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TEG On-Vehicle Performance and Model Validation and What It Means for Further TEG Development

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A high-temperature thermoelectric generator (TEG) was recently integrated into two passenger vehicles: a BMW X6 and a Lincoln MKT. This effort was the culmination of a recently completed Department of Energy (DOE)-sponsored thermoelectric (TE) waste heat recovery program for vehicles (award #DE-FC26-04NT42279). During this 7-year program, several generations of thermoelectric generators were modeled, designed, built, and tested at the couple, engine, and full-device level, as well as being modeled and integrated at the vehicle level. In this paper, we summarize the history of the development efforts and results achieved during the project, which is a motivation for ongoing research in this field. Results are presented and discussed for bench, engine dynamometer, and on-vehicle tests conducted on the current-generation TEG. On the test bench, over 700 W of power was produced. Over 600 W was produced in on-vehicle tests. Both steady-state and transient models were validated against the measured performance of these TEGs. The success of this work has led to a follow-on DOE-sponsored TE waste heat recovery program for passenger vehicles focused on addressing key technical and business-related topics that are meant to enable TEGs to be considered as a viable automotive product in the future.

Key words: Thermoelectric, power generation, waste heat recovery, automotive

INTRODUCTION

In the fall of 2004, a team led by Amerigon (now Gentherm) began a Department of Energy (DOE)-sponsored program under DOE award #DE-FC26-04NT42279 to develop a thermoelectric generator (TEG) for passenger vehicles. Team members included BMW, Ford (added during phase 3), and Faurecia (added for phase 5). This program completed in the fall of 2011 with a high-temperature TEG integrated into two passenger vehicles: a BMW X6 and a Lincoln MKT. This paper summarizes the results of this program, with particular attention to the final phase results. The paper also discusses what is next for further TEG development.

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PROGRAM HISTORY

In phase 1 of the program, the boundaries of the thermoelectric (TE) waste heat recovery problem were defined along with the system architecture. An initial model was created for the TEG, which was then utilized in a system model to provide an estimate for vehicle fuel economy improvement over a drive cycle.[1]

In phase 2, a small-scale high-temperature generator building block was designed and built. The goal for this building block was to use it to demonstrate TEG efficiencies $>10\%$ and, when multiple building blocks were linked together, produce power >20 W at temperatures $>400°C$. Further description of this development and results are discussed in previous papers.[2,3]

With limited availability of effective high-temperature materials in the size and shapes