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Procedures for the Quality Assessment of the Assembly Technologies of Copper Pipes for Natural Gas Installations

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Abstract

This paper presents the results of the research work performed by the authors regarding the use of copper made pipes within the natural gas internal installations. Such work had as main result the elaboration of seven testing procedures (described in the paper) required for the quality assessment of the assembly technologies (with press fit or hard soldered joints) of copper pipes and fittings, and also the design and construction of the equipment needed in order to perform these tests.

Key words: *copper pipes, press fit joints, hard soldered joints, quality assessment.*

Introduction

At present, a generalisation of the use of copper as a material for the construction of natural gas internal installations is observed world-wide. Such fact is the result of the advantages that the copper made installation have with respect to the ones made of steel (higher corrosion resistance, smaller pipe thickness required, better behaviour both at low and high temperatures, simpler assembly technologies, etc.).

As a consequence, the authors have investigated in detail both the materials and the assembly technologies used world-wide for copper pipes, and they have developed the procedures required for the quality assessment of these technologies. Finally, a laboratory able to perform the required quality tests and having all the equipment needed (part of it being designed and constructed by the authors) has been set.

The most promising, newest assembly technology was found to be the press fit technology which is using a special sealing element. Such technology can be used for the assembly of copper pipes (with a nominal diameter between 12 and 108 mm) within fuel gas installations at a working temperature between -20^0C and + 70^0C, and a MAOP (maximum allowable operational pressure, i.e. the maximum pressure at which the pipes can be operated in normal conditions) not greater than 5 bar. Another technology that can be successfully used in the same conditions, but with less promising results, is hard soldering. In a previous paper [1], the press fit technology and its advantages are described, together with the required materials for the copper pipes installations.

In this paper, we will focus on the presentation of the seven testing procedures developed for the quality assessment of the assembly technologies of the joints of copper pipes and fittings used within natural gas installations, while in other papers [2, 3] the equipment designed by the authors for the procedures requiring the use of a stand is described.

The testing procedures for the assembly technologies of copper pipes and fittings have been developed in such way that the fulfilment of all technical requirements which guarantee the safe exploitation (both in normal operating condition and in accidental ones – generated by earthquakes, fires etc.) of the natural gas installations is verified. The main scope of these procedures is to verify the tightness of experimental models (made of copper pipes and fittings) subjected to both static and dynamic loading, and also to extreme temperature conditions. The testing conditions for the quality assessment of the assembly technologies have been defined based on the working characteristics of the installations made of copper pipes.

Description of the Testing Procedures for the Quality Assessment of the Copper Pipes Assemblies

In the beginning, it has to be mentioned that the testing temperature should be 23 ± 5 ^{0}C (room temperature) for all the types of testing procedures presented in the followings, if not specified otherwise.

The procedure for the resistance and tightness test of the assemblies copper pipe – fitting under internal hydrostatic pressure is illustrated in figure 1, while the specified parameters for this procedure are shown in table 1. The test consists of subjecting an experimental model to an internal hydrostatic (water) pressure with a specified value for a specified period of time.

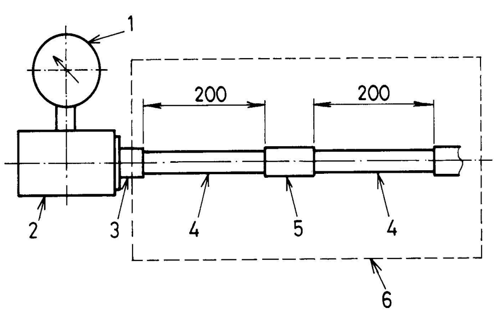

Fig. 1. Device for the internal (hydrostatic or pneumatic) pressure tests of the assemblies: *1* - manometer, *2* - pressure generating device, *3* - sealing element, *4* - copper pipe, *5* - fitting, *6* - experimental model.

The technical requirement of the internal hydrostatic pressure test is that, both during the test and after performing it with the parameters specified in table 1, the assemblies shall keep their tightness (no fluid leaking must be observed).

The experimental model (see fig. 1) contains one or more fittings assembled to a copper pipe with the minimum required length specified in table 1. The free end of the pipe shall be provided with a sealing element. The equipment necessary to perform the test consists of a manual water pump (*2*, fig. 1) connected to a pressure stabilizer (capable of maintaining a constant water pressure at the specified value during the test) and a precise water pressure measurement device (*1*, fig. 1).

Table 1. The parameters of the internal hydrostatic pressure test

Free length of the pipe in the model	Testing pressure	Duration of testing	Number of tests required
200 mm	30 ± 1 bar	48 hours	1

In brief, the testing procedure is the following (fig. 1): the experimental model, *6*, is connected to the pump, *2*, and the air is expulsed from the model; the internal pressure is slowly increased to the specified value and then maintained at such value for the specified test duration (given in table 1) while the end of the copper pipe is free to move; the tightness of the assembly fitting – copper pipe is observed during testing (no water leaking should occur). The result of the test is considered to be positive and the tested type of assembly is considered to be of adequate quality if, after the test, the experimental model keeps its tightness. To this purpose, in the end the experimental model is submitted to the resistance and tightness test under internal pneumatic pressure, following the procedure described below.

The procedure for the resistance and tightness test of the assemblies copper pipe – fitting under internal pneumatic pressure is illustrated in the same figure 1, while the specified parameters for this procedure are shown in table 2. The procedure consists of subjecting an experimental model to three successive internal pneumatic (air) pressure tests each one with a specified value and with a duration of 10 minutes (see table 2). The technical requirement of the internal pneumatic pressure test is that, during the three phases of the test (performed with the parameters specified in table 2), the assemblies shall keep their tightness (no air leaking must be observed at any pressure value up to their nominal pressure).

Table 2 The parameters of the internal pneumatic pressure test

Free length of the pipe in the model	First pressure test	Second pressure test	Third pressure test	Duration of testing	Number of tests required
200 mm	1,1·nominal pressure (minimum 3 bar)	110 mbar	22 mbar	10 min. / phase	1

The experimental models (see fig. 1) shall be the same as the ones used for the internal hydrostatic pressure test described above. The pressure can be applied simultaneously to several experimental models, if necessary. The equipment required to perform the test consists of an air compressor (*2* in fig. 1), a connection system of the experimental model to the pressure generating device (*3* in fig. 1) and a precise air pressure measurement device (*1* in fig. 1).

In brief, the testing procedure is the following (fig. 1): the experimental model, *6*, is connected to the air compressor, *2*; the first step of internal pneumatic pressure is applied with the specified value and maintained for the specified duration (given in table 2); the tightness of the assembly fitting – copper pipe is observed during testing by keeping the experimental model in a water tank (no air leaking should occur); the test is then repeated for the second and third pressure step (see table 2). The result of the test is considered to be positive and the tested type of assembly is considered to be of adequate quality if no air leaking is detected in any phase of the testing procedure.

The testing procedure for the influence of temperature upon the tightness of the assemblies aims at determining their tightness in case the working temperature varies, and is to be performed according to the data specified in table 3. An experimental model made of copper pipe and fittings is subjected to temperature variations, i.e. to a specified maximum temperature for a specified duration and then to a specified minimum temperature for a specified duration. The technical requirement of the working temperature influence upon tightness test is that, after performing it with the parameters specified in table 3, the assemblies shall keep their tightness (the assemblies must fulfil the exploitation conditions, i.e. keep their tightness, in the temperature domain between –20 ^{0}C and 70 ^{0}C).

The experimental model (fig. 2) contains one or more fittings assembled to a copper pipe with the minimum required length specified in table 3. The required equipment consists of a heating device (electrical furnace), a cooling device (freezer), and a temperature measurement device.

Table 3. The parameters of the working temperature influence test

Maximum testing temperature	Minimum testing temperature	Number of tests required	Free length of the pipe in the model
70 ± 2 ^{0}C	- 20 ± 5 ^{0}C	1	200 mm

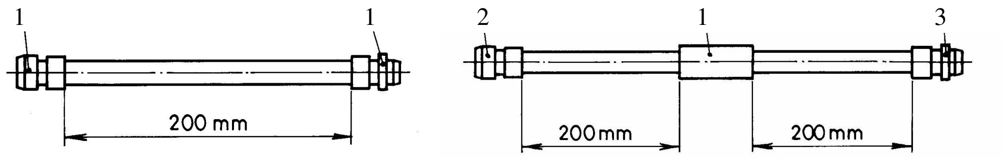

Fig. 2. Experimental models for the temperature influence test: 1 - fitting, 2 - cap, 3 - pressure connection.

In brief, the testing procedure is the following: the experimental model is heated to the specified maximum temperature and maintained for the specified duration of one hour; the model is then cooled in air, for one hour, down to the room temperature; the two steps above are repeated seven times; the experimental model is then cooled down to the specified minimum temperature and maintained for the specified duration of 24 hours, after what the model is brought to the room temperature.

The result of the test is considered to be positive and the tested type of assembly is considered to be of adequate quality if, after the test, the experimental model keeps its tightness. To this purpose, in the end the experimental model is submitted to the resistance and tightness test under internal pneumatic pressure, following the procedure described above.

The procedure for the vibration resistance and tightness test, *under symmetrically alternating bending loads* shall be performed in accordance to the data shown in table 4. The experimental model is subjected to vibrations by means of an alternating deformation with constant specified amplitude, a specified frequency and a specified duration (number of load cycles).

Table 4. The parameters of the vibration resistance test under bending loads

Testing pressure	Amplitude of deformation	Number of cycles	Frequency	Number of tests required
Atmospheric	± 1 mm	10^6	20 Hz	4

The technical requirement of the vibration resistance test is that the tested assemblies shall keep their mechanical resistance and tightness, after loading them to symmetrically alternating bending with the specified amplitude, frequency and duration. The experimental model used for such test, the required equipment (a specific stand designed and built by the authors) and the steps of the testing procedure are described in [2].

The procedure for the resistance and tightness test of the assemblies under static bending loads is illustrated in figure 3, while the specified parameters for this procedure are shown in table 5. The test consists of loading an experimental model (made of copper pipes and one fitting – fig. 3) with a static bending load (which is function of the pipe nominal diameter) for a specified duration, while subjected to internal air pressure at a specified value.

The technical requirement of the static bending test is that, both under loading and after performing the test with the parameters specified in table 5, the assemblies shall keep both their mechanical resistance and tightness (no air leaking must be observed).

The required equipment (partially designed and build by the authors, fig. 3) consists of: two supports which sustain the ends of the experimental model; the device which applies the test load (a force obtained by means of calibrated weights) in the middle of the model, and an air pressure generating device (an air compressor).

Table 5. The parameters of the static bending test

Testing pressure	Testing load, *F*	Maximum deformation of the annealed medium-hard pipes	Duration of testing	Number of tests required
5,5±0,5 bar	Equation (1)	100 mm	1 hour	1

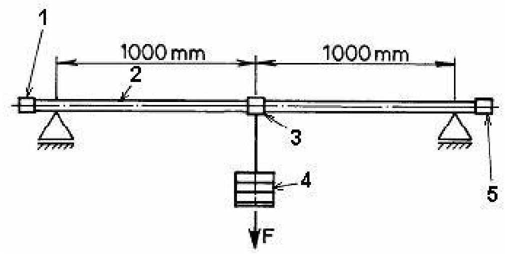

Fig. 3. Device for the static bending test of the copper pipes assemblies: 1 - cap, 2 - pipe, 3 - fitting, 4 - weight, 5 - pressure connection.

In brief, the testing procedure is the following: the experimental model is connected to the air compressor, the internal pressure is slowly raised up to the specified value (table 5) and than maintained at such value during the test; the test load, F, is then applied having the value calculated with the equation below:

$$F = \textit{Nominal Pipe Diameter} \times 10 - 40 \quad (1)$$

The deformation of the annealed medium-hard copper pipes is limited to 100 mm.

The result of the test is considered to be positive and the tested type of assembly is considered to be of adequate quality if, both during and after the test, the experimental model keeps its tightness, i.e. no air leaking is detected. To this purpose, the tightness is verified during testing by applying on the model a special solution which identifies any air leak. In addition, in the end the experimental model is submitted to the resistance and tightness test under internal pneumatic pressure, following the procedure described above.

The procedure for the resistance and tightness test under dynamic torsion loads is to be performed according to the data included in table 6. The experimental model is subjected to an alternating torsion load with constant specified amplitude, for a specified number of load cycles and a specified duration of a cycle, at atmospheric pressure.

Table 6. The parameters of the resistance test under dynamic torsion loads

Testing pressure	Amplitude of rotation	Number of cycles	Duration of a cycle	Number of tests required
Atmospheric	$\pm 5^0$	10	1 sec.	4

The technical requirement of the dynamic torsion resistance test is that the tested assemblies shall keep their mechanical resistance and tightness, after loading them to symmetrically alternating torsion with the specified parameters (from table 6). The experimental model used for such test, the required equipment (a specific stand designed and built by the authors) and the steps of the testing procedure are described in [2].

The testing procedure for the working capacity at high temperatures of the assemblies aims at determining their resistance and tightness at high values of the working temperature, and shall be performed in accordance to the data specified in table 7. An experimental model (made of copper pipe and fittings, see fig. 2) is warmed at a specified high temperature and subjected for a specified duration to a specified internal pressure developed by using nitrogen as working gas. During testing, the gas volume lost as a result of the fact that the assembly is loosing its tightness is measured.

The technical requirement of the high temperature working capacity test is that, while performing it with the parameters specified in table 7, the nitrogen volume lost at each end of the tested fitting shall be no greater than 30 dm^3 per hour. The assemblies for which the gas lost as a result of leakage is within the specified limit are considered to fulfil the quality requirements regarding the exploitation at high temperatures.

Table 7. The parameters of the high temperatures working capacity test

Testing temperature	Testing pressure, PML	Lost flow rate at each end	Duration of testing
$650 \pm 10\ ^0C$	$5 \pm 0,5$ bar	30 dm^3/h	30 minutes

The required equipment consists of an electrical furnace in which the experimental model is kept at a high temperature, a device which develops and maintains the required nitrogen internal pressure, a temperature measurement device, and a device which measures the volume of the nitrogen lost by the experimental model during testing. In brief, the testing procedure is the following: the experimental model is placed into the furnace and connected to the pressure generating device; the model is warmed and then maintained at the specified temperature; nitrogen is introduce in the model at the specified pressure which is then kept constant during testing; the nitrogen flow rate lost by the model as a result of leakage is measured.

Conclusions

The authors have developed seven testing procedures, described in this paper, for the quality assessment of the assembly technologies of the joints of copper pipes and fittings used within natural gas internal installations. The equipment conceived for two of these procedures (the vibration resistance test and the resistance test under dynamic torsion loads) is presented in other papers [2, 3]. In order to validate the procedures conceived, experimental models of copper pipe joints of various types and dimensions have been designed and constructed using the press fit technology. These models have been subjected to tests performed according to the seven procedures defined within a complex testing program.

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Proceduri pentru atestarea calităţii asamblărilor nedemontabile ale ţevilor din cupru pentru instalaţiile de gaze naturale

Rezumat

În lucrare se prezintă rezultatele cercetărilor efectuate de către autori privind utilizarea ţevilor confecţionate din cupru la realizarea instalaţiilor interioare de utilizare a gazelor naturale. Aceste cercetări s-au materializat, în principal, prin elaborarea a şapte proceduri de încercare (prezentate în acest articol), destinate atestării calităţii asamblărilor nedemontabile (prin sertizare sau lipire tare) ale ţevilor şi fitingurilor din cupru, precum şi prin proiectarea şi realizarea unor echipamente necesare pentru efectuarea încercărilor.