XVI IMEKO World Congress
Measurement - Supports Science - Improves Technology - Protects Environment ... and Provides Employment - Now and in the Future
Vienna, AUSTRIA, 2000, September 25-28

MONITORING SYSTEMS FOR PROTECTION AGAINST DUST EXPLOSIONS

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Abstract: Monitoring systems protect grain elevators against uncontrolled blasts and explosions. Many people die in fatal dust explosions every year. They cause material and building losses. In the paper I present the resultants of our experiment with monitoring system: temperature, humidity and other parameters. These systems are working with elastic temperature cables. Many parts of systems designees in intrinsic safety technique. The procedure of designing monitoring system has also been given.
Keywords: Monitoring system for grain elevator, intrinsic safety for sensors and transducers of computer system.

1. INTRODUCTION

The atmosphere in grain elevators are characteristic of grain dust. The major problem with dusts is temperature, and there are two aspects: ignition temperature of dust clouds as smouldering temperature of dust layers, table 1 and table 2. In extremely uncontrolled conditions the explosion of the silo or elevator chamber can happen. Statistically explosion in grain storages occurs once a year on the European scale. Metabolic processes under storage condition are exert an influence to temperature increase. The second reason of explosion in storages are hazardous areas that depend on the of technological process especially during grain loading and unloading.

In the 1990-1957, 1085 dust explosions accident were recorded in USA. In Poland - only a few explosions. As a result of these explosions 640 people died, many were injured and material losses were above 100 mln USD. The energy of explosion of 1 kg of average grain dust in the mixture with air is 3 to 5 times higher then the energy of explosion of 1 kg of TNT and the explosibility of grain dust is found to be about 20 - 50 times bigger then for coal dust

Table 1. The parameters of dusts

Natural products	Min. energy of ignition [mJ]	Min. temperature of ignition [K]	Min. explosion conc. [mg/dm^3]	Maks. explosion pressure [Mpa]
1. wheat	30	723	125	0,75
2. rye	80	532	56	0,41
3. barley	60	573	693	0,52
4. oat	60	623	750	0,60
5. corn	60	673	60	0,78
6. rice	40	505	60	0,60

The prevention again explosion consists in a controlled temperature, humidity grain and inside and outside microcllimate parameters of storages. Efficient monitoring systems are to prevent uncontrolled situation and their operation cannot be the cause of the accident. In this hazardous are use intrinsically safe instrument system.

Table 2. Ignitability and explosibility parameters of grain dust from one polish elevators [3]

Dust No	Maximum particle size [μm]	Humidity [%]	Lower flammab. limit, DGW [kg/m^3]	Maximum explosion pressure [Mpa]	Optimum concetra-tion [kg/m^3]	Maximum rate of pressure rise [Mpa/s]	Minimum energy of ignition [J]	Explosibility parameter K_{ST}
1	90	9,4	0,105	0,685	1,0	9,8	0,065	20
1	90	6,2	0,095	0,730	0,9	11,2	0,048	21
2	125	6,2	0,150	0,590	1,15	7,5	0,100	15

2. MONITORING SYSTEM

One of the most popular methods of determining potential locations of spoilage in stored grains is through constant monitoring of the internal temperatures of the grain mass. In a mass of stored utilises sensors attached at regular intervals to high strength steel cables [1]. The overall monitoring and information system for grain elevators with this temperature cables. Structures of monitor system are following: System is comprised of six basic components present on Fig. 1.

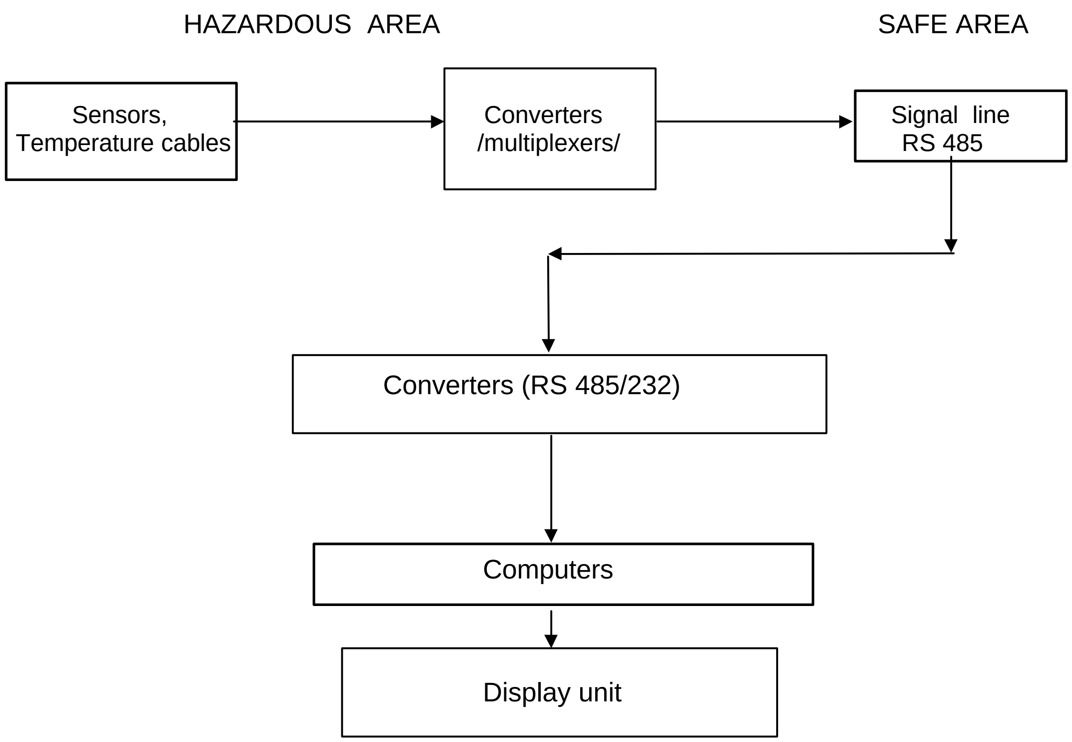

Figure 1. Information flow diagram for a monitoring system using a temperature cables

Under explosive atmosphere are temperature cables and other sensors. This equipment, passive elements, are co-operation with the active elements: converters. All equipment working under hazardous area must be testing, certifies for hazardous locations. Signal line and next apparatus working under normal (safe) atmosphere.

Measuring and information function of monitoring system are presents on Fig.2.

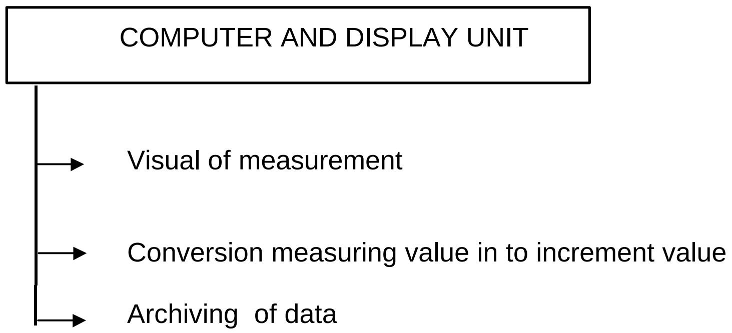

Figure 2. Monitoring function for temperature measuring

One function is untypical: conversion measuring value in to increment value. Storage engineering of grain thinks this parameters how to important this value of measuring. Second parameters are repeatable of measuring.

3. TEMPERATURE CABLES

Temperature cables suspended in the elevators chambers. Due to their function and load, several types of cables produce, their strength ranging from 10 to 100 kN and their length from 10 to 60 m. An example of one of the HD „heavy duty temperature cable" , mechanical resistance to break up to 80 kN, is present in Fig.4.

The distribution of sensors in the cable and location of the cable in the elevator (silo) chamber is the result of the ISO standards [4] and authors experiences. The cable consists of a jacket into which the core is put consisting of very small sensors of temperature and connecting cables. The jacket was made by winding around the high-pressure polyethylene pipe two braids made of steel wires with increased mechanical resistance. The direction of the winding of the layers of the braid is push-pull so that the twisting forces could be compensated. The external surface of the jacket is the polyethylene casing, which is non-toxic for the grain. The structure of this cable permits the installation of the jacket itself in the elevator and then the inserting and pulling out of the core.

Design of temperature cable to intrinsic safety for ensuring that the electrical energy available in a circuit is too low to ignite the most easily ignitable grain dust. EN 50 020, the relevant CENELEC apparatus standard, defines an intrinsically safe circuit as: „A circuit in which no spark or any thermal effect produced in the test conditions prescribed in this standard (which include normal operation and specified fault conditions) is capable of causing ignition of a given explosive atmosphere".

Problems in intrinsically safe system in the contex of ATEX Directives 94/9/EC of the European Parliament and the Council [5] concerning equipment and protective systems intending for use in potentially explosive atmospheres.

Intrinsically circuit consist multi sensors from temperature cable together with converter circuit under explosive atmosphere, Fig. 3. The current and power flow in this circuit must be in safe place on useable area, Fig.5. [6]. This equipment must be certificate. Our temperature cable was tested, Fig. 4, and obtain certification in Polish Safety in Mines Research Institute (GIG „Kopalnia Barbara).

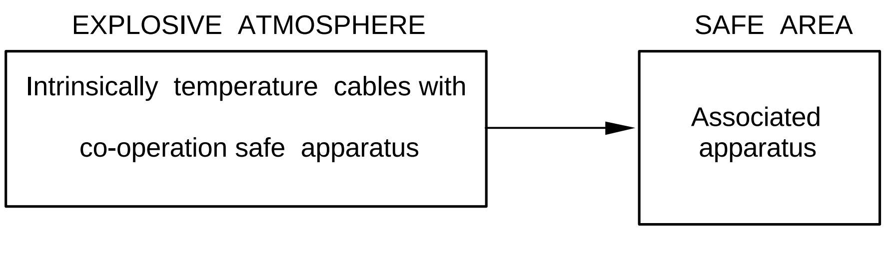

Figure 3. System with certified intrinsically equipment

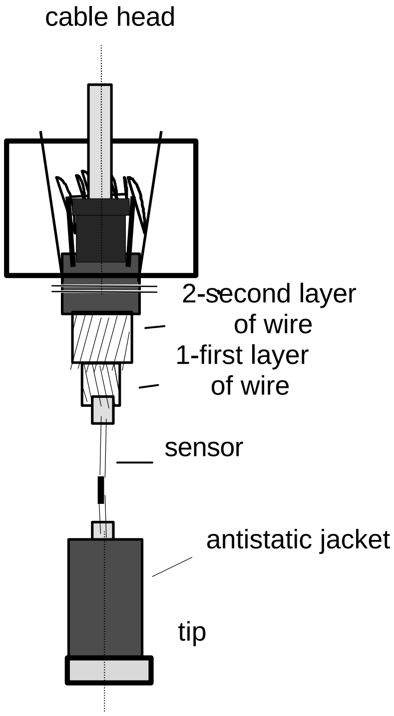

Figure 4. The Heavy Duty temperature cable

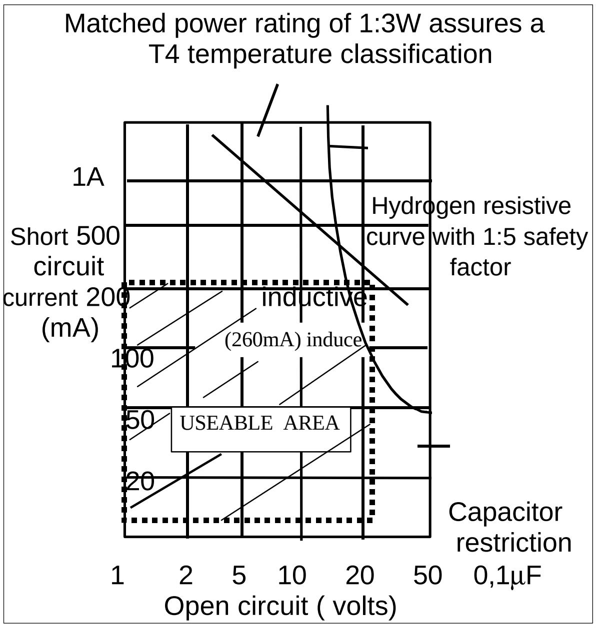

Figure 5. Current and voltage limitations of an intrinsically safe circuit

4. A LOADING OF TEMPERATURE CABLES

These cable are testing under storing, loading and emptying operations. Our cables are supported by the roof of grain bin, Fig. 6. Results of tests are presents H/D ratio [2]. First, we want discussed influence vertical loading on cable from mass of grain. On the end we discussed influence loading in function humidity of grain.

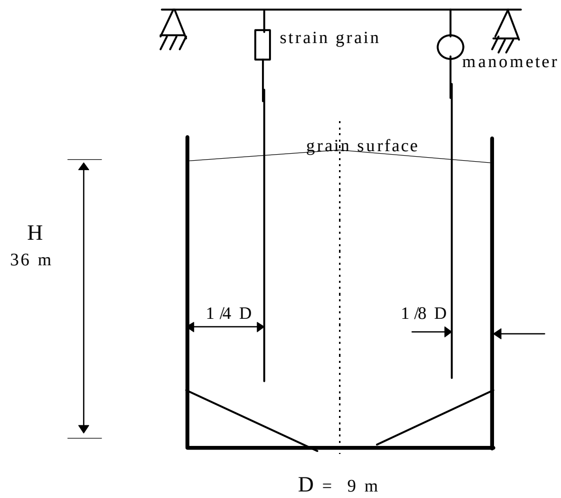

Figure 6. Stand of the cable testing

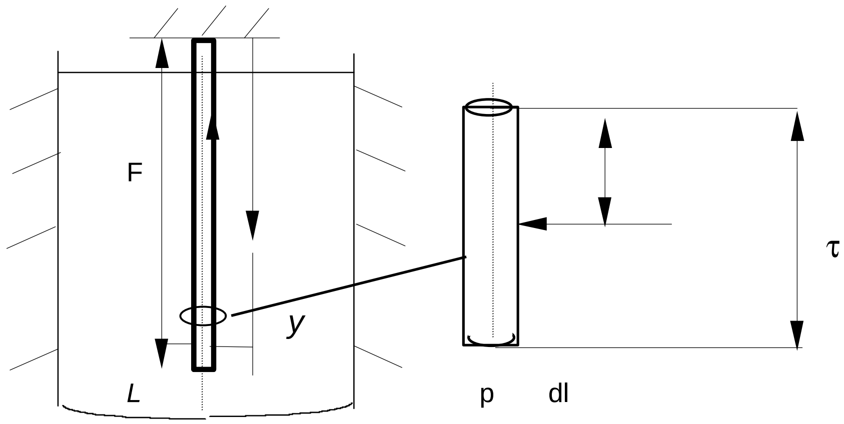

Figure 7. Vertical frictional loads for radial position on temperature cable

where: p - pressure of the grain
- τ - shear stress
- γ - uncompacted bulk weight of the grain
- d - diameter of the cable
- F - load

$$\tau = \mu\, p$$

$$p(y) = \gamma y$$

$$F = \int ˘\, d\, \mu\, \gamma\, y\, dy \equiv ˘\, d\, \mu\, \gamma\, l^{2}/2$$

In practical, on typical humidity of grain, LOAD obtain:

$$F_s = F_{tc} \frac{\pi \mu_{tc} D_{tc} R_h \gamma}{\mu} \{ y + \frac{R_h}{\mu k} [\exp(-\frac{k \mu y}{R_h}) - 1] \} F_w$$

where:

F_{tc} - Multiplication factor

μ - coefficient of friction of grain on steel

μ_{tc} - apparent coefficient of friction of grain on cable

D_{tc} - equivalent diameter of the cable($D_{tc} = \sqrt{4 pow./\pi}$)

R_h - hydraulic radius of bin (area divided by perimeter),

k - the ratio of lateral to vertical grain pressure

y - the depth of grain covering the cable

F_w - Multiplicator Factor depends of humidity
for grain humidity up to: 10 % $F_w = 1$
for grain humidity up to: 20 % $F_w = 2$
for grain humidity up to: 30 % $F_w = 3$

On stand, Fig. 6, there was tested increase of load in function of H/D present on Fig. 8.

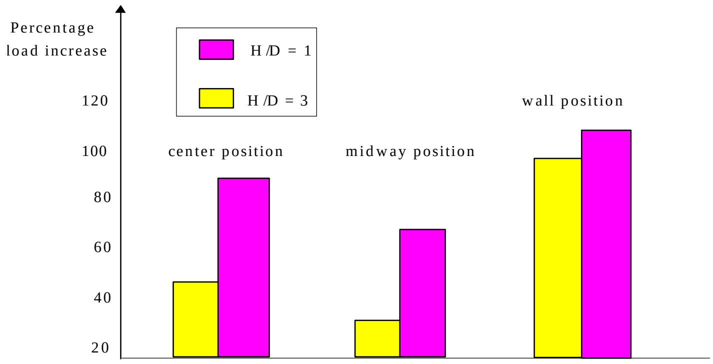

Figure 8. Percentage increase of load in function of H/D

5. CONCLUSION

- The apparatus in grain storages under grain dust are explosive atmosphere and must be certificate to work in this hazardous area,
- The temperature cables must be design like passive part of intrinsically circuit,
- The load on the cables at the wall position was largerthan the centre and midway positions and the load for the wall position decreased slower than the other two positions,
- The load on the cables increase in proportional function of grain humidity.

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