AN OVERVIEW OF DRAUGHT REGULATORS USED IN SOLID FUEL BOILERS

Dumitru Iulian MELINTE[1], Ioan-Cozmin MANOLACHE-RUSU[1], Cornel SUCIU[1]
[1] *„Ştefan cel Mare” University of Suceava, 13 Universităţii, 720229, Suceava, Romania,*
melinte_iulian@yahoo.com

Abstract: *Solid fuel combustion is often used for heating purposes. The combustion process of solid fuels in central heating boilers can be optimized by new automation and control techniques. This can improve a number of qualitative and quantitative parameters, including the response time of the air flow adjustment components, by diminishing it. The delays present in the case of draught regulators are mainly due to the thermal inertia of the control components. This paper aims to highlight the values of these response times, considered dead times in the operation of central heating boilers. This study can be used to develop new design solutions in the future. Experimental measurements were made on two distinct types of draught regulators and two different heating boilers. The obtained results draw attention to the fact that there are inconsistencies between the time values of the combustion cycle. Since these control systems equip a wide range of thermal machines, such as classic boilers respectively those with gasification, it is desirable to increase the reliability of these elements of command and control.*

Keywords: *draught regulator, solid fuel, gasification, boiler, combustion control*

1. Introduction

Man has always wanted a pleasant home climate in addition to other needs. This desiderate is in part obtained and maintained by means of thermal machines. Thermal machines can be used to increase or decrease the ambient temperature by one or more heat exchange mechanisms (conductive, convective or radiant). This paper deals only with heat-generating thermal machines, focusing on wood combustion heating boilers. This raw material is rather easily found in our country, which ensures a low heating cost in family homes heating systems and beyond. Since 1883, the first central heating system in Europe appeared, operating at Peleş Castle. [Peles, 2019]

By the end of the 1970s, the thermal power plants were built empirically, without being equipped with a combustion control system or one to regulate the working fluid temperature. Also, the heating boilers were not equipped with pumps, and thus the circulation of the thermal agent was done through an open, non-pressurized system, with natural convection circulation. The displacement of the heat agent through the pipes was slow and the diameter of the pipes quite large. For this reason, the efficiency obtained by these plants was very low. Other disadvantages of these types of boilers are the large amount of heat lost through the combustion gases respectively due to incomplete combustion.

With the technical progress, the efficiency of the such heating boilers increased as a result of the diminution of these shortcomings which aimed in particular at replacing the old models of installations with new concepts of design, sizing but also by introducing recirculation pumps.

After 1991, a number of foreign producers from the field of thermal installations and central heating plants the Romanian market, the most representative of which are: Viadrus SA (Czech Republic) [Viadrus, 2019], Ferroli Group Spa (Italy), [Ferroli 2019], Atmos (Czech Republic), [Atmos 2019]. Solid-fuel boilers can be classified according to the mode of combustion and supply of fresh gas in conventional boilers, respectively natural gas and boilers with gasification (with forced circulation). They are equipped with draught regulators, emission catalysis systems, temperature sensors, thermostats, etc. These systems are used in order to obtain a good control of the combustion, which leads to high values of the yield and the diminution of pollutant emissions.

2. Draught regulators

The draught regulator is an automatic system for controlling the air flow within the thermal boilers, used to maintain a stoichiometric ratio suitable for complete combustion of the fuel. The lower half of the regulator is immersed in the boiler and attached to a wall of the boiler by means of a removable assembly. The assembly is done by means of a threaded area (4). A cross section of a draught regulator is shown in Figure 1. The thermo-sensitive element of the regulator is a manometric wax sensor having a of high thermal expansion coefficient.

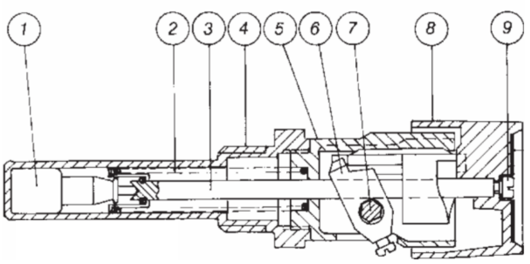

Figure 1 *Structure of a draught regulator [5]*

The draught regulator consists of an outer housing (5), inside which is placed the wax sensor (1) and the drive mechanism. This mechanism consists of a spring (2), a rod (3), a lever (6) and a steering rod (7). The manometric sensor has at one end a piston driven by the fluid pressure generated by the sensitive element, acting along the rod (3). The heat-sensitive element uses as a working material a particular type of wax. This wax remains in a solid state until around 293 K, after which it passes into a viscous state [Robert E. Guisinger, Robert B. Wieland 2019]. The temperature of 353 K is the reference temperature used to adjust the draught flap. Beyond this temperature, the pressure inside the capsule of the manometric sensor overcomes the elastic force of the spring (2), acting on the rod (3). At this point the actuating mechanism is moved in the direction of closing the draught flap. This results in a continuous decrease of the fresh air flow entering the boiler to a minimum value imposed by the boiler manufacturer. After reaching the minimum value of the air flow, the recirculation pump is started up, pushing the heated agent towards the convection elements of the installation. The heating agent returns to the boiler at a temperature lower than that imposed by the control knob (8). The new value of the temperature of the thermal agent leads to the decrease of pressure in the manometric sensor capsule. Thus, the piston retracts under the action of the spring leading to a new opening of the draft flap. Due to the increasing flow of fresh gases, the combustion process will evolve with increased combustion front speeds. This leads to the establishment of an important temperature gradient in the mass of the thermal agent.

The manufacturers recommend that the adjustment of the drive chain length, for the case of the closed draught flap, be made at a temperature of 333K [Technical data 2019]. Only after this adjustment the working temperature is imposed by means of an adjustment knob. The regulators work in the range of nominal values: 303 K - 363 K, [Regulus 2019], and the maximum value of the temperature of the thermal agent must not exceed 383 K.

Although we can find different models of draught regulators, developed by different manufacturers, as exemplified in Fig. 2, they share the same operating principle.

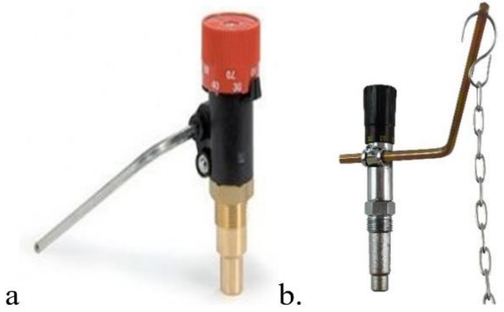

Figure 2 *Draught regulator*
a) Honeywell [9], b) Regulus [8]

Among the largest manufacturers of such regulators are Regulus, Honeywell and Icma.

Following a survey conducted by the authors, it was found that during the warranty period, local service representatives found four major types of faults, in the regions highlighted in Fig. 3. These can consist in the inclination of the drive shaft due to wear in the support areas (2), thread corrosion between the submerged and the upper part (3), spring calibration of the mechanism is off (1) or the loss of the functionality of the wax sensor (4), due to leaks.

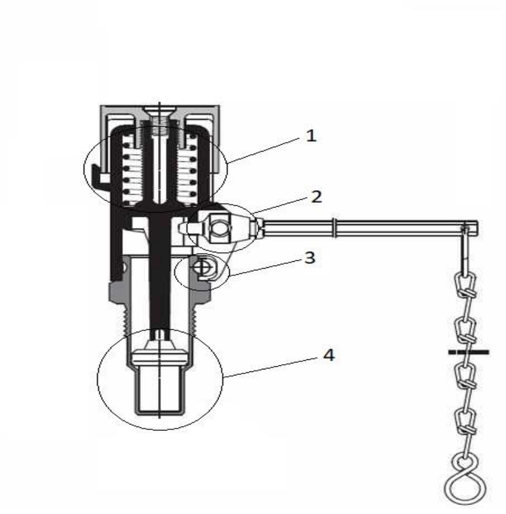

Figure 3 *Malfunctions [10]*

Another technical problem is the high reaction time of this regulator.

3. Methodology and results

In order to highlight the thermal inertia of these types of regulators, a series of experimental measurements were carried out, which aimed at accurately determining the time passed from the moment of stopping the recirculation pump until the opening of the draught flap. These measurements were made for two distinct cases. In the first case, a set of measurements targeted a 40 KW Viadrus heater boiler, and in the second case a 35 KW boiler from the same manufacturer. The total number of identical radiant elements of the installation used in the first case is 205 and 155 in the second case. In both cases, the room temperature of the boilers was brought to 288K, before putting them into operation. We also mention that the boilers were calibrated identically and the temperature of the heat agent in both cases was 295K. After each combustion cycle, the value of the ambient temperature in the boiler room was also measured. Another parameter measured in this study was the temperature difference between closing and opening of the draught flap. It has a unique value of 18 K for all case studies. The time interval corresponding to the time of reaching a temperature difference of 18 K compared to the temperature required to close the flap was recorded. This moment corresponds to the stop of the recirculation pump.

The 40KW boiler was equipped with ICMA draught regulator. In order to reach the operating temperature of the boiler in the first case, a time interval of 1560 seconds was required. The operating temperature corresponds to a thermal agent temperature of 353K, when the draught flap is closed and the circulation pump has started up. The temperature of the working agent dropped in 180 seconds to 333K, corresponding to the shutdown of the pump.

In the second case, the boiler was equipped with a Honeywell regulator. The time required to enter the working mode was measured at 1380 seconds, and the time required to decrease the working agent's temperature by 18K is 190 seconds. The temperature of the environment and the corresponding duration between stopping the recirculation pump and starting the opening of the flap for the two cases are summarized in Table 1.

Table 1: Downtimes for draught regulators

Cycle		1	2	3	4	5	6	7	8
40KW Boiler	T [K]	288	288	291	292	294	295	296	297
	Time [s]	892s	805	752	681	570	480	452	542
35KW Boiler	T[K]	288	288	289	290	293	294	296	297
	Time	810	803	740	684	602	480	451	535

The experimental data showed that in cycles "2", "6" and "7", the measured downtimes are identical or very close for different power boilers. In cases "4" and "5", the waiting time of the lower power station is greater than the waiting time of the large power station. From these measurements we can see that there are anomalies in the functioning of the draught regulator. These are generated by the high thermal inertia of the fluid used in the construction of the regulator submitted to rapid temperature changes.

They influence operation and the transmission times between phases are high.

4. Proposed technical solution

The present paper proposes a new technical solution aimed at reducing or even eliminating the downtimes found in the working of such heating boilers. The working principle of this new system is further described.

The new draught regulating system is schematically shown in Figure 4 and its components are described in table 2. The system is equipped with two temperature sensors, one measuring the care temperature of the thermal agent within the boiler (S1) and the other indicating the thermal agent temperature at the boiler outlet (S2). The draught regulator flap is moved by aid of a stepper motor and the entire system is controlled by means of an Arduino board. The system also controls the recirculating pump.

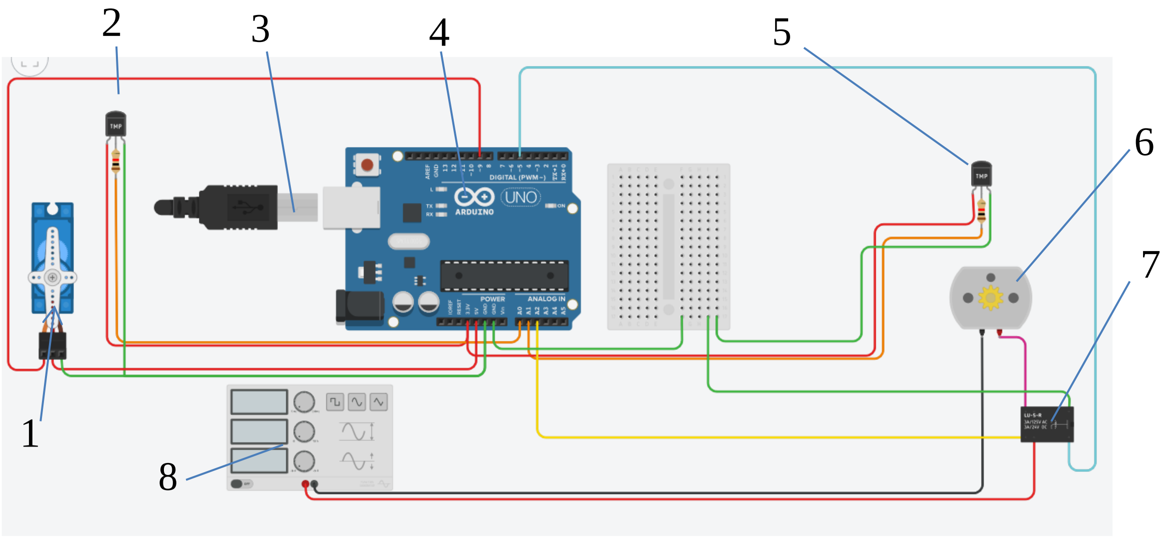

Figure 4 *Automated draught regulator structure and electrical connections*

Table 2: Draught regulator components

No.	Part name
1	Stepper motor
2	Temperature sensor S1
3	5V DC power source
4	Arduino board
5	Temperature sensor S2
6	Recirculating pump
7	Control relay
8	220V AC power source

Firstly, sensors S1 and S2 are set to work as follows: sensor S1 is set to trigger at 338 K and sensor S2 at 353K. For temperatures below the abovementioned values the system is latent, with the draught flap open. After combustion is initiated, boiler temperature starts to rise. When the set temperature (338K) is reached, sensor S1 commands the stepper motor to close the draught regulator flap. At 353K, the flap is completely closed. At the same time, the second sensor, S2, also records an increase in temperature and when it reaches 353 K, it commands the recirculating pump to start. This sends the thermal agent through the boiler outlet and into the heating circuit. Thus, the hot agent is replaced with cooler agent from the convective heaters and the temperature inside the boiler will soon fall under 353 K, which prompts S2 to stop the pump and S1 opens the draught regulator flap, thus reinitiating the burning and heating process. It is envisaged that the moment of stopping of the pump should coincide with opening of the flap, thus ensuring the burning process continuity.

5. Conclusion

It is desirable to have an automatic air flow control system with much better response times in order to shorten the thermal comfort period;

Downtimes also influence the yield due to fragmentation of the combustion process.

The appearance of material thermal fatigue leads to the diminution of the boiler life expectancy.

1) This study shows the need for a system to replace the current draught regulator models in order to eliminate the operating delays.

2) A possible solution would consist of a device driven by a stepper motor to control the flap, electronic temperature sensors and an Arduino board.

The proposed solution could lead to eliminating of the downtimes.

Bibliography:

1. [Peleș 2019] Peleș, Istoricul Castelului Peleș, Available from http://peles.ro/istorice/istoricul-castelului-peles/
2.[Viadrus 2019] Headquaters, Available from https://www.viadrus.cz/headquaters-53.html?lang=en
3.[Ferroli 2019] Ferroli, Available from https://www.ferroli.com/it
4.[Atmos 2019] Atmos, Available from https://www.atmos.eu/en/
5.[Saturn 2019] Available from http://www.saturn.gr/dyn/rec/041409151257_gr.pdf
6.[Ceneo 2019]Available from https://www.ceneo.pl/10570782
7. [Date tehnice 2019] Available from http://www.ludoterm.ro/files/produse/doc_romanian_304.pdf
8.[Regulus 2019] Technical data sheet Available from https://www.regulus.eu/en/rt4-l-draft-regulator
9. [Robert E. Guisinger, Robert B. Wieland 2019] Available from https://patents.google.com/patent/US8357318B2/en
10.[Construkt 2019] Available from https://www.construkt.ro/incalzire-si-acm/regulator-de-tiraj-honeywell-pentru-cazane-pe-combustibil-solid-fr-124-3-4am.html#prod-gallery-3