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Kazanlarda Enerji Verimliliği

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Anahtar Kelimeler

Kazan, enerji verimliliği, enerji etüdü, kazan yakıtları, kazanlarda enerji verimliliği

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Özet

Toplam enerji tüketiminde bina ısıtma sistemleri önemli bir yer tutmaktadır. Bu yüzden, ısıtma sistemlerinin enerji tüketimlerinin en yüksek verimle çalışması istenir. Bu amaçla sıklıkla enerji verimliliği etüdü yapılır. Bu çalışma, binalarda ısıtma sistemleriyle ilgili bir derleme makalesidir. Derlemede ısıtma sistemleri hakkında bilgi verilmiştir. Ayrıca kazan dairesini, kazanlar ve kazan tipleri, yakıtlar tanıtılmıştır. Ayrıca ısıtma sistemlerinde meydana gelen kayıplar tarif etmektedir. Son olarak ısıtma sistemleri için enerji dengesi ve nasıl enerji etüdü yapılabileceği ve enerji tasarruf adımları anlatılmıştır.

Materyal ve Yöntem

Bu çalışmada kalorifer kazanlarıyla ilgili derleme çalışması yapılmıştır. Özellikle yerli literatürde yer alan ve kazanlarda enerji verimliliği ile ilgili olan önemli çalışmalara yer verilmiştir. Çalışmada ayrıca, kazanlarda enerji etüdü ile ilgili bilgilere yer verilmiş, enerjinin korunumuyla ilgili temel denklikler tanıtılmıştır.

Tartışma ve Sonuçlar

Kazanlarda enerji etüdü metodunu detaylı olarak tarif eden çalışmaların yapılması gerekir.

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Energy Efficiency in Heater Boilers

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Abstract
Building heating systems have an important place in the total energy consumption in building sector. Therefore, it is desired that the heating systems of a building should work with the highest efficiency. That leads scientists to focus on energy efficiency studies. This paper is a review study about building heating systems. The heating systems, then the boiler room, boilers and boiler types, fuels are introduced. The paper also describes the losses of heating systems. The energy balance for heating systems, how to make an energy audit and energy-saving steps are explained.

Keywords: Boiler, Energy Efficiency, Energy Audit, Boiler Fuels

1. Introduction

Energy is described as the ability to do work. It is the main factor for the continuation of life and economic progress. Energy consumption increases proportionally to the developing technology [1]. The use of energy in Turkey is increasing faster than in developed countries due to population growth, increase in welfare, development and industrialization. The target is; to contribute to the development by energy efficiency and increasing productivity [2]. Producing or serving by using less energy is called energy efficiency. But avoiding energy consumption does not mean energy efficiency it is called energy saving [3]. Efficiency is generally an effective way of producing with minimal waste and expense as a result of an effort [4]. Energy efficiency increases comfort in buildings and decreases the energy intensity in industries [5]. Energy efficiency can also be described as the use of energy more effectively by utilizing developing technology and known methods. Moreover, researchers state that energy efficiency can be considered as the cheapest energy [3].

According to the data from the International Energy Agency, buildings account for 32% of the total energy consumption worldwide [6]. Energy efficiency in buildings can be divided into groups such as thermal insulation, mechanical systems, lighting systems, household appliances and benefiting from renewable energies [7]. In the housing sector, 85% of energy is consumed for heating and providing hot water [8].

The main purpose of heating systems is to provide thermal comfort of the occupants, by ensuring the thermal balance between the human body and its environment by providing enough thermal energy to an area such as a single room or the whole building [9]. Thermal comfort depends on temperature, humidity, air velocity, indoor air quality, flow rate, average radiation temperature, radiation and diffusion [10-11]. Energy sources in heating vary in terms of the location of the heating equipment and the way of heat transfer. According to the location of the heater, heating systems are classified into four different categories as regional, local, individual and central. Generally, fossil fuels or electricity are used as energy sources [6]. The type and characteristics of heating systems are important in terms of energy efficiency. District heating gains importance in heating systems in terms of providing the required heat regularly, in sufficient quantity and economically [12]. Boilers convert the chemical energy of the fuel into heat energy and transmit it to the carrier fluids that operate with pressure [13]. Devices that can produce steam at the desired pressure, temperature and flow rate are expressed as steam boilers [14]. The first steam boiler was built by Denis Papin in 1860. The first boilers were operating at 2 to 4 atm pressures. Today's boilers that are made of special alloy steels are capable of producing steam up to 300 atu pressure. The heat energy of steam; It is used in industry for heating, drying and cooking processes.

A variety of fuels is used in the boilers. It is thought that there will be developments in two directions in the future of heating systems. The first is aimed at increasing system efficiency. With the emergence of condensing natural gas boilers, developments in this direction have reached a high level [15]. The use of economical, safe and environmentally protective boilers is an important goal [16]. The heat transfer rate and the completion of the combustion affect the energy efficiency of the boilers. The quality of combustion, the design of the burner and the number of pollutants in the fuel affect the flue gas emission. For this reason, it is necessary to monitor the flue gas components in boilers continuously and periodically with the help of flue gas analyzers. In order to keep the thermal efficiency constantly high and the emissions and internal cooling losses under control, the combustion must be monitored [17].

In this study, the issue of energy efficiency in heating boilers is discussed. In the literature, there are not a satisfactory amount of studies that describe energy efficiency and energy audit of boilers. This study is expected to fill this gap. In addition, this study presents important steps for the safe, environmentally friendly and economical operation of boilers.

2. Historical Development Of Heating Technique

Since ancient times, people have sought protection from the cold with various methods. At first, they were warmed by burning fire in the open area, but over time, a method of heating was discovered by leaving a hole in the open fire burned in the middle of the closed area called tandoor. Until the 18th period, heating was carried out with a stove and open-fire barbecue in Anatolia. In Western countries, an open flame heating method called a fireplace was used.

Stoves were first used in China and Russia to heat small volumes. While the first brick stove was used in Denmark at the beginning of the 15th century in Europe, the first cast iron stoves were used in the USA in 1650.

The central heating technique, which is known since the Romans, provides the heating of these environments by transporting the hot fluid prepared in a heating plant to the desired environment. After the 1950s, it started to be applied in all kinds of buildings [18].

3. Contemporary Heating Techniques

Despite limited resources, there is a rapidly increasing energy demand in the world. The construction sector has a large share in total energy consumption. Residential heating in buildings is holding the largest portion of the sector [19]. Recent heating systems that emit fewer pollutants are highly efficient in residential heating. However, each system has advantages and disadvantages. When choosing a heating system for a resident every alternative should be considered individually [6].

Regional Heating: Regional heating systems are widely used in most cold regions. The use of district heating systems in the world has become increasingly widespread since the beginning of the 20th century. It is based on heating and hot water services consisting of multiple buildings and a heating center. Compared to other heating systems, district heating is coming to prominence in terms of energy efficiency [20-21]. Because district heating systems are more stable, adequate and economic [21].

Local heating: The most distinctive feature is they are located inside the building. Different types of local heating systems use different types of fuels. Combi boilers, convection heaters, and radiant heaters are the most common local heating systems [22].

Central heating: These systems provide heat to the interior of a building from a single point. When combined with other systems to control the building climate, the entire system is called an HVAC (Heating, Ventilation and Cooling) system. It is used in many different buildings such as residences, hotels and shopping malls. It is often used to heat buildings and groups of buildings in cold climates.

Individual heating: A heat requirement between 10 and 40 kW is called individual heating. Generally, diesel, natural gas or liquefied petroleum gas (LPG) is used as fuel. The most important feature of the system is; it is independent. Its disadvantage is; it is not economical compared to central heating [18]. In Figure 1, the installation of individual and central heating systems is shown schematically.

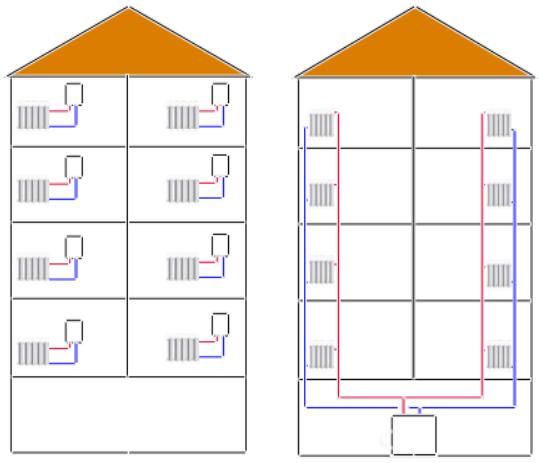

Figure 1. Representative schemes of individual and central space heating systems [23]

4. Boiler Room, Boilers And Fuels

The boilers are designed for steam generation or hot water preparation at the required quality [24]. A boiler produces heat by combustion to generate heat transferred to water to be converted into steam at the desired temperature and pressure [25, 26].

Grille, fuel feeders, combustion chamber or furnace, water or sludge drum, steam drum, main bank, superheater, economizer, air heater, washer, induced draft fan, forced draft fan, secondary air fan, boiler feed water pumps and some auxiliary equipment are the main components of a modern boiler [27].

Grill: Grill bars are produced from high-grade and heat-resistant cast iron. Have a large surface area to maximize the cooling by using underground air [28].

Combustion chamber or furnace: Fuel burns in a boiler's combustion chamber. Combustion produces heat which is then transferred by surrounding heat transfer surfaces [29].

Super Heaters: It is the place where the saturated steam is heated to produce superheated steam. The factor limiting the superheating temperature is the strength of the superheater material [30].

Steam drum: Drums store buffers the excess water. The steam drum plays a key role in a continuous steam supply [31].

Air heater: The air heater is located at the end of the flue gas duct downstream of the economizer [32].

Economizer: The purpose of an economizer is to reduce fuel consumption by heat recovery [33].

Scrubber: Flue gas desulfurization units are known as scrubbers. They are the devices connected to boilers where coal is burned [34]. Wet scrubbers, cyclonic scrubbers, bag filters, and electrostatic precipitators are types of scrubbers. While electrostatic precipitators are known to be the most effective, wet scrubbers are cheaper and meet regulatory requirements [35].

Secondary air: Provides the necessary turbulence in the furnace and is approximately 10% of the total air required for combustion. [27].

4.1. Boiler Types:

Conventional Boilers: These are fuel-burning boilers to provide heat for hot water and central heating. Conventional boilers are designed to prevent flue gas condensation and low-temperature corrosion [36]. The high rate of heat released by the flue gas is recovered in conventional boilers by condensation that enables to use of a Higher Heating Value [37].

System Boilers: They are also known as closed system boilers. There is a hot water cylinder but no water tank. Requires less space than a traditional boiler and multiple users at the same time are enabled [38].

Condensing Boilers: They are widely preferred in recent years. They are preferred because of their compact structures and efficient heating control systems. The purpose of condensing boilers is to recover the sensible and latent heat of the flue gas [39]. Condensing boilers provide high fuel savings by condensing the water vapour in the flue gas. The most important difference is that the heat exchangers have a large area to absorb more heat from the burner and flue gases [40].

Cascade System: These systems are formed by connecting two or more wall-type boilers in parallel instead of large self-condensing floor-type boilers. If the heating capacity is 100 kW or more, cascade boiler systems that are more economic [41].

Combi Boilers: Combi boilers offer an economical alternative to individual single-function gas boilers and instant water heaters. These appliances allow the generation of thermal energy for space heating and hot water production. Compact and highly efficient devices are becoming increasingly popular in many residential buildings [42]. The boiler runs regularly to meet comfort requirements [43]. Contrary to a conventional boiler, it is more convenient in terms of installation and price [44].

4.2. Fuels Used in Boilers

The main fuels used in boilers are natural gas, liquid petroleum gas (LPG), fuel oil, diesel and coal [18].

Natural gas: Natural gas-fired boilers have increasingly dominated the process heating sector due to their high thermal efficiency, relatively low emissions and convenient fuel delivery systems. A conventional natural gas-fired boiler typically has a thermal efficiency of 70-80% [45]. Natural gas is utilized as an alternative fuel that can gradually reduce coal consumption in cogeneration plants [46-47].

Liquid Petrol Gas (LPG): Used as household fuel for several years all over the world [48].

Diesel: Diesel is used in industrial and domestic applications for heat or steam production [49].

Fuel oil: Fuel oil is a dark-colored, less fluid petroleum product. Fuel Oil, which can be used in electricity, heat or steam systems, was preferred in all kinds of industrial factories, facilities and buildings. Fuel oil pollutes the air less than coal. More expensive than natural gas; requires more boiler maintenance. It does not burn as cleanly as natural gas or propane and requires storage tanks [22]. Heavy fuel oil is the fuel used primarily in industrial boilers containing up to 4.0% sulfur [50].

Coal: It is black, carbon content is high. It is formed by undergoing some chemical changes by smoldering combustion of carbonaceous materials in closed and airless places or by staying under the soil layers for a very long time [51]. A major disadvantage of coal is the polluting emissions [52].

5. Boiler Efficiency

Boiler efficiency is defined as the ratio of the net heat absorbed by the fluid to the net heat supplied to the system. This can also be determined by subtracting the heat loss from the net amount of heat supplied to the boiler [53]. To ensure high efficiency and safe operation, a boiler must always supply more combustion air than the stoichiometric air rate [54]. Therefore, to increase boiler efficiency, it is necessary to minimize the wasted heat [55].

Boiler thermal efficiency can be calculated by direct and indirect methods.

a. The direct method: The total energy transferred to the fluid and energy supplied by the fuel should be measured. Then, the boiler efficiency can be calculated as [56];

$$\eta = \frac{m_s h_s - m_w h_w}{B.H_u} \quad (1)$$

Here, m_s is the steam flow (kg/s), m_w is the water flow rate (kg/s), h_s is the enthalpy of the steam (kJ/kg), h_w is the feed water enthalpy (kJ/kg), B is the fuel flow rate (kg/s), Hu is the lower heating value of the fuel (kJ/kg).

b. In the indirect method, the rated heat power of the boiler is determined by calculating the losses, that is, in the indirect method, the boiler efficiency is found by subtracting the sum of the thermal losses calculated as a percentage from 100 [57]. The thermal efficiency in the indirect method can be calculated by;

$$\eta = 1 - \Sigma Z \quad (2)$$

Here, Z is the percentage of various thermal losses. [56].

Thermal losses are namely, incomplete combustion, excess air, heat due to water vapors in the flue gas loss, flue gas temperature, fuel type, boiler load, heat losses from the boiler surface, and heater surface pollution.

6. Energy Audit For Boilers

An energy audit is a study analysis of energy flows in a structure, process or system that aims to reduce the amount of energy input without adversely affecting outputs [16]. A useful audit for an organization should analyze and understand its energy consumption. An energy audit helps to plan energy consumption to increase energy efficiency, and reduce energy waste and costs [58].

Energy audits may provide benefits, some of these are: [59-60]:

• Reduction in specific energy consumption and environmental pollution,

• Reduction in operating costs with systematic analysis (approximately 20-30%),

• Improvement of the overall performance, profitability and productivity of the total system,

• Slower depletion of natural resources and narrowing of the demand-supply gap,

• Prevention of equipment failure.

Energy auditing in a building means recording and analyzing all features of the building envelope, including walls, floors, ceilings, doors, skylights and windows. Heat resistance should be investigated for each of these parts. [61]. Each energy efficiency audit should include measurement, analysis of internal monitoring records, engineering calculations, details based on the opinions of operational personnel, and a detailed report.

The information gathered through measurements, physical inspection and direct communication and interviews with the responsible personnel is organized into the following categories:

1. General information about the company: Process, Sector.

2. General information about the selected boiler: Basic/Optional fuel; Boiler type (steam or hot water boiler), Operation period (years); the purpose of the boiler (technology or heating), Capacity [t/h] and/or [MW]; Operational parameters (temperature/pressure), Plant engagement (permanent, seasonal, etc.).

3. Boiler operating performance: The most common load range in terms of rated load capacity [%], number of working hours per year [h/w]; and specific fuel consumption [m^3 /h, kg/h].

4. Measurement parameters: flue gas temperature [C], flue gas velocity [m/s], load range [%] (during flue gas measurements).

5. Calculated performances: flue gas flow rate [m^3/h], boiler efficiency [%], flue gas losses [%]; annual fuel consumption [GWh/year].

6. Combustion quality (flue gas composition): O_2 [%], CO_2 [%]; SO_2 [ppm], CO [ppm], NO [ppm], NO_x [ppm] and H_2 [ppm], MCO [kg/h] and MNO_x [kg/h].

7. Monitoring and enabling controls: constant and continuous oxygen control; measurement of heat energy distribution rate; flow measurement of boiler feed water and condensate return; combustion quality.

8. Control type: Manual; semiautomatic; Automatic.

9. Reconstruction and/or renovation records: burners and related equipment; heat recovery systems (economizer); pipes, automatic control equipment [62, 63].

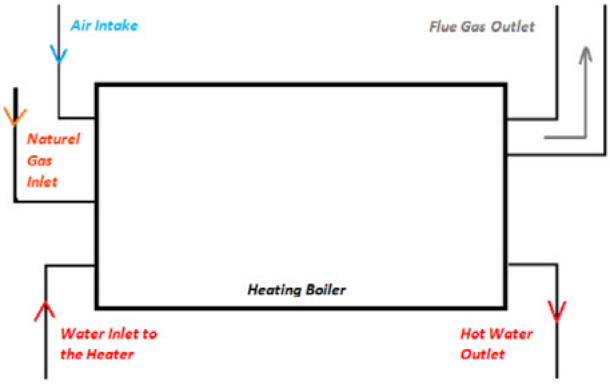

Figure 2. Energy study diagram in the heating boiler

In Figure 2, the inputs and outputs of the heating boiler using natural gas as a fuel are shown with a simple diagram. The first law of thermodynamics expresses the principle of conservation of energy. During a process, energy cannot be created, but it can change form (Equation 3), [64].

The net heat transfer to the working fluid,

$$\dot{Q}_w = \dot{m}_w \times C_{p,w} \times (T_{o,w} - T_{i,w}) \quad (3)$$

Here, m_w is the mass flow rate of the water in [kg/s], $C_{p,w}$ is the specific heat of the water [kJ/kgs], and T_o is the temperature of the water leaving the boiler [C], T_i is the temperature of the water entering the boiler [C].

The energy supplied by fuel (namely natural gas) can be calculated by;

$$\dot{Q}_{ng} = \dot{m}_{ng}\, x\, HHV \quad (4)$$

Here $\dot{m}_{ng}$ is the mass flow rate of the natural gas in [kg/s] and HHV is the higher heating value of natural gas in [kj/kg]. Considering these parameters, the direct energy efficiency of the boiler can be calculated.

7. Energy Saving Steps In Boilers

For the safe, environmentally friendly and economical operation of the boilers, the following rule of thumb should be considered.

a. The heat requirement should be well calculated. Boilers must be selected carefully. Boilers with high efficiency will consume less fuel, thus saving both money and nature.

b. The thermostat setting of the boiler should be adjusted according to the outside temperature, which is not stable during the day.

c. A "Boiler Registry Log" should be employed. The transactions related to the boiler are recorded in the Boiler Registry Log.

d. The amount of fuel used should be measured and recorded. Fuel stock cards should be kept for monitoring fuel consumption.

e. The system in the boiler room should be simple and user-friendly.

f. All leaks (fuel, water) must be detected in daily controls and repaired immediately without endangering life and property.

g. The temperature of the flue gas at the exit of the boiler should be measured and recorded daily. In the case where the flue gas temperature raises 20-30^{o}C from the mean flue gas temperature, it means that the tubes in the boiler are contaminated with soot, dust etc. Because 0.1 mm of the soot layer decreases the efficiency of the boiler by 1%. This increases the cost and environmental pollution.

h. In order to determine whether the fuel is burning efficiently, the flue gas should be tested regularly [16]. Preventive maintenance saves the boiler system from unexpected failures while minimizing energy consumption. Blowdown is a periodic process in boiler tubes [65].

8. Results

Boilers are used to facilitate the heating process. Today the boiler efficiency is considered to be in the range of 75-90%. There are several ways of heat loss from the boiler. Flue gas loss is the largest source of heat loss among others. The purpose of the condensing boilers is to recover the sensible and latent heat of the flue gas.

Energy audit has become very important in the recovery of waste energy. The energy audit is performed to evaluate the boiler's efficiency and to determine the amount of heat removed from the boiler. Boiler efficiency can be increased by controlling and recovering the waste heat.

Natural gas-fired boilers have thermal efficiency in the range of 70-80%, relatively low emissions, and convenient fuel delivery systems. Fuel oil is more expensive than natural gas, does not burn as cleanly as natural gas or propane, and requires more boiler maintenance.

In this paper, a literature review of boilers was conducted. The parameters affecting the boiler efficiency and the bullets for increasing the efficiency are presented.

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