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Heating Efficiency and Condensation Prevention Device UsingWaste Heat

Seho Min[1] and Brenna Kelly[#]

[1]Brooks School, USA
[#]Advisor

ABSTRACT

This research aims to explore ways to increase the energy efficiency of current energy sources in an era when new energy sources are needed. In particular, I want to investigate methods for improving heating efficiency by utilizing waste heat and addressing the problem of condensation that occurs in winter. Condensation is caused by the temperature difference between the inside and outside of a building. Although various methods exist to prevent it, there may be room for improvement. It is therefore proposed that utilizing waste heat to enhance heating efficiencyand prevent condensation represents a potential avenue for more efficient use of energy. Furthermore, this approach could serve to emphasize the need for energy substitution by recycling energy that would otherwise be wasted. It ishoped that the findings of this research will contribute to identifying ways to use waste heat more efficiently in our daily lives.

Introduction

Motivation and Objectives

The world is entering the era of the Fourth Industrial Revolution, which brings with it the necessity for new energy sources. While various eco-friendly energy options are being proposed, finding the most suitable and efficient solution remains challenging due to differing resource utilization among countries. South Korea, despite actively pursuing eco-friendly development, still relies heavily on coal and fossil fuels (UNFCCC, 2020). In light of this, waste disposal and treatment methods present an opportunity to explore the potential of waste heat as a solution.
Projects utilizing waste heat are primarily conducted at the national, local government, and corporate levels, but research on waste heat utilization within households is scarce in Korea. Therefore, I aim to investigate the feasibility of utilizing waste heat in households and propose innovative solutions for heating and preventing condensation.

The current heating method typically involves heating air and distributing the warmed air into the house. However, this often results in the lower levels of the house remaining cold, which presents a significant challenge. Even when warm air is released, it ultimately rises, potentially compromising heating efficiency. In most cases, the heat rising towards the ceiling is transmitted outward, making it difficult to fully utilize the generated heat.

Therefore, maximizing the utilization of waste heat is believed to significantly improve heating efficiency. Additionally, condensation frequently occurs during winter, posing various problems (Collado, 2023). As it createsan environment conducive to mold growth, mold issues can become severe. To address these issues, ventilation and insulation materials (Russell et al., 2007) have been suggested as potential solutions. However, ventilation can leadto energy loss due to drafts, and the use of insulation materials incurs high costs with potentially short-lived effects. Thus, considering alternative solutions for preventing condensation may be beneficial. I propose that waste heat be utilized to develop innovative strategies for condensation prevention and aim to assess their feasibility through experimentation.

Research

Definition of Waste Heat

Waste heat is defined as the heat that is generated or consumed in the process of energy production or consumption but cannot be utilized and is discarded externally. This can be observed in the white steam emitted from factory chimneys. In a qualitative sense, waste heat can be defined as the heat that is discarded, accumulating to 0% of the total energy, and is recycled in various ways. It is defined as the energy that is used and discarded in various fields such as solar power, electricity, coal, biomass, and wind power. It is estimated that when fossil fuels such as coal and oil are converted into other forms of energy, only about 50% of the energy is actually used, while the rest is wasted as heat energy. Waste heat generated during incineration is also used to supply hot water to homes.

Necessity of Energy Conservation and Waste Heat

Rapid Climate Change: The term “climate crisis,” “climate emergency,” or “climate change” is used to describe the phenomenon of rapid changes in global climate patterns due to the gradual increase in the Earth's average temperature, such as global warming. While climate change has occurred in the past, modern climate change is occurring at a much faster rate (IEA, 2007). The current rapid climate change is primarily caused by the emission ofgreenhouse gasses such as carbon dioxide (CO_2) and methane by humans.The majority of greenhouse gasses emitted by humans are produced by burning fossil fuels to use energy.

- Causes of Fine Dust Pollution: It is thought that fine dust particles suspended in the atmosphere are mainly generated when burning fossil fuels such as coal and oil or from emissions from factories and vehicles. The composition of fine dust varies depending on the seasonal and meteorological conditions of the region, but generally consists of atmospheric pollutants such as sulfur compounds and nitrogen compounds that react in the air to form fine dust.

- It is also thought that natural sources of fine dust include natural occurrences such as evaporation of seawater, salt particles formed, pollen from plants, dust, and volcanic eruptions.

- Artificial sources of fine dust include emissions from boilers or power plants burning fossil fuels like coal and oil, which can result in soot. Other examples include emissions from vehicles, dust from constructionsites, and powdered raw materials inside factories.

While reports on the health effects of fine dust have been made since the late 1980s, it was the study by Dockery et al. (1993) that drew the attention of the public to the issue. This study investigated the relationship between air pollution and mortality in six U.S. cities and reported a close association between fine dust and mortality rates. This highlighted the environmental and public health importance of fine dust. In more recent times, Pope et al. (2002) have also highlighted the health significance of fine dust by publishing a paper on the association between long-term exposure to fine dust and mortality rates from lung cancer and cardiovascular diseases. According to this epidemiological study, it seems that the exposure to fine dust is not only associated with respiratory effects but also with systemic diseases such as cancer and cardiovascular diseases.

Current Utilization Examples of Waste Heat

In Denmark, more than half of the country's electricity needs are met by waste heat, while in Finland, waste heat accounts for 9% of its energy (Bühler et al., 2017). Waste incinerators are particularly effective for waste heat recovery and utilization. During waste incineration, the generated waste heat is recovered as energy. The process involves transporting collected waste into garbage containers, which are then stored in designated areas. Cranes areused to break open the bags, mix the waste, and incinerate it. The excess waste heat generated during this process iscaptured through a waste heat boiler, reaching temperatures of up to 400°C (Gustafsson, 2020). Waste heat is also actively recycled in steel and petrochemical plants. In steel plants, waste heat is used to produce steam, and it is estimated that this process covers about 58% of the plant's total electricity consumption. Waste heat boilers for district heating systems utilize high-temperature waste gas heat to generate steam. For instance, waste heat from an incinerator in Uijeongbu is used to supply district heating to 6,000 households. Additionally, recently developed hydrogen production technology utilizes high-temperature waste heat to heat water and separate hydrogen from oxygen (Mohsen Fallah Vostakola et al., 2023). This technology has the potential to produce more than 200 liters of hydrogen from water at 850°C, with an efficiency increase of around 15% compared to conventional methods.

Condensation

Definition of Condensation

Condensation is the phenomenon where moisture in the air forms water droplets on the surface of an object as the temperature of the air, including moisture, drops below the dew point (National Geographic, 2023). Air can containa certain amount of water vapor, and the maximum amount of water vapor that can exist in the air under the same pressure increases with temperature. It is worth noting that condensation occurs primarily during the winter months, when warm and humid indoor air contacts colder surfaces such as walls or windows. This can result in a drop in temperature and an increase in relative humidity. When the air temperature reaches the dew point, the moisture in the air condenses into water droplets and adheres to the surface, leading to condensation. It is important to understand that condensation can occur in two different ways: surface condensation and internal condensation (You et al., 2017). Surface condensation may occur on the surfaces of walls, ceilings, etc., when their temperatures drop below the dew point of the contacting air. Internal condensation, on the other hand, may occur within structures when the temperature of any part of the structure is lower than the dew point, causing moisture to form inside the structure.

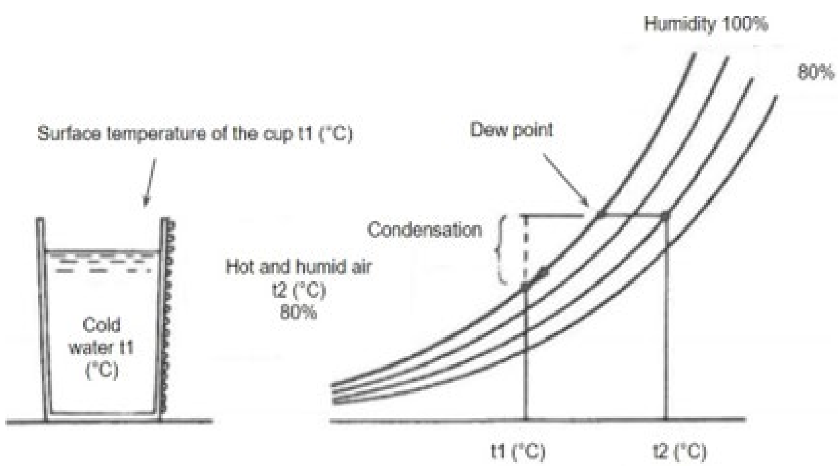

Figure 1. A graph showing the relationship between the temperature versus Humidity to explain the dew point.

Conditions for Occurrence

Condensation is more likely to occur during the winter months when there is a significant temperature difference between the external and internal environments, and when the indoor humidity is high. Inadequate ventilation during the winter or the presence of sources emitting vapor, such as wet laundry or a kettle, also contribute to condensation.

Problems Caused by Condensation

Condensation often appears as water droplets forming on windows exposed to cold winter air. If left unchecked, these droplets can accumulate, leading to damp walls and creating an environment conducive to mold and mildew growth. Mold not only detracts from the aesthetics of a home but can also damage furnishings and finishes, ultimately compromising the integrity of the structure. Additionally, mold poses health risks, particularly for individuals with sensitive skin, who may develop conditions such as atopic dermatitis. Inhalation of mold spores can cause symptoms like nasal congestion, eye irritation, respiratory difficulties, and can even exacerbate asthma.

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Investigation of Heating Methods

Types and Structures of Heating Systems

In most households, one of the following heating systems is commonly used: Firstly, Forced-air furnace: Typically fueled by natural gas, this system contains a burner that heats cold air drawn in from the house. The warmed air is then distributed throughout the home via blowers and ducts. Secondly, there is the heat pump. This is the most common type of heating system, a heat pump works by collecting warm air from outside, compressing it, and circulating it through ducts to heat the indoor air. Usually powered by electricity, this system can be reversed during warmer seasons to cool the indoor space by transferring hot air from indoors to outdoors.

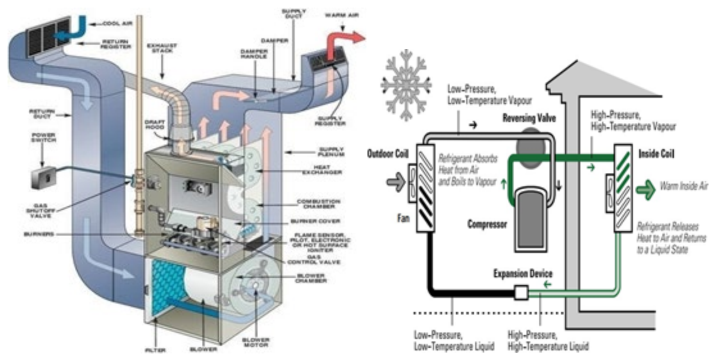


Figure 2. Force air furnace & The Heating Cycle; (Natural Resources Canada, 2022)

Investigation of Gas Range Hood Structure

In a household, the ventilation device mounted above the gas stove is designed to quickly exhaust smoke, steam, and heat generated during cooking to the outside.

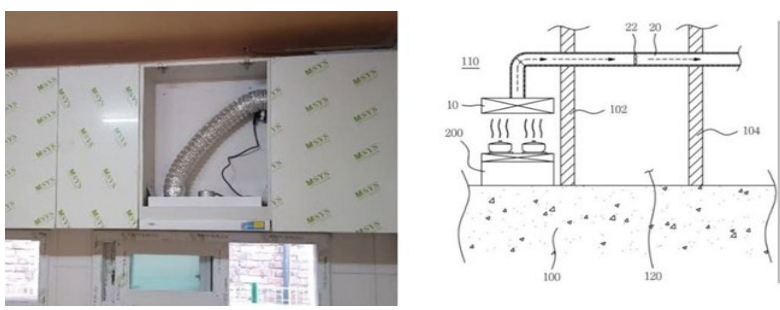


Figure 3. Gas Range Hood Structure in Real life Example

Bernoulli's Principle

In a hose with no friction and an incompressible fluid flowing through it, the same amount of fluid must pass through each section over time. This continuity means that in a narrower section of the hose, the fluid's velocity increases, leading to a decrease in pressure. Conversely, in a wider section, the velocity decreases, resulting in relatively higher pressure. According to Bernoulli's principle, under the assumption of no viscosity or compressibility losses, the total sum of potential energy, pressure energy, and kinetic energy remains constant between any two points along the flow.

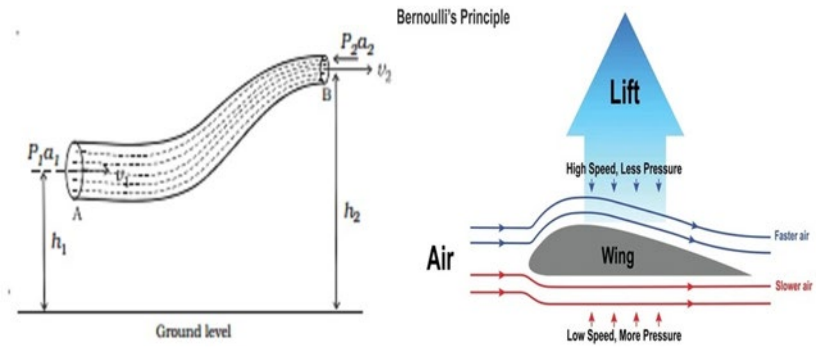


Figure 4. Diagram of Bernoulli's Theorem & Application of Bernoulli's principle in Aircraft

One can find an example of the application of Bernoulli's principle in the design of aircraft, ships, and automobiles. For instance, one might consider the cross-section of an aircraft wing. It is observed that the upper surface is slightly bulged compared to the lower surface. As the aircraft moves forward, it is found that the airflow velocity over the upper surface becomes faster than that passing under the lower surface. This results in a decrease in pressure. This pressure difference generates lift, which causes the aircraft to rise. Additionally, by adjusting the size of the conduit through which fluid flows, one can control the fluid's velocity. This principle is utilized in devices such as spray nozzles and fire hydrants.

Thermal Conductivity

Thermal conductivity is an intrinsic property of a material, where materials with high thermal conductivity transfer thermal energy more efficiently. One unit of thermal conductivity is W/mK. A related but distinct concept is thermal conductance, which refers to the actual degree to which a specific object of defined size and shape transfers heat.

Therefore, even objects made of materials with the same thermal conductivity will have different thermal conductances if their sizes and shapes differ.

$$k = \frac{Q\Delta x}{A(T_2 - T_1)}$$

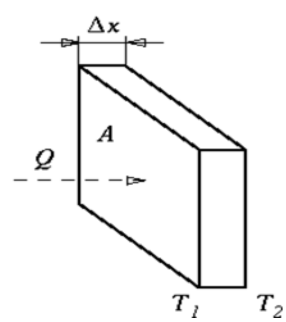


Figure 5. Diagram of conduction heat transfer process from hot (T1) to cold (T2) surfaces (Akoss, 2020)

According to Fourier's law, the rate of heat transfer is defined as $q = -k\nabla T$; where k is the thermal conductivity,A is the cross-sectional area for heat transfer, and L is the thickness (Tim Van Hoolst & Attilio Rivoldini, 2014). As demonstrated in Figure 5, when a space is divided by a wall with temperatures T_1 and T_2 on either side, and when insulating materials of thickness L_1 and L_2 and cross-sectional area A, the relationship between these variables can be expressed as $\frac{l}{k}$, which acts as a resistance to heat transfer. This is analogous to electrical resistance in electromagnetism. Therefore, for efficient heat conduction, it is beneficial to have a larger temperature difference, a shorter conduction length, and a larger cross-sectional area. Additionally, selecting a material with high thermal conductivity can further enhance efficiency.

Process

Observation Of Condensation Sites and Analysis of Condensation Environment

Objectives

In order to gain a deeper understanding of the environmental factors that contribute to condensation occurring in a severe manner, and to identify potential issues that may arise as a result of condensation, I decided to conduct a direct observation of the condensation points and analyze the surrounding environment. By observing the condensation points and learning about the characteristics of the area, I hope to gain valuable insights that can inform future actions.

Method

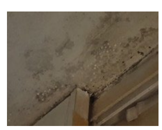
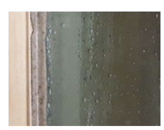
Experiment materials : notepad, notebook, writing materials, infrared thermometer, camera

Procedures:

1) It may be helpful to identify any overlooked areas where condensation occurs.
2) Measuring the surface temperature—either by touch or with an infrared thermometer—can provide useful data.
3) Inspecting and photographing the areas where condensation has occurred will assist in analyzing the problem and inferring its cause.

Results & Analysis

Table 1. Temperature of each place after experimenting

Condensation occurring place	Toilet seat	Warehouse Ceiling	Warehouse Window	mall Window Frame	Utility room window sill
Photo					
Surface Temperature	15.0℃	18.5℃	17.3℃	18.3℃	17.1℃

I observed that the areas of condensation were generally damp and in direct contact with the outside. Specifically, the warehouse ceiling was drafty, and the single-paned windows provided inadequate insulation. Even the double-paned windows showed condensation on the outer panes, which ran down and pooled on the window frames, dampening the wallpaper. The utility room also had single-paned windows. Inside, the temperature was 27°C, while outside it was 8°C, creating a significant temperature differential that contributed to the condensation, which was cooler than the rest of the house. The affected areas showed signs of mold, including discoloration and deformation. Based on these observations, addressing condensation through improved moisture and temperature control would be beneficial.

Identify The Type of Waste Heat in Your Home - Find the Waste Heat Available

Objectives

From my preliminary investigation, I found that the most common methods for utilizing waste heat include waste incineration, power generation, and capturing heat generated in factories. However, there were few instances of waste heat being utilized in home settings. This is likely because the waste heat generated at home is often low-grade, making it more challenging to utilize effectively. Nonetheless, I explored potential sources of waste heat within the home. To detect heat that is invisible to our eyes, I used an infrared camera to identify any hidden sources of heat.

Method

Experiment materials : notepad, notebook, writing materials, infrared thermometer, camera

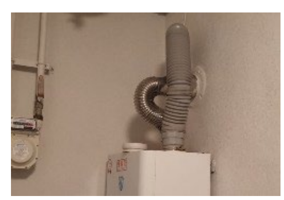
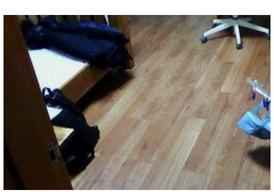
Figure 6. Infrared camera

Procedures :

1) One possible approach to identifying the source of heat in your home is to use an infrared camera. This device can detect infrared rays emitted from an object and measure the extent of the infrared radiation based on the surface temperature and color of the object. It may be particularly useful for checking waste heat.

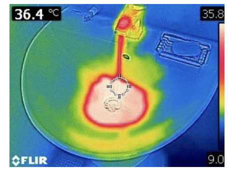
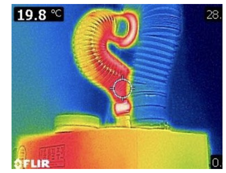
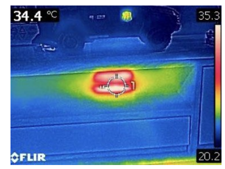
2) It would be beneficial to consider the objects that generate waste heat in the home. These include the TV, gas stove hood, boiler, computer, hot water, room floor, and TV receiver. It may be helpful to measure and observe the temperature of the waste heat generated by these objects. This information can be found in.

Table 2. Types of objects used in experiment

TV	Gas Stove Hood	Hot water	Heater
			
Floor	Computer	TV Receiver	
			

Results

Table 3. Thermal temperature of chosen objects using infrared camera

Objects	TV	Gas Stove Hood	Hot water	Heater
Infrared				
Temperature	29.1℃	107.0℃	36.4℃	19.8℃
Objects	Floor	Computer	TV Receiver	
Infrared				
Temperature	27.4℃	19.0℃	34.4℃	

Following the investigation, it became evident that the objects that could be used as waste heat were the gas stove hood and hot water. This was determined by measuring the temperature of a pot placed on a gas stove while boiling water. It was observed that the hot air generated when cooking food was expelled through the stove hood.
Additionally, the temperature of the hot water was found to be 36.4°C, with the TV console exhibiting the highest heat of 34.4°C among household appliances. It seems that the heater tube has a lower temperature than expected, and it is thought that this may be due to the fact that it is insulated to prevent heat from escaping through the pipe. Other objects seem to have too low a heat level to be utilized. It is the heat generated during food cooking that can be used as waste heat, and it was found to be the highest at 107°C and very hot when the actual hand was placed on the gas stove hood. Furthermore, it appeared that it might be possible to use hot water that would otherwise be discarded.

Manufacture Of Condensation Generator and Condensation Removal Device

Objectives

From the previous experiments, I gained insights into the areas where condensation occurs and explored the potential for utilizing waste heat in daily life. For this experiment, I needed a device to generate condensation and another to remove it, so I decided to create a model. Condensation tends to form around objects that are cooler than their surroundings, especially in high-humidity conditions. One approach to managing condensation is to actively dissipate the accumulated heat or to evaporate the condensation. I will build a device to test these methods and conduct experiments on condensation removal or suppression as described.

Method

Experiment materials: Acrylic box (200mm×200mm×200mm), 5T acrylic board (20mm0×100mm), acrylic board (195mm×9mm5) 2 pieces, arc test preparation reel board (200mm×195mm), hair dryer, mini humidifier, washing machine lake, digital temperature hygrometer, Infrared Camera, Stainless steel (200mm×200mm), Funnel, Glue gun.

Figure 7. Materials used for this experiment

Procedures:

1) Prior to construction, blueprints were created to select and prepare the necessary materials for production. The condensation generator will be made from an acrylic box that is sealed to be waterproof, with a metal plate used to create a dividing compartment inside. It is believed that if ice water is added to one compartment, the metal plate may experience a relatively low temperature due to the ice water. In the othercompartment, it is thought that the water vapor contained in the moist air may adhere to the metal plate, potentially leading to condensation. It is proposed that the condensation eliminator may utilize the wind to remove the condensation that has formed on the metal sheet. As the air reaches the end of the tube, the tube itself will be forced to narrow in size, using the Bernoulli principle to make the air flow faster.

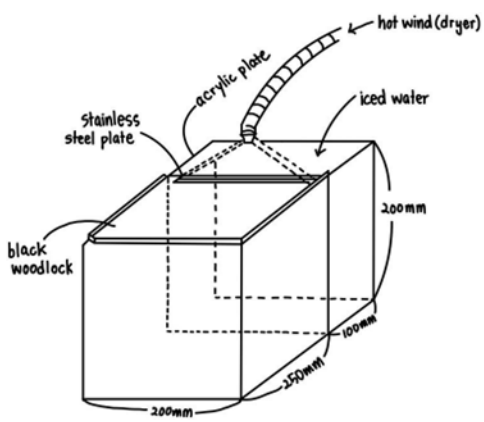


Figure 8. Blueprints for production procedure

2) Attach one acrylic plate 200mm×100mm, two acrylic plates 195mm×95mm, and one acrylic plate 195mm×100mm to the pre-cut acrylic box (200mm×200mm×200mm) using acrylic glue.

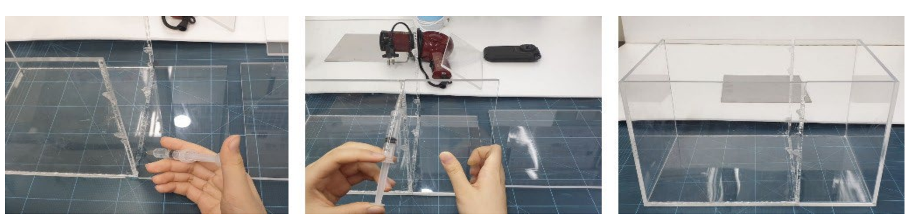


Figure 9. Making containers using acrylic plates and combining them together with acrylic glue

3) Secure the stainless steel plate with a glue gun at the point where the width of the acrylic box made in step 2 is divided into 200 mm and 100 mm.

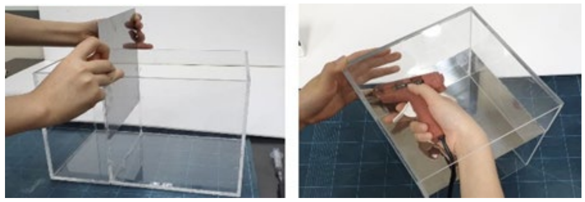


Figure 10. Securing the plates inside the acrylic box

4) Check that the box you made in step 3 is not leaking water. Pour water into the box and tilt it.

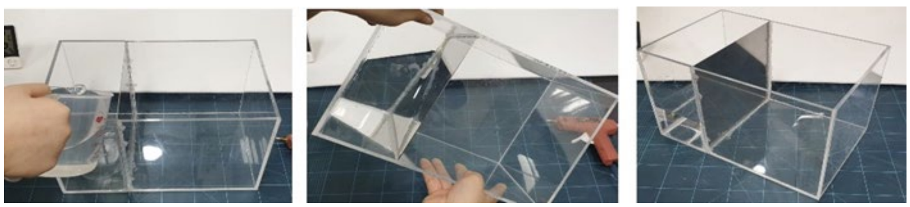


Figure 11. Checking to see if there is any water leakage by pouring and tilting the acrylic box

5) Once you've confirmed that the water isn't leaking, you might want to consider creating a condensation trap. One way to do this is to place ice water in one compartment of a stainless steel plate, a mini-humidifier in the other to help create condensation, and a black woodlock to cover the humidifier.

Figure 12. Creating a condensation trap using ice water and humidifier in the opposite sides with the black woodlock covering top

6) Turn the humidifier on and off repeatedly to see how the stainless steel plates change. Over time, dew formed on the stainless steel plate on the side with the humidifier.

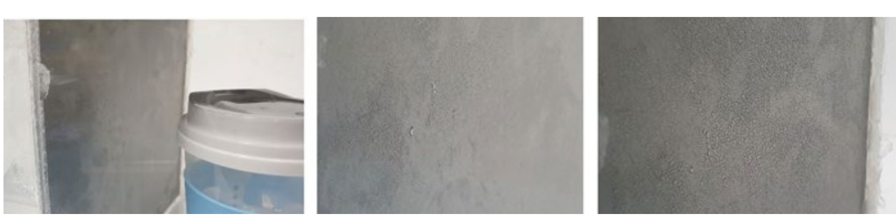


Figure 13. Proceeding with the experiment by turning on and off to create a dew

7) Build an additional device to remove the dew you created in Step 6. The washing machine lake is too long, so cut off as much of it as you want with a hobby knife. At one end, attach a small funnel, which will use the Bernoulli principle, with a glue gun. Use a woodlock to make a triangular column-shaped device that can direct air over a large area. Cut the required size and shape with a knife and glue them together with a glue gun. Put the funnel with the hose between the woodlocks and connect them with the glue gun.

Figure 14. Creating additional device to remove dew created from previous step

8) Drill holes in the wood locks covered by the acrylic box, attach the connections you made in step 7, and secure with a stand to keep the lake from tipping.

Figure 15. Combining the product created in step 6 and 7 together

Results

The condensation generator performed as anticipated. After approximately 10 minutes, the dew was readily apparent, and after another 10 minutes, it was possible to observe it from a distance. The condensation removal device was constructed and connected to complete the production of the experimental device.

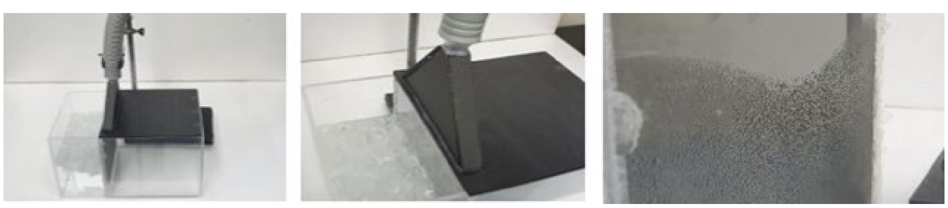


Figure 16. Testing for a final check on the experiment

Experiment to Check Whether Condensation Is Removed According to Wind Temperature

Objectives

In a previous experiment, I developed a mechanism that has the potential to generate and eliminate condensation. Moving forward to the next experiment, my objective is to remove the dew formed in the previous experiment. I hope to gain insight into the effectiveness of cold and hot air in dew removal by using a hairdryer for this experiment. The results will be compared to understand which temperature of air is more efficient. This experiment is based on the assumption that there is a device capable of absorbing waste heat, and I will be simulating wind using a hairdryer.

Method

Experimental Materials : Condensation eliminator, hairdryer, stopwatch

Figure 17. Materials to be used for experiment.

Procedures :

1) I position a hair dryer near the end of the condensation removal device and introduce cold air, observing the effects over a period of 30 minutes. I use a stopwatch to time the experiment and take pictures of the condensation at 5-minute intervals to monitor whether and how the condensation decreases over time.

Figure 18. Testing to check whether changes are made to condensation through cold air

2) Once the above process is complete, I bring the hair dryer close to the end of the condensation removal device again. This time I introduce hot air and observe the changes. The experimental procedure is identical to the previous one.

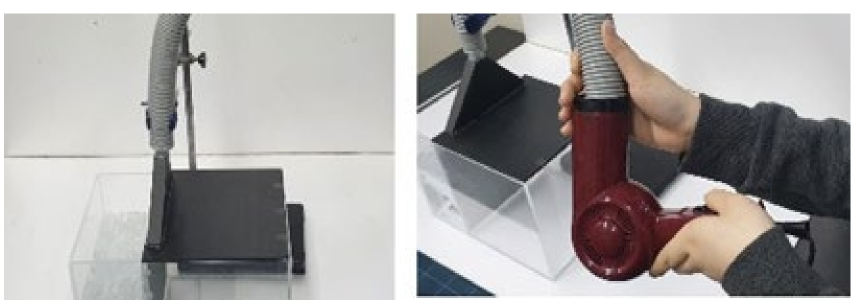


Figure 19. Testing the same procedure on the previous step with hot air

3) During the observation of condensation disappearance in steps 1 and 2, I noticed that the direction of the wind was not towards the condensation. To address this, I decided to install a wind guide barrier and conducted the experiment again. I cut a piece of wood to fit the wind hole in the lid, ensuring that the windfrom the hair dryer

convects through the pipe and directly targets the stainless steel plate without diverging elsewhere.

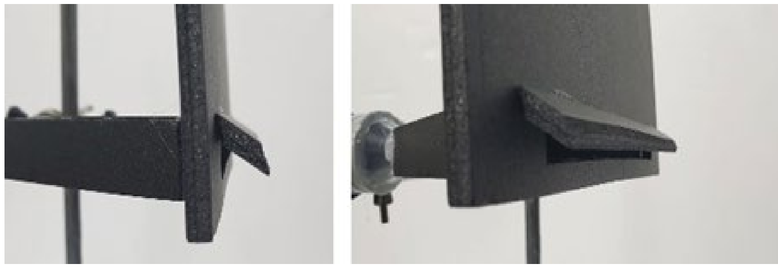


Figure 20. Adding wind barrier to guide the wind to a specific direction for condensation to occur

Result Analysis

When I introduced cold air, I observed a reduction in the amount of dew. However, the rate at which the dew decreased was slow, and it took a considerable amount of time to observe the reduction.

Table 4. Observation from hot air experiment from initial. 10 minutes, 20 minutes and 30 minutes

Initial	10 minutes passed	20 minutes passed	30 minutes passed
			

When I introduced hot air, the quantity of dew decreased rapidly. Comparing this with the very first experiment, I found that introducing hot air was more effective in removing dew than introducing cold air. The experiment results showed that hot air is significantly more effective in dew removal than cold air. This highlighted the necessity of utilizing the hot air from waste heat for dew removal.

Table 5. Observation from cold air experiment from initial. 10 minutes, 20 minutes and 30 minutes

Initial	10 minutes passed	20 minutes passed	30 minutes passed
			

Experiment To Confirm the Suppression Of Condensation Occurrence Of Condensation RemovalDevice

Objectives

In the previous experiment, I focused on removing dew formed by a condensation device using wind. For this experiment, I aim to determine whether it is possible to prevent dew formation and assess the feasibility of condensation prevention. Based on the observation that hot air is more effective at removing condensation than cold air, I plan to conduct this experiment using only hot air.

Method

Experimental Materials : Condensation eliminator, stand, mini humidifier, hairdryer, stopwatch, ice, beaker

Figure 21. Materials to be used for the experiment

Procedures :

1) In previous experiments, I filled a small compartment with ice water and operated a humidifier in a larger compartment to induce dew formation. However, in actual double-pane windows, the space between the panes is much narrower, and the dew formed in the larger compartment was not completely removed during the experiment. To better simulate real conditions, I decided to conduct the experiment in a narrower space,matching the dimensions of a double-pane window more closely.

Figure 22. Conducting a new experiment in a narrower space

2) After filling the larger compartment with ice, I conducted a preliminary experiment to generate and removedew, aiming to verify the effectiveness of the setup. The results indicated that more dew was removed when ice was placed in the larger compartment compared to the smaller one. I anticipate that the previous experiment would have been more effective at removing dew if ice had been used in the larger compartment. For the formal experiment, I will first wipe off any condensation on the stainless steel plate and then proceed with the dew suppression test.

Figure 23. Preparing for dew suppression experiment

3) In a state without initial condensation, I will conduct an experiment to determine if condensation

forms when the condensation removal device is activated. The procedure involves taking a photo every 5 minutes. After each 5-minute interval, I will turn on the humidifier for 1 minute to introduce continuous water vaporand accelerate the experiment. The total duration of the experiment is set to 30 minutes.

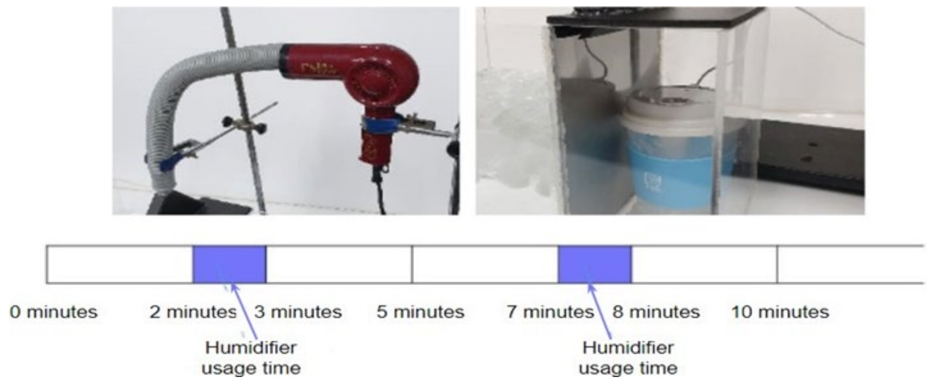
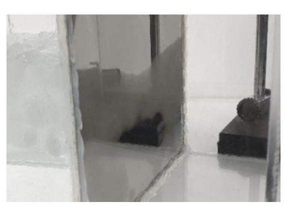
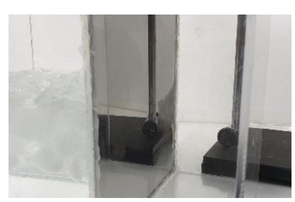


Figure 24. Testing to see the effectiveness of a condensation removal device

Result Analysis

Despite continuously supplying water vapor with the humidifier, no dew formation was observed. While the humidifier was operating, only the area where the ice was located became misty with water vapor. However, once the humidifier was turned off, the stainless steel plate cleared up after a short period. These results suggest that applying waste heat to areas prone to condensation can effectively suppress it. Since condensation commonly occurs on cold walls, glass surfaces, or wall corners, targeting these areas with waste heat can be an efficient method for preventing condensation.

Table 6. Observations with no dews formed even when water was continuously supplied for initial, 10 minutes, 20 minutes and 30 minutes

Initial	10 minutes passed	20 minutes passed	30 minutes passed
			

Experiment To Check the Heating Efficiency by Inhaling and Discharging the Heated Air and UsingWasted Water

Objectives

In my previous investigation of waste heat, I explored utilizing heat from a gas range hood and wastewater. My experiments confirmed that hot air can effectively suppress or eliminate condensation. I hypothesized that this heat could be reclaimed before it becomes waste, potentially improving heating efficiency. To test this hypothesis, I designed a model that incorporates both air containing waste heat and waste heat water. The model features a devicethat captures unused air from the upper part of a gas range or heater and a system that uses waste heat from water for heating. While this model mainly serves to demonstrate potential utilization strategies and may not precisely reflect actual performance, it aims to replicate the process and assess its feasibility.

Method

Experimental Materials: Stand, mini humidifier, hemispherical cooling fan, wires, 2 sets of 2 batteries, 2 battery fittings, stopwatch, wires, gas stove, copper pipe, acrylic plate

Figure 25. Materials used for this experiments

Procedures :

1) Make a hemispherical cooling fan. First, cut the wooden chopsticks to the appropriate size for the support to fix the propeller in the center. Drill a hole in the hemisphere so that the wind can go out. Connect the wooden chopsticks and the hemisphere using a glue gun. Connect the wire connected to the propeller to the switch and connect it to the battery. Turn on the switch to check if the propeller is working well.

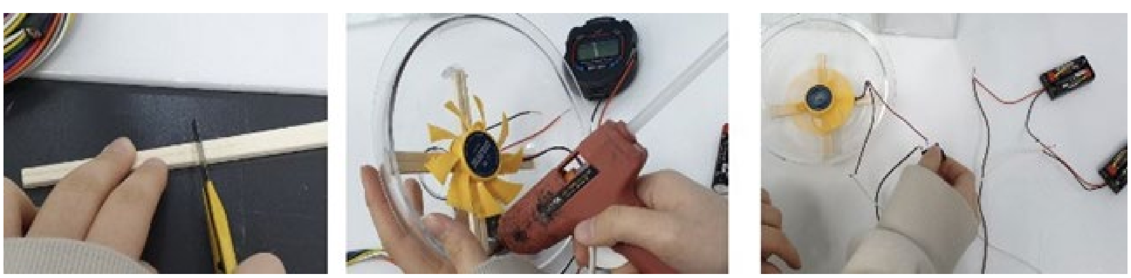


Figure 26. Process of creating a hemispherical cooling fan

2) Despite the well constructed hemispherical cooling fan, I noticed an unexpected airflow pattern. Instead of rising upwards as intended, the air was escaping from the bottom of the hemisphere where I placed my hand over it. The propeller was designed to direct the wind upwards, but due to the small size of the hemisphere's upper

hole, it appeared that the air was being deflected downwards. To address this issue, I opted for a smaller motor compared to the previously used propeller.

Figure 27. Troubleshooting and refining a design based on observed performance due air leak

3) When constructing a hemispherical cooling fan, begin by cutting wooden chopsticks and affixing them tothe four sides of a hemispherical tube using a glue gun. Then, connect a wire to a small motor, which will allow the air to ascend rapidly due to its size.

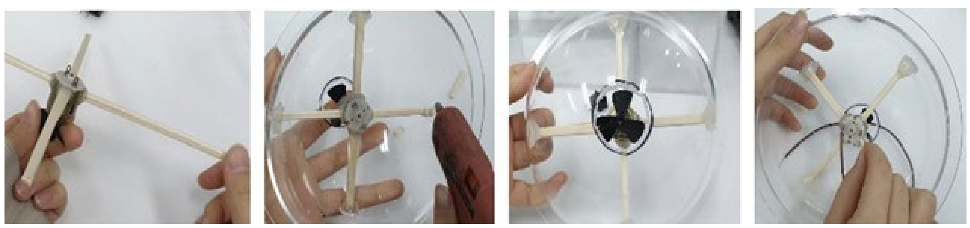


Figure 28. Construction of a hemispherical cooling fan

4) Once you've confirmed that the wind is flowing in the desired direction from the cooling fan, secure it tothe end of a lake. To prevent tilting, stabilize the cooling fan with a stand and establish a wire connection.

Figure 29. Final step to make the cooling fan by ensuring it with the support of a stand

5) To test the efficiency of this gas range hood device model and the hemispherical cooling fan, I initiated thegas range after generating condensation. The aim was to observe if the heat could effectively enter the cooling fan and eliminate the condensation. However, during this experiment, the intense heat from the gas range caused the propeller to melt, leading to a premature termination of the experiment. Consequently, I replaced the melted propeller and reattached the slightly melted glue gun.

Figure 30. Testing the efficiency of a gas range hood device model and the hemispherical cooling fan

6) To verify its ability to intake hot air, I placed a pot filled with water on a portable gas stove and brought it to a boil. I then connected the cooling fan, which was attached to the hood device, to a DC power supply and activated it. From a design perspective, I hypothesized that if air from a wide area is forcibly moved through the cooling fan into a narrow tube due to Bernoulli's principle, the increased air speed will decrease the pressure, creating a pressure difference that allows the air to be sucked in and passed more smoothly. I used an infrared camera to measure the temperature of the air and confirm whether the hot air was being inhaled and passing through the tube.

Figure 31. Testing to verify the ability of the hemispherical cooling fan to intake hot air using Bernoulli's principle

7) This time, I plan to create a device that harnesses waste heat water. I believe that the majority of the heat retained by hot water can be transferred to the floor through a process of circulating the floor of the house once before being drained into the sewer. To ensure even distribution throughout the floor model, I bent a copper pipe into the shape of the letter 'E', then covered it with a wood lock and an acrylic plate.

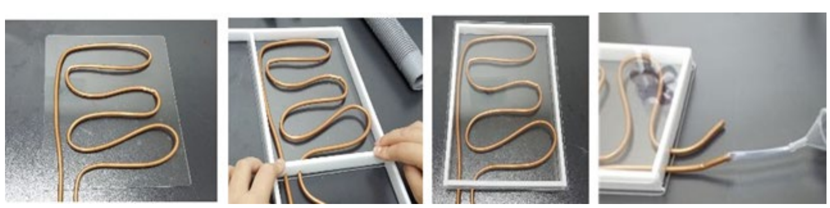


Figure 32. Planning to create a device that harnesses waste heat from hot water

8) I attached a silicone tube to the copper pipe, connected a funnel, and linked the washing machine hose and funnel. After pouring hot water into the funnel for one minute, I checked if the water was exiting through the opposite tube. I then divided the top of the floor model into three sections - top, middle, and bottom. After that, I measured the temperature of each part using an infrared camera to observe the temperature distribution across the floor model.

Result Analysis

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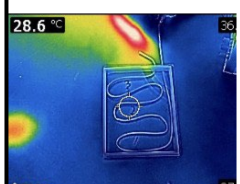
Figure 33. Checking temperature using the infrared camera

Table 7. Temperature of before and after hot water intake of the device

Measurements	**re hot waterintake**	**r hot waterintake**
Top		
Middle		
Bottom		

Time(sec)/°C	**0s**	**10s**	**20s**	**30s**	**40s**	**50s**	**60s**	**ΔTemperature**
Top	26.5°C	27.3°C	28.0°C	28.6°C	27.8°C	28.3°C	28.8°C	+2.3 °C
Middle	26.4°C	28.0°C	28.1°C	28.6°C	28.4°C	28.7°C	28.6°C	+2.2°C
Bottom	26.1°C	28.3°C	28.7°C	28.7°C	28.7°C	29.4°C	29.2°C	+3.1°C

I confirmed that the heated air, at approximately 48.5°C, was effectively drawn from a wide hemisphere into a narrow tube by the electric motor. The heated air was then successfully transmitted through the tube to its endpoint,allowing the air from the ceiling to be utilized more effectively. Additionally, I verified that hot water, poured through the funnel and flowing via gravity through the copper pipe, exited through the opposite tube. Over time, I observed a temperature increase in the floor model: the top section rose by 2.3°C, the middle by 2.2°C, and the bottom by 3.1°C. This temperature increase demonstrated that copper, with its high thermal conductivity, efficiently transmitted heat through the floor. This confirmed the heat transfer process as effective in my model.

Discussion

In summary, I investigated and tested various methods to utilize waste heat generated within the home, confirming its potential usability. Specifically, I demonstrated that waste heat could be used to prevent or eliminate condensation through experiments and explored its practical applications. I developed a system to capture and discharge waste heat and examined a heating system that leverages this heat. The study confirmed that waste heat can be actively utilized in domestic settings, suggesting potential benefits for energy conservation and environmental preservation. For example, I explored how waste heat could be applied to windows to prevent condensation and mold growth.

Additionally, I modeled systems for capturing and utilizing waste heat, gaining insights into its practical applications. The findings indicate that waste heat has significant potential for contributing to energy efficiency and environmental protection. It is hoped that future advancements will lead to the development of eco-friendly and energy-efficient home and building systems based on these results, aimed at reducing energy consumption and safeguarding the environment.

Conclusion

In the course of my research, I have explored various ways to utilize waste heat in households. I've found that it has several potential benefits, including reducing or completely stopping condensation, as well as increasing effective heating. Through careful experimentation, I was able to prove that waste heat can be used to reduce humidity issues which in turn decreases mold condensation and improves indoor air quality.

My primary goal is to develop new methods to use waste heat to enhance combustion and prevent condensation. In my tests, I discovered that hot air from waste heat is more effective than cold air in removing condensation. This study highlights how thermal waste management solutions can be incorporated into residential systems to reduce electricity consumption and ensure environmental sustainability.

Understandably, residential properties could benefit from such systems, especially in areas with high humidity and significant temperature differences—such as tropical climates. In these regions, using waste heat to control humidity on windows can be a feasible technique that improves building efficiency while consuming much less energy.

However, there are still some unanswered questions and other ideas that should not be overlooked. For instance, examining lessons learned from historical heating patterns in current experiments could provide valuable insights. Moreover, developing simulators to evaluate the effectiveness of these systems could offer critical information toguide their future application.

Subsequent research could address questions such as: What are the best ways to incorporate waste heat into existingheating systems without requiring major infrastructure changes? It is also essential to assess the long-term impact of waste heat utilization on indoor air quality and building materials. By addressing these issues, research and development in waste heat management can pave the way for the creation of more environmentally friendly and energy-efficient housing systems. Ultimately, this will lead to a reduction in energy consumption and better protection of the environment.

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