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Comparison of the cooling effects of a locally formulated car radiator coolant with water and a commercial coolant

[1]Efeovbokhan, Vincent Enontiemonria, [2]Ohiozua, Ohireme Nathaniel
[1, 2] *Department of Chemical Engineering, Covenant University, Canaan Land, Ota, Nigeria*

Abstract

The cooling properties of a locally formulated coolant (sample C) vis-a-vis, its boiling characteristics and specific heat capacity were investigated along side with a common coolant-water (as sample A) and a commercial coolant (sample B). The results of the investigation showed that sample C gave the best performance compared to the other two samples A and B: the boiling points of sample C was 110^0C*, sample A* 100^0C*, and sample B* 101^0C*. This means that the possibility of a boil-out of sample C from the radiator is little compared to samples A and B. Also, for the same quantity of coolant more heat would be required to raise sample C to its boiling point than for samples A and B. In other word, better cooling would be achieved using sample C. The specific heat capacity for sample C was 4238* $Jkg^{-1}K^{-1}$*, which was also a good compromise against samples Abut better than sample B having 4266* $Jkg^{-1}K^{-1}$ *and 4208*$Jkg^{-1}K^{-1}$ *respectively.*

Key Words: *Radiator coolants, Corrosion inhibitors, Overheating, Engines.*

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I. Introduction:

A coolant is a fluid which flows through a device in order to prevent its overheating, transferring the heat produced by the device to other devices that utilize or dissipate it. An ideal coolant has high thermal capacity, low viscosity, is low-cost, and is chemically inert, neither causing nor promoting corrosion of the cooling system.[1-3]. It is usually compounded with a high boiling point liquid which also serves as an anti-freeze agent against extremely cold conditions and problem of overheating in hot weather. A higher boiling temperature means that the coolant can cool better as your engine gets hotter. It also reduces the chance of blowing a head gasket. About a third of the heat energy produced by an internal combustion engines ends up as waste heat in the cooling system [4]. Radiator coolant raises the boiling point of the water, allowing it to carry more heat away from the engine, and thereby preventing engine damage due to overheating. The coolant extracts and disperses more heat fast from the engine and also responds fast to cooling in the radiator for another cycle. That fluid referred to as coolant or antifreeze or anti-boil removes heat around and through the engine to radiator which helps to moderate the engines temperature. [5]. Coolants when circulated throughout the engine it improve heat resistant property, maintain optimal internal operating temperature and deter scales in the engine cooling system that clogs the radiator fins. [6]. The cooling system of the car engine is very important because improper care of the cooling system leads to an engine failure. Aside from optimal engine performance, maintaining the coolant level will go a long way towards prolonging the life of the radiator and other components in the cooling system. Decrease in the cooling system's ability to absorb, transport and dissipate heat caused by low coolant level, loss of coolant (through internal or external leaks), poor heat conductivity inside the engine because of accumulated deposits in the water jackets are some of the major causes of overheating [7]. If the coolant in an engine cooling system is changed before corrosion inhibitors reach dangerously low levels, corrosion damage is prevented [8]. Therefore it is important to use a coolant to avoid possible engine failure, a car coolant or antifreeze is used in internal combustion engines, and for many other heat transfer applications. Compounds are added to the water to both raise the boiling point and reduce the freezing point temperature of the mixture. Corrosion inhibitors may also be added at this stage if desired. The term Colligative agent may better describe the benefits of these compounds in warm climates, since they not only achieve freezing point depression in an extremely cold weather when mixed with water; they coincidentally achieve boiling point elevation of water. Inhibitors are chemicals that react with a metallic surface, or the environment involved, this surface is exposed to, giving the surface a certain level of protection. Inhibitors often work by adsorbing themselves on the metallic surface, protecting the metallic surface by forming a film. Inhibitors are normally distributed from a solution or dispersion. Some are included in a protective coating formulation. Inhibitors slow corrosion processes by either: Increasing the anodic or Cathodic polarization behaviour, reducing the movement or diffusion of ions to the metallic surface and increasing the electrical resistance of the metallic surface. [9] Colligative agents are properly referred to as both antifreeze and "anti-boil" when used for both properties. The term engine coolant is widely used in the automotive industry, which covers its primary function of heat transfer. Coolants, when circulated throughout the engine improve heat resistant property of additives, maintain optimal internal operating temperature and deter scales in the engine cooling system that clogs the radiator fins. [10]. Over heating results when coolants are not used. Overheating could result in accelerated deterioration of the oil and subsequently the engine itself. [11]. Basically in this research, coolant has become a remedy for the problem of overheating and freezing of a cooling system. Coolants are formulated to have the right mix of water and antifreeze to provide adequate freezing and boiling protection. The commonest antifreeze used is ethylene glycol and has a freezing point of 8.6°F (-13°C) and a boiling point of 388°F (198°C), and is completely miscible with water. Ethylene glycol could just as well be called "anti-boil." In industries, ethylene glycol is used as a solvent [12-16].

II. Materials And Methods

Three different coolants including water (Sample A), a coolant purchased from auto car care products, Ota (Sample B), and the formulated coolant (Sample C), were considered. Sample C consists essentially of a 50/50 blend of ethylene glycol and water, 1% corrosion inhibitor and a Dye (green) added to taste were all mixed in their correct proportions.

2.1 Determination of Boiling Point of Coolant

A simple and widely used method for determining the identity of a car radiator coolant is by measuring the temperature at which it boils. This temperature, called the boiling point, is a physical property. Boiling point is formally defined as the temperature at which the vapour pressure of the liquid becomes equal to the pressure at the surface of the liquid. The boiling point of a liquid can change if the pressure at the liquid's surface changes

2.1.1 Procedure

150 ml coolant in a 250ml beaker was set on wire gauze over a Bunsen burner and a thermometer placed in the coolant so that it does not touch the beaker. The thermometer must not be used as a stirring rod. The coolant was heated with continuous stirring, measuring and taking temperature readings every one minute until the coolant began to boil. The temperature at which the coolant began to boil was then noted. The experiment was terminated when the temperature remained constant at this boiling point for five consecutive readings.

2.2 Determination of the Specific Heat Capacity of Coolant by Method of Electrical Heating [17].

Specific heat capacity is the amount of energy needed to increase the temperature of one gram of a substance by one degree Centigrade. The property of specific heat (kcal/kg c) describes the amount of heat required to raise a certain mass through a certain temperature change.

2.2.1 Procedure:

The joule calorimeter and its stirrer without the jacket and heating coil were first weighed. The calorimeter is then filled with the coolant to about 2/3 of its volume. The calorimeter was placed in the jacket and a heating coil connected to a rheostat was immersed in the coolant such that when the circuit was closed, a current of 1.5-2.0A was produced in the circuit. As the circuit was closed the stop watch was started at the same time. The temperature of the coolant at one minute interval was recorded, while stirring the coolant gently and keeping the current constant by means of the rheostat. The circuit was opened to cut off the current after the temperature has risen by about 5^oC but without stopping the watch, recording of the temperature was continued at one minute interval until the temperature has fallen by about 2^oC below the highest recorded temperature. Both the steady current and potential difference maintained during the experiment were also recorded.

2.2.2 Calculating the Specific Heat Capacities of Coolants:

The heating and cooling curve for each coolant is first plotted on three different graphs to enable the computation of the areas A_1 and A_2 under each graph. The specific heat capacity (c) of the coolants may then be calculated using the formula:

$VIt_0 = (m_0c_0 + mc)[(T_2 + p) - T_1]$ .... (1)

Or from equation1

$C = \frac{1}{m}\left[\frac{VIt_0}{(T2+p) - T1} - m_0c_0\right]$.................................... (2)

Where

m_o =mass of calorimeter + stirrer, = 80g=0.080kg

c_0 = specific heat capacity of calorimeter = 380 $Jkg^{-1}K^{-1}$.
C = specific heat capacity of the liquid.
T_1 = initial temperature of liquid, (^{0}C).
T_2 = recorded highest temperature of liquid, (^{0}C).
t_0 = the time taken for coolant temperature to rise by 5^{0}C (s)
p = Cooling correction, (^{0}C) given by the formula $P = \frac{A_1}{A_2} q$…………………………..(3)

Where A_1 = area under the heating curve.
A_2 = area under the cooling curve.
q = temperature difference at the point of cooling = 2^{0}C
Only $t_{0,}$ T_1, T_2 and *p* will have to be determined to calculate the specific heat capacities of the respective coolants.
Data for the three samples are plotted separately on three different graphs to enable the determination of the area A_1 and A_2 under the heating and cooling rate curves (figs. 3.2)

III. Results And Discussion Of Results

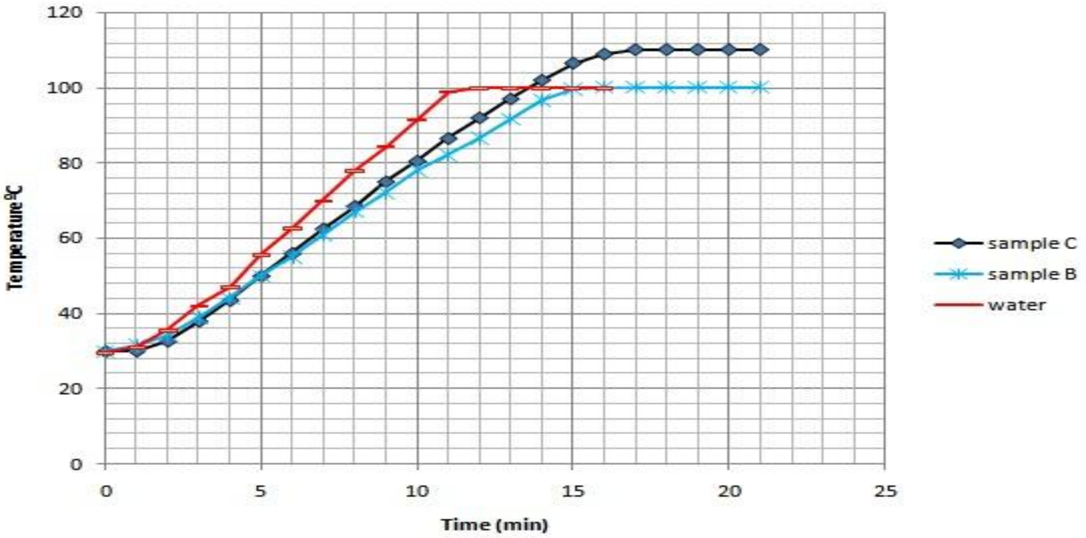

Figure 3.1. Boiling Point Curves for Three Coolants

3.1 The Effects of Boiling Points of the Three Coolants on Cooling.

From Fig 3.1 the curves indicate that water as a coolant (sample A), responds quickest to temperature variations per unit time compared to the other two coolants, samples C and B. For the same quantity of coolants, the temperature of water was highest at any given time up to a time of 12 minutes when it begins to boil and then flattens up at 100^{o}C. This only indicates that it takes shorter times when compared to the other two coolants in an engine block, where it is expected to extract heat before it begins to boil and hence quantity of heat extract or cooling rate of the engine is low. Sample B has a slightly higher boiling point (101^{0}C) than water except that it is able to accommodate more heat before reaching its boiling point. This is shown by the sluggish rise in temperature before reaching its boiling point. The formulated sample C has the highest boiling point of 110^{0}C. Fig 3.1 indicates for sample C, the rate of heat absorption and temperature rise is the average of that of sample A and sample B except that its overall boiling point is much higher. This is boiling point elevation due to the Colligative property of the additives. It shows that sample B (coolant purchased from the auto care shop) has more dissolved solid additives than the other two coolants, hence it gave the slowest rate of heat absorption. Water, which did not have any dissolved solid additives, absorbed heat fastest than the rest. The high boiling point of sample C must have been due to the high boiling component (mono-ethylene glycol) used as part of its formulation. The elevated temperature of coolant C is advantageous as it well able to extract more heat to bring it to boil which means higher cooling rates in the engine block.

Table 3.1 Determining the Specific Heat Capacity of Sample C

Hearing and cooling Time (min)	Heating and Cooling Temperature (^{0}C)
0	29
1	29
2	29.3
3	30.1
4	31
5	33.2
6	33.5
7	34.1
9	34.5
11	35.1
13	35
15	34.9
17	34.8
19	34.7
21	34.6
23	34.5
25	34.4
27	34.2
29	34.1
31	34
33	33.9
35	33.8
37	33.7
39	33.6
41	33.5
43	33.3
45	33.2
47	33.1
49	33

Table 3.2 Determining the Specific Heat Capacity of Sample a (Water)

Hearing and cooling Time (min)	Heating and Cooling Temperature (^{0}C)
0	28.5
1	28.8
2	29
3	30
4	31
5	32
6	33
7	33.5
8	34.5
9	35
10	35
11	35
12	35.1
13	35.1

14	35
15	35
16	35
17	34.9
18	34.9
19	34.8
20	34.8
21	34.7
22	34.7
23	34.6
24	34.6
25	34.5
26	34.4
27	34.4
28	34.2
29	34.2
30	34.1
31	34
32	34

Table 3.3 Determining the Specific Heat Capacity of Sample B

Hearing and cooling Time (min)	Heating and Cooling Temperature (^{0}C)
0	29.5
1	29.6
2	30
3	32.5
4	33.5
6	34.5
7	34.9
8	34.9
10	34.8
12	34.5
14	34.4
16	34.2
18	34.1
20	34
22	33.9
24	33.8
26	33.7
28	33.6
30	33.5
32	33.4
34	33.3
36	33.2
38	33.1
40	33.1
42	33
44	33
46	32.9

3.2 The Effects of Specific Heat Capacities of The three Coolants on Cooling.

Tables 3.1 – 3.2 are the values of heating and cooling temperatures versus time obtained for the three radiator coolants considered. Their Specific heat capacities were then computed from their plotted values shown in figs. 3.2 – 3.4 below.

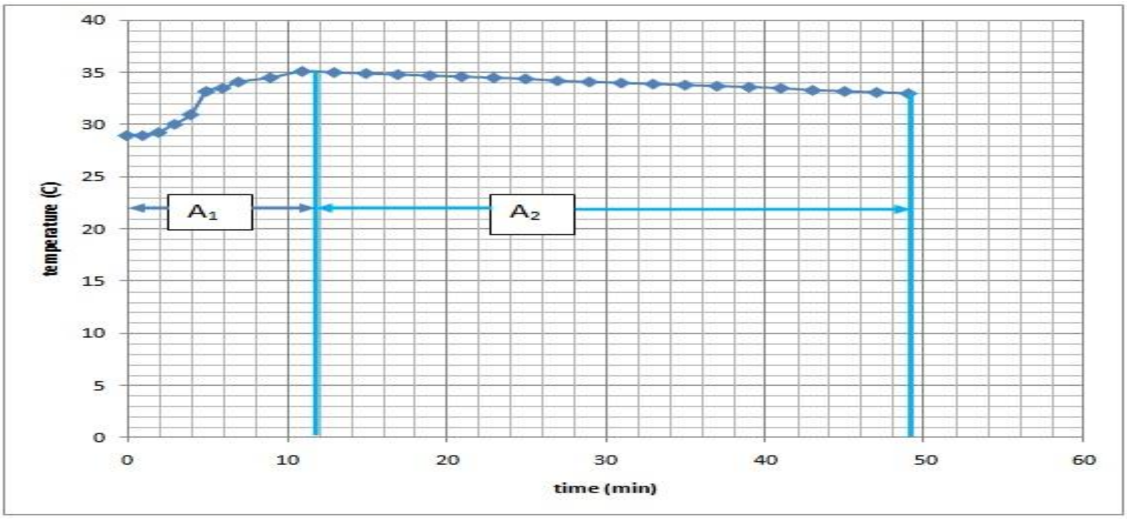

FIGURE 3.2. The specific heat capacity curve for sample c

A_1 = 477.33unit^2 and A_2 = 1260.7unit^2

Cooling correction, $p=\frac{A_1}{A_2}q = 0.757^0C$

initial temperature of sample C,$T_1 = 29^0C$

Recorded highest temperature of sample C,$T_2 = 35.1^0C$

t_0= 7mins =420 s

$$c = \frac{1}{m}\left[\frac{VIt_0}{(T2+p)-T1} - m_0 c_0\right]$$

$$c = \frac{1}{0.094}\left[\frac{4 \times 1.75 \times 420}{(35.1+0.757)-29} - 0.080 \times 380\right] = 4238\ Jkg^{-1}K^{-1}$$

The result of the specific heat capacity for water is as shown below:

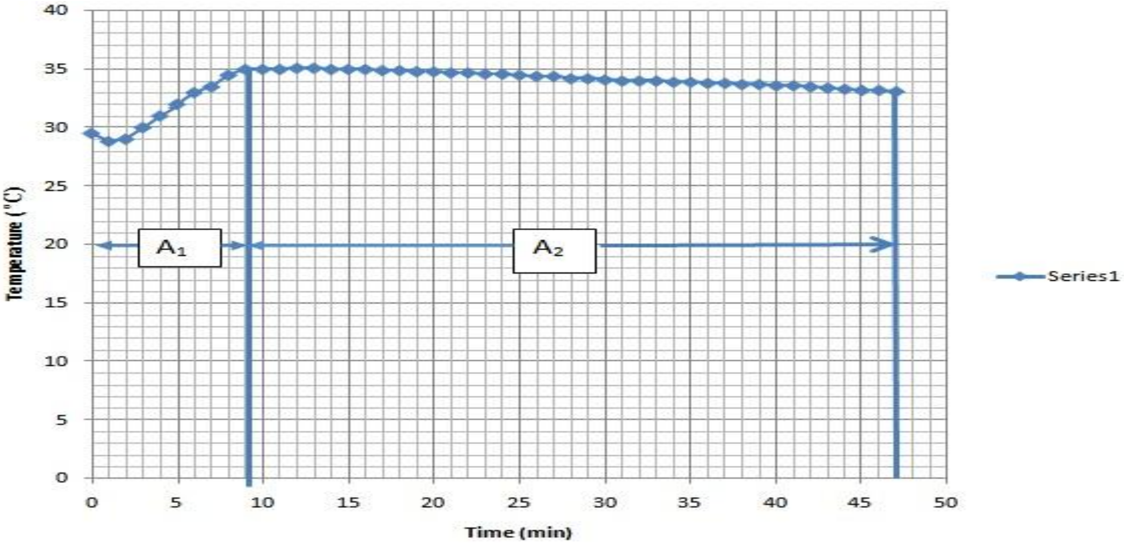

Figure: 3.3: The specific heat capacity curve for water

A_1 = 250 unit^2   **A_2 = 1233.4 unit^2**

Cooling correction, $p=\frac{A_1}{A_2}q = 0.41^0$C

initial temperature of sample C,T_1 = 28.5^{0}C

Recorded highest temperature of sample C,T_2 =35.1^{0}C

t_0= 7mins =420 s

$$c = \frac{1}{m}\left[\frac{VIt_0}{(T2+p)-T1} - m_0 c_0\right]$$

$$c = \frac{1}{0.094}\left[\frac{4 \times 1.75 \times 420}{(35.1+0.41)-29} - 0.080 \times 380\right] = 4265.8\text{Jkg}^{-1}\text{K}^{-1}.$$

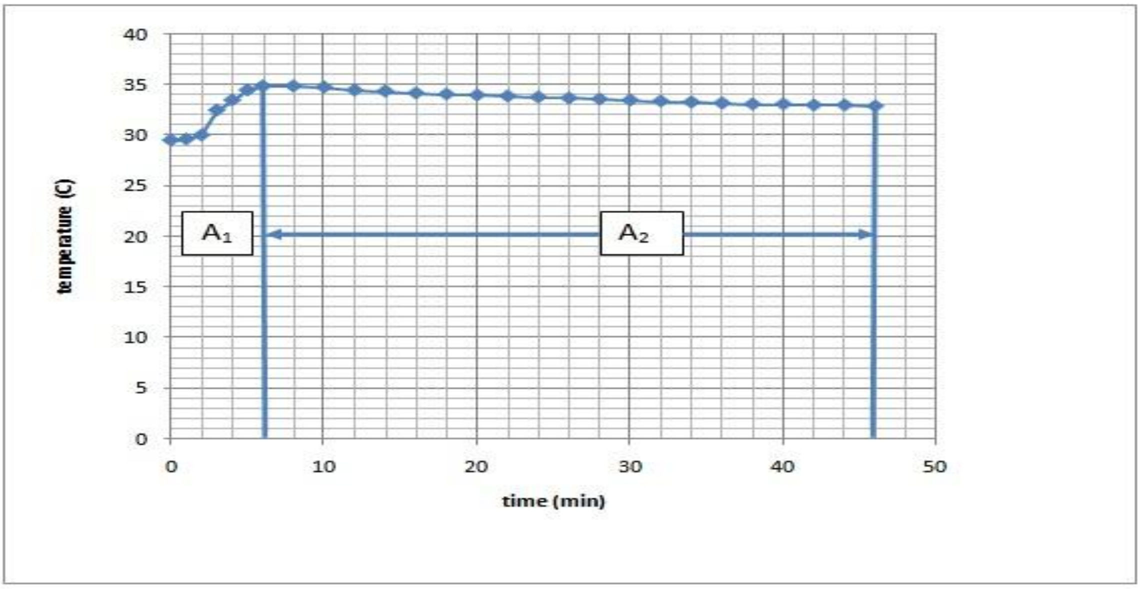

FIGURE 3.4. The specific heat capacity curve for sample B

A_1 = 330.33 unit^2   **A_2 = 1279.71 unit^2**

Cooling correction, $p=\frac{A_1}{A_2}q = 0.516^0$C

initial temperature of sample B,T_1 = 29.5^{0}C

Recorded highest temperature of sample C,T_2 =34.9^{0}C

t_0= 6mins =360 s

$$c = \frac{1}{m}\left[\frac{VIt_0}{(T2+p)-T1} - m_0 c_0\right]$$

$$c = \frac{1}{0.094}\left[\frac{4 \times 1.75 \times 360}{(34.9+0.516)-29.5} - 0.080 \times 380\right] = 4208.12\text{Jkg}^{-1}\text{K}^{-1}$$

A liquid with a high specific heat has more capacity to absorb heat than a liquid with a lower specific heat. From the graphs (figs. 3.2 – 3.4) the specific heat capacities of the three coolants were obtained. As expected the specific heat capacity of water was higher than those of coolants C and B. Generally, pure water has much higher capacity to absorb heat than most known liquids. The challenges with water are its attendant corrosion problems and its low boiling and relatively ‘high’ freezing points. Both these properties are not favourable in hot and extremely cold conditions. In areas where temperature drops far below 0^{0}C, the water becomes solid in the radiators. Sample C which combines the high boiling and low freezing properties of ethylene glycol and the high specific heat capacity of water in a 50/50 mixture gave improved properties which bettered using glycol alone apart from glycol high toxicity level and cost . Sample C gave higher specific heat capacity than sample B making it a better coolant.

4. CONCLUSION:

- The boiling point of the formulated radiator coolant (sample C) was found to be 110^{o}C, higher than the other two coolants (Samples A and B).
- Sample C would require more heat relative to samples A and B, to raise a unit mass of the coolant to its boiling point.
- Better extraction of heat by sample C results in better cooling effect on car engines.
- The use of a high boiling point solvent (mono-ethylene glycol) at the right proportion helps to raise the boiling point of water by as much as 10 degrees.
- The specific heat capacity of Sample C gave 4238 $Jkg^{-1}K^{-1}$, as against that of water which gave 4265.8$Jkg^{-1}K^{-1}$.
- A blend of 50/50 mix of water and ethylene glycol in which corrosion inhibitors have
- been incorporated is much more effective than using water and ethylene glycol alone. While water alone is good coolant but the enormous corrosion problems associated with it, is enough to discourage its use.

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Author Biography

Efeovbokhan, Vincent Enontiemonria is both a Lecturer and a researcher in the Department of Chemical Engineering, Covenant University, Ota Nigeria. He had his first and second degrees in Chemical Engineering from the Federal University of Technology, Owerri (Nigeria) and the University of Benin, Benin City (Nigeria) respectively. He is a registered Engineer with the Council for the Regulation of Engineering in Nigeria (COREN) and a corporate member of two professional bodies. Some of the courses he teaches amongst others include Engineering Mathematics, Chemical Engineering Process Analysis, Chemical Reaction Engineering etc. His research interests are in renewable energy, product development and bio-chemical engineering. He has published nine papers in International Journals, one conference paper and featured in a number of exhibitions and fairs to display numerous new products he has developed.