Mariusz BRONISZEWSKI[1] and Sebastian WERLE[2*]

ASSESSMENT OF POSSIBILITIES FOR REUSING WASTE HEAT TO COVER NEEDS FOR HEATING IN BULTEN POLAND S.A.

OCENA MOŻLIWOŚCI WYKORZYSTANIA CIEPŁA ODPADOWEGO W CELU ZASPOKOJENIA ZAPOTRZEBOWANIA NA MOC GRZEWCZĄ W ZAKŁADZIE BULTEN POLSKA S.A.

Abstract: Contemporary industrial and economic development, due to the dynamic progress of civilization and technology, requires significantly increased amount of energy. For this reason, we are looking for ways to use energy in a smart way, thus improving energy efficiency. One of many possibilities is to recover waste heat from energy-intensive technological processes. The process that creates a great potential for the waste heat collection and management is the process of fasteners' heat treatment.

The aim of the work is to evaluate the possibility of becoming independent from a district heating network in the production of fasteners for automotive industry plant Bulten Poland S.A. The idea is to use heat recovery systems installed on two hardening lines (air/water exchange) and on air compressors (oil/water exchange), which produce the necessary compressed air for bolts production processes. In addition, heat recovery is provided also in the oil bath of one furnace (oil/water exchange). The analyzed solution also assumes installation of two gas boilers, which will take a supporting role in case of extremely low outdoor temperatures and the necessity for increased needs for heat.

An essential element of the carried out work is implementation of a superior energy management system (SyNiS), which enables efficient control of the sources' power and the direction of heat transfer.

Keywords: energy efficiency, heat recovery, waste heat, SyNiS, industrial energy audit, sustainable development

1. Introduction

Energy efficiency has recently been treated as one of the energy resources. The European Union, through its policy, enforces and promotes certain actions aimed at

[1] Bulten Poland S.A., ul. Bukietowa 60, 43-300 Bielsko-Biała, Poland, phone: +48 33 498 36 47, email: mariusz.broniszewski@bulten.com

[2] Institute of Thermal Technology, Silesian University of Technology, ul. Konarskiego 22, 44-100 Gliwice, Poland, phone: +48 32 237 29 83, fax: +48 32 237 28 72.

* Corresponding author: sebastian.werle@polsl.pl

improving the energy efficiency [1] of installations and equipment, aiming increasing of energy efficiency of all energy market participants. EU efforts are geared towards ensuring that energy efficiency is a permanent part of the internal energy market. With the increase in energy efficiency, new business niches appeared for innovative services and products [2].

In the years 2008–2012, retail electricity prices for industry increased average by 3.5% yearly. It is estimated that electricity prices for industry in the EU are two times higher than in the USA and 20% higher than in China [3]. Besides that fact, in Poland (in the years 2010–2015) significantly increased energy consumption have been noticed (by 2.2%) [4]. Therefore, increasing energy efficiency should be essential for each big company, who wants to participate in sustainable development.

The beginning of the energy efficiency improvements at the factory is an energy audit that takes into account relevant European or international standards, such as EN ISO 50001 (Energy Management System) [5] or EN 16247-1 (energy audits) [6]. In Poland, the Energy Efficiency Act [7] imposed the obligation to perform periodic energy audits (every 4 years) in large companies operating in the country. This obligation can be considered as a problematic obligation or as an opportunity to conduct a thorough analysis of the possibilities of introducing actions to improve energy efficiency in the company.

An example of the industrial audit scope:

1. Local vision.
2. Description of buildings and technological processes of the plant, especially in terms of their need for a different form of energy.
3. Description of the heating system of the plant (source, transmission networks, installation and receiving capacity of heat).
4. Description of cooling systems at the plant.
5. Description of the heating system technology.
6. Description of the compressed air system (compressor, air parameters and its quantity, receiving capacity).
7. Consumption analysis for the past two years:
   a) electrical energy,
   b) heat,
   c) coolant,
   d) Compressed air,
   e) fuel (natural gas, coal, oil etc.),
   f) other utilities (water, sewage).
8. Analysis of demands for:
   a) energy to heat buildings,
   b) energy to produce hot water,
   c) energy for ventilation and air conditioning,
   d) energy (heat, electricity and cooling) for production processes.
9. Energy wasted from technological processes.
10. Analysis of energy efficiency for each type of energy.
11. Analysis of the compressed air system.

12. Analysis of the possibilities of using wasted energy from technological processes.
13. Analysis of the possibility of the use of Renewable Energy Sources.
14. Analysis of the possibility of the use of cogeneration systems.
15. Technical concepts of modernization improvements.
16. Analysis of applicable tariffs and the amount of ordered power for electricity, heat and gas with analysis of possibility to optimize further.
17. Estimation of investment and the effects of the implementation of the proposed solutions.
18. Economic efficiency analysis of the implementation of individual solutions.
19. Analysis of the possibility of external financing modernization.
20. Analysis of ecological effects.
21. Analysis of the possibility of obtaining and selling Certificates of Energy Efficiency.
22. The assumptions for the Company's Control System SyNiS.
23. Conclusions.

A big encouragement for companies is the ability to obtain energy efficiency certificates (so-called. “White certificates”) which can be sold for additional revenue. The amount obtained from the sale of certificates, in part covers the costs of the work related to the increase of energy efficiency in the company.

The aim of this study is to evaluate waste heat recovery system for the industry using heat treating processes. The study incudes an energy analysis and economic evaluation. The results will indicate the possibility of realizing an Energy Project in Bulten Poland S.A. Furthermore, the proposed system will promote energy efficiency improvements in the industry.

2. Current situation

Currently, the heat for the plant distributes a single-function heat exchanger powered from a high-temperature heat network. The heat distributor is Therma Co, while the heat generator is a power plant within Tauron group. Existing heat substation is obsolete and is in poor technical condition. The pumps tend to have temporary failures, repair of pumps due to their age is very troublesome. In addition to the current heating needs, the existing heating substation is oversized (it was designed to transfer much higher amount of heat than currently ordered). A dozen or so years ago, he supplied a residential block a few hundred meters from the plant. After the modernization of the residential block, the heat started coming from the city, however the heat substation in the factory remained unchanged. Oversized heat substation results lower efficiency of production and transfer of heat to objects located on the premises.

There are two main circuits with separate regulators and separate exchangers.

1. Large circuit powered by 4 exchangers type JAD 12.114 with parameters $100^{o}C/80^{o}C$.

2. Small circuit powered by 4 exchangers type JAD 3.18 with parameters $80^{o}C/60^{o}C$.

The small circuit supplies open space, part of the production hall and administration building. Circulation of the water forces the Grundfoss Magna 32-120F pump.

Table 1

Heating degree day (HDD) and standard season heat usage calculations

	Jan	Feb	Mar	May	Apr	Jun	Jul	Aug	Sep	Oct	Nov	Dec
$T_{1\ external}$ (2005–2015) [^oC]	–1.7	–2.3	4.9	8.0	12.4	16.2	19.2	17.1	15.1	8.9	4.4	0.1
$T_{2\ external}$ (2015) [^oC]	1.6	0.8	5.4	9.0	12.8	17.0	20.8	22.1	15.0	8.3	9.3	3.6
Nd (number of days in heating season)	31	28	31	30	5	0	0	0	5	31	30	31
$T_{3\ internal}$ [^oC]	16	16	16	16	16	16	16	16	16	16	16	16
$\Delta T_1 = (T_3 - T_1)$ [^oC]	17.7	18.3	11.1	8.0	3.6	–0.2	–3.2	–1.1	0.9	7.1	11.6	15.9
$\Delta T_2 = (T_3 - T_2)$ [^oC]	14.4	15.2	10.6	7.0	3.2	–1.0	–4.8	–6.1	1.0	7.7	6.7	12.4
$HDD_{stand.} = \Delta T_1 \cdot Nd$	548.7	512.4	344.1	240.0	18.0	0.0	0.0	0.0	4.5	220.1	348.0	492.9
$\Sigma\ HDD_{stand.}$	2728.70											
$HDD_{2015} = \Delta T_2 \cdot Nd$	446.4	425.6	328.6	210.0	16.0	0.0	0.0	0.0	5.0	238.7	201.0	384.4
$\Sigma\ HDD_{2015}$	2255.70											
$\Sigma\ HDD_{stand.} / \Sigma\ HDD_{2015}$	1.21											
Heat usage $_{2015}$ [GJ]	1597.6	1286.9	826.4	577.4	0.0	0.0	0.0	0.0	0.0	401.4	862.9	994.0
Heat usage $_{stand.\ season}$ [GJ]	1932.6	1556.8	999.7	698.5	0.0	0.0	0.0	0.0	0.0	485.6	1043.8	1202.4
Σ Heat usage $_{stand.\ season}$ [GJ]	**7919.40**											

The large circuit supplies the other buildings. The water circulation in the system forces a rotary pump (7.5 kW and capacity 48–60 m^3/h). A large circuit divides into five separate circuits that supply the individual objects/halls.

The heating substation has only a basic temperature adjustment. There is no return water temperature control from individual circuits (no thermometers installed on the return pipeline). Due to the lack of thermostatic valve heads on radiators and large flow (large rotary pump with constant speed), there is a slight difference in temperature between the supply and the return. This results in a reduction in the efficiency of heat usage. Moreover, too high return temperature violates the conditions of the agreement with heat supplier.

The heaters are mostly plate heaters (type VK22) and ribs (type GZ 32-90). Most of them are equipped with thermostatic valves, however there are no thermostatic heads on the valves at the production halls.

Table 1 shows heating degree day (HDD) and Heat usage $_{\text{stand. season}}$ [8, 9] based on data usage in Bulten Poland S.A. in 2015. The calculations covered average outdoor temperatures in multi-year period 2005–2015 (T_1) and measured in 2015 (T_2). The number of the heating season days are determined in the certain regions of Poland (Nd). The outdoor temperature (T_3) was set at 16°C, suitable for production halls. After calculations, the heat demand during the standard season has been established [Σ Heat usage $_{\text{stand. season}}$].

3. Proposed system

According to conclusions of conducted energy audit, there is an economically justified possibility of abandoning the supply of network heat and building on-site heat sources based on waste heat recovery installations and boilers as an auxiliary source. The modernized heating system of the plant will prioritize the use of available waste heat sources. The auxiliary source will work only if there is no heat from the recovery systems or if their performance is insufficient relative to the current demand. The above conditions will be ensured by the proper design of the installation and the implementation of an active control system supervising the work of generating sources (SyNiS).

An auxiliary heat source will be a cascade of gas boilers with a total power of 900 kW. The primary and priority source of heat will be heat recovery installations within:

1. Heat recovery from compressor cooling (oil / water heat exchanger).
2. Heat recovery from the exhaust stream of Aichelins' quenching furnace.
3. Heat recovery from the exhaust stream of Dowas' quenching furnace.
4. Heat recovery from the Aichelins' oil quenching bath (oil / water heat exchanger).

Maximum potential of recovered heat:

- from the air compressors 6 112 [GJ/year],
- from the Aichelins' exhaust stream 4 365 [GJ/year],
- from the Dowas' exhaust stream 4 134 [GJ/year],
- from the oil baths' heat exchanger 4 455 [GJ/year].

Total: 18 965 [GJ/year].

The maximum heat recovery potential is expressed by the amount of heat we are able to recover when sources work with nominal power throughout the year.

In order to increase the efficiency of use of waste heat and improve the functionality and flexibility of the heating system, the company's heat distribution network will be able to distribute heat from two locations (compressor room and heat treatment department). As the amount of heat recovered at the heat treatment department will be greater than the heat demand of this facility, the heat transfer will be driven by the newly designed pipeline to the adjacent hall and from there will be distributed through existing pipeline to other facilities.

The heat receivers will be: the company's internal network and hot water storage tanks for refilling water in technological washers. It is also planned to heat up the water for social purposes, in changing rooms and bathrooms.

3.1. Heat recovery form air compressors

For the heat recovery from the hot compressor cooling oil, an external "Duotherm" heat recovery system provided by the BOGE compressor manufacturer will be installed. The system is based on a plate heat exchanger to which the oil circuit from the compressor is connected and the water circuit from the recovery installation. The amount of heat received in the heat exchanger is controlled by an integrated three-way valve with a thermostatic actuator. The flow of water in the compressor circuits will be forced by the operation of variable-speed rotary pump controlled by an analogue signal to maintain the constant water temperature measured behind the heat exchanger. The flow of heated water is directed towards the heat buffer, which simultaneously functions as a hydraulic clutch. In order to measure the amount of heat generated, it is planned to install the LC1 heat meter.

3.2. Heat recovery form exhaust (Dowa and Aichelin)

The exhaust gas economizer in the bypass of the main exhaust pipes. Behind the economizer will be installed exhaust gas fan with adjustable capacity. The system will be able to return to the existing state by opening the appropriate throttle and thrust breakers. Automation should protect the installation from overheating (expected during the summer season) by automatically opening the cold air intake to the economizer. Fan control (switching, modulation, shutdown) and throttle opening will be done by PLC controller.

3.3. Heat recovery form oil bath (Aichelin)

The oil circuit between oil bath and oil cooler is characterized by high temperature (75^{o}C) and high flow (>100 t/h). In order to recover heat from the circulating oil, an additional exchanger is proposed as a first oil cooling rank. Heat exchanger must be connected in series to the oil circuit in front of the existing exchanger. The oil flow will be forced by the existing pump, so the additional exchanger has to characterized by sufficiently low flow resistance on the oil side to keep the flow at a similar level as the existing one. The new system will be able to easily return to the state before the modernization by opening / closing the proper shut off valves (bypassing the new exchanger). The temperature sensor of the oil flowing into the exchanger will protect the oil against excessive cooling in the circuit. If the oil temperature falls below the set point, the valve will be closed on the water side – the heat transferred to the heat buffer will be blocked. During operation there is no danger of water overheating in the circuit as the oil temperature is controlled by the existing cooler, the electrovalve opens the cooling water supply to the cooler when the oil temperature exceeds 77°C.

3.4. Energy management control system (SyNiS)

In the internet era it is possible to provide full remote control over all the units connected to the SyNiS system. Data acquisition, adjusting of running parameters, instant error and emergency reporting and measuring the totality of energy used are possible, thanks to the central control unit.

Data from measuring sensors is collected by a Programmable Logic Controller on site. With low data flow, a single controller can operate multiple units. Recorded data allows for viewing of utility expenditure (gas, electricity, water, heat, cold) and allows for the PLC to autonomously control running parameters of the system.

An easily programmable touch-screen controller is specially selected for each substation, allowing for adjustable algorithms and constant communications between devices and the system users via Internet connection. The substation is equipped with appropriate measuring instruments and actuators (pumps, two- and three-port valves, heat meters, water meters, solenoid valves and temperature sensors) linked to the PLC.

A server collecting all the data can provide easily accessible on-demand reports and visualization of findings. The application can also automatically warn the operator (ex. via text message) about any exceeded parameters. Additionally, the server prevents unauthorized access enforcing password authorization. The users can be divided between the ones with only access to the present status, past data and reports, as well as technicians also being allowed to adjust the parameters. It also allows the current administration of the counters (water meters, heat meters, electricity meters, gas meters, etc.).

The communication between the actuators, sensors, PLC and server is established over dedicated network protocols, designed specifically for particular SyNiS systems. The server uses internet connection to provide data access to the service team, supplier, operators and the final consumer.

The data acquisition system can present obtained data in convenient charts and tables and transmits data to the billing department. Additionally it can provide any required statistics, calculations, reports and analysis on any archived data, which offer consider-

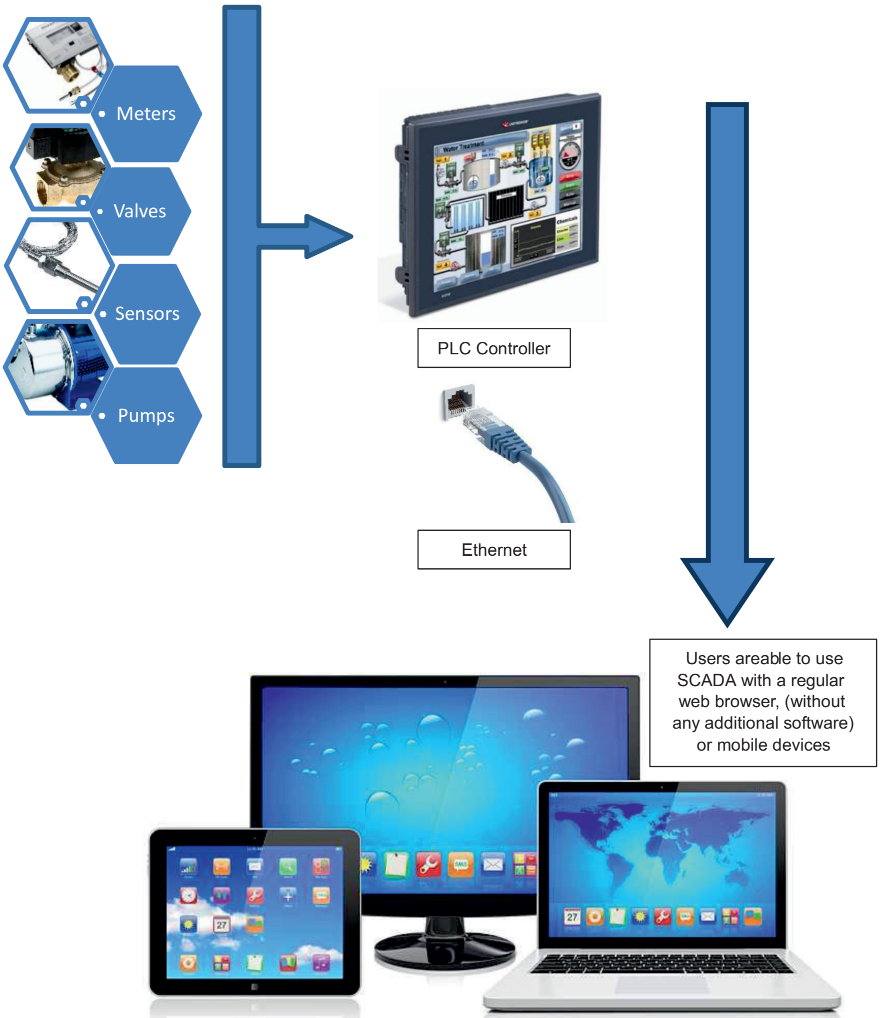

Fig. 1. Simplified SyNiS system concept

able potential in predicting energy use, easy billing, loss prevention and fine tuning of the system to further improve savings.

4. Results and discussions

Contemporary industrial and economic development, due to the dynamic progress of civilization and technology, requires significantly increased amount of energy. For this reason, we need to look for ways to use energy in a smart way, thus improving energy efficiency.

Power consumption in Poland is the highest since 1988, in 2016 exceeded 164 TWh. In 2016 electricity production in Poland increased to about 162.6 TWh and was higher by 0.53% than a year earlier, and its consumption increased to about 164.6 TWh and was higher by 1.97% than last year [4]. Figure 2 shows constantly increasing energy usage in Poland through last years.

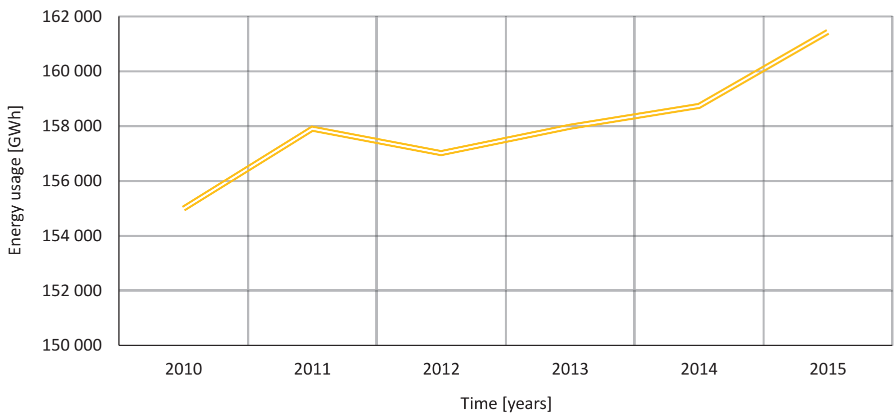

Fig. 2. Energy usage in Poland 2010–2015

The aim of the work is to propose solutions which will lead to independence from a district heating network in the production of fasteners for automotive industry plant Bulten Poland S.A. The Energy Project will result in eliminate energy Bulten Poland S.A. buys from the city (Therma Company). Figure 3 shows participation of network heat in overall energy consumption.

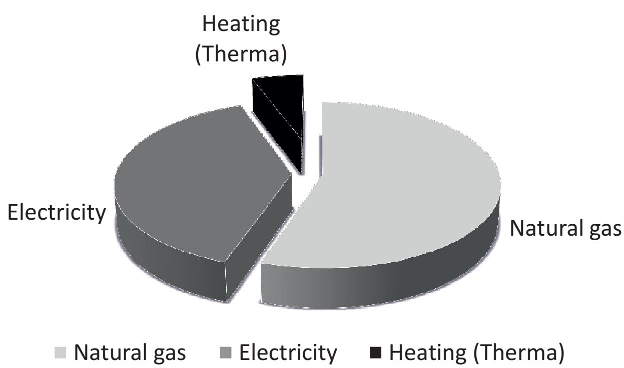

Fig. 3. Participation of network heat in Bulten Poland S.A.

As we can see (Fig. 4) we have much more heat for reuse than we are able to utilize. More studies have to be done to explore the possibilities of reusing recover heat in other ways (such as: transferring heat into coolness, generating an electricity form recovered heat etc.). Particular lines show summed up amount of energy we can recover from each

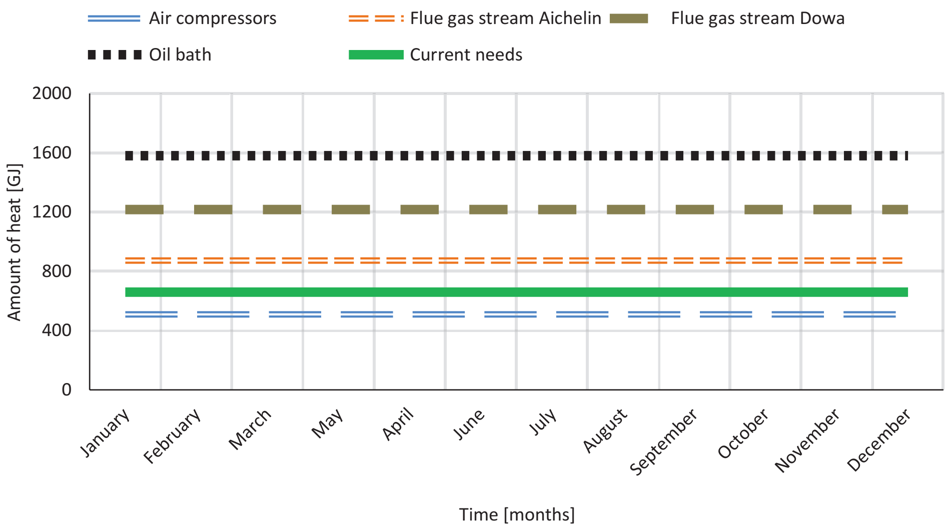

Fig. 4. Average current needs for heating in Bulten Poland S.A. vs. maximum potential of recovered heat

stage (blue line – amount of energy we can recover form air compressors, orange line – amount of energy we can recover form air compressors and flue gas stream Aichelin etc.).

5. Conclusions

Nowadays, we observe constantly increasing energy consumption. One of the way to improve energy efficiency is to reuse waste heat from energy-intensive technological processes. Conducting an energy audit can lead to significantly increasing energy efficiency by investing in recovering heat systems. Recovering heat form HT processes in a plant can lead the plant to the independency within energy supply. The costs of well thought investments are economically justified.

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[1] Bulten Polska S.A.,
[2] Instytut Techniki Cieplnej, Politechnika Śląska, Gliwice

Abstrakt: Współczesny intensywny rozwój przemysłu i gospodarki, wynikający z dynamicznego postępu cywilizacyjnego i technicznego, wymaga coraz większych nakładów energii. Z tego powodu poszukiwane są możliwości wykorzystywania zużywanej energii w sposób racjonalny, dbając tym samym o poprawę efektywności energetycznej. Jedną z możliwości jest odzyskiwanie ciepła odpadowego z energochłonnych procesów technologicznych. Procesem, który stwarza duży potencjał odbioru i zagospodarowania ciepła odpadowego, jest proces obróbki cieplnej elementów złącznych.

Celem pracy jest ocena możliwości uniezależnienia się od dostaw ciepła z miejskiej sieci ciepłowniczej w Zakładzie produkcyjnym elementy złączne dla przemysłu motoryzacyjnego Bulten Polska S.A. Zaproponowano wykorzystanie systemów odzysku ciepła zainstalowanych na dwóch liniach do hartowania wyrobów (wymiana powietrze–woda), oraz na sprężarkach olejowych (wymiana olej–woda), które produkują sprężone powietrze niezbędne w procesach produkcji śrub. Dodatkowo przewidziano odzysk ciepła w wannie olejowej jednego z pieców (wymiana olej–woda). Analizowane rozwiązanie zakłada również instalację dwóch kotłów gazowych, które będą pełnić rolę wspomagającą, w przypadku niższych temperatur zewnętrznych i konieczności dogrzania zakładu.

Istotnym elementem przeprowadzonych prac jest wdrożenie nadrzędnego systemu zarządzania energią (SyNiS), umożliwiającego efektywne sterowanie mocą źródeł oraz kierunkiem przesyłu ciepła.

Słowa kluczowe: efektywność energetyczna, odzysk ciepła, ciepło odpadowe, SyNiS, przemysłowy audyt energetyczny, zrównoważony rozwój