FMEA-ANALYSIS OF RESTRICTED PRESSURE DEVICE FOR BIOMASS COMBUSTION

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Abstract
The issue of boilers used to burn biomass is highly topical at the moment in view of the high prices of gas and overall use of natural resources and waste material. The use of biomass is a relatively new field which is being slowly introduced into practice and there is a constant search for new sources of various types of materials which put less burden on the environment.

Keywords: biomass, risk, boilers,

1 Introduction

Biomass can play an essential role in the future if transformed into different forms of energy – mainly electricity, gas and liquid fuels. One of the reasons for that is greater availability of biomass compared to fossil fuels, also the technologies for its use have been tested in practical industrial applications. In some countries, growing biomass for the purpose of generating energy can provide solution for the present-day crisis because of the overproduction of agricultural commodities. If biomass was grown and used at an acceptable level, it would not lead to the increase of CO_2 in the atmosphere as only as much of it would be released into the atmosphere when burning biomass as the plant received during its growth by photosynthesis. Today, biomass is an important source of fuel because it provides one-seventh of the world‘s energy consumption. It is mainly used for heating and is considered the main source of fuel for almost half of the global population.

2 Restricted technical devices

According to the Decree No 508/2009 Coll. a fired or otherwise heated technical device which is subject to the risk of overheating and is intended for the production of steam or for heating liquids with a temperature higher than the boiling point at a pressure of up to 0.05 MPa with nominal heat capacity of more than 100 kW is classified as a restricted technical pressure device.

2.1 Legislative regulations related to restricted technical devices from the year 1970 till the present day

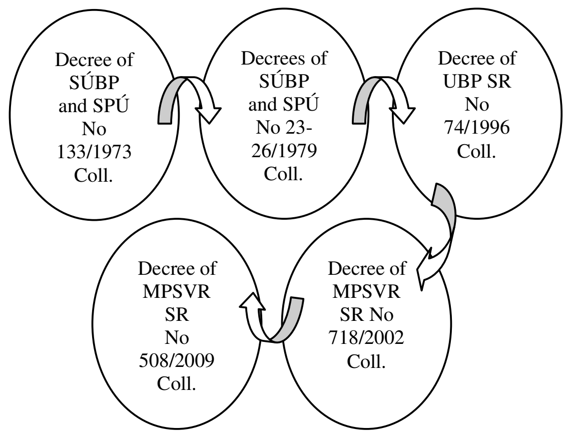


Fig.1

The reason for the issue of the decree on restricted technical devices was, apart from other considerations, the legislative need to bring the requirements set in the Decree in compliance with the requirements imposed by Act 124/2006 Coll. on safety and health protection at work as well as the requirements set out in European regulations for this type of products (e.g. conformity of the classification of restricted devices based on parameters) [1].

The Decree was issued on the basis of the enabling provision of paragraph 30 section 1 (a) and (c) of Act No 124/2006 Coll. on safety and health protection at work. In general, the Decree is an executive statute of the Act on safety and health protection at work for technical devices with emphasis on restricted technical devices as specified in this statute.

Application of the requirements of Act No 124/2006 Coll. is particularly important in the following areas:

- Controlling activities (Article 9 of the Act on safety and health protection at work),
- safety of constructions, working premises, installations and working procedures (Article 13 of the Act on safety and health protection at work)
- Verification of the fulfillment of safety requirements for technical equipment (Article 14 of the Act on safety and health protection at work)
- Activity Execution Certificate and Activity Execution Permit (Article 16 of the Act on safety and health protection at work) [**1**].

The article dealing with the inspection of technical devices is related to the provision of Article 5 section 1 and 2 of the Regulation of the Government of the Slovak Republic No 393/2006 Coll. on the minimum safety and health requirements for the use of working equipment

2.2. Requirements for inspection and testing of boilers

Boiler operators are obliged to carry out periodic inspections and maintenance to ensure safe operation of boilers. Routine preventive maintenance and inspections help operators to detect malfunctioning, identify the reasons for these breakdowns as well the necessity and scope of the maintenance service including the need for repairs and alteration (reconstruction) of boilers. During operational maintenance the detected malfunctions are eliminated and failures are troubleshooted along with all the necessary repairs or adjustments of boilers.

Types of tests [2]:

- Official test and recurrent official test,
- External inspection,
- Internal inspection,
- Leakage test,
- Pressure test

Operational inspections of boilers are performed at regular intervals based on their type, design, structure, condition, age, operational conditions of boilers, however, within the period of three months at the latest as of the date when the last operation inspection was performed. The pressure test is carried out every six years as part of the recurrent official test.

Preparation of a boiler for internal inspection

Before cleaning the boiler by the personnel who enter the boiler and before performing the internal inspection the boiler must be safely and reliably disconnected from other boilers and pipe lines that could be under pressure. Drainage and leach pipe lines, main pipe lines, supply pipe lines, gas and oil pipe lines of the incineration equipments etc., must be safely disconnected using steel blind flanges (stoppers) of sufficient thickness installed forward of the respective valves on the side of the dangerous part in such a way as to reliably ensure safety of the persons working inside the boiler. Electrical devices must be safely disconnected from the source of electrical energy as well. [3].

Before carrying out inspection it is necessary to properly ventilate the combustion chamber as well as other inspected areas. Efficient ventilation must be also ensured during inspection of the boiler, cleaning, servicing and repair works too. Inside the pressure vessel as well as in the combustion chamber only workers over 18 years of age may work who are specially instructed and who have professional experience.

Before entering the pressure vessel, combustion chamber or the flue system of the boiler it is necessary to make sure that the temperature inside the boiler is not higher than 50^{o} C, the pressure vessel is empty and sufficiently ventilated as well as that there is no danger of the release and fall of slag, ash build-ups, or lining. If it is the case, then the build-ups and the damaged lining must be safely cleared away from outside before entering the combustion chamber to prevent injuries and damage to the boiler as a result of their fall. [4].

The necessary protective measures must be taken as well as personal safety equipment, aids and means such as platforms, safety nets, safety helmets etc. must be used in places where safety of the personnel might be threatened. Parts of the boiler being serviced must bear a safety precautionary note giving the proper warning. [4].

Leakage test

The leakage test must be performed after every inspection of the boiler or after opening the pressure vessel. Before closing the boiler it must be thoroughly inspected to ensure that no foreign objects or persons are left in it. After closing the pressure vessel of the boiler, the valves of all pipelines connected to it are shut off except the valve on the water supply pipe and deaeration valves. The pressure vessel is then filled with water max $50\ ^{o}C$ with deaeration valves open. [3].

Pressure test

Pressure test is carried out within the period of six years at the latest as of the date of the previous pressure test conducted to a specified overpressure value. Before the pressure test is performed, the safety valves must be disabled. Before carrying out both leakage and pressure tests the boiler must be properly cleaned from the side of the combustion products in order to assess the technical condition of the boiler. [3].

Table 1
Ways of classifying biomass [5]

According to the source	According to composition	According to the ways of obtaining
1 Woody biomass	Dendromass	Biomass specifically grown
2 Agricultural biomass	Phytomass	Waste biomass
3 Waste biomass	Organic waste	

[a] Reprinted from *Exploring Chemistry with Electronic Structure Methods*, J. B. Foresman and A. Frisch, 1993, p. 216

Table 2
Advantages and disadvantages of using biomass [6]

Advantages of using biomass	Disadvantages of using biomass
1 It is renewable	Lower heating value than fossil fuels
2 It can be grown specifically	Raw biomass decomposes quickly
3 It is a local source	Higher demands on storage space
4 A more stable price	Requires treatment of the basic form of biomass
5 It can be burned in different forms	
6 Burning biomass is environment-friendly	Complicated manipulation with fuel in comparison with gas
7 Ash as a waste product from the burning can be used as a high quality fertilizer	More complicated servicing of boilers, e.g. cleaning and disposal of ash

Table 3
Categorization of technical devices based on the degree of hazard [1]

1 Category A	**Technical devices with a high degr**	**Restricted technical devices**
2 Category B	**Technical devices with a higher degree of hazard**	
3 Category C	Technical devices with a lower degree of hazard	

3 Heating device for combustion of biomass firematic 25-150 BioControl

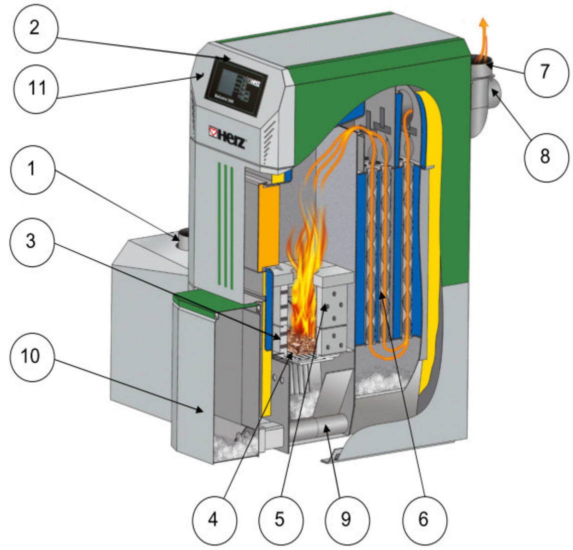


Fig. 2

1 - burn back protection – RSE, 2 - integrated regulation HERZ BioControl 3000, 3 – automatic ignition by hot air fan , 4 – pivoting
grate, 5 – combustion chamber with 2 zones, 6 – tube heat exchanger, 7 – Lambda probe, 8 – variable speed induced-draught fan , 9 – removal of ash and flue ash, 10 – ash bin, 11 – safety temperature limiter

The combustion chamber consists of the fuel feeding system from the supply bin to the boiler, drop chute with a tight valve RSE, an intermediate hopper with infra-red sensors to monitor the level of fuel, a feed auger, a retort integrated into the boiler and a plate heat exchanger. The whole device is controlled by the electronic unit Biocontrol 3000 with the respective inlets and outlets. [7].

Fuel is transported from the main store to the intermediate hopper and from there by the feed auger into the retort. Fuel is injected into the combustion retort in a preset amount for the ignition corresponding to the ignition stroke. After the fuel is fed, ignition is activated automatically by the hot air ignition fan. Combustion is continuously controlled by the temperature sensors and lambda probe installed in the flow of combustion gasses or the temperature sensor in the combustion chamber [7].

The amount of the inducted combustion air is regulated according to the adjusted underpressure. The secondary air is driven by two secondary-air fans. This air flows into the combustion chamber through the nozzles installed in the area of the secondary air. The preheated secondary air drawn to the fire thus provides continuous burning and combustion with a low content of harmful substances. The supply of the primary air as well as the supply of the secondary air are continuously adjustable. The amount of fuel injected and the secondary air supplied is adjusted on the basis of measurements taken by a lambda probe which monitors the values of combustion products. [7].

Automatic cleaning of the retort takes place at the predetermined intervals. The burner is cleaned automatically and the removed ash falling into the combustion area is taken into the mobile ash container by means of an ash screw. The whole process takes place during operation of the device [7].

A plate heat exchanger is integrated in the boiler. The boiler can be equippped with automatic cleaning of the heat exchanger surfaces and removal of flue ash into a separate flue storage bin, which is an optional equipment. Heat exchanger surfaces are generally cleaned semi-automatically using a lateral rod. [7].

Boiler output can be adjusted to the demand for heat by intelligent operation of HERZ firematic BioControl boiler. It can be reduced by 30% of the nominal heat output. Such an operation requires a moisture resistant chimney that can convey products of combustion with temperature below 150°C.

Digital control unit BioControl 3000 and integrated lambda probe help achieve a high level of efficiency performance even with varying levels of fuel quality.

BioControl regulation typically built into the boiler is a central unit which controls:

- combustion process,
- equitermically regulated heating circuits,
- preparation of hot water ,
- accumulator,
- solar circuit ,
- increase of the return water temperature.

Safety devices (mutually independent systems) [7]:

- fuel burn-back protection (RSE) – drop chute , with a tight burn-back flap driven by a spring-return motor,
- electronic temperature control in the feed auger,
- automatic, thermally activated sprinkler extinguishing system (RSH),
- protection against overheating is provided by a safety heat exchanger .

These boilers burn wood chips G30-G50/W35 according to ÖNORM M7133 standard, or Swisspellet or DIN Plus pellets according to ÖNORM M 7135. To reach the nominal output moisture content in the fuel must not exceed 25%. The firewood must be in natural, untreated form. Under no circumstances must foreign objects such as stones, soil, parts of metals enter the device [4].

4 Risk assessment using FMEA method

FMEA (Failure mode and effect analysis) is the basis of maintenance philosophy aimed at failure-free operation - Reliability Centered (RCM). Its task is to perform the analysis in such a way as to minimize negative effects and help solve problems effectively or prevent them. [8].

There are several types of FMEA depending on what it applies or is related to. 5 basic types of FMEA are: system, design, process, service and software.

The analysis form includes details of the name of the analyzed part, its function, and description of the failure, cause or reason for the failure, the resulting effect of the failure, impact on the quality, safety and environment as well as proposed measures.

Part of the form is analysis of „criticality"involving risk assessment, such as risk rate value/priority – MR/P used for the estimation of risk.

MR/P is defined as a product of the selected values Vz, Vy, Od, i.e.

MR/P = Vz * Vy * Od,

where:

Vz – represents the severity of a failure for the given system, i.e. how significant the impact of a subsystem failure on the system as a whole might be

The probability of occurrence of the failure in the system is characterized by the quantities:

Vy – characterizes the occurrence of this failure (or its cause),

Od – characterizes probability of identification the causes for the failure.

All the three characteristics are assessed on a scale of 1–10, [8]

Table 4

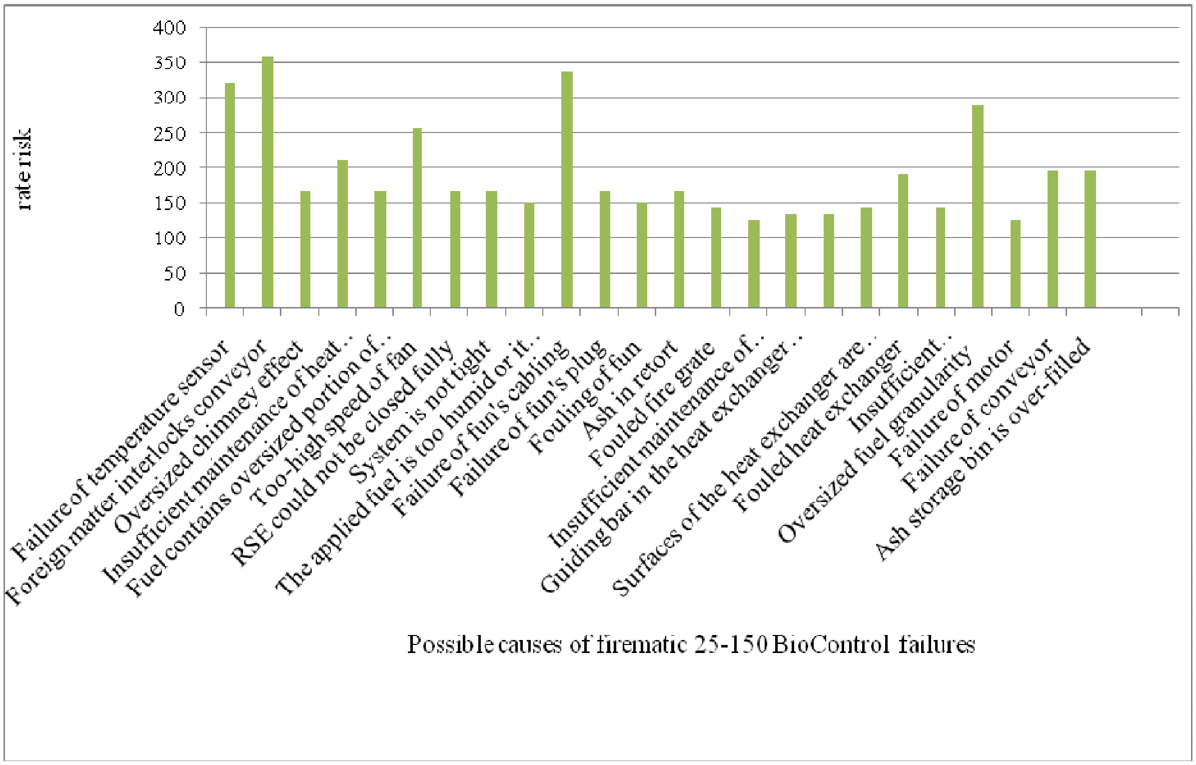
Example of FMEA for tube heat exchanger

Plant/Operation:	FMEA	No FMEA: 6 Page: 1 z 1
Process/system: HEAT EXCHANGER		Author: Tomašková Marianna
Subprocess/Subsystem:	Team:	Date: 21.6.2013

Part	Function	Prejav poruchy	Possible reasons	Possible effects	Q	B	E	Vy	Vz	Od	MR/P	Recommendations
TUBE HEAT EXCHANGER	part of the boiler where combustion products transfer heat (energy) to the heat-carrying substance, usually by a single to three duct tube heat exchangers	•safety switch on the heat exchanger warns of heat exchanger malfunction	• guide rod is not lubricated	• discontinuance of the production of heat, hot water, the boiler is not able to produce heat or to warm water • corrosion, forming of sludge (mud), clogging if heat exchanger surfaces	A	N	N	4	8	6	192	• regular lubrication with a suitable grease
			• preset cleaning time is too long		A	N	N	2	5	4	40	• cut down on the time of cleaning
			• preset cleaning time is too short		A	N	N	2	5	4	40	• extend the time of cleaning
			• guide plate is improperly adjusted		A	N	N	4	7	6	168	•test of adjustment of the guide plate
		• boiler performance decreases	• Heat exchanger surfaces are badly smeared		A	N	N	8	8	4	256	• regular cleaning of the surfaces of heat exchanger
			• unsuitable heating water		A	N	N	5	7	3	105	• test the quality of heating water
			• insufficient maintenance of the heat exchanger		A	N	N	7	8	3	168	Regular lubrication of the guide rod, cleaning of the heat exchanger

Table 5

Risk rate for the heating device [9]



6 Conclusion

FMEA analysis of the biomass boiler shows that malfunctions may occur in different component parts similarly as it is in the case of a gas boiler. Biomass boilers require more attention to maintenance to ensure longer high efficiency performance and service life of the boiler.

Most important malfunctions occur due to the following reasons:

- insufficient control,
- insufficient maintenance,
- small repairs ,
- replacement of individual components.

Risks in the operation of biomass boilers:

- damage to the structure of the boiler body,
- explosion when the maximum operating pressure is exceeded,
- risks associated with the exhaust of combustion products,
- burn-through to the supply bin or fuel store,

- formation of low temperature corrosion,
- burns caused by high surface temperature of the boiler.

The choice of the optimal heating system depends on several factors. They include mainly the interior layout of the house, thermal and technical properties of the building, and operational requirements of the user as well as climate conditions. Operational safety is the most important requirement for the device. Non-functional or damaged parts of the boiler could cause fire or explosion that is why it is absolutely necessary to strictly adhere to the norms and procedures to ensure safe operation of the boiler.

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