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THE INTRISTICALLY SAFE MONITORING SYSTEM WITH INTELLIGENT SENSORS

Andrzej Kobosko, Zbigniew Pietrusiński

Industrial Research Institute for Automation and Measurements, Warsaw, Poland

Abstract -The paper presents the extended intrinsically safe systems of temperature monitoring which use heavy duty temperature cables with intelligent sensors. . Intelligent sensors are connected in unique 1-Wire interface. Similarly, other sensors detecting humidity, flow on base 1- Wire interface, may be controlled in this system.

These systems are applicable to grain elevators and co-operation objects in the same storage, for example: silos batteries, horizontal storages and others. In these large-area objects there are many independent computer stations co-operating with the central station.

Application tests have confirmed advantages of the intelligent sensors and their usefulness in temperature monitoring systems and particularly: accuracy, reliability, facility for intrinsically safe systems, low cost etc.

Keywords: intelligent sensors, monitoring system, grain elevator

1. INTRODUCTION

Temperature monitoring systems for grain elevators perform a very important task. They maintain optimal microclimate parameters, below critical values which might cause self grain ignition and explosion in storage [1], [2]. Sometimes we hear about fatal accidents as a result of monitoring systems going out of order or because error of service during the technological process. Statistically, such explosions happen once a year in Europe and in Poland there were a few explosions during the last 10 years. The explosions often cause great material losses and sometimes induce injuries or even death of people.

Monitoring systems must assure precision operation. Sensors and temperature cables must operate in a hazardous area and other apparatus are under intermittent hazard under abnormal conditions of grain dust. Surface temperature of these elements must be below ignition temperature of grain dust. Over current and short current flow increases the temperature of devices, but the value must be always below ignition temperature. Electrostatic field which is created during grain slid down is very dangerous, because short current ignition sparks are often a source of explosion.

Due to this effect we use intrinsic safety technique. Intrinsic safety is a technique for ensuring that the electrical energy available in a circuit is too low to ignite the most easily ignitable mixture of gas, dust and air. The design of the circuit and equipment is intended to ensure safety both in normal use and in all probable fault conditions

One of the methods of protection for equipment used in hazardous atmospheres is the "explosion proof" symbol Ex. This equipment must have national testing certification and approval for electrical equipment for use in potentially explosive atmospheres in surface industries and notified to the European Communities Commission

The temperature monitoring systems allow for reduction costs of grain preservation and for improvement of grain condition, considering reduction necessary technological operations such as throw over the grain and diminishing costs of power.

The temperature intelligent sensors gave possibility to develop more efficient monitoring systems.

2. THE MAIN IDEA OF MONITORING SYSTEM

Industrial Research Institute for Automation and Measurements in Warsaw has developed the temperature monitoring system based on Dallas Semiconductor 1-Wire network. The system uses Dallas intelligent temperature sensors, which assure resolution 9 to 12 bit and accuracy of ±0.5%. It is possible to measure the other environmental parameters via 1-Wire network as well.

2.1. Dallas 1-Wire networks

The 1-Wire net [3], [4], [5], sometimes called MicroLAN, is a cheap communication system, where a single master communicates over a single data line plus ground reference with slave devices, using 1-Wire protocol (Fig. 1). The net is MASTER/SLAVE type defined by the open drain architecture. It uses conventional CMOS/TTL logic levels, where a resistor connects the data line of the net to the 5V supply of the bus master. The master is typically a micro-controller or a personal computer with an external 1-Wire interface.

The system consists of three main elements: the bus master with 1-wire interface, the electrical connection between master and slaves, and the slave devices themselves. The master initiates and controls all activities on the 1-Wire net.

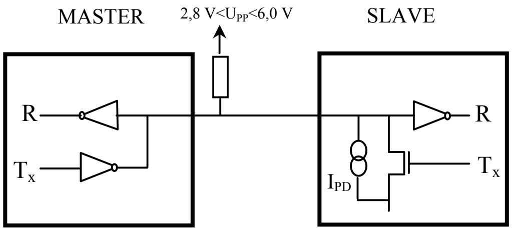


Fig. 1. Simplified schema of the 1-Wire network

2.2. Slave device markings

Each of slave devices contains a unique ROM code that is 64 bits long. The ROM code can be considered as an address of the device. The first 8 bits are a 1-Wire family code. The next 48 bits are a unique serial number. The last 8 bits are a CRC of the first 56 bits. It allows MASTER to make sure that there is no mistake in the address recognition.

2.3. Network topologies

Although 1-Wire networks are often quite free in structure, they can usually be fit into one of a few generalised categories as presented on Fig. 2.

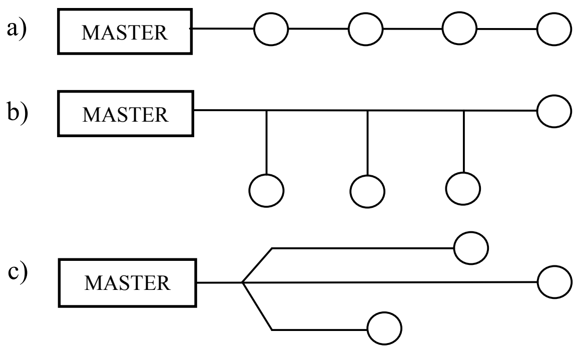


Fig. 2. Typical topologies of 1-Winetworks:
a) linear topology, b) stubbed topology,
c) star topology

2.4. Network terminology

Two terms have evolved that describe measurements and are critical to network performance. These terms are radius and weight.

The radius of a network is the wire run distance from the master end to the furthest slave device, in meters.

The weight of the network is the total amount of connected wire in the network, in meters.

The weight of the network limits the rise time on the cable, while the radius establishes the timing of the slowest signal reflections. A radius of 1-Wire network may ever been greater than 750m. At this distance, the protocol will fail due to the time delay of the cable. In practice, however, other factors usually limit the radius to smaller values then this.

2.5. Powering slave devices

Slave devices of 1-Wire networks can be powered by an external supply, or they can operate in “parasite power” mode, which allows to function without a local external supply. In parasite power mode, the power supply is taken from the 1-Wire bus and stored on the parasite power capacitor, while the bus is high. It provides power when the bus is low.

2.6. Master-end interface

Several factors determine the maximum radius and weight of a network. Some of these factors can be controlled and some cannot.

The master-end interface has a great deal of influence on the allowable size of a 1-Wire network.

In the Table 1, the maximum values of radius and weight of a 1-Wire networks are given, that depends on the master-end interface.

TABLE 1_ Dependence radius and weight of a 1-Wire networks on the master-end interface

Master –end interface	Additional elements	Radius max. [m]	Weight, max. [m]
Simple port pin interface	The pull-up resistor 2 220 Ω	3	3
FET driver interface with slew rate control	The pull-up resistor 1 000 Ω	200	200
The DS1410E parallel port interface	None	3	40
The DS9097 serial port interface	None	3	40
The DS2480B based masters (DS909U, TINI)	The R-C filter R = 100 Ω, C = 4 700 pF	200	200
Advanced Bus Interface	None	500	500

2.7. Switching devices

The method has been devised to allow networks to grow in complexity without growing in weight and radius. The network is divided into sections that are electronically switched-on one at a time. Using 1-Wire switching devices, the network may physically resemble one topology, but may electrically resemble another. The rules of non switched networks, which are given in table 1 can be applied to each segment of a switched network.

3. INTRINSIC SAFE MONITORING SYSTEM

The temperature monitoring system, developed in the Industrial Research Institute for Automation and Measurements, is presented on fig. 3[6].

The particular parts of the system are distributed in 3 areas: safe area, semi-safe area and hazardous area.

Temperature cables (ST) comprising temperature sensors and cables of 1-Wire net are placed in hazardous area. The net contains only 2 wires and the temperature sensors are working in the “parasite power” mode.

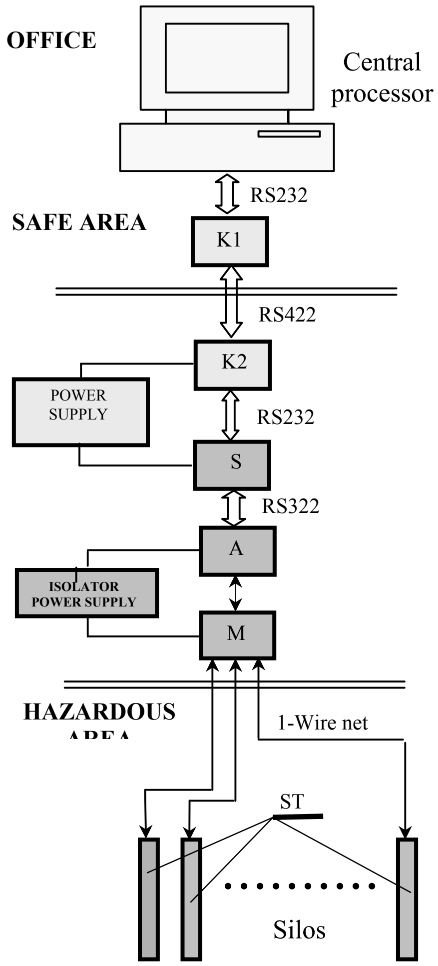
The interface 1-Wire adapter (A) together with driver and multiplexer (M), comprising electronic switches are on the border of hazardous and semi-hazardous area. The network is star topology but together with electronic switches (type DS2409 Dallas) it is changed into linear topology, with in turn enclosed branches. This is accomplished by multiplexer (M), which contains 18 electronic elements DS2409. The cables, enclosed to the 1-Wire adapter one after the other by the multiplexer, contain 10 intelligent digital temperature sensors each.

Maximal weight of the network is equal maximal distance between the multiplexer and the furthest sensor, it was about 120m in the case of described application. The multiplexer allows for considerable diminution of network weight and secures proper work of the system. The interface adapter and the multiplexer are supplied from intrinsic safe isolator power supply +5 V p.

The 1-Wire net is not led to the office, where the computer operation station containing application monitoring programs was placed, because there is considerable distance between office and silos. For that reason the connection between devices in the office and the devices in semi-hazardous area was made by transmission RS 422. That required application two interface converters: converter (K1) RS-232/RS-422 type, that is placed in the office and converter RS-422/RS-232 type placed in the semi-hazardous area. The intrinsic safe isolator (S) is used to separate signals in safe area from signals in hazardous area.

The main advantages of the system are:

- intrinsic safety and low cost of system,
- cheap, simple, 2 wire transmission net,
- intelligent temperature sensors containing sensor, analogue-digital converter and transmission circuit in one miniature case,
- manufactured marking of devices with 64 bit long code,
- parasite power supply by transmission net,
- high accuracy temperature sensors and wide measuring range,
- good resolution – 12 bit,
- alarm levels of temperature sensors, which are defined by users,
- high reliability,
- good resistance to industrial electric disturbance.



K1 - Converter interface RS232/RS422
K2 - Converter interface RS422/RS232
S - Intrinsic safe isolator
A - Adapter and driver of interface 1-Wire
M - Multiplexer 1-Wire
ST - Heavy duty temperature cables with intelligent sensors

Fig. 3. Simplified illustration of intrinsic monitoring system with intelligent sensors

4. DISTRIBUTED TEMPERATURE MONITORING SYSTEM

The experience from application and exploitation monitoring system in grain elevators show modification area in programming and equipment. Research work on the system was concentrated on two base problems:

1. We would like to display and analyse measuring data in some additional computer local stations on other divisions of the storage for example: in

the laboratory, the staff office, the operator office, the weighbridge etc.

2. Displaying at each station measurement data from many storages, for example: elevators , batteries of silos, horizontal storages and others.

The principle of the functioning the monitoring system, presented in item 3, was based on a single operator station. One computer accomplishes all functions: controlling 1-Wire net, software diagnostic test, displaying functions in operator place, processing data and others.

The computer has to control 1-Wire net using rigorous, time dependent protocol sending data by a long distance transmission line. In this system we do not have the possibility of radio transmission between office with operator station and remote battery of silos and elevators with 1-Wire net. In radio transmission we have to buffer data but this is not admissible for control algorithm of 1-Wire net.

The new system was developed following the modernisation of the program, interface and hardware. The system is presented on fig. 4: In the new system some functions of the central processor are realised by local microprocessors.

The measuring and the configuration data are collected in data bases created on Microsoft Access support. The system uses the popular in industrial automation base of distributed control. Microprocessors distributed on the large area are implementing their local tasks.

Every storage object has its own 1-Wire net (ST) and its own local microcomputer (MP). These local microcomputers (MP) control 1-Wire net, collect measuring values of temperature and transmit data to the central operator station (CS). Only final data is transmitted to the central computer and to other local stations (OS).

The computer of central operator station is MASTER of the transmission net RS485.

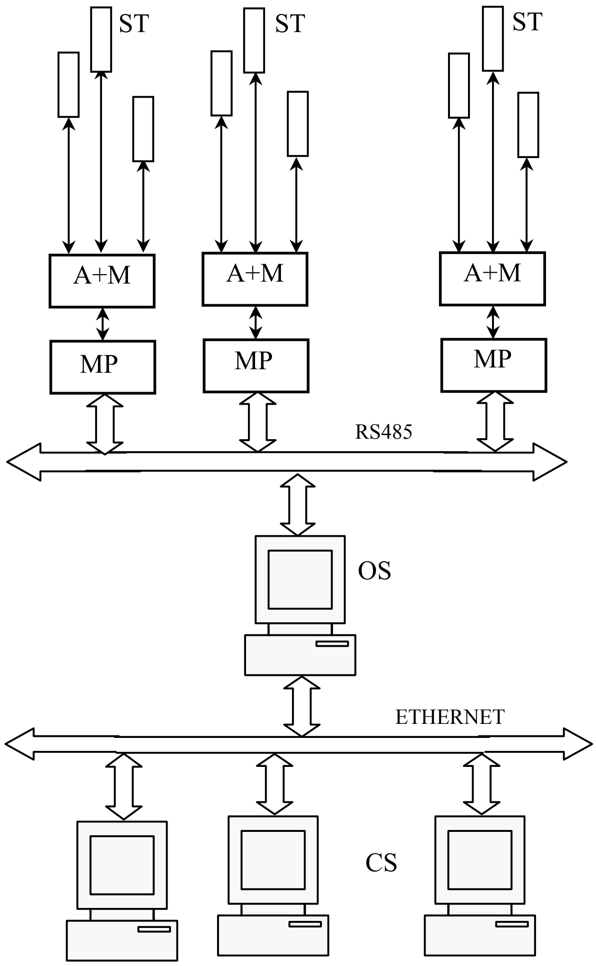
The structure of the system and programs of devices connected to the net, make it possible to use radio transmission to send data from local microprocessors to the central operator station, in the case when wiring is to difficult or to expensive. We can also realise radio transmission between the central operator station and local computer stations. The local stations can be treated as additional operator stations.

Local microprocessors carry out the following functions:

- Scanning local 1-Wire net and storing values of all temperature sensors of 1-Wire network. The scanning is more effective than when using the computer PC of operator station. The local microprocessor is placed very close to the 1-Wire net and it does not perform as many additional tasks as the computer PC of operator station.
- Transmission to the central operator station all measuring data by series interface RS 485 and, or by radio modem.

The local microprocessors (MP) have two interfaces: interface RS485 for the transmission bus and interface RS232 for 1-Wire adapter.

Every local microprocessor is a node transmission net interface RS-485. The MASTER of the network is a PC computer with data archives, in the central operator station.



ST – temperature cables
A+M – adapter and multiplexer 1-Wire bus
MP – local microprocessor
OS – central operator station
CS – local computer stations

Fig. 4. Distributed monitoring system for grain elevators

Network with interface RS 485 reduces multi-core cable for connection two or more objects and chambers of elevator at a large distance. We do not have to use a converters interface RS232/RS485 and RS485/RS232 which were required in a simple monitoring system with 1-Wire net presented on fig 3.

The basic tasks of the operator station and its programming are presented on fig 5 and are as follows:

- configuration of application monitoring system,
- measurement data for the base,
- measuring data display.

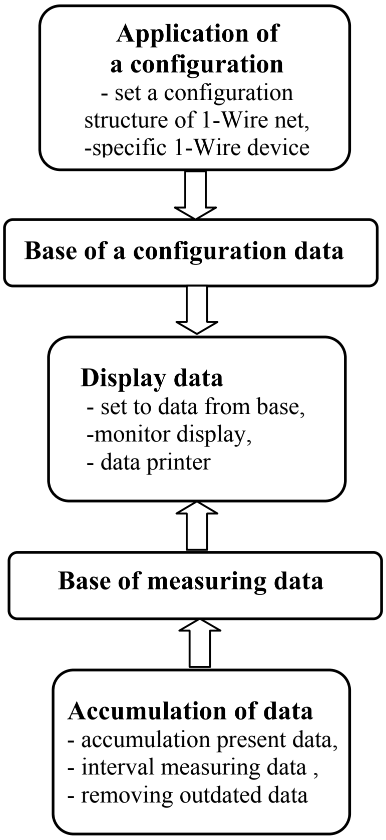


Fig. 5. Base of programming control operating station in distributed monitoring system for grain elevators

The other computer stations have access to the same data bases as the control operating station. They can perform the same presentation and monitoring functions as the control operating station.

5. OPERATOR FUNCTIONS

The following functions for the operator of the system are possible:

- Reading the value of temperature in a freely chosen silo,
- Printing the report of the actual temperature in one of the silos,
- The image of temperature in one silo of the elevator,
- Printing the report of the actual temperature in all silos of the elevator,
- The image and the printing a weekly changes of temperature in all the silos of the elevator,
- The view of the state of thermometers and cables in silos,
- The view of alarm states.

All thermometers of the system are automatically, periodically activated and temperature in all measuring points is scanned. The silos have been marked by letters and numbers according to their technological marks.

Monitoring states are indicated by the following colours:

- green – all temperature values are correct,
- red on yellow background – the temperature is in the alarm zone,
- blue – the temperature value was not measured,
- grey – the operator has disconnected measuring procedure on this silo.

Below on fig. 6, to 8 there are some examples of images presented on screen of a computer station monitor.

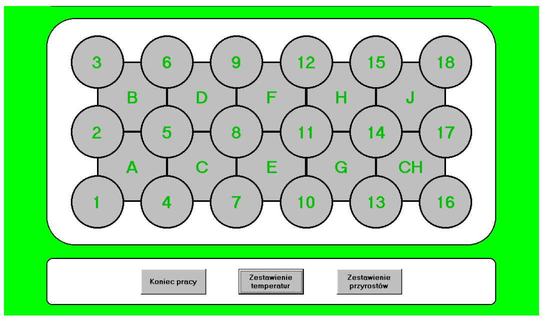


Fig. 6. The basic image with all of the silos of a elevator

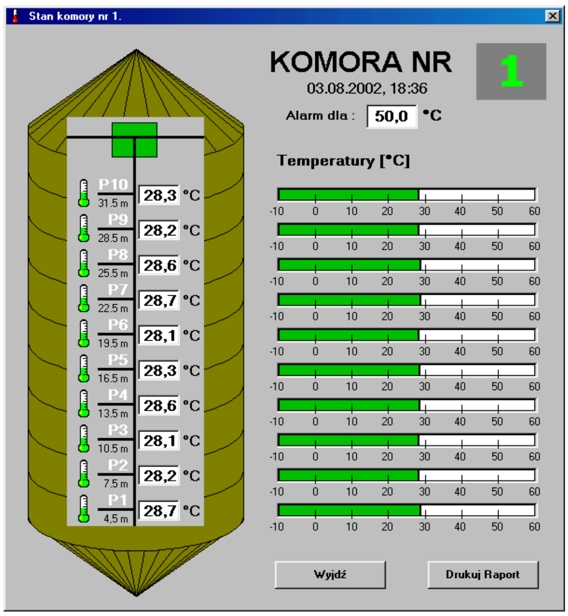
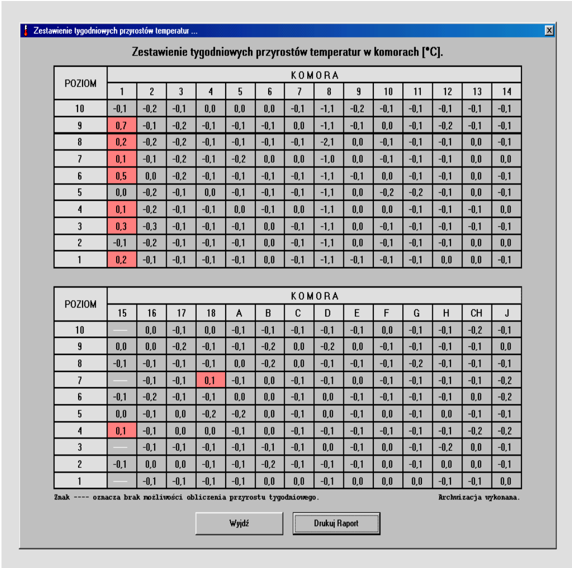


Fig. 7. The image of the actual temperature of one silo.


Zestawienie tygodniowych przyrostów temperatur ...

Zestawienie tygodniowych przyrostów temperatur w komorach [°C].

POZIOM	KOMORA													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
10	-0,1	-0,2	-0,1	0,0	0,0	0,0	-0,1	-1,1	-0,2	-0,1	-0,1	-0,1	-0,1	-0,1
9	0,7	-0,1	-0,2	-0,1	-0,1	-0,1	0,0	-1,1	-0,1	0,0	-0,1	-0,2	-0,1	-0,1
8	0,2	-0,2	-0,2	-0,1	-0,1	-0,1	-0,1	-2,1	0,0	-0,1	-0,1	-0,1	0,0	-0,1
7	0,1	-0,1	-0,2	-0,1	-0,2	0,0	0,0	-1,0	0,0	-0,1	-0,1	-0,1	0,0	0,0
6	0,5	0,0	-0,2	-0,1	-0,1	-0,1	-0,1	-1,1	-0,1	0,0	-0,1	-0,1	0,0	-0,1
5	0,0	-0,2	-0,1	0,0	-0,1	-0,1	-0,1	-1,1	0,0	-0,2	-0,2	-0,1	0,0	-0,1
4	0,1	-0,2	-0,1	-0,1	0,0	-0,1	0,0	-1,1	0,0	0,0	-0,1	-0,1	-0,1	0,0
3	0,3	-0,3	-0,1	-0,1	-0,1	0,0	-0,1	-1,1	0,0	-0,1	-0,1	-0,1	-0,1	-0,1
2	-0,1	-0,2	-0,1	-0,1	-0,1	0,0	-0,1	-1,1	0,0	-0,1	-0,1	-0,1	0,0	0,0
1	0,2	-0,1	-0,1	-0,1	-0,1	0,0	-0,1	-1,1	-0,1	-0,1	-0,1	0,0	0,0	-0,1

POZIOM	KOMORA													
	15	16	17	18	A	B	C	D	E	F	G	H	CH	J
10	—	0,0	-0,1	0,0	-0,1	-0,1	-0,1	-0,1	-0,1	0,0	-0,1	-0,1	-0,2	-0,1
9	0,0	0,0	-0,2	-0,1	-0,1	-0,2	0,0	-0,2	0,0	-0,1	-0,1	-0,1	-0,1	0,0
8	-0,1	-0,1	-0,1	-0,1	0,0	-0,2	0,0	-0,1	-0,1	-0,1	-0,2	-0,1	-0,1	-0,1
7	—	-0,1	-0,1	0,1	-0,1	0,0	-0,1	-0,1	0,0	-0,1	-0,1	-0,1	-0,1	-0,2
6	-0,1	-0,2	-0,1	-0,1	0,0	0,0	-0,1	0,0	-0,1	-0,1	-0,1	-0,1	0,0	-0,2
5	0,0	-0,1	0,0	-0,2	-0,2	0,0	-0,1	0,0	-0,1	0,0	-0,1	0,0	-0,1	-0,1
4	0,1	-0,1	0,0	0,0	-0,1	0,0	-0,1	-0,1	-0,1	-0,1	-0,1	-0,1	-0,2	-0,2
3	—	-0,1	-0,1	-0,1	-0,1	-0,1	-0,1	0,0	-0,1	0,0	-0,1	-0,2	0,0	-0,1
2	-0,1	0,0	0,0	-0,1	-0,1	-0,2	-0,1	-0,1	-0,1	0,0	-0,1	0,0	0,0	-0,1
1	—	-0,1	-0,1	-0,1	-0,1	0,0	0,0	-0,1	0,0	0,0	0,0	-0,1	-0,1	0,0

Znak ---- oznacza brak możliwości obliczenia przyrostu tygodniowego. Archwizacja wykonana.

Wyjdź Drukuj Raport

Fig. 8. Image of weekly changes of temperature of all the silos of the elevator.

6. BASIC PARAMETERS

Basic technical parameters of the system are presented in Table 2.

TABLE 2.

No	Parameter	Value
1	Measuring temperature	-55 °C to +125 °C
2	Accuracy	± 0.5 °C between -10 °C do +85 °C
3	Resolution	9 to 12 bit
4	Number of temperature cables (temperature points)	practical no limits
5	Period of actuation	about 5 min
6	Strength of the temperature cable	$\geq$ 50 kN – for cables of ϕ = 15 mm

One of the methods of protection for equipment used in hazardous atmospheres is “explosion proof” symbol Ex. Temperature cables and sensors are used in dust grain in elevators and must be designed for intrinsic safety in a hazardous area in a flammable atmosphere. This equipment must have national testing, certification and approval for electrical equipment for use in potentially explosive atmospheres in surface industries and notified to the European Communities Commission.

The temperature cable and co-operation isolated intrinsically safe circuits of the presented system have a Polish certificate to work in grain dust atmosphere.

7. CONCLUSION

Application tests have confirmed the advantages of the intelligent sensors and their usefulness in the temperature monitoring systems and particularly: accuracy, reliability, facility for intrinsically safe systems, low cost etc. It is also possible to monitor the other parameters of environment via 1-Wire net.

The 1-Wire net and new intelligent sensors allowed to reduce wiring of the system (1-Wire net needs only 2 wires) and to simplify converters and other functional blocks of the monitoring system.

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Author(s):

Dr Eng. Andrzej Kobosko, Electronic Automation Group, Industrial Research Institute for Automation and Measurements - PIAP, 02-486 Warszawa, Al. Jerozolimskie 202, Poland, tel.: (48, 22) 8740 263, fax: (48, 22) 87 40 220, e-mail: akobosko@sg.piap.waw.pl.

Dr Eng. Zbigniew Pietrusiński, Electronic Automation Group, Industrial Research Institute for Automation and Measurements - PIAP, 02-486 Warszawa, Al. Jerozolimskie 202, Poland, tel.: (48, 22) 8740 376, fax: (48, 22) 87 40 220, e-mail: zpietrusinski@sg.piap.waw.pl.