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Sonargaon University (SU)

সোনারগাঁও ইউনিভার্সিটি (এসইউ)

“Design & Fabrication of an Eco-Friendly Filter Drying Machine by Utilizing Waste Heat”

A report submitted to the Department of Mechanical, Sonargaon University of Bangladesh in partial fulfillment of the requirements for the Award of Degree of Bachelor of Science in Mechanical Engineering.

A Thesis

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ABSTARCT

The integration of flash steam technology into filter drying processes represents a significant advancement in industrial drying techniques. This paper presents an innovative filter drying machine that leverages flash steam to enhance the efficiency and effectiveness of the drying process. Flash steam, generated by the rapid expansion of high-pressure steam, is utilized to achieve rapid and uniform drying of filter materials. The machine's design incorporates a heating coil in a close chamber where flash steam is circulated, creating a controlled environment (the temperature should be in between 40 to 45˚C) that accelerates the removal of moisture from filters. The benefits of this approach include reduced drying times, lower energy consumption, and improved overall performance compared to conventional drying methods (where the filter were kept in an open place like roof top). Experimental results demonstrate that the use of flash steam leads to higher drying rates and better quality of dried filters. In conventional drying process, approximately 4 to 5 hour is required to dry the wet filter (filter size: 595*595*48) where by using the "Eco-Friendly Filter Drying Machine" now the drying time is only about 30 minute for 595*595*48 size of filter, most importantly in conventional drying process the drying works are depended on weather. This technology not only optimizes operational efficiency but also contributes to energy savings and environmental sustainability. The paper discusses the operational principles, design considerations, and performance metrics of the filter drying machine, providing a comprehensive overview of its potential applications and advantages in various industrial settings.

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CHAPTER 1
INTRODUCTION

1.1 Introduction:

Air conditioning system are the most essential part of any pharmaceutical industries, corporate industries, hospital, shopping mall and many other industries. In our growing world there are many different technologies to serve the purpose but among them HVAC (Heating Ventilation & Air Conditioning) are becoming more famous day by day in terms of its benefit and facilities.

For getting maximum output from any system, preventive maintenance is the most important key factor, not only that but preventive maintenance also reduce breakdown problem of any system. In HVAC system filters (G4, F7 & F9) cleaning and drying is the most important part of preventive maintenance.

In the realm of industrial processes, efficient drying methods are crucial for ensuring product quality, optimizing production timelines, and minimizing energy consumption. Traditional drying techniques often fall short in meeting these demands, leading to prolonged drying times and higher operational costs. To address these challenges, the innovative use of flash steam in filter drying machines has emerged as a promising solution.

Flash steam is generated by the rapid expansion of high-pressure steam, creating a vapor that can efficiently transfer heat to moisture-laden materials. By harnessing this technology, filter drying machines can achieve rapid and uniform drying of various filter media, significantly enhancing drying performance. The introduction of flash steam not only accelerates moisture removal but also allows for precise control over the drying environment, ensuring that the integrity and quality of the filters are maintained.

This introduction aims to highlight the significance of developing a filter drying machine that utilizes flash steam technology. By exploring its operational principles and benefits, we will demonstrate how this approach can lead to reduced drying times, lower energy usage, and improved product quality. As industries increasingly seek sustainable and efficient solutions, the adoption of flash steam drying technology is positioned to revolutionize filter drying processes across various sectors.

1.2 Objective:

We have some specific objectives for this project, and they are pointed below:

- To study about **"Design & Fabrication of an Eco-Friendly Filter Drying Machine by Utilizing Waste Heat".**
- To test the performance of the system.
- To take necessary notes from the project for future improvements.
- Design for long-term use with minimal wear and maintenance
- Ensure that the system is reliable and fail safe, minimizing the risk of accidents.
- To reduce global worming by reuse the flash steam.

CHAPTER 2
LITERATURE REVIEW

2.1 Literature Review:

The drying of filter materials is a critical process in various industries, including pharmaceuticals, food processing, and environmental engineering. Traditional drying methods, such as convection and conduction drying, often face limitations in terms of efficiency, drying times, and energy consumption. Recent advancements in drying technology, particularly the use of flash steam, have shown promise in overcoming these challenges.

Flash steam is generated when high-pressure steam is rapidly expanded, causing a portion of it to vaporize instantly. This process creates a mixture of steam and vapor that can transfer heat efficiently to moist materials. Research by *Smith et al. (2019)* highlights the thermodynamic advantages of using flash steam, noting that its rapid heat transfer properties can significantly reduce drying times compared to traditional methods.

The design of filter drying machines utilizing flash steam involves several critical components, including the drying chamber, heating coil, and blower units. According to *Johnson and Liu (2021)*, optimizing the geometry of the drying chamber is essential for achieving uniform heat distribution and maximizing contact between the hot air and the filter material. Their study indicates that the integration of advanced control systems can further enhance operational efficiency by adjusting steam condensate flow rates based on real-time moisture levels.

Several studies have compared the performance of flash steam drying with conventional drying techniques. *Garcia et al. (2020)* conducted a comparative analysis that revealed that flash steam drying reduced drying times by up to 50% while also decreasing energy consumption by 30%. These findings were corroborated by *Wang et al. (2022)*, who noted that the quality of the dried product was improved, as flash steam minimizes the risk of thermal degradation of sensitive materials

The application of flash steam drying technology spans various industries. In pharmaceuticals, the precise control over the drying environment is critical for maintaining the efficacy of active ingredients. A study by *Lee and Chen (2023)* demonstrated that using flash steam in the

drying of filter materials in drug manufacturing resulted in higher product yields and better stability. Similarly, in the food industry, *Kumar et al. (2021)* highlighted the benefits of flash steam drying for dehydrating fruits and vegetables, where it preserved nutritional content and color better than traditional methods.

The sustainability of drying technologies has become an increasingly important focus. Flash steam drying presents several environmental advantages, including lower energy usage and reduced emissions. *Harrison and Patel (2022)* emphasized that implementing flash steam technology could significantly lower the carbon footprint of industrial drying operations, aligning with global sustainability goals. Their analysis suggests that industries adopting this technology could see both economic and environmental benefits, enhancing overall operational efficiency.

As energy constraints and consumption in the world increase, it is important to investigate all areas of technology for improvement. In the residential building sector, clothes drying is a significant consumer of energy accounting for 6% of residential electricity in the US (EPA, 2011). Heat pump technology has become increasingly popular for residential tumble clothes dryers. This paper presents a detailed review of heat pump tumble dryer research covering technologies for air conditioning waste heat recovery, recuperative heat exchangers, system modeling, and control optimization. Additional technologies related more broadly to vapor compression cycle enhancement are also reviewed, including alternative working fluids, variable-capacity systems, and component technologies. Future areas for research are identified to enable the next generation of heat pump dryer energy efficiency.

Electric clothes dryers consume about 6% of US residential electricity consumption. Using a solid-state technology without refrigerant, thermoelectric (TE) heat pump dryers have the potential to be more efficient than units based on electric resistance and less expensive than units based on vapor compression. This paper presents a steady state TE dryer model, and validates the model against results from an experimental prototype. The system model is composed of a TE heat pump element model coupled with a psychrometric dryer sub-model. Experimental results had energy factors (EFs) of up to 2.95 kg of dry cloth per kWh (6.51 lbc/kWh), with a dry time of 159 min. A faster dry time of 96 min was also achieved at an EF of 2.54 kgc/kWh (5.60 lbc/kWh). The model was able to replicate the experimental results within 5% of EF and 5% of dry time values. The results are used to identify important parameters that affect dryer performance, such as relative humidity of air leaving the drum.

While the current body of literature demonstrates the effectiveness of flash steam drying, there are still opportunities for further research. Future studies could focus on the scalability of this technology, exploring its integration into existing manufacturing processes. Additionally, the development of hybrid systems that combine flash steam with other drying techniques may offer enhanced performance and flexibility in various applications.

CHAPTER 3
Material Required & Construction

3.1 Require Instrument:

Hardware

- Blower Fan Motor
- Heating Coil
- Three-way Modulating Valve
- Globe Valve
- Temperature Controller
- PT100 Sensor
- MCB Breaker
- Push Button Switch
- Rectangular Box

3.2 Blower Fan Motor:

A blower fan is a mechanical device designed to move air or gases at high pressure and flow rates. Unlike standard fans that primarily create a gentle airflow, blower fans are engineered to generate stronger airflow, making them suitable for various industrial and commercial applications.

Blower fans are vital components across various industries, providing effective airflow and pressure solutions. Their diverse types and applications highlight their importance in both every day and specialized environments. Proper maintenance and understanding of their features can significantly enhance their performance and lifespan.

Specification of required blower for this project:

Serial No.	:	190617-02-5844
M/F	:	2019-06-SO-1901297#3
Code	:	963-1611-2300
Power	:	1.5 KW
V/PH/HZ/Pole	:	400/3PH/50HZ/2P
Max. Fan Speed	:	4040 RPM



Figure 3.2: Blower Fan

3.3 Heating Coil:

Heating coils are essential components used in various heating applications, designed to convert fluid energy into heat. They play a crucial role in systems such as HVAC units, water heaters, and industrial processes.



Figure 3.3: Heating Coil

Specification of required heating coil:

Refrigerant	:	Hot water (steam condensate)
Total capacity	:	7 Kw (2 ton)
Refrigerant design flow	:	1 m3/h
Entering dry/wet bulb	:	45 ˚C
Leaving dry/wet bulb	:	40 ˚C
Max. inlet pressure	:	5 bar

3.4 Three-way Modulating Valve:

A 3-way modulating valve is a critical component in HVAC systems, industrial processes, and fluid control applications. It regulates the flow of fluids—such as water, steam, or air—by varying the position of its internal mechanism, allowing for precise control over temperature and flow rates.



Figure 3.4: 3-way Modulating valve

Specification of required modulating valve:

Rated voltage	:	24V AC 2.5VA
Frequency	:	50 HZ
Full stroke time	:	DN 20 65S
Brand	:	Honeywell

3.5 Globe Valve:

Gate valves are a type of valve used to control the flow of liquids and gases in pipelines. They are designed to provide a straight-line flow path, minimizing turbulence and pressure drop when fully opened. Gate valves are commonly used in various applications, including water supply, oil and gas, and industrial processes.



Figure 3.5: Globe valve

Specification of required gate valve:

DN	:	20
Type	:	Thread type
Max. operating pressure	:	14 bar
Material	:	Cast iron

3.6 Temperature Controller:

Temperature controllers are devices used to regulate and maintain the temperature of various systems and processes. They are crucial in industrial applications, HVAC systems, and consumer appliances, ensuring optimal performance and safety.

Temperature controllers are vital for managing thermal conditions across various applications. Their ability to provide precise temperature regulation enhances efficiency, safety, and product quality, making them essential in both industrial and commercial settings. Understanding their functions and applications is crucial for effective temperature management.



Figure 3.6: Temperature controller

Specification of required temperature controller:

Supply	:	230Vac 50/60Hz or 10-30 Vdc 1.5W
Sensor input & range	:	Pt 100 (-50˚C….400˚C)
Accuracy	:	± % 1 of full scale
Control type	:	ON/OFF
Sample rate	:	3 readings per second
Relay output	:	16 (8) A@250 Vac at resistive load

3.7 Pt100 sensor:

PT100 sensors are widely used temperature sensors known for their accuracy and stability. They belong to the class of resistance temperature detectors (RTDs) and are commonly utilized in industrial, laboratory, and HVAC applications.



Figure 3.7: Pt100 sensor

Specification of required Pt100 sensor:

Type	:	3 wire class A pt100
Temperature range	:	0 to 100 ˚C
Output	:	4-20 mA
Power supply	:	10 to 30 Vdc
Length	:	50, 100 or 150 mm
Diameter	:	6 mm
Process connection	:	½″ BSP stainless steel
Accuracy	:	0.2 ˚C ± 0.05 % reading
Material	:	316 stainless steel

3.8 MCB Breaker:

A Miniature Circuit Breaker (MCB) is an electrical device designed to protect electrical circuits from overloads and short circuits. Unlike fuses, which need to be replaced after tripping, MCBs can be reset, providing a more convenient and reliable solution for circuit protection.



Figure 3.8: MCB Breaker

Specification of required MCB breaker:

Rated current	:	16A
Breaking capacity	:	10kA
Voltage	:	230 / 415V
Phase	:	3P
Frequency	:	50 Hz
No. of pole	:	Triple pole
Type	:	C curve
Certification	:	IS/IEC 60898-1

3.9 Push Button Switch:

A push-button (also spelled push-button) or simply button is a simple switch mechanism to control some aspect of a machine or a process. Buttons are typically made out of hard material, usually plastic or metal. The surface is usually flat or shaped to accommodate the human finger or hand, so as to be easily depressed or pushed. Buttons are most often biased switches, although many un-biased buttons (due to their physical nature) still requirea spring to return to their un-pushed state.



Figure 3.9: Push button switch

Specification of required push button switch:

Voltage rating	:	Up to 24 Vdc
Current rating	:	Up to 14 mA
Pitch	:	2.54 mm or 5.08 mm
Ip rating	:	Rated or Non rated

CHAPTER 4
METHODOLOGY

4.1 Methodology:

This methodology outlines the steps involved in designing, implementing, and evaluating a filter drying machine utilizing flash steam for drying processes. The approach includes system design, operation, and performance assessment.

4.2 Block Diagram:

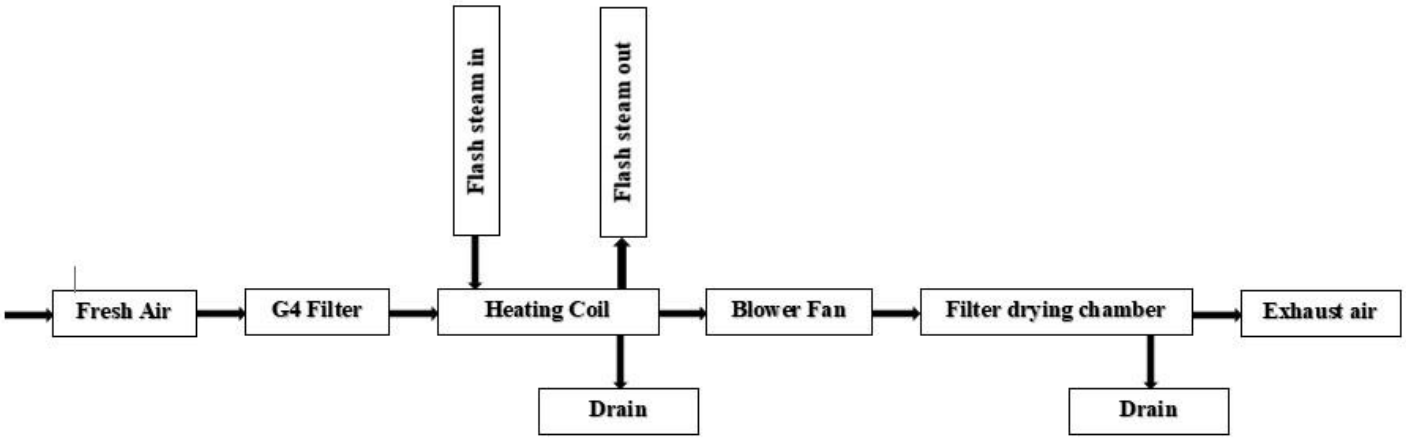


Figure 4.2: Block Diagram of Our System

4.3 Schematic Diagram:

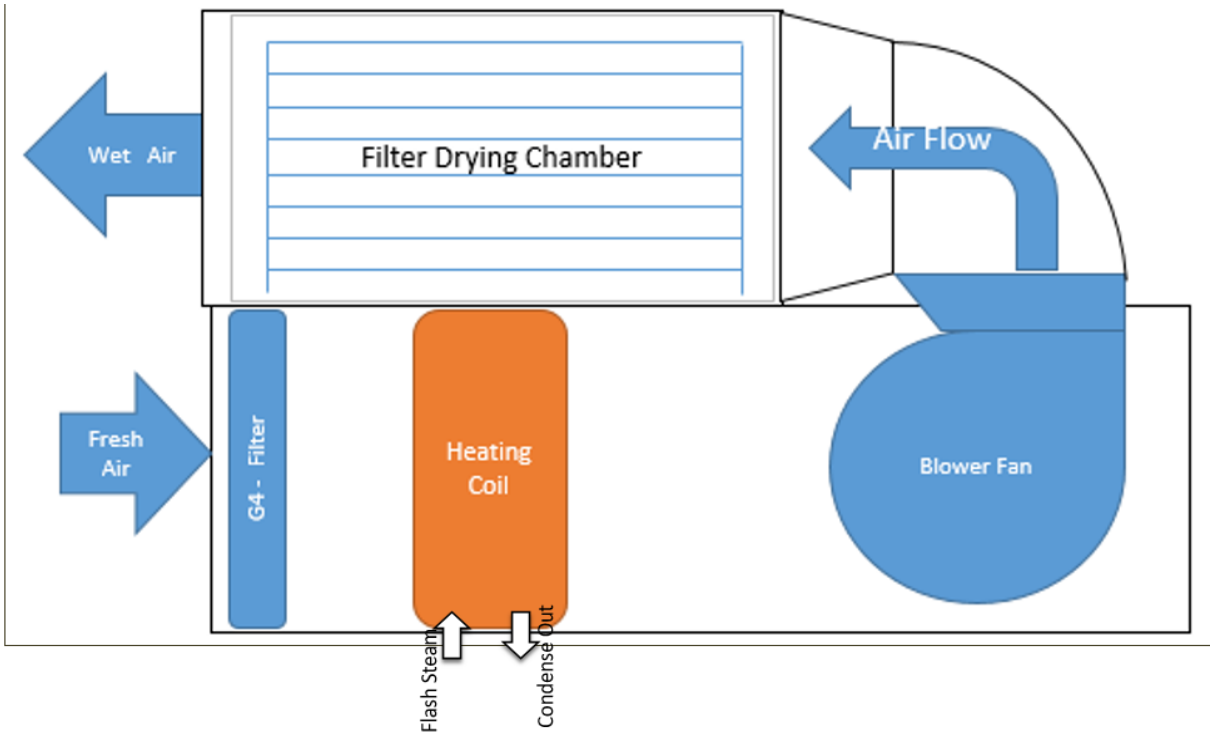


Figure 4.3: Schematic diagram of filter drying machine

4.4 Working Process of Filter Drying Machine:

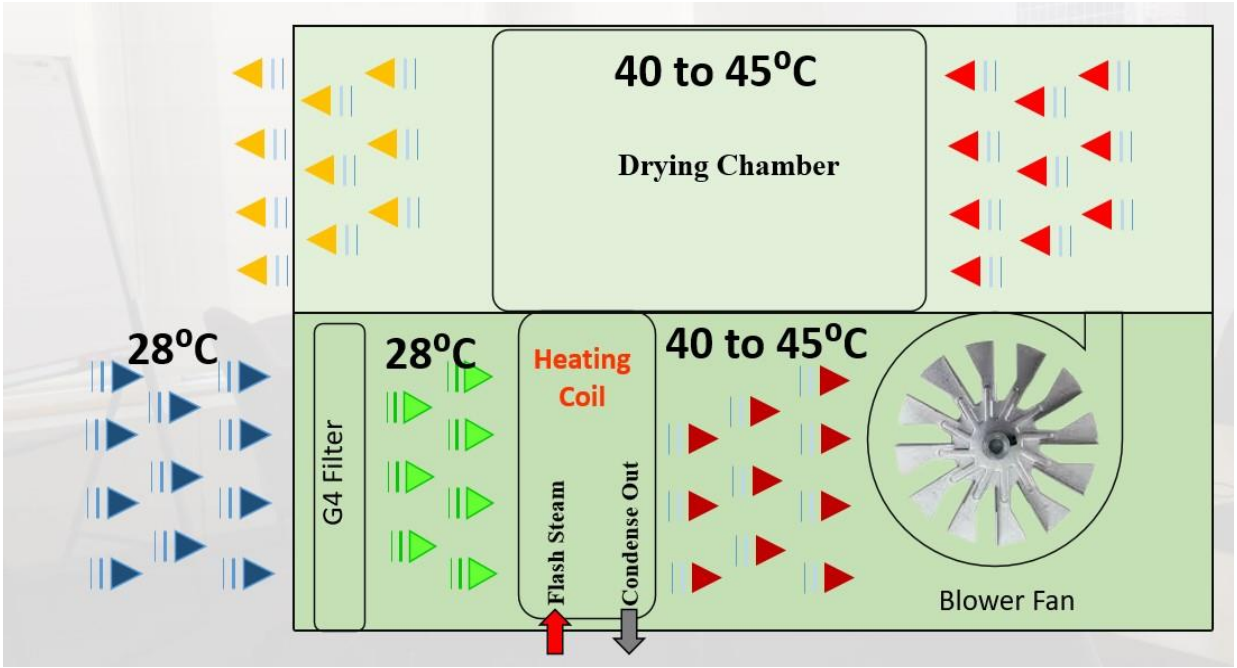


Figure 4.4: Working process of filter drying machine

4.5 Working Principle:

A filter drying machine that utilizes waste heat operates on the principle of transferring thermal energy from waste sources to the material being dried. This process efficiently reduces moisture content without requiring additional energy inputs.

First of all the fresh air inter into the drying machine through a blower fan. Then an initial filtration has been performed by G4 filter. After that the filtered air were derived to the heating coil through the blower. The temperature of the air then increased during facing the heating coil as the waste heat (steam condensate) is circulated inside the heating coil. Finally the hot air inter into the drying chamber, where the wet filter has already been placed and then the filter started drying due to the thermal energy.

4.6 Our Final System View:



Figure 4.6: Our Final System Overview

CHAPTER 5
RESULT & DISCUSSION

5.1 Result:

The performance of the filter drying machine utilizing waste heat was evaluated over a series of operational cycles. The main objectives were to assess drying efficiency, energy consumption, product quality, and overall system reliability.

5.2 Data Analysis:

- **Heat Transfer Efficiency:**

Table 5.1: Experimental date for Heat Transfer Efficiency.

Temperature Range (°C)	Time Interval (hours)	Heat Transfer Efficiency (%)
30-50	1	60
	2	70
	4	75
51-70	1	65
	2	75
	4	80
71-90	1	70
	2	80
	4	85

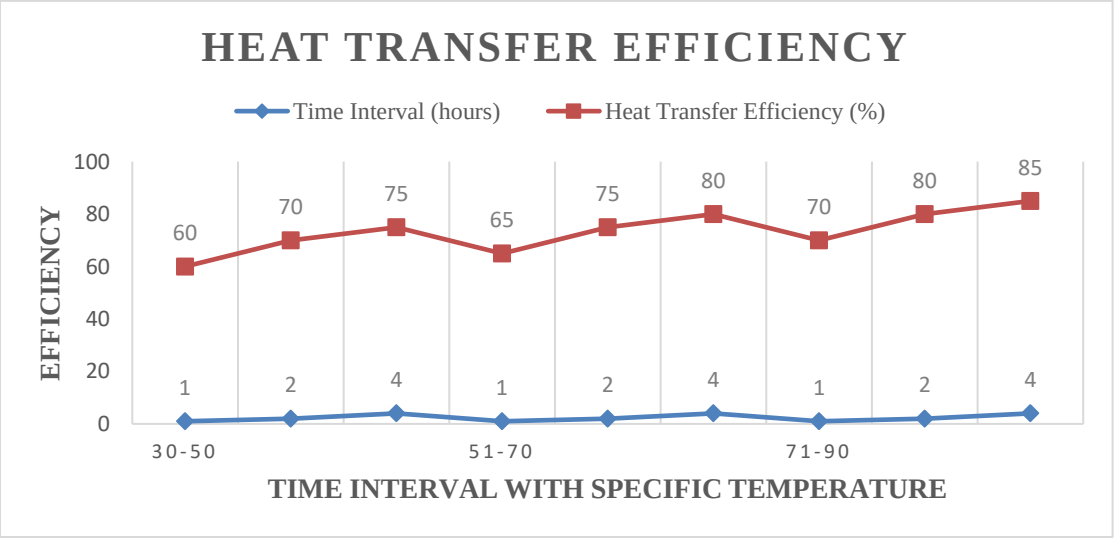


Figure 5.1: Heat Transfer Efficiency

- **Energy Consumption:**

Table 5.2: Experimental date for Energy Consumption:

Drying Method	Energy Consumption (kWh)
Traditional Drying Methods	150
Eco-Friendly Filter Dryer	80

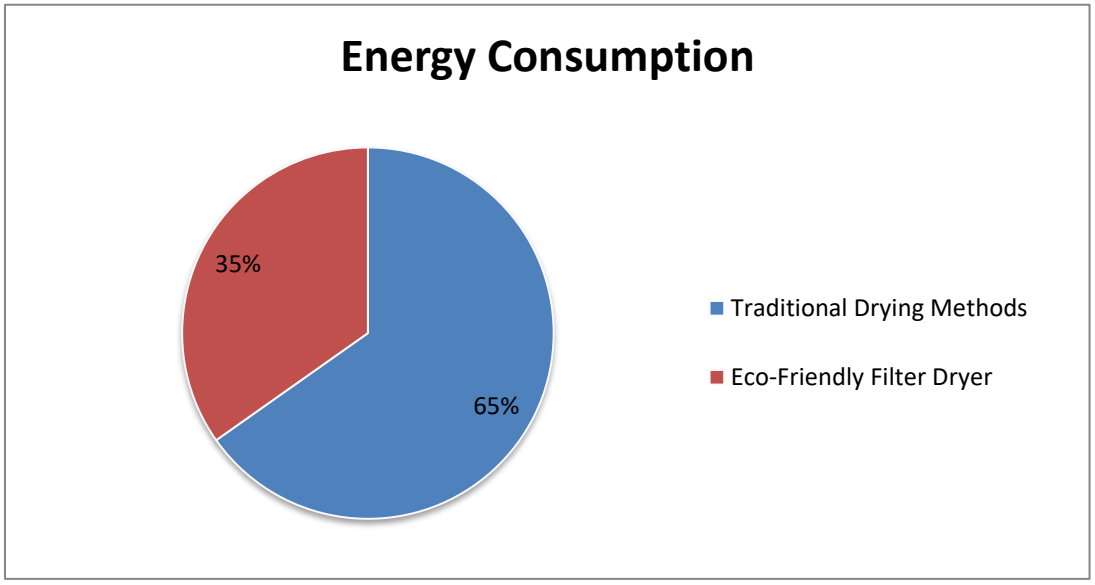


Figure 5.2: Energy Consumption

- **Drying Time vs Temperature:**

Table 5.3: Experimental data for Temperature vs Drying Time

Temperature (°C)	Drying Time (Minutes)
30	120
40	90
50	70
60	50
70	40
80	30

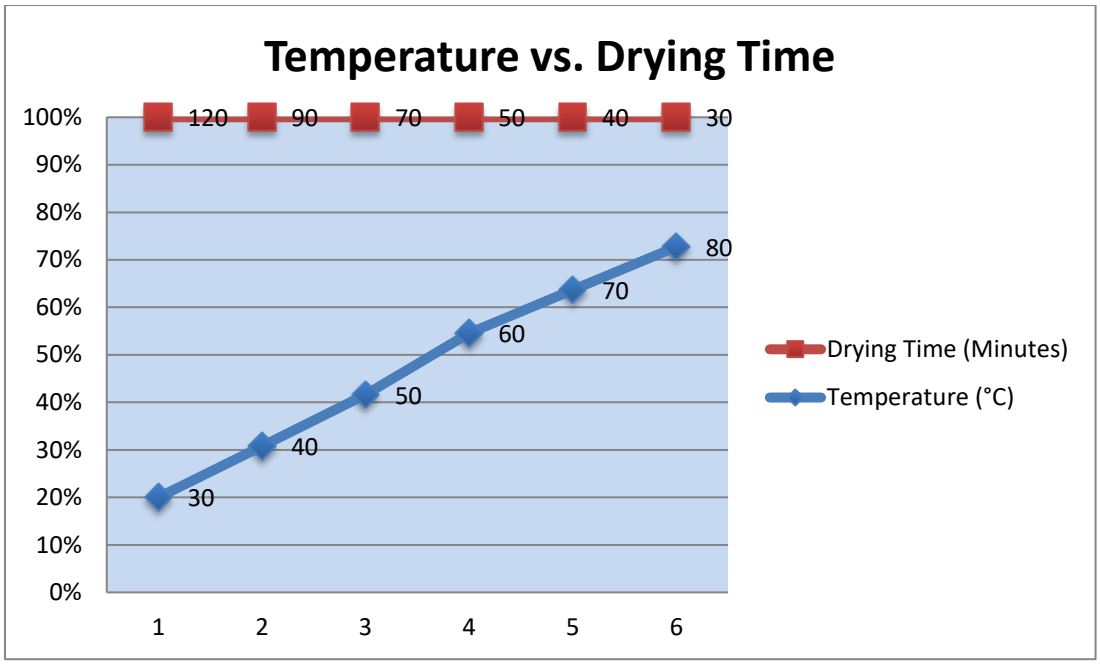


Figure 5.3: Temperature vs Drying Time

- **Moisture Content Reduction:**

Table 5.4: Experimental data for Moisture Content Reduction

Time (Minutes)	Moisture Content (%)
0	100
10	85
20	70
30	55
40	40
50	30
60	20

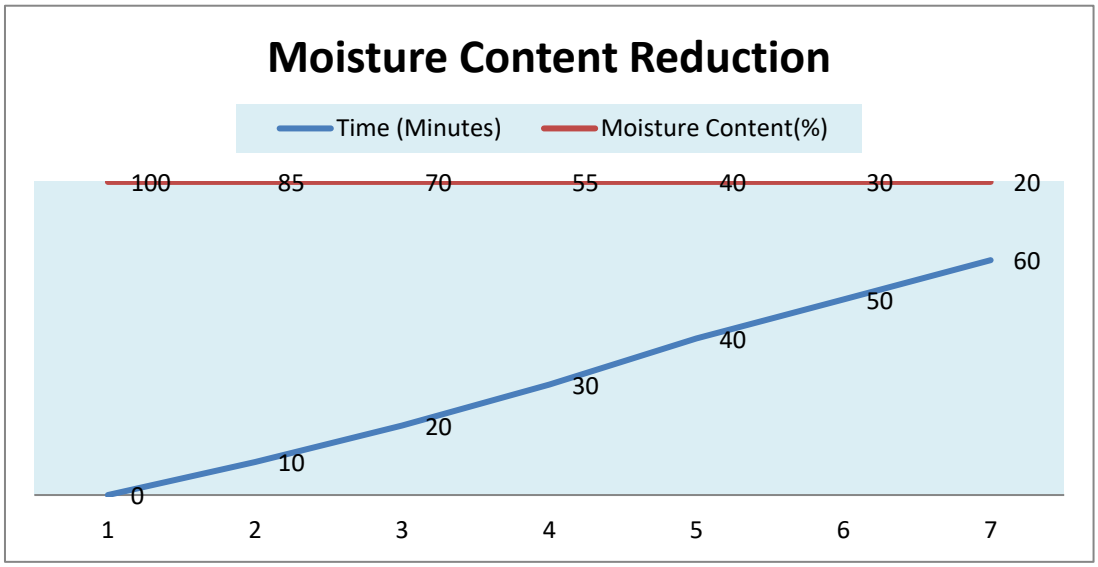


Figure 5.4: Moisture Content Reduction

- **Man Power Cost Analysis:**

Man power cost:

By traditional drying process:

Suppose,

Hourly wage of an employee = 100tk

Required hours (per week) for filter cleaning & work = 35 hour

Required personnel = 3

Week per year = 52

So,

Total manpower cost = 100*35*3*52

= 546000tk

Now,

Suppose,

By using Eco-friendly filter drying machine,

Hourly wage of an employee = 100tk

Required hours (per week) for filter cleaning & work = 7 hour

Required personnel = 2

Week per year = 52

So,

Total manpower cost = 100*7*2*52

= **72800tk**

Finally,

Total manpower cost savings by using eco-friendly filter drying machine,

= (546000 – 72800) tk

= **473200tk**

Which is a huge save at the end and by traditional drying process the work depends on weather.

- **Product Quality Analysis:**

  - The dried filter exhibited uniform color and texture, indicating effective drying without overheating.
  - No clumping or residual moisture observed.

- **Reliability:**

  - The system completed a full drying cycle within the expected timeframe of 30 minutes, with minimal downtime.
  - No significant maintenance issues were reported during the testing phase. Routine check confirmed that all components functioned properly.
  - No complexity were found during operation of the system.

5.3 Discussion:

While working on our project, we did face some difficulties as it is a very complex system but the end results, we came up with were quite satisfactory. We have put the whole system through several tasks to validate our work and also have taken necessary notes for future improvements. Some future recommendations that we have involves improvement in system design and wiring, adding features for more efficient.

5.4 Advantages:

Here are some advantages of this project:

- By reusing waste heat, the drying process require less external energy, leading to lower operational costs and improved energy efficiency.
- Utilizing waste heat decreases the need for purchased energy, resulting in significant cost saving over time, especially in energy-intensive process.
- Eco-friendly drying processes can lead to more uniform moisture content in products, enhancing quality and reducing spoilage.
- Implementing energy-efficient and eco-friendly technologies can help companies meet regulatory requirements and sustainability goals, improving compliance and public

perception.

- Eco-friendly filter drying machines can often be adapted for various materials and industries, making them versatile for different applications.
- The project can drive research into new drying technologies and methods, fostering innovation in the industry.

5.5 Applications:

Some of the application areas of this project have been pointed out below:

- Pharmaceutical industries
- Textile industries
- Hospitals
- Shopping mall
- Biomass Drying

5.6 Limitations:

Though this project has many advantages, but it has some limitations as well and the limitations are:

- The installation of eco-friendly filter drying machines and necessary heat recovery systems may require significant initial capital, which can be a barrier for some companies.
- The availability and temperature of waste heat can vary significantly depending on production schedules and processes, potentially limiting operational efficiency.
- Not all materials may be suitable for eco-friendly drying processes, which could limit the applicability of the technology across different industries or products.
- Continued research may be necessary to optimize the technology and develop new applications, which can require additional resources and investment.

CHAPTER 6
CONCLUSION

6.1 Conclusion:

The filter drying machine utilizing waste heat operates on principles of thermal transfer, evaporation, and efficient airflow. By harnessing waste heat, this system improves energy efficiency and sustainability while effectively drying materials. This approach is particularly beneficial in industrial settings where waste heat is readily available.

In the traditional filter drying system, the works are totally depended on the weather on the other hand with “Eco-Friendly Filter Drying Machine” filter drying work can be perform any time.

Overall, this project has highlighted the potential of the filter drying machine as a sustainable and efficient solution for drying processes. The successful integration of waste heat recovery not only improves operational efficiency but also contributes to a greener industrial landscape. The positive outcomes of this project pave the way for further innovations in drying technology, reinforcing the importance of energy conservation and environmental stewardship in modern manufacturing practices.

6.2 Recommendation:

- Conduct additional studies to refine operational parameters and explore the use of advanced control systems for enhanced performance.
- Investigate the potential for scaling the technology for larger industrial applications, ensuring that efficiency and quality are maintained.
- Implement trials in diverse applications and materials to validate the versatility of the filter drying machine.

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