Device for Measuring The Level of Bulk Materials in Bunkers

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Abstract - **The problem for measuring the level of bulk materials in bunkers is solved by selecting the method at constriction and scheme decision, the capacities converter at allows detection of small changes of capacities, the high sensitivity and stability. This method enabled for calibration in two parts, one for manufacture and second for device exploiting.**

Keywords - **Level of bulk material.**

I. INTRODUCTION

A necessary condition for the automatic control of transport lines in glass production and their normal work is to ensure the control over the level of bulk material in silos and material mixture in bunkers.

The silos which provide the dozing line with material need signaling when the lowest (minimum) and highest (maximum) levels of material are reached and at the same time a command should come for a stop of unloading or loading.

To get the exact information for the level of material used in glass production (sand, soda, dolomite, feldschpad, limestone etc.), the primary converters of level into electrical signal, it is necessary for them:

- to function reliably in an environment of a lot of dust, noise and vibrations;
- to be in accordance with the peculiarities of the material: chemical activity, abrasives, hygroscopic capacity, humidity, .adhesion etc.
- to be located in immediate proximity to or inside the silos, within a wide temperature range from -15°C to +45°C;
- to be in accordance with the way the silos and bunkers are loaded with material and material mixture - from transport pipes loading the material in the middle of the silos i.e.the profile of the material is at its maximum in the center of the silo;
- to be in accordance with the shape of the silo and the material from which its walls and bottom were made.

The main problem in designing the device to control the minimum and maximum levels of material in silos to be used in glass production is the choice of method for measuring the level of the material as well as the concrete engineering design of a primary converter.

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II. EXPOSITION

A. Choice of a method to control the minimum and maximum levels of bulk material in silos for the needs of glass production

A large number of methods for measuring the level of bulk material in covered vessels are applied in practice. The instruments for measuring and control are rated in four groups - weight, hydrostatic, electromechanical and electrical.

The largest groups of devices, whose sensitive units function on the principle of converting certain qualities of the controlled environment into respective signals for the level, are the electrical level meters: resistance, capacitive, inductive, photoelectrical, thermal, acoustic, radar, laser radar, radioactive etc.

The great variety of methods and equipment for positional and uninterrupted control of the level of bulk material doesn't make the choice of just one of them for a particular application easier. Most of these methods have certain disadvantages, which make them inapplicable, and some of them can only have limited application - for instance only as positional ones and only for maximum or for minimum level at that.

With the choice of method it is necessary to take into consideration all the requirements concerning the concrete working conditions of the primary converters.

On the basis of the examination of all the devices for constant and positional control of the level of bulk material and after a large number of laboratory and factory experiments, the capacity method for positional control of the level has been chosen.

The chosen method has a wide range of advantages in comparison with the other methods in use - the simple and technological design providing great mechanical strength as well as the lack of movable parts which is a prerequisite for high reliability.

The main problem, which arises when capacity converters for level control are used, are the very small values of dialectical permeability ε of bulk material for glass production. The dialectical permeability ε is different for the different materials and it is very close to that of air. It depends on the temperature, the humidity and thickness of the materials. This dependence leads to the need to use a method and a scheme allowing for a stable control over the variation of very small capacities.

There are plenty of methods for measuring small capacities. The disadvantages of the existing methods are their comparatively low sensitivity and insufficient stability in registering the very small variations of capacity.

B. Choice of a concrete engineering solution

1. *Choice of a scheme solution*

The solution of the problem for registering very small variations of capacity, with high sensitivity and stability, is based on the possibility for the frequency of a crystal oscillator to change within a small range when the capacity of a capacitor is changed, and it (the capacitor) is connected in the chain of the crystal oscillator; at the same time the stability of the generated variations depend on the stability of the oscillator.

When this change in frequency of the generated variations is registered in a certain way, a possibility arises for registering very small variations of the capacity connected to the scheme.

Device [1], is offered for the control of the level of bulk material and material mixture in bunkers. It consists of 2 parts: converter block **1** and measuring - converter block **5.**

The scheme of the device is shown in Fig.1.

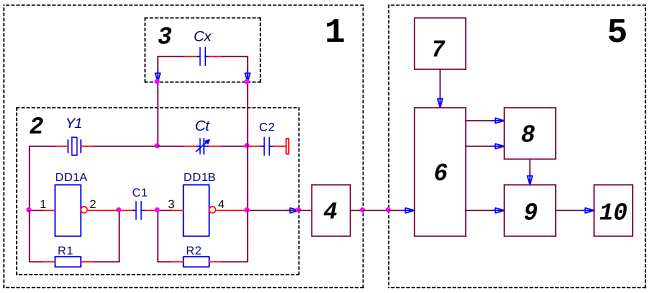

Fig.1. Device for the control of the level of bulk material

Converter block 1:

3 - primary converter "level-capacity";
the design is shown in [1],
in the scheme it is replaced with the capacitor C_X.
Parallel to the C_X capacitor the adjusting C_t is also connected.

2 - secondary capacitor "capacity - frequency", made according to the classical scheme of a crystal oscillator with logical elements;

4 - connecting block;

Measuring - converter block 5:

7 - second crystal oscillator;
6 - control block;
8 - comparing block;
9 - memory;
10 - indication block

The operation of the device is as follows.

When the capacity is connected in series with the crystal oscillator Y1 between the electrodes of the primary converter "level - capacity" Cx, the frequency of the series resonance of the crystal oscillator is changed to the following value:

$$f_S{}' = \frac{1}{2\pi.\sqrt{L_S.\dfrac{C_S.C_X}{C_S + C_X}}} \qquad (1)$$

where:

$\boldsymbol{C_S}$ - dynamic capacity from the equivalent replacing scheme of the crystal resonator*;*

$\boldsymbol{L_S}$ - dynamic induction of the equivalent replacing scheme of the crystal resonator.

When the level of the bulk material is changed between the electrodes of the measuring capacitor Cx the dialectical permeability ε of the environment between them is changed, and respectively - the capacity of the measured capacitor as well:

$$C_X = C_{X0} + \Delta C_X \qquad (2)$$

This leads to a frequency change in the crystal oscillation stabilizer **2**, which is registered by the comparing block **3**. Block **8** is a digital comparator. Its output signal is determined by the rate of the frequencies of the two generators - **2** and **7**. The output information is recorded in the memory **9** and is registered by the indication **10**. Blocks **8** and **9** are controlled by block **6** through the impulses coming from the second crystal oscillation stabilizer **7**.

The dependency of the frequency of the generated variations Eqs. (1) on the level of the bulk material between the electrodes of the primary converter, and respectively on its capacity, is non-linear:

$$f_S{}'' = \frac{1}{2\pi.\sqrt{L_S.\dfrac{C_S.(C_{X0} + \Delta C_X)}{C_S + C_{X0} + \Delta C_X}}} = f_S.\sqrt{1 + \frac{C_S}{C_{X0} + \Delta C_X}} \approx f_S.\left(1 + \frac{1}{2}.\frac{C_S}{C_{X0} + \Delta C_X}\right) \qquad (3)$$

The sensitivity is having maximum with materials that have very small dialectical permeability.

To ensure high technological qualities of the device during its operation, the trimmer capacitor C_t is connected parallel to the measuring capacitor Cx. It regulates the sensitivity of the scheme - for the different materials with different dialectical permeability $\boldsymbol{\varepsilon}$.

To lessen the temperature instability of the generated variations it is necessary to select a suitable crystal resonator. Best results will be reached with the use of a crystal resonator with the so called *"AT - section*" [2], having frequency - temperature characteristic in the form of a cubic parabola. It is characterized with very low temperature instability ($\Delta f/f \leq \pm 15.10^{-6}$) within a wide temperature range (-60°C ÷ 100°C). With a selected, in the production of the crystal resonator, variation of the section angle, the temperature instability can be lessened additionally (to $\Delta f/f \leq \pm 5.10^{-6}$) within the temperature range (-30°C ÷ 60°C).

For an additional lessening of the temperature instability of the crystal generator traditional methods can be used: schemes for temperature compensation (for instance - connecting an additional capacitor with a selected temperature coefficient, parallel or in series to the primary converter "level - capacity" *Cx*; this role may be played by the trimmer capacitor *Ct*). Possibility used passive or active thermostat. Also this case complicated device and construction.

2. Choice of a construction for the primary converter "level - capacity"

Device [1] is offered for the control of the level of bulk material in silos and material mixture in bunkers. It uses a primary converter "level - capacity".

Its construction is shown in Fig.2.

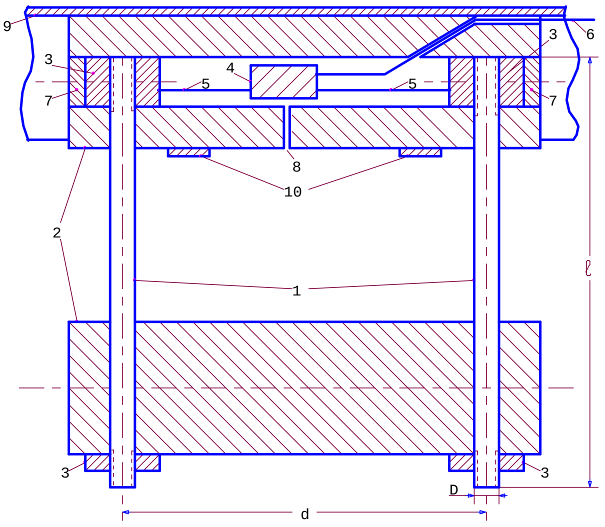

Fig.2. Construction of the primary converter "level-capacity"

The main part of the construction are the electrodes **1** of the measuring capacitor - two pieces of stainless steel pipes, joined in one construction with two insulating rods **2** made of textolite. The materials used in the construction elements as well as the construction itself meet the requirements for sufficient mechanical strength and resistance to the chemical and abrasive influence of the controlled bulk material.

The capacity of the thus constructed capacitor with cylindrical electrodes, with air used as dielectric, is determined with the following expression [2]:

$$C = \varepsilon_o . \varepsilon_в \frac{l}{4.\ln \frac{2.d}{D}} \text{ [F]}, \qquad (4)$$

where:

- $\varepsilon_o \approx 8{,}85.10^{-12}$ - the absolute dielectric permeability;
- $\varepsilon_в = 1{,}000594$ - relative dielectric permeability of the air;
- ℓ [m] - length of the electrodes;
- d [m] - distance between the electrodes;
- D [m] - diameter of the electrodes.

The distance between the electrodes is selected making a compromise between the concerns for sufficient mechanical strength of the construction and avoiding the adhesion of the material between them at high humidity or in case of eventual freezing? Electrode dimensions and distances between them are with the peculiar characteristics of any of the measured materials.

The fixing of the electrodes to the insulating rods is made with steel insertions ***3***, accommodated in the recess of the upper insulating rod ***2***. The insulating washers **7** protect the recess from permitting material and humidity.

The construction of the converter "level - capacity" is fixed with steel clamps **10** to the steel girder **9** with Π - shaped profile which is intended to ensure and protect the construction against mechanical attacks when filling the bunker. The steel girder is fixed to the walls of the bunker in a way providing the location of the constriction along its axis.

In the upper insulating rod there is one main opening along its axis, with the circuit board **4**, where the components of the secondary converter **2** are located. The metal electrodes **1** are connected through short conductors **5** to the circuit board **4**, thus providing a minimum mounted capacity. The output signal from the crystal oscillation stabilizer mounted onto the circuit board **4** is sent to the measuring - converter block **5** (from Fig.1) via coaxial cable **6** to the control block thus suppressing to a great extent the possible external interference.

The upper insulation rod has a second opening **8** for adjusting the secondary converter **2** during the device production as well as during its mounting in the silo.

Additional lowering of the temperature instability of the generated variations can also be done with a certain alteration of the device construction - when mounting the components of the second crystal oscillation stabilizer **7** onto the circuit board **4** together with components from the secondary converter "capacity - frequency" **2**. The use of two generators with components having the same parameters provides constant rate of the frequencies of both generators, with a change in temperature as well as under the influence of other destabilizing factors (for example, ageing of the components). However, this makes the construction more complicated to a certain extent as a second signal cable is needed.

III. Conclusion

The offered method and the scheme and construction of the device for controlling the minimum and maximum levels of bulk material in silos provide very high sensitivity and stability of the received results under the influence of destabilizing factors - temperature, ageing, interference etc. The device construction meets the requirements for sufficient mechanical strength and resistance to the abrasive and chemical influence of the controlled material.

The application of the offered method for measuring the level of bulk material is recommended above all for positional control, due to the non-linear dependency of the frequency of the generated signal on the level of the material.

The device can also be used for uninterrupted control, under limited conditions - connecting additional devices for linearization of the dependency of the generated signal frequency on the level of material, temperature stabilization or compensation of the instability of the generated signal etc. In this case the electrodes' length should be in accordance with the height of the silo.

The device has been introduced in the glass production of the Republic of Bulgaria and has its own patent licence [1].

References

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