

Development of an Underarmor 10-kW Thermoelectric Generator Waste Heat Recovery System for Military Vehicles

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Quantum Well Thermoelectric Generator for Stryker

- Purpose: Develop preliminary design of Quantum Well thermoelectric generator
 - Army TACOM funded
 - Caterpillar provided engine data
- Working on integrating Quantum Well thermo-electric generator with CAT diesel engine in a Stryker vehicle
 - This program is a primer for integrating with truck system
 - Prior test with PACCAR/Kenworth was oriented towards testing of the 1 kW generator

Quantum Well Thermoelectric Generator for Stryker

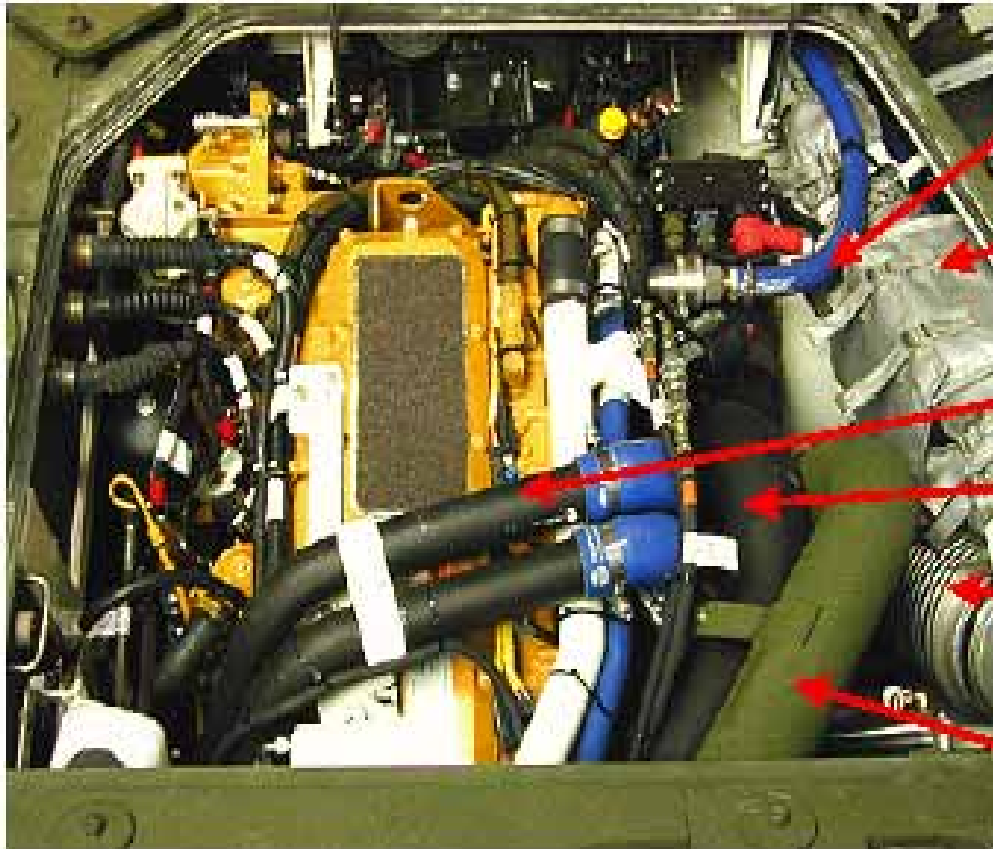
Preliminary Design Topics

- Stryker vehicle arrangement
- QW TE Generator
 - Design for Stryker
 - Prior TE Waste Heat Generators
- QW TE Module
- In-Situ APU
- Predicted Performance

Army Stryker Vehicle



Stryker Caterpillar 3126 300 hp (224 kW) Diesel Engine



APU Hydraulic Line

APU Exhaust Blanket

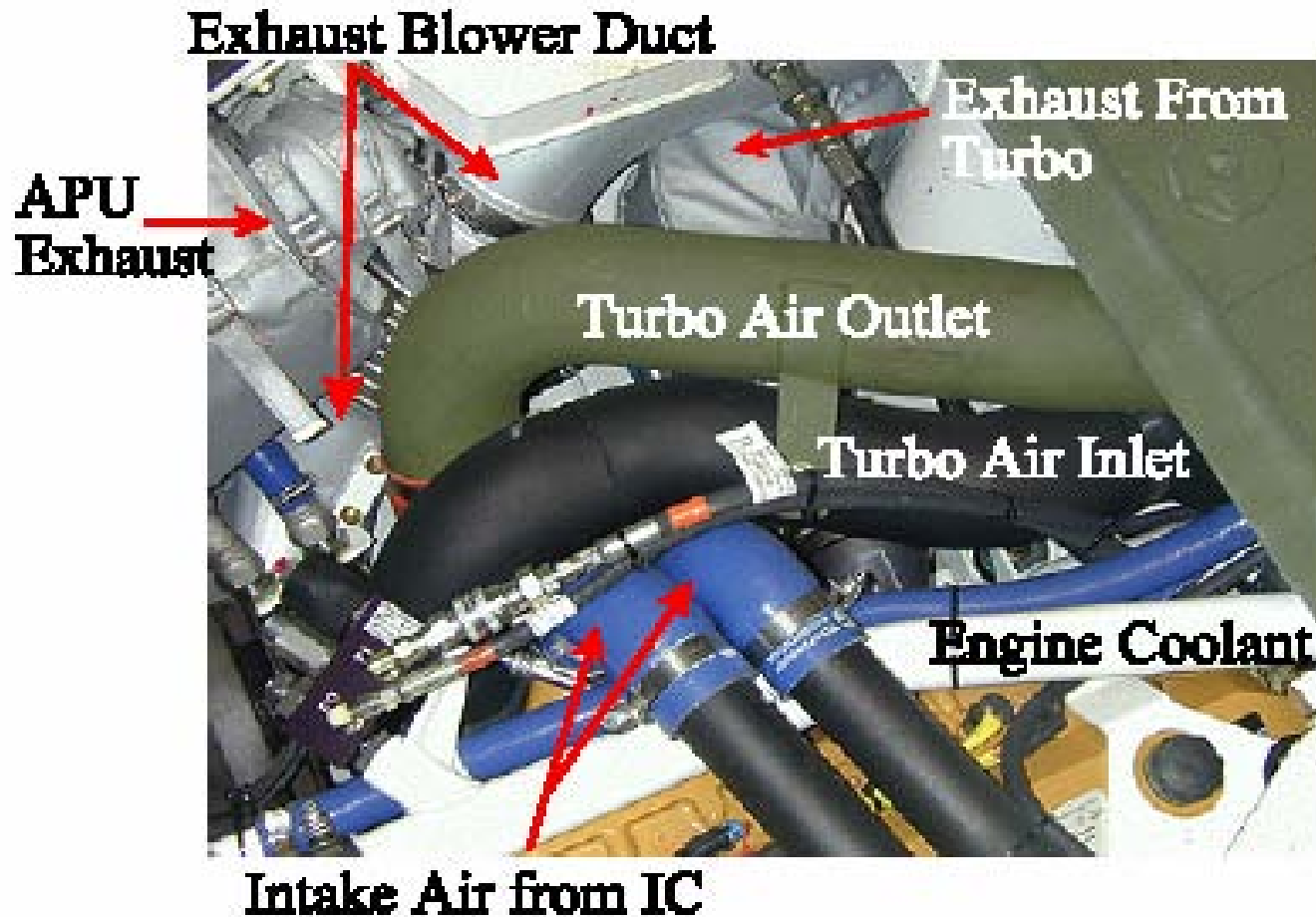
Intake Air From IC

Turbo Air Inlet

Exhaust Blower Outlet

Turbo Air Outlet

Stryker Exhaust Region



Stryker Strut and Muffler



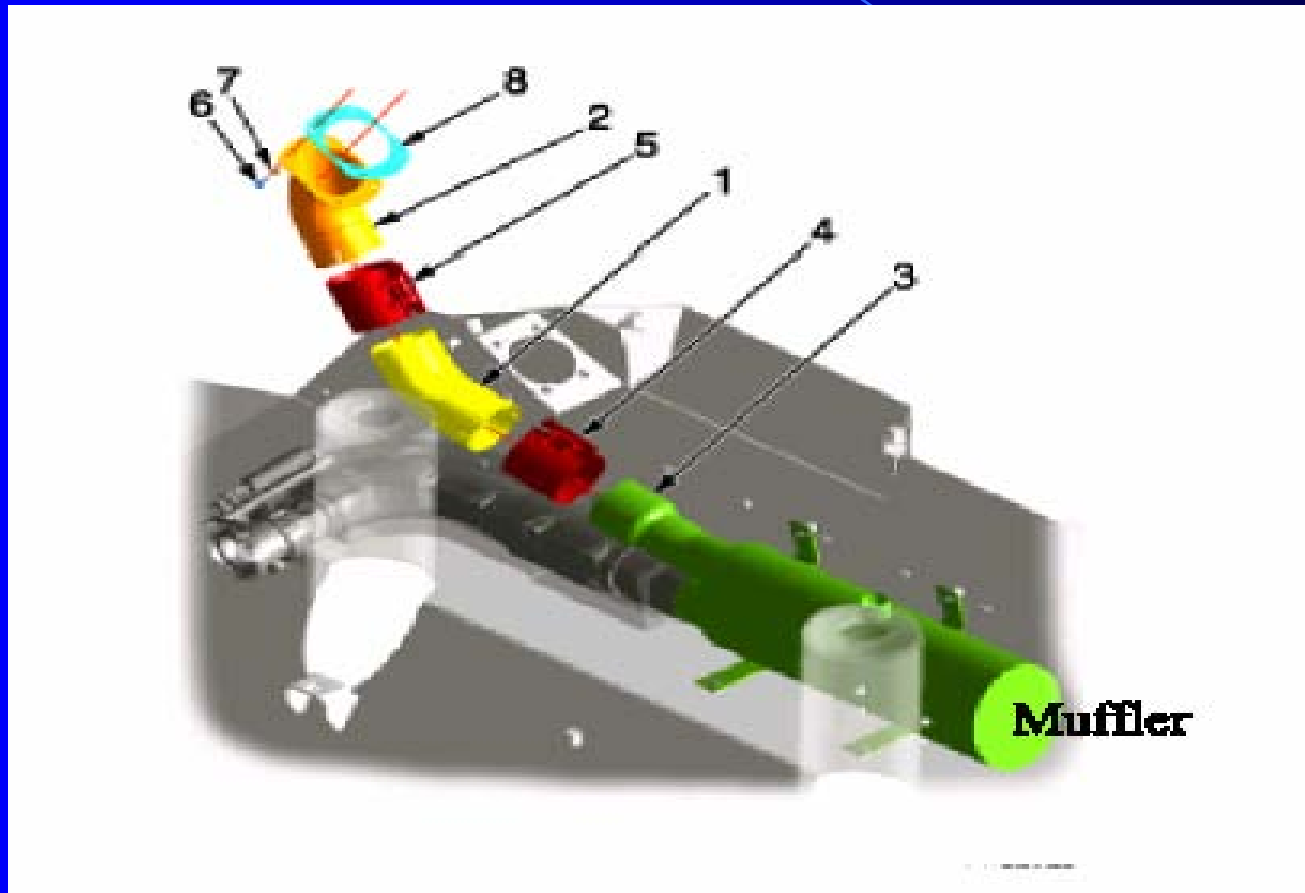
Stryker Interior in Back of Driver

Similar strut arrangement on other side for muffler

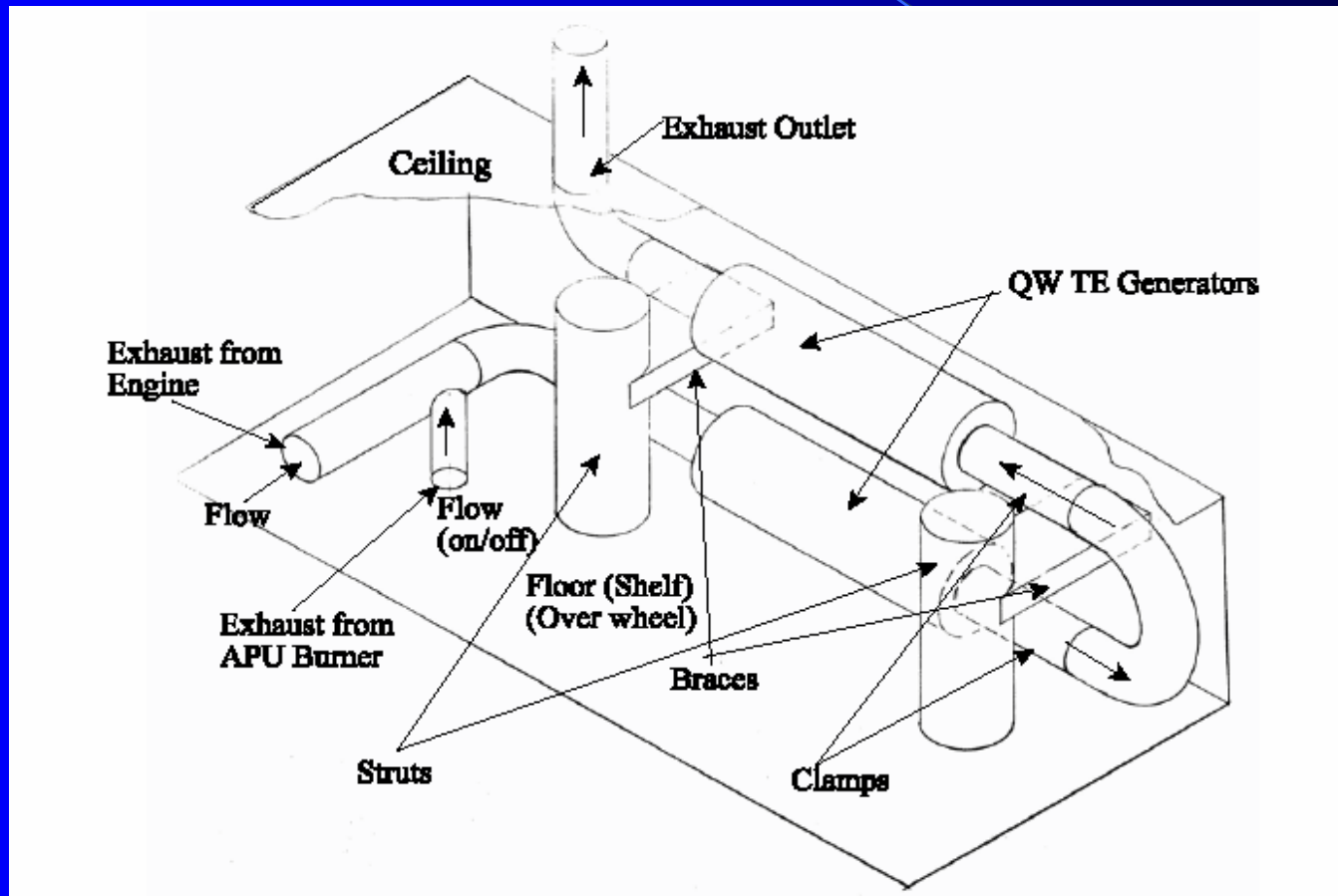


Stryker Drawing Inside Hull

Muffler can be replaced by QW TE Generators



Underarmor Arrangement of Two 5 kWe QW TE Generators



Five kWe QW TE Generator

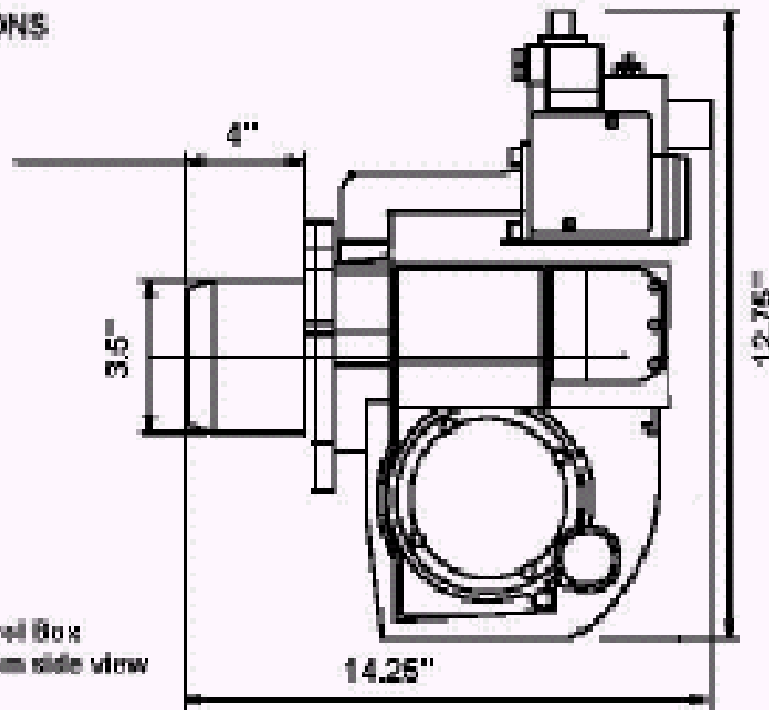
- Packaged in 10 in. diameter by ~27 in. long space
- Exhaust gas QW TE generator pressure drop matched to muffler
 - Swirl enhances gas heat transfer
- Contains 64 QW TE modules in octagonal arrangement
- Separate APU burner

APU Burner for QW TE Generator

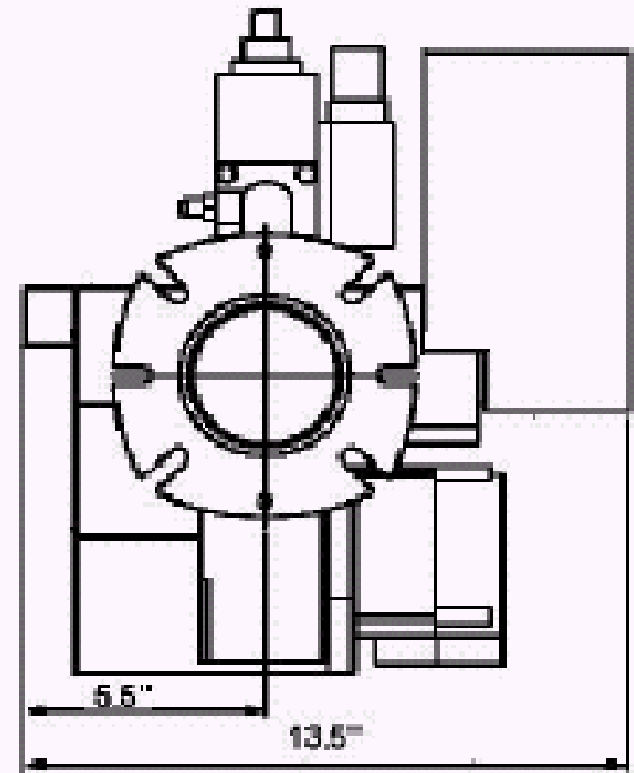
Pioneer 2K diesel burner from HeatWise

Technical Data
SU-2A Gas Burner

DIMENSIONS



Note: Control Box
Omitted from side view



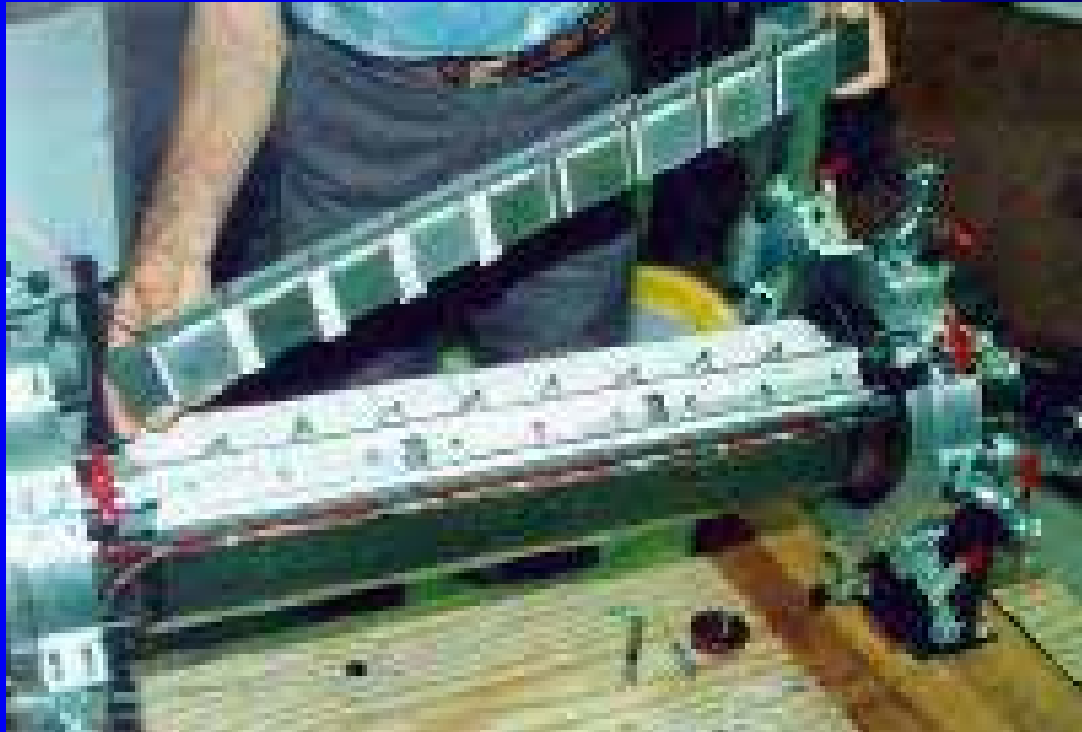
1kWe Bi₂Te₃ TE Generator

Mounted under cab of class 8 truck on test track



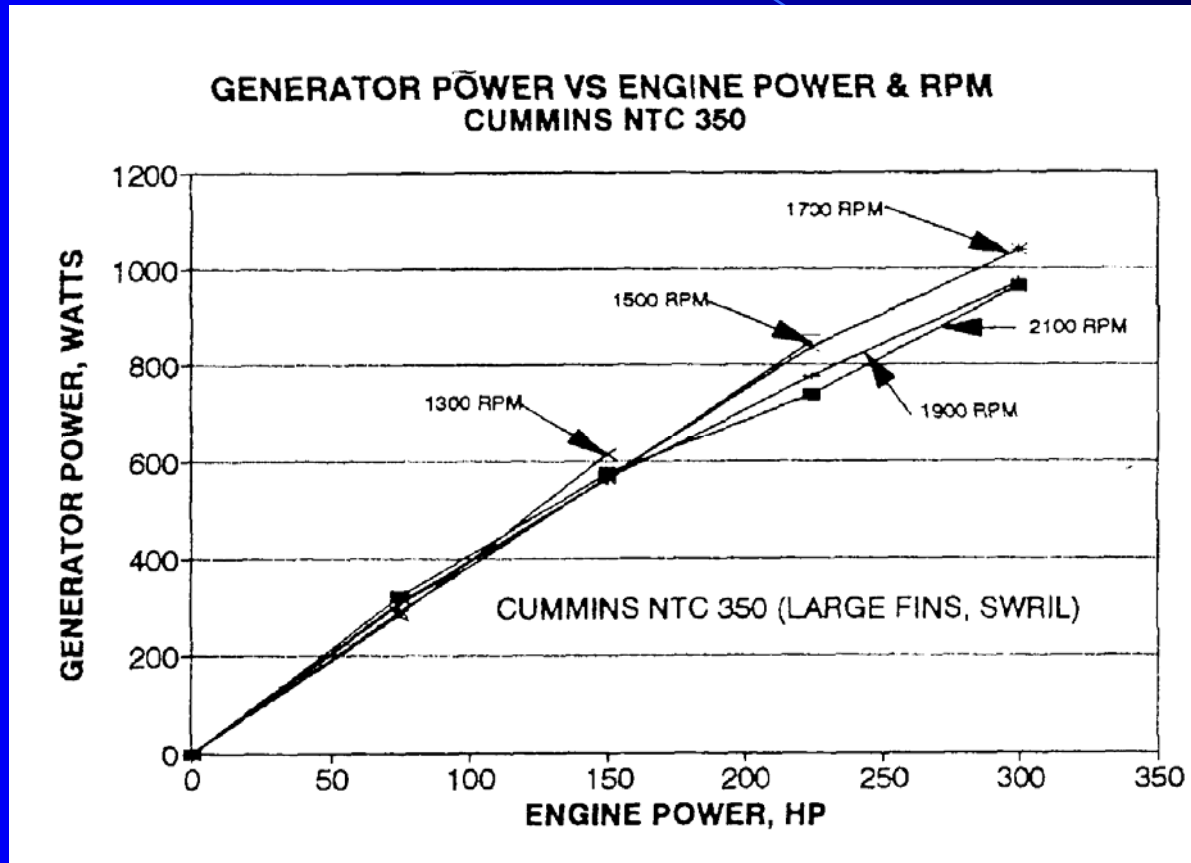
Assembly of the Array's of 9 Bi₂Te₃ TE Modules for 1kWe TE Generator

Total of 72 Modules



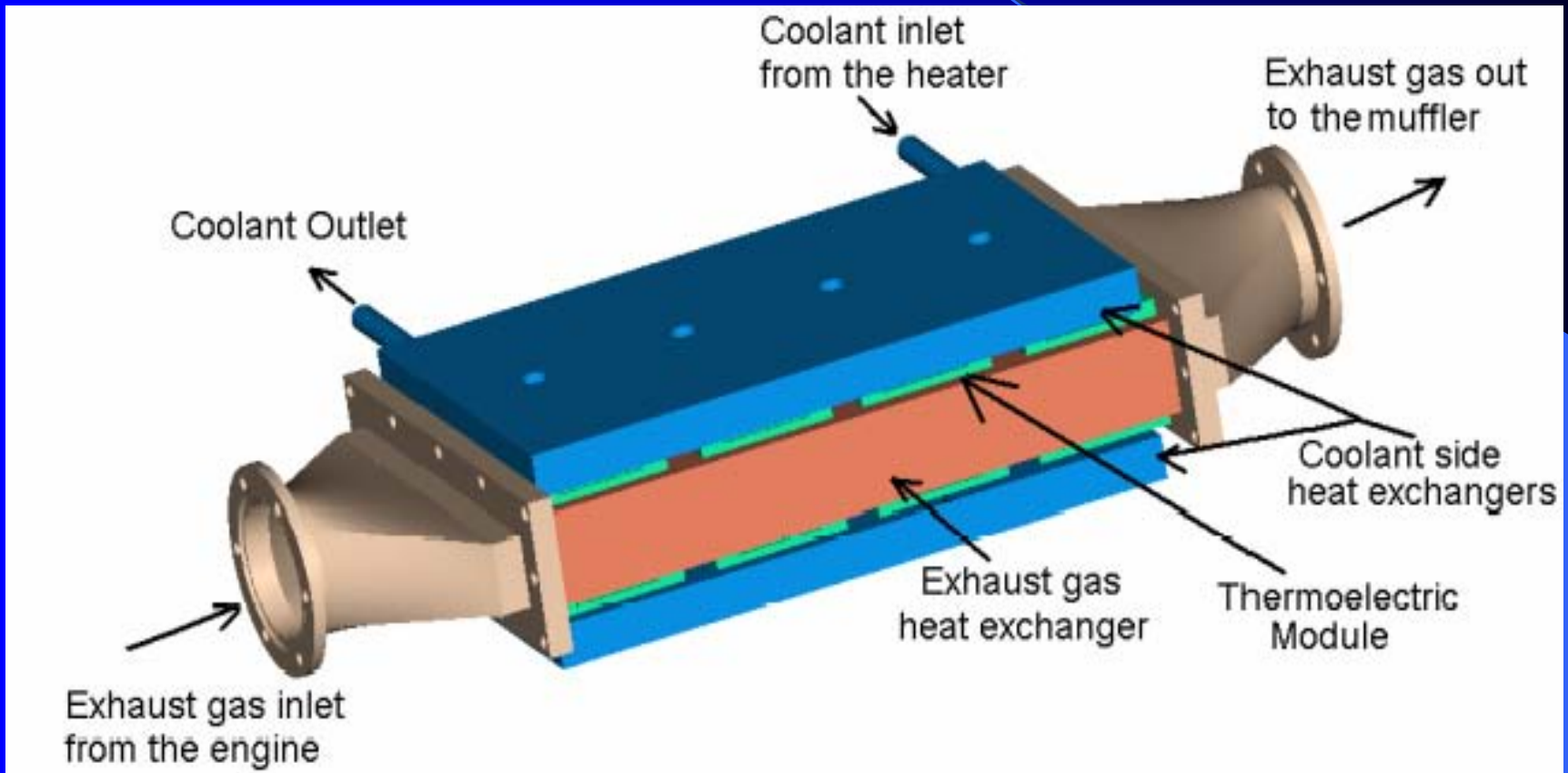
Redundancy provided by parallel connects

Data From 1 kWe Bi₂Te₃ TE Generator on Cummins Engine

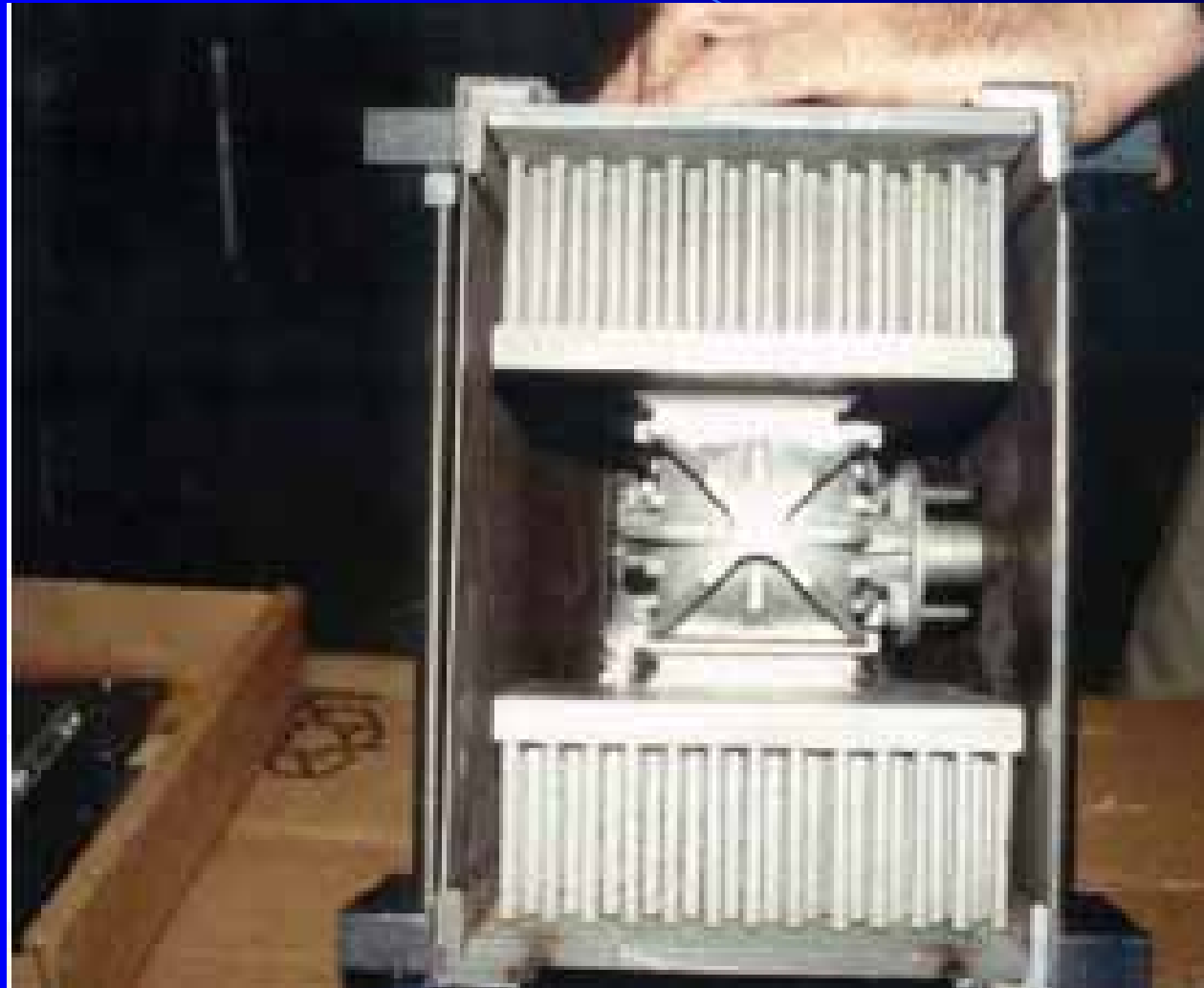


Rendering of 300 We Bi₂Te₃ TE Generator

Currently under test in Sierra pickup truck

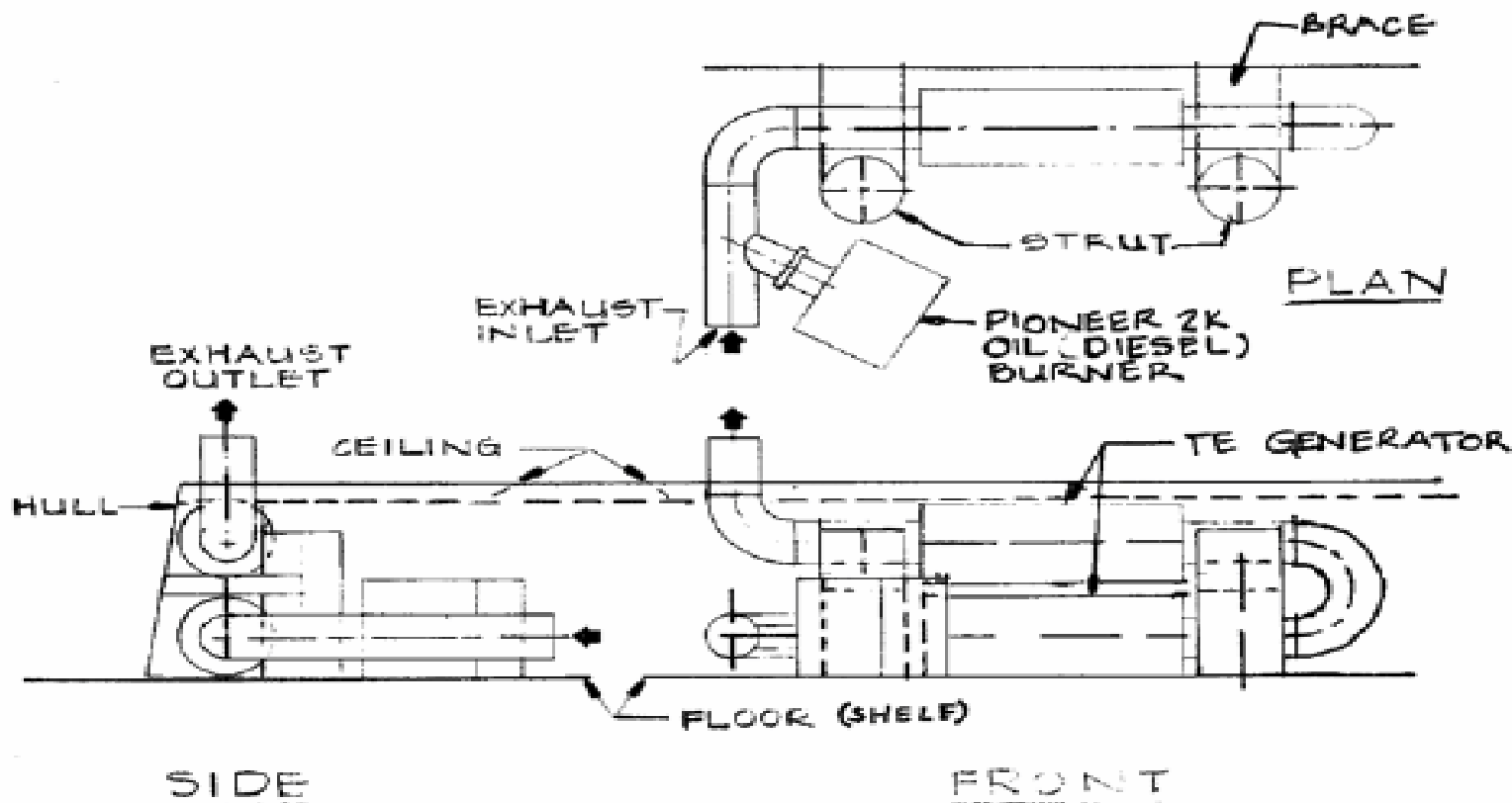


20 We Self-Powered Heater

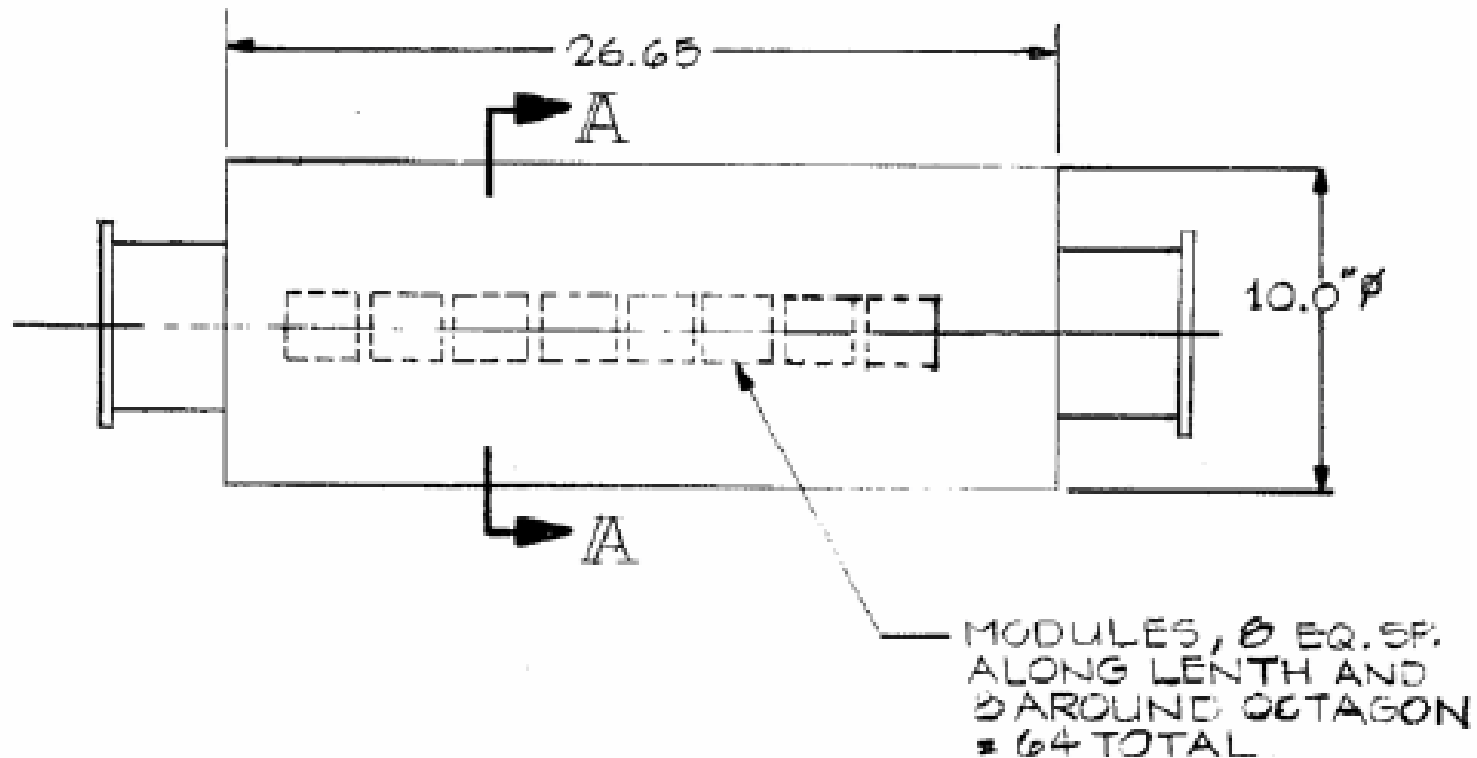


Stryker Exhaust with Two 5kWe QW TE Generators

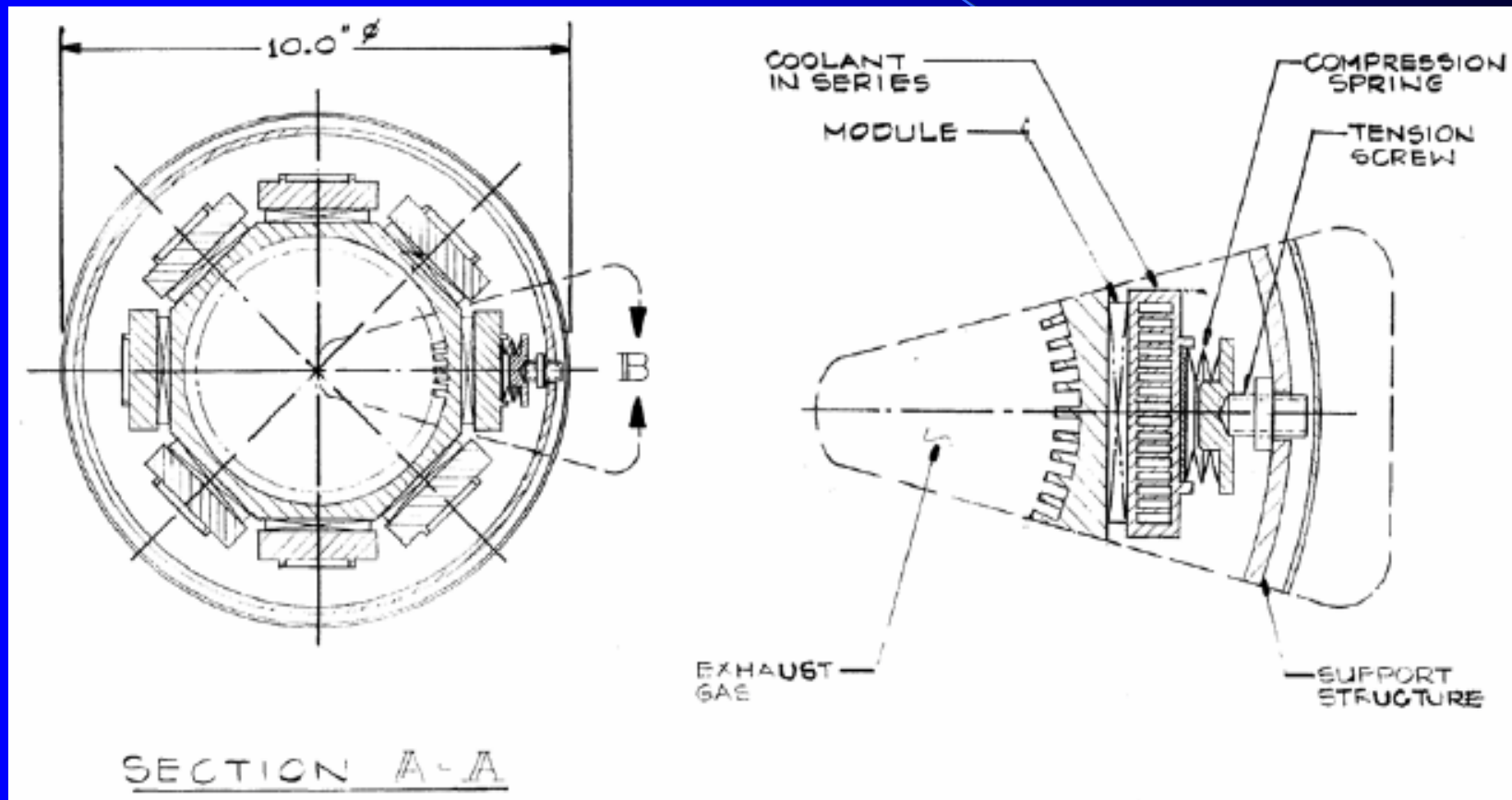
APU Burner shown near exhaust inlet to TE generator



Side View of One of Two 5 kWe QW TE Generators for Stryker

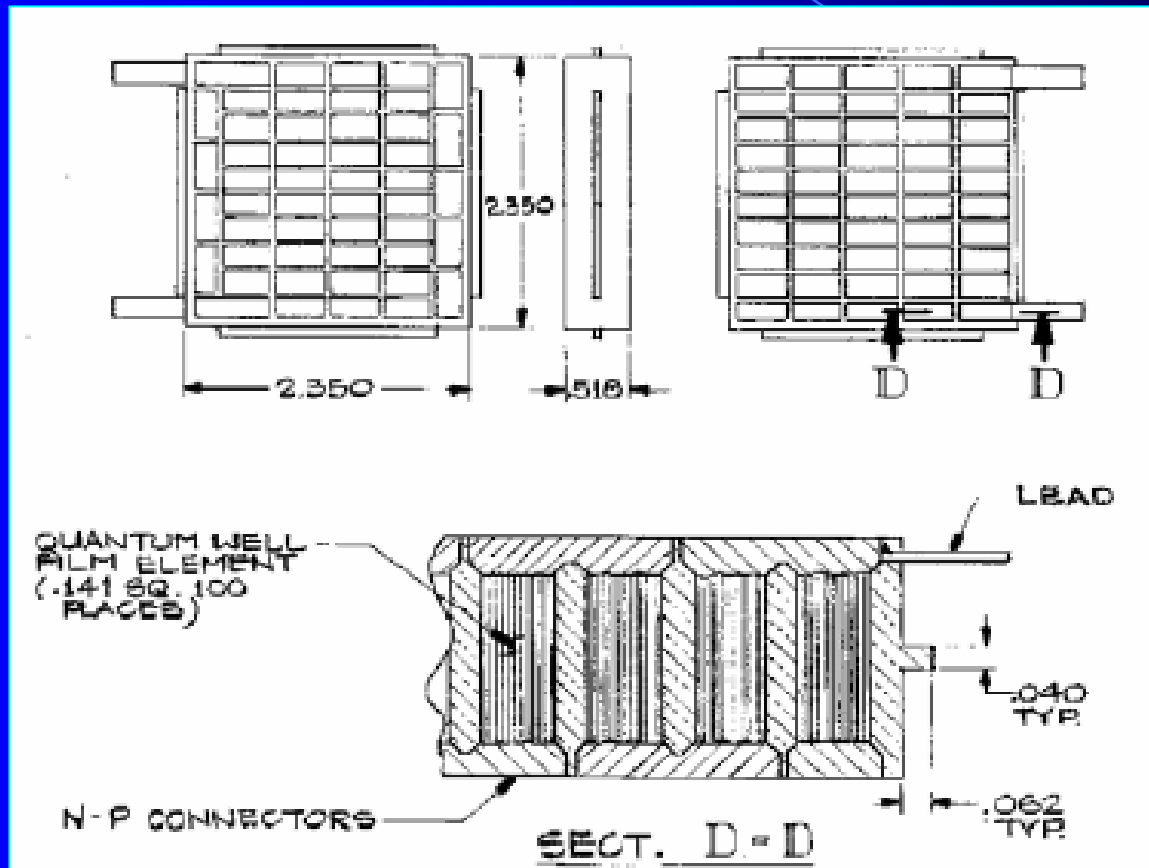


Cross-section of 5 kWe QW TE Generator - Octagonal Arrangement



QW 50 We Module

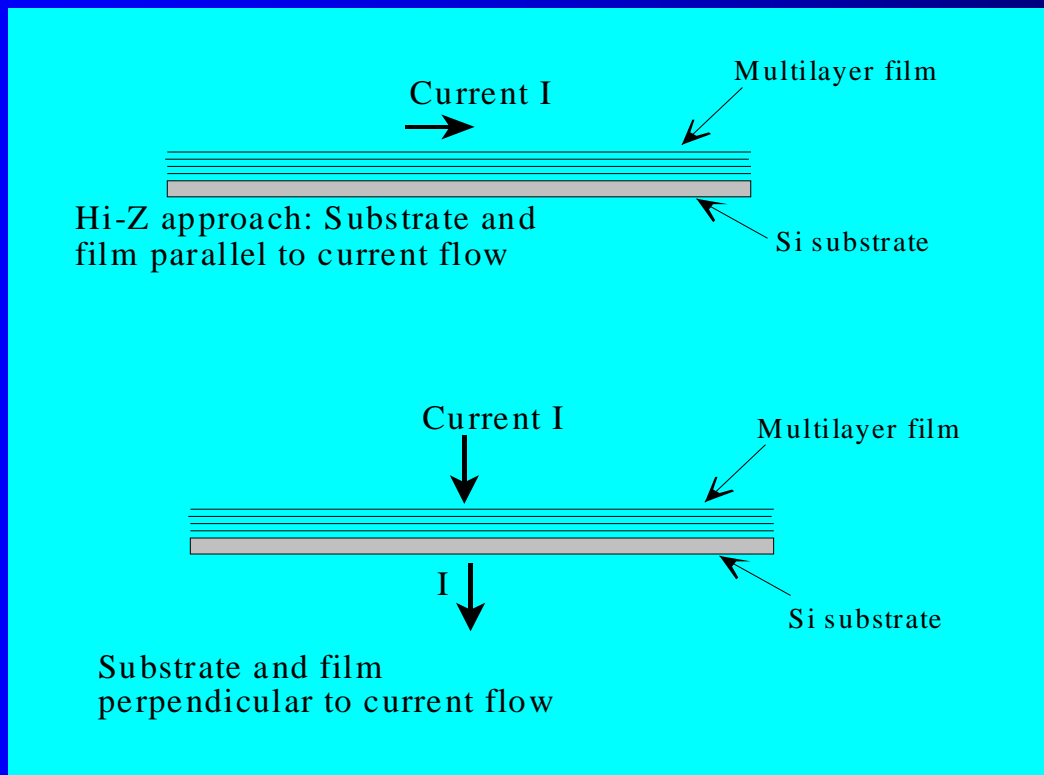
At temperature difference of 200 C, provides 3.5 times the power of today's Bi₂Te₃ TE module



QW Films Parallel or Perpendicular to Current Flow

Hi-Z uses parallel approach to give higher Zs

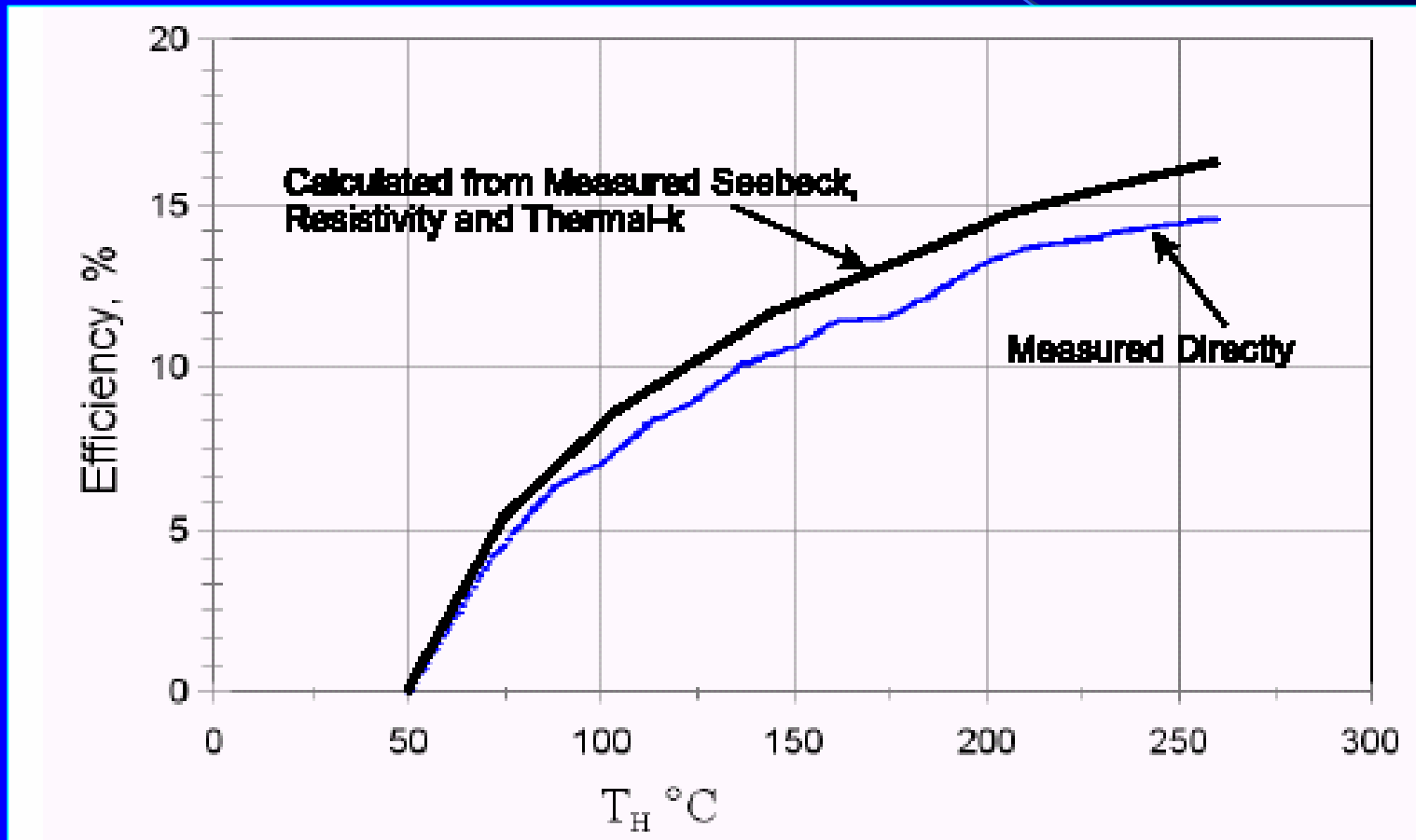
- QW Module with Parallel QW Films
Films in contact with each other in each element



QW Couple Efficiency vs. Temperature

B4C/B9C P and Si/SiGe N-type QW are 11 mm thick.

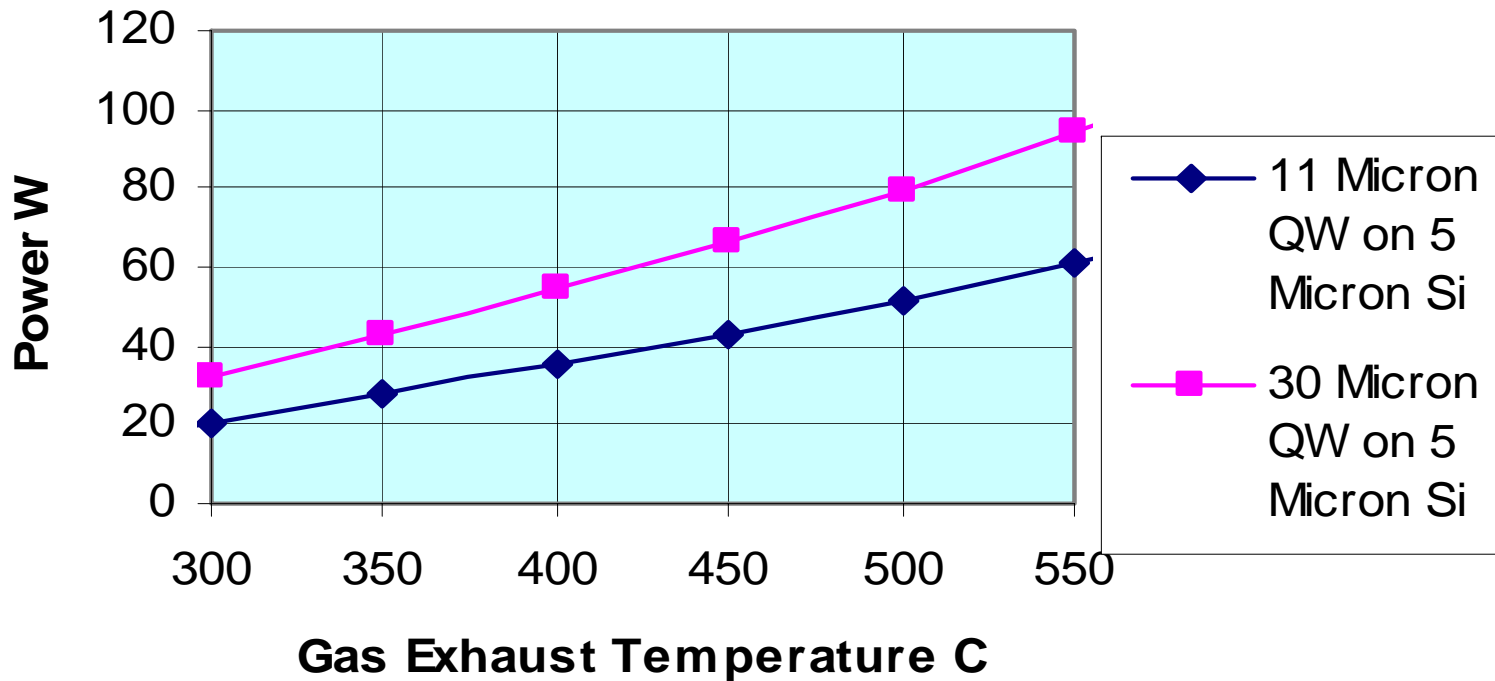
Si substrate is 5 mm thick. Over 100 data points were obtained.



Predicted QW Module Power

Si Substrate with B4C/B9C P and Si/SiGe N-type QW.

Thicker films improve efficiency.

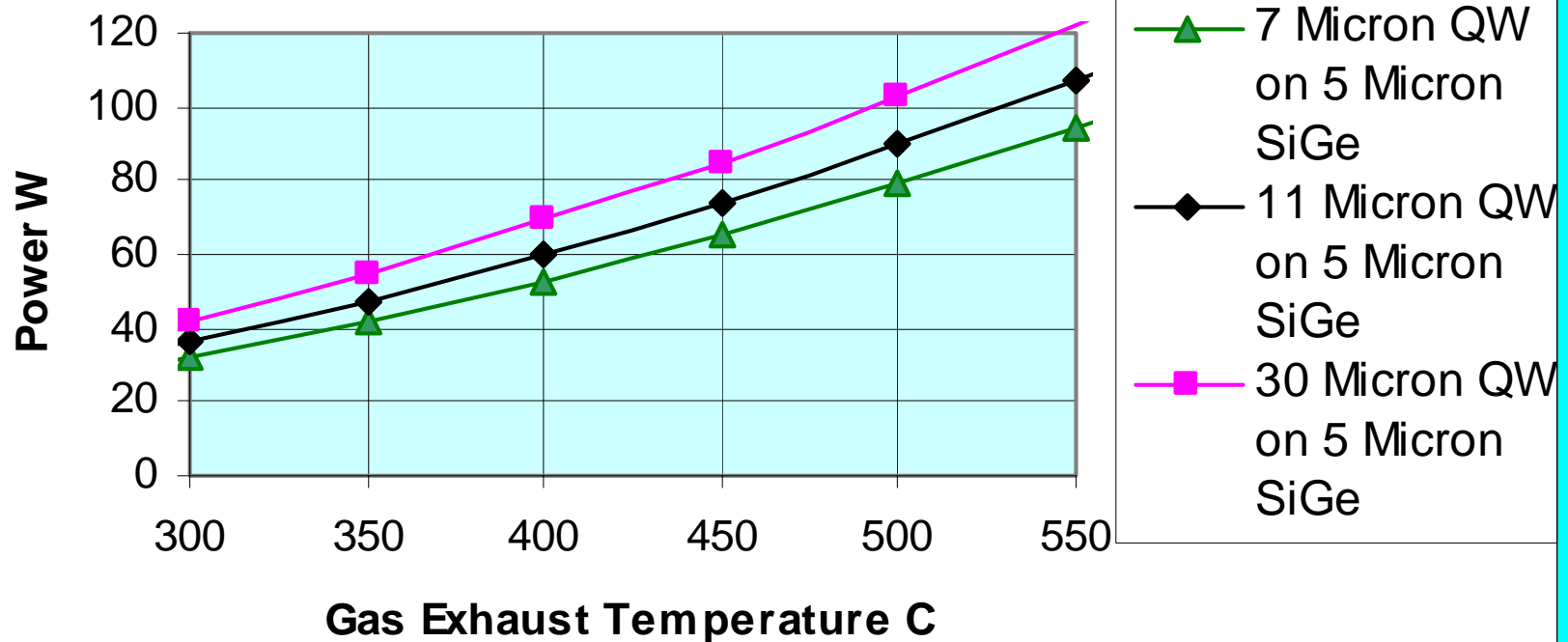


Caterpillar Diesel Engine

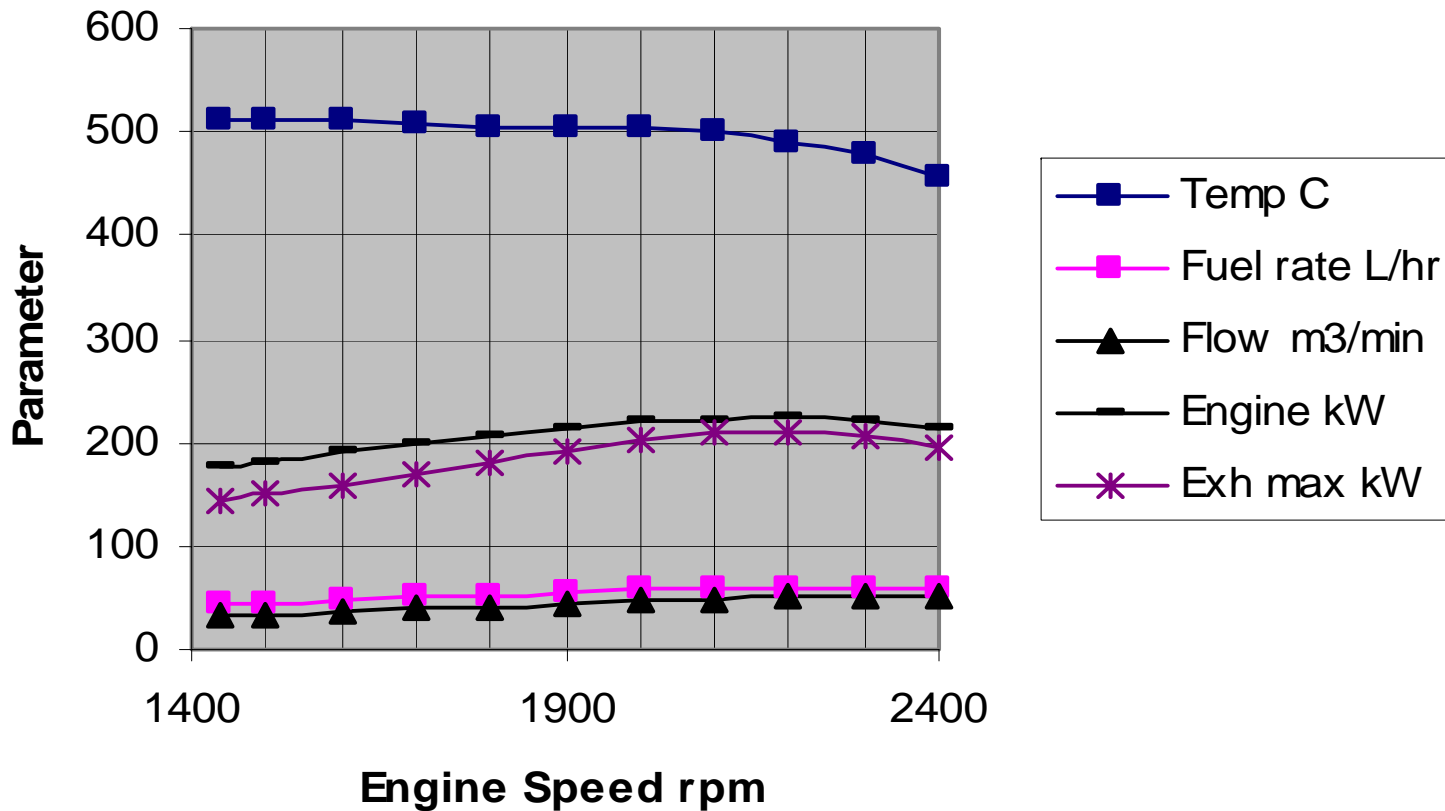
- CAT 3126 300 hp at 2200 rpm
 - Exhaust temperature 495°C
 - Exhaust gas flow 1778 cfm
 - Engine power 224 kW
 - Exhaust power 209 kW

Predicted QW Module Power

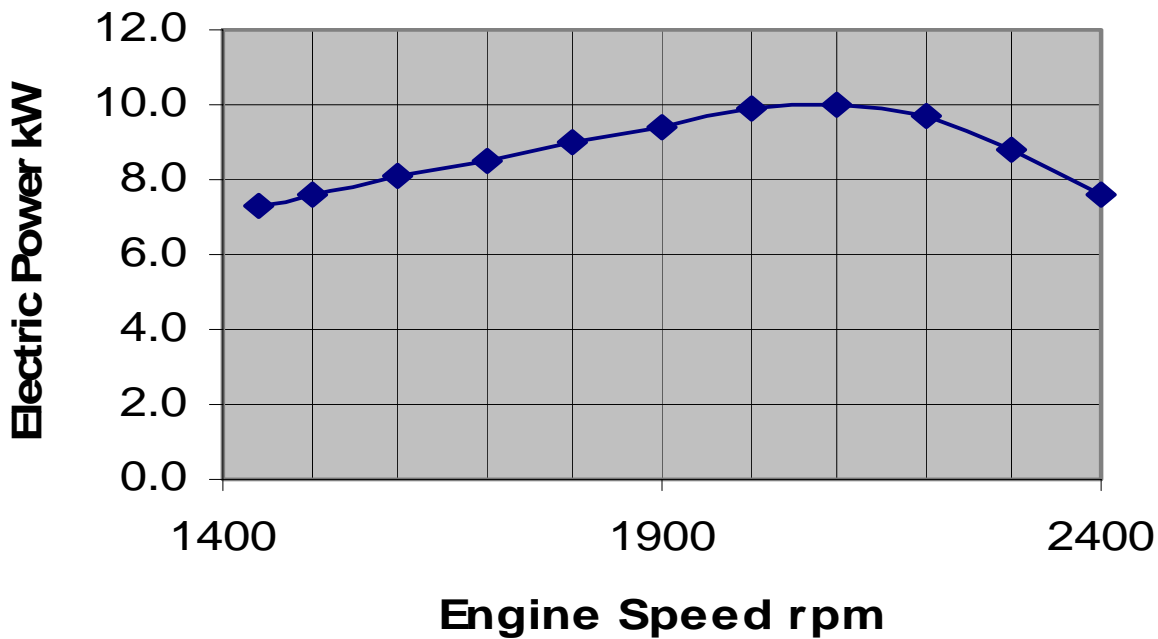
SiGe Substrate with B4C/B9C P and Si/SiGe N-type QW.
Lower conductivity substrate than Si improves efficiency.



Stryker CAT 3126 300 hp Diesel Performance Data



Predicted Stryker QW TE Generator Power



QW TE Generator for Stryker

- Conclusions
- QW TE generators can be sized to give 10 kWe in Stryker exhaust stream
- QW TE modules give 15 to 20% efficiency at Stryker exhaust temperatures
- Continuing QW film development and low resistance ohmic contacts required
- One TE generator with 64 QW modules is predicted to give 5 kWe
- QW TE generator gives 3 to 4 times power of Bi₂Te₃ TE generator in same space
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