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STUDY ON THE HIGH TEMPERATURE BEHAVIOR OF ASSEMBLIES OBTAINED BY CRIMPING COPPER PIPE FITTINGS USED IN NATURAL GAS SUPPLY INSTALLATIONS

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***Abstract:** This paper presents the results of research on the high temperature behavior of assemblies obtained by crimping copper pipe fittings used in natural gas supply installations. For the realization of this study, 18 specimens were made by crimping copper pipe fittings with outer diameters $D_e = 15/18/22$ mm and wall thickness $w_t = 1.0$ mm. All 18 specimens were tested at elevated temperatures using the facility developed by the authors. The specimens were charged with nitrogen at a pressure of 5 bar, and placed inside the oven at a temperature of 650 °C for 30 minutes. The results obtained confirm the reliability of the crimping technology for use in natural gas supply installations, ensuring tightness under extreme conditions.*

***Key words:** fitting; copper pipes; experimental determinations; experimental stand; operational safety*

1. INTRODUCTION

Currently, globally, there is a growing trend of using copper as the main material for applications in the distribution of liquefied natural gas, natural gas, but also for uses in fire extinguishing systems, applications in solar energy systems, compressed air distribution pipes, heating systems, air conditioning systems, [1-7]. The natural gas transmission and distribution infrastructure is one of the most critical types of networks, which requires high resistance and safety conditions in operation. Given the importance of safe operation, two methods of assembling fittings on copper pipes have been authorized: brazing and crimping, [5-14]. The two authorized technologies (brazing and crimping), meet the safety standards imposed by the standards in the field, [15-17]. The technical standards for the design, construction technology and operation of these installations, made of copper pipes and fittings, are based on a set of procedures for the technical certification of assembly technologies and on experimental tests of the behavior of the assemblies under all types of stresses:

mechanical, thermal, fatigue and leakage, specific to the use of natural gas [17- 21]. This paper is the result of extensive research materialized in the articles [19 - 21] and RELANSIN project no.1698 /2003 - Modernization of copper pipe assembly systems for their use in natural gas distribution plants, [12]. In the paper [19] the development of a stand for testing technologies for non-detachable joining of copper pipes is presented. In this regard, the authors designed and subsequently built an equipment for evaluating the resistance to torsion, bending (vibration) and high temperature operation of pipes made of copper pipes and fittings. One of the biggest challenges of the study was the alignment of Romanian standards with European ones.

The developed equipment allows testing according to the procedures defined by the authors, based on the relevant European standards. In the paper [20], the authors present a study on the use of new materials in natural gas transmission and distribution facilities in Romania, as an alternative to steel and polyethylene. In general, in Romania, steel pipes and fittings are used for the transport and

distribution of natural gas. The authors study the implementation of copper pipes in these natural gas transmission and distribution networks, and in this they have carried out a series of research focusing on the evaluation of the behavior of assemblies made of copper pipes and fittings made by crimping. The paper details the procedures and equipment designed and built for the evaluation of the quality of joints made of copper pipes and fittings. The research results significantly contribute to the possibility of using new materials, such as copper pipes in natural gas facilities in Romania, by aligning national standards with European ones and developing the procedures and equipment necessary for the evaluation of the quality of these materials and the related assembly technologies. In [21], the authors present the development of a high-temperature performance testing system for crimped copper pipe and fitting assemblies used in natural gas supply facilities. The purpose of the work is to evaluate the reliability and operational safety of these assemblies under high temperature conditions, thus ensuring compliance with applicable standards and regulations. In the study, the authors describe the design and construction process of the test system, emphasizing the importance of precise temperature and pressure control to simulate real-world operating conditions. The system is designed to subject copper pipe and fitting assemblies to thermal and mechanical cycles, thus evaluating their behavior over time and identifying potential weaknesses or failures that could occur in service and jeopardize operational safety. The results show that crimped copper pipe and fitting assemblies perform well at high temperatures and are able to maintain the structural integrity and tightness required for use in natural gas installations. These findings support the widespread adoption and implementation of these materials and technologies in the field of natural gas distribution, providing a viable alternative to traditional materials.

This paper presents the results of the studies and research carried out in order to assess the quality of crimped copper pipe-fitting assemblies used in natural gas supply installations, representing a preliminary step in the process of homologation of this technology

for use in natural gas distribution systems in Romania.

2. MATERIAL AND METHOD

2.1 Development of press-fitting technology for copper pipe fittings used in natural gas supply installations

Figure 1 shows the experimental model consisting of a 200 mm long pipe with two fittings at the ends, [12].

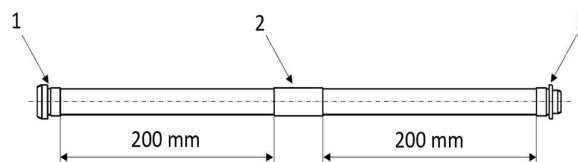


Fig. 1. Experimental model with two pipes: 1 – cap; 2 – fitting; 3 – pressure connection.

2.2. Development of the methodology for certifying the quality of assemblies obtained by crimping copper pipe fittings used in natural gas supply installations

The methodology for certifying the quality of assemblies obtained by crimping copper pipe fittings used in natural gas supply facilities is a set of technical requirements and experimental testing procedures for the characteristics of the assemblies. Using the results of previous studies and research, the methodology for technical certification of the quality of pressed assemblies was finalized and a national technical standard was developed for the design, construction and operation of natural gas distribution pipeline systems made according to the proposed technology [12, 19, 20, 21].

The scope of the Quality Certification Methodology is assemblies obtained by crimping copper pipe fittings with standardized diameters up to 108 mm, operated at a pressure of up to 5 bar. The methodologies and procedures presented by the authors were based on the Draft Standard VP 614 Unlösbare Rohrverbindungen für metallene Gasleitungen; Pressverbinder, developed by DVGW (German Gas and Water Association), [16] and the draft European standard EN 1254 - Part 7, which regulates press joints of metallic pipes with fittings with diameters between 6 and 108 mm for use in hot water, cold and mixed water,

heating and cooling water, natural gas and liquefied gas.

The experimental test procedures of copper pipe fitting assemblies are designed to verify the fulfillment of the technical conditions that guarantee the safe ex-operation of natural gas distribution installations both under normal operating conditions and in accidental situations generated by earthquakes, fires, etc. The experimental test procedures are mainly aimed at verifying the tightness of experimental models subjected to static/dynamic/high temperature stresses.

In this work, the P7 procedure was used, previously developed by the authors in [21], which refers to the verification of functionality at high temperatures. The values of the parameters corresponding to the high temperature test temperature, T ($^{\circ}\text{C}$), PML 1 - pressure per 1 linear meter (bar), PML 5 - pressure per 5 linear meters (bar), leakage flow rate at each fitting end (dm^3/h) respectively test duration, d (min) are presented in Table 1.

Table 1

High temperature test parameters				
T ($^{\circ}\text{C}$)	PML1 (bar)	PML2 (bar)	Flow loss rate at each fitting head, (dm^3/h)	d (min.)
650 ± 10	1 ± 0.5	5 ± 0.5	30	30

The experimental model shown in Fig. 1, obtained by crimping a two-pipe copper socket, [12, 19, 20, 21] is connected to the pressure source of the working system for checking the high temperature serviceability.

Figure 2 shows the system used for the verification of the high temperature capability, [21].

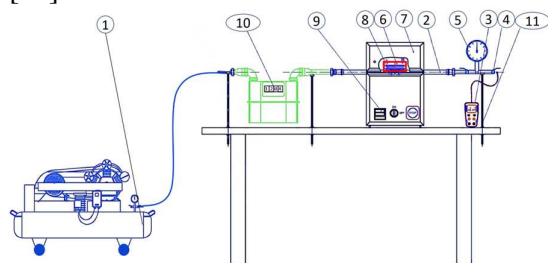


Fig. 2. System for checking the high temperature serviceability:

- 1 - compressor; 2 - test specimen; 3 - gas detector;
- 4 - purge vent; 5 - pressure gauge; 6 - heat source;
- 7 - electric oven; 8 - thermocouple; 9 - controller;
- 10 - meter; 11 - threaded rod bracelets.

The experimental system shown in figure 2 uses a compressor (1) to generate and maintain a constant nitrogen pressure of 5 ± 0.5 bar, necessary to fill the test specimen (2) shown in figure 1. At the downstream end of the experimental system there is a gas detector with a specific nitrogen cartridge (3) and a purge vent (4) to remove air from the system. The internal pressure is monitored by means of a pressure gauge (5) mounted at the downstream end of the specimen (2) and calibrated for a measuring range between 10 and 25 bar.

After charging the installation with nitrogen, the experimental model (2) is placed inside the heat source (6) of the electric oven (7) at a temperature of 650 ± 10 $^{\circ}\text{C}$. The temperature in the oven is measured in real time by means of a thermocouple (8), and the set and actual temperature values are displayed on the display of the controller (9).

Pressure and temperature are kept constant and checked for 30 minutes. During this time, using the flow meter (10) located between the compressor and the test specimen, record gas losses due to possible leaks. The meter (10), test specimen (2), pressure gauge (5), gas detector (3) and purge vent (4) were fixed to the system table using threaded rods (11).

The crimped copper pipe-fitting assemblies used in natural gas supply installations meet the requirements for high temperature operation if there is no or less than $30 \text{ dm}^3/\text{h}$ nitrogen leakage, [12, 21].

In order to evaluate the in-service performance of the system for high temperature testing of crimped copper pipe-fitting assemblies used in natural gas supply installations, the test plan consists of three experimental reliability tests, the first one to validate the proper functioning of the electrical test-tube and the next two to verify the performance and the proper functioning of the system (see Fig. 2), in all cases using the limit value testing technique, [21].

Using the system presented in figure 2, all 18 specimens were tested in turn in the heat source enclosure of the electric oven at a constant temperature of 650 $^{\circ}\text{C}$, each of which was charged with nitrogen at a pressure of 5 bar for 30 min (see Table 1).

During the time allocated for the test (30 min), the temperature T (in the heat source enclosure of the electric oven) and the pressure p (in the test specimen enclosure) were measured.

Figure 3 shows the crimped specimens with outer diameter $D_e = 15$ mm and wall thickness $w_t = 1.0$ mm, before testing.



Fig. 3. Crimped specimens with outer diameter $D_e = 15$ mm and wall thickness $w_t = 1.0$ mm.

Figure 4 shows the crimped specimens with wall thickness $w_t = 1.0$ mm after testing at high temperature.

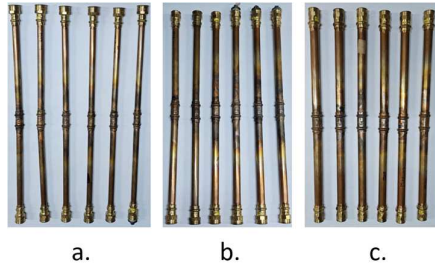


Fig. 4. Crimped specimens with wall thickness $w_t = 1.0$ mm, after testing: a. $D_e = 15$ mm; b. $D_e = 18$ mm; c. $D_e = 22$ mm.

3. RESULTS AND DISCUSSION

Using the results obtained from the verification of the high temperature serviceability of crimped copper pipe-fitting assemblies used in natural gas supply installations with outside diameter $D_e = 15$ mm and wall thickness $w_t = 1.0$ mm, the graphs in Figures 5 and 6 were drawn.

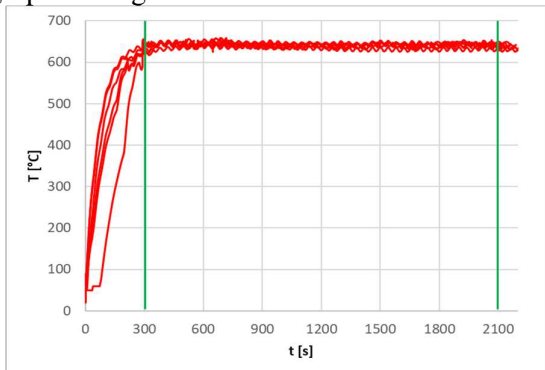


Fig. 5. Temperature variation during testing of crimped specimens with outer diameter $D_e = 15$ mm and wall thickness $w_t = 1.0$ mm.

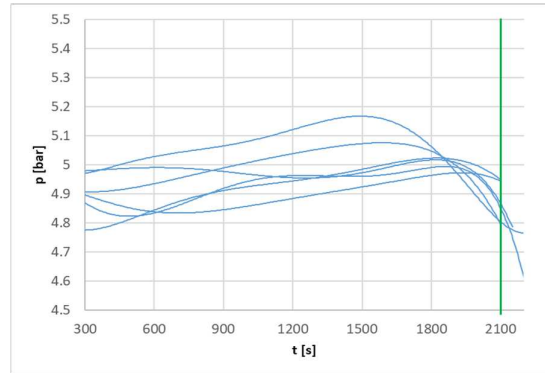


Fig. 6. Pressure variation when testing crimped specimens with outer diameter $D_e = 15$ mm and wall thickness $w_t = 1.0$ mm.

Using the results obtained from the verification of the high-temperature operating capacity of crimped copper fitting-pipe assemblies used in natural gas supply installations with outer diameter $D_e = 18$ mm and wall thickness $w_t = 1.0$ mm, the graphs in Figures 7 and 8 were drawn.

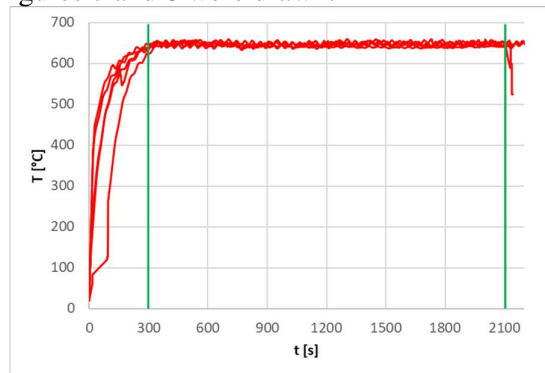


Fig. 7. Temperature variation during testing of crimped specimens with outer diameter $D_e = 18$ mm and wall thickness $w_t = 1.0$ mm.

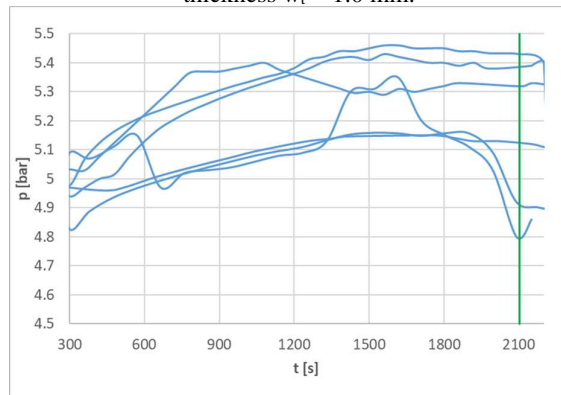


Fig. 8. Pressure variation when testing crimped specimens with outer diameter $D_e = 18$ mm and wall thickness $w_t = 1.0$ mm.

Using the results obtained from the verification of the high-temperature operating capacity of crimped copper

fitting-pipe assemblies used in natural gas supply installations with outer diameter $D_e = 22$ mm and wall thickness $w_t = 1.0$ mm, the graphs in Figures 9 and 10 were drawn.

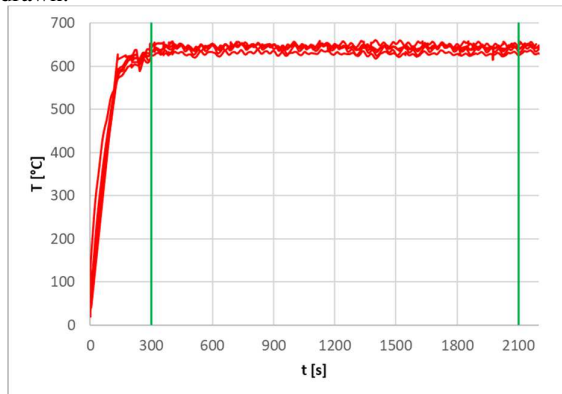


Fig. 9. Temperature variation during testing of crimped specimens with outer diameter $D_e = 22$ mm and wall thickness $w_t = 1.0$ mm.

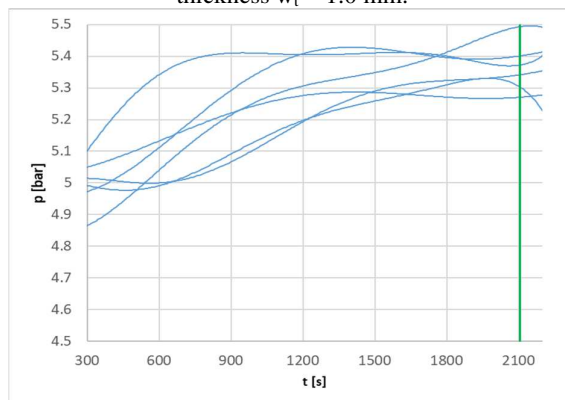


Fig. 10. Pressure variation when testing crimped specimens with outer diameter $D_e = 22$ mm and wall thickness $w_t = 1.0$ mm.

By analyzing the graphs in Figures 5 to 10 it can be concluded that all crimped assemblies of the 18 copper specimens with wall thickness $w_t = 1.0$ mm and outer diameter $D_e = 15/18/22$ mm were strong and tight for at least 30 min at the elevated temperature $T = 650 \pm 10$ °C and test pressure $p = 5 \pm 0.5$ bar, the parameters stipulated in Table 1.

In order to analyze how the outer diameter $D_e = 15/18/22$ mm of the copper pipe with wall thickness $w_t = 1.0$ mm and the variation of the high test temperature T in the range 650 ± 10 °C influence the pressures p in the specimens, using the maximum values of the temperatures and pressures recorded during the experimental determinations performed on the 18 crimped copper pipe-fitting specimens, we have plotted the graphs in Figures 11 and 12.

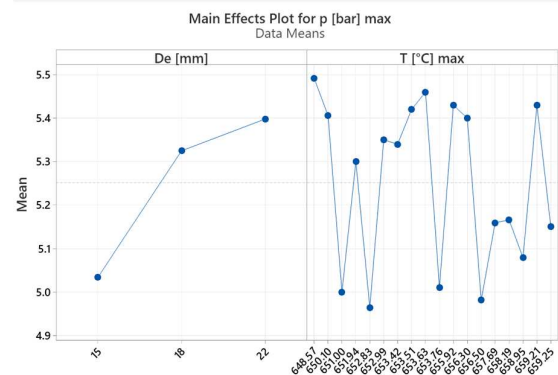


Fig. 11. Influence of the outer diameter $D_e = 15/18/22$ mm of the copper pipe with wall thickness $w_t = 1.0$ mm and the variation of the high-test temperature T in the range of 650 ± 10 °C on the pressures p in the crimped specimens.

Analyzing the graphs in Figure 11, it is found that, regardless of the outer diameter $D_e = 15/18/22$ mm of the copper pipe with wall thickness $w_t = 1.0$ mm and the variation of the high-test temperature T in the range 650 ± 10 °C, the pressure values in the crimped specimens vary in the range $p = 5 \pm 0.5$ bar.

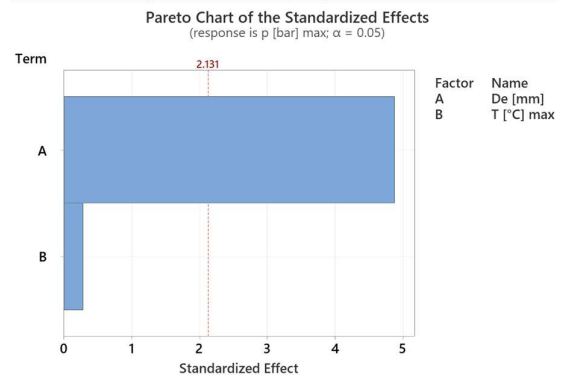


Fig. 12. Pareto chart regarding the influence of factors (A = outer diameter; B = variation of high-test temperature) on pressure (p).

Analyzing the Pareto chart in figure 12, it results in the extent to which the outer diameter $D_e = 15/18/22$ mm of the copper pipe with wall thickness $w_t = 1.0$ mm (parameter A) and the variation of the high test temperature T in the range of 650 ± 10 °C (parameter B) influence the pressure p in the crimped specimens.

Of the 2 parameters considered, A and B, the outer diameter D_e of the copper pipe significantly influences the pressure p in the crimped specimens.

Figure 13 presents the results of the optimization of the procedure for verifying the high temperature operating capacity (P7) of

crimped copper fitting-pipe assemblies used in natural gas supply installations.

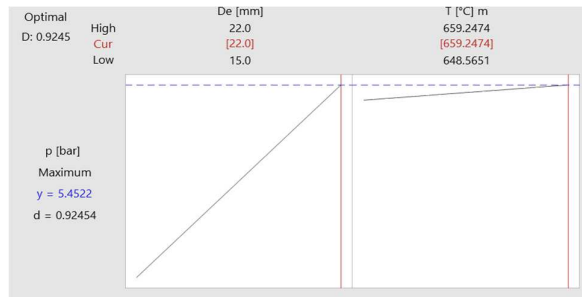


Fig. 13. Optimization of the procedure for verifying the high temperature operating capacity of crimped copper fitting-pipe assemblies used in natural gas supply installations.

Analyzing the graphs in figure 13 we observe how each of the two factors, the outer diameter $D_e = 15/18/22$ mm of the copper pipe with wall thickness $w_t = 1.0$ mm and the variation of the high-test temperature T in the range of 650 ± 10 °C, influences the pressure p in the crimped specimens.

The vertical red lines (continuous) indicate the setting of the factors (D_e and T), and the red numbers on each column indicate their current value.

The horizontal blue line (dashed) indicates the response corresponding to the factor settings, and the blue number indicates the response corresponding to their value.

The optimization (efficiency) of the procedure for verifying the high-temperature operating capacity of copper fitting-pipe crimped assemblies used in natural gas supply facilities was achieved in the case of testing specimens with an outer diameter $D_e = 22$ mm and a wall thickness $w_t = 1.0$ mm, at a temperature of $T = 659.2474$ °C, (Fig. 13).

The results obtained after applying all seven experimental verification procedures for the quality of copper fitting-pipe crimped assemblies confirm the fulfillment of the technical conditions that guarantee the safe operation of natural gas supply facilities, both under normal operating conditions and in accidental situations caused by earthquakes, fires, etc.

4. CONCLUSION

To carry out the study, a system was designed to check the high temperature serviceability (see Fig. 4) by means of which 18 crimped specimens with outside diameters

$D_e = 15/18/22$ mm and wall thickness $w_t = 1.0$ mm, 6 of each, were tested at a constant temperature of 650 °C, 18 specimens each loaded with nitrogen at a pressure of 5 bar for 30 min.

The results obtained from the experimental determinations confirm that crimping fittings on copper pipes is a viable and efficient solution for use in natural gas supply installations. This method ensures a secure and durable connection, demonstrating its compatibility and reliability under the specific operating conditions of these installations.

Using Minitab, the influence of the outer diameters and the variation of the high test temperature on the specimens pressures were analyzed, the conclusion being that the outer diameter D_e significantly influences the value of the pressures in the specimens. In the context of the results obtained and the interest shown in them, studies and research are being continued on the modernization of copper pipe assembly systems for use in natural gas distribution plants.

5. REFERENCES

- [1] Shirgaokar, M., Ngaile, G., Altan, T., Yu, J.-H., Balconi, J., Rentfrow, R., & Worrell, W. J. (2004). Hydraulic crimping: application to the assembly of tubular components. *Journal of Materials Processing Technology*, 146(1), 44–51.
[https://doi.org/10.1016/s09240136\(03\)00843-4](https://doi.org/10.1016/s09240136(03)00843-4)
- [2] Cao, R., Meng, M., Wang, Z., Chen, Y., Ye, Y., & Huang, X. (2021). Failure Analysis and Reliability Improvement of Crimping Assembly of Copper-Clad Aluminum Conductors for Aerospace. In *2021 22nd International Conference on Electronic Packaging Technology (ICEPT)* (pp. 1–5). 2021 22nd International Conference on Electronic Packaging Technology (ICEPT). IEEE.
<https://doi.org/10.1109/icept52650.2021.9568165>

- [3] Rajak, A. K., & Kore, S. D. (2017). Experimental investigation of aluminium–copper wire crimping with electromagnetic process: Its advantages over conventional process. *Journal of Manufacturing Processes*, 26, 57–66. <https://doi.org/10.1016/j.jmapro.2017.01>.
- [4] Shirgaokar, M., Cho, H., Ngaile, G., Altan, T., Yu, J.-H., Balconi, J., Rentfrow, R., & Worrell, W. J. (2004). Optimization of mechanical crimping to assemble tubular components. *Journal of Materials Processing Technology*, 146(1), 35–43. [https://doi.org/10.1016/s0924-0136\(03\)00842-2](https://doi.org/10.1016/s0924-0136(03)00842-2).
- [5] Boczkal, S., Mitka, M., Hrabia-Wiśnios, J., Płonka, B., Węglowski, M. St., Węglowska, A., & Śliwiński, P. (2025). Analysis of the Structure and Properties of Welded Joints Made from Aluminum Alloys by Electron Beam Welding (EBW) and Friction Stir Welding (FSW). *Crystals*, 15(3), 208. <https://doi.org/10.3390/cryst15030208>.
- [6] Nothdurft, P., Riess, G., & Kern, W. (2019). Copper/Epoxy Joints in Printed Circuit Boards: Manufacturing and Interfacial Failure Mechanisms. *Materials*, 12(3), 550. <https://doi.org/10.3390/ma12030550>
- [7] Zhang, Y., Shi, J., Liao, G., Li, R., Peng, J., Kuang, S., & Shen, F. (2025). Effects of Tool Structure and Process Parameters in Friction Stir Welding on the Temperature and Mechanical Properties of Dissimilar Copper–Aluminium Welded Joints. *Metals*, 15(2), 193. <https://doi.org/10.3390/met15020193>
- [8] Faes, K., Nunes, R., De Meester, S., De Waele, W., Parmar, H., Esperto, V., & Rubino, F. (2025). The Influence of Welding Parameters on the Performance of Ultrasonic-Welded Copper-to-Copper Joints. *Journal of Manufacturing and Materials Processing*, 9(2), 55. <https://doi.org/10.3390/jmmp9020055>
- [9] EN 1251-1, Copper and copper alloys – Plumbing fittings – Part 1: Fittings with ends for capillary soldering or capillary braying to copper tubes.
- [10] Zisopol D.G., Dumitrescu A., Materiale și tehnologii primare. Aplicații practice și studii de caz. Editura Universității din Ploiesti, ISBN 973-719-047-5, 2005.
- [11] EN 1254 Copper and copper alloys – Plumbing fittings – part 7: Fittings with press ends for metallic tubes.
- [12] Ulmanu, V., Zecheru, Gh., Drăghici, Gh., Minescu, Zisopol, D.G., Et Al., Modernizarea sistemelor de asamblare a țevilor din cupru în vederea utilizării acestora la instalațiile de distribuție a gazelor naturale. Lucrările contractului de cercetare nr. 1698/2003 – F2/2003, Beneficiar: RELANSIN.
- [13] EN 549, Elastomeric materials for seals and diaphragms for gas appliances and gas systems.
- [14] EN 682, Elastomeric seals – Materials requirements for seals used in pipes and fittings carrying gas and hydrocarbon fluids.
- [15] DVGW 534, Pipe connectors and pipe joints in drinking water installation.
- [16] DVGW VP 614, Permanent tube connections for metallic gas pipelines - pressed joints.
- [17] EN 1057 Copper and copper alloys – Seamless round copper tubes for water and gas in sanitary and heating applications.
- [18] EN 1775, Gas pipework for buildings – Maximum operating pressure up to and including 5 bar – Functional recommendations.
- [19] Zisopol, D. G., Dumitrescu, A., Minescu, M., Badicioiu, M., & Caltaru, M. (2022). Equipment for quality assessment of the copper pipes and fittings used within natural gas installations. *Journal of Engineering Sciences and Innovation*, 7(3), 373–386. <https://doi.org/10.56958/jesi.2022.7.3.373>
- [20] Zisopol, D. G., Dumitrescu, A., Minescu, M., & Dinita, A. (2022). New materials intended for use within natural gas installations and quality testing procedures. *Journal of Engineering Sciences and Innovation*, 7(2), 241–252. <https://doi.org/10.56958/jesi.2022.7.2.241>
- [21] Ilie, F.; Zisopol, D.; Minescu, M. Research Regarding the Construction and Reliability of the High -Temperature Performance Testing System for Crimped Copper Pipe and Fitting

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Studiu privind comportarea la temperaturi ridicate a ansamblurilor obținute prin sertizarea fittingurilor de țevi din cupru utilizate în instalațiile de alimentare cu gaze naturale

Abstract: Această lucrare prezintă rezultatele cercetărilor privind comportamentul la temperaturi ridicate al ansamblurilor obținute prin sertizarea fittingurilor de cupru utilizate în instalațiile de alimentare cu gaze naturale. Pentru realizarea acestui studiu, au fost realizate 18 epruvete prin sertizarea fittingurilor de cupru cu diametre exterioare $D_e = 15/18/22$ mm și grosimea de perete $w_t = 1,0$ mm. Toate cele 18 epruvete au fost testate la temperaturi ridicate utilizând instalația dezvoltată de autori. Epruvete au fost încărcate cu azot la o presiune de 5 bar și plasate în cuptor la o temperatură de 650 °C, timp de 30 de minute. Rezultatele obținute confirmă fiabilitatea tehnologiei de sertizare pentru utilizarea în instalațiile de alimentare cu gaze naturale, asigurând etanșeitatea în condiții extreme.

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