NEW METHODS TO CHECK THE SAFETY PARAMETERS FOR NON-METALLIC PIPES INTENDED FOR USE WITH LIQUID FUEL

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Abstract: The non-metallic pipes are being used on a wider scale with the installations that convey and store oil products because of their improved parameters compared to the metallic pipes (erosion of metallic pipes and the risk of occurrence of stray currents are the most important reasons in favor of use of non-metallic pipes).

Evaluating the compliance of underground non-metallic pipes for oil products is a stringent aspect both for the designers, manufacturers and users and for the third bodies involved in certification or inspection.

For the case of non-metallic pipes there has to be considered the hazards that can come up due to the emitted combustible vapors and form an explosive mixture. This is the reason why these pipes should meet the essential safety requirements stated by the regulations in force. The paper shows the test results on the safety parameters of non-metallic pipes and the specific test stands that have been designed and manufactured at LIEx – INCD INSEMEX Petrosani.

Key words: potentially explosive atmospheres, underground non-metallic pipes, safety requirements

1. INTRODUCTION

Conformity assessment and testing of non-metallic pipeworks for petroleum products represents an issue for designers, manufacturers, users and for the third party bodies which are involved in the certification or surveillance activities. This assessment is required as consequence of the explosion risk which exists and should be minimized having in view personnel and environmental safety and to prevent goods and installations damaging.

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2. CONSIDERATIONS ON PREVENTION AND PROTECTION AGAINST FORMATION OF EXPLOSIVE ATMOSPHERES AND AVOIDING IGNITION SOURCES WHEN USING NON-METALLIC UNDERGROUND PIPELINES

Explosion prevention and protection have a major importance for personnel safety and health, because explosions put in danger both life and health of workers as a result to the uncontrolled effects of flames and pressure (hot radiations, flames, pressure waves, particles spread out), due to the presence of toxic reaction products and oxygen consumption in the air that should be breathed. In order for an explosion/ignition to occur the condition of three factors simultaneously meeting in the same volume (figure 1): the flammable substance in form of vapors, gas, mists or powders, presence of a oxidizing substance (air or oxygen) as support for the violent combustion (explosion) and the presence of an ignition source in form of a spark (of an electric or mechanical nature), hot surfaces etc.

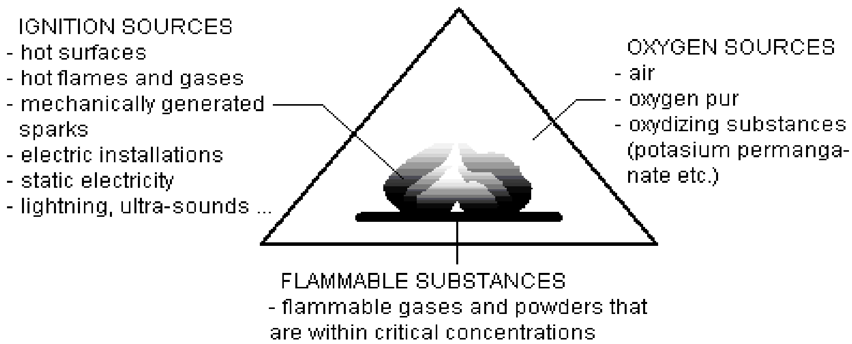

Fig. 1. The ignition triangle

If hazardous explosive atmospheres can be formed, protective measures are needed so as to prevent the ignition of them or to diminish the adverse effects of explosions and ensure workers' and installations safety.

Prevention of dangerous explosive atmospheres forming should be of a first priority. This can be achieved by the following: using of replacements for flammable substances, limited concentrations, inertising and prevention or limitation of explosive atmospheres formation around equipment or installations.

If it is not possible prevention of dangerous explosive atmospheres, ignition should be avoided by protective measures that avoid or mitigate probability of ignition sources occurrence. It should be estimated the probability of a simultaneously occurrence of a dangerous explosive atmosphere and an ignition source in the same place so the extent of the required protective measures can be accordingly determined.

Thus, the first step in explosion risk assessment is to determine if an explosive atmosphere may appear and in which circumstances then it should be assessed if this one can be ignited and how.

3. STANDARDIZED SAFETY AND TEST REQUIREMENTS FOR NON-METALLIC UNDERGROUND PIPELINES USED TO CONVEY PETROLEUM PRODUCTS

The combustible vapors emitted by the liquid fuels in the atmosphere may form and explosive mixture and this is the reason why it is necessary for the pipework systems to comply with the essential safety requirements regarding explosion danger. These requirements have in view, on one side, prevention of an explosive atmospheres formation around the pipework by preventing leakages at the jointing points, and on the other side prevention (avoidance) of intrinsic ignition sources of the explosive atmosphere, as, for example, the static electricity.

A safety issue in this matter occurred when the non-metallic pipework systems developed superior performances compared to the metallic ones. Corrosion on the metallic conduits, as well as the danger of stray currents (dispersion, run type) are two valid arguments in favor of using non-metallic pipes (made of plastics and rubber) in installations for conveyance of petroleum products in the petrol-chemical industry, in the fuel distribution and storage stations, and other industry fields.

In order to prevent explosive atmospheres occurrence, all pipeworks (the conduits and the jointing elements) must fulfill the following requirements:

- withstand to foreseeable pressure regimes;
- fulfill their function without significantly alter the properties under action of the fuel conveyed (to be compatible with the transported fuel): the manufacturers must provide all details regarding influences of different fuels on the materials that could affect the installation integrity;
- to provide a proper resistance to fuel permeation through materials, in order to limit the amount of vapors that is transferred to the environment: in order to ensure the allowed limits are not over-passed, tests of permeability to petroleum fuels must be carried out;
- they must support all the strains they are subject to, during storage, transport, installation and operating of the system. The significant tests should include traction, crush, torsion, impact and bending and to prevent static charges accumulation.

Taking into account the theoretical considerations regarding formation, accumulation and discharge of static electricity, a series of protective measures can be defined, and they may be applied according to case, to prevent the fire or explosion danger, as follows: earthing, use of adequate materials, antistatization of materials, choosing the proper constructive form (surface, distance towards the conductive elements earthed, thicknesses of the non-conductive materials); avoiding of dangerous rubbings (limitation of conveyor belts speed or the flow speed through conduits); environment conditions (high humidity), usage of charges neutralizers.

The main factors which determine the level of electrostatic potential generated during fuel flow within conduits are: fuel's electric conductivity, flow speed, conduit material, existence of some particles or immiscible phases as for example, water. Also, existence of narrowing, filters along the path can influence the level of electrostatic charge.

Prevention of explosion danger due to static electricity sources of ignition on non-metallic pipelines can be achieved either by decreasing the fluid flow speed in the pipes, or by using conductive or insulating materials for pipes or insulating pipes having a dielectric rigidity greater than 100 kV (in the case of using a non-porous polyethylene layer, the pipe wall thickness must be greater than 4 mm).

The standard SR EN 14125 specifies the requirements for underground pipework systems used to convey combustible liquids and their vapors from the petroleum products storage stations, as given the minimum performance requirements within the aimed goal, for safety and environment protection, and it applies for: transfer pipes to dispersion tanks where there is a positive pressure, vacuum aspiration and siphon; filling conduits from the fuel trucks to tanks; vapor recovery and venting conduits, secondary containment conduits; connectors (jointing systems).

According to this standard, to certify the pipework systems it is necessary to follow laboratory tests (type tests):

- *Electric tests*: tests regarding determination of electric capacity, tests regarding determination of transverse resistivity (volume resistivity), tests regarding determination of superficial resistivity (of surface), tests regarding determination of dielectric rigidity;
- *Tests of resistance to fuels*: test of compatibility with fuels, of permeability to fuels; test of deformation by absorption of fuel;
- *Mechanical tests on pipes*: crush test, bending test for verification of the allowed bending radius, shock (resilience) test, piercing test, traction test;
- *Positive hydrostatic pressure, negative (vacuum) and cyclic pressure*:

Hydrostatic pressure test. All the pipes and connecting joints (so mounted to form one or more assemblies with a length of 375 mm or three times the outer diameter, whichever is the greatest value) are previously conditioned at (50±2) °C and are tested for at least 5 minutes at the pre-established pressure, according to the pipe or jointing system type. The inner pressure is then raised to reach the inferior test pressure specified for that specific application, and finally the pipes are checked for leakages. The same test procedure applies at a temperature of (23±2)°C. If necessary, the pressure can be raised up to occurrence of an anomaly, leak or damage.

Vacuum test (−0,9 bar). This test is applicable to pipes and jointing elements for aspiration by depression after sample conditioning in air at a temperature of (23±2)ºC for at least 16 h. Each sample is voided at an internal pressure of (−0,9±0,05) bar ((0,1±0,05) bar absolute) after which the sample is insulated from the vacuum pump and it is maintained at least for 30 minutes at a temperature of (23±2)ºC. The inner pressure is noticed and the inner and the outer part of the sample are examined before and after dismounting to notice possible signs of sample destruction or damage.

Cyclic pressure test. This test applies for pipes and jointing elements for positive pressure, after their conditioning in water at a constant temperature (21,5±3,5)ºC for at least 1 hour. Each sample is submitted to a cycle of pressures between a minimum of 1,0 bar and a maximum of 4,0 bar over the environment pressure, for 1,5×106 cycles at a rate not lesser than 25 cycles per minute and the environment temperature of (21,5±3,5)ºC and the samples are inspected for leaking at the end.

On the basis of studying the norms and standard requirements, there have been carried out three test procedures for pressure testing (hydrostatic, depression and cyclic pressure test; fuel compatibility and permeability test), mechanical tests (crushing, bending radius, shock-resilience, piercing, traction) and electric tests-static electricity (electric capacity, transverse resistivity, superficial resistivity and dielectric rigidity), procedures that form the basis of their implementation in the laboratory's quality system having in view extending its capacity of testing and assessment of conformity for non-metallic underground pipework systems for petroleum products.

Taking into account analysis of the safety requirements and laboratory tests above presented, as well as the test procedures carried out according to the European standards, a technical documentation has been carried out for the purpose of setting up a set of stands for pipe testing to hydrostatic and cyclic pressures, vacuum test. These stands ensure exigency in verifications for the requirements provided in the standards SR EN 14125 and SR EN13463-1.

4. TEST STANDS

For tests to hydrostatic and cyclic pressure the hydraulic stand shown in figure 2 has been conceived. It consists in the following sub-assemblies: PGS- pressure generation system; PPGS- pressure pulses generation system; PH_1- manually operated hydraulic pump; PH_2- electrically operated hydraulic pump; RR- regulatory relay; RP_1- regulator of loading pressure; RP_2- regulator of discharging pressure; Ac- diaphragm accumulator; TP- pressure transducer (digital manometer); M_1, M_2- analog manometers; R_1, R_2, R_2' and R_3- shut-off valves; EV, EV_1, EV_2- electric valves; T_1, T_2- water tank; IT- thermostated enclosure, C- coupler for the assembly to be tested.

The hydrostatic pressure test is carried out for two thermal regimes: 23 ºC and 50 ºC at a lowest and highest test pressures between (+5,0±0,1) bar and (+30,0±1,0) bar, according to provisions in SR EN 14125:2005. Cyclic pressure test is carried out on pipes and pipe assemblies at a temperature of (+21,5±3,5) ºC and cycle of pressures of minimum 1,0 bar and maximum 4,0 bar over the ambient pressure, for $1,5 \times 10^6$ cycles having a rate of 20/25 cycles per minute.

One software was conceived to processing, recording and displaying the test results, the following parameters can be entered: test duration, in minutes; measuring interval in seconds, for pressure; measuring interval in seconds, for temperature; in case of cyclic pressure test the total number of cycles can be entered – implicitly this is $1,5 \times 10^6$.

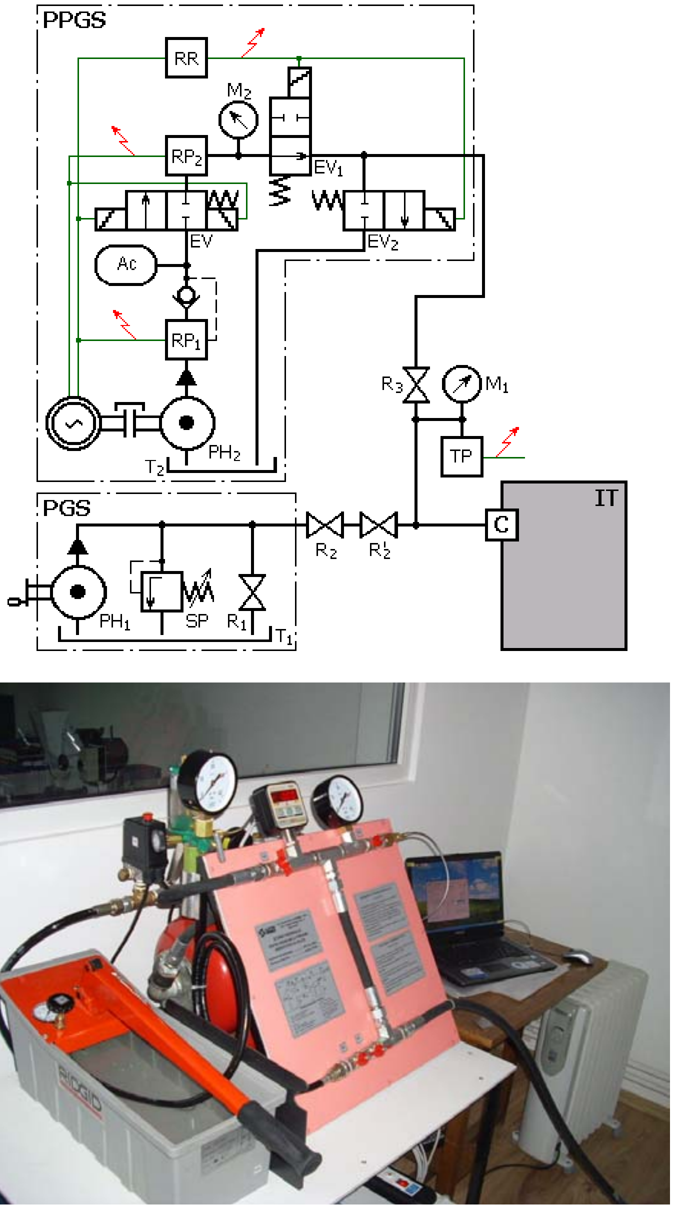

Fig. 2. Test stand for hydrostatic and cyclic pressure:
hydraulic diagram and view

The vacuum test stand for non-metallic underground pipes and their fittings is shown in figure 3 and it consists in the following sub-assemblies: SV- vacuum system; PV- vacuum pump; M- manometer; TD- negative pressure transducer; R_1, R_2, and R_2'- shut-off valves; C- coupler for the assembly to be tested.

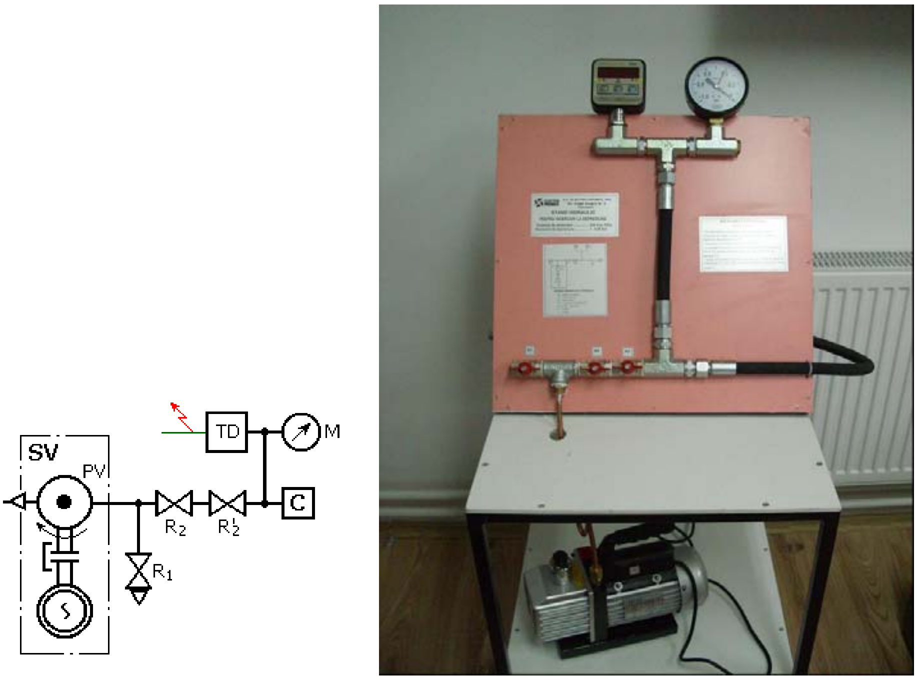

Fig. 3. Test stand for negative pressure: hydraulic diagram and view

The application to interface with the stand is similar to the application shown in the hydrostatic test stand and it is designed to pick data from the stand through connection to the serial port or a simulated serial port through a converter USB-RS232. The data received from the stand are current temperature and pressure; these can be saved and thus test evolving diagrams can be drawn.

These stands were used to carry out demonstrative laboratory tests, there had been tested the resistance to hydrostatic pressure and vacuum, as well as the long term resistance (reliability), at cyclic pressure on several non-metallic pipelines assemblies having different overall sizes, provided with jointing elements (joints) that would ensure an adequate sealing.

In order to implement the test methods within the LIEx laboratory of INCD-INSEMEX Petrosani, having in view an extend of the laboratory's competence field, there had been kept into account the general requirements for the competence of testing/gauging, including test samples sampling methods, training and qualification of personnel within the laboratory, as well as choosing and gauging of equipment in use, requirements laid down in SR EN ISO / CEI 17025. To properly perform the tests there have been elaborated test procedures according to this standard and considering all the imposed factors. There have been produced specific test procedures which take into consideration all the required factors in order to perform the tests.

5. CONCLUSIONS

For checking the safety requirements stated by the standards in force, there have been produced two test stands intended for the underground non-metallic pipes and their connecting elements. There have been used modern elements to generate and measure the hydrostatic pressure and the depression, to maintain constant the temperature of the test environment and to calculate the number of cycles made and the number of cycles to be made.

The test stands are equipped with software that processes, records and displays the test results at the end or in real time.

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