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Article

Automatic return system for hot water recovery in the shower

Sistema automatico de retorno para la recuperación de agua caliente en la regadera

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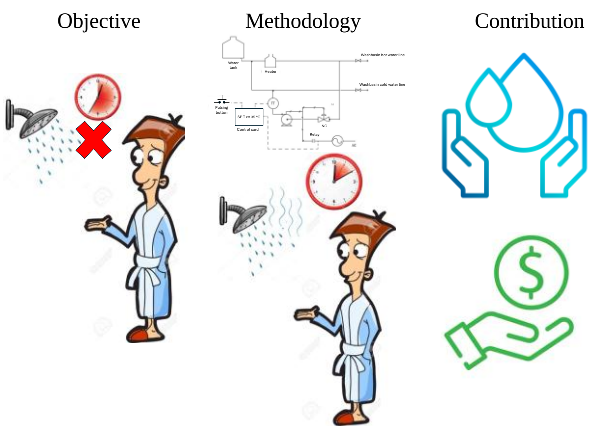
Abstract

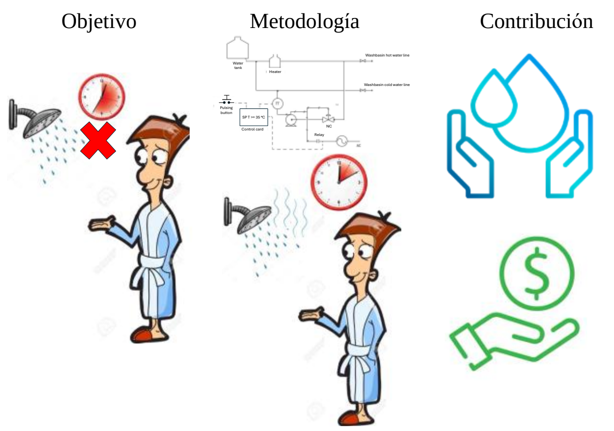
The objective of this work was to design, build and install a device to recover the water wasted in low-cost showers, while waiting for the liquid to reach a comfortable temperature. The novelty of this work is that anybody with basic knowledge of Arduino®, or other open-source microcontrollers can build the system, recovering water and at the same time reducing costs. The system can be installed in any home using the existing water pipelines. In addition, it has a functional, compact and adaptable structure, which does not require modifications in the hydraulic installation nor affect the aesthetics of the place where it will be installed, thus facilitating its implementation in any residential home without the need of complex or expensive renovations.



Sustainability, Water Saving, Arduino

Resumen

El objetivo de este trabajo fue construir e instalar un dispositivo basado en un sistema de recuperación en líneas de agua caliente de bajo costo para regaderas sanitarias, con la intención de reducir el desperdicio de agua durante el tiempo de espera desde que se abre el grifo hasta que el agua alcanza una temperatura confortable para su uso. La novedad de este trabajo radica en proponer un sistema que puede ser construido por personas con conocimientos básicos en Arduino® u otros microcontroladores de código abierto, lo cual reduce costos. Este sistema se puede instalar aprovechando las líneas originales de tubería de agua fría y caliente en el sistema hidráulico sanitario de cualquier casa habitación. Además, cuenta con una estructura funcional, compacta y adaptable, que no requiere modificaciones en la instalación hidráulica ni afecta la estética del espacio donde se instalará, facilitando así su implementación en diversos entornos residenciales sin necesidad de reformas complejas ni costosas.



Sustentabilidad, Ahorro de Agua, Arduino

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Introduction

UNICEF states that there are around 750 million people in the world who do not have access to water. One of the main causes is due to its unequal distribution, and the fact that where there is a regular water service, with poor infrastructure or poor culture of water saving, the result is a great deal of water wasted in some parts of the planet (OECD, 2016).

According to the Organization for Economic Cooperation and Development (OECD), several of the most densely populated cities in our country are on the list where water is wasted the most when compared to cities in the 34 member countries of such organization. The average water loss in cities with a population of more than 1.5 million inhabitants is 21%. In our country, the cities of Chihuahua, Mexico City and San Luis Potosí lose on average of 40% of the liquid supplied within the hydraulic network service. An extreme case is the capital of Chiapas, Tuxtla Gutiérrez, where the amount wasted reaches up to 60%.

A person taking a 10 minute shower, can spend more than 200 liters, which represents a 12% of the total water consumed in the household (Muñoz, 2018). In addition, when people take a bath, they have different preferences regarding the temperature. Some like a lukewarm temperature, while others prefer very hot water. Whatever the desired temperature is, it must be obtained by mixing cold and hot water. In this process, while the user waits, more than 8 liters are spent to get the water to a comfortable temperature (Sánchez, 2018), and normally it goes down the drain. An alternative to this water waste is automatic return systems on hot water lines, also known as recirculation systems. They are a technology implemented to optimize the availability of hot water in large facilities, residential and commercial buildings. These systems have become increasingly popular due to their benefits in terms of energy efficiency and reduction of water waste. The efficiency of these systems can be measured in terms of energy and water savings. For example, a study by Zhen J. et al. (2020) found that implementing recirculation systems can reduce water consumption by up to 30% compared to conventional systems without recirculation.

Additionally, Zhou L. et al. (2021) noted that the energy used to maintain hot water could decrease by 15-20% due to the reduced need to reheat the water frequently. The commercial systems available in the market vary in size, capacity, and features. Companies like AquaReturn® or Grundfos and Taco offer recirculation pump solutions equipped with advanced thermostats and smart control options, allowing precise temperature and water flow adjustments. The choice of equipment depends on the size of the installation, the demand for hot water, and the specific needs of the user. The initial cost of these systems can vary widely. A basic system for a single-family home are from $1500 to $3,500, including installation. For larger commercial installations, the cost range from $5,000 to $20,000 or more, depending on the complexity and size of the system. Although the initial investment can be significant, the return on investment can be achieved within 3 to 5 years due to savings in water and energy. That is why the objective of this work was to build a low-cost recirculation system that does not require significant modifications when installed in a home.

Methodology

This work is inspired by the operation of the AquaReturn® commercial products and the NESS® Technology Bypass Module. Applying heat transfer principles, as well as instrumentation and process control, the designed system is activated when a button is pressed, initiating a cicle of water recirculating from the hot line to the heating system through the cold water line until its temperature is equal to or greater than 35 °C. The connection diagram to the Arduino board is shown in Figure 1, the simulation of the connections was carried out using the Fritzing V. 1.0.3 program. The programming code with which the tests were started was as follows:

```
#include "max6675.h"
int ktcSO = 8;
int ktcCS = 9;
int ktcCLK = 10;
int temp;
int setpoint;
MAX6675 ktc(ktcCLK, ktcCS, ktcSO);
void setup() {
```

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```
pinMode(7, INPUT_PULLUP);
  pinMode(13, OUTPUT);
  Serial.begin(9600);
  setpoint = 35; // Temperatura de Set Point
  digitalWrite(13, LOW);
}
void loop()
{
 int estadoBoton = digitalRead(7);
 if(estadoBoton == 0)
 {
       Serial.println ("Iniciando Secuencia de Recirculación");
       delay (200);
do
{
       recirculacion();
} while (temp < setpoint);
    }
}
 void recirculacion(){
 Serial.println ("Recirculando");
  temp = ktc.readCelsius();
   Serial.print("Temp:°C ");
   Serial.println(temp);
  if (temp < setpoint)
  {
  digitalWrite(13, HIGH);
  Serial.println ("Bomba funcionando");
  delay(500);
  }
  else
  {
   digitalWrite(13, LOW);
   Serial.println ("Bomba apagada");
   Serial.print ("Temp >= ");
   Serial.print (temp);
   Serial.println (" °C");
  }
 }
```

From the initial programming code, modifications were made using the Arduino IDE Version: 2.3.2.

Box 1

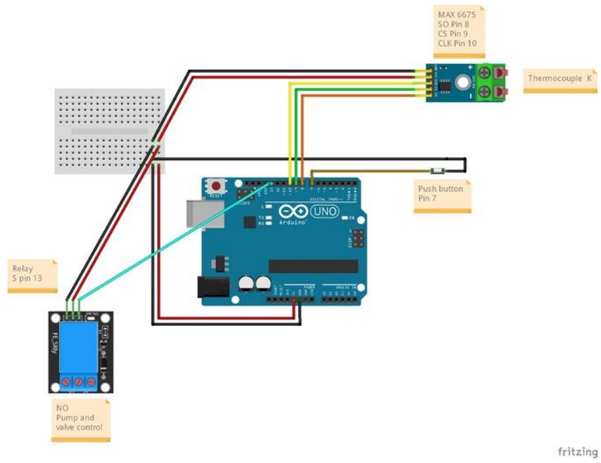

Figure 1
Title Connection diagram to the Arduino Uno®

Once the code was written, with the respective modifications, the physical control system was integrated and assembled, using an Arduino UNO board, a SRD-05VDC-SL-C relay, a K-type thermocouple and a mini micro board to unify the system connections, and later be added to the drinking water installation using a general diagram of instrumentation and pipelines of a traditional home, which was made using the Visio ®2019 program. Finally, the tests of the recovery system were carried out to verify its operation and effectiveness.

Results

A prototype was designed, built and installed, and the overall Piping and Instrumentation Diagram (PID) is shown in Figure 2. Figure 3 shows the prototype in its early stages of construction and preliminary testing. The most relevant details of the results obtained are described below:

This prototype was connected to the existing cold and hot water service lines of the farthest washbasin in a house considered to be a medium socioeconomic level. Its installation did not require modifications to the house's hydraulic system, and it behaved as expected: Pressing the activation button the water recirculated to the heating system until the temperature in the hot water line was equal to or greater than 35 °C, which eliminated the waiting time required for hot water to come out of all the faucets connected to this line.

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In addition, the results of the tests carried out determined that in the case in which the water temperature in the heater is less than 35 °C, and to avoid the unwanted loop, it was appropriate to reprogram the prototype so that it stops 30 seconds longer than normally required when the water temperature of the heater is equal to or greater than 35 °C. It is worth mentioning that the main programming parameters were adjusted according to the results obtained and considering the comments from the owners of the house where the system was installed after one month of use. At the end of the tests, the prototype was installed and has maintained its operation after one year without requiring additional adjustments.

Box 2

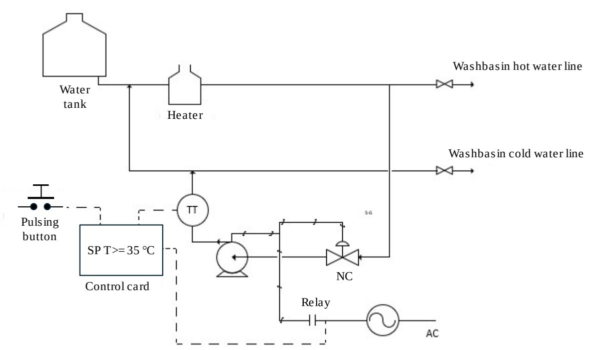

Figure 2
Title PID of the prototype built and installed

Box 3

Figure 3
Title Prototype in its early stages of construction and preliminary testing

The results obtained in this work contribute to the development of strategies that allow the transfer of this type of technology in support of the development of a Social and Solidarity Economy (SSE).

Conclusions

A system for recovering water that is normally wasted while waiting to reach the desired temperature, was built and installed in a house in the middle of the socioeconomic level of the state of Mexico. The results of this work, show a viable alternative to reduce water waste. According to our estimates, if all the water that is normally wasted while waiting to reach the desired temperature were recovered in all the houses in the lower and middle socioeconomic level of the municipalities of the State of Mexico, around 90 or 100 million liters would be saved daily, a quantity sufficient to supply one million people daily, that is, the equivalent of covering the water needs of the municipality of Nicolás Romero, State of Mexico, for around 2 days. It is worth mentioning that the prototype built can be installed in solar heaters as well as gas, electrical or other kind of heaters.

This work contributes to the development of prototypes that can reduce water use. We consider that it has the potential to be an adequate base in the development of multidisciplinary integrative projects in schools with educational models based on competencies, and it can also serve as a trigger for the development of Social and Solidarity Economy (SSE).

Declarations

Conflict of interest

The authors declare no conflict of interest.

Author contribution

Medina Mendoza, Manuel: Conceptualization contribution. Ideas; overall formulation or evolution of research goals and aims. Methodology. Development or design of methodology; creation of models. Software Programming, software development; designing computer programs; implementation of the computer code and supporting algorithms; testing of existing code components.

Dorantes Rodríguez, Rubén José: Contributed to the Project administration. Management and coordination responsibility for the research activity planning and execution.

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Nicolás Bermúdez, Jesús: Contributed to Writing - Review & Editing. Preparation, creation and/or presentation of the published work by those from the original research group, specifically critical review, commentary or revision, including pre-or post-publication stages. Visualization, preparation, creation and/or presentation of the published work, specifically visualization/ data presentation. Funding acquisition, acquisition of the financial support for the project leading to this publication

Fuentes Romero, María Teresa: Contributed to formal analysis. Application of statistical, mathematical, computational, or other formal techniques to analyze or synthesize study data. Investigation, conducting a research and investigation process, specifically performing the experiments, or data/evidence collection. Resources, provision of study materials, reagents, materials, patients, laboratory samples, animals, instrumentation, computing resources, or other analysis tools contributed to research method and technique.

Availability of data and materials

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Abbreviations

OECD	Organization for Economic Cooperation and Development
PID	Piping and Instrumentation Diagram
SSE	Social and Solidarity Economy

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Background

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