PAKISTAN INSTITUTE OF CHEMICAL ENGINEERS
Since 1969

Journal of the Pakistan Institute of Chemical Engineers

Journal homepage: www.piche.org.pk/journals

DOI: https://doi.org/10.54693/piche.05223

Check for updates

A Study of Boiling Heat Transfer via an Aqueous Solution of Commercial-Grade Engine Coolant and Pure Water

W. Ahmed, S. Ali, N.A. Khan[a*], N.H. Syed, U. Ghani

Submitted: 06/07/2024, Accepted: 14/11/2024, Published: 18/11/2024

Abstract

Commercial grade motor radiator coolant is a mixture of glycol, corrosion inhibitors, inorganic compounds, and water. These radiator coolant formulations enhance the thermal efficiency and lifespan of combustion engines. In this study we added a radiator coolant solution in a distilled water to investigate potential improvements in the heat transfer rate. Thus, the heat dissipation from a coiled Nichrome wire (electrically operated) was analyzed in open air, pure water, and various concentrations of aqueous coolant solutions. The boiling of coolant aqueous solution at concentrations of 5% wt./wt., 10% wt./wt., 15% wt./wt., and 20% wt./wt. were compared with pure water. In general, a heat transfer coefficient values increases with coolant concentration. For example, at 5% wt./wt., the heat transfer coefficient is 40 W/m²·K, whereas at 20% wt./wt. concentration, it rises to 140 W/m²·K. Moreover, qualitatively the bubble size in pure water is significantly larger than that of bubbles of the coolant solutions. Turbidity and total dissolved solids increase with coolant concentrations, whereas at a 20% wt./wt. concentration, the surface tension decreases to 68.8 mN/m. This study suggests that adding an engine coolant solution into standard boiler feed water or similar cooling system devices will improve the heat transfer rate and therefore reduces fuel cost for producing steam.

Keywords: Pool Boiling, Vapor Bubbles, Coefficient of Heat Transfer

1 Introduction:

Chemical process industries consist of an integrated system of heat exchange equipments [1-3]. In principle, there is always a need to elevate the temperature of a substance or fluid to a desired value for further processing [4,5]. Similarly, in some cases the heat generated from exothermic systems must be dispersed to a nearby heat sink in order to maintain the normal functioning of the equipment [6]. The term “autothermal management system” is relatively new concept referring to heating one fluid with the help of associated exothermic inventory system [7]. Sometimes chemical process intensification may require readjustments along with the piping network to attain an enhanced heat transfer rates [8]. Moreover, a well-equipped cooling and heating system is critical for the normal operation of all advance scientific and analytical instrumentations. For example, a magnetic resonance imaging (MRI) machine used for generating human organ images contains a complex cooling system that utilizes the principle of boiling and condensation in order to keep the temperature of the main circular magnet in safe operational range [9,10]. As a whole, the fundamentals of a heat transfer are same for all engineering applications, that is a heat will flow from a high to low temperature sink [11-13,14]. The fluids or the solid surfaces can be heated or be cooled when a contact is established with a separate fluid or solid substance at a different temperature [13]. For example, in order to takeaway a heat from a hot surface, one may utilize air fans or blowers or a liquid is managed to flow over the

Department of Chemical Engineering, University of Engineering and Technology Peshawar, Pakistan
Corresponding Author: Naseer Ahmed Khan, (naseerahmedkhan@uetpeshawar.edu.pk)

heated surface in order to absorb heat [15-17]. This absorption of heat energy will eventually increase the fluid temperature. The rise of the temperature in most of the cases is in a sensible range [18,19]. However, during boiling an addition to sensible heat, a latent heat is also absorbed by a boiling liquid. In brief, the principles of boiling and condensation can be applied to heated surfaces that emit significant heat [20,21]. From an engineering point of view, the high temperature surfaces can be broadly categorized as high flux (10^2 - 10^3 Wcm^{-2}) and ultra- high flux (10^3 - 10^5 Wcm^{-2}) heat releasing surfaces [22].

Each liquid boils at a specific temperature at a given pressure. [23]. The temperatures and pressures at which a boiling system is in equilibrium are referred to as saturation temperature and saturation pressure. Under atmospheric pressure, water, ethanol, and pentane boil at 100 °C, 78 °C, and 36 °C, respectively [24]. Solid surfaces that can initiate boiling dissipates heat at temperatures higher than the liquid saturation temperature [25]. Super computer electrical circuits which are operated at a temperature of 30 °C are placed in dielectric liquids to maintain the temperature below 30 °C [26-28]. Dielectric liquid boils at around 30 °C [27]. Similarly, water is employed where the operated surface temperature is maintained at or around 100 °C [29]. Water has a high specific heat capacity than the other liquids, making it useful in a variety of engineering applications [30]. During boiling, numerous vapor bubbles originate from a heated solid surface [31-34]. Due to low density and buoyancy force, these vapors rise towards the liquid surface and then departs from a liquid phase [35,36]. These vapors eventually come into contact with the water containing condenser tubes, where the latent heat is collected from the vapors, resulting a phase change from vapor to liquid [37,38]. This overall process is at equilibrium, where the rates of vaporization and condensation being equal.

The number of vapor bubble nucleation sites on a heat-emitting surface rises with an increase in the temperature differential between the heated surface and the liquid saturation temperature [39,40]. Moreover, a vapor bubble will grow in size when the temperature of the liquid around the vapor is a bit higher [41]. In contrast, the bubbles will collapse into the liquid bulk if the bubble temperature is less than the surrounding liquid. [41,42]. These conditions are referred to as saturated and subcooled boiling regimes [43]. Most of the engineering application are in the nucleate boiling regime where bubbles are continuously leaving the heated solid surface [43]. Heat transfer coefficient values are high in the nucleate boiling regime when compared to convective and film boiling regimes [44]. Furthermore, a liquid can be boiled in a container like a pool, while in flow boiling, the liquid change phase as it flows over a heated surface [27,45, 46]. In comparison, flow boiling has high heat coefficient values, therefore it can efficiently absorb more heat than pool boiling [47].

As per literature, modifying the morphology/elemental structure of a heating surface or liquid composition may enhance heat transfer rates during boiling [47-49]. The heated surface can be altered by alloying, adding cavities, sintering to provide more nucleation sites, metal/ceramic coating, and changing the shape of the surface [49-53]. Till now, various correlations have been proposed for the calculation of the heat transfer rates [54-56]. These correlations include different coefficients ratios [57-59]. In most practical applications, the ability to change the heating surface is extremely limited, if not impossible [60,61]. Consequently, this could be the reason that the effect of change in fluid chemistry/composition is usually the focus of scientific research discussing pool boiling [49,62-64]. The role of additives including nanofluid and surfactants has been studied in numerous recent studies [64]. Moreover, the magnetic field has also been used to increase the heat transfer coefficient [65-68].

In Pakistan, industries use boilers to produce steam, which is then used for heating and, in some cases, for electricity generation [69-71]. Every effort is being made to limit the concentration of hardness causing salts, such as calcium and magnesium carbonates and sulphates, which forms scaling when water boils [72-74]. That is the basic reason why indigenous boilers encounter difficulties with prolonged operational hours [75]. Similarly, a number of technical issues regarding the cooling of the X-ray machines has been reported while using the water for the cooling of energized X-ray tubes [76-78].

Fortunately, auto industry uses different types of radiator coolants to not only limit corrosion inside the internal combustion engine, but also to improve water cooling performance [79-81]. These coolants contained additives, corrosion inhibitors, and glycol to improve the heat absorbing capacities of the cooling fluid [82-84]. This work proposes using coolant solutions in indigenous boilers to improve the number of working hours of boiling systems. Therefore, a boiling heat transfer via aqueous coolant solutions was studied and compared with pure water. A spiral heating coil element was employed to replicate a situation where the heating surfaces has complex shapes that could affect the heating rate, while a heating element was set up to operate on a standard 220 volt alternating current (AC).

2 Methodology:

Thermodynamically, during boiling, the temperature of the liquid is elevated to the saturation temperature at a specified pressure, where the change in phase becomes visible. This study is mainly an inclusion of submerging a heated surface (about slightly lower to mid-position in a pool of liquid), which essentially induced boiling, in a bulk liquid. The specifics of the experimental configuration are outlined as follows.

2.1 Experimental unit:

An indigenously designed experimental setup was used to study the boiling heat transfer via a pure water and varied aqueous solutions of radiator coolant as shown in Figure 1. The experimental setup consists of a pool of water in a glass container, heating element, condenser piping, thermocouples, and series circuit electrical wiring. Electric current dissipated heat as it passed through a Nichrome element. The temperature of the water flowing inside a condenser at the inlet and outlet was measured with the help of thermocouples (thermometer 1, and thermometer 2 and shown in Figure 1). The temperature of the bulk liquid inside the glass container was measured with a mercury thermometer (thermometer 3). Voltage (V), current (I), resistance (R), and temperature of the Nichrome heating element was noted for the power dissipation calculations.

2.2 Electrical circuitry:

The Nichrome heating element is the main component of the carried-out pool boiling study. Nickel-Chrome alloy, a heating element made of 80% nickel and 20% chromium, with a melting temperature of 1200 °C, was installed in a series circuit. A household alternating current having a voltage of 220 volts was employed to produce heat. Overall, the circuit consisted a voltage regulator, ammeter, resister 1 (light bulb), and resister 2 (Nichrome heating element) as shown in Figure 2. Both

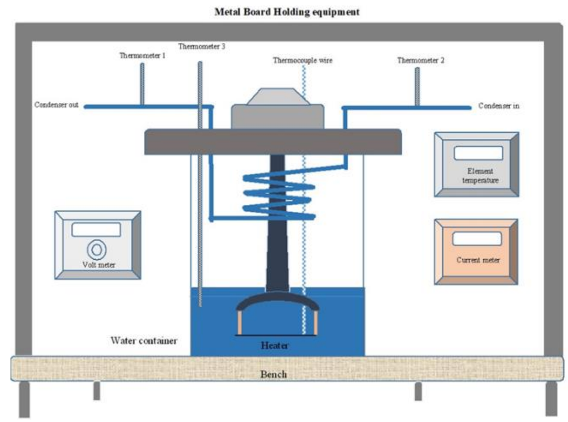

Figure 1: A home built experimental pool boiling setup

of these resisters are connected in a series circuit. The resister 2 is a heating element and installed to produce heat. The amount of current was varied with the voltage regulator and light bulb of different power rating, such as 500 W, 1000 W, and 5000 W. The energy released from a heating element (resister 2, Nichrome element) will eventually generate the temperature. The bulb power rating determines the amperes flow through the heating element (resister 2).

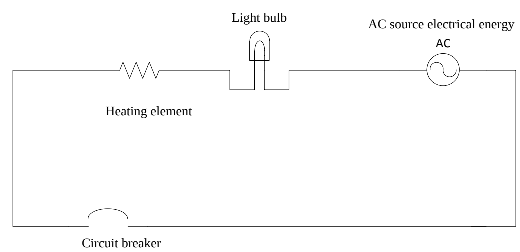

Figure 2: Electrical circuit in a boiling heat transfer experimental unit

The power formula (power = voltage × current) was applied to find out the heat energy released by a heating element wire. The power value was then divided by the surface area of a heating element to determine the energy emitted per unit area (watts m^{-2}). To calculate the surface area of the heating wire, the coiled wire was stretched to make it straight. The geometrical formula equation of the surface area (2Πr2 + 2ΠrL), where Π, r, h is 3.141, radius, and length, respectively) was used to determine the external surface area. The cross-sectional area of the wire was measured with a screw gauge, and the length was measured with a ruler.

2.3 Prepared coolant solutions:

An aqueous solution of engine radiator coolant with different concentrations was used to evaluate its heat carrying ability. While the exact chemistry of the radiator coolant employed in the present study was unidentified, In any case engine cooling systems typically has a coolant formulation comprising organic acids, inorganic acids, corrosion inhibitors, water and glycol [85,86]. These coolants also contain chemicals that prevent the production of rust particles within the vehicle engine [87]. These coolant solutions transfer the heat produced in the combustion cylinder to the open air. The inside wall temperature is approximately 250 °C, whereas the external wall of the combustion piston chamber, which is in contact with the coolant, is reduced to around 130 °C [88-91]. Normal untreated water when used as a coolant in combustion engines causes corrosion and that is why radiator coolant solutions are preferred over the distilled water [92]. A percent weight by weight of coolant composition (coolant/aqueous solution), that is 5 wt./wt., 10 wt./wt., 15 wt./wt., and 20 wt./wt. as shown in Figure 3 were prepared to examine the vapor bubbles and heat transfer coefficient of the boiling system.

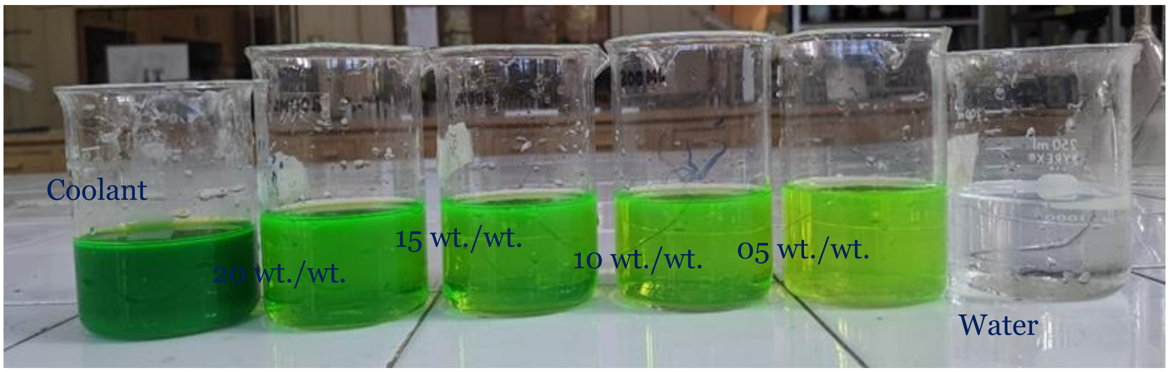

Figure 3: Different concentration of the coolant solution used in the pool boing experiments

2.4 Equation of the coefficient of heat transfer:

The overall heat transfer coefficient was determined by calculating the heat transferred from the heating element (Nichrome wire) to the water circulating inside the condenser. The heat absorbed by the condenser water increased its temperature by a few degrees. i.e. there was a difference of temperature at the condenser inlet and outlet points. Although heat transfer from a heating element is three-dimensional, however for simplicity heat losses to the surroundings (container walls) were ignored, and just heat transfer to the condenser was recorded for the calculations. The mass flow rate of water in the condenser was maintained to about 0.01 kg/s. The input temperature of the water was 29°C ± 1. While when heat was being absorbed, the condenser outlet temperature increased up to some high degrees. The saturation temperature (ts) of all aqueous solution remained at 100 °C for all conducted experiments. The exponential increase in the water temperature flowing inside the condenser was calculated by a log mean temperature difference (ϕ_m) equation.

$$\phi_m = (\phi_1 - \phi_2)/(ln\,\phi_1/\phi_2) \text{ equation 1}$$

where ϕ_1 is the temperature difference between the saturation temperature and the inlet temperature while the ϕ_2 is the saturation temperature minus condenser outlet temperature. Equation 1 is a dimensionless number.

The overall heat absorbed ($Q^\bullet$) in the condenser was calculated by a heat absorption equation.

$$Q^\bullet = m^\bullet C_p(T_o - T_i) \text{ equation 2}$$

where $m^\bullet$ (0.01 kg/s), Cp (4184 J/kg·°C), To (°C), Ti (°C), is condenser water mass flow rate, specific heat capacity of water, To is the water outlet temperature, and Ti is the water inlet temperature, respectively.

An overall heat transfer coefficient (U) was calculated by dividing heat absorbed in the condenser ($Q^\bullet$) with log mean temperature difference (ϕ_m) and with the surface area of the condenser. The surface area of the condenser was 0.032 m^2. Mathematically overall heat transfer coefficient for different aqueous solution of coolants was calculated as

$$U = \frac{Q^\cdot}{\phi_m \times 0.032} \quad \text{equation 3}$$

2.5 Analytical equipment:

The turbidity of the coolant aqueous solution was measured using a micro TPW portable turbidity meter. This meter is manufactured by HF Scientific USA. This apparatus uses light scattering to measure the suspended additives and organic homogeneous compounds in the coolant solution. The PH of the solution was determined using the usual paper strips. Density is a measure of mass per unit volume of the aqueous solutions. The concentration of total dissolved solids as assessed by corresponding current conductance was determined using a SENSOREX spectrum meter. Finally, the stalagmometer was used to for the estimation of the surface tension of the solutions by comparing their masses and the number of drops.

3 Results and discussion:

In steam boilers, the operating conditions where the temperature difference between the heated surface and the bulk liquid is too large result in the entire heated surface being covered with water vapors rather than the liquid water. This phenomenon, known as film boiling, occurs when a film of steam resists the flow of heat from the heated surface to the bulk liquid, eventually elevating the temperature of the heating element to the point where the heat emitting component melts. The reduction in heat flux is due to the low heat transfer coefficient of steam. Similar to steam, the air heat transfer coefficient is also lower in comparison to that of liquid water. The present study qualitatively examined the heat emitted by a heated element in air and in liquid water.

3.1 Thermal dissipation of Nichrome heating element in air:

A Nichrome element was installed in a series circuit under a standard 220-volt potential difference to qualitatively compare the thermal conductivity of air and aqueous solutions. This means that the Nichrome element was not submerged in a water solution and was instead exposed to the outside air as shown in Figure 4. The current flow within the close series circuit was controlled by resistor 1, which is a light bulb. The values of the voltage across resister 1 and resister 2 varies depending on the power rating of the bulb (resister 1). The resistance and voltage are high (resistance = voltage / current) across low power rating light bulbs. Whereas increasing the power (watt) rating of the light bulb (resister 1) allows more current to flow within the circuit. This essentially indicates that a light bulb with a low power rating has high resistance and voltage.

As the voltage across the light bulb decreases, the voltage across the heating element (resistance 2) increases, resulting in increased power dissipation (power = voltage × current). With this rise in the heat dissipation, the temperature of the heating element increases enormously as shown in Figure 4. For example, with 500 W (resister 1) bulb, the temperature near the heating element (resister 2) increases to 150 °C. While when a 500 W bulb is replaced with a 5000 W bulb, heat emission increases, and the temperature of the nearby heater 69 element rises to 330 °C. This large increase in temperature softens the wire, causing the coil to become straighter or extended, as seen in Figure 4. Thus, at high heat flux levels, the air cannot efficiently transfer heat, as seen by the heating element continuous deformation along its length.

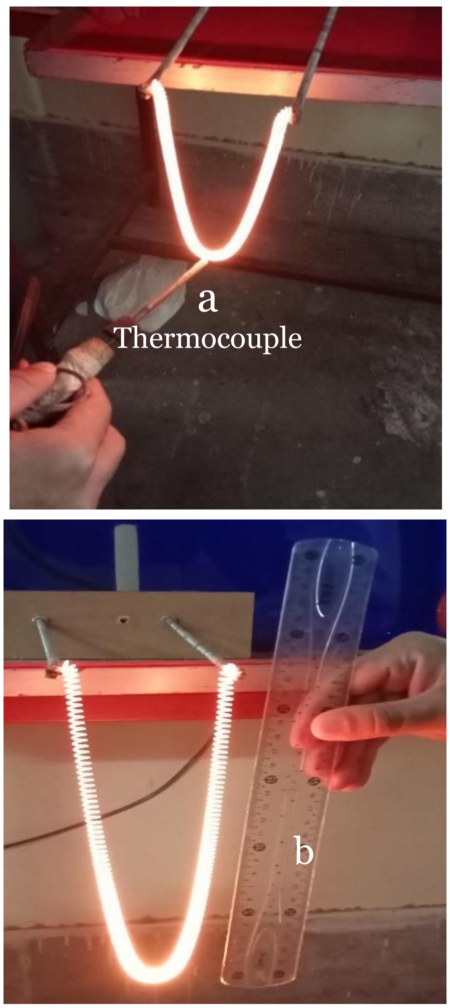

Figure 4: Heating element with a varied heat dissipation rate; temperature rise in image a is 150 °C, whereas image b is 330 °C.

The measurements of the voltage, current, and heating element temperature are shown in Table 1. In general, with the increase in voltage across the heating element increases the rate of heat dissipation. The main power supply was kept at 220 volts for all readings. The temperature of the heating wire rises as the voltage rises, and the wire resistance emits heat. The highest temperature surrounding the heating element that it reached was approximately 330 °C, resulting in a permanent deformation of the heating element as shown in Figure 4. Increasing the power rating could ultimately lead to the melting of the heating element, a phenomenon commonly described in literature as a burnout condition [93,94]. The experiments conducted in current work did not determine the melting temperature or burnout of the nichrome resistance wire.

Solid materials emitting high heat flux dissipation can be maintained within an operational range when immersed in a suitable liquid. If the temperature is not maintained, the heat-emitting material will eventually melt. A liquid pool can absorb generated heat, which may be utilized for various engineering applications. For example, one of the most important applications of pool boiling is in the nuclear power industry, where pressurized steam is produced at temperatures of around 400 °C [95]. In general, the chemistry of the liquid and its boiling temperature play critical roles in heat absorption during any phase change process. Supercomputers, for example, must keep their temperatures below 30 °C, which can be achieved by immersing them in dielectric liquids.

Table 1: Power setting of the heating element with obtained temperatures in open air.

S. No	Voltage (volts)	Current (Amperes) ± 0.3	Power = (voltage × current) watts	Heating element temperature
1	55	1.8	100	150 °C
2	88	1.8	158	200 °C
3	145	2.1	305	270 °C
4	162	2.2	356	330 °C

3.2 Thermal dissipation of heated nichrome element in liquids:

A radiator coolant with various aqueous compositions was studied for heat transfer operation. As shown in Table 2, with the increase in the coolant amount, the total dissolved solids and turbidity values increases. Explicitly, the increase of the coolant concentration from 5% wt./wt. to 20% wt./wt. increase the turbidity and total dissolved solids (TDS) to 20% and 60%, respectively. In general, the coefficient of the heat transfer of water increases with lowering the surface tension values [96-98].

Table 2 shows that adding coolants to water decreases overall surface tension levels. Because ethylene glycol and water comprise the majority of the radiator coolant composition, the overall drop in surface tension from 5% wt./wt. to 20% wt./wt. is just about 8%. Finally, the PH of the solution does not change much at the studied coolant concentrations.

Table 2: Chemical properties of the coolant aqueous solutions.

S. No	PH	TDS (mg/L)	Turbidity (NTU)	Surface tension (mN/m)	Concentration of the solution
1	8.39	436	3.8	74.4	5 % wt./wt.
2	8.56	684	3.7	72	10 % wt./wt.
3	8.68	836	4.2	70	15 % wt./wt.
4	8.72	1029	4.8	68.6	20 % wt./wt.

In process industries, nucleate boiling is the operational regime that exhibits the highest heat transfer rates compared to convective and film boiling. Figure 5 shows that when a heating element with a power rating of 356 watts (values given in Table 1) is placed in a pool of radiator coolant aqueous solution, its temperature drops to roughly 116 °C from 330 °C (as was determined in air, Figure 4). During the boiling process, the temperature of a pool of aqueous solution and pure water stayed at 100 °C. Figure 5 depicts a comparison of a nucleate boiling of a 20% wt./wt. solution and pure water. A heating element with a complex spiral configuration was

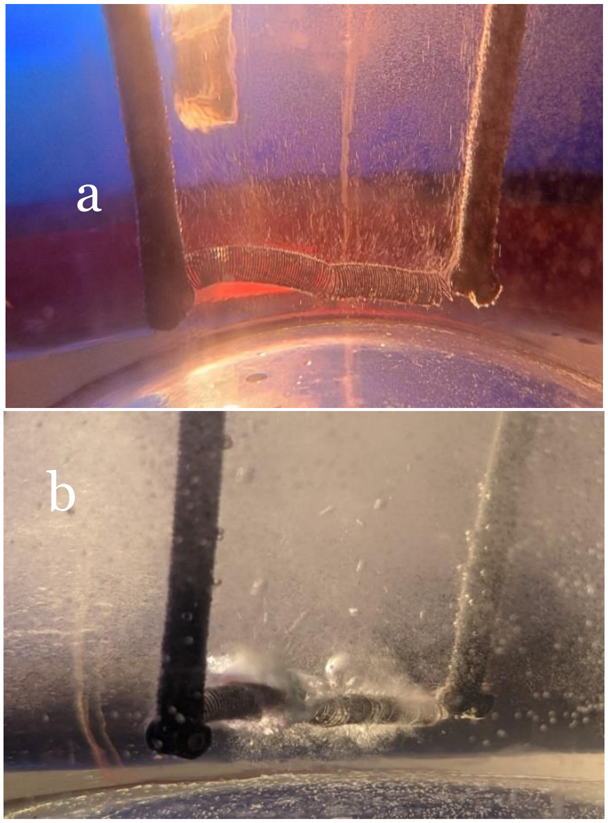

Figure 5: Heat dissipation from Nichrome coiled wire in (a) 20% wt./wt. coolant solution and (b) pure water.

employed, and the boiling processes exhibited notable differences between the aqueous solution and pure water. Firstly, the wire length did not enlarge as compared to Figure 4, suggesting that heat can be effectively dissipated via the boiling process. More importantly, with the addition of coolant solution in water the boiling becomes much smoother as compared to pure water. The formation of large bubbles during the boiling of pure water creates an explosive impact, resulting in repeated vibrational shocks to the vessels, hence posing a significant operational risk in engineering applications. The boiling of a 20% wt./wt. aqueous solution produced extremely small bubbles that ascended to the surface as shown in Figure 5 a.

Heat transfer from a heating source occurs in three dimensions. To simplify, the observed heat transfer value in this study is aligned with the direction of bubble movement, indicating that the temperature increases of the water flowing within the condenser was determined to compare the heat transfer rates in pure water and aqueous solution. In short, the inflow of water to the condenser absorbs energy and raises its temperature to a higher value. The increase in temperature of the condenser water under identical conditions varies based on the composition of the pool boiling water following the addition of the coolant. According to the literature, water surface tension affects the heat transfer ability [97,98]. In general, the addition of the coolant in water lowers the surface tension values [99]. As shown in Table 3, when utilizing a 20 wt./wt. coolant solution, the heating element with a rating of 356 watts loses significantly less heat to the surroundings. This reduction in loss is due to tiny bubbling states that occur on the heating element surface. As shown in Figure 5, the bubbles are significantly smaller and thus rise up through the pool of water, eventually reaching the condenser. The water mass flow rate ($m^{\bullet}$) and specific heat (C_p) of the water is 0.01 kg/s and 4200 j/kg•K respectively.

Table 3: Rate of heat absorption by a condenser containing water, power rating, and approximate heat loss.

S.No.	Concentration of the coolant in the water.	Heat absorption in condenser ($Q^{\bullet}$, watts)			Power rating of the heating element (watts)	Heat losses (Heating power – condenser heat absorption)	Percent heat lost (heat losses/ heating element power)
		($m^{\bullet}$) • (C_p)	(T_o - T_i)	$Q^{\bullet} = m^{\bullet} \times C_p \times (T_o - T_i)$ (watts)			
1	5% wt./wt.	42	31 - 29	84	356	272.4	76%
2	10% wt./wt.	42	33 - 30	126	356	230.4	65%
3	15% wt./wt.	42	34 - 29	252	356	104.4	29%
4	20% wt./wt.	42	36 - 29	294	356	62.40	18%

In any case, the overall heat transfer coefficient (U) values increase as coolant concentrations increase

(Figure 6). The upper limit values of the coefficient trend were not calculated because observing the bubbles became more difficult as coolant concentration increased. In general, adding coolant to water improves the heat transfer coefficient. The saturation temperature of the water was almost same 100 °C as because major portion of the coolant solution is water. In short, the trend indicates that increasing the coolant volume will improve the heat transfer coefficient values.

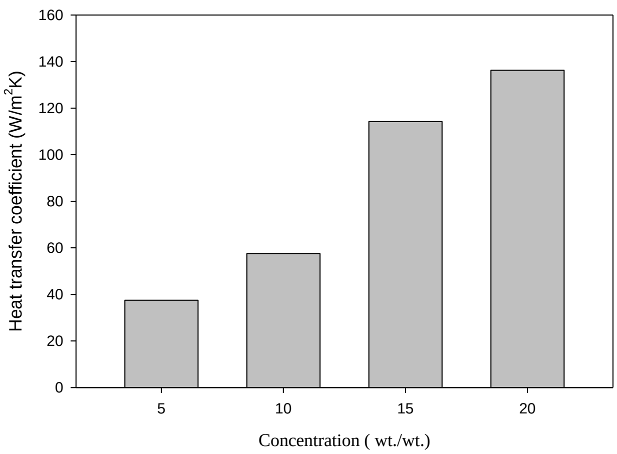

Figure 6: Overall heat transfer coefficient at coolant concentration of 5% wt./wt., 10% wt./wt., 15% wt./wt./ and 20% wt./wt.

Conclusions:

The boiling heat transfer rate is primarily determined by the fluid properties and the heat emitting surfaces. When boiling, heat emission surfaces was wholly submerged in a pool of liquid. In this study, the physicochemical properties of pure water were altered by mixing a commercial grade radiator coolant into pure water to evaluate heat transfer rate during the vaporization and condensation processes. A 220 volts AC current was managed to emit heat from a Nichrome wire. Heat dissipation was regulated by changing the current flow, resistor, and voltage in a series electric circuit. At higher heat dissipation rates, air cannot efficiently transfer heat to a low temperature surrounding atmosphere, hence the length of the coiled wire expands substantially due to excessive temperature accumulation. When placed in pure water or an aqueous coolant solution, the same Nichrome wire conducts heat far more efficiently than the air. Similarly, by increasing the volume of coolant in pure water, the surface tension decreases and the overall heat transfer coefficient increases.

Nomenclature:

Voltage	V
Current	I
Alternating current	AC
Resistance	R
Temperature	T
Radius	R
Length	L
Log mean temperature difference	ϕm
Power unit	W
Overall heat absorbed	$Q^\bullet$
Water mass flow rate	$m^\bullet$
Specific heat capacity	Cp
Water outlet temperature	To
Water inlet temperature	Ti
Overall heat transfer coefficient	U
Total dissolved solids	TDS

References:

[1] A. Sayar and N. Eskin, “Experimental and theoretical analysis of a monolith type auto-thermal reforming reactor,” *Int. J. Hydrogen Energy*, vol. 44, no. 21, pp. 10232–10249, Apr. 2019, doi: 10.1016/j.ijhydene.2019.03.016.

[2] A. Amin, “Review of autothermal reactors: Catalysis, reactor design, and processes,” *Int. J. Hydrogen Energy*, vol. 65, pp. 271–291, May 2024, doi: 10.1016/j.ijhydene.2024.03.372.

[3] B. F. Hagh, “Stoichiometric analysis of autothermal fuel processing,” *J. Power Sources*, vol. 130, no. 1–2, pp. 85–94, May 2004, doi: 10.1016/j.jpowsour.2003.11.041.

[4] L. Xia *et al.*, “A review of low-temperature heat recovery technologies for industry processes,” *Chinese J. Chem. Eng.*, vol. 27, no. 10, pp. 2227–2237, Oct. 2019, doi: 10.1016/j.cjche.2018.11.012.

[5] M. Rehfeldt, T. Fleiter, and F. Toro, “A bottom-up estimation of the heating and cooling demand in European industry,” *Energy Effic.*, vol. 11, no. 5, pp. 1057–1082, Jun. 2018, doi: 10.1007/s12053-017-9571-y.

[6] J. Li, G. . Peterson, and P. Cheng, “Three-dimensional analysis of heat transfer in a micro-heat sink with single phase flow,” *Int. J. Heat Mass Transf.*, vol. 47, no. 19–20, pp. 4215–4231, Sep. 2004, doi: 10.1016/j.ijheatmasstransfer.2004.04.018.

[7] H. Liu, M. Wen, H. Yang, Z. Yue, and M. Yao, “A Review of Thermal Management System and Control Strategy for Automotive Engines,” *J. Energy Eng.*, vol. 147, no. 2, Apr. 2021, doi: 10.1061/(ASCE)EY.1943-7897.0000743.

[8] F. J. Keil, “Process intensification,” *Rev. Chem. Eng.*, vol. 34, no. 2, pp. 135–200, Feb. 2018, doi: 10.1515/revce-2017-0085.

[9] F. Natukunda, T. M. Twongyirwe, S. J. Schiff, and J. Obungoloch, “Approaches in cooling of resistive coil-based low-field Magnetic Resonance Imaging (MRI) systems for application in low resource settings,” *BMC Biomed. Eng.*, vol. 3, no. 1, p. 3, Dec. 2021, doi: 10.1186/s42490-021-00048-6.

[10] K. Pieterman, J. A. M. Dam, and H. Postma, “Low Temperature Closed Cooling System for MRI Magnets,” in *Advances in Cryogenic Engineering*, Boston, MA: Springer US, 1986, pp. 533–541. doi: 10.1007/978-1-4613-2213-9_61.

[11] S. E. G. Jayamaha, N. E. Wijeysundera, and S. K. Chou, “Measurement of the heat transfer coefficient for walls,” *Build. Environ.*, vol. 31, no. 5, pp. 399–407, Sep. 1996, doi: 10.1016/0360-1323(96)00014-5.

[12] B. Jacimovic, S. Genic, and D. Lelea, “Calculation of the Heat Transfer Coefficient for Laminar Flow in Pipes in Practical Engineering Applications,” *Heat Transf. Eng.*, vol. 39, no. 20, pp. 1790–1796, Dec. 2018, doi: 10.1080/01457632.2017.1388949.

[13] A. V. Dmitrenko, “Analytical determination of the heat transfer coefficient for gas, liquid and liquid metal flows in the tube based on stochastic equations and equivalence of measures for continuum,” *Contin. Mech. Thermodyn.*, vol. 29, no. 6, pp. 1197–1205, Nov. 2017, doi: 10.1007/s00161-017-0566-x.

[14] S. Muhammad and J. R. Khan, “Sensible Heat Transfer on a Rotating Surface,” *J. Pakistan Inst. Chem. Eng.*, vol. 42, no. 2 SE-Articles, pp. 35–44, Aug. 2014, [Online]. Available: https://piche.org.pk/journal/index.php/jpiche/article/view/121

[15] A. A. Rezwan, S. Hossain, S. M. A. Rahman, and M. A. Islam, “Heat Transfer Enhancement in an Air Process Heater Using Semi-Circular Hollow Baffles,” *Procedia Eng.*, vol. 56, pp. 357–362, 2013, doi: 10.1016/j.proeng.2013.03.132.

[16] A. A. Ramadhan, N. Kapur, J. L. Summers, and H. M. Thompson, “Performance and flow characteristics of miniature EHD air blowers for thermal management applications,” *J. Electrostat.*, vol. 93, pp. 31–42, Jun. 2018, doi: 10.1016/j.elstat.2018.03.004.

[17] M. Khaled, F. Mangi, H. El Hage, F. Harambat, and H. Peerhossaini, “Fan air flow analysis and heat transfer enhancement of vehicle underhood cooling system – Towards a new control approach for fuel consumption reduction,” *Appl. Energy*, vol. 91, no. 1, pp. 439–450, Mar. 2012, doi: 10.1016/j.apenergy.2011.10.017.

[18] C. R. C. Rao, H. Niyas, and P. Muthukumar, “Performance tests on lab–scale sensible heat storage prototypes,” *Appl. Therm. Eng.*, vol. 129, pp. 953–967, Jan. 2018, doi: 10.1016/j.applthermaleng.2017.10.085.

[19] G. Li, “Sensible heat thermal storage energy and exergy performance evaluations,” *Renew. Sustain. Energy Rev.*, vol. 53, pp. 897–923, Jan. 2016, doi: 10.1016/j.rser.2015.09.006.

[20] T. G. Karayiannis and M. M. Mahmoud, “Flow boiling in microchannels: Fundamentals and applications,” *Appl. Therm. Eng.*, vol. 115, pp. 1372–1397, Mar. 2017, doi: 10.1016/j.applthermaleng.2016.08.063.

[21] S. Rashidi, F. Hormozi, and M. M. Sarafraz, “Fundamental and subphenomena of boiling heat transfer,” *J. Therm. Anal. Calorim.*, vol. 143, no. 3, pp. 1815–1832, Feb. 2021, doi: 10.1007/s10973-020-09468-3.

[22] G. Liang and I. Mudawar, “Review of pool boiling enhancement by surface modification,” *Int. J. Heat Mass Transf.*, vol. 128, pp. 892–933, Jan. 2019, doi: 10.1016/j.ijheatmasstransfer.2018.09.026.

[23] H. Y. She and B. E. Sleep, “The effect of temperature on capillary pressure-saturation relationships for air-water and perchloroethylene-water systems,” *Water Resour. Res.*, vol. 34, no. 10, pp. 2587–2597, Oct. 1998, doi: 10.1029/98WR01199.

[24] Y. Utaka, Y. Kashiwabara, and M. Ozaki, “Microlayer structure in nucleate boiling of water and ethanol at atmospheric pressure,” *Int. J. Heat

Mass Transf., vol. 57, no. 1, pp. 222–230, Jan. 2013, doi: 10.1016/j.ijheatmasstransfer.2012.10.031.

[25] H.-S. Roh, “Heat transfer mechanisms in pool boiling,” *Int. J. Heat Mass Transf.*, vol. 68, pp. 332–342, Jan. 2014, doi: 10.1016/j.ijheatmasstransfer.2013.09.037.

[26] U. Sajjad, A. Sadeghianjahromi, H. M. Ali, and C.-C. Wang, “Enhanced pool boiling of dielectric and highly wetting liquids – A review on surface engineering,” *Appl. Therm. Eng.*, vol. 195, p. 117074, Aug. 2021, doi: 10.1016/j.applthermaleng.2021.117074.

[27] K. C. Leong, J. Y. Ho, and K. K. Wong, “A critical review of pool and flow boiling heat transfer of dielectric fluids on enhanced surfaces,” *Appl. Therm. Eng.*, vol. 112, pp. 999–1019, Feb. 2017, doi: 10.1016/j.applthermaleng.2016.10.138.

[28] M. Arik and A. Bar-Cohen, “Effusivity-based correlation of surface property effects in pool boiling CHF of dielectric liquids,” *Int. J. Heat Mass Transf.*, vol. 46, no. 20, pp. 3755–3764, Sep. 2003, doi: 10.1016/S0017-9310(03)00215-1.

[29] M. C. Barma, R. Saidur, S. M. A. Rahman, A. Allouhi, B. A. Akash, and S. M. Sait, “A review on boilers energy use, energy savings, and emissions reductions,” *Renew. Sustain. Energy Rev.*, vol. 79, pp. 970–983, Nov. 2017, doi: 10.1016/j.rser.2017.05.187.

[30] J. J. Manyà, M. J. Antal, C. K. Kinoshita, and S. M. Masutani, “Specific Heat Capacity of Pure Water at 4.0 MPa between 298.15 and 465.65 K,” *Ind. Eng. Chem. Res.*, vol. 50, no. 10, pp. 6470–6484, May 2011, doi: 10.1021/ie102462g.

[31] S. T. Hsu and F. W. Schmidt, “Measured Variations in Local Surface Temperatures in Pool Boiling of Water,” *J. Heat Transfer*, vol. 83, no. 3, pp. 254–260, Aug. 1961, doi: 10.1115/1.3682252.

[32] M. Dadhich and O. S. Prajapati, “A brief review on factors affecting flow and pool boiling,” *Renew. Sustain. Energy Rev.*, vol. 112, pp. 607–625, Sep. 2019, doi: 10.1016/j.rser.2019.06.016.

[33] H. Sakashita and A. Ono, “Boiling behaviors and critical heat flux on a horizontal plate in saturated pool boiling of water at high pressures,” *Int. J. Heat Mass Transf.*, vol. 52, no. 3–4, pp. 744–750, Jan. 2009, doi: 10.1016/j.ijheatmasstransfer.2008.06.040.

[34] J. S. Kim, A. Girard, S. Jun, J. Lee, and S. M. You, “Effect of surface roughness on pool boiling heat transfer of water on hydrophobic surfaces,” *Int. J. Heat Mass Transf.*, vol. 118, pp. 802–811, Mar. 2018, doi: 0.1016/j.ijheatmasstransfer.2017.10.124.

[35] S. Yu *et al.*, “Influence of buoyancy on heat transfer to water flowing in horizontal tubes under supercritical pressure,” *Appl. Therm. Eng.*, vol. 59, no. 1–2, pp. 380–388, Sep. 2013, doi: 10.1016/j.applthermaleng.2013.05.034.

[36] A. Maeda, T. Yamagata, and N. Fujisawa, “Onset of exchange flow in combined buoyancy and forced pipe flow in unstable density gradient,” *Int. Commun. Heat Mass Transf.*, vol. 70, pp. 9–14, Jan. 2016, doi: 10.1016/j.icheatmasstransfer.2015.11.003.

[37] S. Qin, R. Ji, C. Miao, L. Jin, C. Yang, and X. Meng, “Review of enhancing boiling and condensation heat transfer: Surface modification,” *Renew. Sustain. Energy Rev.*, vol. 189, p. 113882, Jan. 2024, doi: 10.1016/j.rser.2023.113882.

[38] R. Rabiee, B. Rajabloo, M. Désilets, and P. Proulx, “Heat transfer analysis of boiling and condensation inside a horizontal heat pipe,” *Int. J. Heat Mass Transf.*, vol. 139, pp. 526–536, Aug. 2019, doi: 10.1016/j.ijheatmasstransfer.2019.05.046.

[39] H. Auracher and W. Marquardt, “Experimental studies of boiling mechanisms in all boiling regimes under steady-state and transient conditions,” *Int. J. Therm. Sci.*, vol. 41, no. 7, pp. 586–598, Jun. 2002, doi: 10.1016/S1290-0729(02)01352-2.

[40] A. K. Das, P. K. Das, and P. Saha, “Performance of different structured surfaces in nucleate pool boiling,” *Appl. Therm. Eng.*, vol. 29, no. 17–18, pp. 3643–3653, Dec. 2009, doi: 10.1016/j.applthermaleng.2009.06.020.

[41] J. Kim, “Review of nucleate pool boiling bubble heat transfer mechanisms,” *Int. J. Multiph. Flow*, vol. 35, no. 12, pp. 1067–1076, Dec. 2009, doi: 10.1016/j.ijmultiphaseflow.2009.07.008.

[42] A. Stojanovic, S. Belosevic, N. Crnomarkovic, I. Tomanovic, and A. Milicevic, “Nucleate pool boiling heat transfer: Review of models and bubble dynamics parameters,” *Therm. Sci.*, vol. 26, no. 1

Part A, pp. 157–174, 2022, doi: 10.2298/TSCI200111069S.

[43] J. Kim and M. H. Kim, "On the departure behaviors of bubble at nucleate pool boiling," *Int. J. Multiph. Flow*, vol. 32, no. 10–11, pp. 1269–1286, Oct. 2006, doi: 10.1016/j.ijmultiphaseflow.2006.06.010.

[44] Y. Sato and B. Niceno, "Nucleate pool boiling simulations using the interface tracking method: Boiling regime from discrete bubble to vapor mushroom region," *Int. J. Heat Mass Transf.*, vol. 105, pp. 505–524, Feb. 2017, doi: 10.1016/j.ijheatmasstransfer.2016.10.018.

[45] S. G. Kandlikar, "Similarities and Differences Between Flow Boiling in Microchannels and Pool Boiling," *Heat Transf. Eng.*, vol. 31, no. 3, pp. 159–167, Mar. 2010, doi: 10.1080/01457630903304335.

[46] V. K. Dhir, H. S. Abarajith, and D. Li, "Bubble Dynamics and Heat Transfer during Pool and Flow Boiling," *Heat Transf. Eng.*, vol. 28, no. 7, pp. 608–624, Jul. 2007, doi: 10.1080/01457630701266421.

[47] M. Piasecka, "Heat transfer research on enhanced heating surfaces in flow boiling in a minichannel and pool boiling," *Ann. Nucl. Energy*, vol. 73, pp. 282–293, Nov. 2014, doi: 10.1016/j.anucene.2014.06.041.

[48] A. Sathyabhama and A. Dinesh, "Augmentation of heat transfer coefficient in pool boiling using compound enhancement techniques," *Appl. Therm. Eng.*, vol. 119, pp. 176–188, Jun. 2017, doi: 10.1016/j.applthermaleng.2017.03.029.

[49] G. Liang and I. Mudawar, "Review of pool boiling enhancement with additives and nanofluids," *Int. J. Heat Mass Transf.*, vol. 124, pp. 423–453, Sep. 2018, doi: 10.1016/j.ijheatmasstransfer.2018.03.046.

[50] M. Ebrahimi-Dehshali, S. Z. Najm-Barzanji, and A. Hakkaki-Fard, "Pool boiling heat transfer enhancement by twisted-tape fins," *Appl. Therm. Eng.*, vol. 135, pp. 170–177, May 2018, doi: 10.1016/j.applthermaleng.2018.02.040.

[51] D. Cooke and S. G. Kandlikar, "Effect of open microchannel geometry on pool boiling enhancement," *Int. J. Heat Mass Transf.*, vol. 55, no. 4, pp. 1004–1013, Jan. 2012, doi: 10.1016/j.ijheatmasstransfer.2011.10.010.

[52] K. G. Rajulu, R. Kumar, B. Mohanty, and H. K. Varma, "Enhancement of nucleate pool boiling heat transfer coefficient by reentrant cavity surfaces," *Heat Mass Transf.*, Aug. 2004, doi: 10.1007/s00231-004-0526-4.

[53] S. Launay, A. G. Fedorov, Y. Joshi, A. Cao, and P. M. Ajayan, "Hybrid micro-nano structured thermal interfaces for pool boiling heat transfer enhancement," *Microelectronics J.*, vol. 37, no. 11, pp. 1158–1164, Nov. 2006, doi: 10.1016/j.mejo.2005.07.016.

[54] B. B. Mikic and W. M. Rohsenow, "A New Correlation of Pool-Boiling Data Including the Effect of Heating Surface Characteristics," *J. Heat Transfer*, vol. 91, no. 2, pp. 245–250, May 1969, doi: 10.1115/1.3580136.

[55] E. Teodori, A. S. Moita, and A. L. N. Moreira, "EMPIRICAL AND MODELING-BASED CORRELATIONS FOR POOL BOILING ON MICROSTRUCTURED SURFACES," *Interfacial Phenom. Heat Transf.*, vol. 2, no. 3, pp. 273–292, 2014, doi: 10.1615/InterfacPhenomHeatTransfer.2015011663.

[56] W. Leiner, "Heat transfer by nucleate pool boiling—general correlation based on thermodynamic similarity," *Int. J. Heat Mass Transf.*, vol. 37, no. 5, pp. 763–769, Mar. 1994, doi: 10.1016/0017-9310(94)90114-7.

[57] A. Ayoobi, A. F. Khorasani, M. Ramezanizadeh, and A. Afshari, "Experimental investigation of transient pool boiling characteristics of ferrofluid in comparison with deionized water," Appl. Therm. Eng., vol. 179, p. 115642, Oct. 2020, doi:10.1016/j.applthermaleng.2020.115642.

[58] Y. Zhang, D. Lu, Z. Wang, X. Fu, Q. Cao, and Y. Yang, "Experimental investigation on pool-boiling of C-shape heat exchanger bundle used in PRHR HX," *Appl. Therm. Eng.*, vol. 114, pp. 186–195, Mar. 2017, doi: 10.1016/j.applthermaleng.2016.11.185.

[59] H. Chu, X. Yu, H. Jiang, D. Wang, and N. Xu, "Progress in enhanced pool boiling heat transfer on macro- and micro-structured surfaces," *Int. J.*

Heat Mass Transf., vol. 200, p. 123530, Jan. 2023, doi: 10.1016/j.ijheatmasstransfer.2022.123530.

[60] M. Jamialahmadi and H. Müller-Steinhagen, "A New Model for the Effect of Calcium Sulfate Scale Formation on Pool Boiling Heat Transfer," *J. Heat Transfer*, vol. 126, no. 4, pp. 507–517, Aug. 2004, doi: 10.1115/1.1777579.

[61] , M. Jamialahmadi and , H. Müller-Steinhagen, "Scale Formation During Nucleate Boiling - A Review," *Corros. Rev.*, vol. 11, no. 1–2, pp. 25–54, Jun. 1993, doi: 10.1515/CORRREV.1993.11.1-2.25.

[62] Y. H. Jeong, W. J. Chang, and S. H. Chang, "Wettability of heated surfaces under pool boiling using surfactant solutions and nano-fluids," *Int. J. Heat Mass Transf.*, vol. 51, no. 11–12, pp. 3025–3031, Jun. 2008, doi: 10.1016/j.ijheatmasstransfer.2007.09.023.

[63] T. Sayahi and M. Bahrami, "Investigation on the Effect of Type and Size of Nanoparticles and Surfactant on Pool Boiling Heat Transfer of Nanofluids," *J. Heat Transfer*, vol. 138, no. 3, Mar. 2016, doi: 10.1115/1.4031883.

[64] S. Etedali, M. Afrand, and A. Abdollahi, "Effect of different surfactants on the pool boiling heat transfer of SiO2/deionized water nanofluid on a copper surface," *Int. J. Therm. Sci.*, vol. 145, p. 105977, Nov. 2019, doi: 10.1016/j.ijthermalsci.2019.105977.

[65] M. Zarei Saleh Abad, M. Ebrahimi-Dehshali, M. A. Bijarchi, M. B. Shafii, and A. Moosavi, "Visualization of pool boiling heat transfer of magnetic nanofluid," *Heat Transf. Res.*, vol. 48, no. 7, pp. 2700–2713, Nov. 2019, doi: 10.1002/htj.21498.

[66] A. Abdollahi, M. R. Salimpour, and N. Etesami, "Experimental analysis of magnetic field effect on the pool boiling heat transfer of a ferrofluid," *Appl. Therm. Eng.*, vol. 111, pp. 1101–1110, Jan. 2017, doi: 10.1016/j.applthermaleng.2016.10.019.

[67] P. Rahmati, M. Ebrahimi-Dehshali, and A. Hakkaki-Fard, "Enhancement of pool boiling heat transfer using ferromagnetic beads in a variable magnetic field," *Appl. Therm. Eng.*, vol. 164, p. 114439, Jan. 2020, doi: 10.1016/j.applthermaleng.2019.114439.

[68] P. Naphon, "Effect of Magnetic Fields on the Boiling Heat Transfer Characteristics of Nanofluids," *Int. J. Thermophys.*, vol. 36, no. 10–11, pp. 2810–2819, Nov. 2015, doi: 10.1007/s10765-015-1993-1.

[69] A. F. Savaş and C. Kocabaş, "Reducing surface heat loss in steam boilers," *Open Chem.*, vol. 20, no. 1, pp. 1458–1466, Dec. 2022, doi: 10.1515/chem-2022-0241.

[70] S. Hasnain, M. K. Ali, J. Akhter, B. Ahmed, and N. Abbas, "Selection of an industrial boiler for a soda-ash production plant using analytical hierarchy process and TOPSIS approaches," *Case Stud. Therm. Eng.*, vol. 19, p. 100636, Jun. 2020, doi: 10.1016/j.csite.2020.100636.

[71] M. T. Siraj, B. Debnath, A. Kumar, A. B. M. M. Bari, A. Samadhiya, and S. B. Payel, "Evaluating barriers to sustainable boiler operation in the apparel manufacturing industry: Implications for mitigating operational hazards in the emerging economies," *PLoS One*, vol. 18, no. 4, p. e0284423, Apr. 2023, doi: 10.1371/journal.pone.0284423.

[72] A. S. Tyusenkov and S. E. Cherepashkin, "Scale inhibitor for boiler water systems," *Russ. J. Appl. Chem.*, vol. 87, no. 9, pp. 1240–1245, Sep. 2014, doi: 10.1134/S1070427214090080.

[73] P. Olczak, Z. Kowalski, J. Kulczycka, and A. Makara, "Eco-innovative method of cleaning heat exchangers from boiler scale," *Manag. Prod. Eng. Rev.*, Mar. 2020, doi: 10.24425/mper.2020.132940.

[74] F. Luo, B. Dong, J. Xie, and S. Jiang, "Scaling tendency of boiler feedwater without desiliconization treatment," *Desalination*, vol. 302, pp. 50–54, Sep. 2012, doi: 10.1016/j.desal.2012.06.020.

[75] G. A. J. Begg, W. M. Hebblethwaite, and G. Cooke, "Operating Experience with La Mont Boilers, with Special Reference to Feed Water Problems," *Proc. Inst. Mech. Eng.*, vol. 155, no. 1, pp. 346–375, Jun. 1946, doi: 10.1243/PIME_PROC_1946_155_054_02.

[76] A. Müller, "An X-ray Generator with a Water-cooled Rotating Target," *Br. J. Radiol.*, vol. 4, no. 39, pp. 127–131, Mar. 1931, doi: 10.1259/0007-1285-4-39-127.

[77] J. Arthur *et al.*, "Microchannel water cooling of

silicon x-ray monochromator crystals," *Rev. Sci. Instrum.*, vol. 63, no. 1, pp. 433–436, Jan. 1992, doi: 10.1063/1.1142722.

[78] T. C. Furnas, "A progress report on a new, portable, water-cooled, rotating-anode X-ray tube with very small focus," *Nucl. Instruments Methods Phys. Res. Sect. A Accel. Spectrometers, Detect. Assoc. Equip.*, vol. 299, no. 1–3, pp. 246–250, Dec. 1990, doi: 10.1016/0168-9002(90)90785-5.

[79] P. Leduc, P. Smague, A. Leroux, and G. Henry, "Low temperature heat recovery in engine coolant for stationary and road transport applications," *Energy Procedia*, vol. 129, pp. 834–842, Sep. 2017, doi: 10.1016/j.egypro.2017.09.197.

[80] A. Broatch, P. Olmeda, J. Martín, and A. Dreif, "Improvement in engine thermal management by changing coolant and oil mass," *Appl. Therm. Eng.*, vol. 212, p. 118513, Jul. 2022, doi: 10.1016/j.applthermaleng.2022.118513.

[81] M. Starostin and S. Tamir, "New engine coolant for corrosion protection of magnesium alloys," *Mater. Corros.*, vol. 57, no. 4, pp. 345–349, Apr. 2006, doi: 10.1002/maco.200503886.

[82] G. Vroomen, S. Lievens, and J. Maes, "Influence of Engine Coolant Composition on the Electrochemical Degradation Behavior of EPDM Radiator Hoses," in *Engine Coolant Testing: Fourth Volume*, ASTM International100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, 1999, pp. 183–195. doi: 10.1520/STP38246S.

[83] K. Kiryu, K. Tsuchiya, T. Shimomura, T. Yanai, K. Okada, and H. Hirabayashi, "The Effect of Coolant Additives and Seal Composition on Performance of Water Pump Seals of Automotive Engines," Feb. 1989. doi: 10.4271/890609.

[84] J. De Kimpe, S. Lievens, and S. Yan, "Characterization of an Organic Salt Based Engine Coolant," Jan. 2015. doi: 10.4271/2015-26-0063.

[85] P. L. Sathyanarayanan and R. Ramprabhu, "Study on the effect of different combinations of engine coolant additives on the heat dissipation rate of radiators," *Proc. Inst. Mech. Eng. Part D J. Automob. Eng.*, vol. 219, no. 10, pp. 1173–1179, Oct. 2005, doi: 10.1243/095440705X34838.

[86] W. Zhou, N. N. Aung, A. Choudhary, and M. Kanouni, "Evaluation of corrosion resistance of magnesium alloys in radiator coolants," *Corros. Eng. Sci. Technol.*, vol. 46, no. 4, pp. 386–391, Jun. 2011, doi: 10.1179/174327809X409187.

[87] H.-M. Nieh, T.-P. Teng, and C.-C. Yu, "Enhanced heat dissipation of a radiator using oxide nano-coolant," *Int. J. Therm. Sci.*, vol. 77, pp. 252–261, Mar. 2014, doi: 10.1016/j.ijthermalsci.2013.11.008.

[88] H. Liu, J. Ma, L. Tong, G. Ma, Z. Zheng, and M. Yao, "Investigation on the Potential of High Efficiency for Internal Combustion Engines," *Energies*, vol. 11, no. 3, p. 513, Feb. 2018, doi: 10.3390/en11030513.

[89] M. Jia, E. Gingrich, H. Wang, Y. Li, J. B. Ghandhi, and R. D. Reitz, "Effect of combustion regime on in-cylinder heat transfer in internal combustion engines," *Int. J. Engine Res.*, vol. 17, no. 3, pp. 331–346, Mar. 2016, doi: 10.1177/1468087415575647.

[90] C. Guardiola, P. Olmeda, B. Pla, and P. Bares, "In-cylinder pressure based model for exhaust temperature estimation in internal combustion engines," *Appl. Therm. Eng.*, vol. 115, pp. 212–220, Mar. 2017, doi: 10.1016/j.applthermaleng.2016.12.092.

[91] L. Fonseca, P. Olmeda, R. Novella, and R. M. Valle, "Internal Combustion Engine Heat Transfer and Wall Temperature Modeling: An Overview," *Arch. Comput. Methods Eng.*, vol. 27, no. 5, pp. 1661–1679, Nov. 2020, doi: 10.1007/s11831-019-09361-9.

[92] L. C. ROWE, "An Evaluation of Inhibitors for Corrosion Prevention In An Engine Cooling System★," *Corrosion*, vol. 13, no. 11, pp. 72–78, Nov. 1957, doi: 10.5006/0010-9312-13.11.72.

[93] T. G. Theofanous and T. N. Dinh, "HIGH HEAT FLUX BOILING AND BURNOUT AS MICROPHYSICAL PHENOMENA: MOUNTING EVIDENCE AND OPPORTUNITIES," *Multiph. Sci. Technol.*, vol. 18, no. 3, pp. 251–276, 2006, doi: 10.1615/MultScienTechn.v18.i3.30.

[94] Y. KATTO and M. KUNIHIRO, “Study of the Mechanism of Burn-Out in Boiling System of High Burn-Out Heat Flux,” *Bull. JSME*, vol. 16, no. 99, pp. 1357–1366, 1973, doi: 10.1299/jsme1958.16.1357.

[95] A. Adamantiades and I. Kessides, “Nuclear power for sustainable development: Current status and future prospects,” *Energy Policy*, vol. 37, no. 12, pp. 5149–5166, Dec. 2009, doi: 10.1016/j.enpol.2009.07.052.

[96] W.-T. Wu, Y.-M. Yang, and J.-R. Maa, “Nucleate pool boiling enhancement by means of surfactant additives,” *Exp. Therm. Fluid Sci.*, vol. 18, no. 3, pp. 195–209, Nov. 1998, doi: 10.1016/S0894-1777(98)10034-1.

[97] M. M. Mahmoud and T. G. Karayiannis, “Pool boiling review: Part I – Fundamentals of boiling and relation to surface design,” *Therm. Sci. Eng. Prog.*, vol. 25, p. 101024, Oct. 2021, doi: 10.1016/j.tsep.2021.101024.

[98] S. M. S. Murshed, D. Milanova, and R. Kumar, “An Experimental Study of Surface Tension-Dependent Pool Boiling Characteristics of Carbon Nanotubes-Nanofluids,” in *ASME 2009 7th International Conference on Nanochannels, Microchannels and Minichannels*, ASMEDC, Jan. 2009, pp. 75–80. doi: 10.1115/ICNMM2009-82204.

[99] N. Kumar, M. Q. Raza, and R. Raj, “Surfactant aided bubble departure during pool boiling,” *Int. J. Therm. Sci.*, vol. 131, pp. 105–113, Sep. 2018, doi: 10.1016/j.ijthermalsci.2018.05.025.