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# Thermal Performance in Radiator by Principle Thermodynamic

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**Abstract**

The thermal performance of automotive radiators plays an essential role in vehicle cooling systems and all other related systems. Experiments to measure the air velocity at a certain point of a rectangular radiator are being performed to determine the velocity of airflow from the radiator cooling fan. From this experiment, the fan's specific issues are not covered by the fan due to its rectangular shape. When a radiator fan is commonly used with housing to supply airflow to the radiator's entire surface, specific points on the radiator are still not covered with the required airflow velocity or exposed to airflow. Research on the principles of heat transfer and its range concerning compact heat exchangers will form the basic knowledge that will be mastered by the principles of fluid mechanics and thermodynamics.

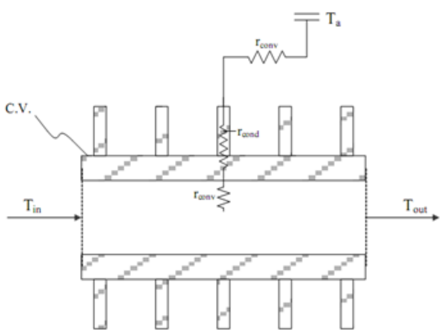


*Key-word: - Airflow, Velocity, Heat transfer, Radiator*

## 1. Introduction

The heat exchangers' performance that emits heat from different engines and condensers from the passenger compartment for comfort is also used as radiators. With the increasingly sophisticated design of vehicles, there is a greater demand for compact heat exchanger units for engine cooling and passenger comfort. This study proves the data and results on the development of radiators in the field of industry. Compact heat exchangers are used in various applications, including in the heat rejection system in automobiles, residential air conditioning, oil cooler, and radiator. One of the essential objectives of past investigations on compact heat exchangers has been developing a high-performance heat exchanger.

For current radiator designs, a typical configuration is to use parallel tubes with aluminum fins attached to them. There are three modes of heat transfer in these designs: conduction between tube walls with fins and two ways others with convection. The convection mode is due to the coolant flowing in the tubes, and the second is caused by the air flowing through the radiator. Associated with each type of heat transfer is a thermal resistance, which obstructs the heat transfer rate, as shown in Figure 1 below.





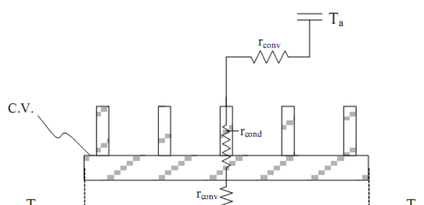



**Figure 1** A control volume thermal diagram

$$r_{cond} = \frac{R_{cond}}{L_{pipe}} \quad \text{(Eq. 2.0)}$$

$$R_{cond} = \frac{L_{fin}}{k_{fin} A_{fin}} \quad \text{(Eq. 2.1)}$$

$$r_{conv} = \frac{R_{conv}}{L_{pipe}} \quad \text{(Eq. 2.2)}$$

$$R_{conv} = \frac{1}{hA_{SA}} \quad \text{(Eq. 2.3)}$$

Here, Tin represents the fluid inlet temperature, $T_{out}$ represents the outlet fluid temperature, and $T_a$ represents the ambient air temperature. As shown by Eq. 2.0, thermal resistance due to conduction per unit length ($r_{cond}$) is equal to the total resistance due to conduction ($R_{cond}$) divided by the length of the pipe ($L_{pipe}$). Eq. 2.1 defines Rcond. In this equation, $L_{fin}$ is the fin's length, $k_{fin}$ is the thermal conductivity associated with the fin material, and Afin surface is associated with conduction. In this case, it would represent the bottom surface area of the fin. In Eq. 2.2, $r_{conv}$ is equal to the total resistance due to convection ($R_{conv}$) divided by the pipe's length. Here, $R_{conv}$ is equal to 1 divided by-product of the convective coefficient associated with the air (h) and the surface area exposed to the atmosphere (A.S.A). This can be seen by Eq. 2.3.

In current radiator designs, the most considerable thermal resistance is caused by the convective heat transfer ($R_{conv}$) associated with the air. This comprises over 75% of the total thermal resistance. The second-largest thermal resistance is caused by the convection that is related to the fluid. Together, these resistances comprise over 97% of the total thermal resistance. Since there is a considerable thermal resistance associated with the air, increased heat transfer performance must address this side. Therefore, a radiator needs to design a radiator that reduces the percentage of thermal resistance associated with the air.

Heat exchangers serve a specific purpose in controlling a system's or substance's temperature by adding or removing thermal energy. Although there are many different sizes, levels of sophistication, and types of the heat exchanger, they all use a thermally conducting element, usually in the form of a tube or plate, to separate two fluids, such that one can transfer that energy to the other. The heat exchanger is used to faces a fundamental challenge, fully defining the problem to be solved, which requires an understanding of the thermodynamics and transport properties of fluids. Such knowledge can be combining with some simple calculations to define a specific heat transfer problem and select an appropriate heat exchanger.

To determine the overall heat transfer coefficient for assessing the performance of the heat exchanger. Any deviation from the design heat transfer coefficient will indicate the occurrence of fouling. Heat exchanger performance is usually evaluated by the overall heat transfer coefficient 'U' that is defined by the equation:

$$Q = U \times A \times LMTD \quad \text{(Eq.3.0)}$$

where,

Q = Heat transferred in kCal/hr
A = Heat transfer surface area in m2
LMTD = Log Mean Temperature Difference in °C
U = Overall heat transfer Coefficient kCal/hr/m2/°C

When the hot and cold stream flows and inlet temperatures are constant, the heat transfer coefficient may be evaluated using the above formula. It may be observed that the heat pick up by the cold fluid starts reducing with time.

We built an experimental testing setup to test the performance characteristic of various automotive radiator designs under simultaneous actual heat dissipation loading and various climatic conditions. This research measures the flow characteristics of automotive compact heat exchanger units under real conditions using experimental techniques.

## 2. Methodology

**2.1 Introduction**

Radiators are installed in automobiles to remove heat from the coolant. The use of higher output engines with tightly compacted underhood packaging, new emission components, and aerodynamic front end styling with narrower openings are creating a hostile thermal environment in the engine compartment. These results show a smaller volume of underhood cooling air. So, to handle higher volume flow rates of air, axial flow fans are used to cool the radiators. These fans consume a considerable amount of power from the engine, and hence the performance of the axial flow fan is an essential parameter of the engine cooling system's efficiency.

**2.2 Experimental with the actual radiator**

An experiment to determine an actual radiator's temperature distribution was done by using the Proton Magma 12V engine block. Three K-type thermocouples were used to measure the temperature at various points on the radiator to log the temperature. The temperatures were used and analyzed so the critical cooling point could be known. Figure 2 until 4 shown the experimental process.

**Figure 2** Actual radiators were done by using the Proton Magma 12V engine block.

**Figure 3** Three K-type thermocouples were used to measure temperature
at various points on the radiator to log the temperature.

**Figure 4** The temperatures were used and analyzed so the critical cooling point could be known.

## 3. Result and discussion

### 3.1 Introduction

The apparatus is three units of UT33C Multimeter, three units of thermocouple probe,1 unit of Velocicalc Plus, and 1 set of Proton Magma12V engine block (Run at approximately 900 – 1000 rpm).

### 3.2 Air velocity versus distance

An experiment to measure air velocity at a certain point of a rectangular radiator was being carried out to determine the airflow velocity from the radiator cooling fan. From this experiment, the fan's specific points were not covered by the fan due to its rectangular shape. Even though a typical radiator fan comes with a housing to supply airflow to the whole radiator surface, specific points on the radiator are still not covered with sufficient airflow velocity or exposed to any airflow. The results and graphs are as below:

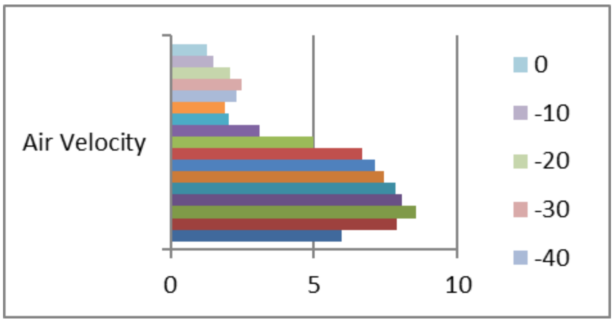



**Figure 5** Air velocity at a certain point on the left part of the radiator from the center.

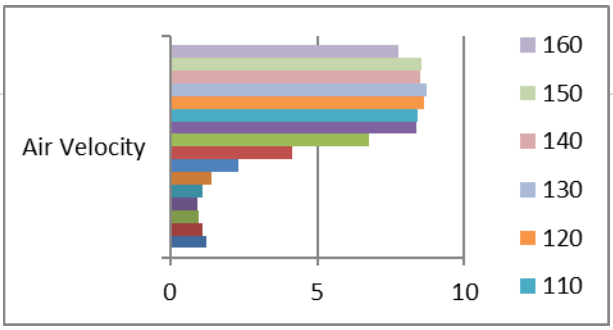


**Figure 6** Air velocity at a certain point on the right part of the radiator from the center.

Figure 5 and 6 shows the comparison of air velocity at a certain point for rectangular along tube profile using experimental setup reading taken for different point. Base air velocity point on the left part goes increases, the point on the right amount of radiator from the center goes on decreases.

**Table 1** Air velocity at a certain point of a radiator.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Point | -160 | -150 | -140 | -130 | -120 | -110 | -100 | -90 | -80 |
| Air Velocity | 5.95 | 7.9 | 8.55 | 8.05 | 7.85 | 7.45 | 7.15 | 6.70 | 5.0 |
| Point | -70 | -60 | -50 | -40 | -30 | -20 | -10 | 0 | 10 |
| Air Velocity | 3.1 | 2.05 | 1.89 | 2.32 | 2.47 | 2.07 | 1.49 | 1.27 | 1.25 |
| Point | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Air Velocity | 1.11 | 0.96 | 0.93 | 1.10 | 1.43 | 2.31 | 4.15 | 6.75 | 8.35 |
| Point | 110 | 120 | 130 | 140 | 150 | 160 | | | |
| Air Velocity | 8.40 | 8.65 | 8.7 | 8.5 | 8.55 | 7.75 | | | |

### 3.3 Measurement at specific point versus times

Apparatus :

- Three units of UT33C Multimeter
- Three units of a thermocouple probe
- One unit of Velocicalc Plus
- 1 set of Proton Magma12V engine block
- Rpm ±900-1000

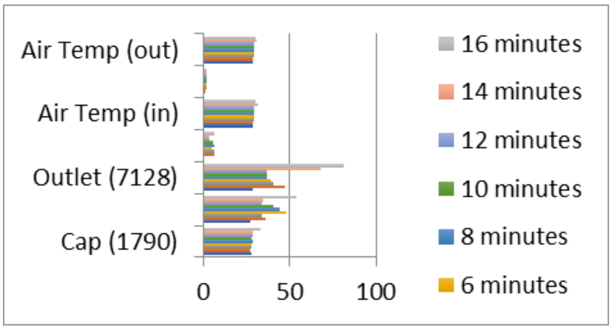



**Figure 7** Measurement at certain point versus times -0-16 minutes (engine stop).

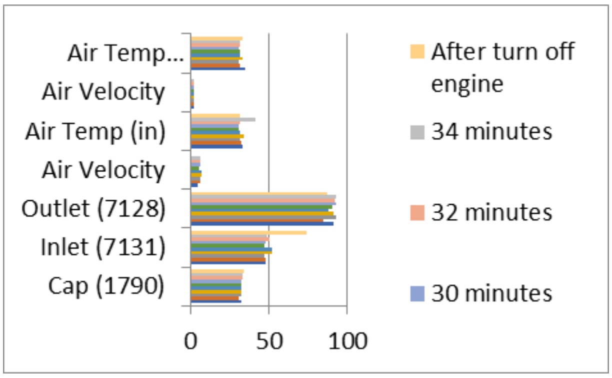



**Figure 8** Measurement at certain point versus times 18-34 minutes (engine stop).

Figure 7 shows measurement at specific points versus times -0-16 minutes (engine stop), and 3.4 shows measurement at times 18-34 minutes (engine stop). After turn off the engine, the result of the inlet is lower than an outlet. The air temperature inlet is lower than the air temperature outlet.

**Table 2** Temperature at a certain point when the engine stop.

| Point | After turn off the engine |
|---|---|
| Cap (1790) | 34 ºC |
| Inlet (7131) | 74 ºC |
| Outlet (7128) | 87 ºC |
| Air Velocity | 0.01ms$^{-2}$ |
| Air Temp (in) | 31.8 ºC |
| Air Velocity | 0.03ms$^{-2}$ |
| Air Temp (out) | 33.5 ºC |

### 3.4 Temperature measurement with fan running

An experiment measuring the temperature at a certain point on the running engine radiator was conducted with constants as stated below :

- Radiator fan switched ON
- Inlet Temperature = 94˚C
- Outlet Temperature = 45˚C

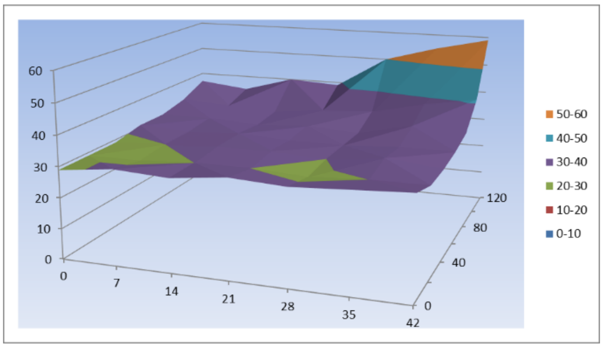



**Figure 9** Temperature measurement at a certain point with fan

### 3.5 Temperature measurement at a certain point without fan running

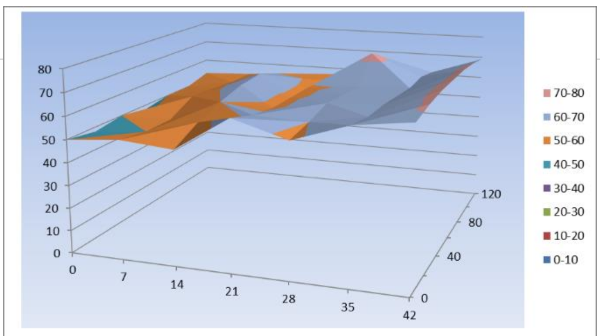


**Figure 10** Temperature measurement at a certain point without the fan running

An experiment measuring the temperature at a certain point on the running engine radiator was conducted with constants as stated below :

- Radiator fan switched OFF
- Inlet Temperature = 94˚C
- Outlet Temperature = 45˚C

## 4. Conclusion

This study shows the spatially resolved heat transfer coefficients for rectangular geometry. This study provides experimental database data representing several geometries. The most obvious disadvantage in the use of this design is the increased pressure through the arrangement. The study will be accurately predicted using CFDs, and optimization techniques are an appropriate choice for round radiators. Future efforts in using this technique must incorporate adiabatic wall temperature into the optimization function. The main goal of this effort is to minimize the average adiabatic wall temperature throughout the network. It will help the thermal interaction get up from the entrance louver with the next downstream louver surface.

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