

Study of static charge accumulation in HDPE gas pipelines

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Abstract. The accumulation of static charge in polyethylene pipes of gas network systems is a familiar process, which is paid attention to mainly to prevent accidents on pipelines. incidents related to static electricity can occur both during assembly works (coil tapping) and during the operation of gas pipelines (gas venting, etc.). Despite the fact that repeated attempts to study this process have been made by major operating organizations, today we can state that these regularities have not been studied in full. In this work we have made an attempt to describe theoretically the process of static charge accumulation on a pipe body, as well as to evaluate experimentally the adequacy of the proposed models.

1 Introduction

At the present time, the modern trend in the development of gas distribution networks is the widespread use of plastic materials, including the introduction of polyethylene pipelines wherever it is permissible from environmental conditions [3, 14, 16]. Earlier the temperature range of operating was considered as one of the main limiting factors, but at the present time the accumulated experience proves the possibility of PE pipelines application even at negative temperatures [1, 15].

One of the important peculiarities of PE pipelines is the accumulation of a static charge in the process of operation. Serious research of such processes, however, was carried out only for insulation of high-voltage wires (the occurrence of delamination and breakdown in the vapor-gas cavity was studied). The process of static charge accumulation has both potentially positive features (pitting detection detection on pipelines) and negative ones, which can manifest themselves in the phenomenon of pipe body breakdown. In addition, static electricity can cause accidents during some technological operations, such as blowdown, pipeline sectioning and so on [2, 19].

For a detailed study of the process of static charge accumulation, a laboratory setup was developed and a number of experiments were conducted, based on the results of which experimental values of the ignition threshold of independent discharge were obtained.

2 Theoretical investigation

Since 1993, there have been a number of micro-hole (5 to 50 μm diameter) incidents on gas distribution pipelines in the United States [13]. Most of these have been identified during accident investigations, while other cases have

been accidental. In terms of pipeline geometry, the identified cases involved pipelines in the range from 1/2" to 4" and SDR from 10 to 11.5. The greatest number of incidents were observed during blowdown and filling operations of the pipeline [12, 17]. Thus, in a number of cases, polyethylene is capable of accumulating a charge on the inner surface, which can lead to breakdown and local melting of the pipe body.

3 Conducting research

3.1. Experimental studies

The experimental setup consists of a section of pipeline with a high-voltage electrode ("ionizer module") at one end in the form of a ring with four needles. An image of the experimental setup is shown in Figure 1.



Fig. 1. 3-d model of the ionizer experimental setup

Four steel needles are arranged symmetrically around the perimeter of the ring. A more dense

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arrangement of the needles should not increase the discharge, because there is an effect of "mutual" quenching of discharges on neighboring needles - even when the needles are arranged symmetrically, when the tension on all needles is the same, the discharge is not ignited on all needles if the needles are too close to each other [2]. A needle is the most convenient form for igniting an electrical discharge; a metal ring is used to embed the needles in the structure of a sealed pipeline. The beads on the edges of the ring, facing into the air, serve to reduce the electric field in the air near the ring and prevent the ring from being coronated toward the air [4]. Figure 2 shows how the electrodes are positioned relative to each other and the pipe. The grounded electrode is shown in blue and the high-voltage electrode is shown in red. The black lines show the contour of the polyethylene pipe.

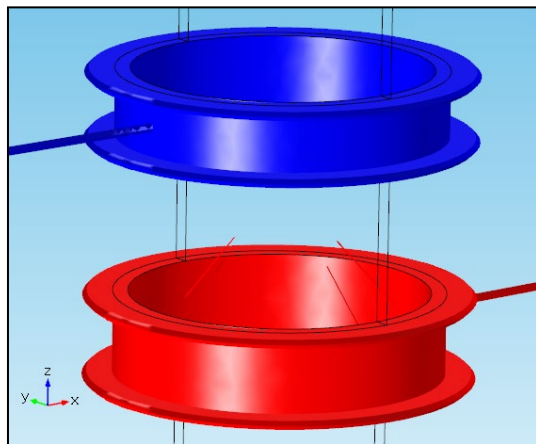


Fig. 2. Electrode - insertion into a polyethylene pipe

Measurement of the electrostatic field is carried out by the measuring transducer PZ-80 (Figure 3), which contains a converting element in the form of a mechanical modulator. The electric signal comes from the converting elements through the signal matching unit to the analog-digital converter and signal processor, which calculates all the measured quantities. Technical characteristics of the digital converter PZ-80 are presented in Table 1.

Table 1. Technical characteristics of the digital transducer PZ-80

Parameter	Unit of measurement	Meaning
Measurement range of electrostatic field intensity (ESI)	kV/m	0.3 – 200
Permissible error limits of measurement of the electrostatic field intensity ESI	%	±15
Weight	gram	250

Figure 3 shows the measuring device PZ-80 and the display unit Ecophysics-110A.



Fig. 3. Measuring device PZ-80 and the display unit Ecophysics-110A

Operating principle of PZ-80 electric and magnetic field intensity meters is based on conversion of field intensity into electric voltage signal, which then goes to analog-digital converter [5]. After filtering and detection operations the measurement of field intensity and its representation on the indicator is performed. Transformation of the alternating electric field strength is performed by means of a dipole measuring transducer, formed by two plane-parallel plates. The test side for static electricity accumulation by polyethylene pipelines of gas distribution systems is shown in Figure 4.

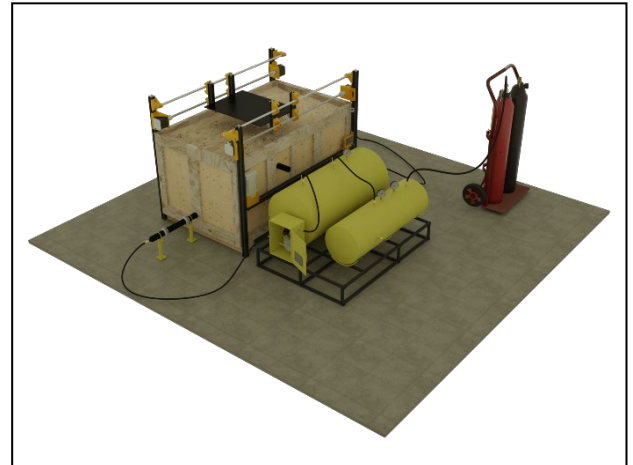


Fig. 4. Test side for static electricity accumulation in polyethylene pipelines

3.2 Theoretical investigation

In the process of experimental work, we measured the current that the "ionizer" gives at different lengths of the section of the tube between the "ionizer" and the ion collector grid (starting with a small distance, 10 centimeters, 20 cm, 50 cm, etc., all the way up to the length of the box) [6]. Of the measurements in this case, only the measurement of the electric current is involved. Calculation of threshold voltage, at which an independent electric discharge occurs in the given geometry, is performed by integration of ionization coefficient, which

is a function of field strength specific for the given type of gas [7].

$$\int_A^B \alpha(E) ds = M_{cr}(1)$$

Integration is performed along the electric field line AB, the beginning and the end correspond to the surface of the electrode or solid insulator (depending on where this field line goes from the gas region).

The method consists in finding the voltage when the value of integral (1) at least on one power line in this area reaches the critical M_{cr} number which value depends on the type of discharge which can be implemented in this system: for corona or barrier discharges M_{cr} is in the range of 6...15, for streamer discharge - in the range of 15...20. In this case we take $M_{cr} = 15$ - since corona discharge should occur in this system, we will get an estimation for the threshold voltage from above. In addition to the threshold voltage itself, the method makes it possible to determine the area in which a discharge can occur at a given voltage [8]. The dependence of the CH_4 ionization coefficient on the field strength is shown in Figure 5.

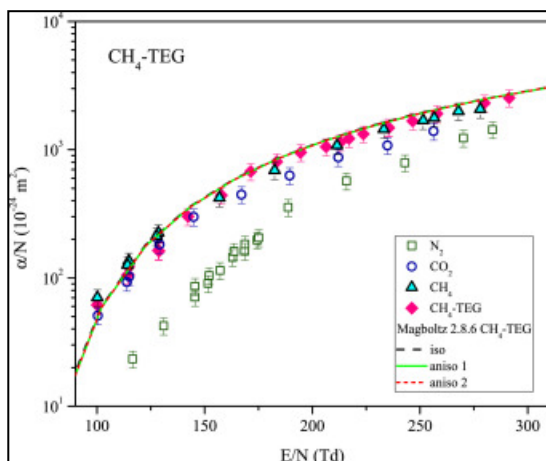


Fig.5. dependence of the CH_4 ionization coefficient on the electric field strength

The electric field is calculated in the quasi-static approximation, the Laplace equation is solved by formula (2) (without taking into account the volume and the surface charge, because the method considers the field distribution immediately before the ignition of the discharge)

$$-\nabla \cdot \epsilon \nabla \varphi = 0. \quad (2)$$

In the volume the dielectric permittivity of polyethylene ($\epsilon=2.35$), gases ($\epsilon=1$) are set. On the surfaces of electrodes, the boundary conditions of fixed potential (equal to voltage or zero for grounded elements) are set, on the outer surface in the air zero potential is set (imitation of grounded room walls), on the outer "ends" of the pipe the condition of power lines parallel to the boundary is set.

The key parameters that affect the discharge ignition threshold are needle length and the needle radius [9]. With the parameters listed below in the description of the

system components, an ignition threshold of 18 kV was achieved. This is a relatively high value compared to the ignition threshold value typical for corona discharge in a single-needle system - 4...8 kV.

Consider the question of whether the electric field will prevent the ions from drifting outside the electrode system through the tube. As shown in the graph (Figure 6), in the region where the field is rotated toward the grounded electrode (and is thus rotated relative to the direction of gas pumping), the drift velocity of the ions is below 10 m/s, i.e., a gas flow with a speed near the tube axis of about 20 m/s should effectively carry the ions outside the electrode system.

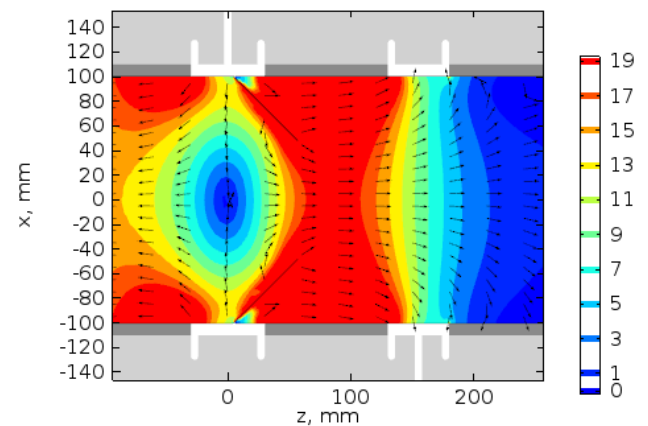


Fig. 6. Ion flux drift velocity under the action of electric field at 18 kV

In the course of preliminary tests of the developed unit, for the first time in the practice of industrial application on a real section of PE pipe, important results were obtained: it was established that polyethylene gas pipelines accumulate charge most quickly when the gas contains hot moisture, and also that the charge tends to accumulate when there in the presence of suspended mechanical particles in the gas. The opposite is also true, which in its turn leads researchers to look for effective methods to reduce the risks of static electricity [10, 11].

4 Conclusion

As a result of the studies, the peculiarities of the phenomenon of static charge accumulation in polyethylene gas pipelines have been established. Theoretically predicted and the first results in terms of gas flow ionization have been obtained. For further consideration, the introduction of antistatic additives (aerosols) into the gas flow before carrying out technological operations seems to have a certain potential as a method of minimizing the negative effects [18].

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