COMPARATIVE STUDY ON THE TEMPERATURES OF WELDING THE POLYETHYLENE FITTINGS – SOCKETS – HIGH DENSITY POLYETHYLENE PIPE

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ABSTRACT: This paper aims to approach an important issue from a theoretical and experimental point of view, in terms of safety in the operation of polyethylene pipes used in gas distribution. The study is based on the analysis of welds performed on fittings and high density polyethylene pipes, abiding by the work procedure and using approved equipment and machines, in accordance with the law. A parallel is drawn between the correct and incorrect welds, emphasizing the disadvantages of the incorrect ones and the dangers they pose.

KEY WORDS: branch tee, polyethylene, temperature distribution.

1. INTRODUCTION

The polyethylene production is continuously developing worldwide, which is due to the fact that its use and demand are constantly growing. The satisfactory physical and mechanical characteristics of these pipes and especially the price recommend them for the development of the natural gas distribution systems. The efficiency of a pipeline system depends, in addition to the cost of the pipes and fittings, on the installation cost, the maintenance cost and the durability. The advantages of polyethylene pipes (Figure 1) for the transportation and distribution of natural gas, compared to steel pipes, are shown through numerous features. [5]

Figure 1. Assemblies of polyethylene fittings and pipelines of various sizes used in natural gas distribution

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The better and permanent change of the mechanical strength of the polyethylene pipes and implicitly of the internal operation pressure has the following consequences:

a. reduction of wall thickness, with significant economic effects;

b. increase of productivity of the pipe extrusion operation;

c. reduction of residual stresses determined by the welding operation;

d. possibility of installing pipes in soft soils without a sand bed. [3]

Usually the damages of the under pressure high density polyethylene pipes are visible first by the appearance and then increase/propagation of cracks in the brittle part of the material. Designing polyethylene pipes cannot rely on short-term test results, due to the influence of long-term operating factors, mainly creep and pressure fluctuations. An important part is also played by the fittings required for the connection between pipes made of polyethylene or other material, such as metal. [5]

In Romania the use of polyethylene pipes for building gas distribution networks is relatively new and because of this, the experience in the field is limited. The first gas distribution systems using tubular HDPE material were built in our country according to certain projects developed by B.C. GAS CANADA within the oil system rehabilitation program (the period between 1996 and 1997) funded by the World Bank, and comprising approximately 1000 km of pipelines. (e.g. the gas distribution network in Copşa Mică, Sibiu county). As the funding sources multiplied and the local administration budgets developed, the interest of companies to build natural gas distribution systems with HDPE pipes has increased, currently being well-established pipes and fittings manufacturers in our country (PALPLAST, VALROM, POLITUB, etc), which produce high density 316 type PE pipes, especially for use in the natural gas distribution. The quality of the raw materials and that of the production technology imposes certain basic elements for this field of use. Type 316 pipes are identified by marking them in yellow according to UNI 4437 and can be produced with a series of coextruded also yellow bands (which cannot be deleted); thus, the gas pipeline can be identified in any circumstances. In terms of the evolution of the performance proven by the polyethylene pipes designed for gas distribution, the development of the class of polyethylene pipes with a guaranteed minimum tensile strength of 10 MPa (PE100) allowed the use of polyethylene pipes to transport and distribute natural gas with pressures up to 6 bar. The enhancement of pressure from 4 to 6 bar (the 8 bar solution), in the new distribution areas, intends to limit the costs and the number of network components (pressure regulators, tubes of different diameters and the respective fittings). [5]

2. GENERAL INFORMATION ON HIGH DENSITY POLYETHYLENE PIPELINES AND FITTINGS

The improvement of the performance of polyethylene pipes for gas distribution, the development of the polyethylene pipes class, guaranteed for a minimum tensile strength of 10 MPa (PE100), allowed the use of polyethylene pipes for the transport and distribution of natural gas of pressures up to 8 bar.

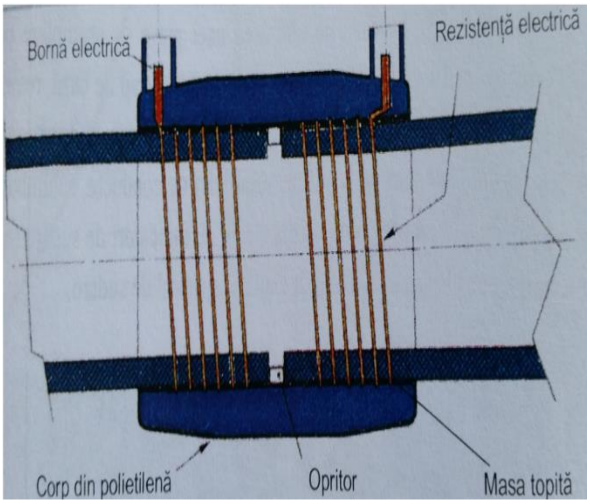
The increase of pressure from 4 bar to 8 bar (the 8 bar solution) in the new distribution areas is intended for limiting the costs and the number of network components (pressure regulators, pipes of different sizes and their respective fittings). [5]

There are two methods of connecting the polyethylene pipes:

a. Electrofusion Welding

Welding by using electrofusion fittings has become increasingly used due to the simplicity of the operation and the high quality of the coupling. The polyethylene fitting is obtained through molding and contains an electrical resistance inside its wall connecting the inner surface of the fitting to the external surface of the pipe.

a.



b.

Figure 2. Welding with an electrofusion welding machine (a. Sbox welding machine in operating position; b. constructive principle of the electrofusion polyethylene socket)

The electrofusion technology is automatic. The most modern welding equipment (Figure 2) entirely eliminates “the human factor”. In order to achieve high quality joints by using this procedure, it is essential to use auxiliary devices, such as scrapers, for chamfering the pipe ends and the aligners. As in the case of butt welding, it is very important to clean the contact surfaces on the pipe and on the fitting. [5]

b. But or Thermofusion Welding

The technological order of operations, the rules and the detailed regulations are given in the technological instructions of each welding equipment manufacturer (Figure 3), precisely indicating the welding parameters: pressure, time, temperature. The welding parameters which have been used depend on the basic material and also on the standard dimension ratio SDR. The manual, semiautomatic and automatic machines have been equally used in butt welding. It is required to use skilled personnel for doing this type of welds.

Figure 3. Machine for butt welding pipelines and fittings

The butt welding procedure consists of the following stages:

1. Fix the pipe ends in the holders of the welding machine;
2. Clean the ends and mill them in order to level them;
3. Pre-heat the surfaces to be joint by means of the heating plate (21ºC);
4. Withdraw the plate and immediately compress the two ends;
5. Cool the coupling in the machine until it reaches the temperature of about 60°C;
6. Disassemble the ends of the pipe from the clamps of the welding machine. The ambient temperature for this type of welding must be between 0 and 45° C. [3]

The polyethylene fittings come in different standardized sizes and they can be specific for one of the two types of procedures, electrofusion or butt welding. For the electrofusion welding, the fittings have an integrated heating element which allows the added material to make the fusion between the connecting fitting and the polyethylene pipe, so that they become a unitary assembly. The butt welding fittings are slightly differently constructed because they do not contain a heating element, the heating being done by means of the hot plate.

Figure 4. Fittings required for electrofusion and butt welding

The two types of coupling have both advantages and disadvantages, as follows: the electrofusion fittings are more expensive because of the manufacturing technology which requires the installation of the heating wire, but they have the advantage that the contact surface between the pipes is wider thus having a greater mechanical strength; the butt welding fittings have the advantage of being cheaper and can be used in very large diameters (Figure 4). [4]

As a result of the market studies conducted by means of a questionnaire, the following problems have been detected:

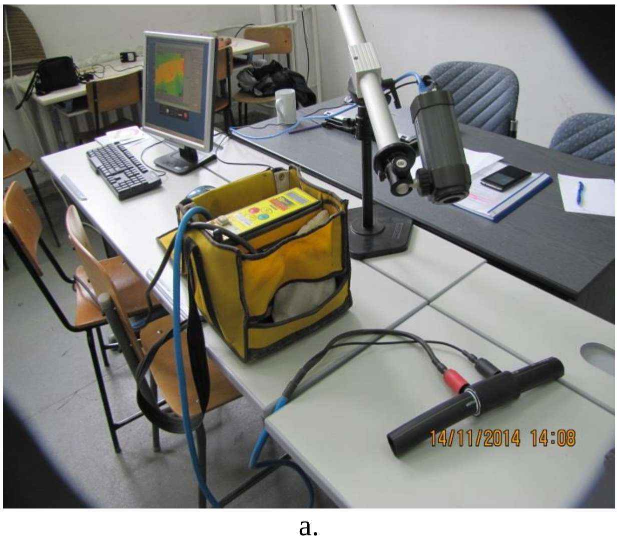
- Non-linearity of the assembly;
- Incomplete fusion; the welding control was not visible;
- Expulsion of the molten material outwards or inwards;
- Interrupted or shortened spires;
- Ovality of the ends;
- Failure to complete the welding cycle (machine error);
- Failure to seal the fitting for the self-threading branch tee; [1]
- There were some changes in the position during welding, and because of the high temperature, the part detaching from the pipe and running the risk of an incorrect and incomplete performing of the operation.

Thus, a frequently used fitting was selected for this study – which has the functional role of making the connection between two polyethylene parts, a polyethylene part and a polyethylene pipe or two high density polyethylene pipes (Figure 5). [2]

Figure 5. Electrofusion socket for connecting polyethylene pipes

3. DESCRIPTION OF THE WORK EQUIPMENT AND THE MEASURING METHODS. MAKING MEASUREMENTS

The conducted study required the following equipment: 1. Sbox Machine for welding polyethylene, manufactured by the Fusion Company, Great Britain, which allows performing polyethylene welds for fittings up to 180 mm in diameter and which tracks the welding cycle, so that if it is not properly completed, the machine will record the error and will show it in the welding protocol; 2. High technology camera ThermoVision A320 which allows measuring and recording the temperature both in a general and a particular area; 3. Software for acquiring the values measured by means of the thermal camera – it allows creating both an overall and a detailed picture. 4. The welding assembly composed of high density polyethylene pipe with the diameter Dn 32 SDR11 used in natural gas distribution and the electrofusion socket Dn32.



a.

b.

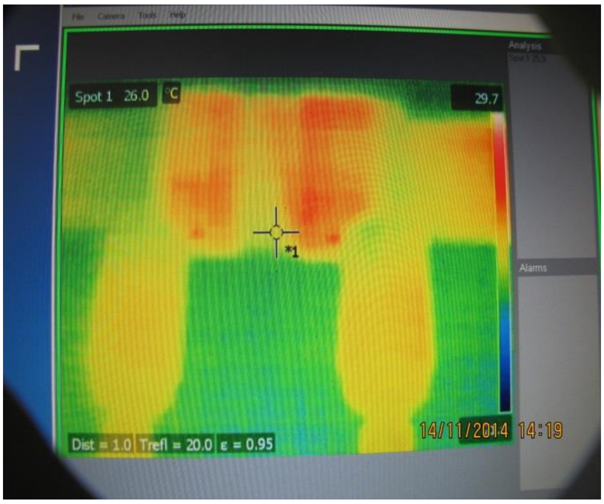
Figure 6. Assembly for welding and measuring the temperatures (a. general framework of measurements; b. thermographic camera for measuring temperatures)

The welding technology was respected and standard machines and tools were used. The mark on the pipe was performed, the metal scraper was used to remove the coating on the Dn32 pipe in the welding area, the welding area was pickled with a special pickling solution after which the electrofusion socket with the diameter Dn32 was fixed and the welding procedure began. The measurement performed on the work assemblies (3 tests) were conducted at an ambient temperature of 22°C. The Sbox polyethylene welding machine allows the automatic adjustment of the operating voltage and the progressive increase of the welding temperature, which is observed in the images taken during the measurements. The study was conducted in order to highlight the problems that can arise when the procedure is not followed, when the cut of the pipes which are to be welded is done at the wrong average angles of 75 degrees and 90 degrees by means of the special knife which must be used according to the working procedures. (Figure 7)

a.

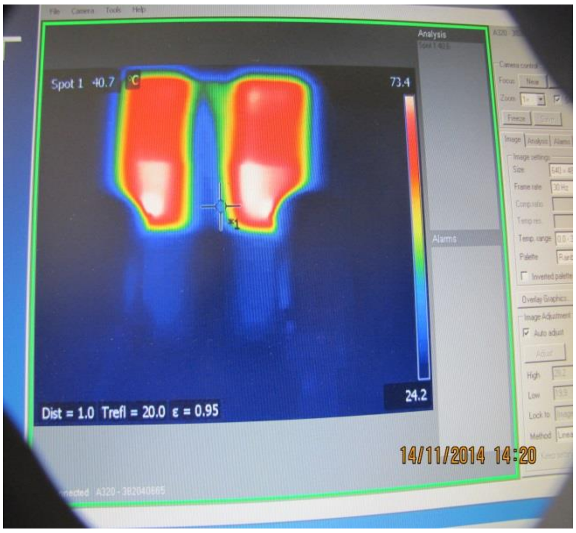
b.

Figure 7. Correct a. and incorrect b. preparation of welding specimens: polyethylene pipe and electrofusion Dn 32 sockets



a.

Figure 9.a. Highlighting the temperature rise in the three welding stages: a. Initial, b. Middle, c. Final, for welding in appropriate working conditions



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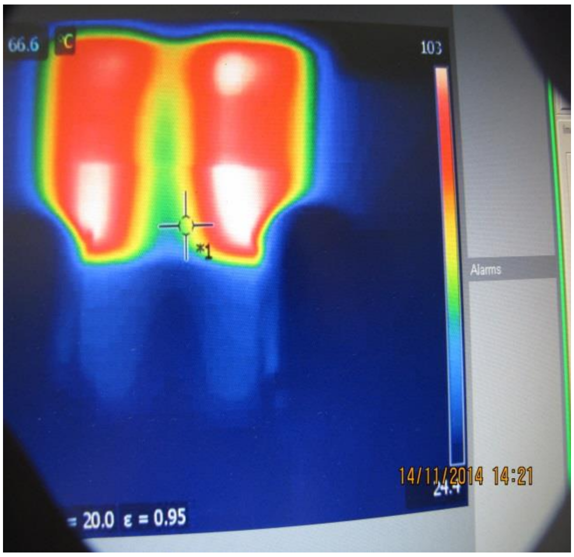

c.

Figure 9.b. Highlighting the temperature rise in the three phases of welding: a. Initial, b. Middle, c. Final for welding in appropriate working conditions

Following the measurements of the temperature during the welding process, it can be stressed that it takes 40 seconds to weld the fitting, the time being automatically set by the welding machine, the latter receiving information from the fitting and automatically making the adjustment. The time until the temperature was rising and then was stabilized was 3 minutes and twenty seconds, much longer than the welding time (Figure 9). In terms of the differences in the welding temperatures, these occurred for the obtained maximums, namely 103 degrees Celsius for the correct welding and 105.7 degrees Celsius for the incorrect welding.

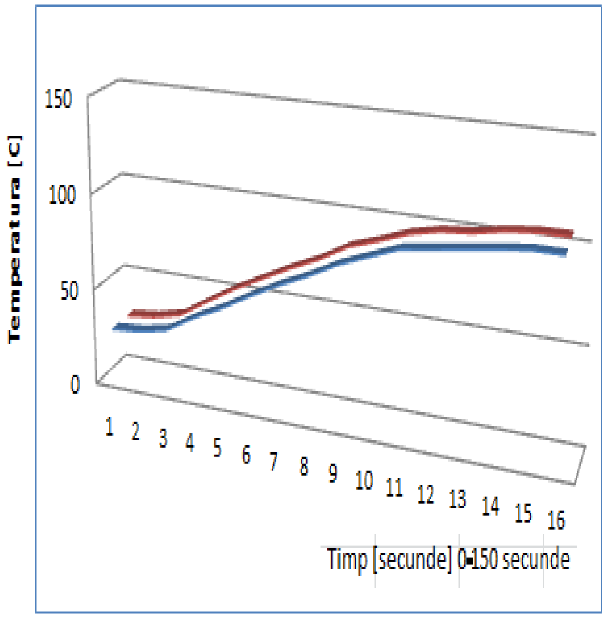

Figure 10. Difference of temperatures between tests

Time [sec]	Temp. Correct welding [C]	Temp. Incorrect welding [C]
	[C]	[C]
0	28.2	28.2
10	29.7	30.1
20	32.9	33.7
30	42	43.2
40	49.5	52.4
50	58.2	60.4
60	66.3	68.3
70	73.4	75.3
80	81.6	84.1
90	87.8	89.3
100	93.9	95.1
110	96.2	98.6
120	98.6	100
130	101	103.2
140	103	104.9
150	103	105.2

Figure 11. The obtained average values for the two types of conducted measurements

4. CONCLUSIONS AND SUGGESTIONS

- The study intends to highlight certain aspects related to the correct and incorrect welding procedures, and the problems that can occur in achieving accurate welds;
- The most commonly used methods of welding are presented (electrofusion or butt-thermofusion welding) with their advantages and disadvantages;
- The problems encountered in practice were taken into account and their occurrence was tried to be avoided during the tests;
- The welds were done by personnel authorized to perform welds by ISCIR (State Inspection for Control of Boilers, Pressure Vessels and Hoisting) so that the results could be validated;
- It was observed that the welding time for the fitting Socket Dn32 for the corect welding was 45 seconds, and the time during which the part heated was 150 seconds, but the temperatures for the two studied sockets were 103 degrees Celsius for the correct welding and 105.2 degrees Celsius for the incorrect welding socket;
- It is observed that the area of contact between the pipe and the fitting is smaller in the incorrect welding and the temperature at which the fitting detaches is therefore higher and thus the cooling time will be longer, the working procedure being prolonged;
- It is recommended to use a device to fix the sockets, which will maintain a colinearity between the sockets and the pipes, thus increasing the safety in operation of fittings and high density polyethylene pipes.

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