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Heat Recovery in Professional Laundry Care Process

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This paper tackles various specific issues related to professional laundry care process. Design of efficient system of heat recovery in professional laundry is conditioned by successful management of these specifics. The paper also gives several suggestions for the design.

Measurement method including original software for data processing was designed for more efficient acquisition of humid air parameters in outlet stream from drying equipment (i.e. dryer, ironer, tunnel finisher). These parameters are relevant for determination of the amount of applicable waste heat and its time course. This method has minimum impact upon equipment operation and its technical readiness to measure and is thus suitable for irregular measurements in laundry facilities.

The paper also presents case study of heat exchanger design for heat recovery based on requirements from real laundry operations. Plate-type air-air heat exchanger preheats drying air for tumble dryers while using waste heat from tunnel finisher.

1. Introduction

Need for reduction of energy intensity of commercial washing, drying and ironing is shared by both manufacturers of laundry equipment and companies concerned with technological support. These companies operate in the whole world and often provide solutions to energy and water savings in laundry premises. These solutions include:

- waste heat recovery systems,
- flash steam recovery,
- solar energy utilization,
- waste water treatment (incl. lint filtration),
- steamless laundry concept,
- and laundry (energy) management systems.

One of the main problems encountered by companies developing laundry equipments is the lack of opportunities to perform quality research in real operations due to operators' reluctance and fear of decrease of machinery performance and increase of breaks related to machinery resetting.

NETME Centre – New Technologies for Mechanical Engineering, a regional research and development centre at the Faculty of Mechanical Engineering at the Brno University of Technology – established a working group researching professional laundry care process. Complex services based on contract and collaborative research concerning analysis and optimization of commercial laundry premises along with space for testing of new machinery and solutions are facilitated thanks to unique infrastructure (to be finished in 2013) involving in-house laundry testing facilities.

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This paper continues to explore the topic of energy intensity reduction in laundry premise already presented in Bobak et al. (2010 and 2011) and deals with issues of design of heat recovery systems in laundry premises. Due to limited extent of this paper, general rules of heat exchange and heat exchanger design cannot be presented in detail. They are discussed in depth in following articles and proceedings, e.g. Turek et al. (2010) discusses heat exchanger network design in waste-to-energy applications and Jegla et al. (2010) presents a tool for particulate fouling prevention of heat transfer equipment.

Some of the methods of laundry energy intensity reductions were already mentioned. Now, attention will be drawn to heat recovery because of its great potential in energy savings.

2. Issues related to heat recovery in laundry

Prior to commencing design of heat recovery systems in laundry, several problems have to be addressed:

- Diversity of heat and process media sources,
- Polluted process media,
- Process dynamics,
- Discontinuity and low concurrence of processes,
- Lack of operation data.

Following chapter will present concepts to handle these factors.

2.1 Diversity of heat and process media

Diversity of heat sources in laundry is advantageous for reduction of dependency upon given type of fuel and/or heat supply and enable to operate the laundry event in case of failure of one source. However, this diversity is accompanied by increase in number of process media and certain restrictions given by local legislation may apply.

Substitution of steam heated dryer with natural gas heated dryer does not really diversify heat sources provided that steam was generated in natural gas boiler. Outlet stream from natural gas heated dryer basically qualifies for flue gas stream and thus high demands on quality (material, gaskets) and regular inspections due to presence of aggressive and harmful pollutants apply. Whereas dryer with indirect heating (e.g. steam heating) exhausts only hot air with evaporated water from linen. High demands on heat exchangers with heat recovery in flue gas stream have negative impact on purchase price and operation costs.

2.2 Polluted process media

Basically, all main outlet streams from laundry equipment contain certain amount of pollutants. Their implementation in heat recovery systems requires elimination of these pollutants (via filtration, separation) or adjustment of heat exchangers, which eliminates performance reduction caused by fouling. Overview of main pollutants is given in Table 1.

Table 1: Overview of pollutants in outlet process streams from laundry equipment

Equipment	*Outlet stream*	*Pollution of outlet stream*
Washer (CBW, WEX)	Hot waste water from prewash and main wash	Solid and organic pollutants, dissolved detergents
Dryer (SYD, COD) and Tunnel Finisher (TUF)	Hot humid air	Textile dust and fabrics, moisture
Cylinder Heated Ironer	Hot humid air	Textile dust, moisture
Chest Heated Ironer	Hot humid air	Wax from cylinder permeable surface, textile dust, moisture

2.3 Process dynamics

Professional laundry care process involves large amount of dynamic subprocesses which are typical of batch machines (e.g. washer extractor, dryer, low-capacity cylinder heated ironer). Unbalanced loading may instigate this negative factor even in semicontinuous laundry machines (e.g. high-capacity chest heated ironer, continuous batch washer). This problem of efficiency is often solved by employing autonomous measurements and control in heat recovery systems, which increases purchase costs. Figure 1 presents time course of flow rate, temperature and absolute humidity of air at the outlet from steam heated mid-range capacity dryer in the processing time of 3 batches as these units are significant for determination of amount of waste heat in the outlet. Data were acquired in real laundry premise.

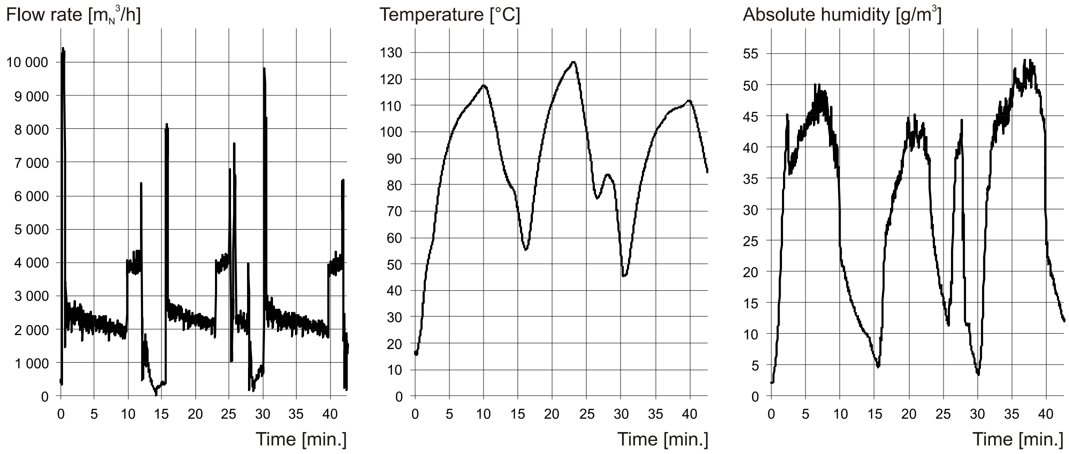

Figure 1: Time course of flow rate, temperature and absolute air humidity at the outlet from dryer

2.4 Discontinuity and low concurrence of processes

Extraction of waste heat does not immediately lead to energy savings. Waste heat must be at the same time utilized or stored for further utilization. However, purchase price of large scale heat storages is rather high. Economic analysis of heat storage in energy systems is discussed in Forsström et al. (1987). Lately, utilization of heat storage employing phase change principle has been favoured as presented in Robak et al. (2011).

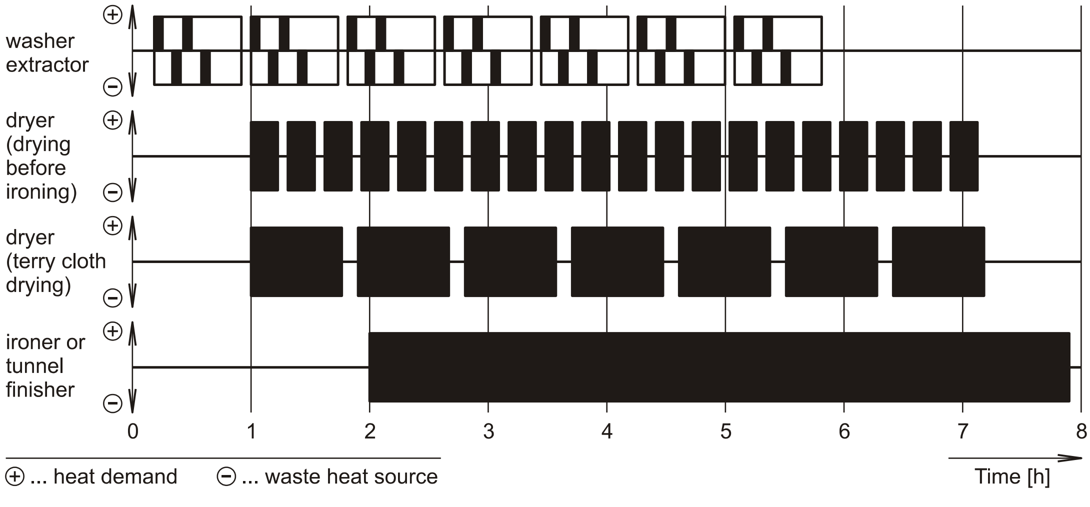

Figure 2: Operation diagram of main laundry equipment (without built-in heat recovery)

Possibilities to utilize waste heat from equipment for straight heating (preheating) of another equipment are limited by low concurrence of operations of particular machines in the laundry premises. Figure 2 presents an operation diagram of main laundry apparatuses. It clearly shows that direct heat recovery between apparatuses is restricted due to succession of washing, drying and ironing (especially at the beginning and at the end of working day), and due to interruptions in machine operation caused by linen loading and unloading.

2.5 Lack of operation data

Determination of amount of waste heat from laundry equipment cannot rely on data from manufacturer. First, lot of manufacturers do not provide this information; second, if they do, it may not be relevant in given specific operation conditions. Since most laundry premises are not equipped with measurements and record devices, operation data have to be measured in site and in such a manner that interferes with laundry operation at minimum level. Operators' concerns were given in the Introduction.

3. Design of heat recovery system

3.1 Opting for hot and cold stream

Opting for suitable hot and cold process streams is conditioned by factors given in Chapter 2. Leaving aside thermodynamics, following criteria are to be considered when opting for suitable streams:

- Minimum amount of pollutants,
- Hot stream always available for heating of cold stream,
- Hot stream of the most stable parameters,
- Utilization of streams not conditioned by local legislation (e.g. amount of flue gas).

These criteria cannot be fulfilled completely in real operation. It is engineers' choice which of the restrictions they accept and deal with without increasing investment and operational costs of designed system.

In the case of professional laundry care process, drying apparatuses (i.e. dryer, ironer and tunnel finisher) are among the largest energy consumers and also waste heat producers. It is thus only logical to start the process optimization with these pieces of equipment.

3.2 Measurement of operation data

To determine the practically available waste heat rate associated with outlet streams from drying equipments incl. its development during machine drying cycle, a measuring method is proposed. The method is based on continuous measuring properties of humid air (velocity, relative and absolute humidity, temperature). Besides the determining the energy potential, the method can be used to evaluate energy intensity and evaporating capacity of the equipment. In order to streamline the data processing, original software tool called Torreo with user-friendly interface was developed.

The only necessary preparation in this measuring method is to drill two holes for humidity/temperature and vane/temperature probe with diameter of about 20 mm into the outlet stream pipeline. This is especially relevant for mobile measurements. Figure 3 shows the measuring equipment and Figure 4 presents a user interface of Torreo software.

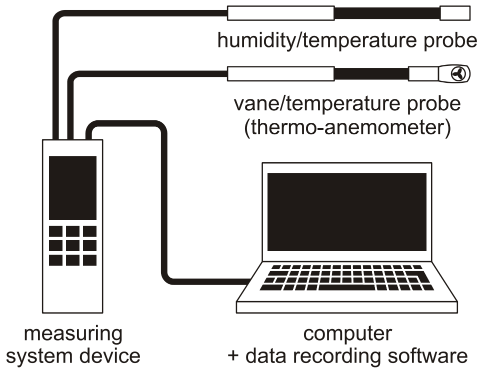

Figure 3: Measuring equipment

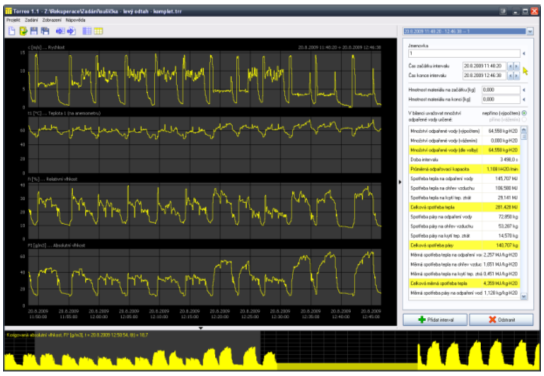

Figure 4: Torreo software user interface

3.3 Financial analysis

Comprehensive financial analysis has to be performed prior to commencing any investments. This is a vital piece of information for an investors' decision whether or not the proposed design is financially advantageous. Analysis has to consider both investment costs and costs related to operation of heat recovery system (e.g. power consumption of fans or pumps equaling added pressure drop in process streams, high maintenance costs) and savings related to reductions of fuel and/or heat/power supply.

4. Case Study

Heat recovery system was designed based on real laundry premises data applying facts discussed in previous parts of this paper. Figure 5 presents a case study situation. Plate-type air-air heat exchanger (Figure 6) employs waste heat from tunnel finisher (TUF) for preheating of drying air in system dryers (SYD). TUF lost heat rate - given by waste air flow rate of 2 000 m^3/h, 95 °C temperature and absolute humidity of 196 g/m^3 - was determined to reach 216 kW. Occurrence of textile dust resulted in design of plain-plate heat exchanger. Parameters are given in Table 2.

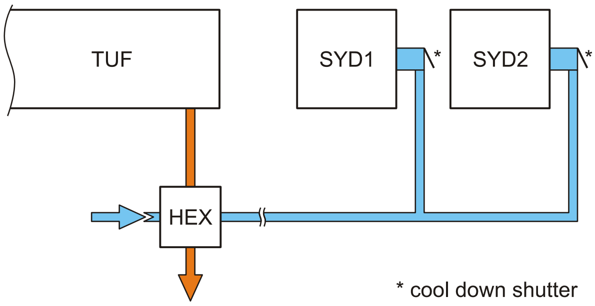

Figure 5: Case study situation

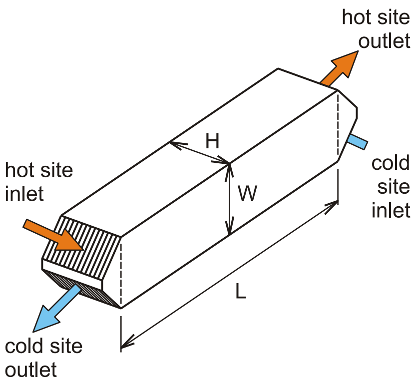

Figure 6: Heat exchanger

System is not equipped with automatic control thanks to satisfactory stability of outlet stream from TUF. Pipeline hydraulic calculation shows 150 Pa increase in hot stream pressure drop, which may be overcome by existing fan in TUF; increase in cold stream pressure drop equals to extra 750 Pa due to streaming thru heat exchanger plus 400 Pa due to streaming in pipelines. Pressure drop in cold stream thus requires installment of suitable fan.

Table 2: Parameters of designed heat exchanger with plain-plates

Parameter	*Value (unit)*	*Parameter*	*Value (unit)*
Nominal heat rate	100 kW	Spacing of plates – hot site	4 mm
Length of a plate (L)	2 130 mm	Spacing of plates – cold site	8 mm
Width of a plate (W)	558 mm	Plate thickness	1.2 mm
Height of a block of plates (H)	558 mm	Plate material	Steal
Number of plates in a block	81	Flow configuration	Countercurrent
Hot site flow rate	1 672.6 kg/h	Cold site flow rate	12 852.3 kg/h
Temperature at hot site inlet	95.0 °C	Temperature at cold site inlet	25.0 °C
Temperature at hot site outlet	70.2 °C	Temperature at cold site outlet	52.6 °C
Pressure at hot site inlet	1.2 bar a	Pressure at cold site inlet	1.0 bar a
Pressure drop at hot site	150 Pa	Pressure drop at cold site	750 Pa
Heat transfer coef. at hot site	33 W/m^{2}K	Heat transfer coef. at cold site	77 W/m^{2}K
Overall heat transfer coefficient	23.2 W/m^{2}K	Heat transfer surface area	99 m^2
Mean temperature difference	43.7 °C		

5. Conclusion

A heat recovery system with nominal heat rate of 100 kW was designed. The design is based on operation data acquired in real laundry premise using developed measuring method. The case study demonstrates a technical feasibility of the heat recovery project at laundry premises and generates input data for following financial analysis and helps support decision making process.

Future work in the field of professional laundry care process will be focused on completion of the laundry laboratory infrastructure. The laboratory will be a big step toward simplification of acquisition of process data from laundry premises and particular laundry equipment performance.

Acknowledgement

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Nomenclature

CBW	Continuous batch washer
COD	Compact dryer
H	Height of a block of plates
HEX	Heat exchanger
L	Length of a plate
SYD	System dryer (for CBW)
TUF	Tunnel finisher
W	Width of a plate
WEX	Washer extractor

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