Combustion Exhaust Gas Heat to Power using Thermoelectric Engines

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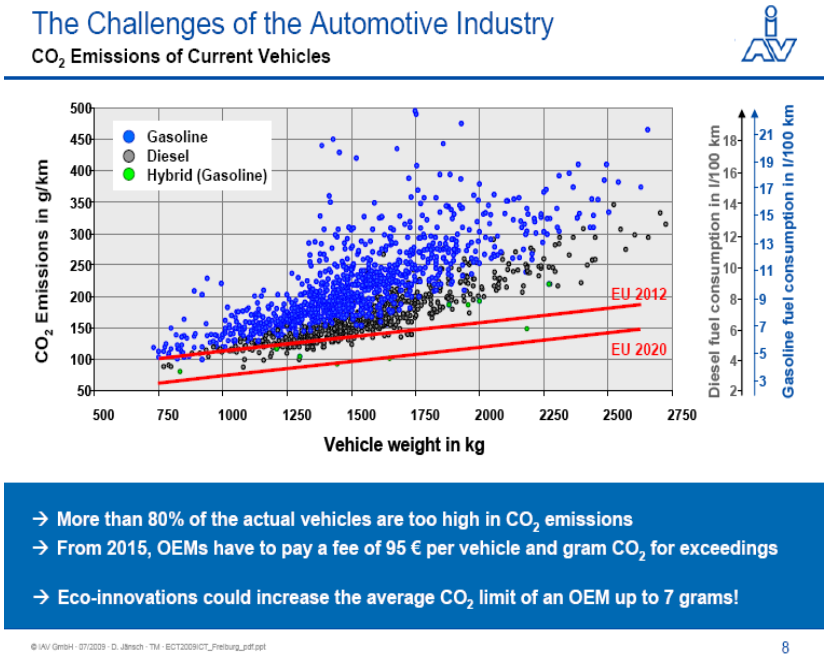
AMERIGON *Advanced Thermoelectric Solutions*

Automotive TEG Market Motivated by Emissions Rule Making

Market motivation based on CO_2 penalty cost avoidance[1]

First WHR products fielded (Faurecia, Valeo, et al) capture waste heat to improve engine cold start and increase occupant comfort in cold climes.

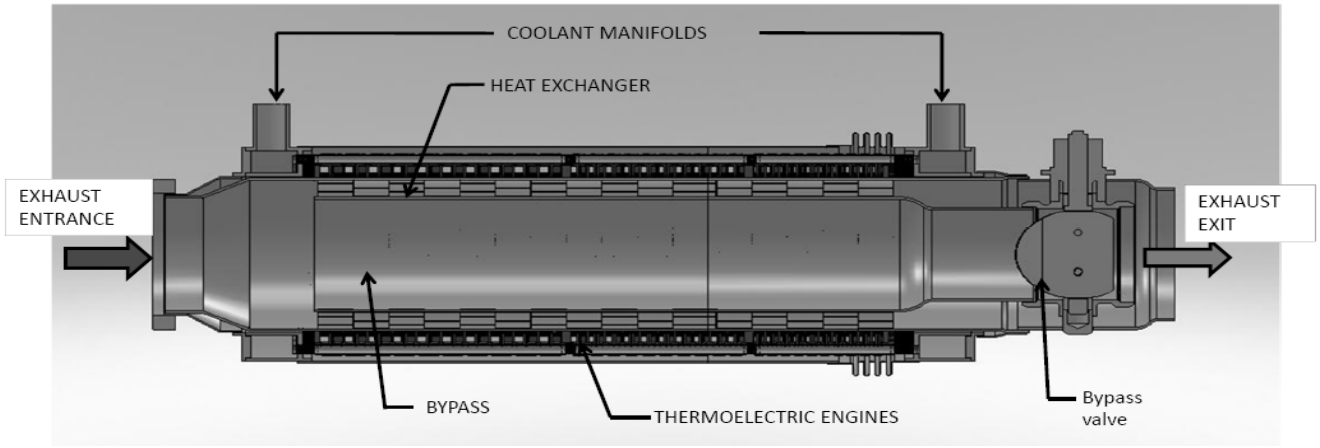
Many technology options implemented and underway to meet the new requirements:

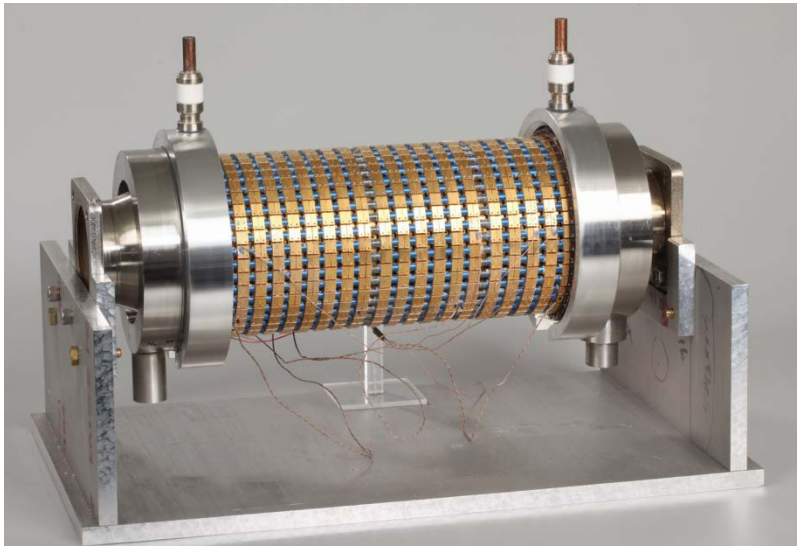


Source: IAV GMBH, D. Jaensch, ICT 2009

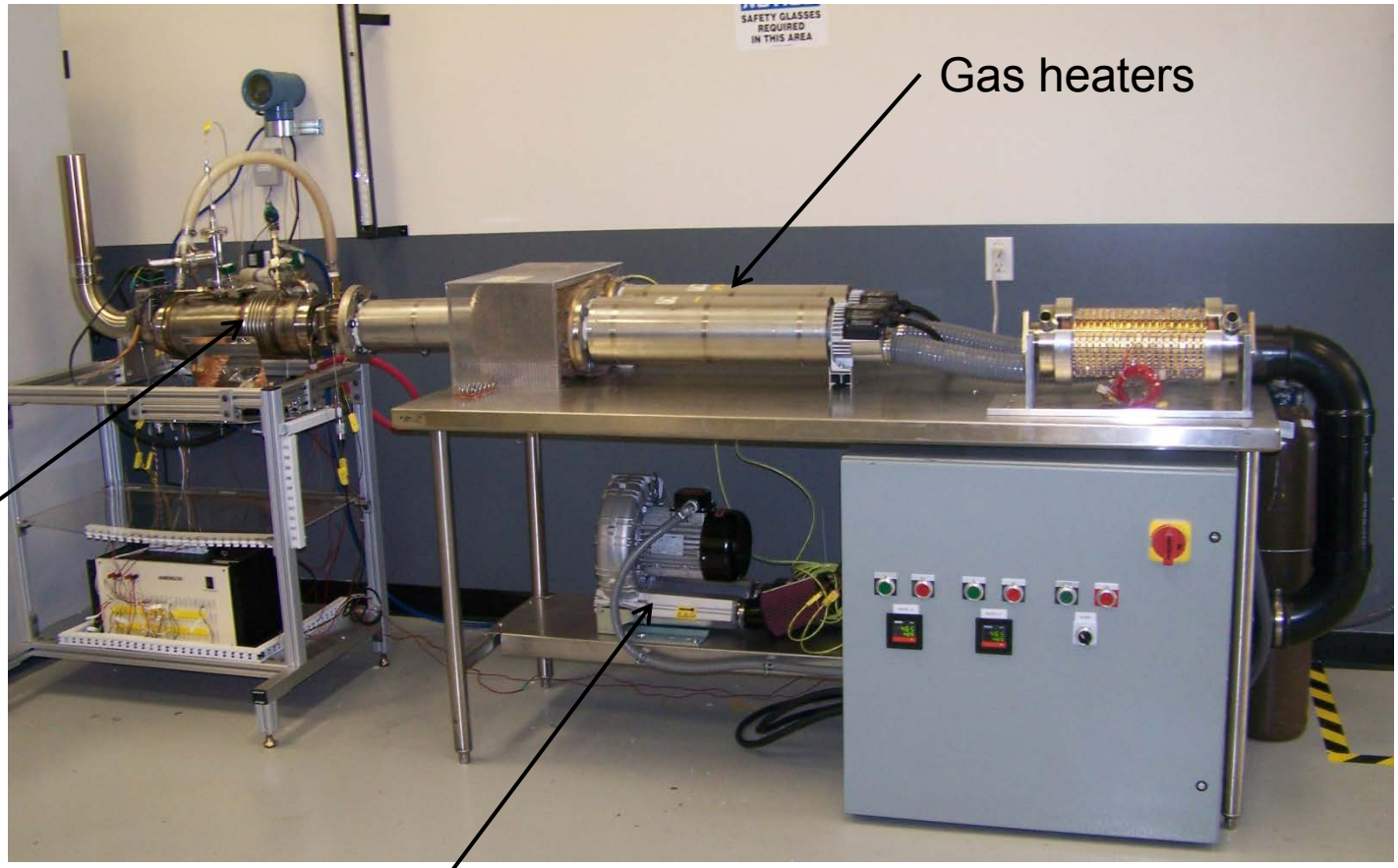
1. Regulation (EC) No 443/2009 of the European Parliament and of the Council of 23 April 2009 setting emission performance standards for new passenger cars

Cylindrical TEG





Bench Test Setup

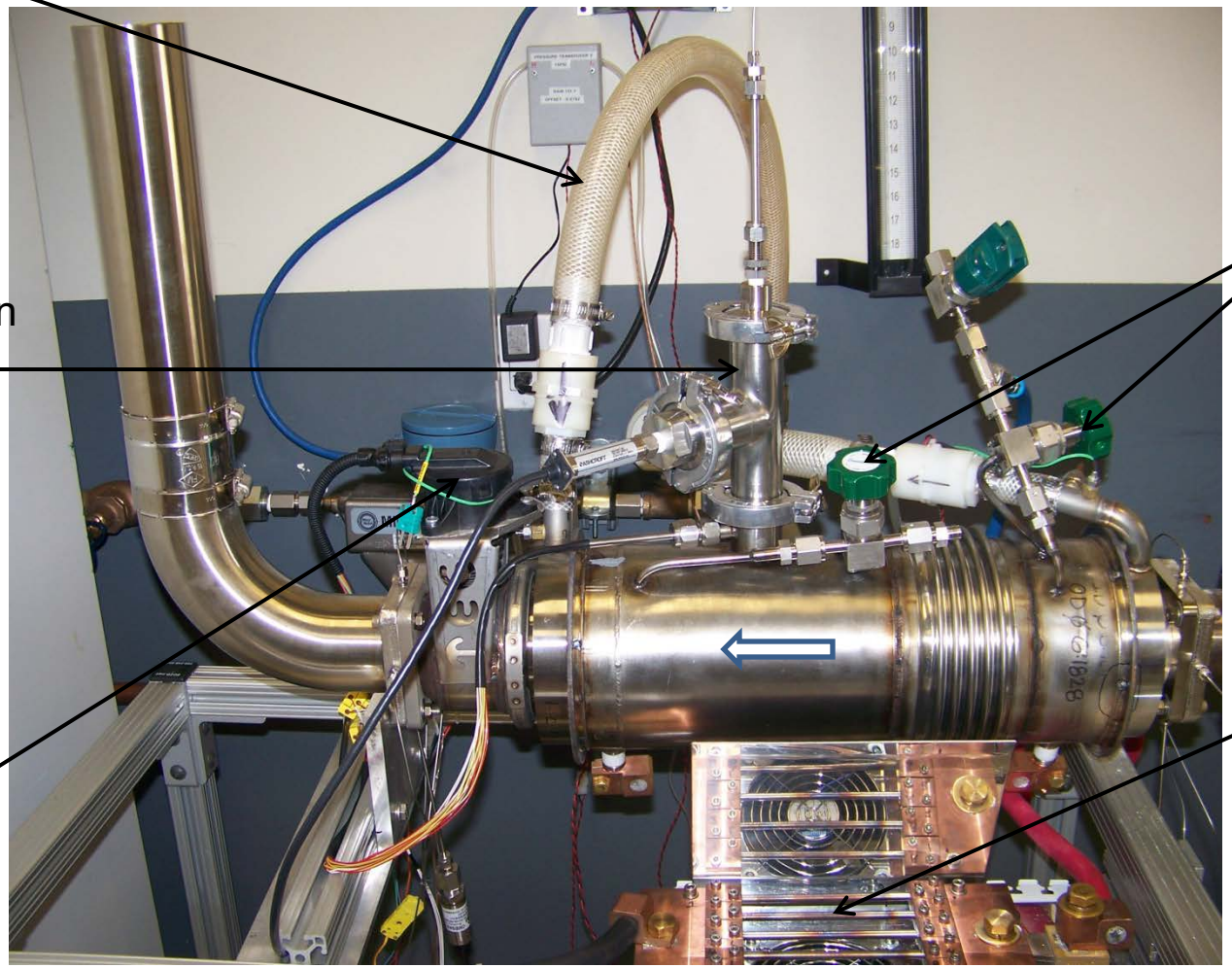


Gas heaters

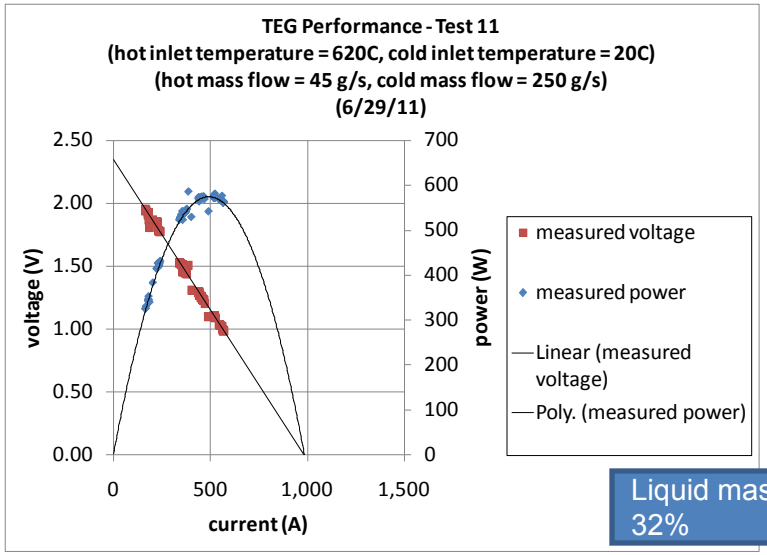
TEG under test

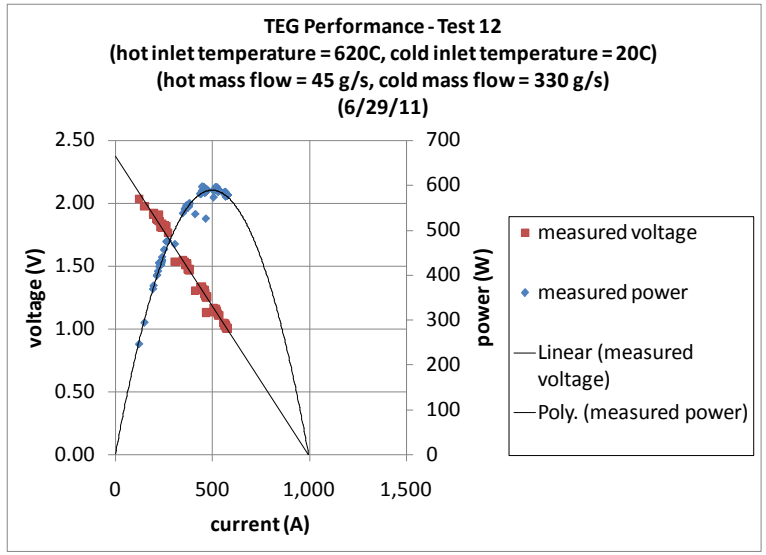
Blower

Bench Test Setup

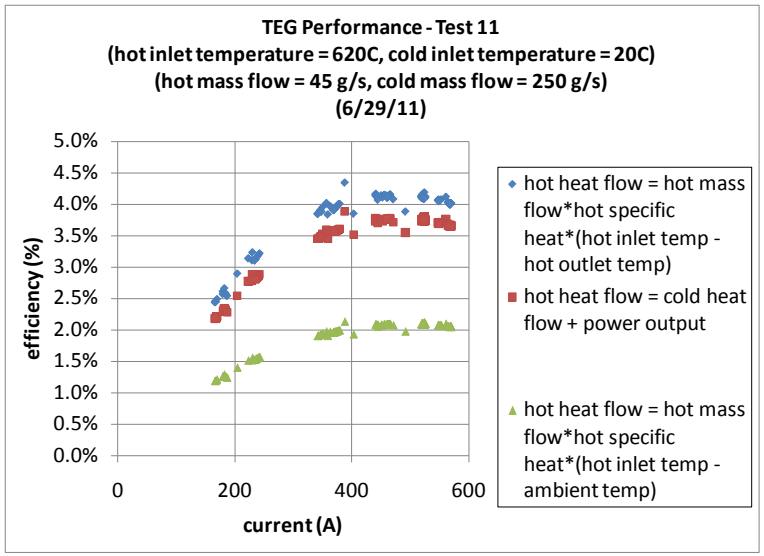


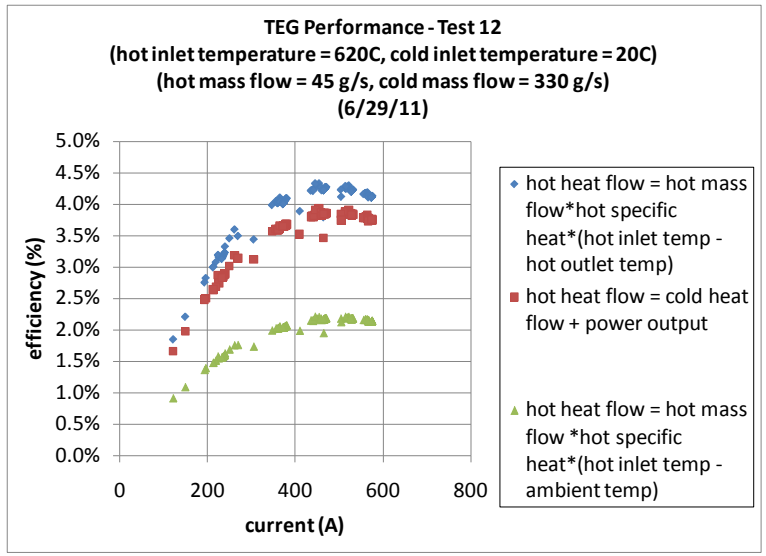
Voltage, Power, & Efficiency



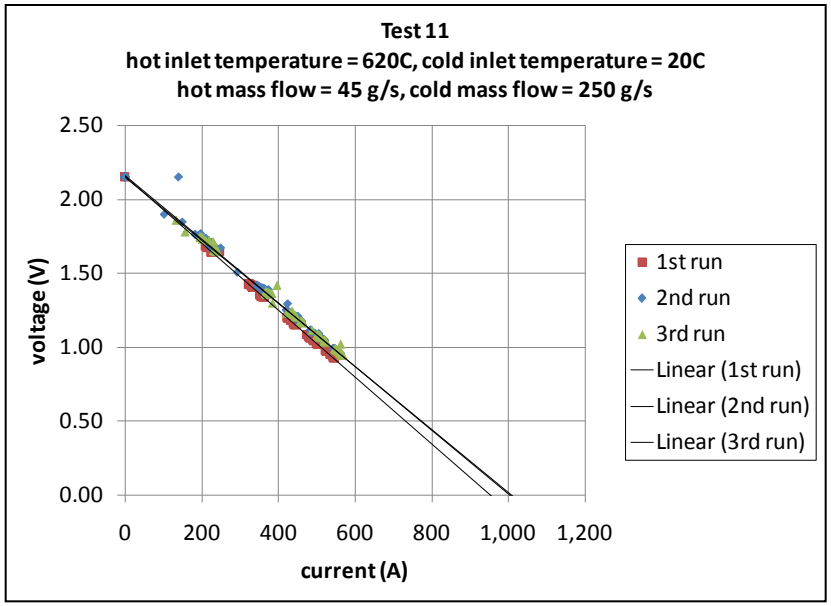


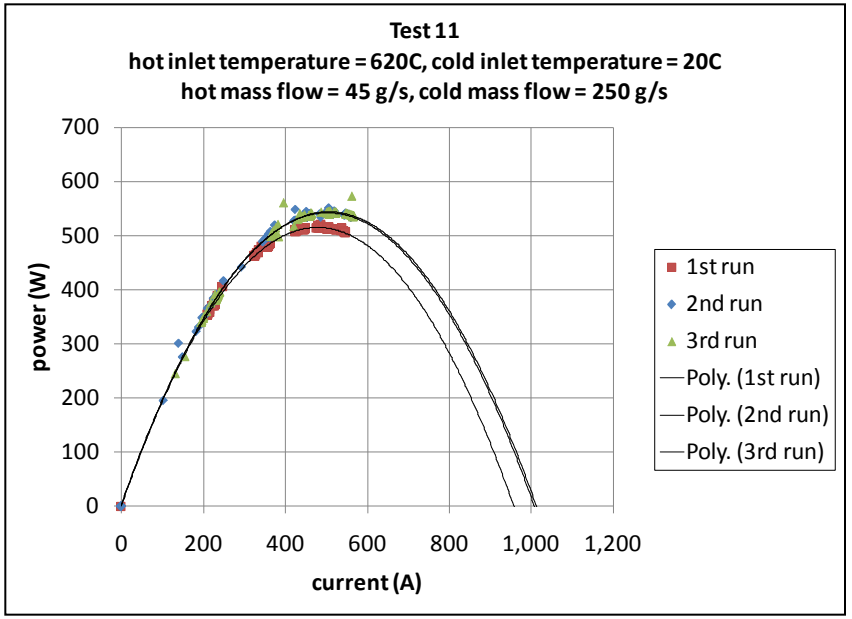
Liquid mass flow ↑ 32%





Run Repeatability

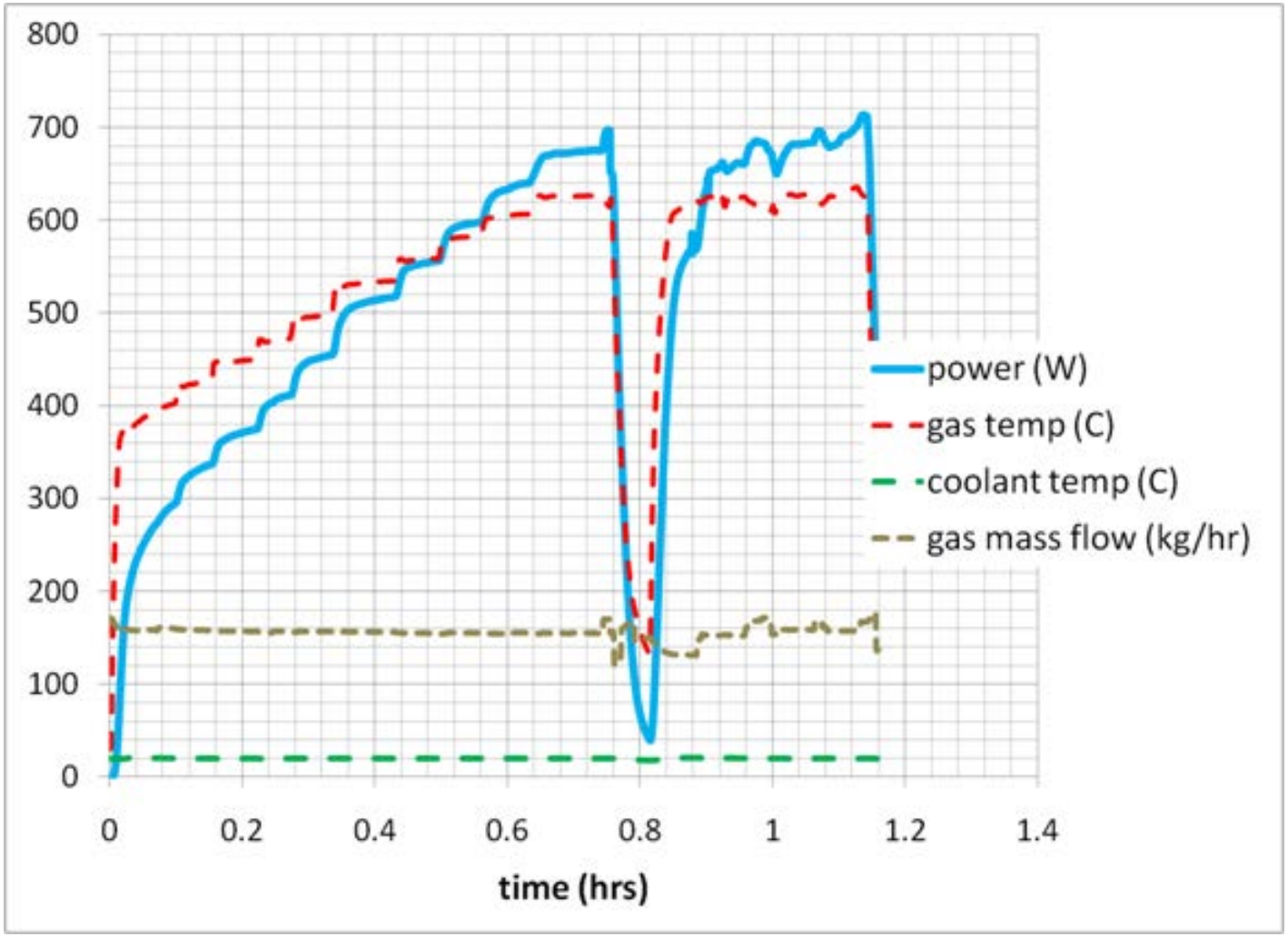




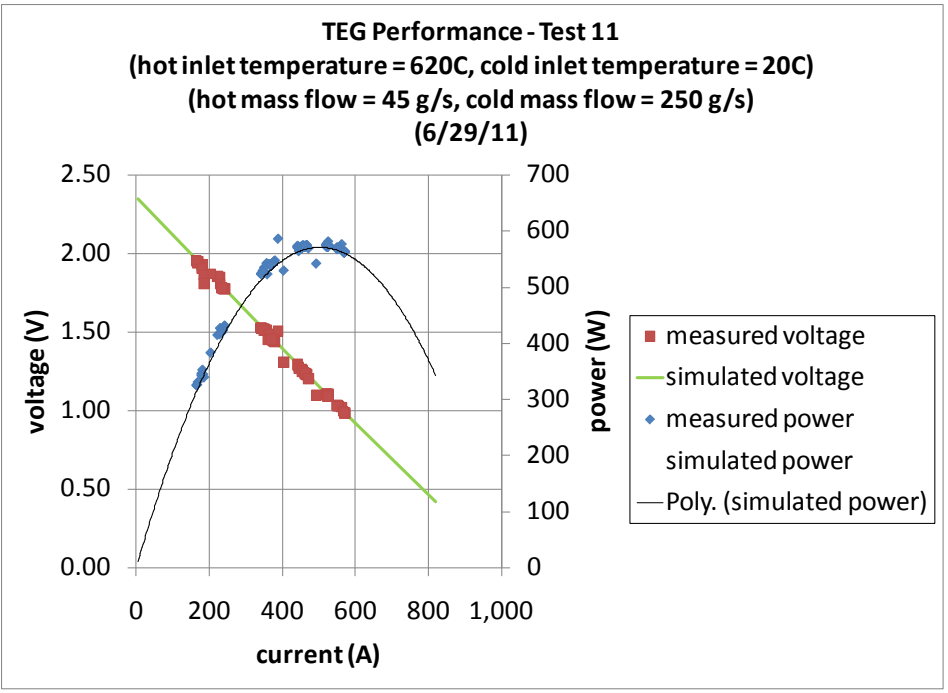
The three runs were performed over a period of two weeks (over 25 hours of testing) and show good repeatability.

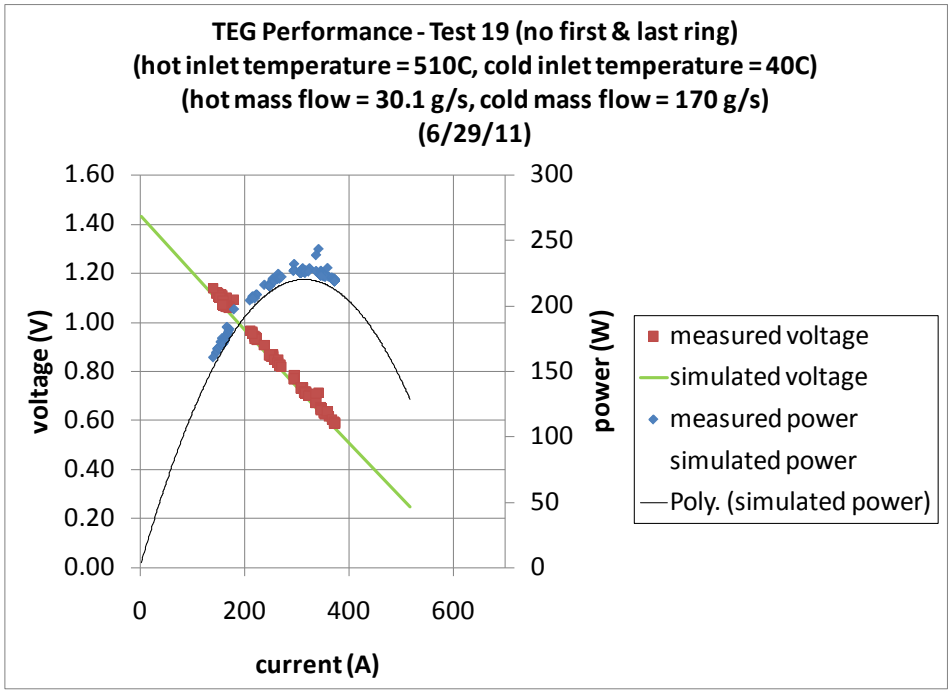
- There is a 9% decrease in electrical resistance from run 1 to run 2 due to “settling in” of the device interfaces
- This reduction in electrical resistance caused a 5% increase in peak power

Bench Test Peak Performance

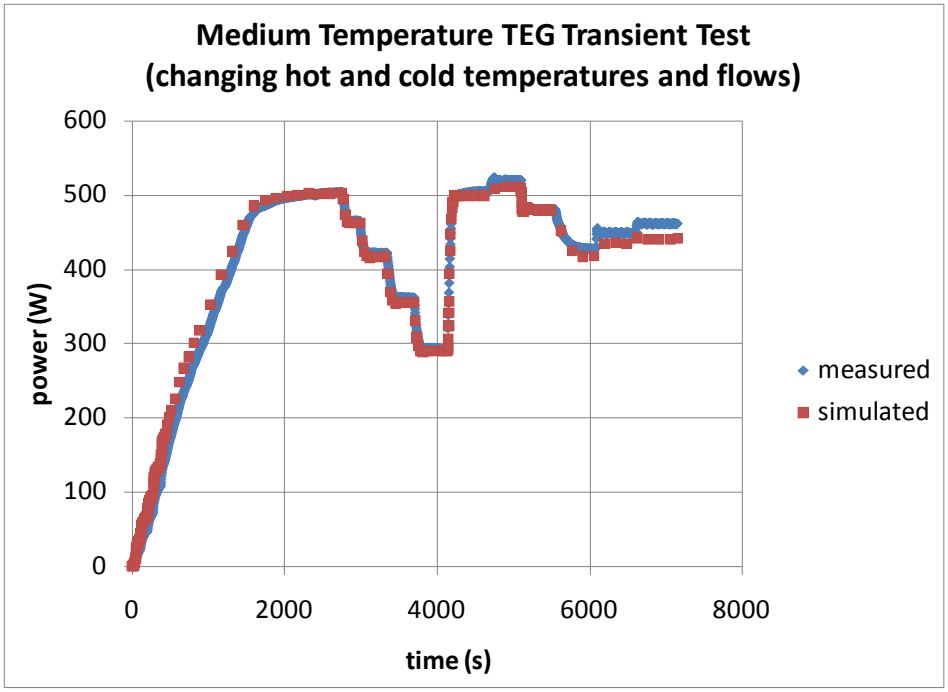


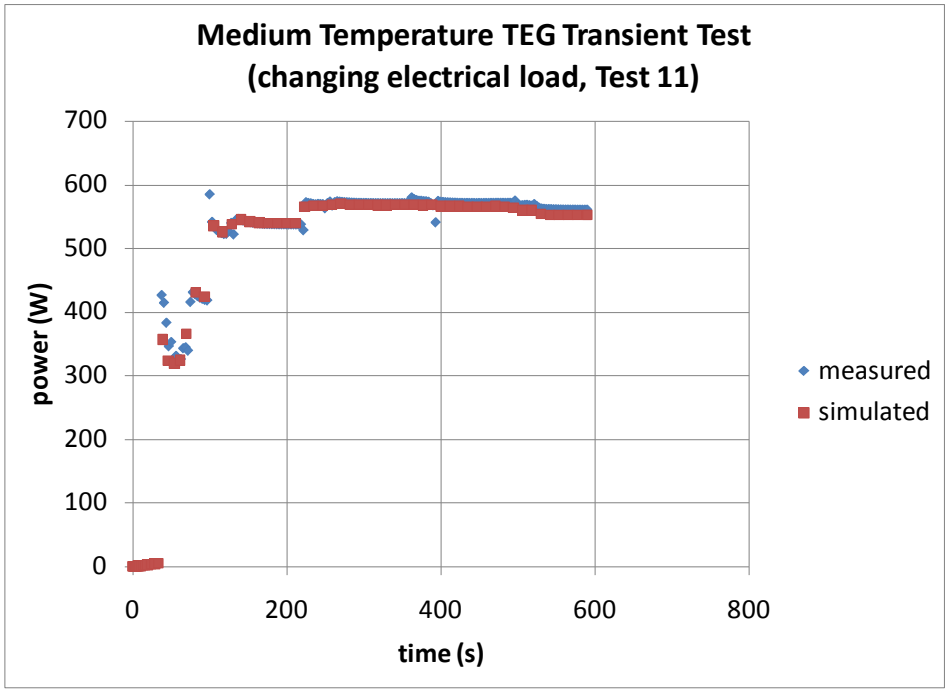
Power & Voltage Validation





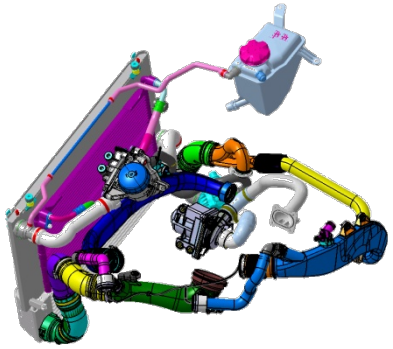
Medium Temperature TEG Transient Model Validation



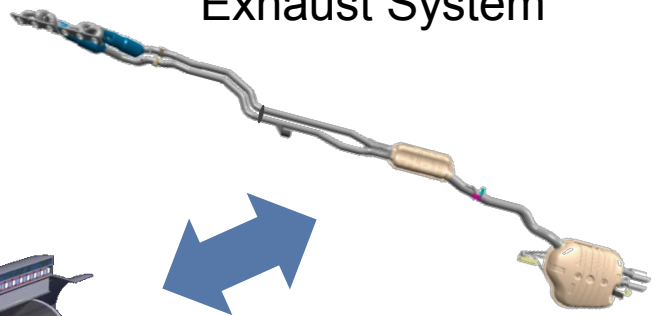


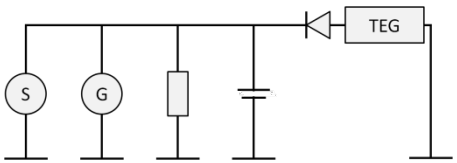
BMW THERMOELECTRIC WASTE HEAT RECOVERY.
KEY ASPECTS OF THE SYSTEM INTEGRATION.

Cooling System

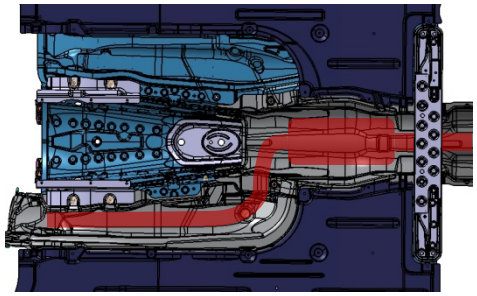


Exhaust System



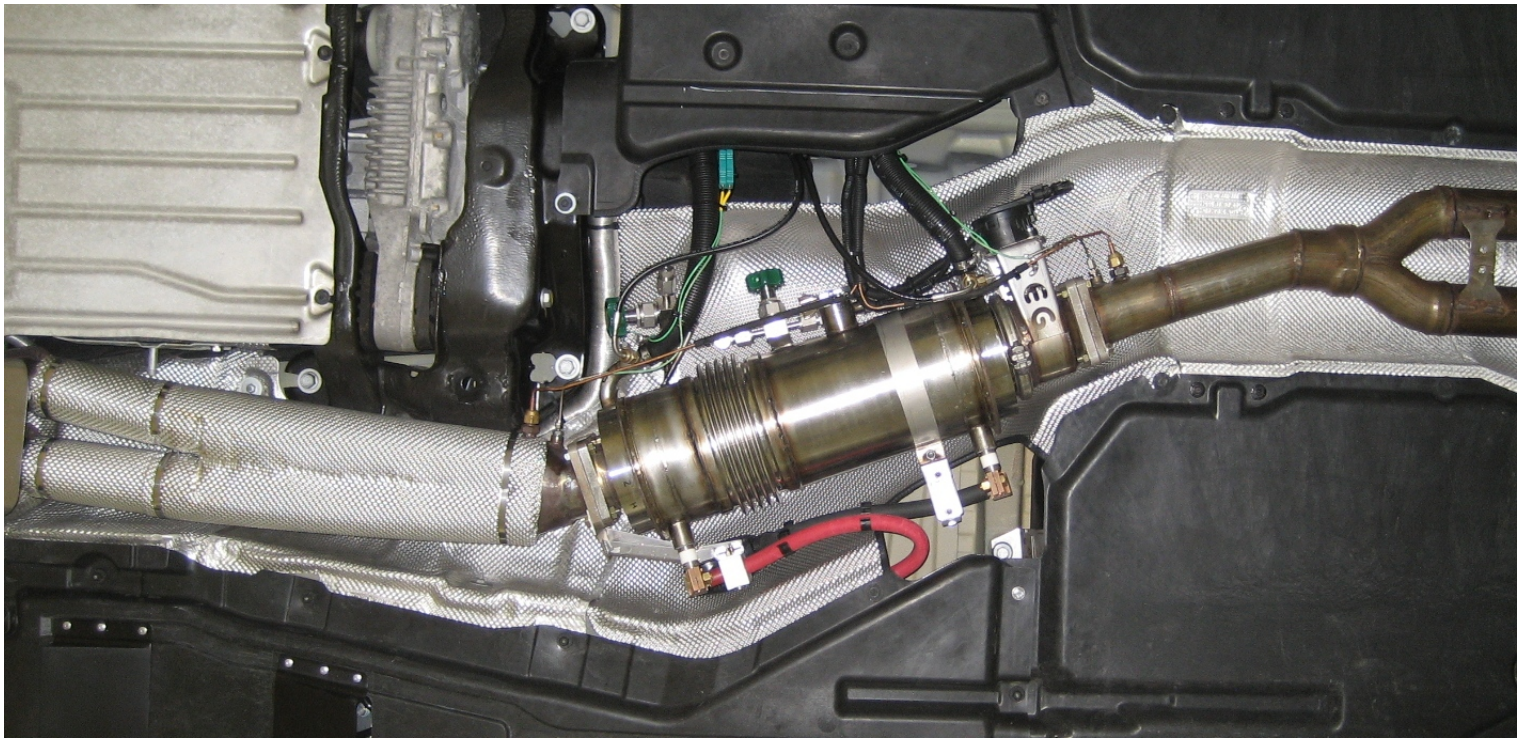


Vehicle Power Supply



Package

BMW THERMOELECTRIC WASTE HEAT RECOVERY.
BMW X6 PROTOTYPE VEHICLE.

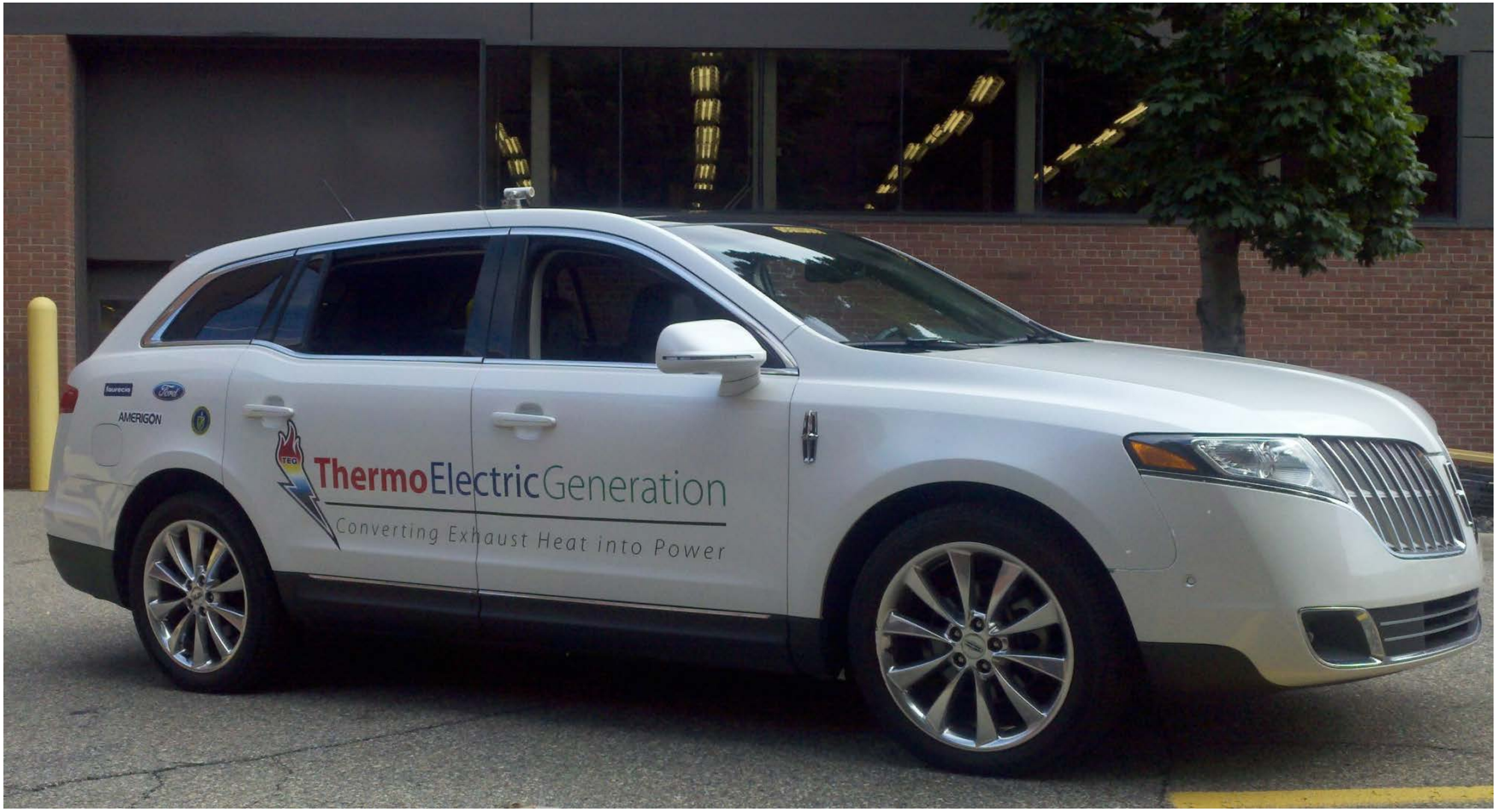


Fully integrated in vehicle exhaust and cooling system.

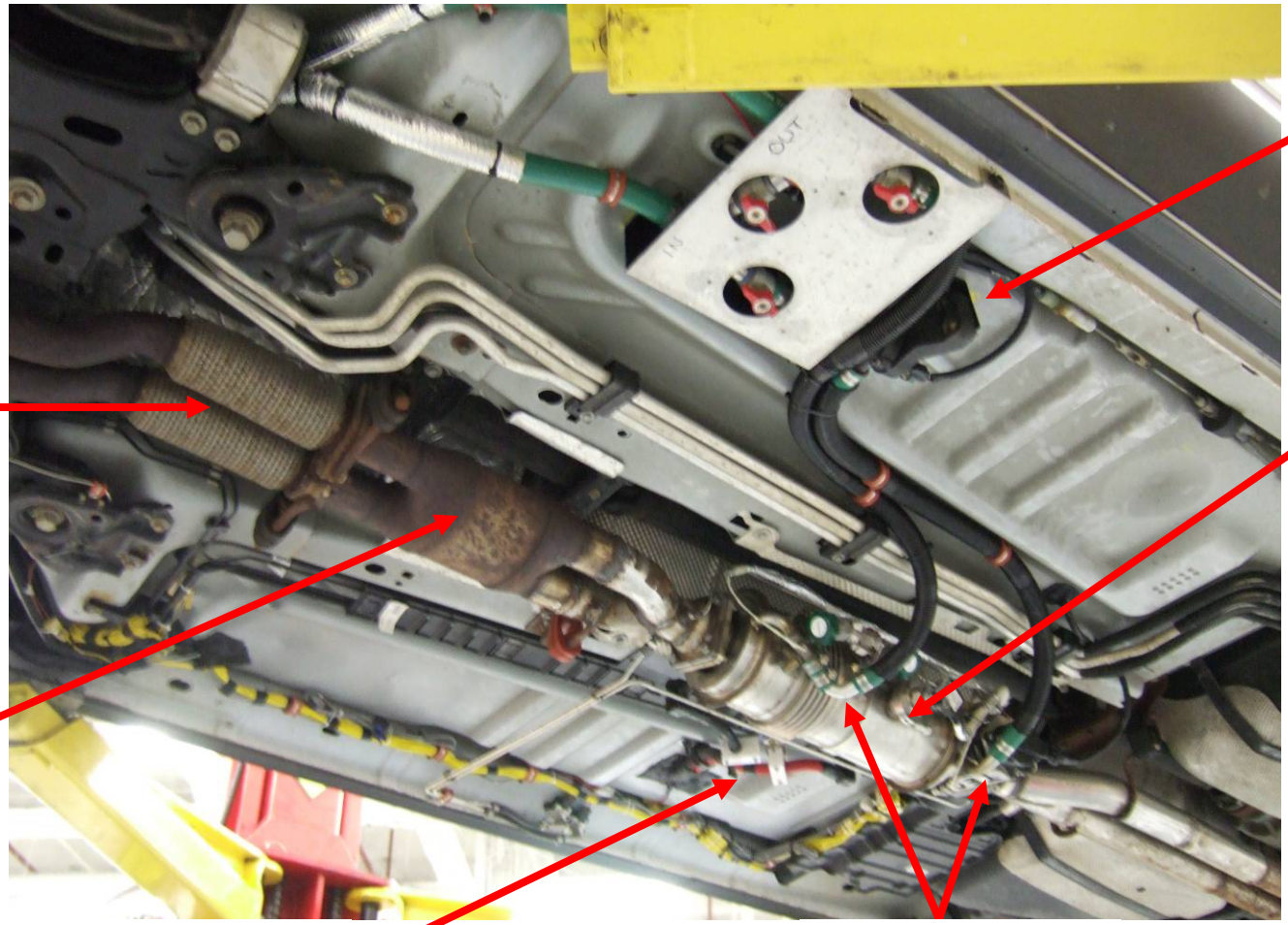
Automated control strategy for auxiliary water pump and exhaust valve.

TEG visualization concept integrated into the central information display.

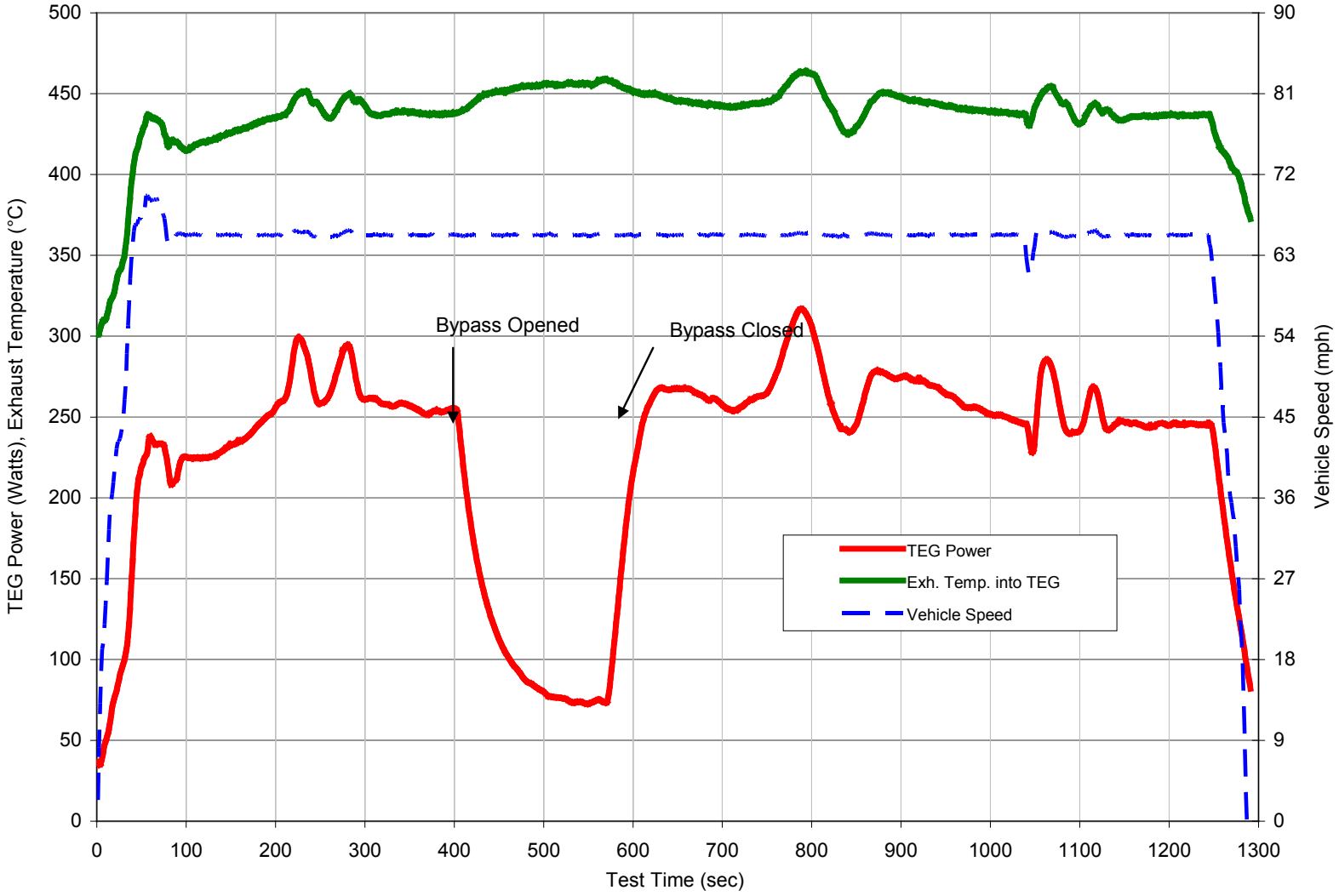
Test Platform: Lincoln MKT AWD 3.5L V6 GTDI Engine



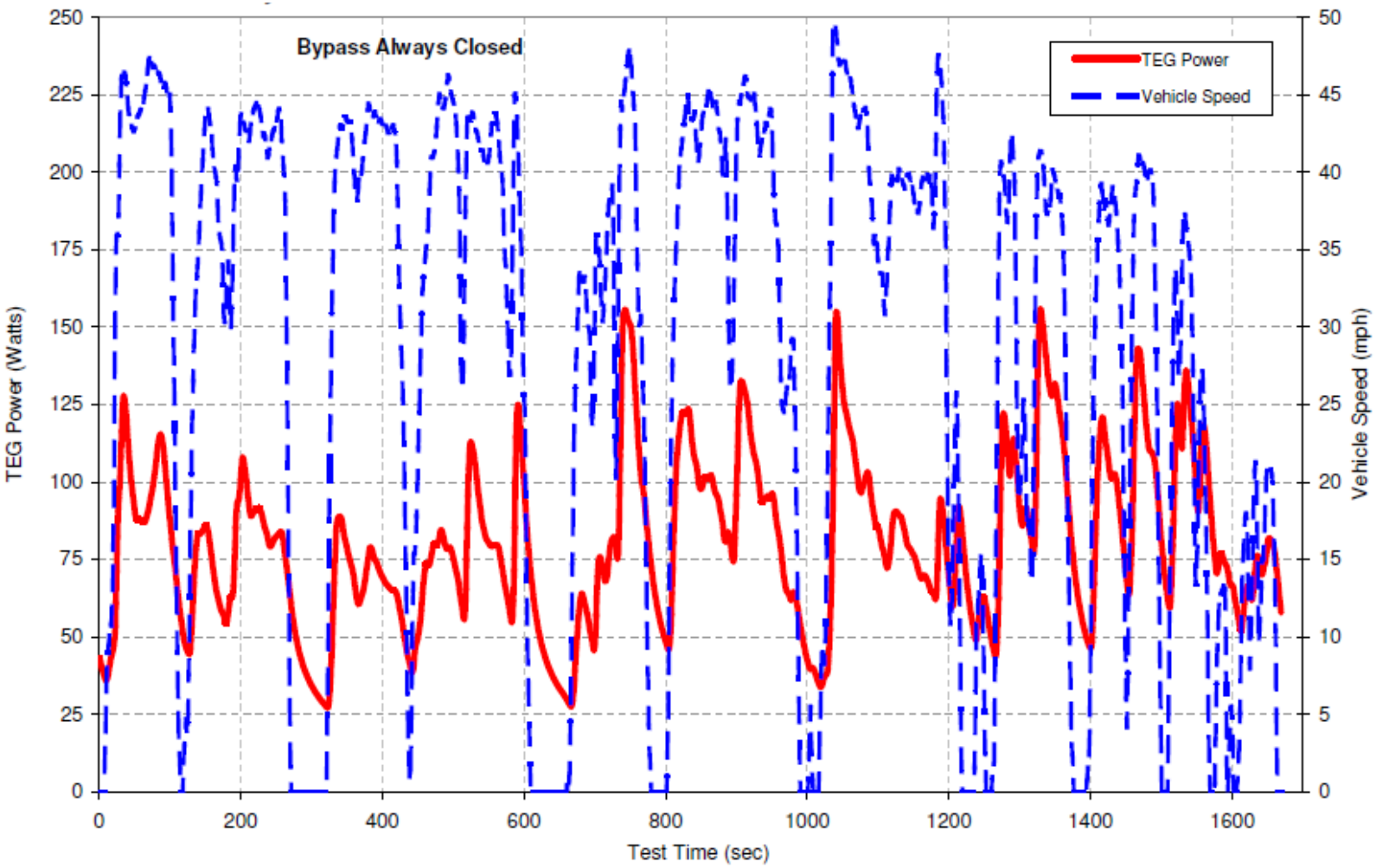
TEG & Exhaust System Packaging



65mph Freeway Cruise



Lincoln MKT, 3.5L GTDI City Driving



Summary

A cylindrical TEG incorporating segmented TE engines and coaxial gas bypass has been modeled, designed, built and tested at Amerigon.

- The TEG is compatible with inlet gas in the 600^0C range with thermoelectric material surface temperatures in the 500^0C range.
- Peak power produced in bench testing at Amerigon was over 700 watts. Power produced during vehicle operation will be lower as the cold side circuit will be hotter than in bench testing.

Vehicle level TEG system evaluations are underway at BMW and Ford.

The DOE sponsored Amerigon TEG program has formally concluded. Final results will be reported in November this year.

Amerigon, BMW, Ford and Faurecia will continue in a new program funded by the DOE to make implementation ready TE materials and engines over a four year program period.

Acknowledgements

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Amerigon's Team