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The Development of Industrial Waste Heat Power Generation

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Abstract: *In recent years, the global emphasis has shifted towards addressing issues such as rapid economic growth, energy shortages, waste heat from internal combustion engines, and environmental concerns. Internal combustion engines typically convert only 30-40% of fuel energy into useful mechanical work, with the remainder being dissipated as heat into the atmosphere through cooling systems and exhaust gases. This results in entropy generation and significant environmental pollution. Technologies like thermoelectric generators (TEGs) offer a promising solution for capturing and converting this waste heat into usable energy*.

Keywords: Thermoelectric generators, waste heat recovery, environmental pollution, internal combustion engines

I. INTRODUCTION

For over a century, internal combustion engines have dominated as the power source for automobiles and other vehicles. Increasing fuel costs and concerns over dependency on foreign oil have driven advancements in engine technology to reduce fuel consumption. This research introduces a novel approach to energy generation by utilizing waste heat. The project employs a mechanical system combined with embedded technologies to transform mechanical energy into electrical power efficiently. The system includes an Arduino controller, a liquid crystal display (LCD), and other components to enhance user interaction and functionality. To deliver power to the circuits, we also use a traditional battery charging medium. The TEP Transducer is being used in this research.An outfit that transforms one type of energy into another is called a transducer. This encompasses mechanical, electrical, thermal, and light energy as well. Any device that converts energy is appertained to as a transducer, indeed though the term generally implies the operation of detectors or sensors(1).

The generated electrical energy powers a fan and is stored in a battery. An inverter then converts 12V DC to 230V AC to supply power to various AC/DC loads. Additionally, a TEP transducer is employed, which facilitates the transformation of thermal energy into electrical energy. This robust system effectively recycles heat energy and contributes to reduced environmental pollution.

FEATURES OF TEG

- Silent operation with high reliability, typically offering over 100,000 hours of continuous operation.
- Compact, lightweight, and easy to use.
- Operable at high temperatures, making them suitable for extreme environments.
- Ideal for small-scale or remote applications.
- Environmentally friendly and position-independent.

II. EXPERIMENTAL SETUP

Power generation from waste of industries

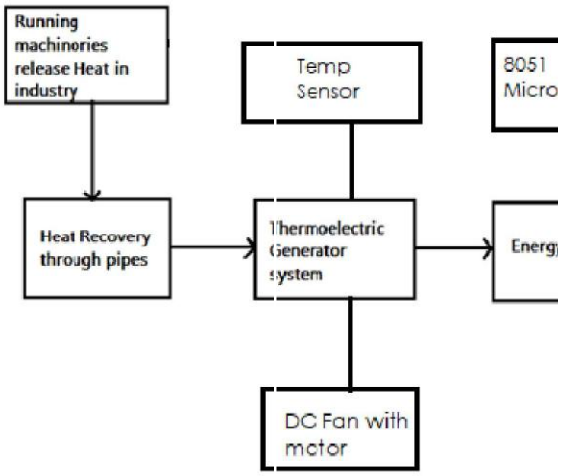


Fig 2.1:- Block Diagram of system

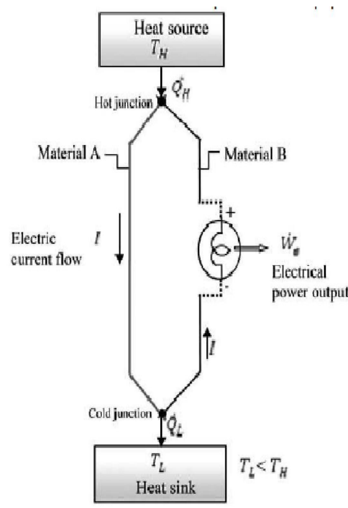


Fig 2.2:- Working Principle

A TEG consists of two sides: one hot and one cold. When there is a temperature difference, electrons are pushed from the n-type leg on the hotter side to the p-type leg on the cooler side through a metallic connection. This movement creates a continuous flow of heat, which generates a steady electrical current, provided the temperature difference remains consistent.

- Transforming mechanical energy into electrical energy is an example of non-traditional energy utilization. The project establishes a reliable and efficient energy generation system based on thermoelectric principles.
- Industrial machines constantly operate to produce goods, generating substantial heat as a byproduct. This waste heat is harnessed to produce energy, potentially reducing air pollution.
- A heat pipe is utilized to channel waste heat to a TEG module coupled with a heat sink. The TEG simultaneously converts thermal energy into electrical energy. A temperature sensor within the system quantifies the heat.
- A DC fan connected to the system visually demonstrates the conversion process, with its speed increasing as the temperature rises.

- Generated electrical energy is stored in batteries and later converted from DC to AC using an inverter. This AC energy is utilized to power various loads within the industry, such as fans, air conditioners, and lights.
- An 8051 microcontroller (AT89S52) and an LCD display are included to monitor battery voltage levels.
- The system starts by capturing heat waste during industrial production processes. It then converts this heat into electricity, which is stored in batteries. The stored electricity is converted to AC via an inverter, and a microcontroller displays voltage levels. The inverter is ultimately connected to AC loads. This technology can potentially reduce heat waste and address vehicle-induced air pollution if implemented in the automotive industry.

COMPONENTS SPECIFICATION

- Thermoelectric plates
- Exhaust fan with an aluminum heat sink
- Silencer - Heat source (e.g., an engine)
- DC motor with a fan
- Battery
- Inverter module
- Temperature sensor
- Controller board (8051 microcontroller)
- LCD display (16x2)
- Wiring
- Switches
- LED bulb
- Metallic frame
- Connector circuit board
- Adapter

NECESSITY OF TEG (THERMO ELECTRICAL GENERATOR) :-

TEGs are favoured for waste heat recovery due to their noiseless operation, absence of hazardous materials, and capability to convert significant amounts of waste heat into usable energy. These systems play a pivotal role in reducing industrial air pollution and enhancing energy efficiency.

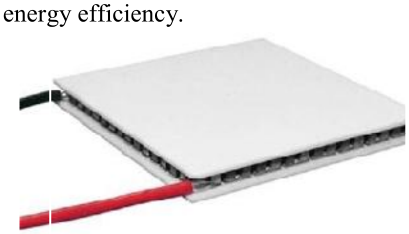


Fig 2.1: Teg

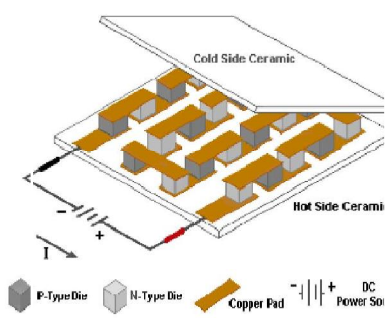


Figure 2.2: Internal Structure of Teg

POWER GENERATION BY SEEBECK EFFECT:

The Seebeck effect involves generating an electrical current by applying a temperature gradient across two dissimilar conductors. For example, in an exhaust gas pipe with a temperature differential of approximately 373K, TEGs can produce up to 10W of power. This technology is particularly effective in industrial applications where steady gas flow facilitates heat recovery.

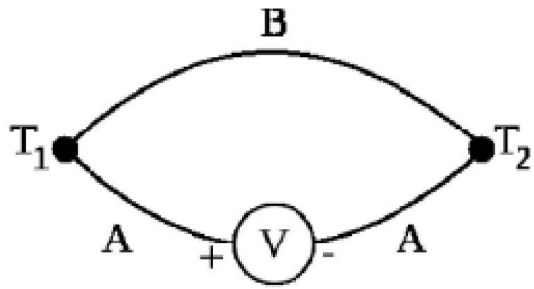
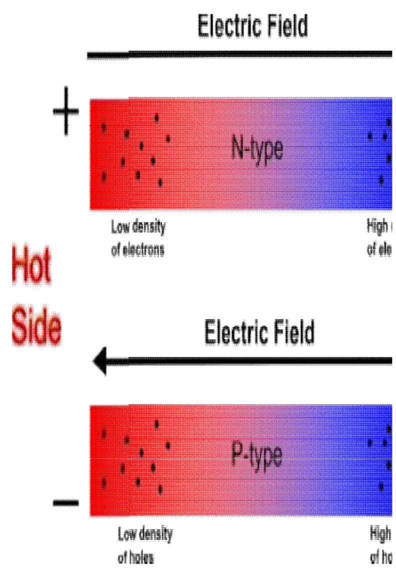
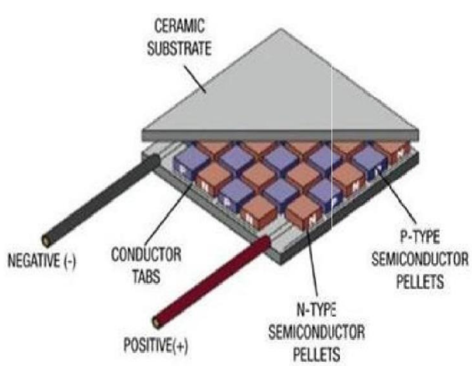


Fig 2.3: Seeback Effect

CAD MODEL



OVERALL SYSTEM



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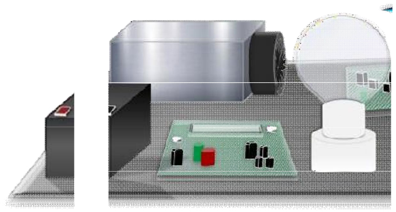


Fig 2.4: Overall Setup

BENEFITS

Thermoelectric generators (TEGs) are solid-state devices without any moving components during operation. This lack of mechanical parts reduces maintenance requirements and eliminates the use of chlorofluorocarbons. Additionally, they have a compact and adaptable design, allowing for precise temperature control to a very fine degree [10].

Unlike conventional refrigeration systems, TEGs are suitable for harsher environments and more compact spaces. They offer flexibility in control by adjusting the voltage or current input and are characterized by their extended operational lifespan.

II. RESULT & CONCLUSION

The implementation of TEG systems offers both direct and indirect benefits.

Direct Benefits:

- Improved efficiency of combustion processes.
- Reduced operational costs and utility consumption.

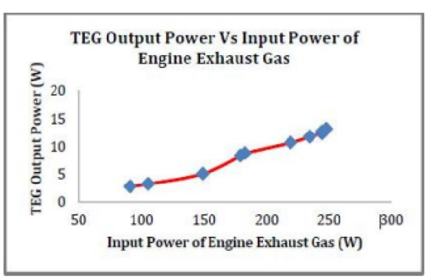
Indirect Benefits:

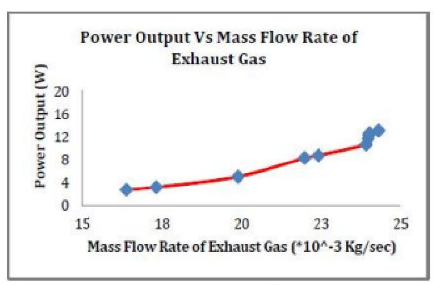
- Decreased pollution due to reduced emissions of harmful gases like NOx and CO.
- Minimized equipment size and auxiliary energy consumption due to lower fuel usage.

The experimental results obtained are tabulated as follows:

Table 1: Voltage generated and boosted for different temperatures

TEMPERATURE DIFFERENCE (K)	VOLTAGE WITHOUT BOOSTING (VOLT)	VOLTAGE AFTER BOOSTING (VOLT)
79	0.02295	1.43
99	0.0269	2.52
119	0.03443	3.20
139	0.04017	3.84
149	0.04017	3.84
159	0.04591	4.93
179	0.05165	5.36
199	0.05739	6.09





TEG Output Power Vs Input Power pf Exhaust heat Gas Power Output Vs Mass Flow Rate of Exhaust Heat Gas

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III. CONCLUSION

The process of harnessing and converting waste heat generated by industrial machinery into electricity. Adopting this technology within the industrial sector can facilitate enhanced monitoring of machine performance and emission levels. By integrating the thermoelectric system into operations, substantial amounts of electricity can be generated, which can then be used to power industrial equipment. Furthermore, this system effectively utilizes waste heat, reducing its contribution to environmental pollution. Industrial implementation of such systems plays a vital role in mitigating environmental contamination.

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