The International Journal of Energy & Engineering Sciences, 2024, 9 (2) 93-102
ISSN: 2602-294X - Gaziantep University

INVESTIGATION OF THE USE OF WASTE HEAT OBTAINED FROM HIGH PRESSURE CRUDE OIL PUMPS IN CENTRAL HEATING SYSTEMS

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ABSTRACT

The fact that 83% of energy needs are met from fossil fuel resources, their negative effects on the environment and human health, and the energy crises experienced in the global market have pushed humanity towards the efficient use of energy and renewable energy sources. In this study, the provision of central heating in a pressurization station with waste heat recovery is investigated. Nowadays, with the heat recovery systems in the facilities, great gains have been achieved both in terms of cost and in the effects on human and environmental health without the need for fossil fuel energy sources. Great energy savings can be achieved by recovering waste heat from both flue gases and engines in the plants. Renewable energy sources and waste heat recovery are of great importance to reduce the effects of global warming, protect the ecological balance and reduce the negative effects on human health.

Keywords: Energy, waste heat recovery, district heating systems, energy efficiency, energy saving.

1. INTRODUCTION

As the world population increases rapidly, the need for energy increases day by day. Increasing energy demand necessitates the correct use and efficiency of energy. A large part of our energy needs are met from fossil fuels [1].

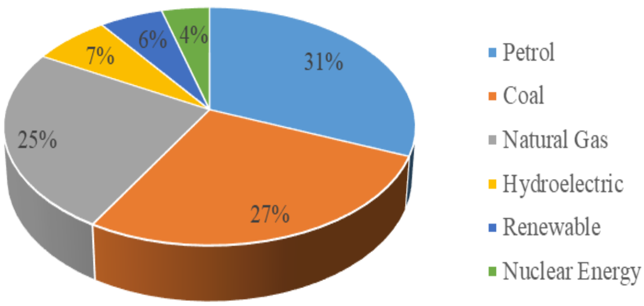

Figure 1. Global Primary Energy Consumption Rates in 2020 [2]

As shown in Figure 1, the global primary energy consumption rates for 2020 are presented in a pie chart. Petrol accounts for the largest share at 31%, followed by coal at 27% and natural gas at 25%. The chart highlights the significant reliance on fossil fuels, which collectively make up the majority of the global energy consumption [2].

Although some of the energy is supplied from renewable energy sources, the vast majority is provided from fossil fuels. The limited amount of fossil fuels, which have a large share in energy needs, and their harm to the environment, energy crises in the global market and climate changes direct humanity to the efficient use of energy, the utilization of renewable energy sources and the evaluation of waste heat sources [3,4]. The direct release of exhaust gases generated as a result of combustion in facilities increases both the need for energy and environmental damage. Identifying and recovering the potential of both flue gases and industrial waste heat is of great importance [5]. In this way, the effects of global warming and air pollution will be reduced and waste heat resources will be utilized at the maximum level [6]. Fossil fuel sources are mostly used for heating a particular facility or region. Examining the waste heat recovery potential of these facilities will reduce environmental damage and prevent energy waste. Heat exchangers play a crucial role in this process by efficiently transferring thermal energy from waste heat sources to heating systems, thereby maximizing energy recovery and minimizing losses [7].

2. CRUDE OIL RESERVES AND CRUDE OIL PIPELINES IN TÜRKİYE

Crude oil, which has a large share in energy, has an important place in countries. Not every country is rich in crude oil resources. Compared to other countries of the world, Türkiye has low crude oil reserves [8].

Table 1. Crude Oil Reserves in Türkiye [9]

	Crude Oil Reserves (Billion Barrels)	Producible Oil (Billion Barrels)
2010	6.9	1.2
2011	7.0	1.3
2012	7.1	1.3
2013	7.0	1.3
2014	7.2	1.4
2015	7.2	1.4
2016	7.2	1.4
2017	7.3	1.4
2018	7.4	1.5
2019	7.5	1.5
2020	7.5	1.5

As shown in Table 1, Türkiye's crude oil reserves and producible oil quantities between 2010 and 2020 are presented. In 2010, Türkiye's crude oil reserves were 6.9 billion barrels, while this figure increased to 7.5 billion barrels in 2020. Producible oil has increased from 1.2 billion barrels to 1.5 billion barrels [9]. Countries with low crude oil reserves have to import the crude oil they need. Türkiye imports the crude oil it needs and due to its geopolitical position, hosts crude oil pipelines at the point of supply to the international market.

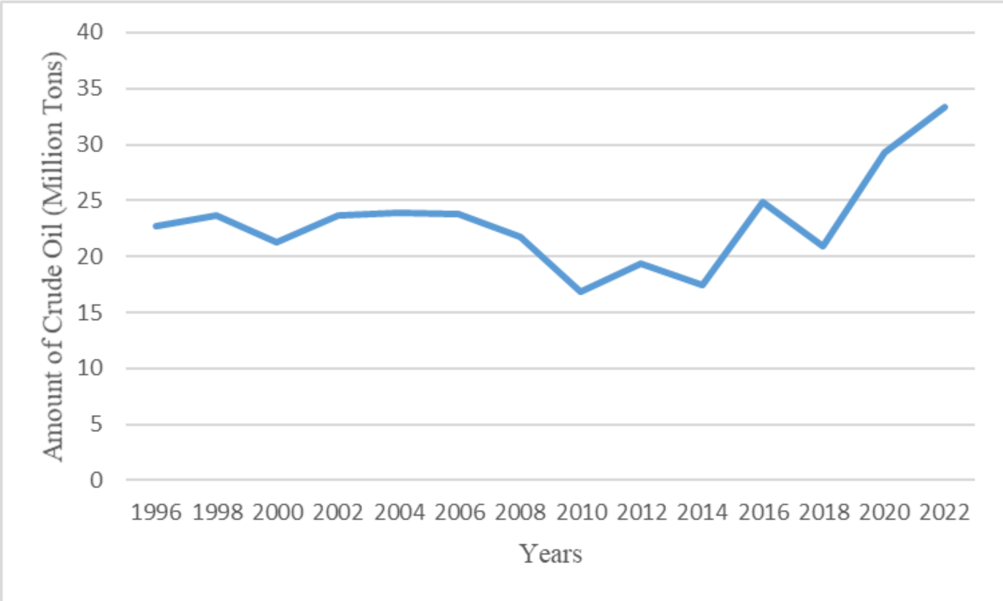

Figure 2. Türkiye's Crude Oil Imports in the 1996-2022 Period (Million Tons) [10]

Figure 2 illustrates the trend in Türkiye's crude oil imports from 1996 to 2022, measured in million tons, as reported by Turkish Statical Institute (TUIK). Türkiye's crude oil imports have increased since the 1996s. Despite the rapid increase in crude oil imports, crude oil production has not increased at the same rate [10].

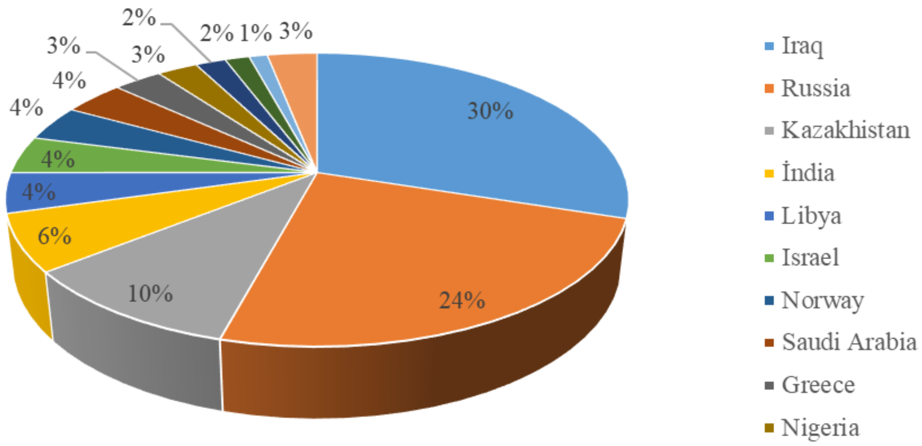

Figure 3. Distribution of Crude Oil Imported by Türkiye in 2021 by Source Countries [11]

In 2021, 30% of Türkiye's crude oil imports came from Iraq, 24% from Russia and 10% from Kazakhstan [8]. As seen in Figure 3, Iraq has the largest share. Countries make a great contribution to their economies by exporting their crude oil reserves to other countries through pipelines. Countries that do not have sufficient resources in terms of crude oil, provide the crude oil they need by importing it through pipelines. Türkiye is one of the countries that supplies the crude oil it needs through pipelines.

Table 2. Crude Oil Pipelines in Türkiye [12]

Location	Length (km)	Capacity (million tons/year)	Number of Pumping Station
Iraq-Türkiye COP	1876	70.9	6
Ceyhan–Kırıkkale COP	448	7.2	2
Batman–Dortyol COP	518	4.5	3
Baku-Tbilisi-Ceyhan COP	1776	50	4

As shown in Table 2, there are four crude oil pipelines operating in Türkiye, each varying in length, capacity, and number of pumping stations. There are 4 crude oil pipelines in Türkiye [12]. The first of these is the Batman-Dortyol Crude Oil Pipeline (Batman-Dortyol COP). It was opened for operation in 1967 as the first crude oil pipeline in Türkiye. There are 3 pumping stations on this line. Iraq – Türkiye Crude Oil Pipeline, which is the first crude oil pipeline of an international nature, was commissioned in 1976. There are 6 pumping stations on this line. Ceyhan – Kırıkkale Crude Oil Pipeline, which is the second national crude oil pipeline of Türkiye, was commissioned in 1986. There are 2 pumping stations on this line. Baku – Tbilisi – Ceyhan Crude Oil Pipeline, the largest international crude oil pipeline in Türkiye, was commissioned in 2006 to transport crude oil to be produced in the Caspian Region to world markets by means of tankers. There are 4 pumping stations on this line.

Table 3. Amounts of Transported Crude Oil Annually (Thousand Barrels) [12]

	IRAQ – TÜRKİYE COP	CEYHAN – KIRIKKALE COP	BATMAN – DORTYOL COP	BTC COP
2022	174,121	31,717	24,979	225,445
2021	186,875	30,664	24,221	200,149
2020	191,855	32,142	24,376	208,064
2019	194,084	34,938	21,536	235,243
2018	134,662	31,300	20,470	255,770
2017	184,927	39,292	19,757	252,763
2016	189,439	35,357	20,092	253,976
2015	192,426	30,982	19,724	262,188
2014	55,984	22,213	17,780	260,675
2013	91,883	23,740	18,195	249,617
2012	134,506	21,962	17,649	250,345
2011	163,276	21,786	17,092	257,143

As shown in Table 3, the annual transported crude oil amounts for Türkiye's four major pipelines are presented for the period from 2011 to 2022. The data indicate significant fluctuations across all pipelines over the years. The Iraq-Türkiye Crude Oil Pipeline (COP) consistently transported the largest volume of crude oil, with a peak of 194,084 thousand barrels in 2019 and a significant drop to 134,662 thousand barrels in 2018. By 2022, the transported volume decreased to 174,121 thousand barrels. The Ceyhan-Kırıkkale COP showed relatively stable transport values with minor fluctuations, ranging from 21,786 thousand barrels in 2011 to 39,292 thousand barrels in 2017. By 2022, the transported volume was recorded as 31,717 thousand barrels. The Batman-Dörtyol COP consistently reported the smallest transport volumes, starting at 17,092 thousand barrels in 2011 and reaching a maximum of 24,979 thousand barrels in 2022. Despite slight increases, it remains the lowest contributor among the four pipelines. The Baku-Tbilisi-Ceyhan (BTC) COP, the largest international pipeline, exhibited significant volumes, consistently surpassing 200,000 thousand barrels annually. The highest value was recorded in 2018 at 255,770 thousand barrels, while in 2022, the transported volume increased to 225,445 thousand barrels.

Türkiye meets its crude oil needs with its 4 crude oil pipelines and continues its reserve exploration activities. In addition, Türkiye has a strategic importance in the transfer of oil and natural gas reserves from regions with rich oil and gas reserves such as the Middle East and Russia to countries with high import dependency. The TANAP (Trans-Anatolian Natural Gas Pipeline) and Turkish Stream projects, which transport Azerbaijani and Russian gas to Europe via Türkiye, have brought Türkiye's strategic importance to the fore. The heat released from the energy used in industry is often released into the atmosphere [13]. In a period when energy crises and economic factors are so important, alternative technologies are being used to increase efficiency. In the industry, studies on the recovery of heat energy generated as a result of the process have started to come to the agenda frequently [14]. Thus, the waste of heat energy that cannot be used and lost in the system has gained even more importance. This lost energy can be significantly reduced by waste heat recovery. In addition, the evaluation of the waste heat source provides economic benefits, reduces environmental pollution and prevents the deterioration of the ecological balance.

3. DISTRICT HEATING BY USING WASTE HEAT

A large amount of fossil fuels are used to meet the heating needs of a particular enterprise, facility or region, and the chemical gases generated by the combustion of these fuels harm the environment. At this point, the utilization of the waste heat source gains great importance. District heating can be provided with waste heat recovery without fossil fuel consumption and without causing environmental pollution. In this study, the provision of district heating will be examined by utilizing the waste heat obtained from the high-pressure crude oil pump in the pressurization station.

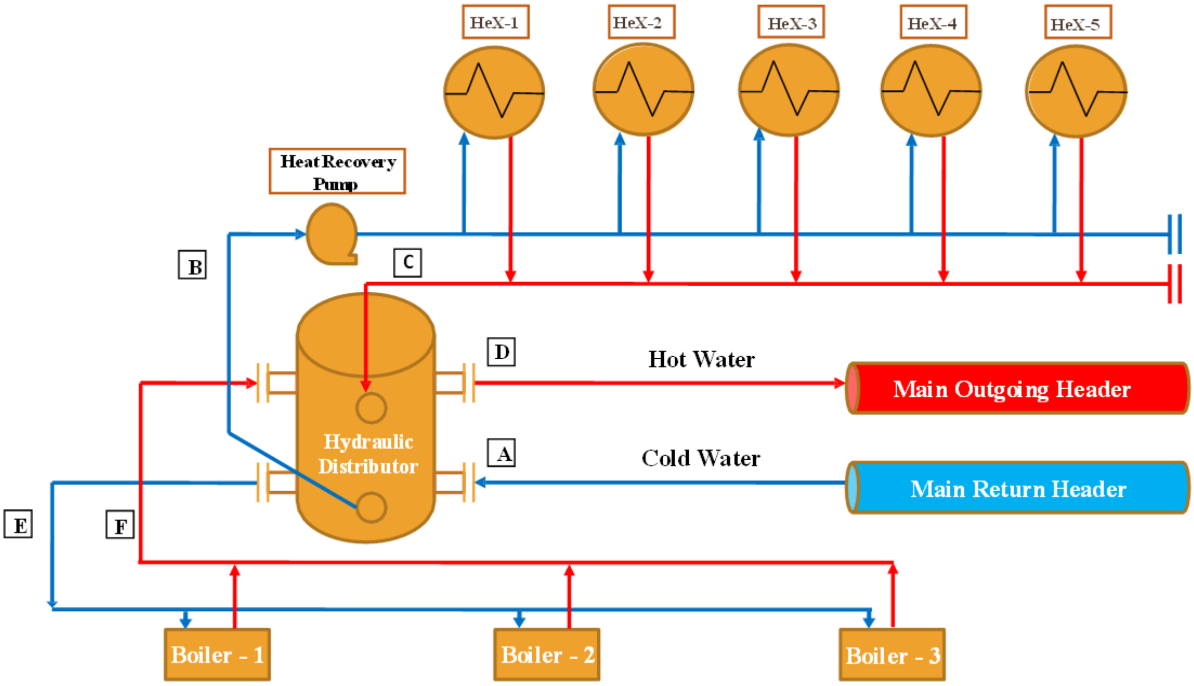

Figure 4. Schematic Diagram of the Heating System

As shown in Figure 4, the schematic illustrates the configuration of the heating system. The pressurization station has 5 main machines that drive the pump. The heat energy of the cooling water of the natural gas-fired machine, which drives the pump that pressurizes the crude oil is transferred to the heat center by means of a plate heat exchanger. Heat exchangers are connected in a parallel configuration and each is installed in the cooling circuit between the pump engine and the cooling unit.

For the secondary source of heat energy, the system consists of three natural gas/diesel fired boilers installed in the heat center, for the case of insufficient heat energy arriving from the heat recovery system. Boilers are parallel to the heat recovery system, also shall feed the hydraulic distributor vessel.

The hydraulic distributor vessel is the central unit consisting of a heat-insulated steel body equipped with two primary nozzle-connections for:

- Main pump heat recovery system
- Alternative heat supply system (Natural gas/diesel-fired boiler units)

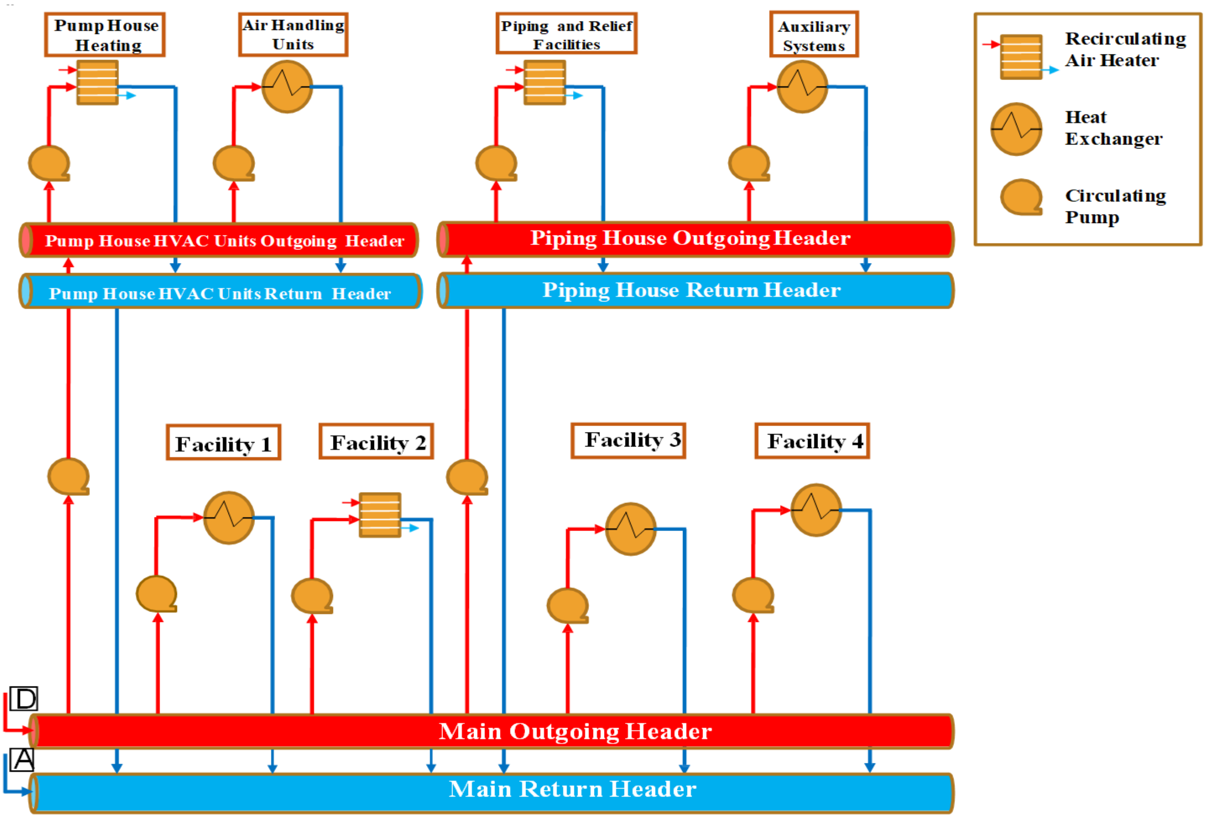

Figure 5. Schematic Diagram-2 of the Heating System

The flow through the heat recovery circuits of the main pumps are controlled by a temperature control valve, holding the temperature above the preset limit. Therefore in the outgoing line, a temperature indicator unit is installed providing a signal to the temperature controller. A 3-way valve is located within the heat recovery circuit by-passing the hydraulic distributor. This 3-way valve provides flow to the hydraulic distributor as soon as the supply temperature of the heat recovery circuit reaches the preset limit. In case, no heating water of appropriate temperature is available from the heat recovery system, the hydraulic distributor gets completely disconnected from the heat recovery system and the natural gas/diesel-fired heating units will meet the demand completely. The hot water coming from the heat exchangers, which is the primary heat source of our closed heating circuit (indicated by the letter C in the diagram), enters the hydraulic distributor. Hot water passes through the hydraulic distributor to the main outgoing header. (indicated by the letter D in the diagram). At the main outgoing header unit, the heating circuits are connected to the facilities and each circuit is equipped with a separate circulating pump (dual type).

Temperature and pressure variations in turbines reveals critical insights into optimizing the temperature profile and heat gain of heat exchangers, which are integral to efficient heat recovery systems [15,16].

For buildings heating, there are 2 types of heating systems:

- Domestic type radiators
- Industrial type recirculating air heaters applied with air fans

Where radiators are installed, they are fed from a local circuit with a heat exchanger, connected to the plant heating system. Where recirculating air heaters are installed, they are continuously on line. Temperature is controlled by the room thermostat switching on and off the fan. Facility 3 and 4 are equipped with radiators. In these facilities, the heat distribution system is installed in the attic area within the building ceiling and the roof. Fed by heat exchangers via heat distributors individual heating circuits for radiators.

The hot water returning from the facilities comes to the hydraulic distributor through the main inlet collector.(indicated by the letter A in the diagram). The water whose temperature has dropped to the hydraulic distributor goes back to the heat recovery exchanger with the heat recovery pump. (indicated by the letter B in the diagram). If the temperature is not sufficient for the system, the boilers are activated. (indicated by the letter E in the diagram). The water is heated in the boilers and included in the system. (indicated by the letter F in the diagram). It can be seen that in the figure 5, there is a second sub-heat distributor unit to the Piping House to feed the following facilities:

- Piping House and Relief Facilities Air Heating
- Auxiliary Systems

There is a third sub-heat distributor unit to the Pump House to feed the following units:

- Heating of the hall by means of recirculating air heaters located inside.
- Heating of supply air is provided by Air Handling Unit 1 (AHU-1) via a heating coil installed within the unit. AHU-1 is located outside of the building.
- Heating of supply air (alternatively) provided by Air Handling Unit 2 (AHU-2) via a heating coil installed within the unit. AHU-2 is located outside of the building.

Both, the recirculating air heater loop and the heating coils for AHU 1/2 are supplied by heating circuits connected to this heat distributor unit. The allowable temperature range for the Pump House is 5ºC - 45 ºC. Temperature control is managed by the use of recirculating air heaters and AHU’s. In addition to Pump House heating, there is a cooling unit for the Pump House. (AHU-3). The operation of the main pumps causes a heat radiation of 166,9 kW per pump.

In order to keep the air temperature in the Pump House below the allowable limit of 45°C, a separate Air Handling Unit (AHU-3) is foreseen to be set in operation. For additional cooling AHU-3 is equipped with a spray humidifier lowering the temperature of the incoming air. By means of this spray humidifier, the supply air will be applied with water up to the maximum achievable humidity. The waste heat energy from the cooling water of the machine is used not only for central heating but also for space conditioning. The desired ambient temperature is achieved by the waste heat energy entering the air handling unit via a collector.

4. CONCLUSIONS

In conclusion, the rapid depletion of fossil fuels and fluctuations in the energy market have led to the most efficient use of energy. In many industrial plants, waste heat cannot be utilized and heat energy is released into the atmosphere. Recent studies have brought waste heat recovery to the agenda and companies have started to work on this issue. Waste heat recovery has become important both in terms of energy saving and optimum levels of economic cost. The waste heat potential in the facilities can be examined and a significant energy gain can be realized. In conclusion, this study highlights the significant potential of waste heat recovery systems in industrial facilities, specifically within crude oil pressurization plants. By utilizing the cooling water from high-pressure pump engines, district heating was successfully achieved without the need for additional fossil fuel consumption. The findings show that each main pump generates 166.9 kW of heat energy, which is effectively recovered and utilized for central heating and space conditioning. Additionally, the study demonstrates that through the waste heat recovery system, the facility achieves a significant reduction in energy costs and minimizes environmental pollution by avoiding the release of unused thermal energy into the atmosphere. The results also indicate that the recovered heat is sufficient to maintain the temperature range of 5°C to 45°C in facilities such as the Pump House, Piping House, and Relief Facilities, with supplemental heating provided by natural gas/diesel-fired boilers only when necessary. The system's efficiency in supplying heating through recirculating air heaters and heat exchangers ensures continuous operation without compromising performance. By leveraging waste heat, this approach effectively reduces energy waste and greenhouse gas emissions while achieving substantial cost savings.

These findings confirm that implementing waste heat recovery systems in industrial pressurization stations can lead to significant environmental and economic benefits, further supporting global efforts to reduce fossil fuel dependency and combat climate change.

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