

# Some Aspects of Diagnostics and Calibration of Measurements and Control Lines in the Ship's Hazardous Areas

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**Abstract-** In the paper there are presented some important aspects of education of the measurement and controlling different electrical and non-electrical quantities in the hazardous areas. Special attention is put on the diagnostics and calibration matters. It concerns maritime industry, but the problem is similar in the ashore industry and shown considerations can be easily adapted.

## I. Introduction

The development of the industry from one side and science from the other create new demands for the measurement and control of different electrical and non-electrical quantities. Most of them are realised in normal environmental conditions but in many places depending on processes connected with product, transport or storage of dangerous goods concern hazardous areas applications. The last group refers mainly to specific ships, like liquefied gas tankers, chemical and crude oil tankers or offshore rigs. The measurement and control inside the hazardous areas demand designing, assembling and maintenance in compliance with specific requirements from safety reasons.

In the hazardous areas on vessels here are used different techniques of explosion protection. Mainly there are used: flameproof enclosure (EEx d, Ex d), increased safety realisation (EEx e, Ex e), pressurised enclosure (EEx p, Ex p), intrinsic safety technique (EEx i, Ex i) ) and rather rarely, other solutions. The type of the explosion protection which is used depends on many factors such as the type of the hazardous zone, the kind of dangerous cargo, the rate of power etc.

Safety maintenance of the electrical equipment in hazardous areas requires from the crew special knowledge and skills but mainly it concerns the ship electricians. It is worth to underline that the explosion protection properties of electrical equipment are generally different from the functional ones. It means that the electrical equipment explosion protected can lose its explosion protected properties but still work because it is in a good condition from the functional side. Such a situation can appear on ships and is extremely dangerous. From that reason future ship electrical engineers studying at Gdynia Maritime University on the Faculty of Marine Electrical Engineering are introduced into a special course of measurement and control in the hazardous areas, which is a part of the didactic process [1].

## II. The fundamentals of the measurement and the control line in the hazardous areas

In order to maintain properly any electrical equipment in hazardous areas it is necessary to understand mutual relations among all the aspects concerning the fire triangle. It results in many parameters and dependencies in the form of international, regional or local standards, rules and specification useful for designers, operators and for all who are concerned with the above problem. For maritime economy the adequate rules and standards are created by IMO (International Maritime Organisation), different international maritime industry organisation, e.g. ICS (international Chamber of Shipping), IACS (International Association of Classification Societies) or National Maritime Administrations. In European Community the ATEX directive can be accepted by the Classification Societies although it is not mandatory for the maritime industry [3, 4, 5].

First of all, it is necessary to understand the nature of explosive atmosphere, which is a mixture of flammable substances in form of gases, vapours, mists, dust or fibres with air. It is worth to underline that sometimes a substance generally deemed as not flammable, e.g. hydraulic oil, can create an explosive atmosphere during leakage from pressurised system as the mixture of the oil mist with air. The explosive atmosphere for most specific flammable substances can be described by the same parameters as LFL (Lower Flammable Limit), UFL (Upper Flammable Limit), minimum ignition energy, auto ignition temperature, ignition temperature, MESG (Maximal Experimental Safe Gap), MIC (Minimum Ignition Current) useful for explosion protection technique [2, 6].

Taking under consideration the probability of occurring the explosive atmosphere, the hazardous areas are divided into zones (zone 0, zone 1, zone 2 for gas and zone 20, zone 21, zone 22 for dust). The space of zone depends on many factors and mainly depends on the physical properties of flammable substances, places of emission, ventilation, sources of emission, step of emission capacities. Depending on the zone and property of flammable substances the adequate explosion protection is used.

For zone 0 and zone 20 only the intrinsic safety technique is an adequate and independent solution. The intrinsic safety solution concerns two cases. The first concerns the independent mobile equipment such as a mobile phone or other communication equipment or measurement equipment of LEL, O<sub>2</sub>, C<sub>n</sub>H<sub>m</sub>, pressure calibrators, flashlights, etc. All of them have to be certified in order to be used in the hazardous areas. The second one is more sophisticated and concerns intrinsically safe circuits which are characteristic for measurement and control lines [2].

### III. Measurement and control lines in intrinsically safe realisation

The intrinsic safety philosophy is based on an energy criterion, which essence is the postulate that in the hazardous area, both during the normal working conditions and in the emergency, the energy that is sufficient to cause ignition of explosive atmosphere can neither be stored nor released.

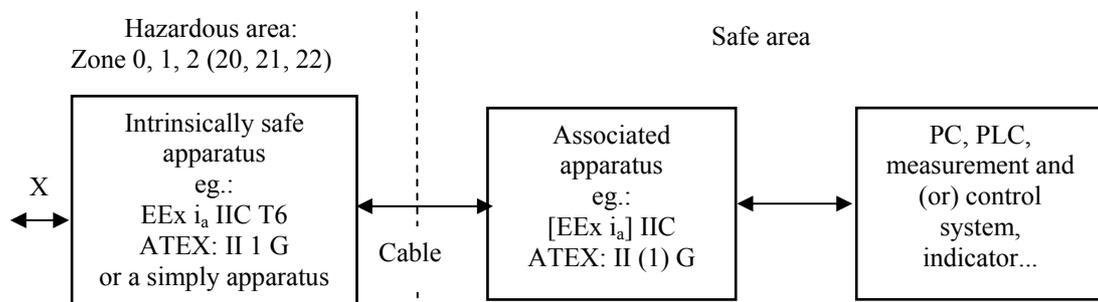


Figure 1. Intrinsically safe circuit; X- measured or controlled parameter

In the hazardous area the measurement line create the intrinsically safe circuit, which can be divided into three parts. The first one is located in the safe area, whereas the second one in the hazardous area. Both parts are connected with a cable which is in both areas: the safe and the hazardous and which constitutes the third part of the intrinsically safe circuit. The part in the safe area (the associated apparatus) plays the role of a power engineering limiter of the energy supplied to hazardous area. The part installed in the hazardous area, together with cable and with the input of the associated apparatus, must be made in a way preventing both collecting the energy sufficient to cause an explosion and heat the surfaces of the devices placed there to the temperature causing auto-ignition of explosive atmosphere.

In order to fulfil all above safety criteria for the intrinsically safe equipment there are used special solutions during designing. In general, during the assembling of the intrinsically safe circuit a safety is the basic criterion. But in realities sometime it is not enough. It is necessary to take under consideration the functional properties of the intrinsically safe circuits.

All the aspects of designing, assembling, validations and maintenance of the intrinsically safe circuits are presented during the lectures, with underlining of using of the proper tools and measurement equipment for diagnostics, repairing and calibrating.

#### III.1 The temperature measurement line

Temperature is the most frequently measured parameter. It can be measured by many methods and for that purpose there are used different sensors. In the field conditions the most popular sensors are the resistance temperature detector Pt-100 and some kinds of thermocouples. For presentation of the differences of diagnostics and checking between normal measurement lines and the measurement line in the hazardous areas, the temperature measurement line with Pt-100 sensor is discussed.

##### III.1.1 The temperature measurement line with Pt-100 sensor in the safe areas

In the safe area the Pt-100 sensor can be connected to the measurement system with two, three or four wires. The wire resistance  $R_k$  for very short connection can be omitted but for several metres and more

the resistance  $R_k$  is too high eg.: for 100m long copper wire of cross section 1 sq. mm the resistance of one wire  $R_k$  has approximately  $1,8\Omega$ . The measurement system has to eliminate the influence of the cable resistances  $R_k$ , which is generally not greater than severally ohms. Depending on the quantity of used wires for connection of Pt-100 sensors different techniques are used for compensation of the cable resistance.

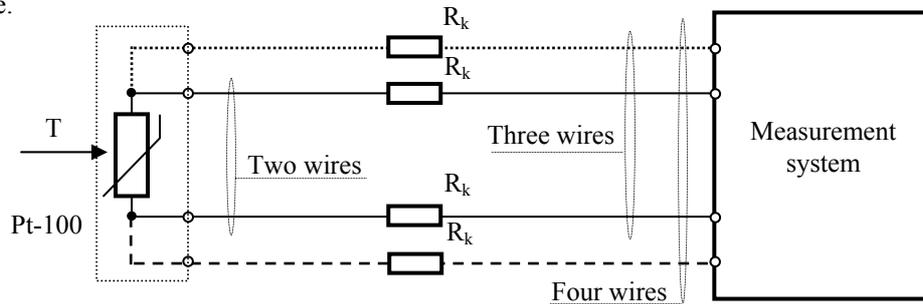


Figure 2. The temperature measurement line with Pt 100 sensor into the safe area; where  $R_k$  - resistance of one wire of the cable

It is possible to use two methods for checking or diagnostic procedure. The first one assumes the usage of a calibrated heater. The advantage of this method is checking the measurement line from the sensor to the indicator without destroying connections and mutual impedance relations between the wires the screen and the ground. The disadvantages are: the usage of a high electric power heater, the fact that almost always there can be checked only higher temperature then the ambient one, relatively long time for stabilising the sensor temperature. The accuracy of this method depends on the quality of the heater or the reference thermometer. The second method utilises the possibility of replacing the sensor with a calibrated resistance or a simulator of the Pt-100 sensor. The simulator of the Pt-100 sensor can be resistance or electronic type. The simulator connected to the measurement line gives possibility to check the line with accuracy correspondent to the standard of Pt-100. The sensor has to be checked separately in laboratory conditions. The advantages of this method are an easy procedure, without the necessity of access to the power supply, quick changing of checked temperature without limitation of the span. In the field conditions it is practically the only method for extremely low temperature (from  $-200^{\circ}\text{C}$  till  $0^{\circ}\text{C}$ ).

### III.1.2 The temperature measurement line with Pt-100 sensor into hazardous areas

From safety consideration for the measurement of temperature by the Pt-100 sensor in the hazardous areas between the sensor and the measurement system there has to be used an associated apparatus which has to be fixed in the safe area. As the associated apparatus there is commonly a Zenner barrier, or rather rarely, a resistance repeater. Because of the lack of place only the case with the Zenner barrier is discussed. It is assumed that all the parameters of the measurement line in the intrinsically safe solution from safety consideration are fulfilled like impedance parameters of the connections cable. The sensor itself is treated as a simple apparatus.

The Zenner barriers can be of different types and give different categories of safety. Independently of the construction details of the Zenner barrier, for one wire it can be represented in the simplified model presented on the Figures 3.

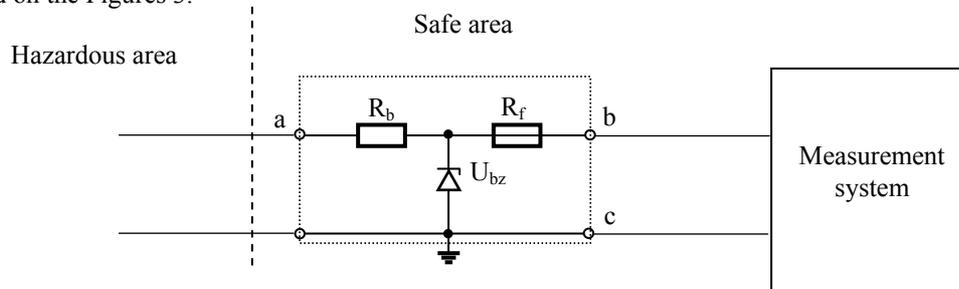


Figure 3. Simplified electrical model of the Zenner barrier as an associated apparatus; where  $R_b$ - equivalent resistance of barrier,  $R_f$ - fuse resistance.

During normal operation conditions the voltage  $U_{cb}$  is much lower than  $U_{bz}$ . Because of that only resistance  $R_{ee}$  named “end to end barrier resistance” which is the sum of all interior series connected resistance (in the case of Figure 3.  $R_{ee}=R_{ab}=R_b+R_f$ ), can have an influence on the measurement line. When the voltage  $U_{cb}$  is higher than  $U_{bz}$  (it can happen in a case of damage), the too high value of current blows the fuse and separates the circuit in the hazardous area from damaged circuit in the safe area.

The measurement line under consideration during normal working condition can be presented on the Figure 4.

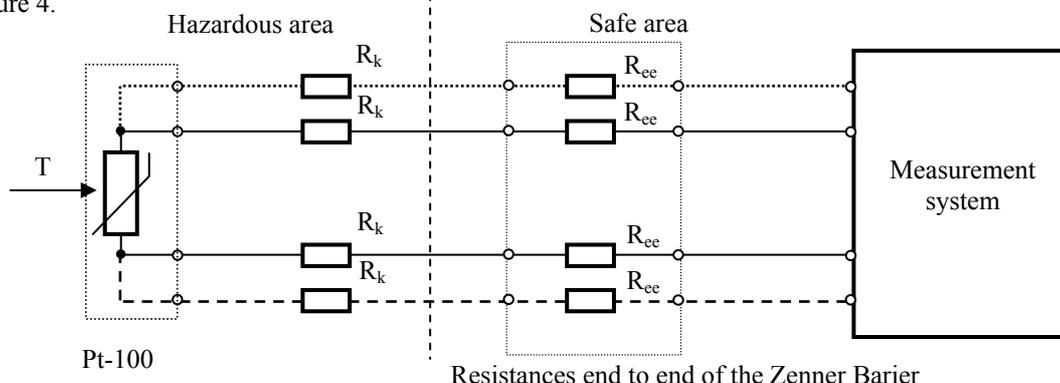


Figure 4. The temperature measurement line with the Pt-100 sensor into hazardous area

The intrinsically safe realisation with the Zenner barrier during normal operation conditions results in introducing into each connecting wire the additional resistance  $R_{ee}$ . The value of the “end to end” resistance  $R_{ee}$  depends on the barrier producer and the kind of connection of the Pt-100 sensor. For two, three wires the connections of the Pt-100 sensor the value of the “end to end” resistance  $R_{ee}$  corresponds to the 18-24 $\Omega$ . For the four wires connection the “end to end” resistance can be even more than 100 $\Omega$ . The intrinsically safe realisation of the temperature measurement line with the Pt-100 sensor with Zenner barrier as the associated apparatus demands of used adequate measurement system. The system has to be able realise compensation both the cable resistance  $R_k$  and end to end resistance  $R_{ee}$  of the Zenner barrier.

In the hazardous areas the checking and the diagnostics can be realised only with the utilisation of certified equipment. In that case for the checking and the diagnostics only the simulator of the Pt-100 is accepted. It is important to connect the simulator exactly into the place of the sensor to check the measurement line with influence of the cable resistances ( $R_k$ ) and the Zenner barrier resistances ( $R_{ee}$ ). The sensor Pt-100 has to be checked separately.

#### IV. Conclusions

In the land industry and at sea many different electrical and non-electrical quantities are measured and controlled. Many of them are realised in the hazardous areas. This creates additional problems concerning safety aspects for people, environment and for the industry itself. From that reason it is necessary to teach the future electrical engineers how to properly design and maintain that specialised measurement and control lines. In Gdynia Maritime University on the Faculty of Marine Electrical Engineering the corresponding course is a part of the didactic process.

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