with a force of over 5000 kg/m^2,

The EACS overtakes these limitations maintaining the possibility to perform any kind of stationary or transitory test thank to a very fast and reliable regulation system able to maintain the pressure level within ± 10mb of the set point, in steady state or transient conditions.



Operating principle

In order to obtain very stable pressure conditions during transient tests (fast variations of intake air, exhaust gas and fuel flow rates), the solution consists in producing the desired pressure levels within a single volume **(C1)**, from which the engine draws the flow of intake air and into which it introduces the flow of exhaust gas.

To the same volume, other engine devices affected by ambient pressure (like pressure sensor) should be connected.

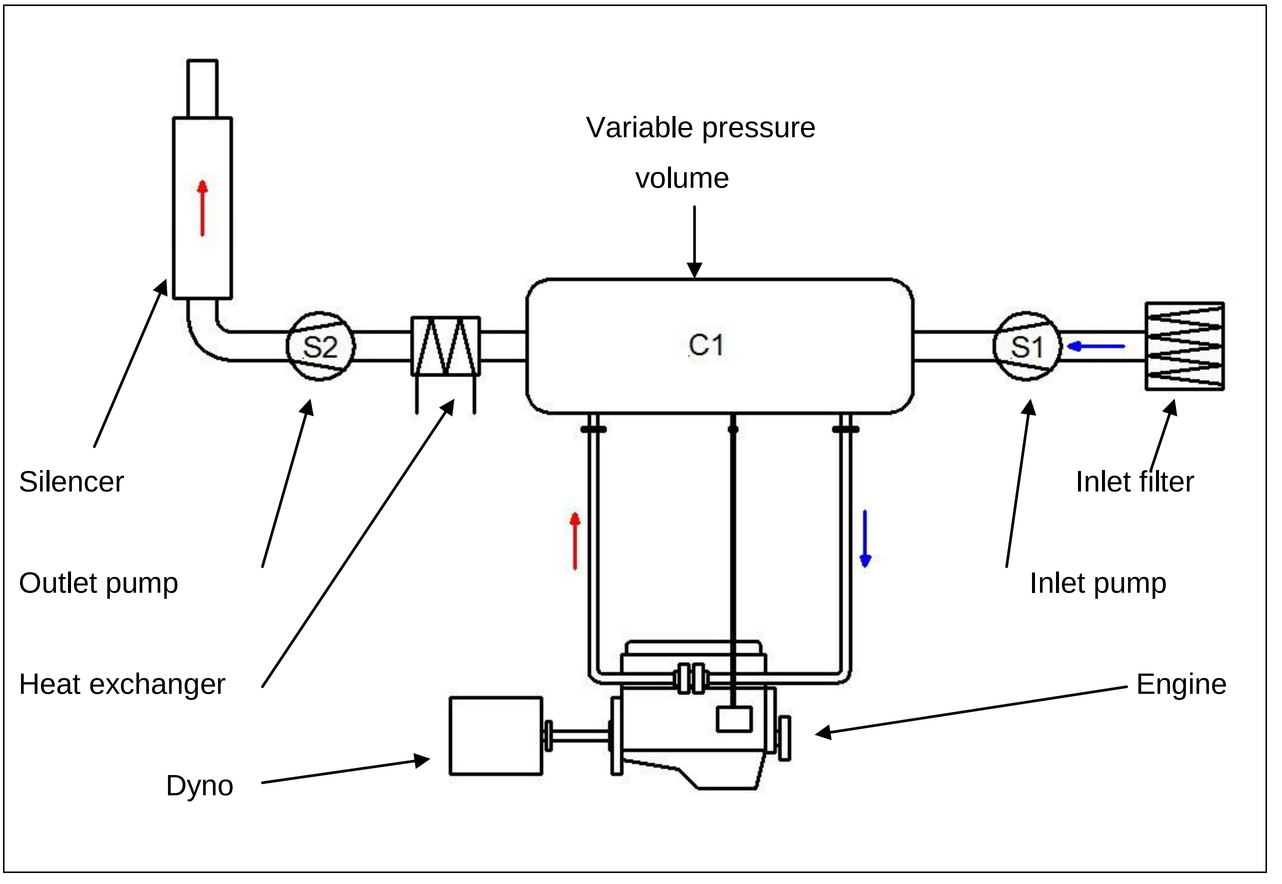
Since the engine takes the air and it introduces the exhaust gas into the same volume, mass variations are, in the case of naturally aspirated engines, due to the variations of the fuel flow-rate and to the fact that the temperature of the gas going in is higher than the temperature of the air going out.

In turbo engines, as turbo-charging pressure conditions vary, in addition to the effects described above, a variation in the air mass entrapped in the engine also occurs, which is equivalent to the volume of the pipes of the heat exchangers and the manifolds situated between the compressor and the turbine.

The EACS is managed by a control system able to stabilize the pressure in less than 1 second thus maintaining pressure oscillations lower than 10 mbar.

The system is composed by two identical volumetric blower assemblies (Roots type or similar): the first one (**S1**) draws the air from the external ambient and delivers the air flow to the volume **V**; the second one (**S2**) draws the air mixed with the exhaust gases from the volume and conveys it to the exhaust stack without any further dilution.

A heat exchanger is inserted before the pump **S2** in order to reduce the temperature and the volume of the exhaust flow.



EACS scheme

Main advantages of the **EACS** system are:

a) By changing the relative speed of the two blowers it is possible to obtain the desired pressure inside the volume in a regular and continuous manner, from positive to negative values, regardless of exterior ambient pressure.

b) Since the stability of the pressure inside the volume is obtained by controlling the speed of the extraction unit, the reaction time of the system is extremely short (lower than 1 second).

c) By changing the speed of the blowers synchronously, it is possible to control the total flow and hence to adapt it to the size of the engine being tested. when the engines tested are small, it is possible to reduce the total flow (and hence the amount of energy used up).

d) Since the pressure generated inside the volume differs from the ambient pressure, one of the two pumps always works in driven mode and therefore, through the inverter, recovers a part of the energy absorbed by the other pump: this makes it possible to minimise the amount of energy used up to obtain the pressure level inside the volume.

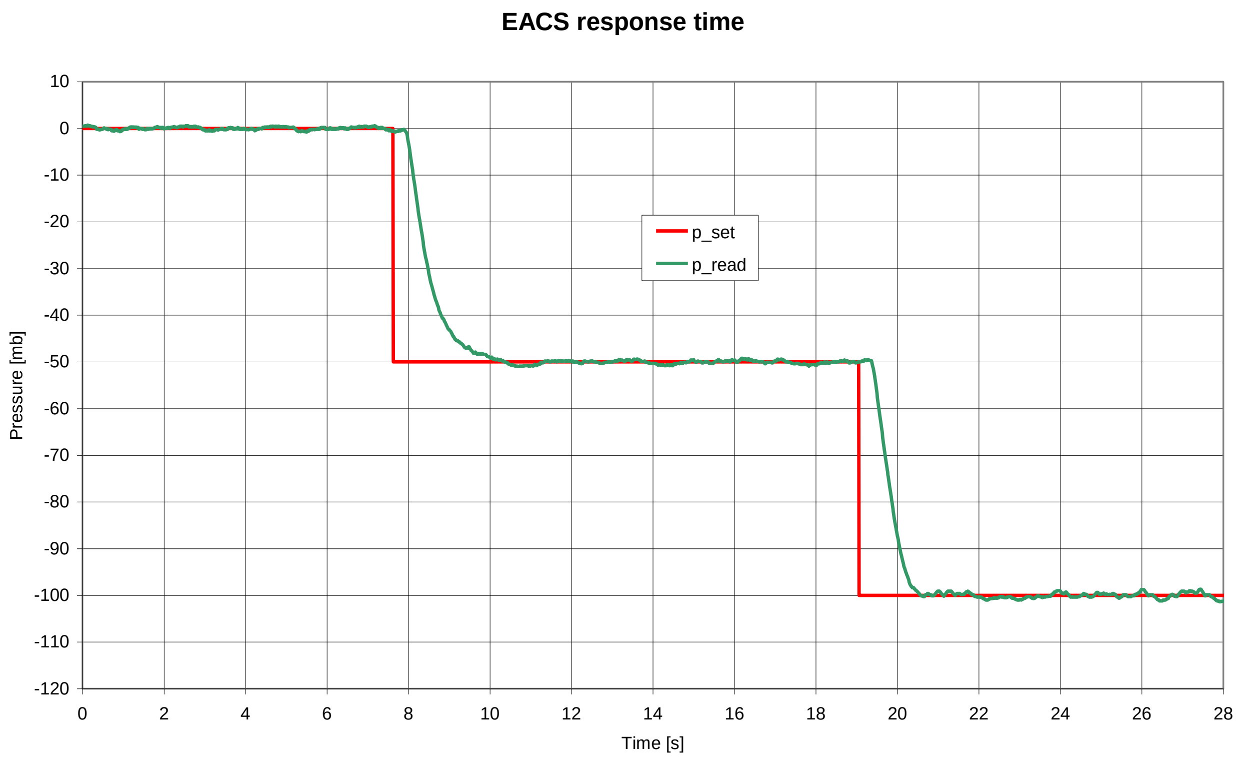
Technical data

- Air flow size ....1000 – 2000 – 4000 m^3/h
- Minimum pressure.......................................-500 mbar (about 5500 m)
- Maximum pressure......................................+100 mbar (about -800 m)
- Pressure accuracy ....± 1 mbar
- Pressure stability...± 1 mbar (steady state)
  ± 5 mbar (transient)
- Pressure regulation response time..............< 1 sec

Results

The diagram shows the pressure set point (red line) and the real pressure inside the volume (green line).

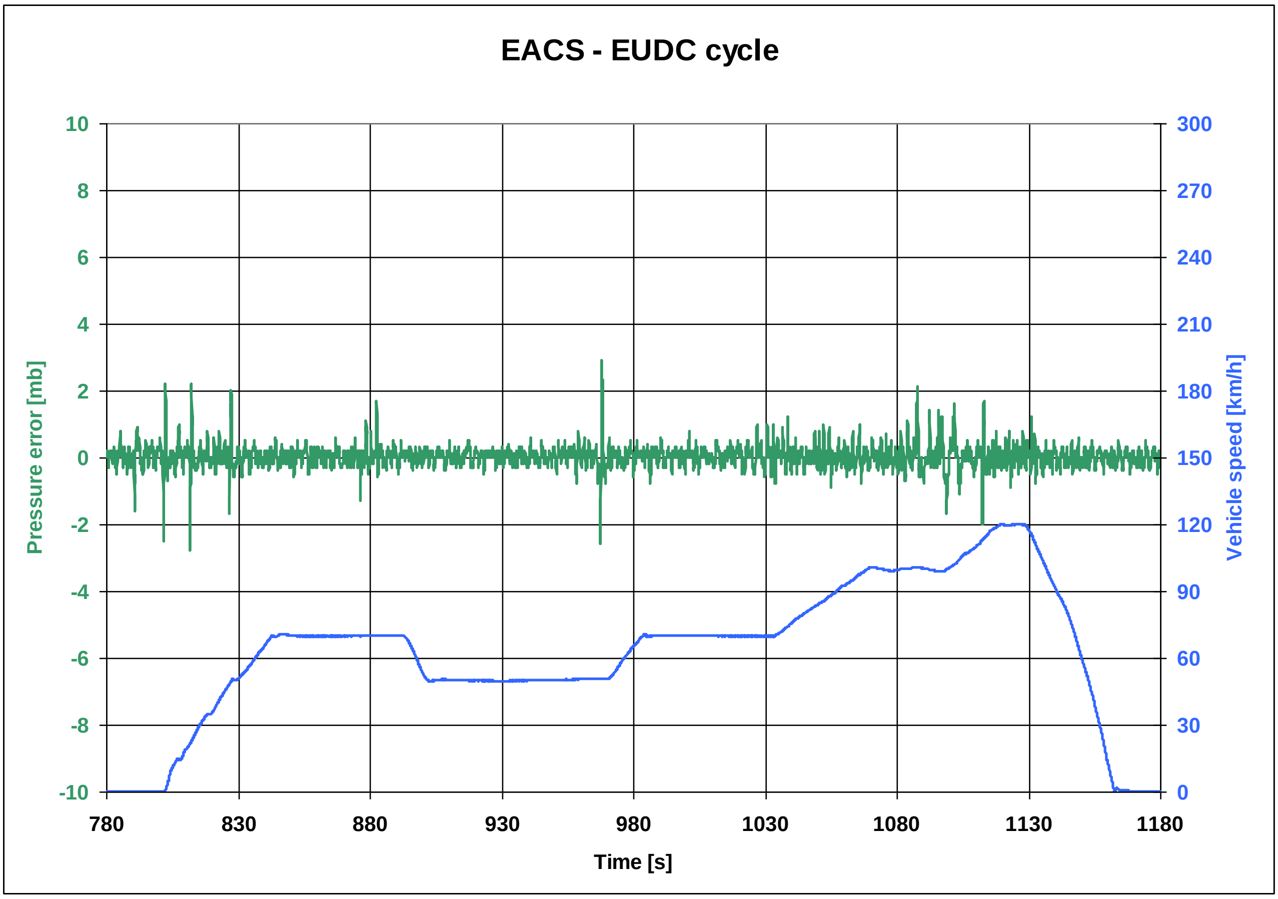
A set point variation from 0 to - 50 and -100 mb is generated with a constant flow from and to the engine; the graphic show that the new pressure level is reached in less than 2 seconds and the pressure stability is less than ± 1 mb.



This diagram shows the simulated pressure variation during an EUDC driving cycle at a simulated altitude of 1000 meters, with a 2 litres turbocharged diesel engine vehicle.

The system response time is less than 2 second with a maximum pressure variation of about ± 3 mbar.

Again the pressure stability in steady state conditions is less than ± 1 mbar.



The following diagram shows the pressure inside the volume in the case of extreme engine running conditions.

The test is running with a 1.9 liters displacement diesel turbocharged engine and a simulated altitude of 1800 meters, corresponding to a set point of -150 mb relative.

At the beginning of the test, from second 17 to second 35, 3 full throttle accelerations was executed, from idle conditions up to 5000 rpm.

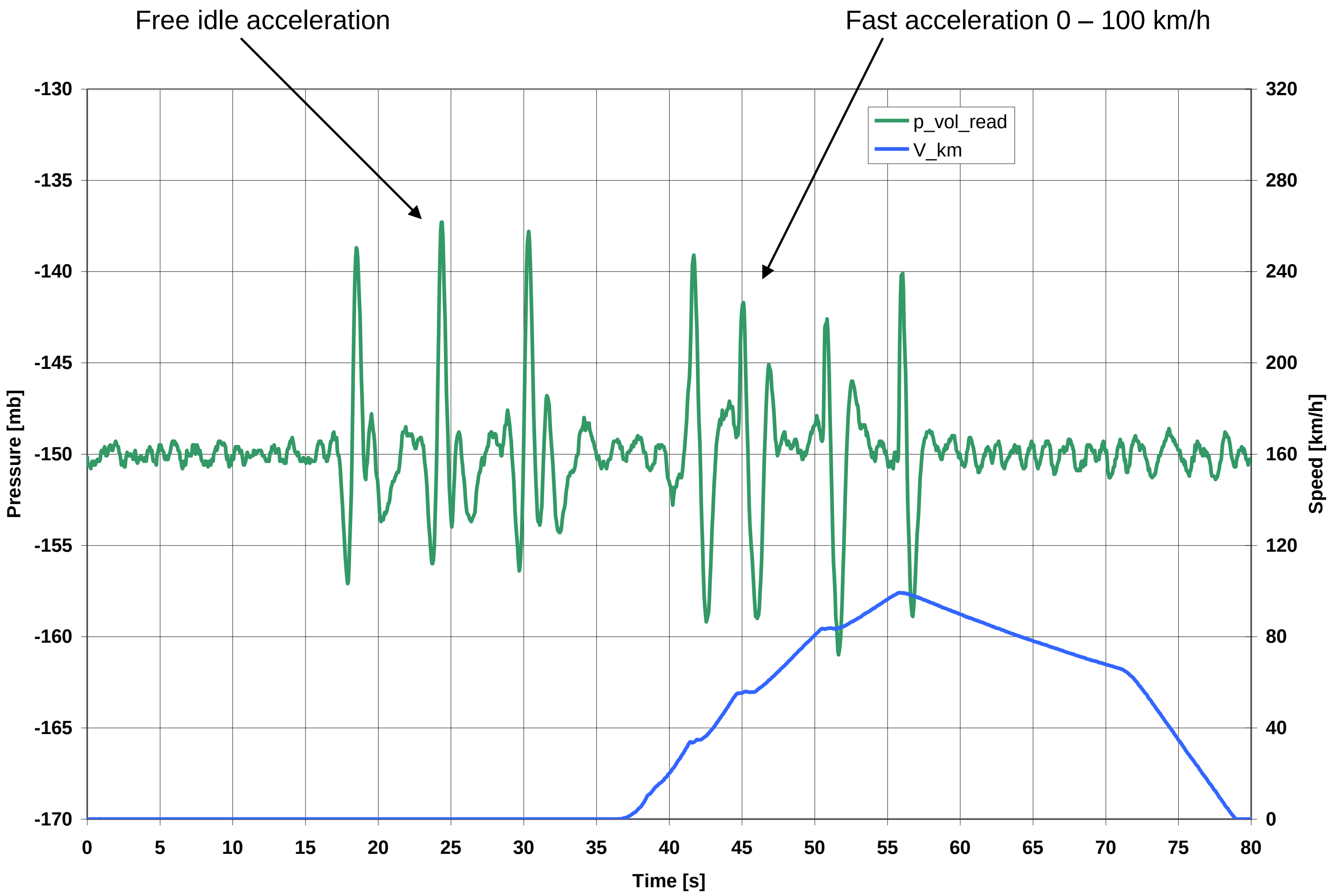
The graph shows that, when the engine speed is increased, the volume pressure goes down because an air mass is trapped inside the engine (air pipes, intercooler, manifold), while, when the throttle is released, this mass goes back to the volume and the pressure has a positive peak. The graph shows also that in les than 2 seconds the pressure regulation loop can bring again the pressure inside the limits of ±5 mb over the set point.

At the end of the test, from second 37 to the end, an acceleration from 0 to 100 km/h was executed, using the max engine power.

In this test important pressure variation happen only during gear shift, when the engine load conditions has very fast variation, while during the acceleration with the clutch engaged (for example from second 37 to second 42) the pressure variation is lower than ±2mbar.

These results are obtained using a very low working volume (about 0.5 m^3) that is good for running emission cycle that require quite low variation on engine speed and load.

In the case of test with very fast variations of engine working conditions, or in case of bigger engine displacement, a bigger working volume can be used (for example 2 or 3 m^3)



Free idle acceleration
Fast acceleration 0 – 100 km/h
p_vol_read
V_km
Pressure [mb]
Speed [km/h]
Time [s]
-130
-135
-140
-145
-150
-155
-160
-165
-170
320
280
240
200
160
120
80
40
0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

Final note:

On the technical specification is written that the system can work with pressure values down to -500 mbar (corresponding to 5.500 meters over sea level); in the tests here reported, the pressure set is lower because the standard air pipes on the vehicles cannot work with a pressure lower than -150 mb.

This means that, for test at lower pressure level, is necessary to modify the engine air pipes to be able to work at the testing pressure.

EACS (testing prototype 2000 m^3/h)

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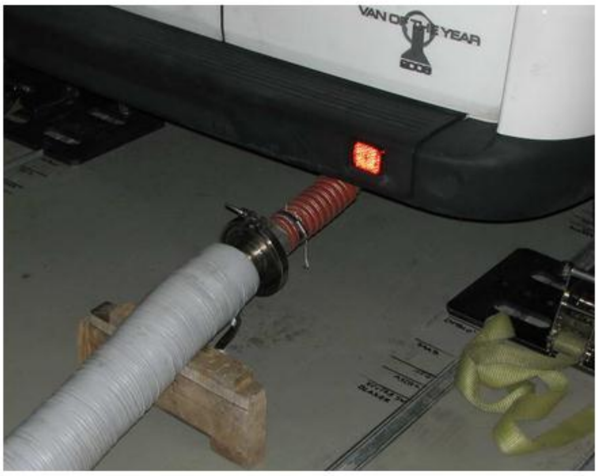
Patent Pending

EACS (testing prototype 2000 m^3/h)



Vehicle connections

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