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CONTINUOUS MEASUREMENT OF THE QUALITY OF STEAM

KONTINUÁLNÍ MĚŘENÍ KVALITY PÁRY

DIPLOMOVÁ PRÁCE

MASTER'S THESIS

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Biomedical Engineering and Bioinformatics

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TITLE OF THESIS:

Continuous measurement of the quality of steam

INSTRUCTION:

1) Perform a literature search of basic physical properties of steam for sterilization of medical supplies.
2) Analyze and describe the method of assessing the efficiency of sterilization of medical supplies.
3) Design options for measurement of physical quantities pressure, temperature, flow, humidity and other medical supplies for sterilization.
4) Propose a method for continuous monitoring of quality steam sterilization.
5) Select the relevant parameters of physical quantities and design methodology for evaluation.
6) Design methodology for the evaluation of the measured data and their interpretation.
7) All of the above suggestions evaluate and provide correlated with the standard for sterilization of medical supplies.

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[3] CIBULKA I. : Základní fyzikálně-chemické veličiny a jejich měření, VŠHT v Praze, 2006.

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WARNING:

ABSTRACT

The diploma thesis deals with the measurement, analysis, and then finding the appropriate physical parameters for analyzing the quality of saturated steam sterilization. This work aims to determine the critical parameters system of steam generator to operate according to the norm CSN. Part of the project is the description of the physical sterilization, saturated steam, methods and sensors for the control of steam sterilization. Sterilization, saturated steam, the steam sterilization parameters of, measuring the quality of steam

KEYWORDS

Sterilization, saturated steam, parameters of the steam sterilization, measuring the quality of steam.

ABSTRAKT

Diplomová práce se zabývá měřením, analýzou a následným nalezením vhodných fyzikálních parametrů pro analýzu kvality syté sterilizační páry. Tato práce si klade za cíl určit, kritické parametry systému vyvíječe páry pro provoz dle norem ČSN. Dílčí částí projektu je popis fyzikální sterilizace, syté páry, metod a senzorů pro kontrolu sterilizační páry.

KLÍČOVÁ SLOVA

Sterilizace, sytá pára, parametry sterilizační páry, měření kvality páry

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DECLARATION

I hereby declare that I have elaborated my master's thesis on the theme of " Continuous measurement of the quality of steam " independently, under the supervisit of the diploma thesis supervisor and with the use of technical literature and other sources of information which are all quoted in the master's thesis and detailed in the list of literature at
the end of the master's thesis.
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I would like to thank my supervisor Ing. Vladimír Holcman, Ph.D. for his invaluable assistance for all consultations and valuable advice in processing my thesis.
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Author's signature

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1. Introduction

Human in life and working environment daily exposed too many different factors, which include among others living with the microorganism. Most of them are harmless to humans, some are for life necessary and essential, but there are those types of microorganisms that can cause serious and fatal diseases or spoil materials and products.

With the development of agriculture and industry, domestication of animals, construction of the town or implementation of new technologies to create suitable conditions for microorganisms. To their subsequent propagation helps transport by land, sea and in the air. Changes in human habits and customs is changing environmental conditions and pathogens and the faster these changes are, the faster discovering new disease-causing isolated cases, local epidemic, or the uncontrolled spread of long known infections such as cholera, malaria, measles, etc.

Sterilization is a set of action that are used to kill all microorganisms, including resting forms. Perhaps the most important is the sterilization of medical devices. Sterilization or disinfection is also used in other fields. An example might be the conservation and preservation of historical sites and documents. Is also significant applications in the food industry. Because each material has an individual reaction to temperature, humidity and other physical and chemical effects, it is important to develop new effective but friendly methods of sterilization.

The main objective of the project is to find suitable physical parameters for analyzing the quality of saturated steam of the sterilization according to the norm CSN EN 285+A2, which is the first step to replace the old processes of this analysis. Processes used because they have a number of shortcomings. Between the bases includes impossibility to include of automation and impossibility of continuous measurement of a parameter. Using the appropriate parameters will be possible to create a modern automated system that will measure the physical properties of saturated steam of the sterilization continuously and without serious drawbacks.

The project also deals with the physical sterilization using saturated steam and other options for sterilization and disinfection. Describes the basic parameters for the correct operation, also the advantages and disadvantages and suitability for using a particular material. In the next part of the semester project is dedicated the saturated steam, its formation, physical properties and parameters that are necessary for the utilization steam during physical sterilization in sterilization chambers. The project also deals with methods that are used to control the quality of steam and effectiveness sterilization, such as checking the content of non-condensable gases, dry steam or overheated.

Finally dedicated sensors for measuring certain physical quantities such as temperature, pressure, humidity, flow, dew point or the electrical conductivity of the water which is used for the preparation of saturated steam. For each physical quantity is selected several suitable sensors for the measuring the properties of saturated steam of the sterilization and described the principles or advantages and disadvantages of using the process of sterilization.

2. Sterilization and Disinfection

It is an important to distinguish between sterilization and disinfection. Sterilization results is a destruction of all forms of microbial life, while disinfection results is destruction of specific pathogenic microorganisms because disinfection is faster and less expensive, some hospitals substitute high level disinfection for sterilization of medical instruments. Sterilization and disinfection are so essential for using in the medicine for surgical instruments (e.g. scalpels, needles) in preventing healthcare must be sterilized to not transfer the infections between the patiens.

Sterilization and disinfection both of them are decontamination process, the principle of this process is killing or removing pathogenic microorganisms from the environment or the subject by a process of sterilization or disinfection, regardless of their reduction. It is the use of physical or chemical means to destroy, remove or inactivate the living organisms on a surface so in this case the organisms are no longer infectious. [1][2][3][7]

Sterilization divided into two sections, first section is physical such as steam, heat, plasma, and radiation. Second section is chemical such as ethylene oxide and formaldehyde.

2.1 Disinfection

Disinfection describes the process of eliminating or destroying of the most pathogenic microorganisms and disinfectants could be used alone or in a combination in the health care.

It contains alcohols like chlorine, formaldehyde and hydrogen peroxide. Every commercial product is used for a specific thing therefore, users must be carefully to ensure the correct product for the concrete use.

Protective disinfection is carried out wherever we can assume the presence of infections, including when the infection occurs. It is a part of complex hygienic measures in various medical facilities, spa facilities, and in facilities for production, processing, storage, distribution and sale of food. Its purpose is to prevent the development of infection.

Selecting the procedure of disinfection is based on the knowledge about the ways and mechanisms of infection and the possibility of influencing the effectiveness of disinfection by environmental factors (temperature, pH, moisture, protective effect of organic matter). The purpose is that the surfaces or objects in the environment of intact skin were no microorganisms which cause infectious diseases.

By definition, the disinfection destroys microorganisms by physical, chemical or combined procedures on inanimate objects in the environment and on intact skin. [4][5]

2.1.1 High-level disinfection

Destroys all microorganisms (bacteria, viruses, fungi, and some bacterial spores), but does not guarantee the killing of other organisms (e.g. highly resistant spores). It is used for decontamination instruments with optics which can not be sterilized by physical or chemical but before the process, the items must be clean and dry if they have been contaminated biological material. Cleaned and dried objects are must be completely immersed into the solution for a higher level of disinfection. It is necessary to be immersed and filled with a solution and the hollow portion of the device. [1][4][5][6]

2.1.2 Physical methods of disinfection

Physical methods are ecological advantageous because microorganisms are killed by physical processes using dry or wet heat and radiation.

- Boiling water under atmospheric pressure for 30 minutes.
- Boiling in pressurized pots for 20 minutes.
- Disinfection in washing and steam equipment at temperatures above 90 ° C.
- UV radiation wavelength germicidal lamp is 253.7 - 264 nm.
- Pasteurization - heating to 60-65 ° C for 30 minutes or 134 ° C for a few seconds, after rapid cooling.

Other physical disinfection methods is filtration, annealing, combustion, sunbathing, etc. are used for special conditions. [3][5][8]

2.1.3 Chemical methods of disinfection

When chemical disinfection of microorganisms is destroyed by chemical solution or aerosol disinfectants determined concentration and exposure to death or restrictions multiplication effect. Disinfectants have a wide or narrow range of disinfection efficacy and are intended for professional use or for small consumers.

Some ways for carrying out chemical disinfection: [3][5][8]

Immersion: Disinfected Items are immersed in disinfectant solution with no air bubbles.

Wiping: In a disinfectant soaked cloth to dry.

Spraying: Splashed surfaces with a clean cloth, spraying are recommended for small areas.

Disinfectant aerosols: Dispersing system consists of air, dispersed droplets then disinfectant product, there is aerosol cold or warm.

Gassing: Use of gaseous or dry aerosol for disposal of fungal spores in indoor air rooms. The advantage is that in Space does not involve any moisture.
Evaporation vapors: Disinfecting solutions
Foam: Foams have high cleaning and degreasing properties.
Disinfectants are based on the type of chemicals, here some types of chemicals with Types of chemicals with disinfectant action:
Hydroxides
Acid and some salts (inorganic, organic, acid esters, peroxide acids)
Oxidizing agents (ozone, hydrogen peroxide, metal peroxides, organic peroxides)
Halogens (chlorine, chlorine dioxide, bromine, fluorine)
Metal compounds (sulfur, nitrogen, phosphorus, bromine)
Alcohol (methanol, ethanol, propanol)
Aldehydes (acetyl, formaldehyde)
Cyclic compounds (phenol, alkyl phenol, cresols)
Combined

2.1.4 Physical - chemical disinfection

Physical methods are ecological advantageous because microorganisms are killed by physical processes using dry or wet heat and radiation.
Boiling water under atmospheric pressure for 30 minutes.
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2.1.5 Disinfection procedures

The treatment of the patient's doctor and nurse access to wash their hands. For drying hands preferably used disposable material. Always disinfect your hands after contact with patients with infectious diseases, biological material, etc.
During surgical procedures personal use protective clothing designed just for the workplace, hats, protective mask that covers the nose and mouth, and sterile solves.

Protective equipment for each patient is individualizing put off immediately after examination or operation. Syringes and needles are disposed generally without separation. Other single-purpose devices are disposed after use as infectious material. [8]

2.2 Sterilization

Sterilization describes a process which destroys all the living microorganisms, including bacterial spores. As a sterile can be described only those objects and substances which have killed all microorganisms. Tools and utilities must be sterile which violate the wholeness of the skin and mucous membranes. Tools, utilities and objects are sterilized in accordance with the manufacturer's instructions. Result of sterilization is dependent on the default number of microorganisms and their resistance to sterilization agents to the subject, which is sterilized, and also at the time of exposition of sterilizing agents.

If the sterile material is not correctly treated during the preparation before sterilization may contain pyrogens, therefore, the preparation before sterilization for tools is necessary.

All items to be sterilized must be in preparation before sterilization thoroughly cleaned, disinfected, dried and checker for functionality, ruggedness and packaged in sterilization packaging. [3]

2.2.1 Preparation before sterilization

The result of preparation before sterilization is a clean, dry, functional and Packaged, it is done either by manual wash or washer machine. The objects contaminated with biological material especially the blood in order to prevent contagion it is necessary manual wash and to the cleaning adding disinfection product.

Solutions in decontaminating containers are used at a concentration recommended for manual wash and disinfection of medical devices. Preparation before sterilization is performed by physical or chemical methods followed by mechanical cleaning, rinsing with potable water to remove residues of chemicals and dead bodies microorganism then the objects must be dried and packed into a sterilization packaging.

Cleaning takes place in washing and disinfection machines using acidic, alkaline or enzymatic means. [3][5]

Table 1: Preparation before sterilization [5]

Preparation before sterilization	
Objects contaminated biological material	**Objects uncontaminated biological material**
Disinfection	Mechanical cleaning
Mechanical cleaning	Rinse with a potable water
Rinse with a potable water	Drying
Drying	Packaging
Packaging	

2.2.2 Methods of sterilization

Divide into two parts physical and chemical methods.

Table 2: Physical and chemical sterilization [3]

Methods of sterilization	
Physical sterilization	**Chemical sterilization**
Steam sterilization	Formaldehyde
Dry heat sterilization	Ethylene oxide
Plasma sterilization	
Radiation	

2.2.3 Physical sterilization

2.2.3.1 Steam sterilization

First introduced was in 1880, it is the oldest and most widely used. The process used moist heat under pressure as pressure cooker. The first commercial steam sterilizer, which used saturated steam under pressure, was sold in the United States in 1933. It is fast, non toxic, friendly to the environment, and economical, it is sterilization with saturated steam under pressure in steam sterilizers, the sterilization chamber must be completely vented in order to steam could easily penetrate into the material. Sterilization exposition time is counted from the moment when the chamber reached the desired temperature and pressure to stop the flow of steam to the device. [8][9]

Steam sterilization is suitable for objects of metal, glass, ceramics, porcelain, rubber, textiles, paper and other materials resistant to sterilization parameters.

Exposition time parameters:

Table 3: Steam parameters with exposition time [8]

Temperature (°C)	Pressure (kPa)	High pressure (kPa)	Exposition (Min)
115	170	70	35
121	200	100	20
125	240	140	15
134	300	200	10

Effective sterilization is only saturated with water vapor, which is produced from water with defined limits for the content of chemical substances. Wet steam is able to pass smaller amount of thermal energy. [3][4]

There are three types of steam sterilization:

Small-volume sterilizers directly in the chamber without a vacuum pump to suck the air before sterilization

Biggest sterilizers with a vacuum pump, manometer or thermometer with a time control

Big-volume device in operating hall must have a vacuum pump, casing, recording equipment during the pressure, temperature and automatic cycle control and printer records the formal parameters of sterilization. [8]

2.2.3.2 Heat sterilization

Dry heat in the form of hot air is used only minimally in health care. Whereas steam sterilization is easy due to steam delivering both heat and moisture to the items being sterilized. Dry heat sterilization parameters are simply time and temperature. After attaining the sterilization temperature, the temperature must be maintained for a minimum length of time.

Figure 1: Heat sterilization

This (time at temperature) must be demonstrated to occur in the case of every pack placed in the sterilizer. In order to provide air circulation while direct current temperature, the devices are equipped with fan. [1][8]

For devices without forced air circulation the volume of the chamber must be less than 5 liters, when a larger volume should be doubled sterilization exposition. Sterilizer device is opened until the temperature on the thermometer drops to at least 60 °C. Sterilization by hot air is suitable for sterilizing objects of metal, glass, porcelain, ceramics, for ointments and powders. Temperatures up to 160 ° C can be used for drying the glass. Hot air sterilization is performed in devices with forced air circulation by the following parameters:

Table 4: Heat sterilization [3]

Temperature (°C)	Exposition (min.)
160	60
170	30
180	20

2.2.3.3 Plasma sterilization

Plasma sterilization is the newest and the most reliable method of sterilization which used in healthcare. This is basically the use of very simple chemical process to destroy all microorganisms and potential pathogens. It is using plasma which generated in the electromagnetic field, which in high vacuum acts to vapor hydrogen peroxide or other chemical substances at temperature 50-60 °C at a pressure 0.04 kPa and sterilization for 10 minutes. This method is suitable for metallic medical devices or equipment of plastic and optics. [4][5][10]

Table 5: Plasma sterilization [3]

Temperature (°C)	Pressure (kPa)	Exposition (min.)
50	0.0004	10

2.2.3.4 Radiation sterilization:

It is performed in special radiation centers, where the sterilizing effect is induced by gamma rays produced by isotope Cobalt 60 or cesium 137 (^{60}Co or ^{137}Cs) and the recommended dose is 25 kGy. The radiation sterilization provides the killing of all forms of microorganisms and does not depend on temperature, pressure, humidity, thermal conductivity and other factors which affect other sterilization methods. It is only used in the industrial production of the new sterilization or expired material that does not change the functional and visual characteristics during repeated radiation. [4][5]

2.2.4 Chemical sterilization

Chemical sterilization is designed for material that can not tolerate high temperatures and can not be sterilized by physical means. Sterilization takes place in the devices provided for overpressure or under pressure at a temperature of 80 °C. After sterilization the material must be ventilated in a special cabinet which calls (aerators) well-ventilated area to reduce the risk of toxic chemical residues. Ventilation time depends on the time and quality flushing phase after finishing the process of sterilization, temperature, material, and the kind of sterilization gas and the intensity of ventilation. The sterilized material can fill up to three quarters (¾) of the chamber volume, not touching the walls and stored vertically in order to facilitate the access of sterilizing gas to objects. Objects designed for chemical sterilization must be inserted into the instrument dry and packed in approved packaging for the gas to reach. [10][8]

2.2.4.1 Ethylene oxide sterilization

Ethylene oxide (EO) has been used as a sterility in healthcare since the 1950s. It is a colorless, odorless, and flammable gas. It is used in mixtures with carbon dioxide in order to suppress explosive and flammable in a special pressure devices which is a protoplasmic poison. Sterilized items must be ventilated before using for health reasons to remove residues of gas. The sterilization cycle takes place at a temperature of 37 ° C to 55 ° C, relative humidity 70% to 90%, under pressure 50 kPa, pressure 450 kPa and the sterilization exposition is 3 hours.

Ethylene oxide does have some disadvantageous including a relatively long sterilization cycle and the need for aeration for a specified amount of time and several days ventilated of sterile equipment. The main advantage is that it can sterilize heat- or moisture-sensitive medical equipment without deleterious effects on the material used in the medical devices. It is suitable for thermo labile materials, optical instruments, sharp tools or porous materials, such as foam, paper or feathers. [2][3][6][9]

Table 6: Ethylene oxide sterilization [3]

Temperature (°C)	Pressure (kPa)	Exposition (min.)
37-55	650	180

2.2.4.2 Formaldehyde sterilization

Formaldehyde is used as a disinfectant and sterility in both its liquid and gaseous states and it is classified as a high level disinfectant and is chiefly used to preserve anatomical specimens. Sterilization of formaldehyde is carried out in special pressure instruments and the method is based on the action of a gaseous mixture of formaldehyde with water vapor at temperatures up to 80 ° C, under pressure to 90 kPa and sterilization exposition between15 to 25 minute. Instruments for sterilization are installed in separate rooms with ventilation because formaldehyde has a carcinogenic effect. It is designed to sterilize heat-sensitive objects, sharp metal objects, some optical devices, rubber. [1][2][6]

Table 7: Formaldehyde sterilization [3]

Temperature (°C)	Pressure (kPa)	Exposition (min.)
60	10-20	25
80	10-20	15

2.3 Storage and transport sterile material

Packaging used to protect sterilized items from secondary contamination until use. The objects in sterilization devices inserted in approved packaging or sterilization boxes. Packages are closed by sealer or waterproof adhesive bonding. Sealing of packages in any other way is unacceptable.

There are two types of packaging: Expendable packaging and solid packaging.

Expendable packaging: such as paper or folia, each package with sterilization object must be marked with the date of sterilization, expiration date sterilization materials and the code of worker who is responsible for the inviolate of the package.

Solid packaging: For repeated use such as container and cartridges. Container is used for steam sterilization and a cartridge is used for hot air sterilization.

Items with expired expiration are sterilized by the same method as had been sterilized but in a new packaging. The expiration date of sterile material depends on the method of sterilization, the type of packaging, the way how it is closed and number of packages. For the storage of sterilized materials, the recommended temperature is 15-25 ° C and relative humidity air is 40-60 %.

Material must be packaged in three packages:

Primary packaging: The package system is sealed or closed which creates a microbial barrier enclosing a medical device.

Secondary packaging: Package contains one or more medical devices and each of them is packaged in primary packaging.

Transport packaging: It is a package for primary and secondary packaging designed for protection during transport and storage. [3][6][8][11]

3. Sensor for measurement of physical values

3.1 Flow measurement

For flow measurement gases and liquids are a very much different devices using different physical principles, the term flow is often used to describe the mean flow velocity which determines volumetric or mass flow rates. Flow meter is a device that measures the rate of flow or quantity of a moving fluid in an open or closed conduit. Sensors used for measuring flow a flow volume of fluid can be classified according to different aspects, such as the used by measuring methods. Methods of flow measurement is divided into some main groups as the method of volume and speed, etc.:

3.1.1 Volumetric methods

The principle of volumetric is:

- Measuring the volume of gas or liquid in measuring areas
- Cyclical filling and emptying measuring space
- Measure of the flow volume is the number of measuring cycles

They can by divided into two groups:

Discontinuous functions (disposable) which are used in laboratories for calibration and verification, measurement is performed in 2 phases: Measuring and emptying. Measuring the phase when the delimited space is completely filled with gas and subsequently measure its quantity. Then, the measurement is interrupted and occurs to an emptying phase when measuring space will be emptied and will be the next measurement. The second group is continuous function, which include several of measuring space that is gradually filled and emptied. [14][21][22][23][24]

3.1.2 Speed methods

The principle of speed is:

- Detection of the flow velocity of the measured fluid in the measuring point
- The mean flow velocity in the measuring profile

The flow is determined from the measured flow velocities. The speed method can be measuring be speed probes which they are based on sensing differential pressure and used for laboratory purposes or accurate discontinuous measurement such as the Pitot tube which is placed in the opposite of the gas flow, the tube is with one end bent at right angles toward the flow direction and also Prandtl tube which sense the pressure in one place. [14][21][22][23][24]

3.2 Humidity measurement

The term humid air is a mixture of dry air and water vapor. Humidity gives content of water vapor per unit volume of air which is the real state of a mixture of dry air and water vapor at the same time depends on the temperature. During measurement is typically used any of the following three units:

- **Absolute humidity (density of water vapor)**
  Expresses the ratio of the mass of water vapor and the volume of wet gas. Content of water vapor in the air is limited. Air is saturated with water vapor and other humidity does not accept. The specific value depends mainly on the temperature and growing temperature grows.
- **Relative humidity**
  Ratio of the absolute gas humidity and maximum absolute humidity it expresse the percentage saturation of the dry air with water vapor at the given temperature.
- **Dewpoint temperature**
  It is the temperature at which air is no longer able to accept any vapor, the temperature at which the maximum air saturated water vapor (relative humidity reaches 100%). Dewpoint is always less than or equal to the actual temperature. [14][25][26]

Humidity measurement is carried out by measuring device, which called a hygrometer, basic methods divided into the following:

- Hydrometric method
- Psychrometric method
- Dewpoint

3.2.1 Hydrometric method

Humidity of air is provided on the basis of absorption of water vapor hygroscopic substance. Hygroscopic substance either absorbs all the water vapor contained in a gas sample or the gas humidity around the sensor hygrometer equalize the pressure of water vapor above the surface of a hygroscopic substance which forms a basic part of the sensor. [14][26][27]

3.2.2 Psychrometric method

The basic for psychometric methods are two thermometers dry and wet, which measures air temperature. Dry thermometer measures the temperature of air without affect, wet thermometers is still rising wetting liquid. [14][26][27]

3.2.3 Dew point method

Determining humidity gas through a dew point consists in determining the dew point temperature, it is the temperature at which the gas is saturated with water vapor. By measuring the temperature dew point and temperature of the gas can be specified relative humidity of gas. The essence of dew point measurement is to determine the dew point temperature and determines the dew cooled surfaces. The mirror reflects the beam from the LED diodes to the sensor and if the mirror dew, occurs reduces of the luminous flux, which is evaluated by an electronic circuit. [14][26][27]

3.3 Pressure measurement

Pressure is defined by the ratio of the element forces F acting on the element surface S in the normal direction and the SI unit for pressure is the pascal (Pa), equal to one newton per square meter (1 Pa = 1 N/m2):

$$p = \frac{F}{S} = \frac{m.g}{S} \qquad (1)$$

F - force

S - surface

m - weight

g - gravity acceleration

Pressure p can be defined by the hydrostatic column of liquid of density ρ and height h (g is the Earth's gravitational acceleration):

$$p = h\,\rho\,g \qquad (2)$$

Hydrostatic pressure gauges are relatively simple, reliable and accurate, their disadvantage that they do not provide a signal suitable for remote transmission and other processing control circuit. Instruments for measuring pressure are generally called pressure gauges.

However, pressure gauge is also called (manometer) is used for device for measuring overpressure, device for measuring under pressure is called vacuum gauge, device to measure the pressure difference is called (differential) pressure gauges, devices that are designed to measure barometric pressure are barometers and devices that measure absolute are called absolute pressure gauges. [12][13][14]

3.3.1 Deformation of pressure gauges

The principle function of deformation gauges is based on the flexibility of deformation, and thus the change of the geometrical shape suitable the pressure of specific elements under the effect of the measured pressure.

The deformation elements are made of carbon and nickel steel, phosphor and beryllium bronze and other suitable alloys.

The most commonly used deformation elements are Bourdon tube, membrane, box and bellows. [12][13][14]

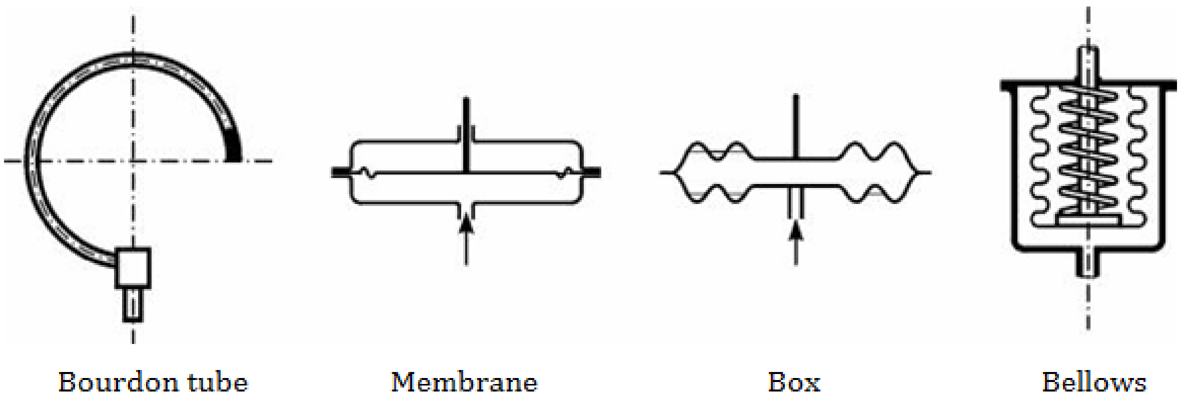


Figure 2: Deformation elements [13][14]

The tube pressure gauges (Bourdon tube) are the most common type of deformation gauges and the pressure measurement element is bourdon tube which is elliptical in a cross section and is bent into a circular arc of a spiral or helix. One end of the tube is fixedly connected to the body, with a thread for connection of pressure. The free end of the tube is closed and is connected with a marker on the scale. During the effect of the internal pressure the tube is trying to change the cross-section into the circular and consequently the original curvature changes to a circle of larger radius and the free end of the tube performs a movement.

Figure 3: Bourdon tube pressure gauge

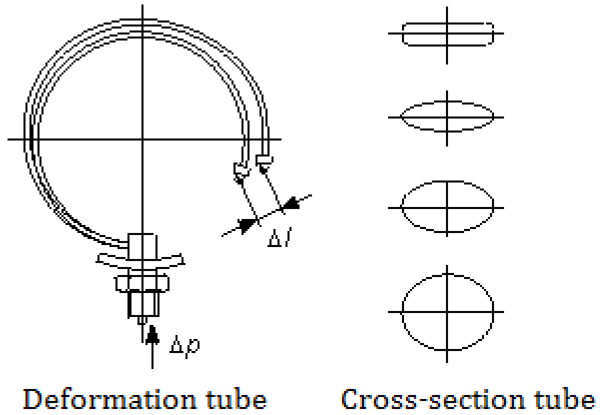


Figure 4: Bourdon tube (with examples of cross-sections) [13][14]

Measuring ranges tube pressure gauges are from 0 to 0.5 MPa to 2 GPa. Tube gauges (Bourdon tube) is commonly used for measurement overpressure (underpressure).

Other possible of deformation pressure sensor includes a membrane manometer where pressure measurement element is a metal membrane, this method is suitable for measuring very quickly pulsating pressures. Other options are boxed and bellows

gauges used mainly in barometric pressure or in regulation technology (pneumatic transmitters, transducers, etc.). [12][13][14]

The main advantages of deformation gauges are:

- The robustness of the design
- Small size and low weight
- Simplicity and reliability in operation
- Simple operation and maintenance
- Large measuring range

The disadvantages include:

- Limiting the use of the measuring range according to the character of operation
- Permanent deformation sensing element during operation

3.3.2 Capillary pressure gauges

They are the simplest capillary pressure gauges, which are mainly used as a laboratory for very accurate measurement of small to medium pressure. The size of pressure is given by the height of the liquid column. As a liquid pressure measurement is the most commonly used water, mercury or oil. The principle of operation is based on the effect of hydrostatic pressure, which draws column liquid according to the formula $(p = h \rho g)$. Liquid pressure gauges are based on the balance of the measured pressure and pressure effects liquid column. Construction and principle are suitable for pressure and differential pressure. As the liquid filling is used a large amount of substances, particularly water, ethyl alcohol, kerosene and benzene. [14][15]

3.4 Temperature Measurement

Temperature is one of the most important thermodynamic properties, which determine the state of the substance and appears on many physical laws. [14][16]

Temperature scales differ in some ways:

- Kelvin temperature scale (K) is the base unit of thermodynamic temperature measurement (T) in the International System (SI) of measurement. It is defined as 1/273.16 of the triple point of pure water.
- Celsius temperature scale (°C) is the scale based on 0 for the freezing point of water and 100 for the boiling point of water, it is derived from Kelvin thermodynamic scale. Celsius temperature (t) is equal to the difference of thermodynamic temperature (T) and temperature 273.15 K according to the formula:

$$t(°\mathrm{C}) = T - 273.15\,K \tag{3}$$

3.4.1 Dilatation thermometer

They are based on thermal expansion of substances (solid, liquid or gas), when the volume of the substance depends on its temperature. According to the construction of the dilatation thermometers which divided into:

- Rod Thermometer: They are based on the different thermal length expansion of two construction parts of the solids, which are connected at one site. Temperature range up to 1000°C.

Figure 5: Rod thermometer

- Bimetallic Thermometer: They are based on the different thermal expansion of two metallic materials. Temperature range from -100°C to 500°C.

- Glass Thermometer: They are based on the thermal of volumetric expansion of the liquid in the glass. Glass thermometer consists of a bank thermometer, measuring capillaries, packing tubes and scale plate. Temperature range from -190°C to 600°C.

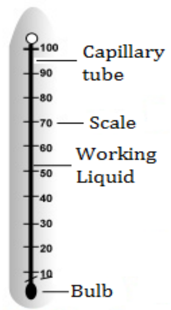


Figure 6: Glass thermometer

- Liquid Pressure Thermometer: Principle liquid pressure thermometers are the same as glass thermometers but measurement of volume expansion is converted into pressure measurement. Most often is filled with mercury and the temperature range from -30°C to 500°C.

Figure 7: Liquid Pressure Thermometer

- Vapor-Pressure Thermometer: It works on the principle of measurement saturation vapor pressure thermometer liquid in a closed system. Temperature range from -270°C to +350°C.

Figure 8: Vapor-Pressure Thermometer

- Gas Pressure Thermometer: A gas thermometer measures temperature by the variation in volume or pressure of a gas. It is filled with gas most often nitrogen. Temperature range from -250°C to +800°C. [14][16]

Figure 9: Gas Pressure Thermometer

3.4.2 Metal resistive sensors

The principle of metal resistive temperature sensors is the temperature dependence of resistance of the metal on the temperature, metal with rising temperatures is also a rising resistance and the most often used metal materials such as platinum, nickel, copper. Today is one of the most thermometers used in the laboratory which is used for measuring wide range temperatures from -200 °C to +800 °C. [14][17]

Figure 10: Metal resistive sensor

3.4.3 Semiconductor resistive sensors

Semiconductor resistive sensors use the same as metal resistive temperature sensors the temperature dependence of the resistance. Thermistor (resistor) is one of the basic semiconductor resistive sensors which the temperature dependence is about ten times greater than the resistance thermometers (metal resistive temperature sensors), but nonlinear.

Thermistors are typically designed to be used up to 150 °C, exceptionally up to 300 °C. Due to the small size of thermistors, thus the small time constant of the response, there is a bigger risk of the electrical overloading (power supply higher current causes excessive heating).

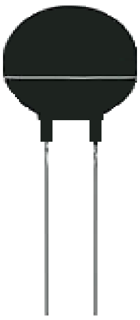


Figure 11: Thermistor

The advantage of the thermistor compared to the resistance thermometers is the high dependence of resistance on temperature, thus the quick response and the disadvantage is the nonlinear dependence of resistance on temperature, the lower stability and reproducibility, and a smaller range of applicability. [16][18]

3.4.4 Thermocouples

Thermocouples convert a thermal energy into an electric energy, the principle is based on the Seebeck Effect which was discovered by T.J Seebeck in 1821, he discovered that when two metals of different wires are joint together and if temperature of the junctions is different then a voltage flows through the wires. Seebeck effect arises because that in the warmer parts of the conductor, the charge carriers has is bigger
energy, therefore penetrate into the colder places. [16][19][20]
His experiment proved that a voltage exists between the two ends of a conductor when the conductor's ends are at different temperatures, his work showed that this voltage is proportional to the temperature difference. They are cheap, interchangeable, fast response, they do not need a power source, during the measurement do not show the measured heat flow as resistance thermometers and can measure a wide range of temperatures. The disadvantage is a lower precision and less reproducible.

4. Saturated steam

The vapor which is in equilibrium with its liquid is called saturated steam and saturated steam is produced in an enclosed space with rising temperature proportional to the increasing pressure. It is in equilibrium with the water phase and it is in constant contact.

In the initial phase of evaporation the liquid in a closed container, the number of molecules which are leaving the liquid is greater than the number of molecules which are returned back into a liquid (Figure 12a). The volume of liquid is reduced and at the same time the density and vapor pressure is increased. After some time, the number of returning and leaving molecules will be aligned (Figure 12b).

A volume of vapor and liquid does not change, the pressure and density of the whole system remains constant. [28][29]

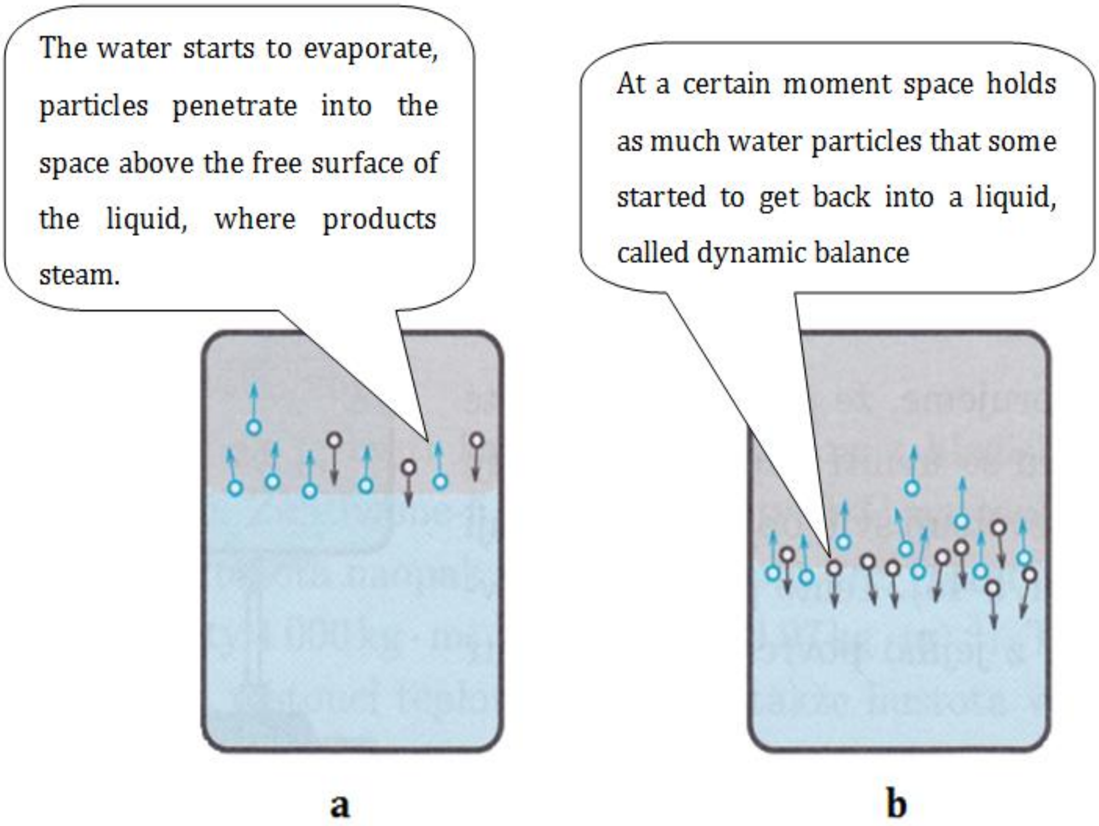


Figure 12: Formation of saturated steam [28]

4.1 Physical parameters of saturated steam

At a constant temperature of the saturated steam pressure does not depends on the volume of steam. If the volume of the space above liquid isothermal increases, part of the liquid will evaporate and once again will create the equilibrium relationship. For this reason saturated steam does not apply for the state equation for an ideal gas, saturated steam is substantially different from the ideal gas. [28]

Another important characteristic is the growth of the saturation vapor pressure with increasing temperature of the liquid. If there is an increase in temperature of the liquid and its saturated vapor, the internal energy of the system will increase. Evaporate another part of the liquid, which has the effect of increasing the density and mean velocity of molecules of saturated steam. These changes cause an increase of pressure. The dependence of the saturation vapor pressure at the temperature can be seen in (Figure 13). The graph of dependence pressure of saturated steam at a temperature is called the curve of saturated steam, where each point corresponds to one state when system saturated vapor and liquid are in equilibrium state. Dependence is determined by the temperature T and pressure p, this dependence is not linear and is different for different substances.

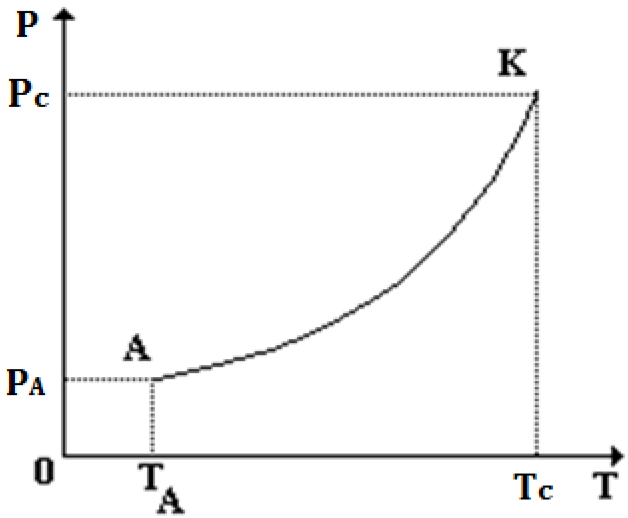


Figure 13: The curve of saturated steam [28]

Starting point *A* corresponds to the smallest value of the temperature T_A and pressure p_A where saturated vapor and liquid are in equilibrium state. The temperature T_A is the temperature of solidification at a pressure p_A. While increasing the temperature of the liquid equilibrium system increases the density of saturated steam, while the density of the liquid decreases, but the interface between the saturated vapor and liquid is completely clear.

However, with a steady increase temperature occurs to the critical temperature T_C, where is the density of saturated steam is equal to the density of the liquid, between the liquid and the saturated vapor interface disappears, and the substance becomes homogeneous.

At temperatures higher than the critical temperature, the substance in the liquid state does not exist. Therefore, the saturated steam curve ends at point *K* which is called the critical point, it is the endpoint of the curve saturated steam and shows the critical state of the substance. Critical status is determined by the critical temperature T_C, critical pressure *Pc* and density ρ_K.

From the curve can also gain important information and it is the boiling temperature of the liquid at a certain pressure. If the liquid boils, it will be creating inside bubbles saturated steam, which increases its volume and output to the free surface of the liquid. This process occurs when the saturation vapor pressure inside the bubble is equal to the external pressure. In case of increases the external pressure the result is boils up when saturated steam pressure increase. [28]

4.2 Parameters of saturated steam for sterilizing chamber

The sterilizer must be designed to operate with steam power, which has not more than 2 m from the connection sterilizer included steam trap.

The use of saturated steam for sterilization leads to the best and fastest results. However, it is necessary to observe certain parameters that lead to these results, one of the basic parameters are temperature characteristics. Duration keeping the temperature not less than 15 min, 10 min and 3 min for the respective sterilizing temperature of 121 °C, 126 °C a 134 °C. The temperature of saturated steam must be calculated according to equation:

$$T = A + B\,(InP + C)^{-1} \tag{4}$$

Where *T* is the temperature of saturated steam in Kelvin, *P* is the time-averaged measured pressure in *MPa*, *A* equals 42.6776 *K*, *B* equals to -3892.7 *K* and *C* equals
-9.48654 *K*.

Parameters leading to the best possible saturated steam sterilization include the:

- Dryness: Not less than 0.95 for metal objects and 0.90 for other types
- Impurities: Steam for sterilization chamber must not contain impurities in such an amount that might disturb the sterilization process or damaged or contamination of the sterilizer.
- Overheated steam: When the supplied steam is expanded to atmospheric pressure overheated steam must not exceed 25 °C.

- Non-condensable gases: Saturated water steam must contain no more than 3.5% of the non-condensable gases. [30]

Table 8: Pollution of condensate from steam generator in the sterilizer [30]

The decisive factor	Condensate
Silica (SiO_2)	≤0,1 *mg/l*
Iron (Fe)	≤0,1 *mg/l*
Cadmium (Cd)	≤0,005 *mg/l*
Lead (Pb)	≤0,05 *mg/l*
Residues of heavy metals except Iron, Cadmium and Lead	≤0,1 *mg/l*
Chlorides	≤0,1 *mg/l*
Phosphate (P_2O_5)	≤0,1 *mg/l*
Conductivity (at 25 °C)	≤3 *µS/cm*
pH (degree of acidity)	5 to 7
Appearance	colorless, clear and free from debris
Hardness	≤0,02 *mmol/l*

5. Electronic control system of pure steam generator with plate exchanger

For the control system of the steam generator was used system with a central processing unit AD-CPUW2 (AMIT), which contains controller core, RAM, power supply, circuits serial lines and Ethernet interfaces. AD-CPUW2 has processor core designed in the form of DualCPU.
DualCPU represents the distribution of the communication and process component, where each of them controls a separate processor.

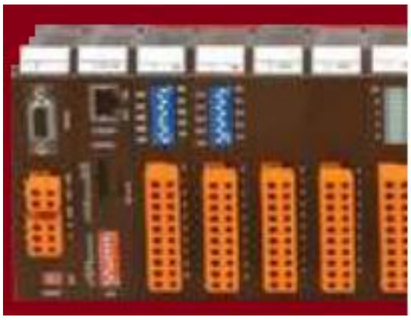


Figure 14: Central unit AD-CPUW2

Processors communicate with each other via SPI bus. The central unit contains the following communication protocols:

- RS232 interface
- RS485 interface
- Ethernet interface
- Slot for MicroSD card
- Web server

The central unit provides internal communication with other input / output modules, which then communicates with the individual sensors and valves. The whole system contains:

- 2 pieces of digital input units which collect binary data mainly from the system of security elements. Are used the unity of AD-DI8A - each with 8 isolated inputs.
- 1 piece of digital output units which are designed for controlling individual power components and control 16 of under pressure valve.
- 2 pieces of analog input units which are designed to scan all the physical quantities such as temperature and pressure.

- 1 piece of analog output unit which used to control the individual analog outputs, such as fan and inverter.

5.1 Electronic system for collecting data from individual sensors measuring physical

For the system of control and data collection of the sensors is used PLC (Programmable Logic Controller). PLC is relatively small industrial computer which is used in process automation in real-time. In our case, the PLC system for data collection and communication with superior PC, in which the measured data is stored. For data collection were used PLC company Elsaco, data were collected from all the sensors and visualization tool subsequently evaluated for graphical views and then saving to file. Data were collected at a frequency of 3 GHz for sensors that have a speed of response. For other sensors was the speed of one sample per minute.

According to the technical analysis of the whole system were selected mainly from places in the whole system for data collection, It was the points:

- Before exchanger - (temperature, pressure)
- After exchanger - (temperature, pressure)
- Before reduction valve of pressure - (temperature, pressure)
- After reducing valve of pressure (temperature, pressure)
- In the steam generator - (conductivity)
- Input of demineralised water - (conductivity)

In all these point measurements were done continuously from the start of system to completion and data were stored in text files. Subsequently, data were analyzed.

5.2 System Elsaco CCPU03 for data collection

CCPU-03 is a compact unit microcomputer system PROMOS line 2. It is intended as a central unit for larger assembly or as a separate communication central. The default is fitted with a USB interface for programming applications in the FRED and Ethernet interface for connection to a superior level control. It can optionally also be fitted with M-BUS channel for direct connection of smart meters, such as heat meters. The microcomputer is a good basis for jobs with complex computations and large memory requirements, such as regulators systems, compact regulators, units for collection and storage of data, etc. The unit consists of a processor module MCPU-01 motherboard input / output and board indication.

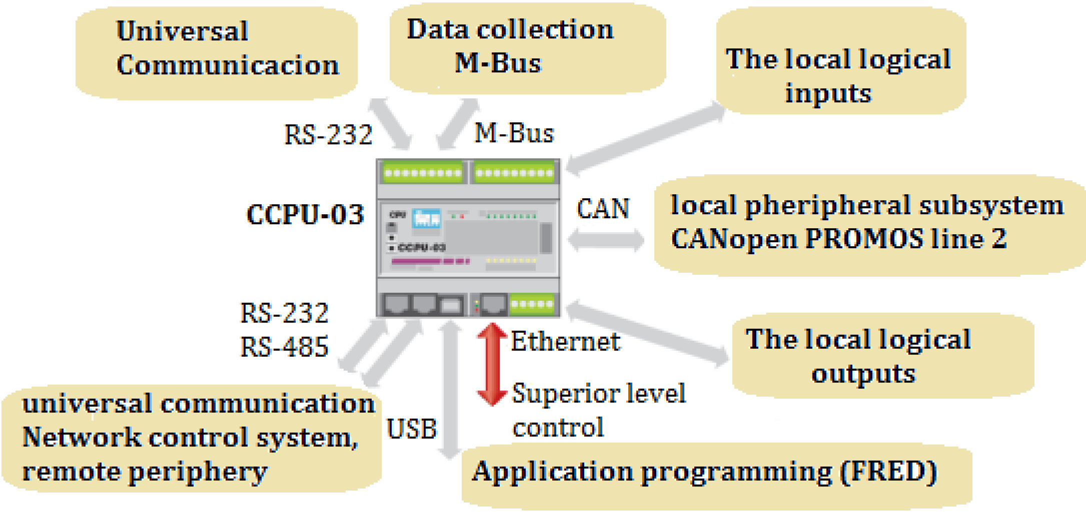


Figure 15: Communication options of the central unit CCPU-03

With these units, the whole system communicated with superior visualization tool, which subsequently saved data to a file. The central unit is equipped with both Ethernet and USB, which allowed remote and central monitoring of the whole process.

The central unit was attached to the universal analog module CAIO12, which ensures the collection of data from individual sensors.

5.3 CAIO12

CAIO-12 is a peripheral unit on the CANopen bus (CAN2.0A, the communication Speed 500 kb / s) with 12 universal slots for analog inputs / outputs. This unit was used to collect data from individual sensors at speed 3 Hz.

Control units and communication bus provides built-in microcomputer. On the front panel is selection switches network address of the module and to block the function of outputs. The bus is connected with the module by connecting bridges InCo or ten wire cables, which contains its own communication lines and power supply. The unit is constructed and arranged in a compact box, which is mounted on a DIN rail.

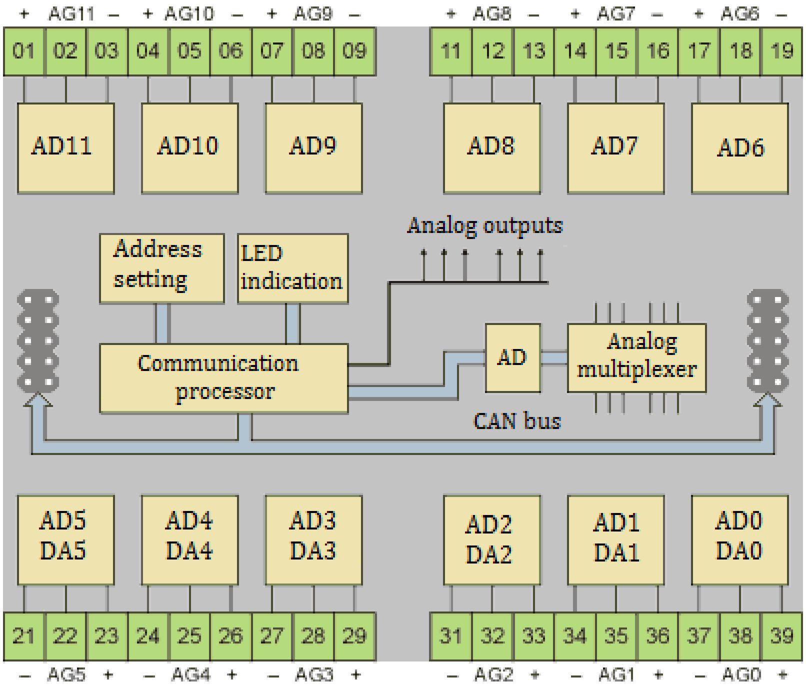


Figure 16: Block diagram of the CAIO-12

The (Figure 16) shows a part of the visualization which used to characterize the whole system and as a helper during distribution of individual measuring nodes.

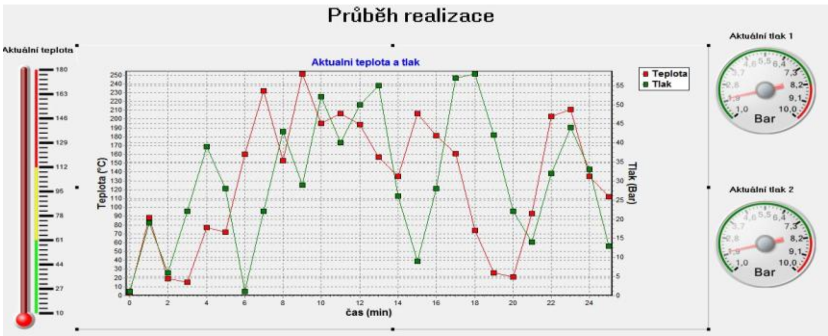


Figure 17: Realization process

At each measuring point is placed a temperature sensor, pressure possibly conductivity according to characteristics of individual measurement nodes. Data from individual sensors are sent either after industrial bus RS485 to PLC, or are loaded directly from the converter temperature / current in PLC. Then data is sent by TCP / IP protocol to the central PC, which is set on-line communication with the PLC.

6. Filtration signal

Filters play a vital role in data acquisition systems to remove selected frequencies from an incoming signal and minimize artifacts (i.e. mains interference and noise). Signal filtering is often used to eliminate unwanted frequencies from the receiver signal. [31]

6.1 Types of filters

There are two standard filters found in most impedance plane display instruments, they are the high pass filter (HPF) and low pass filter (LPF). Some instruments also have a band pass filter (BPF), which is a combination high and low pass filter. Filters are adjusted in Hertz *(Hz)*.

6.1.1 High Pass Filter (HPF)

The high pass filter is one that passes high frequency signals and filters out the low frequencies. The HPF is basically filtering out changes in the signal that occur over a significant period of time and is used to eliminate low frequencies which are produced by slow changes.

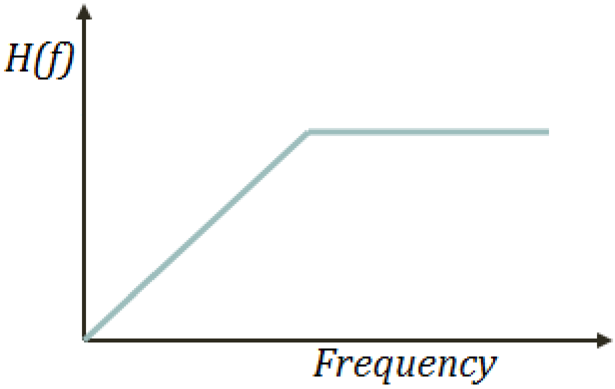


Figure 18: High pass filter

6.1.2 Low Pass Filter (LPF)

The low pass filter is one that passes low frequency signals and filters out the high frequency. In other words, all portions of the signal that change rapidly (have a high slope) are filtered, such as electronic noise. The main function of the LPF is to remove high frequency interference noise. Lowering the LPF frequency will remove more of the higher frequencies from the signal and produce a cleaner signal.

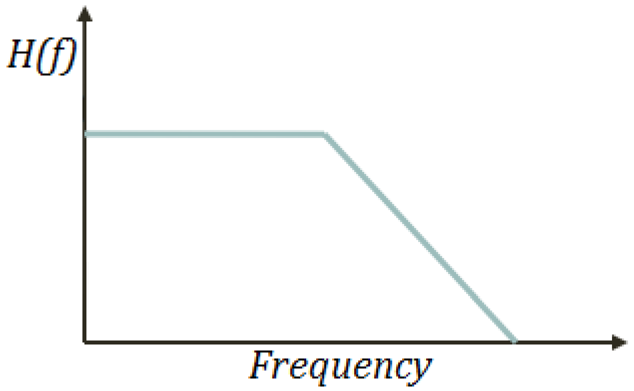


Figure 19: Low pass filter

6.1.3 Band Pass Filter

The band pass filter allows a specific range of frequencies to pass, while blocking lower and higher frequencies.

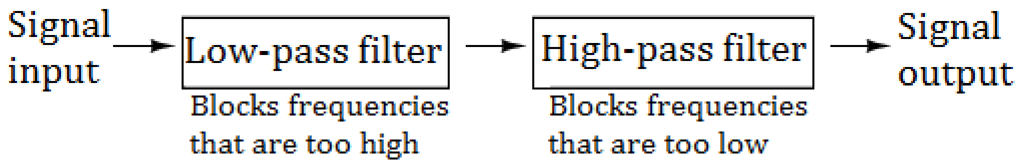


Figure 20: Diagram of band pass filter [32]

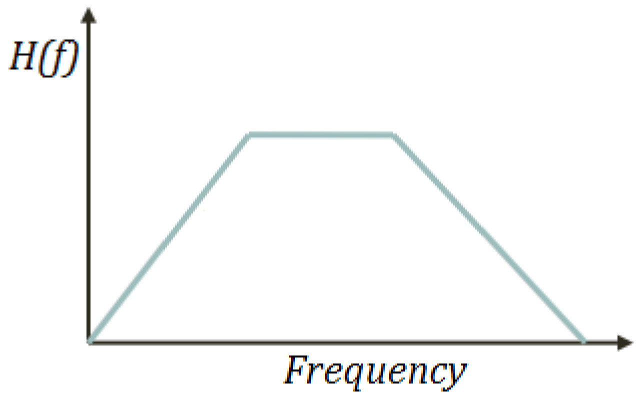


Figure 21: Band pass filter

6.1.4 Median filter

Median filter belongs to the non-linear filters which operate on the principle of separation. It is used mainly to suppress the impulse noise. Median filter takes for each pixel in the image of its surroundings. Of all those pixels selects the median, which becomes the new value of the processed pixel and this value is written to the central of pixel. The advantage of the median filter is preserving the edges of objects. [36][37]

7. Connecting the System

7.1 The selected sensors for measuring physical parameters

To measure the electrical conductivity of sensors are used from the company JUMO series T20.2924. These sensors are made of stainless steel. Two-electrode system is used for detecting the extent from 0.05 *µS/cm* to 1 *mS/c*, using this sensor is suitable for temperature up to 200 *°C* and pressure of 17 *bar*. In the system there are three sensors for conductivity at different levels of the steam generator. As a converter for conductivity sensor is used converter JUMO series T20.2731. Converter works on the principle of the current loop (4-20 *mA*). [33]

As the temperature sensors are selected sensors for industrial applications JUMO of series T90.2020. Pt100 - 3 wire connections is suitable for measuring ranges from -50 *°C* to 400 *°C*. In the system is connected 7sensors, 4 of them having a length of 80 *mm* and the remaining 3 have a length of 160 *mm*. These sensors are already connected with converters which operate on the principle of the current loop (4-20 *mA*). In the system there are four Pt100 JUMO, series T90.2150 which can be moved because of the possible measurements on different locations in the system. These sensors are working again in the range from -50 *°C* to 400 *°C*. Converters for these sensors are STI and STID from the company Sensit that also operate on the principle of current loop (4-20 *mA*). [33][34]

For the pressure sensing is used a pressure sensor JUMO, T40.3025. The range of detection is from 1 *bar* to 6 *bar* and can work at temperatures up to 200 *°C*. The base is a silicon sensor with a membrane of stainless steel. In the system there are three pressure sensors, and again are connected with the converter, which is also based on the principle of current loop (4-20 *mA*). [33]

The last parameter of sensed is humidity, which is recorded by a sensor EE31 from the company E + E. The basis of this sensor is stainless steel, covered with polycarbonate or strong metal sheath. Also this sensor is based on the principle of current loop (4-20 *mA*). Using this sensor and humidity sensing is generally only additional measurement because the sensor is not calibrated to such a high temperature, which is located in the system. Its values are only indicative and rather than exact values, indicate a change of humidity in the system. In addition, the humidity of pure steam flowing into the sterilizer is the minimum. [35]

7.2 Schematic diagram of clean steam

The system begins supplying demineralised water using pumps and check valves. Measurement of water flow is provided by connecting the water meter. After this part of the system followed by the location of the pressure expansion vessel, which is responsible in case of decrease flow of demineralized water this flow increase. For the exact control of the flow demineralized water into a system after the pressure vessel located manometer, which is separated from the system by manual shutoff valve. For the flow correction is after the manometer located control valve with pipe reductions. Subsequently, into the system is located plate heat exchanger Alfa-LAVAL which has the task preheated demineralized water flowing into the steam separator. Preheating is secured technical warmer condensate, which is conversely drained out of the system. Part of demineralized water is then fed to a steam separator and part is guided through the plate heat exchanger where it is heated. The steam separators are available in three different levels of demineralized water placed three sensors for measuring conductivity. The location of these sensors is selected to analyze the purity of the water in the whole volume of the separator.

Data collected by the sensors will continue within the diploma thesis processed. That the water level does not exceed the maximum level is connected to the separator chamber level control. In this chamber are two regulators of the water level in the boiler, limiting device of the lowest water level and limiting device of the highest water level (Figure 22).These regulators are connected to a regulating valve at the beginning of whole system which if necessary, the flow amplified or muted. Excess amounts of demineralized water from the chamber level regulation diverted directly to waste. From the steam separator is also generated pure condensate led away into the chamber blowdown where the sensor is located for any measurement of electrical conductivity of condensate. Furthermore, pure condensate is discharged from the system through the regulating valve and cock off. Inside the steam separator is placed temperature display for instant control steam temperature and pressure steam display for pressure control. From the top of the separator via the manual shut-off valve drained pure steam. This steam is measured by a pressure sensor, humidity and temperature. The steam flow pipeline to reduction, control valve and other pipeline reduction. After the this part is placed again on the triad sensor pressure, humidity and temperature, for the case that the regulating valve and pipe reduction had an influence on the measured parameters of steam and possible correction of the steam flow. The measured values obtained on both triads of sensors, will continue in the thesis processed and evaluated. Before the flow of pure steam to each sterilizer is connected to the system temperature display and a pressure regulator which is connected to a regulating valve (Figure 22)

Into the system is also supplied technical steam whose the flow is regulated by the regulator pressure and controlled pointer pressure and temperature. Technical steam flows through the filter, followed by a pair of pressure pointer steam. These pointers are located regulating valve flow correction steam. After regulators is placed a plate heat exchanger Alfa-LAVAL, where there is a preheat part of demineralised water with hot technical steam to give vapor flowing into the separator. From the technical steam is then formed condensate, part of which is directly drained into waste. The remainder of the condensate is using condensate drain directed to the cache condensate. Technical condensate is then used to heat the demineralized water flowing into the system. Before diverting technical condensate from the system itself condensate pressure and temperature sensed.

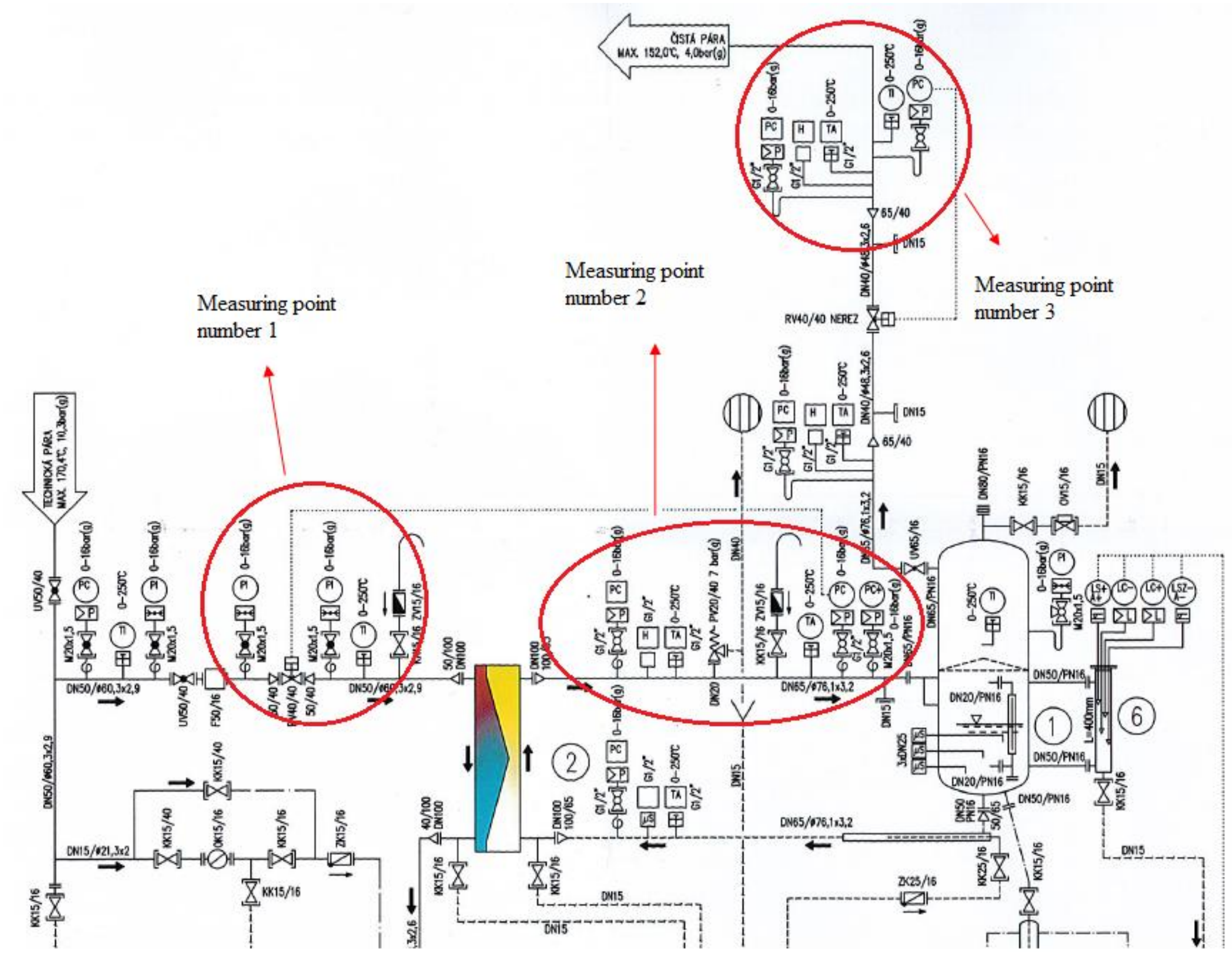
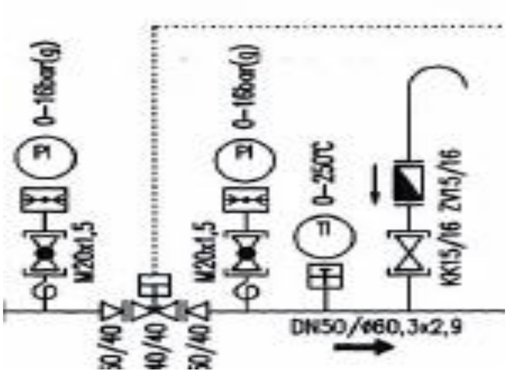


Figure 22: Schematic diagram of clean steam

In the schematic diagram (Figure 22) of the proposed generator of steam as the test system. This system is designed for catering the maximum of 5 units of sterilizers. In the future, it is assumed 4 times larger model for the supply of hospital departments.

The above images are drawn in total 3 measurement zone (points), in which are located the individual sensors measuring temperature and pressure. These zones were selected based on their presumed significance on the final quality of steam.

- Measuring point numbers 1 - Preview element measuring point, figure on the right.

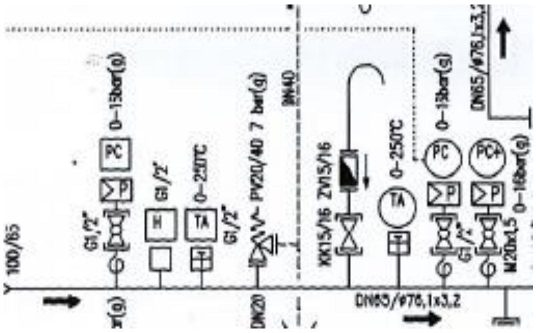


  It is a main point which character quality parameters and industrial steam, which then is used as a source of energy to produce clean steam from demineralized water. This point is classified as significant in terms of its principal energy properties to heat demineralized water in pure steam.

  This measuring point contained sensors:

  - ➢ Pressure - JUMO series T20.2924 (0 - 250 °C)
  - ➢ Temperature application JUMO series T90.2020. Pt100, temperature range (50 - 400 °C)

- Measuring point numbers 2 - Preview element measuring point, figure on the right.

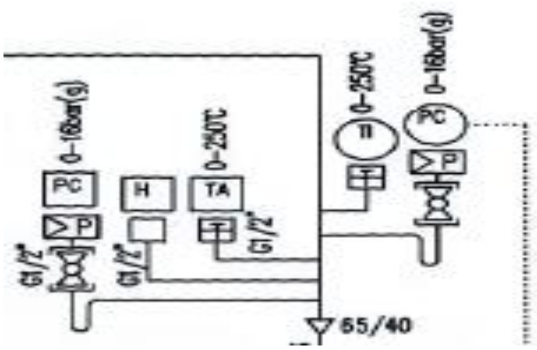


  It is a main point which character energy balance of pure steam, exchangers parameters and individual fluctuations in the fluctuating pure steam. This point is classified as significant in terms of its principal energy properties to heat demineralized water in pure steam.

  This measuring point contained sensors:

  - ➢ Pressure - JUMO series T20.2924 (0 - 250 °C)
  - ➢ Temperature application JUMO series T90.2020. Pt100, temperature range (50 - 400 °C)

- Measuring point numbers 3 - Preview element measuring point, figure on the right.
  It is a main point which character parameters of pure steam and physical output parameters for the whole sterilizer. This point is classified as significant in terms of its parameterization of clean steam output and changes the properties of the regulating valve.



  This measuring point contained sensors:

  - Pressure - JUMO series T20.2924 (0 - 250 °C)
  - Temperature application JUMO series T90.2020. Pt100, temperature range (50 - 400 °C)

Figure 23: Photographic picture of the prototype PA (left) and PB in non-insulated state and control unit with display to observe the physical changes of media in the production of clean steam.

Figure 24: osmosis unit integrated into the production of clean steam

8. Evaluation of the measured data

With regard to the complexity and range measurements and other experimental tests for the these purposes the company ESL a.s. has built an experimental work on the company premises as heating plant Brno. The reason for choosing the place of the workplace was in particular that there is a sufficient amount of technical steam, drinking water and in addition chemical laboratory is able to assess the quality of clean steam and condensate in accordance with the requirements of norm CSN EN 285+2A.

Because in Czech Republic has not been enough experience with measuring parameters of clean steam and there is no certified workplace that deals with this issue.

In the first stage of the experimental work were tests including physical and chemical measurements carried out on non-insulated equipment. Data that are component of this thesis are by insulated system, which is expected for the commercial use.

The following sections contain the results of the measurements for one of the three measuring points.

8.1 Temperature measurement - measuring point number 1

Temperature is one of the most important parameter for obtaining the quality steam of the sterilization. It is measured using a platinum sensor just after the steam generator, when it flows into clean steam sterilizers. Several sensors are located in other parts of the system to better understand the events that take place in the generator. To extend the measurements are still used data from sensors that are placed before (measurement point number one) the plate heat exchanger and after (measurement point number two). There is thus the technical measurement of steam and steam resulting from the demineralized water in the heat exchanger. This data was provided by the cooperating company.

Measurements were carried out at steady system, which has been turned off removal blowdown of condensate and also topping up water was set at minimum. This is not a real operating system, but for evaluation of the whole system, we were forced to minimize factors that would complicate the analysis of the whole system. In this mode, the steam generation system is not fully automated and necessary human intervention in the process.

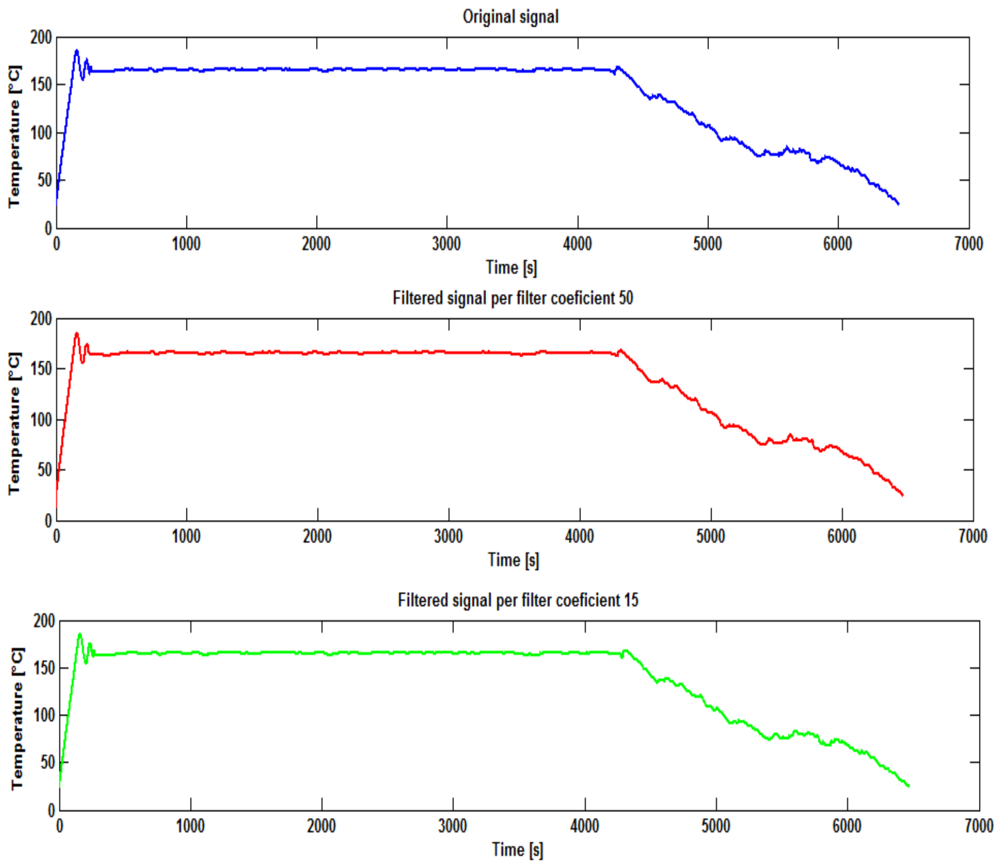


Figure 25: Signal measurement point number 1, date of measurement 10.2.2104 – 10:15

a) Original signal b) Filtration coefficient 50 c) Filtration coefficient 15

In the (Figure 25) describe the process of measurement on the temperature sensor, we can see the original signal which was collected through PLC directly from the given sensor also we can see the filtered signal per filter coefficient 50 which was smoothed by using the median filter which served to me be seen clearly each event, simply the individual changes of the characteristic and the subsequent filtered signal per filter coefficient 15 which served to evaluate the individual events.

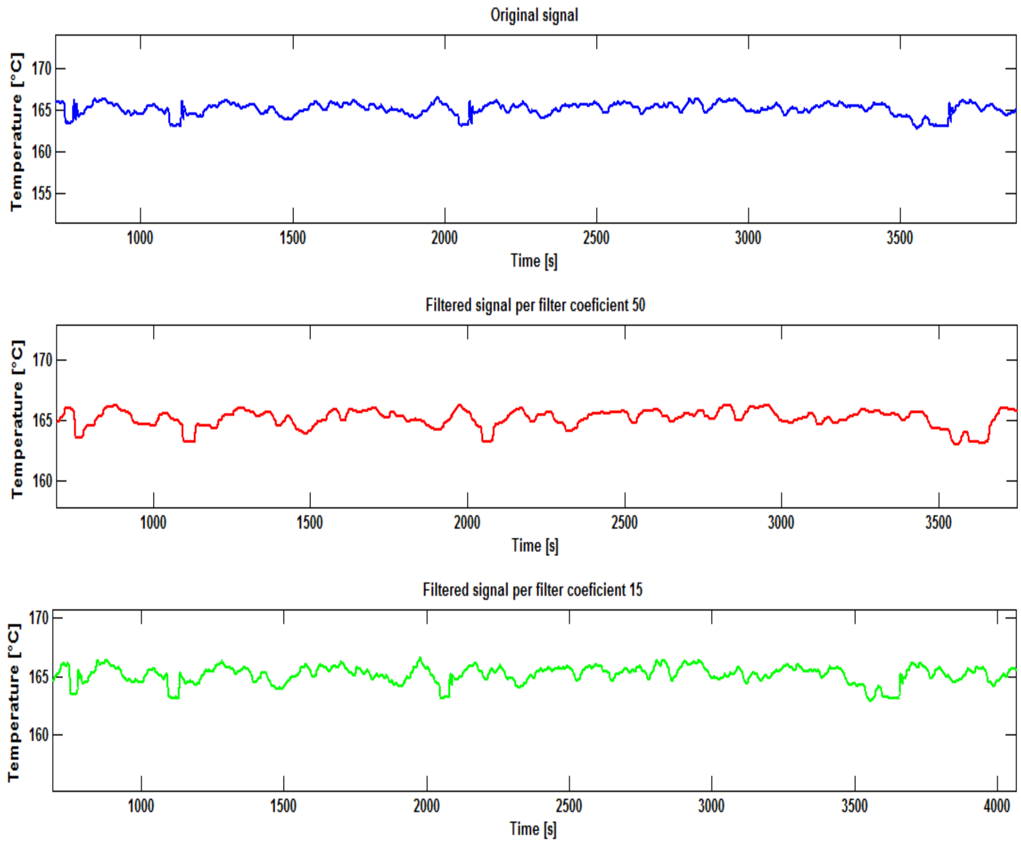


Figure 26: Cropping a useful signal measurement point number 1, date of measurement 10.2.2104 – 10:15

a) Original signal b) Filtration coefficient 50 c) Filtration coefficient 15

The above (Figure 25) is the same as (Figure 26) but it is a view larger image which is shown in more detail process measuring pure steam, smoothed by using the median filter and this figure is served to define the individual changes of events. It could be seen events of temperature values in dependence on time which caused by running flow of pure steam into the sterilizer.

In these figures are shows the coordinates of the beginning and the end of each event which is subsequently analyzed in Chapter 8.4.

On the following (Figure 27) is the measurement point number one, event number one which shows the first event value of temperature pure steam depending on the time when running one of the third sterilizers, it is also shown individual values of the upper limit, lower limit, right limit and left limit.

Events in the signal are caused by running the flow to the first sterilizer, twice in the second sterilizer, three times in the third sterilizer and the last event is four times in the fourth sterilizer.

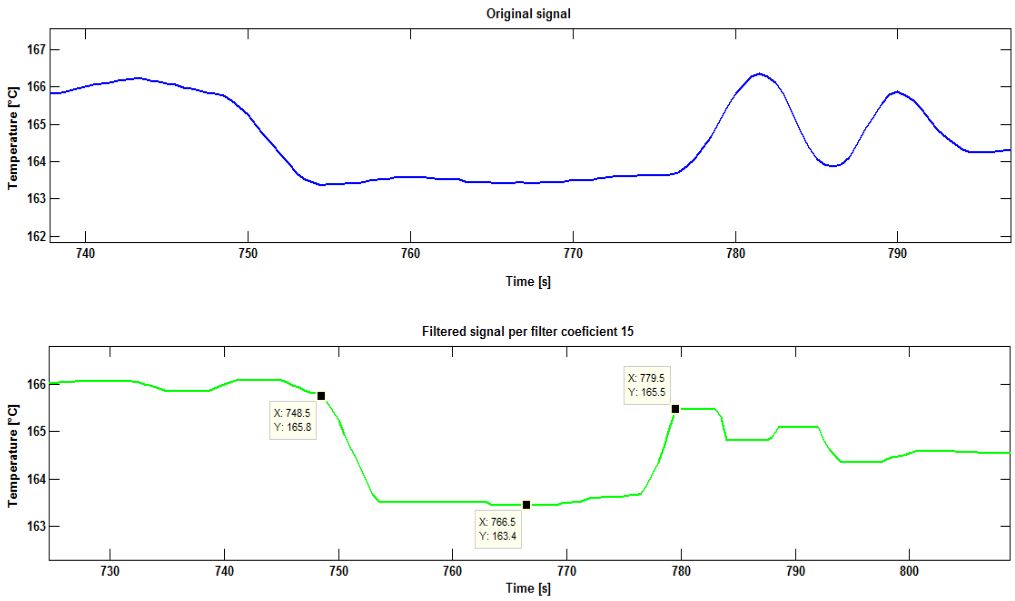


Figure 27: Cropping a useful signal measurement point number 1, event number 1, date of measurement 10.2.2104 – 10:15

a) Original signal b) Filtration signal coefficient 15, event number 1

On the following (Figure 28) is the event number two of measurement point number one which shows the second event value of temperature pure steam depending on the time when running two of the third sterilizers, it is also shown individual values of the upper limit, lower limit, right limit and left limit.

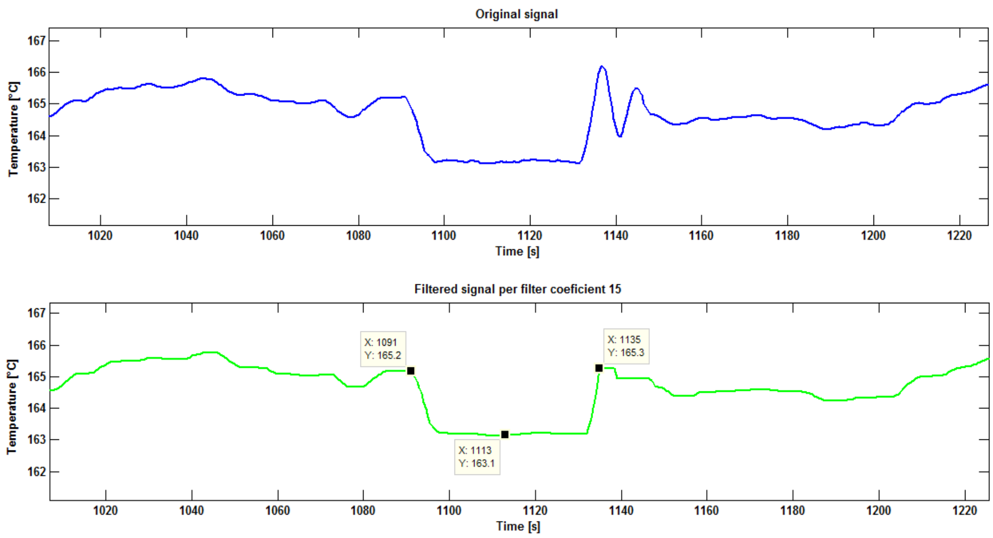


Figure 28: Cropping a useful signal measurement point number 1, event number 2, date of measurement 10.2.2104 – 10:15

a) Original signal b) Filtration signal coefficient 15, event number 2

On the following (Figure 29) is the event number three which shows the second event value of temperature pure steam depending on the time when running two of the third sterilizers, it is also shown individual values of the upper limit, lower limit, right limit and left limit.

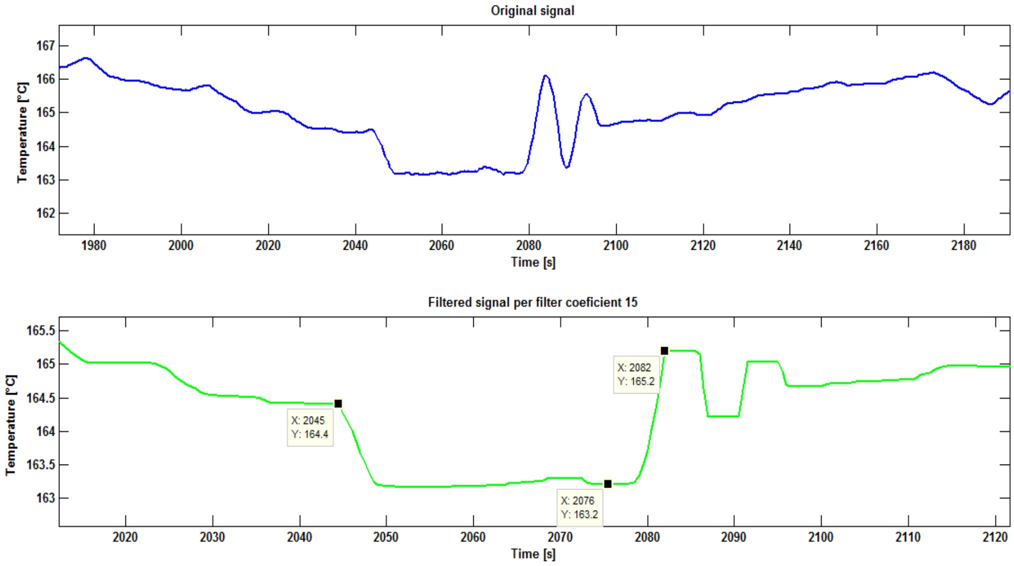


Figure 29: Cropping a useful signal measurement point number 1, event number 3, date of measurement 10.2.2104 – 10:15

a) Original signal b) Filtration signal coefficient 15, event number 3

On the following (Figure 30) is the event number four which shows the third event value of temperature pure steam depending on the time when running all the third sterilizers.

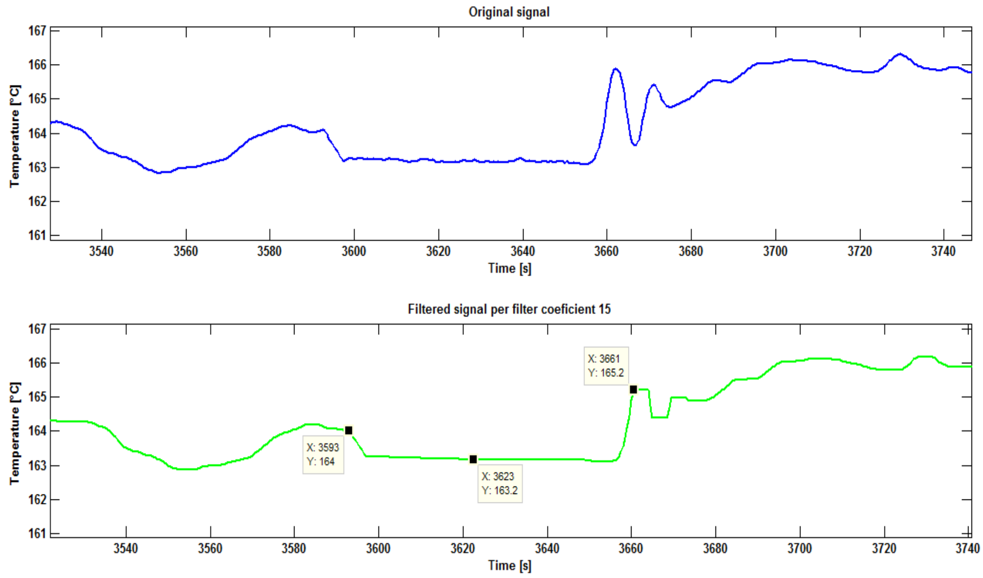


Figure 30: Cropping a useful signal measurement point number 1, event number 4, date of measurement 10.2.2104 – 10:15

a) Original signal b) Filtration signal coefficient 15, event number 4

Table 9: Characteristics of individual event measuring point number one

Measuring point number 1 - 10.2.2014 – 10:15				
	1 Sterilization (stabilization 5 min)	2 Sterilization (stabilization 5 min)	2 Sterilization (stabilization 10 min)	3 Sterilization (stabilization 5 min)
Maximum temperature of events (°C)	165,8	165,2	164,4	164
Minimum temperature of events (°C)	163,4	163,1	163,2	163,2
Difference heights of event (°C)	**2,4**	**2,1**	**1,2**	**0,8**
Start realization of events (s)	748,5	1091	2045	3593
End realization of event (s)	779,5	1135	2082	3661
Difference Width of event (s)	**31**	**44**	**37**	**68**

The above (table 9) shows the characteristics of individual events during simulated 1-3 sterilizers in stabilization times of 5 and 10 min. The table shows the height and width of each event depending on the number of opening sterilization. It is a measuring point number one, date of measurement at 10.02.2014 and time of measurement at 10:15.

8.2 Pressure measurement – measuring point number 3

The next measurement was the vapor pressure, which is sensed again in a stable system. Pressure is recorded not only for pure steam, but also for steam before (measurement point number one) heat exchanger and after (measurement point number two). As in the case of the steam temperature is sensed, one sample per second. Ten seconds before the steam flow into the sterilizer until two minutes after stopping the flow, are recorded two samples per second.

In these figures are shows the coordinates of the beginning and the end of each event which is subsequently analyzed in Chapter 8.5.

In the next (Figure 31) describes the process of measurement on the pressure sensor which was collected by PLC, we can see the original signal, below them is the filtered signal per filter coefficient 50 which was smoothed by using the median filter which served to me be seen clearly each event and the subsequent filtered signal per filter coefficient 15 which served to evaluate the individual events.

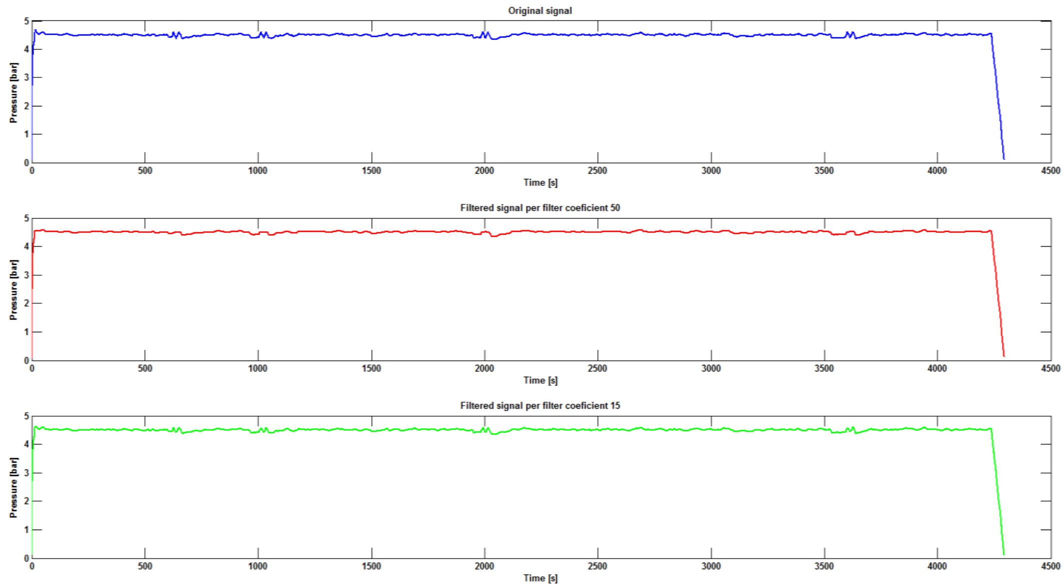


Figure 31: Signal measurement point number 3, date of measurement 15.4.2014 – 09:30

a) Original signal b) Filtration coefficient 50 c) Filtration coefficient 15

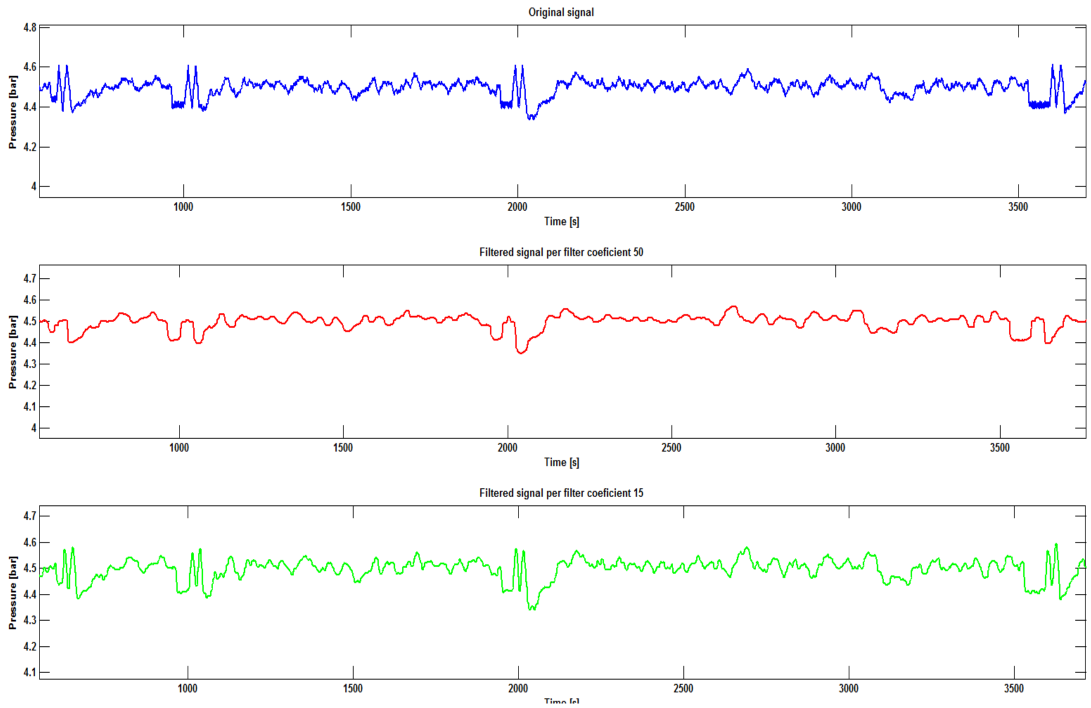


Figure 32: Cropping a useful signal measurement point number 3, date of measurement 15.4.2014 – 09:30

a) Original signal b) Filtration coefficient 50 c) Filtration coefficient 15

The above (Figure 31) is the same as (Figure 32) but it is a view larger image which is shown in more detail process measuring pure steam, smoothed by using the median filter and this figure is served to define the individual changes of events. It could be seen events of pressure values in dependence on time which caused by running flow of pure steam into the sterilizer.

In the following (Figure 33) is the measurement point number three, event number one which shows the first event value of pressure pure steam depending on the time when running one of the third sterilizers, it is also shown individual values of the upper limit, lower limit, right limit and left limit.

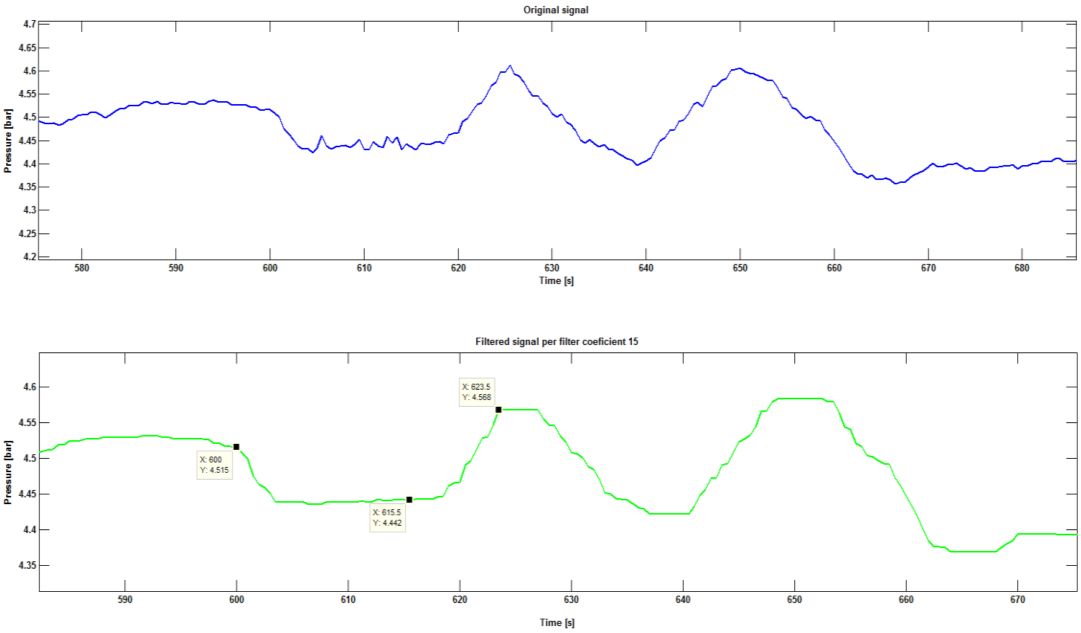


Figure 33: Cropping a useful signal measurement point number 3, event number 1, date of measurement 15.4.2014 – 09:30

a) Original signal b) Filtration signal coefficient 15, event number 1

On the following (Figure 34) is the event number two of measurement point number three which shows the second event value of pressure pure steam depending on the time when running two of the third sterilizers.

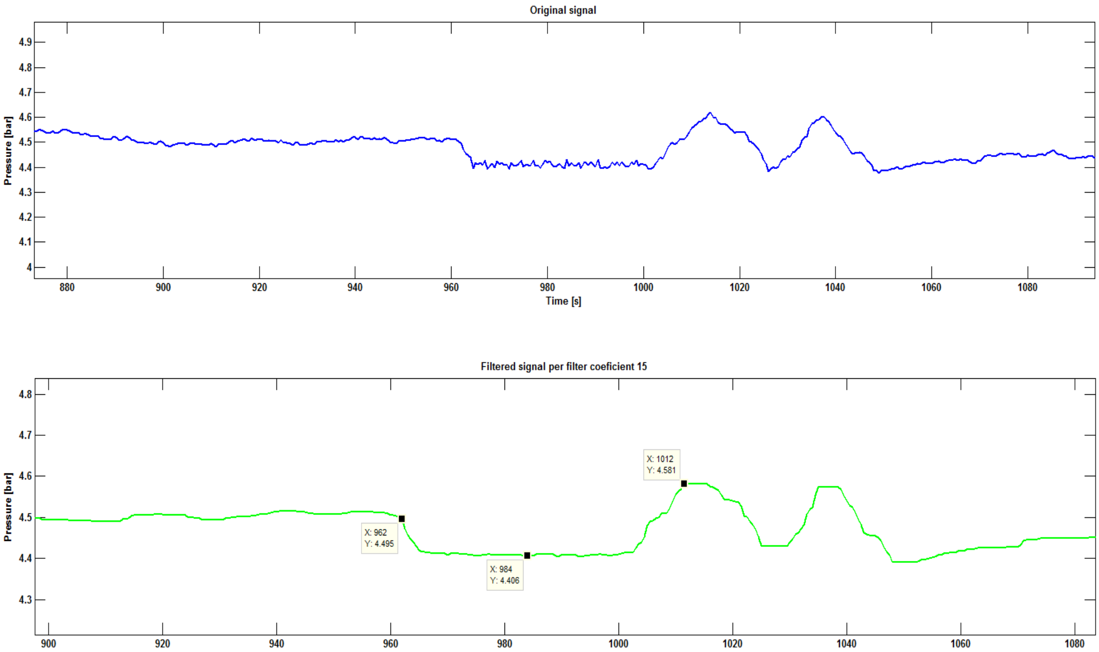


Figure 34: Cropping a useful signal measurement point number 3, event number 2, date of measurement 15.4.2014 – 09:30

a) Original signal b) Filtration signal coefficient 15, event number 2

On the following (Figure 35) is the event number three of measurement point number three which shows the second event value of pressure pure steam depending on the time when running two of the third sterilizers.

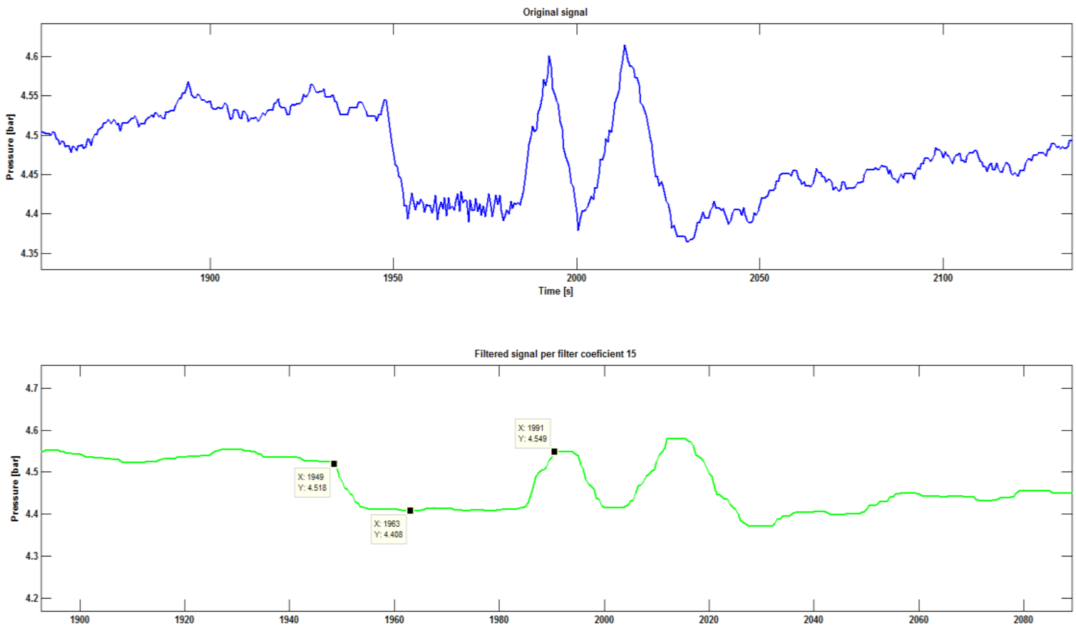


Figure 35: Cropping a useful signal measurement point number 3, event number 3, date of measurement 15.4.2014 – 09:30

a) Original signal b) Filtration signal coefficient 15, event number 3

On the following (Figure 36) is the event number four of measurement point number three which shows the third event value of pressure pure steam depending on the time when running all the third sterilizers.

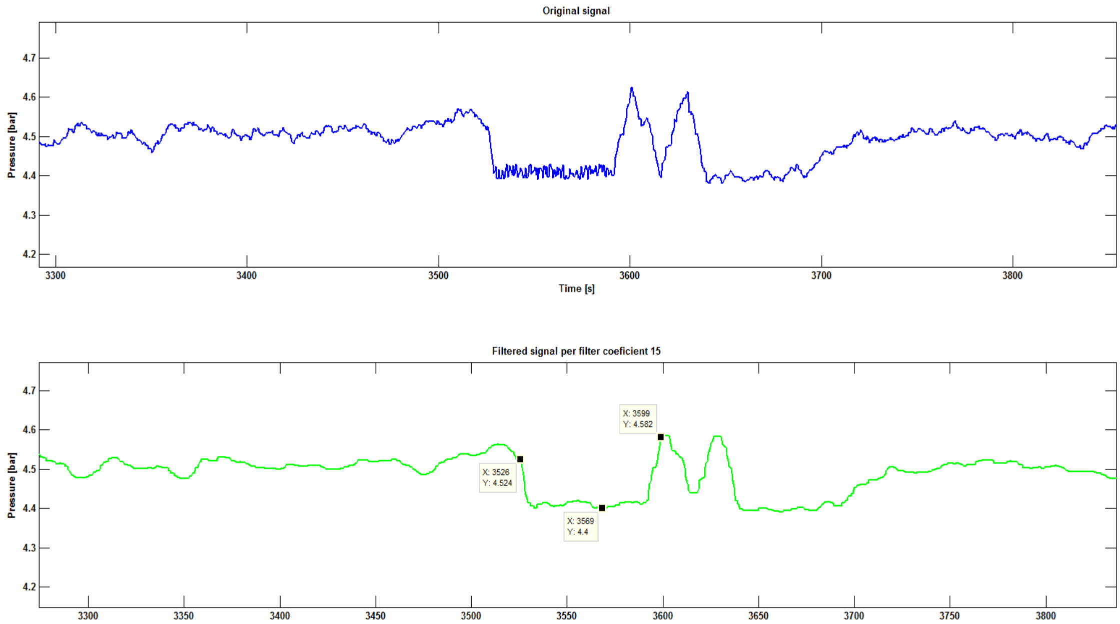


Figure 36: Cropping a useful signal measurement point number 3, event number 4, date of measurement 15.4.2014 – 09:30

a) Original signal b) Filtration signal coefficient 15, event number 4

Table 10: Characteristics of individual event measuring point number three

Measuring point number 3 - 15.4.2014 - 09:30				
	1 Sterilization (stabilization 5 min)	2 Sterilization (stabilization 5 min)	2 Sterilization (stabilization 10 min)	3 Sterilization (stabilization 5 min)
Maximum temperature of events (bar)	4,513	4,495	4,482	4,519
Minimum temperature of events (bar)	4,437	4,41	4,411	4,402
Difference heights of event (bar)	**0,076**	**0,085**	**0,071**	**0,117**
Start realization of events (s)	600,5	963,5	1949	3528
End realization of event (s)	625	1012	1991	3600
Difference Width of event (s)	**24,5**	**48,5**	**42**	**72**

The above (table 10) shows the characteristics of individual events during simulated 1-3 sterilizers in stabilization times of 5 and 10 min. The table shows the height and width of each event depending on the number of opening sterilization. It is a measuring point number three, date of measurement at 15.04.2014 and time of measurement at 09:30.

In the following (Figure 37, Figure 38, Figure 39, Figure 40, Figure 41 and Figure 42) shows the process pressure in the measurement of pure steam which was collected by PLC, process signal was smoothed by using the median filter.

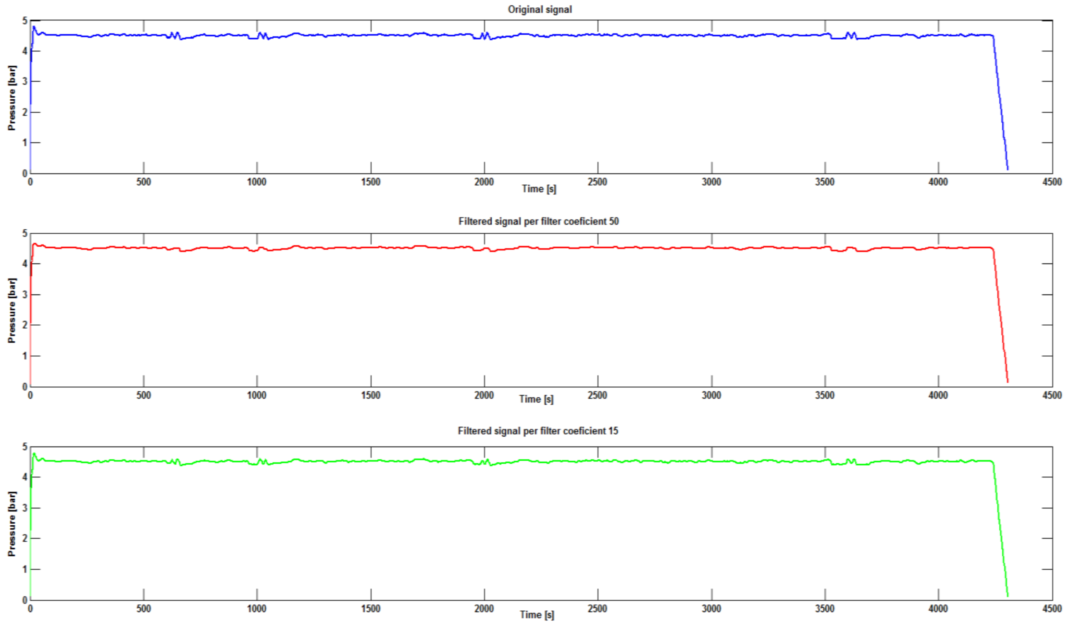


Figure 37: Signal measurement point number 3, date of measurement 15.4.2014 – 10:40

a) Original signal b) Filtration coefficient 50 c) Filtration coefficient 15

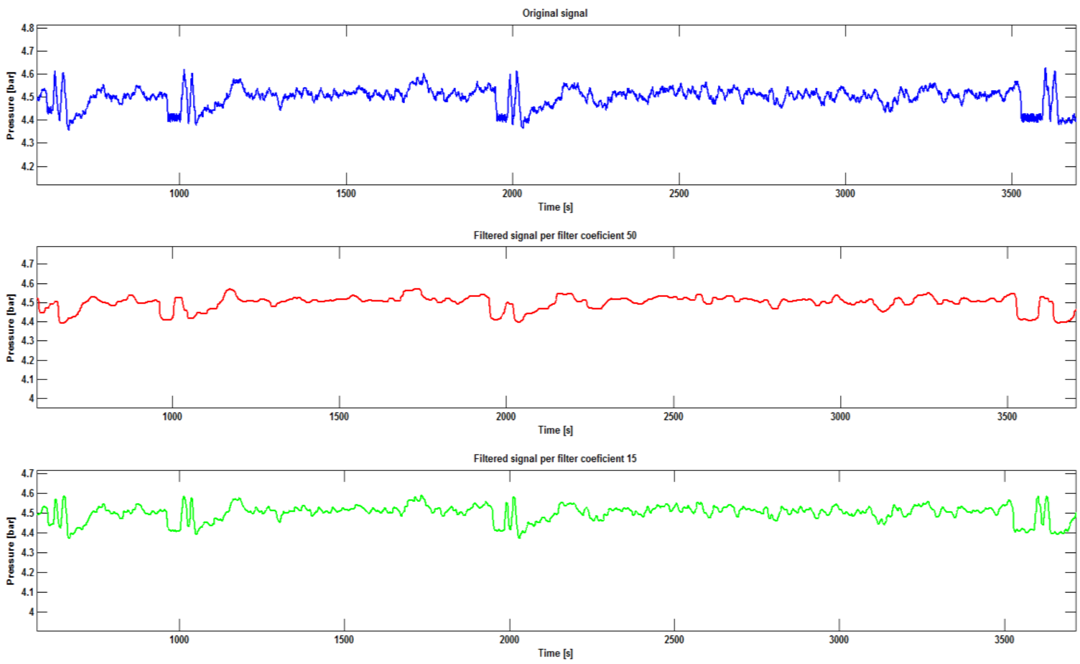


Figure 38: Cropping a useful signal measurement point number 3, date of measurement 15.4.2014 – 10:40

a) Original signal b) Filtration coefficient 50 c) Filtration coefficient 15

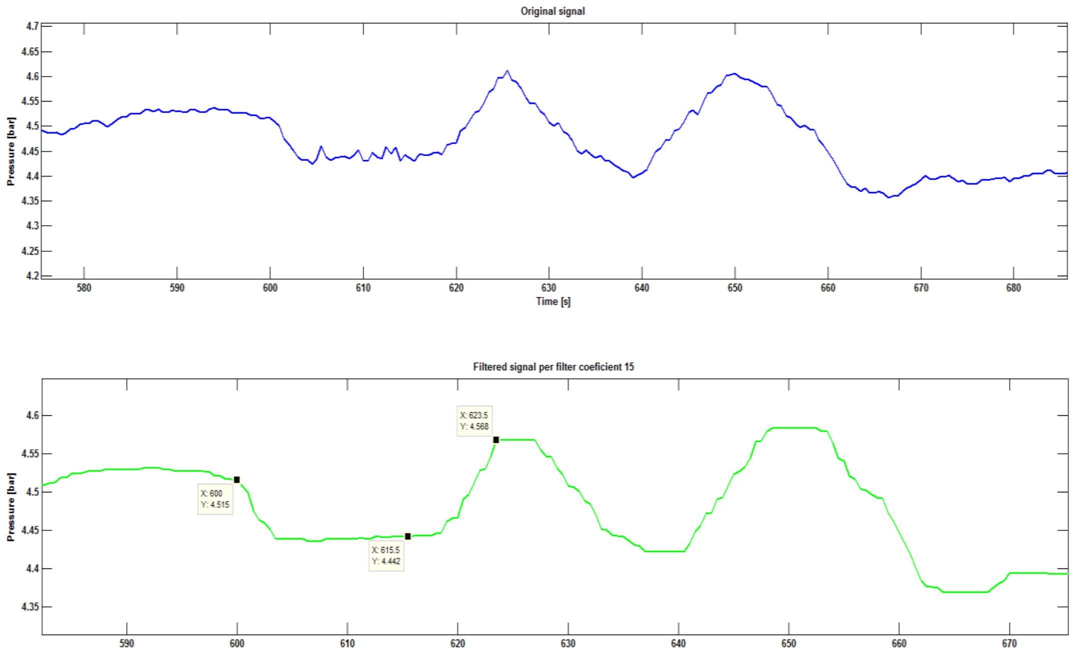


Figure 39: Cropping a useful signal measurement point number 3, event number 1, date of measurement 15.4.2014 – 10:40

a) Original signal b) Filtration signal coefficient 15, event number 1

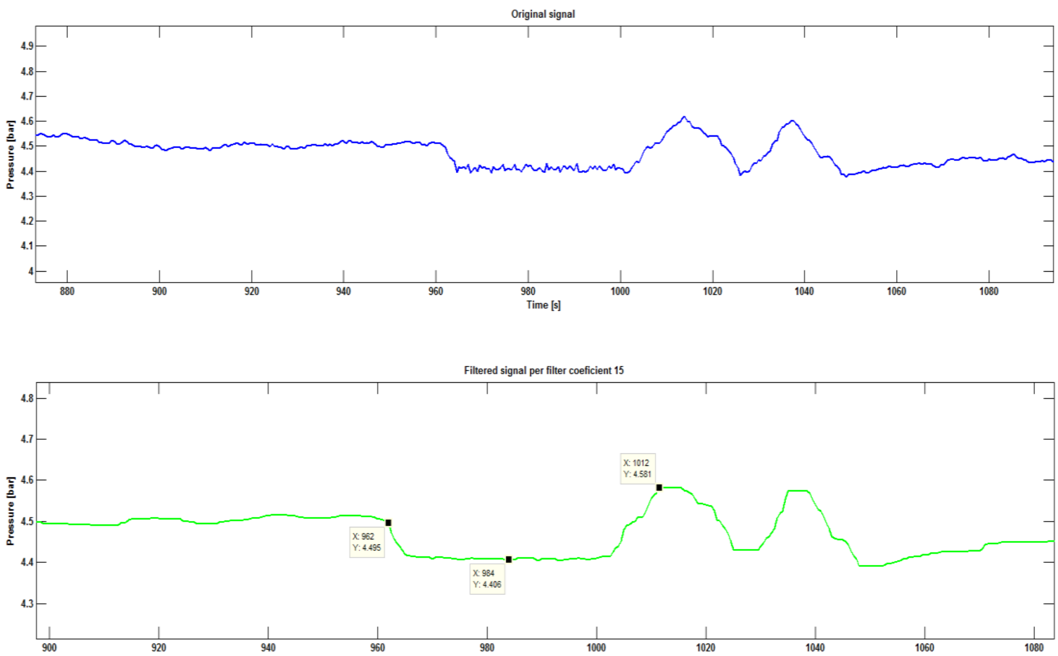


Figure 40: Cropping a useful signal measurement point number 3, event number 2, date of measurement 15.4.2014 – 10:40

a) Original signal b) Filtration signal coefficient 15, event number 2

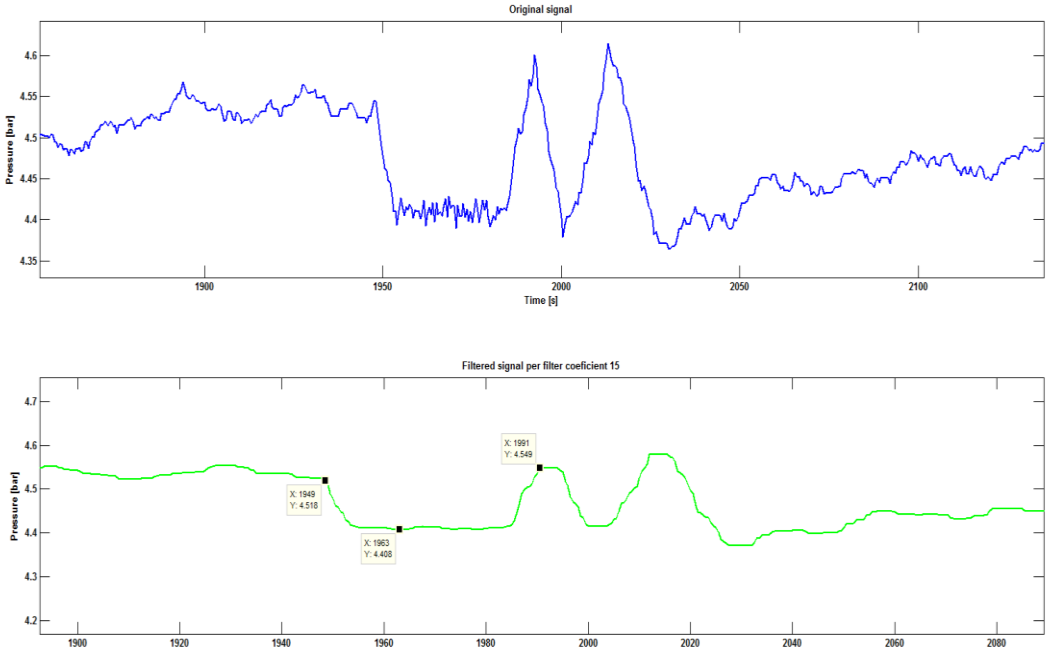


Figure 41: Cropping a useful signal measurement point number 3, event number 3, date of measurement 15.4.2014 – 10:40

a) Original signal b) Filtration signal coefficient 15, event number 3

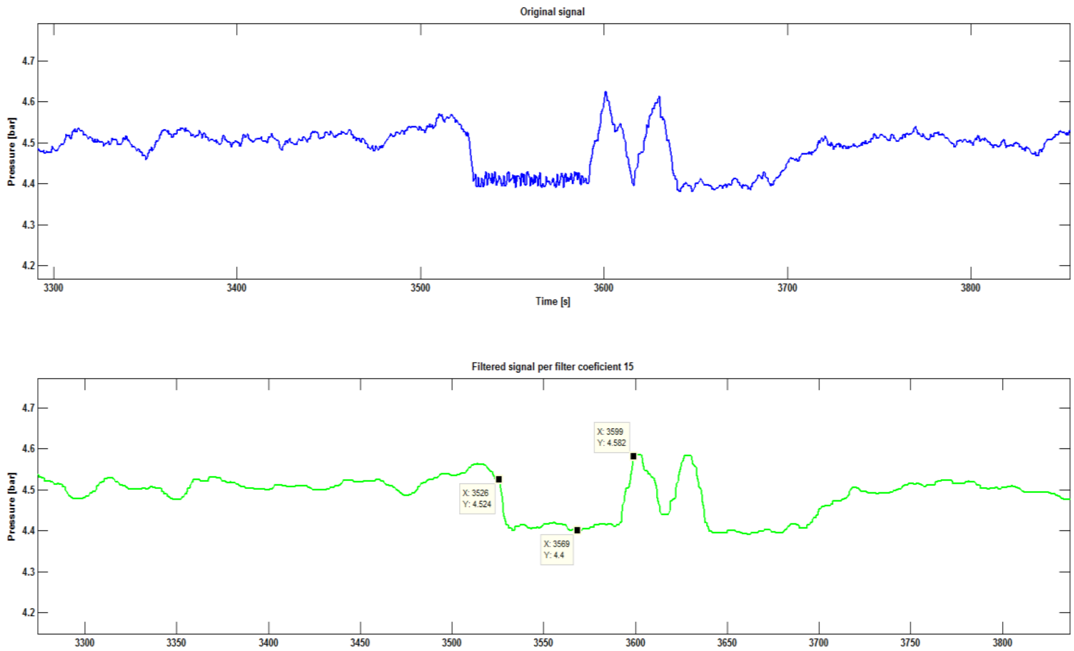


Figure 42: Cropping a useful signal measurement point number 3, event number 4, date of measurement 15.4.2014 – 10:40

a) Original signal b) Filtration signal coefficient 15, event number 4

The previous figure shows that during the running into the flow of pure steam into the sterilizer, there are changes in the value of pressure and create events in the charts.

The first event is start flow to the first sterilizer, the subsequent two events belong to the lunch of two sterilizers, also the two events belong to the lunch of three sterilizers and last event is to create a running flow of pure steam into three sterilizers at the same time.

Table 11: Characteristics of individual event measuring point number three

Measuring point number 3 - 15.4.2014 – 10:40				
	1 Sterilization (stabilization 5 min)	2 Sterilization (stabilization 5 min)	2 Sterilization (stabilization 10 min)	3 Sterilization (stabilization 5 min)
Maximum pressure of events (bar)	4,515	4,495	4,518	4,524
Minimum pressure of events (bar)	4,442	4,406	4,408	4,4
Difference heights of event (bar)	**0,073**	**0,089**	**0,11**	**0,124**
Start realization of events (s)	600	962	1949	3526
End realization of event (s)	623,5	1012	1991	3599
Difference Width of event (s)	**23,5**	**50**	**42**	**73**

The above (table 11) shows the characteristics of individual events during simulated 1-3 sterilizers in stabilization times of 5 and 10 min. The table shows the height and width of each event depending on the number of opening sterilization. It is a measuring point number three, date of measurement at 15.04.2014 and time of measurement at 10:40.

8.3 Measuring the electrical conductivity of demineralised water in stable system

The last parameter was measured electrical conductivity of demineralised water in the steam separators. The figures show the measure.

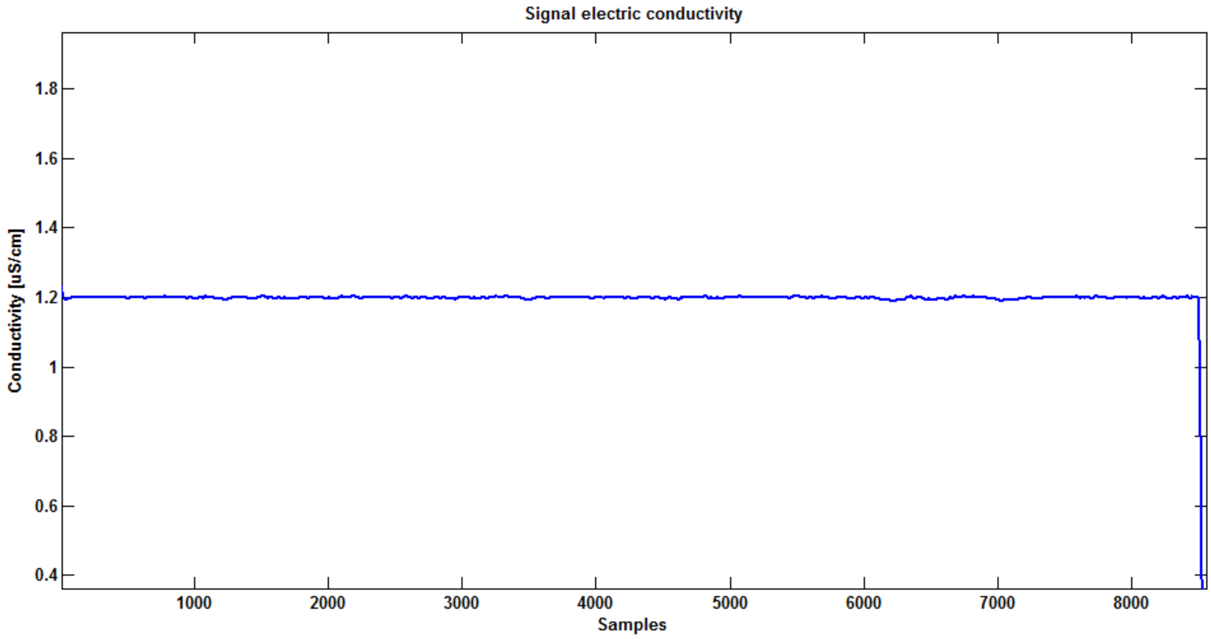


Figure 43: Process of electric conductivity

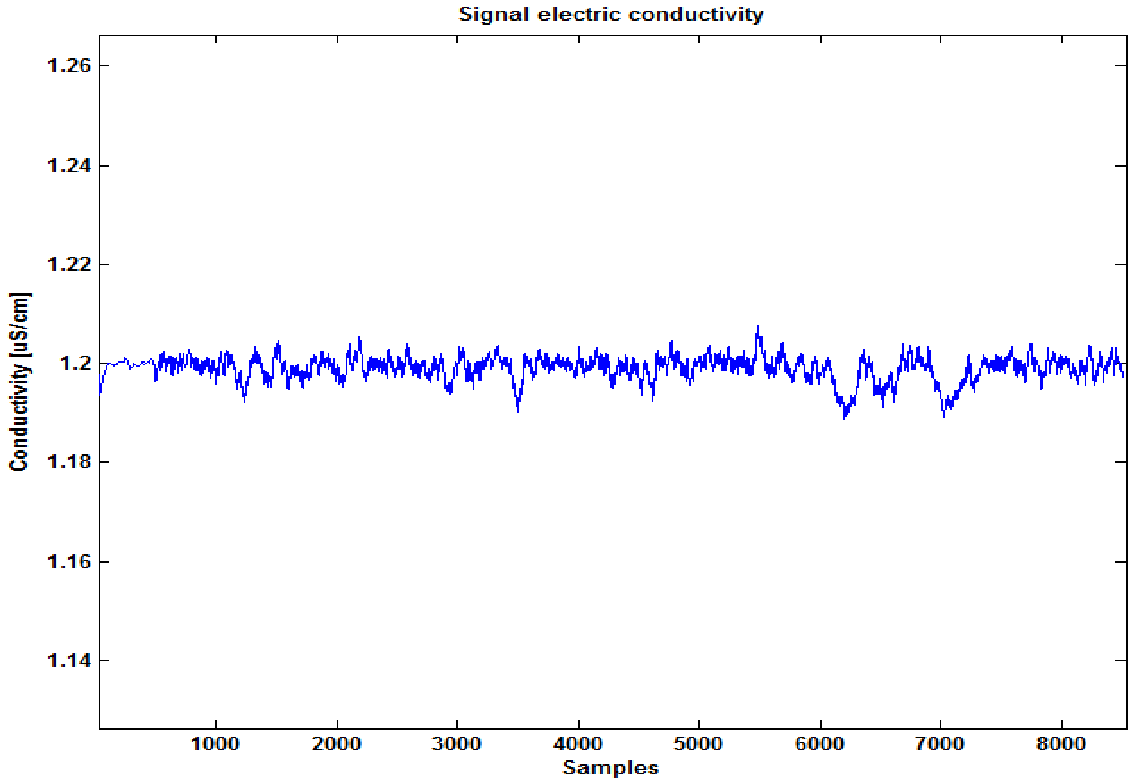


Figure 44: Cropping a process of electric conductivity

From the previous figures it is evident that triggering a different number of sterilizers has no effect on electrical conductivity of demineralized water in steam separator. Throughout the measurement of water conductivity values remained stable system almost the same with only occasional small fluctuations.

8.4 Evaluation of the temperature steam sterilization of system stable

Parameter in which there was the largest change during the measurement was the temperature steam. In the following tables (Table 12, 13 and 14) are processed and analyzed the differences events of temperature pure steam in terms of their height and width.

Table 12: Analysis of height and width events for measuring point number 1 - first Realization

Measuring point number 1 - 10.2.2014 – 11:18				
	1 Sterilization (stabilization 5 min)	2 Sterilization (stabilization 5 min)	2 Sterilization (stabilization 10 min)	3 Sterilization (stabilization 5 min)
Maximum pressure of events (°C)	165,6	164,4	164,6	165,2
Minimum pressure of events (°C)	163,1	162,7	162,7	162,28
Difference heights of event (°C)	**2,5**	**1,7**	**1,9**	**2,92**
Start realization of events (s)	749	1093	2049	3600
End realization of event (s)	780,5	1137	2087	3668
Difference Width of event (s)	**31,5**	**44**	**38**	**68**

Table 13: Analysis of height and width events for measuring point number 1 - second Realization

Measuring point number 1 - 10.2.2014 – 13:00				
	1 Sterilization (stabilization 5 min)	2 Sterilization (stabilization 5 min)	2 Sterilization (stabilization 10 min)	3 Sterilization (stabilization 5 min)
Maximum pressure of events (°C)	165,8	165,7	164,8	165,3
Minimum pressure of events (°C)	163,5	163,1	163,2	163,2
Difference heights of event (°C)	**2,3**	**2,6**	**1,6**	**2,1**
Start realization of events (s)	748,5	1095	2049	3600
End realization of event (s)	780	1137	2086	3669
Difference Width of event (s)	**31,5**	**42**	**37**	**69**

Table 14: Analysis of height and width events for measuring point number 1 - Third Realization

Measuring point number 1 - 18.2.2014 – 14:05				
	1 Sterilization (stabilization 5 min)	2 Sterilization (stabilization 5 min)	2 Sterilization (stabilization 10 min)	3 Sterilization (stabilization 5 min)
Maximum pressure of events (°C)	165,6	165,4	164,7	165,2
Minimum pressure of events (°C)	163,1	162,8	162,7	162,8
Difference heights of event (°C)	**2,5**	**2,6**	**2**	**2,4**
Start realization of events (s)	750	1094	2051	3600
End realization of event (s)	781	1139	2089	3669
Difference Width of event (s)	**31**	**45**	**38**	**69**

Table 15: Analysis of heights and widths events for all realizations

The resulting table				
Measuring point number 1				
	1 Sterilization (stabilization 5 min)	2 Sterilization (stabilization 5 min)	2 Sterilization (stabilization 10 min)	3 Sterilization (stabilization 5 min)
Difference heights of event (°C)	**2,425**	**2,25**	**1,675**	**2,055**
Difference width of event (s)	**31,25**	**43,75**	**37,5**	**68,5**

From the results it can be deduced that launch on different number of sterilizers has no effect on the temperature change of pure steam. When running 3 sterilizers at the same time there was a decrease to a very similar value of temperature when running 1 or 2 sterilizers. In all measuring temperature of pure steam the values decrease almost the same and therefore the work will deal primarily width event which are dependent on the number of running sterilizers.

The results according to (Table 15) show that the number of running sterilizers has no effect on the temperature change. Difference in heights for pure steam and the steam before (measurement point number one) the heat exchanger almost comparable, but for the steam after (measurement point number two) the heat exchanger the difference is greater, but again there is no large fluctuation in the minimum temperature for different number of sterilizers.

In the following (Tables 16 and 17) and (Figure 45 and Figure 46) are plotted depending to the number of running sterilizers and width of event for pure steam and for the steam before the heat exchanger and after. The resulting curves are interspersed with linear regression line with equation regression.

Table 16: Dependence of individual events on the amount subscribed of steam for measuring point number 1

Number of opened sterilizers	1	2	3
The amount of steam collected (l)	112	224	336
Ddifference in heights of each events (°C)	2,425	2,25	2,055
Difference in widths of each event (s)	31,25	43,75	68,5

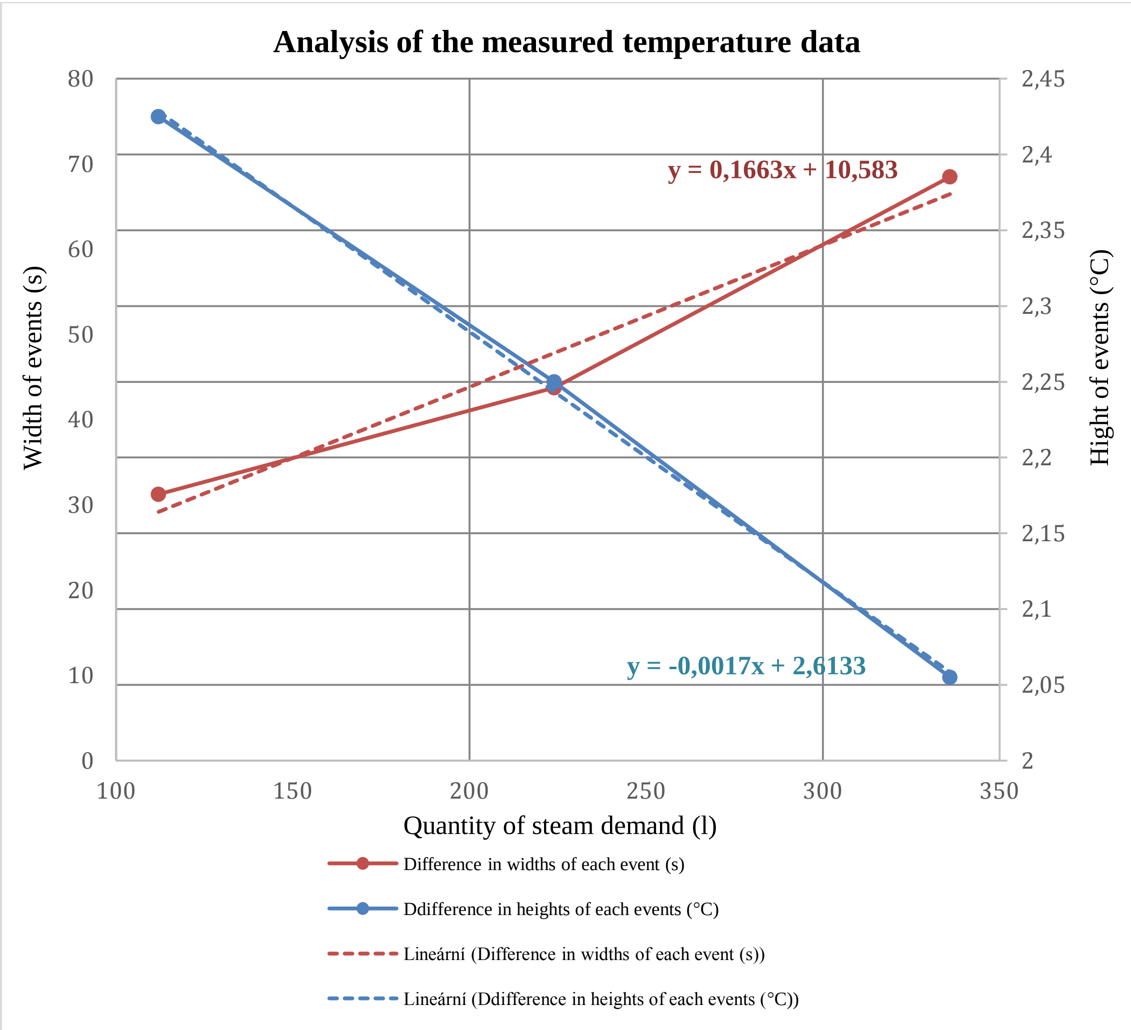


Figure 45: dependence between the number of sterilizers and width of the event for the temperature before the heat exchanger measuring point number 1

Table 17: Dependence of individual events on the amount of collected steam for measuring point number 1

The resulting table				
Measuring point number 1				
	1 Sterilization (stabilization 5 min)	2 Sterilization (stabilization 5 min)	2 Sterilization (stabilization 10 min)	3 Sterilization (stabilization 5 min)
Difference heights of event (°C)	**2,45**	**2,575**	**4,075**	**2,6**
Difference width of event (s)	**19,875**	**43,125**	**40,75**	**67,5**

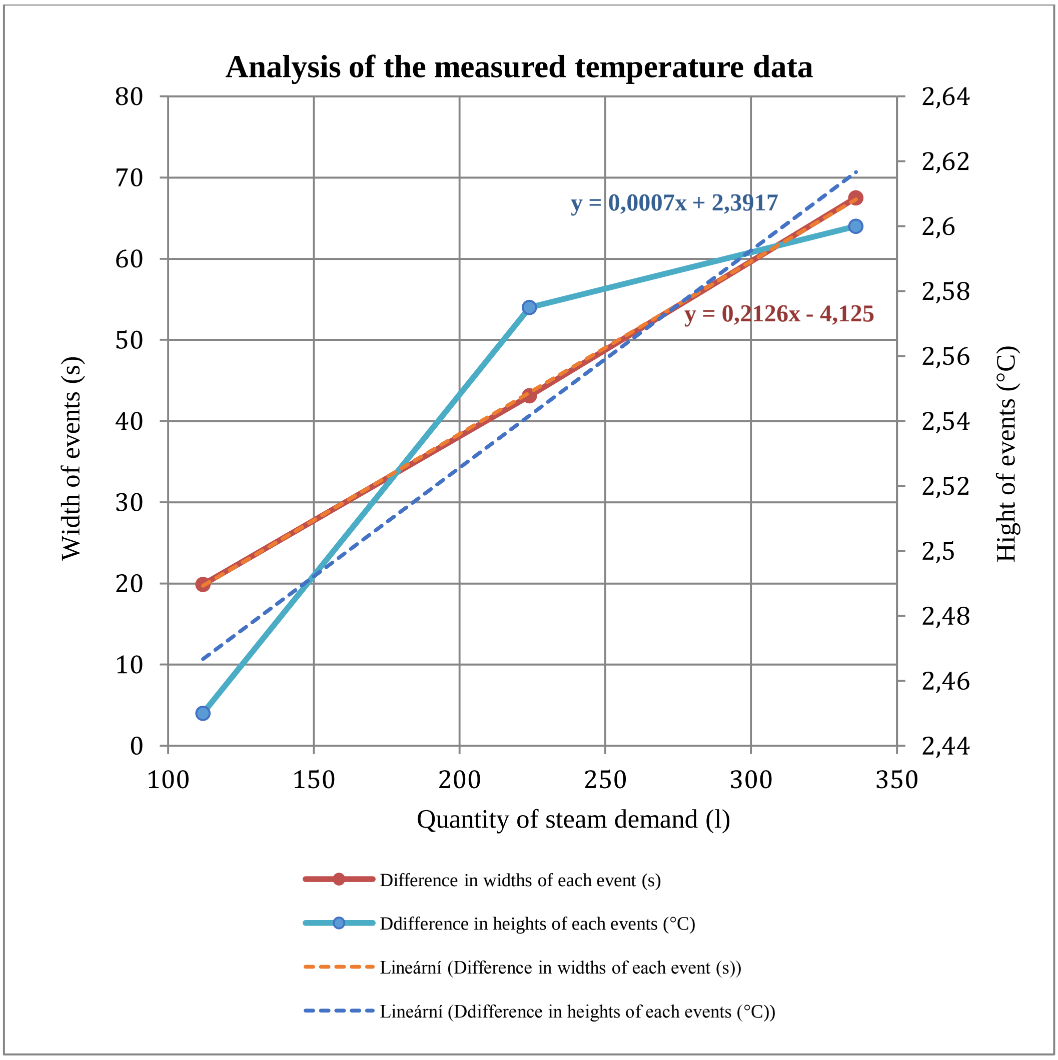


Figure 46: Dependence between the number of sterilizers and width of the event for the temperature before the heat exchanger measuring point number 2

From the results the regression equation for pure steam follow that acceptable values of the width event 10*s* and height events 2.5 °*C* is necessary to keep into the sterilizer a constant flow minimum 66 *l* of pure steam in 1 *s*. For larger volumes will lead to the formation of undesirable events. Whereas that in the regression equations for the steam before and after the heat exchanger is a negative move line will be occur even at the minimum flow of steam to the occurrence of events.

Other information that can be read out from the resulting graph is the fact that the steam separator is able to absorb the effect of running sterilizers sensed parameters. The Directive of pure steam is about 0.0007 lower and the line is not as steep as in the case of steam before the heat exchanger and after. Therefore, changing the width of the event for a greater number of sterilizers is growing for pure steam slowly.

8.5 Evaluation of the pressure steam sterilization of system stable

When measuring the pressure, there was a clear creation of events in the case of pure steam. When measuring the steam pressure before (measurement point number one) the heat exchanger and after (measurement point number two), the events were not exactly identified and if in the measuring were some events, did not match the locations where saw the launch of flow into the sterilizer. For this reason, the thesis deals only the analysis events of pressure values pure steam. In the following tables are again analyzed both width events and change in pressure.

Table 18: Analysis of height and width events for measuring point number 3 - first Realization

Measuring point number 3 - 15.4.2014 – 09:30				
	1 Sterilization (stabilization 5 min)	2 Sterilization (stabilization 5 min)	2 Sterilization (stabilization 10 min)	3 Sterilization (stabilization 5 min)
Maximum pressure of events (bar)	4,513	4,495	4,482	4,519
Minimum pressure of events (bar)	4,437	4,41	4,411	4,402
Difference heights of event (bar)	**0,076**	**0,085**	**0,071**	**0,117**
Start realization of events (s)	600,5	963,5	1949	3528
End realization of event (s)	625	1012	1991	3600
Difference Width of event (s)	**24,5**	**48,5**	**42**	**72**

Table 19: Analysis of height and width events for measuring point number 3 - second Realization

Measuring point number 3 - 15.4.2014 – 10:40				
	1 Sterilization (stabilization 5 min)	2 Sterilization (stabilization 5 min)	2 Sterilization (stabilization 10 min)	3 Sterilization (stabilization 5 min)
Maximum pressure of events (bar)	4,515	4,495	4,518	4,524
Minimum pressure of events (bar)	4,442	4,406	4,408	4,4
Difference heights of event (bar)	**0,073**	**0,089**	**0,11**	**0,124**
Start realization of events (s)	600	962	1949	3526
End realization of event (s)	623,5	1012	1991	3599
Difference Width of event (s)	**23,5**	**50**	**42**	**73**

Table 20: Analysis of heights and widths events for all realizations

Dependence of individual events on the amount of collected steam for measuring point number 3

The resulting table

Measuring point number 3				
	1 Sterilization (stabilization 5 min)	2 Sterilization (stabilization 5 min)	2 Sterilization (stabilization 10 min)	3 Sterilization (stabilization 5 min)
Difference heights of event (bar)	**0,0745**	**0,087**	**0,0905**	**0,1205**
Difference width of event (s)	**24**	**49,25**	**42**	**72,5**

From the previous tables can be once again read out dependence between the number of simultaneously running sterilizers and width of the jump. However, in case of the minimum pressure values, the result is the same as temperature. When running arbitrary number of sterilizers does not occur greater changes in minimum pressure values.

In the following table and graph shows the dependencies between the width and height of individual events and the amount collected of pure steam.

Table 21: Dependence of individual events on the amount subscribed of steam for measuring point number 3

Number of opened sterilizers	1	2	3
The amount of steam collected (l)	112	224	336
Ddifference in heights of each events (°C)	0,0745	0,087	0,1205
Difference in widths of each event (s)	24	49,25	72,5

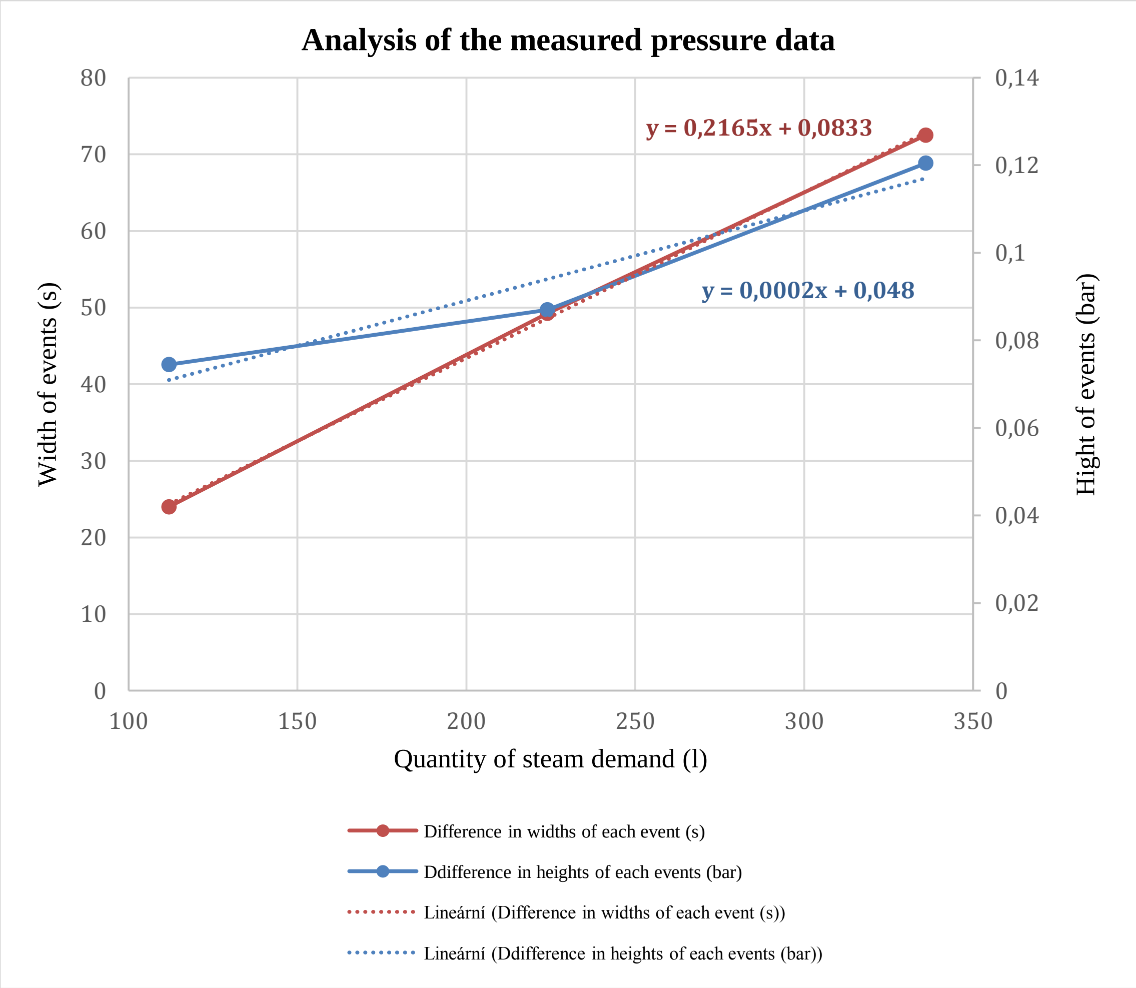


Figure 47: Dependence between the number of sterilizers and width of the event for the pressure before the heat exchanger measuring point number 3

From the results the regression equation for pure steam follow that acceptable values of the width event 10*s* and height events 0.08 *bar* is necessary to keep into the sterilizer a constant flow minimum 44 *l* of pure steam in 1 *s*. In the case of temperature, the volume event for zero temperature equals 66 *l* in 1 *s*. For larger volumes will lead to the formation of undesirable events.

During the flow volume of close-mentioned values will be occur the smallest possible changes in the parameters of pure steam.

All previous measurements were scanned in a stable system. System which has not been completely automated, and which must occur human interference. In this case, the flow of blow down and condensate from the steam separator were switched off and refilling of demineralized water was set to the minimum possible value.

In the case of an unstable system, the system is fully automated. The flow of blow down and condensate from the steam separator is enabled and automated, flow of demineralized water is also controlled by computer and guided by the needs of the separator. In this case there were changes in all parameters within the range 10% of measured values of a stable system. The level of demineralised water in the separator was not in its proper range and has also been very disturb.

None of parameters were not stable, therefore the measurement and evaluation will be continued with the purpose of improving the stability parameters for the automated system.

8.6 Evaluation of the results

Most measurements that took place were effected in a stable system for producing pure steam. There have been three basic parameters of the measurement, which were the temperature and pressure steam sterilization and also the electrical conductivity of demineralized water in steam separator. Was also measured humidity, whose values did not show the exact values not only because of that humidity steam sterilization is minimum, but mainly because the used humidity sensors were not calibrated to such a high temperature and pressure.

In the chapters 8.1 to 8.5 have been presented selected results of individual measurements according to significance of the evaluation parameters. However, in the practical section was measured much more data from other measuring points, which concluded this work and their graphical and tabular, results are given in the appendix at CD. The basic of measurement was launching one or more sterilizers at the same time and scanning the individual parameters during the measurement. Always first occurred to run one sterilizer and then twice after two sterilizers at the same time and finally launched three sterilizers.

The parameter at which there was biggest changes and creation of the biggest events during the measurement was the temperature of steam.

From the measured and calculated values was found that the formation of zero means minimal changes in physical parameters, should be allowed to flow into the sterilizer 45 *l* in 1 *s*. With this flow sterilizer filled slowly, which for small sterilizers is undesirable.

The second parameter, where noted some changes during the measurement was the pressure. Pressure was evaluated only for pure steam because when measuring steam before the heat exchanger and after was not possible to accurately identify the events and processed. From the results for pure steam came out again suitable volume for flow into the sterilizer, which stood at 66 *l* for 1 s.

The last parameter has been processed by the electrical conductivity of demineralized water in the steam separator. This parameter showed no dependence on starting a different number of sterilizers and all the time kept almost constant.

From the resulting calculated volumes for temperature and pressure suggests that if into the sterilizer flow volume of the steam mentioned values, eliminating the parameter events to a minimum.

9. Conclusion

The main contents of the thesis was to find, measurement and analysis appropriate physical parameters for analyzing the quality of saturated steam sterilization according to CSN EN 285+ A2 with a stable completely isolated system.

This element forms the basis for replacement of old analysis process non-condensed gases. Used processes have a number of shortcomings, which include mainly the impossibility automation system and a very large time and financial demands. Finding the appropriate parameters and methods for continuous measurement of certain information for the creation of modern automated systems.

The theoretical part of the thesis deals with the physical description of saturated steam sterilization and other methods of physical and chemical disinfection and sterilization, their principles, parameters for correct functionality, the possibility of using different materials and their advantages and disadvantages.

The next part deals with the description of saturated steam and its properties and parameters that is important to comply the functional sterilization in sterilization chambers and methods for quality control of sterilization steam. These methods, however, have a number of shortcomings and are within the thesis replaced with sensors that detect the parameters of steam sterilization.

In the last chapter of the theoretical part of the thesis describes sensors that could be used for recording the physical parameters. For each variable is selected, several kinds of sensors that are suitable for measuring the properties of the sterilizing steam. The thesis discusses principle and their advantages and disadvantages when used in the sterilization process.

The practical part describes the design and realization of the whole system of measurement, key measuring points, selected measured parameters and sensors for the measurement. As the most important parameters were selected temperature, pressure, humidity and electrical conductivity of demineralised water in the steam separators.

The next chapter is a description of the development of steam sterilization with the located selected sensors. These sensors detect physical parameters that work further processed and analyzed. Part of this chapter is a description of the automated measuring system built on the PLC.

The results show that the greatest changes during measuring occurred in the steam temperature. After evaluating all the measuring was determined that the most appropriate volume of steam that flows per unit of time in the sterilizer is 45 *l*. In case the pressure is the volume of 66 *l*.

The above results apply only to stable system where the blowdown and draining turned off and condensate from the steam of separator and feed of demineralized water was minimum. This system is not completely automated. If unstable, completely automated system where flow blowdown and condensate turned on and demineralised water flows into the separator as required, there was a very large fluctuation for each parameter. In a further study and development, will explore the possibilities for settling the measured physical parameters steam sterilization, to allow for the use of automated systems.

During the analyzes and measurements were also identified shortcomings in the construction of separators especially during automatic operation. Therefore, were suggested minor modifications concerning the blowdown rate, speed committing, water and minimize impact donations usable steam.

All these steps lead to refund the analysis steam using the measuring non condensed gas automated measuring system with continuous evaluation.

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List of Appendices

Appendix 1: Schematic diagram of pure steam

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Appendix 2: Results of measurement point number 2

Name of the file: Measuring point number 2.pdf

Appendix 3: Results of measurement point number 3

Name of the file: Measuring point number 3.pdf

Appendix 3: Program in matlab

Name of the file: Program