SIGURNOSNI ASPEKTI GREJANJA NA ČVRSTO GORIVO U SRBIJI

SAFETY ISSUES IN SOLID FUEL HEATING PRACTICE IN SERBIA

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https://doi.org/10.24094/kghk.018.49.1.125

Usled ekonomske situacije u Srbiji kotlovi starog tipa se koriste. Njihov tačan udeo na tržištu nije poznat. Ova konstrukcija je razvijena u 70-tim godinama, funkcioniše, jeftina je, ali ima nižu efikasnost i više emisije nego moderni kotlovi. Često se ovi kotlovi ugrađuju u zatvorene sisteme toplovodnog grejanja. To nije u skladu sa sigurnosnim pravilima iz standarda. Ovakva praksa može da dovode do eksplozija, ljudskih žrtava i materijalne štete.

Slučajna anketa o načinu instaliranja kotlova na čvrsto gorivo je urađena.

Ovaj rad pokušava da objasni razloge ove štetne prakse, kroz odgovaranje sledećih pitanja. Da li ISPRAVAN sigurnosni ventil može da spreči eksploziju kotla? Da li regulator promaje može da reguliše temperaturu potisa vode pri SVIM režimima? Da li je kotao bezbedan bez sistema za odvođenje VIŠKA toplote? Da li postoji SIGURNA instalacija kotla u prostorije u kojima nema vodovodne mreže? Koji tip kotla na čvrsto gorivo MOŽE biti ugrađen u zatvoren sistem grejanja?

Ključne reči: *sigurnost kotlova; zatvoreni sistemi grejanja; loženje čvrstog goriva; parna eksplozija; standard*

Abstract: Due to economic situation in Serbia old design solid fuel boilers are being used. Their exact market share is not known. This design has been developed in 70s, is functioning, is cost-effective, although having lower efficiency and higher emissions then the state-of-the- art boilers. Often these boilers are installed in closed hydronic heating systems. This is not in accordance with the safety rules prescribed in standards. This practice can lead to explosions, and to loss of human life and property.

Random survey about installations of solid fuel boilers in closed heating systems has been done.

This paper tries to explain the roots of this malpractice, through answering the core questions: Does PROPERLY functioning safety valve prevent boiler explosion? Does draught regulator can regulate boiler flow temperature at ALL regimes? Can boiler be safe without system for removal (dissipation) of EXCESS heat? Can there be a SAFE installation of boiler in a premises without water supply network access point? What type of solid fuel boilers CAN be installed in closed heating system?

Key words: *boiler safety; closed hydronic systems; solid fuel firing; steam explosion; standard*

1 Introduction

Boiler design in question has a fixed grate. Primary air is supplied under the grate by natural draft created by the chimney. Secondary air is missing. Primary air quantity is regulated by draft regulator which is actuated by the boiler supply water temperature. Fuel loading of the boiler is manual. Upon ignition all of the fuel charge (batch) is involved in combustion process, so there is no possibility for precise regulation and division of the combustion process to separate sub processes, heating, drying, devolatilisation and burning. Usually the same boiler is used for both coal and wood firing.

Closed hydronic systems emerged in 60s. They were an improvement to the open ones. In the background fuel switch also contributed to this transition. So for example in West Germany in 50s coal stoves were main device used for heating, and in 60s there was a fuel switch from coal to heating oil with development of oil fired boilers. These boilers could fully automatically deliver heating and hot water. In 70s gas started to gain ground, and oil use decline started after oil crisis in 1973 and 1979.

Theory is clear about the solid fuel boiler installation in the closed systems. So in [1] there is a clear warning: “It is forbidden to use closed expansion vessels when boiler is fired by solid fuel because in case of failure of some boiler component (for example safety valve) there is no possibility to momentarily stop the heating as it is the case with liquid or gaseous fuel”.

On one side we have producers and installers that follow the rule, but on the other we have a producers and installers that don’t follow the rule, and in some cases safety heat exchanger is an option!

How abundant is this combination? Old type solid fuel fired boiler installed in closed systems.

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Precise statistics is not available, but a random survey has been done by third year students in the frame of Steam boilers course. Their task was to find up to five solid fuel fired boilers installed in closed heating system, to explain associated risks to their boiler owners, usually friends or relatives, and to photograph them and gather general data about the boiler. In order to detect which type of heating system is in use, closed or open, closed is defined as “the one having the red cylinder” – closed expansion vessel. In cases where online manuals were available they have been studied to see what are the instructions of the producer relating installation. In some cases boiler plates were missing. One no name boiler example is given on Fig.1.

Results of the survey were alarming. In total there were 48 boilers. 39 boilers (81% of total number) were of the old design without safety heat exchanger. For 4 boilers could not be estimated if they have a safety heat exchanger. There were three pellet fired boilers (6%). And there were 2 boilers (4%) with system for domestic water heating incorporated or detached from the boiler.

One foreign design was very frequent and additional check has been made, its original manual has been found and studied. Producer of this boiler clearly differentiates when it can be installed in closed system and when not. All methods for removal of excess heat are clearly described. But installer did the job against the instructions.

One domestic design was also very frequent and its installation manual has been studied. This manual did not follow the standard concerning the installation of boiler. After thorough study of the manual their technical support has been contacted. After description of the problem to the technical support and risks that accompany it justification for this practice was that there is no water network in the premises where boiler is to be installed, like living room or in the basement. Answer to this justification was that in these cases open system must be used. Technical support then added that installment of inverter with accumulator that ensures uninterruptible pump work during power failure is an option. Response to this argument was that it is helpful but this is just a part of the solution. They were alerted that with explosion of one of their boilers they will be held responsible. Their response to this alert was that they will rethink their practice. Here should be pointed out that this manual, that is online, is accessible to other producers and installers too, and that they can just follow the wrong example.

There was also one domestic design that had ports for connection of safety heat exchanger to the water supply but these ports are not being used, although the boiler is in operation in closed system.

As may already be noticed, here no company names that follow the malpractice are mentioned. This work is not oriented against producers or installers, its purpose is to show that malpractice is present, and to explain the consequences. All data including photographs is available on demand by readers or reviewers.

A B

Figure 1 Old style boiler installed in closed heating system

2 Problem steam explosion

There are two types of explosions that can occur in a boiler. Flue gas side and water side explosion. This paper is concentrated on the latter one.

Energy that is released upon vessel fracture is calculated as difference between internal energy before and after the explosion. Good for the first estimate is the assumption that process is isentropic.[2]

The most important factor is the temperature of the water. In the following tables are given calculations for released energy for different cases. Tab. 1- 3 are representing case in which water temperature is above 100 °C, and pres-

sure is varied. Tab. 1 has results in terms of kJ/kg of released energy, Tab. 2 has results in grams of TNT, and Tab. 3 has results in vapor share in the expanded state 2. Tab. 4 however depicts the case where the temperature of the water is under 100 °C with pressures range much higher than for the first case. As released energy in second case is much smaller results had to be multiplied by 1000.

Table 1 Energy released after vessel rupture when water is overheated (t>100°C)

$(u_1$-$u_2)$ [kJ/kg]		*Temperature* [°C]									
		105	110	115	120	125	130	135	140	145	150
Pressure [bar]	2	1,86	3,84	6,09	8,57	*	*	*	*	*	*
	3	1,85	3,84	6,08	8,57	11,30	14,27	*	*	*	*
	4	1,85	3,84	6,08	8,56	11,29	14,26	17,46	20,89	*	*
	5	1,85	3,83	6,07	8,56	11,29	14,25	17,45	20,88	24,54	28,41
	6	1,84	3,83	6,07	8,56	11,28	14,25	17,45	20,88	24,53	28,41
	7	1,84	3,83	6,07	8,55	11,28	14,24	17,44	20,87	24,52	28,40
	8	1,84	3,82	6,06	8,55	11,27	14,24	17,43	20,86	24,51	28,39
	9	1,84	3,82	6,06	8,54	11,27	14,23	17,43	20,85	24,51	28,38
	10	1,83	3,82	6,06	8,54	11,26	14,23	17,42	20,85	24,50	28,37
	11	1,83	3,82	6,05	8,53	11,26	14,22	17,42	20,84	24,49	28,36

Table 2 Vapor share of the water mixture state after the expansion to the atmospheric pressure

x_2 [%]		*Temperature* [°C]									
		105	110	115	120	125	130	135	140	145	150
Pressure [bar]	2	1	1,9	2,8	3,7	*	*	*	*	*	*
	3	1	1,9	2,8	3,7	4,6	5,5	*	*	*	*
	4	1	1,9	2,8	3,7	4,6	5,5	6,4	7,2	*	*
	5	1	1,9	2,8	3,7	4,6	5,5	6,3	7,2	8,1	8,9
	6	1	1,9	2,8	3,7	4,6	5,5	6,3	7,2	8,1	8,9
	7	1	1,9	2,8	3,7	4,6	5,5	6,3	7,2	8,1	8,9
	8	1	1,9	2,8	3,7	4,6	5,5	6,3	7,2	8,1	8,9
	9	1	1,9	2,8	3,7	4,6	5,5	6,3	7,2	8,1	8,9
	10	1	1,9	2,8	3,7	4,6	5,5	6,3	7,2	8,1	8,9
	11	1	1,9	2,8	3,7	4,6	5,5	6,3	7,2	8,1	8,9

Table 3 Energy released after vessel rupture when water is overheated (t>100°C)

(u_1-u_2) [g TNT]		*Temperature* [°C]									
		105	110	115	120	125	130	135	140	145	150
Pressure [bar]	2	0,464	0,961	1,521	2,143	*	*	*	*	*	*
	3	0,463	0,960	1,520	2,142	2,825	3,567	*	*	*	*
	4	0,462	0,959	1,519	2,141	2,823	3,565	4,365	5,222	*	*
	5	0,462	0,959	1,519	2,140	2,822	3,564	4,364	5,221	6,134	7,104
	6	0,461	0,958	1,518	2,139	2,821	3,562	4,362	5,219	6,132	7,101
	7	0,460	0,957	1,517	2,138	2,820	3,561	4,360	5,217	6,130	7,099
	8	0,460	0,956	1,516	2,137	2,818	3,559	4,359	5,215	6,128	7,097
	9	0,459	0,955	1,515	2,136	2,817	3,558	4,357	5,214	6,126	7,095
	10	0,458	0,955	1,514	2,135	2,816	3,557	4,356	5,212	6,124	7,093
	11	0,458	0,954	1,513	2,134	2,815	3,555	4,354	5,210	6,123	7,091

Table 4 Energy released after vessel rupture when water is subcooled

$(u_1-u_2)\circ 1000$ [kJ/kg]		*Temperature* [°C]									
		90	91	92	93	94	95	96	97	98	99
Pressure [bar]	10	0	0	0	0	0	0	0	0	0	0
	20	1	1	1	1	1	1	1	1	1	1
	30	2	2	2	2	2	2	2	2	2	2
	40	4	4	4	4	4	4	4	4	4	4
	50	5	6	6	6	6	6	6	6	6	6
	60	8	8	8	8	8	8	8	8	8	8
	70	11	11	11	11	11	11	11	11	11	11
	80	14	14	14	14	14	14	14	14	14	14
	90	18	18	18	18	18	18	18	18	18	18
	100	22	22	22	22	22	22	22	22	22	22

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Figure 2 Steam explosion with overheated water [3]

From this data is clear that temperature must be controlled. Pressure increase itself is a main factor that brings the vessel to the rupture, but the temperature is the only factor that causes the pressure increase. Therefore, control over the temperature is simultaneously control over the pressure.

These previous statements and conclusions are not so straightforward, meaning they don't come intuitively. So experiments have been performed to demonstrate the phenomena. Experiments have been performed by heating and plumbing equipment producer Watts USA to show the danger of overheated water in case if there comes to vessel failure. Experiments have been done on gas and electric water heaters. During the experiments pressure and temperature were recorded, and vessel failure has been caused by hydraulic hammer at predefined time, when water is overheated. Overheated here means heated to temperature over 100 °C. Consequence is visible on Fig. 2 B.

Then, a set of experiments have been performed where a temperature is kept bellow 100 °C and pressure was increased with a hand pump (Fig 3.A). Pressure is increased from 20,7 bars, over 27,6 bars to 34,5 bars. Failure of the vessel has been induced by hitting a vessel with a spiked hammer (Fig 3.B). Consequence is visible on third picture (Fig 3.C), and there is no explosion, just a water jet.

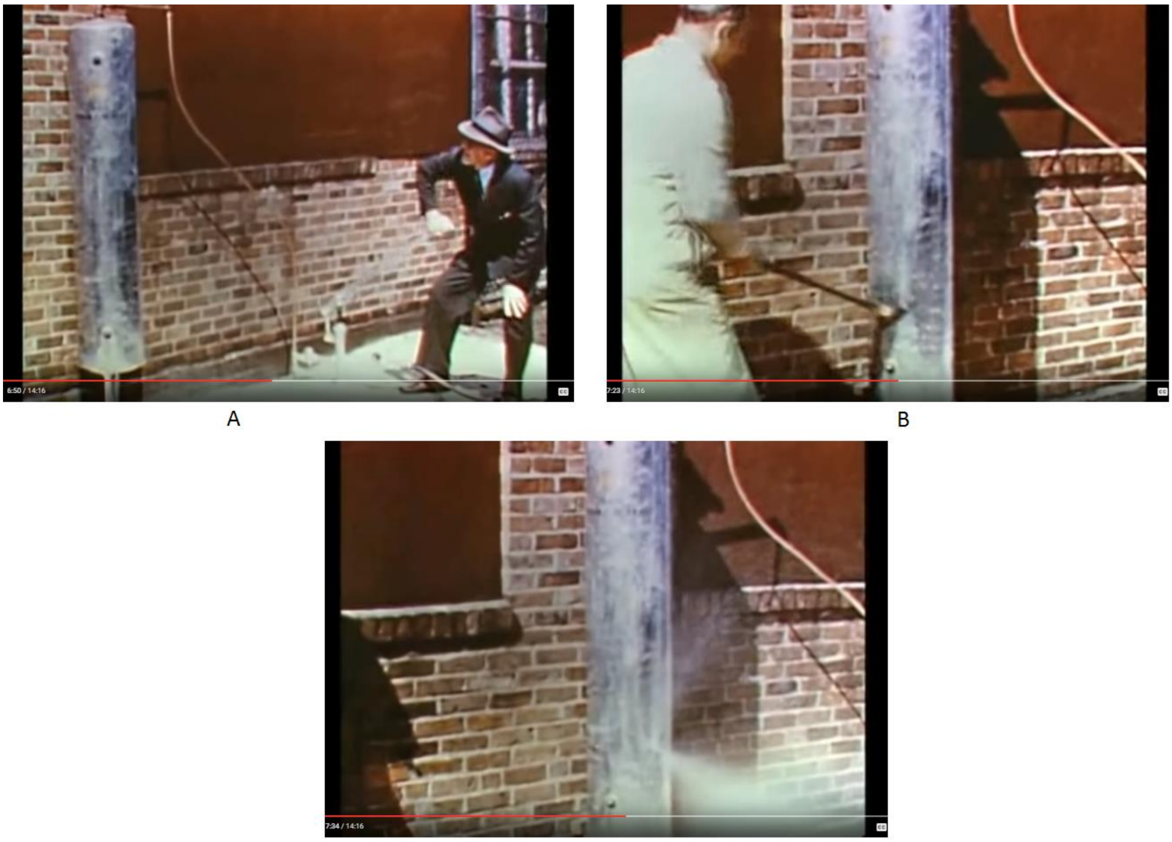


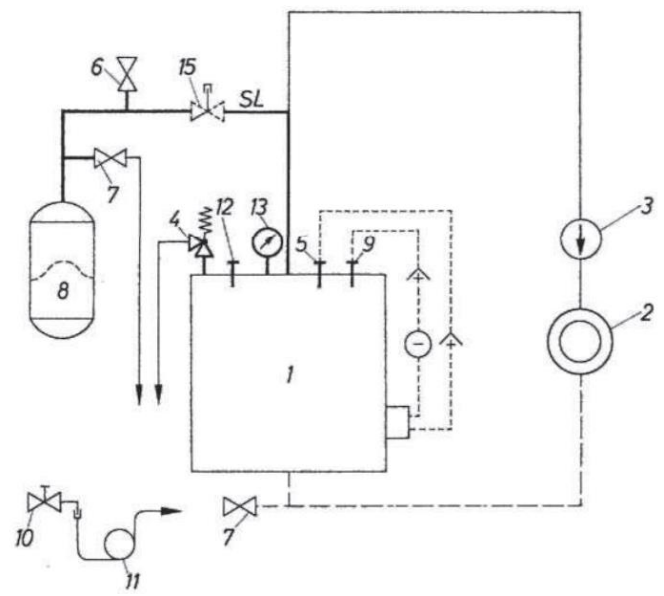
Figure 3 Vessel rupture when temperature of the water is under 100 °C [3]

3 Standards overview

3.1 German standards

First standard that covered safety requirements for closed heating installations was DIN 4751-2. Its third edition was published on 1968-09 † [4].For all types of boilers it is demanded to be quickly controllable. Quick controllability (German: Schnelle Regelbarkeit) term is defined as ability of the boiler to quickly respond to fast changes in heat load at all operating conditions such are loss of electrical power supply and sudden absence of heat dissipation and to keep the water temperature under 115 °C. For solid fuel fired boilers there are additional limitations. Maximum setting of the temperature regulator should be 90 °C and nominal heat output is limited to 93 kW. For them function of temperature control is given to draught controller and function to limit temperature is given to thermal discharge safety device. On the Fig. 4 temperature control device is labeled 9 and temperature limiter is labeled 5. Thermal discharge safety device is actuated by a boiler water flow temperature. At temperature not higher than 100 °C it should open a valve permitting a flow of domestic water through installed water heater, that prevents significant temperature increase of the boiler water. This domestic water is then safely discharged. Effectiveness of the thermal discharge device should be proven by type examination. Standard allows other ways to ensure the quick controllability and these must be tested and approved.

† First edition of DIN 4751-2 was published in June 1964 and second in 1966. First edition is 53 year old rulebook and second 51. These documents were not available to the authors.



Description:
1 heat producing device
2 heat consumer
3 circulation pump
4 safety valve
5 safety temperature limiter
6 air bleeding valve
7 purge valve
8 expansion vessel
9 temperature regulator
10 connection to the water main (supply) system
11 connection pipe
12 thermometer
13 manometer

Figure 4 Elements of the closed heating system [4]

Corresponding to DIN 4751-2:1968-09 is Yugoslav standard JUS M.E6.201:1984, now Serbian SRPS M.E6.201:1984. Present day status of this norm is: withdrawn.

In DIN 4751-2:1994-10 [5] restriction to maximum heat output from solid fuel fired boilers has been removed. And there is distinction between boilers having nominal heat output greater or lesser from 100 kW. Up to 100 kW necessary is: thermal discharge safety device that serves as a temperature limiter and is tested for that function. This device must correspond to the boiler producers' specifications and according to them installed. On the cold water inlet minimal pressure of 2 bars should be available. For temperature control there should be a draught regulator with maximum setting of 90 °C. Above 100 kW there should be thermostatically controlled safety heat exchanger that could also in case of power failure dissipate excess heat. Also there should be fuel to air combustion control.

3.2 English standards

First English standard covering closed heating systems is BS 5449-1:1977 "Code of practice for central heating for domestic premises". [6] Boilers fired by solid fuel should be selected from the list of "Approved domestic solid fuel appliances". Boilers for sealed systems should be selected from Section J4 of the list. Boilers for use with sealed systems require specific controls and should therefore be selected only from those designed specifically for this purpose.

In BS 5449-1:1990 "Specification for forced circulation hot water central heating systems for domestic premises" [7] it is stated that boilers for use with sealed systems require specific controls and shall therefore be selected only from those designed specifically for this purpose and shall be installed in accordance with BS 7074-1. Systems using a solid fuel boiler shall be designed so as to ensure that all heat generated when the boiler is slumbering is dissipated. It is recommended for dissipation of heat generated when the boiler is slumbering to install the necessary heating surface in a gravity circuit to cylinder and/or radiator(s), or to incorporate it in a suitably designed fully pumped system with special controls. Such a circuit should not be provided with user-operated valves.

In Domestic Heating Compliance Guide [8] it is stated that solid-fuel appliances should not be fitted to sealed heating systems with expansion vessels, except where specifically permitted by the manufacturer or where a thermal storage interface device is used.

In UK HETAS (Heating Equipment Testing and Approval Scheme) role is to approve solid fuel domestic heating appliances, fuels and services. It is the official body recognized by government. Products that are approved by HETAS are: boilers, cookers, open fires and stoves and room heaters. Additionally it also lists factory made chimneys and carbon monoxide detectors and alarms suitable for use with solid fuel.

3.3 EU standards

First EU standard covering this topic was [9]. There are no significant differences in current standard concerning the installation recommendations. [10] Serbian standard is identical to corresponding EU standard.

As technology advanced, with introduction of pellet boilers, new boiler classes have been introduced according to whether firing system is rapidly, partly or not at all disconnectable.

By definition:

- rapidly disconnectable firing system is firing system by which, in all instances of operation and malfunction (e.g. such as power failures or sudden absence of heat reduction), the generation of heat can be interrupted so rapidly that hazardous operating states cannot occur either on the water side or on the firing side

- partly disconnectable firing system is firing system where a part of the heat output can be briefly interrupted by the action of control and safety devices without causing hazardous operating states on the firing side.

If the firing system is rapidly disconnectable, the necessary equipment shall consist of a temperature controller and a safety temperature limiter with manual reset.

If the firing system is partly disconnectable, the necessary equipment shall consist of a temperature controller, a safety temperature limiter with manual reset and a thermal discharge safety device for dissipating the maximum heat output possible in the event of a malfunction.

If the heating system is not disconnectable and the nominal heat output is < 100 kW; the necessary equipment shall consist of a temperature controller, a thermal discharge safety device for dissipating the maximum heat output possible in the event of a malfunction.

If the requirements are not fulfilled, the boiler shall be installed in an OPEN vented system according to EN 12828.

Device for dissipating excess heat can be the safety heat exchanger or other device for dissipating excess heat that shall ensure that a maximum boiler water temperature of 110 °C is not exceeded.

4 TESTS. How to prove that boiler is rapidly disconnectable

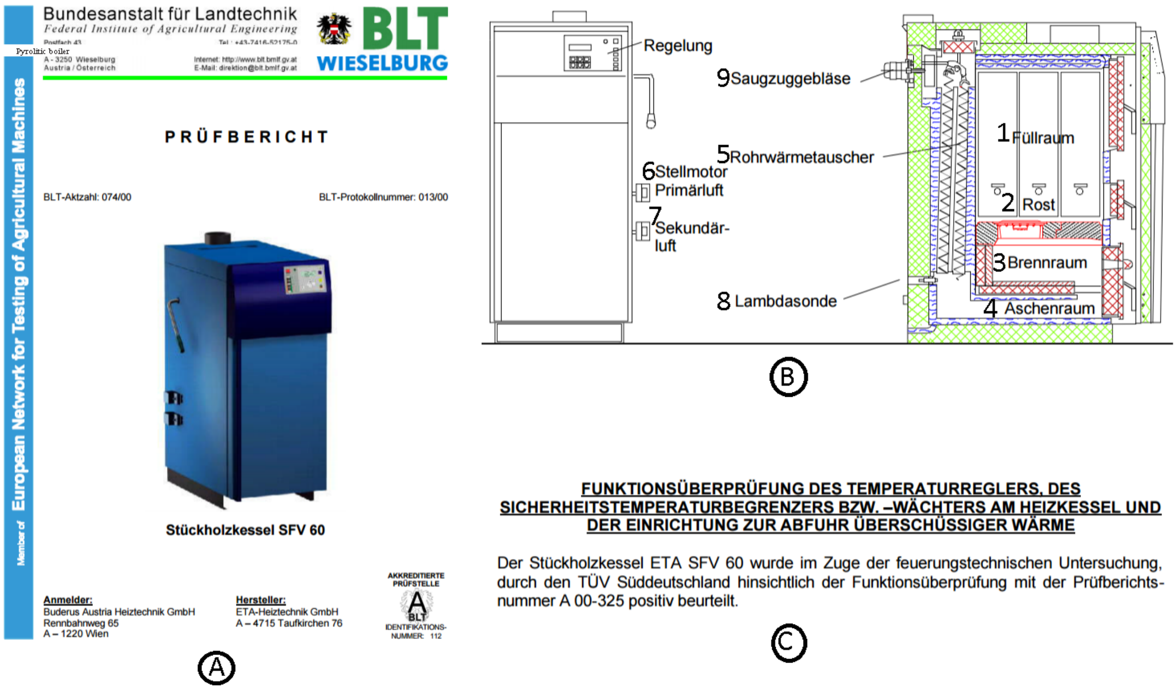


Figure 5 Boiler SFV 60 A) first page of the test report; B) boiler design; C) function test

Standard does not define a design that ensures disconnectability of the firing system. It defines the tests. Boilers that are to be declared as rapidly disconnectable must pass a test to check that functionality. Boilers that are to be declared as partly or non-disconnectable must pass a test that checks the function of the device for dissipating excess heat.

In order to prove that old design boilers must not be installed in closed system, here will be presented test report of pyrolitic boiler. Pyrolitic boiler design is more advanced design of the boiler then the one in question. If it cannot be installed in closed system, then surely, less advanced version cannot be too. Short description of the boiler will be followed with test result concerning the functioning of the system for dissipation of excess heat. Downdraft pyrolitic boiler SFV 60 [11] of nominal capacity 60 kW is presented in Fig.5 B. Wood logs are fed into the primary combustion chamber (1).

On the bottom of it there is a grate (2). Under the grate there is secondary combustion chamber (3) and ash pit (4). Flue gasses flow through secondary combustion chamber to the heat exchanger (5). Motors for primary (6) and secondary air damps (7) are controlled by water temperature. There is also lambda sond (8) which measures the oxygen content in flue gases and controls secondary air. There is a exhaust fan (9). Heat exchanger surfaces are cleaned by inserts. And for safety purpose there is a safety heat exchanger. In Fig. 5 C result is given of the function test for temperature regulator, safety temperature limiter and device for heat dissipation. Boiler SFV 60 got a positive assessment.

In order to show a boiler that can be installed in closed system, here will be presented testing of one pellet boiler. Short description of the boiler will be followed with disconnectability function test.

Pellet boiler SP 241-15 L [12] rated heating capacity is 14,9 kW. Its design is presented in Fig.6 B. Boiler has a pellet container (1). Dosing (2) and charge screw (3) feed pellet to the chamotted combustion chamber.

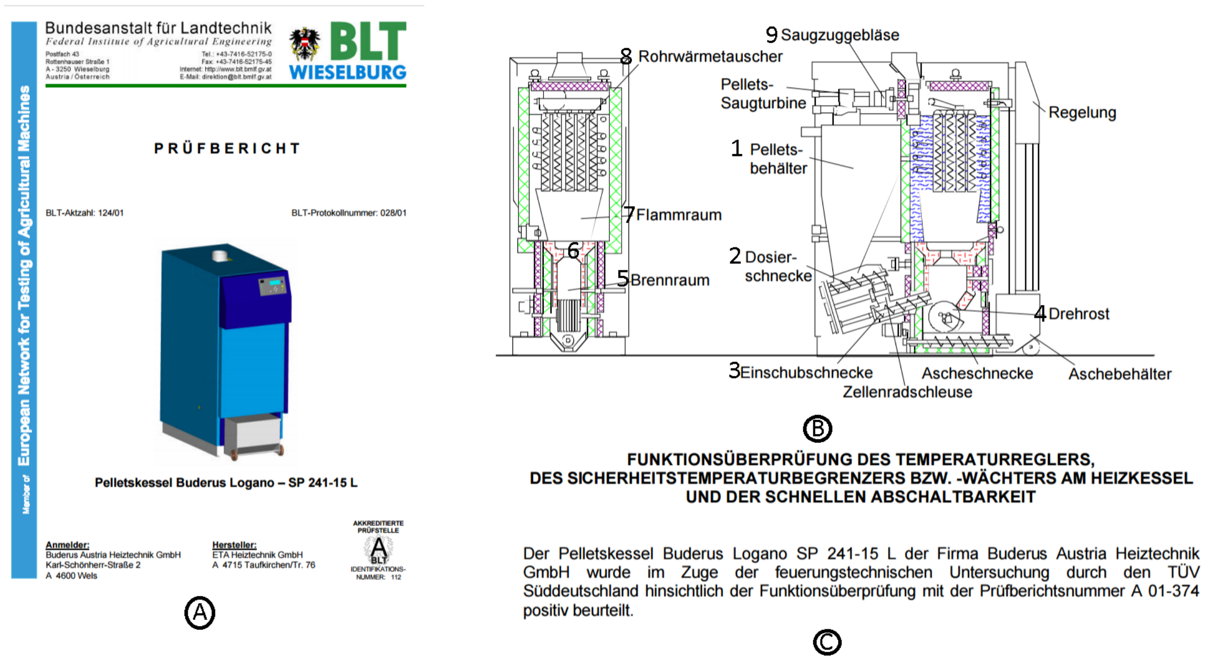


Figure 6 Boiler SP 241-15 L A) first page of the test report; B) boiler design; C) function test

At rotating grate (4) pellets are ignited by hot air fan. Combustion gases from combustion chamber (5) reach a flame chamber (7) by passing through a cross section constriction (6) and then continue to tubular heat exchanger (8) with turbulizers. Amount of combustion air supplied is controlled by means of variable speed induced draught fan (9) and position of the air damper that is operated by electric drive. Lamda probe that is located after the tubular heat exchanger purpose is to control the air to fuel ratio depending on the oxygen content in flue gases. Photocell's role is to prevent overfill of the combustion chamber. Fig. 6 C depicts a results of function tests of temperature regulator, safety temperature limiter and ability to rapidly shutdown. Boiler got a positive assessment.

5 Reasoning behind malpractice

So question is why practice is not following the standard recommendation. There are three possible reasons. First one concerns safety valve, second temperature regulator and third water network.

Logic behind the first can be explained, better understood by posing a following question. If a system is equipped with safety valve, how can this system be unsafe? Or is this system unsafe also in case when safety valve is designed properly and performs accordingly?

In this case safety adjective is a misnomer. Purpose of safety valve is to protect against pressure increase. However it removes small part of the excess heat. Additionally safety valve producers limit their operating temperature at 110 °C so it is questionable how do they operate beyond 110 °C. In case that they manage to maintain the pressure system is closing to the boiling. In closed system boiling is prohibitive.

In order to prevent boiling there are anti-flash margins. For example, if water at 120 °C is to be maintained as water, then the corresponding vapour pressure is 198.53 kPa absolute or 98.53 kPa gauge pressure. However, to ensure that boiling will definitely not occur, a margin should be added to this pressure. British standard [13] recommends that an anti-flash margin equivalent to 11 °C in temperature is allowed. Hence, the minimum pressure required in the system would be the vapour pressure of water at 131 °C is approximately 278 kPa absolute or 178 kPa gauge pressure. [14]

Closed-loop hydronic systems should be designed to ensure that the absolute pressure of the water at all the points in the system remains safely above the water's vapor pressure at all times. This prevents problems such as cavitation in circulators and valves, or "steam flash" in piping. The latter is a situation in which the pressure on the water drops below vapor pressure allowing the liquid water to instantly change to vapor (e.g., steam). This can cause loud banging noises in piping, and wide pressure fluctuations in the system. [15]

In hydronic systems, flashing is the prevalent cause of water hammer. It occurs whenever the actual pressure at any point in the system drops below the vapor pressure and steam bubbles form. This can happen throughout the system when there is a sudden drop in pressure or when the circulating pumps, which provide a certain amount of overpressure, suddenly stop in an inadequately pressurized system. Also, water hammer can be localized at high points of the system, in the vena contracta of throttling devices, or in the eye of the circulating pump impellers, where lowest system pressure is combined with acceleration of the entering water. [16]

Logic behind the second cause can be explained, better understood by posing a following question. In the system under consideration there is a temperature regulator! How can there be any problems with temperature?

Draught regulator (presented on Fig.7) is called also a fire or temperature regulator. It regulates the temperature of the water supplied to the heating system by the boiler adjusting the air supply. Thermostatic control head senses the temperature in the boiler supply line and through lever and chain adjusts the position of the air vent. Closing of the air vent is creating more resistance to the air flow and volume of air drown decreases, and vice versa. Temperature control range is up to 95° C.

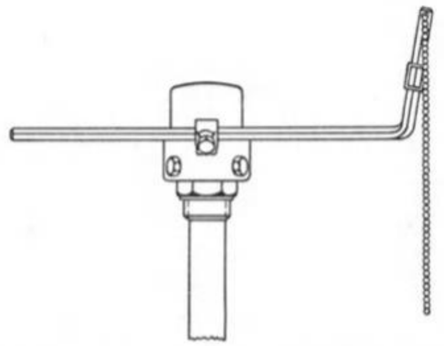


Figure 7 Temperature regulator (or draught regulator) [17]

If the air vent is completely closed, chimney draught is still present, so that combustion air finds a way through non ideal tightness of the system. Effect is that boiler can not produce heat less then a minimum value. So draught regulator can not completely extinguish the fire or stop the combustion process. It will be stopped either when all the fuel is spent or when fuel is removed manually from the boiler furnace. Additionaly this element has been proven as excellent and robust in normal operation modes, i.e. when the temeperature changes in the system are slow, as they usually are, as the outside temperature fluctuations are slow. But in case of rapid changes, draught regulator is not enough. [17]

Third reason is practical. There are no access points to the water network for example in the garage, basement or in the living room. System is filled through a hose that is afterwards removed. But in this case system must be open.

6 What can be done (course of action)

Answering the question who is responsible for the damage can accelerate the mitigation of the problem, boiler producer, installer or buyer.

Disseminating findings among the community, so that they become aware of the risks, and that they know for what to look for and check themselves. It is not that complicated to determine if the boiler has or has not got safety heat exchanger or other type of protection. There was a boiler explosion in which life has been saved by the sheer fact the person after hearing banging noise coming from boiler room didn’t race to the boiler but called fire fighters. Boiler exploded, caused material damage, but nobody was hurt. [18]

Starting conversation and reaching a consensus between academia, producers and installers which course of action should be done in a present situation.

We can follow the practice from Belarus. A kind of a leaflet presented in Fig. 8 that is given to the homeowners explaining the main operational situations. Here the difference is that their boilers are installed in open system so problems with freezing of the safety lines are of primary concern. So in this leaflet answers are given to following questions: What should be done in case of poisoning by the carbon monoxide; What should be done if heating system freezes; What should be done if water pressure approaches to the maximum allowable pressure; What is necessary to be done in order to avoid boiler explosions; What is recommended to be done before heating season; What should be checked during the ignition of boiler; What is forbidden.

Figure 8 Leaflet on safe exploitation of heating boilers stoked by solid fuels [19]

7 Conclusion

In engineering design device functions can be prioritized or ordered in the following way: safety, effectivity, efficiency and emissions. In countries that are better off (of the first world) first three can be considered as solved, and now the focus is on the emissions. Serbia follows this practice, but it should be reassessed if first three functions are achieved.

Overheating should not be downplayed. Overheating in a closed system is a near explosion situation and it should be treated as such. So systems that prevent it cannot be optional. On the other hand a number of components in the system are working against overheating so frequency of explosion occurrence is low. There must be a perfect storm of failures to result in explosion. Our job as engineers is to apply all known rules. Standard clearly states: “Boilers with manual stoking shall be designed in such a way that, when the boiler is operated in accordance with the boiler manufacturer’s operating instructions, the operator does not run the risk of a hazardous operation mode”. So far the practice was such that played the probability card, and if there comes to explosion escape goat was safety valve.

Courses taught on Serbian universities are focused on steam boilers, where heating (i.e. hot water) boilers are left behind. And there is significant difference between these two classes of boilers, in one the sole purpose of the device is to bring water to the boiling and to produce steam and in other it is forbidden to cause water to boil. One could define the latter as “non-boiling” boilers. Heating boilers are present in heating plants of the district heating systems and in the homes where central heating is installed. And the sheer number of these boilers is great. There are capacity, pressure

and temperature level differences between these two applications, but they have much more in common then it is the case between them and steam boilers.

For a future work experiments are planned with all precautionary measures accounted for, to get better insight into dynamics of the system that crosses known safety borders, that is, when it comes to boiling in a closed system.

8 Acknowledgments:

This paper is part of a project supported by the Ministry of Education, Science and Technological Development of Republic of Serbia, III 43008, “Development of methods, sensors and systems for monitoring the water, air and soil quality”.

Special gratitude to then third year students for doing the survey on solid fuel boilers in closed heating systems: Semester 2016/17 Racić, Gagić, Jakovljević, Milošević, Oluški, Subić, Tojaga, Tomić, Vujanović and Jeremić . Semester 2017/18 Đukić, Radanović, Bartula, Jovanov, Miletić and Zeljković.

Thanks to insightful discussions with Dragan Despić from Novi Sad heating plant on issues of practical heating and Slobodan Tašin from Faculty of technical sciences on issues of heating system hydraulics.

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