DEMINERALIZED WATER FLOW CANCELLING EXPERIMENTS WITH ICE PLUG INTO HIGH DIAMETER HORIZONTAL TUBE

(300 NOMINAL DIAMETER)

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ABSTRACT

The isolation with ice plug of a high diameter horizontal pipeline section is a specific technique for repairs activities/ replacements of components owning to thermo-hydraulic installations working with liquid agents. The application of such technique don't assumes stopping of the entire system. The ice plugging inside of the pipeline assumes using of a special device and of an own specific technology for application. The paper contains a brief description of the experimental technological facilities used, followed by setting off the main moments in evolution of two experimental tests carried out on the test section with 300 mm nominal diameter for demineralized water and, finally, by a brief results analysis and some conclusions. The paper is dedicated to the specialists working in the research and technological engineering.

Key words: ice plug, upstream, downstream, nitrogen vapours, flow rate, demineralized water

Introduction

The isolation technique with ice plug of a high diameter horizontal pipeline section is specific for repairs activities/ replacements of components owning to thermo-hydraulic installations working with liquid agents. Its application don't assumes stopping of the entire system. The ice plugging inside of the pipeline assumes using of a special device and of an own specific technology for application. The formed ice plug has to maintain until ending of the maintenance/ repair works carried out in the pipeline system.

The ice plugging device is collar shaped, made of two semi collars I and II, nut bolt detachable joint, outside of the tube. An annular segment is formed into collar assembled on the tube, concentric to tube section and dedicated to liquid nitrogen injected in the process. Generally, the annular segment is equipped with one or two N2 steam outlet at upper side of one of two semi-collars. The intrusion of heat coming from environment into the liquid nitrogen segment is blocked by a voided space owning to each subassembly (semi-collars I and II) and by an additional joint thermal insulation (foam polystyrene, mineral wool ...), [1].

In these conditions, the heat transfer is carried out from working agent circulating in the inner tube to the liquid Nitrogen annular space of the ice plugging device The heat flow transferred by the working agent to the liquid nitrogen annular space interface (tube wall/ collar segment wall); increase the liquid nitrogen vaporisation increasing the pressure in the segment and the liquid nitrogen supply circuit, implicitly, [1]. The liquid nitrogen vapours are ejected through the vapours outlet nozzle(s), to limit the pressure into segment.

The heat and mass transfer, executing continuous between the tube wall and refrigerant ring shaped, determine the local decreasing of the wall temperature, encouraging the ice deposit in subsequent layers.

The thickness of the ice layer deposited at one pass doesn't exceed yet the thickness of boundary layer constitutes a thermal insulator. Thus, inside of the tube, in the device influence area, is developing, by subsequent deposits, and generates a local hydraulic resistance having as a result: decreasing of the fluid flow rate and flow stopping, even. At the time when the primary stopping and then the stable of the flow is done, the ice plugging goes on end long, increasing the pressure upstream freezing sleeve, [2], [3] and [4].

In this area, the experiments confirmed that the plugging device to form and maintain the ice plug for the high diameter pipeline are devising, executing and qualifying by tests, at the same time with the technique itself, apart for each kind of application. Difficulties begin with: pipeline lay-out, the inner diameter size of the pipeline, the working fluid flow rate value, its steady-state flow, fluid temperature, the liquid nitrogen volume available, and with the pressure limit available for the liquid nitrogen injection in the system, etc.

The paper describes, beside the brief description of the experimental technological facilities, some tests performed, the results get and finally, some conclusions are following.

Brief description of the experimental technological facilities

The experimental testing loop can use, according to the application requirements, the industrial water / drinking water / demineralised water and hothouse water, works in open circuit and consists practical in: a circulating pump (P), a tubes and fittings assembly, and a supply-drain vessel (VU/G), **Figure 1**.

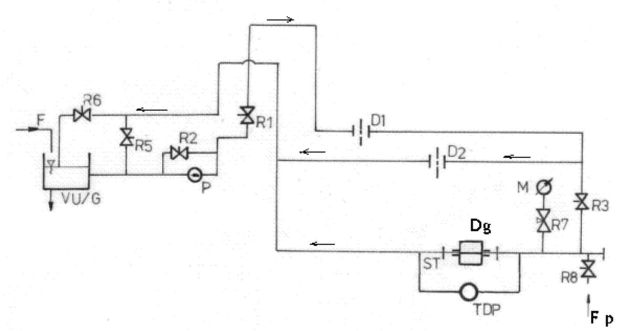

Figure 1 *The experimental testing loop - adapted diagram*

For the experiments, the loop contains a horizontal test section (ST) fitted into two pressure intake ports. The test section (ST) is, in our case, a horizontal tube having a nominal diameter of 300 mm, **Figure 2**.

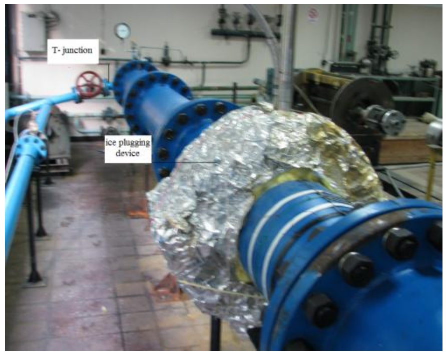

Figure 2 *A 300 mm nominal diameter test section with assembled device*

The ice plugging device inside of a horizontal pipe section having a 300 mm nominal diameter (1), experimental model, is a double segmental sleeve, made of two tight joint half-clamps: the upper half-clamp (8) and lower half-clamp (2), the **Figure 3**, [5].

After assembling of the device on the outside of the horizontal tube, in the area chosen for ice plugging, is practical performing an annular compartment (4) for liquid nitrogen. The liquid nitrogen compartment (4) is thermally insulated to the outside by the vacuum compartments (5) and (3).

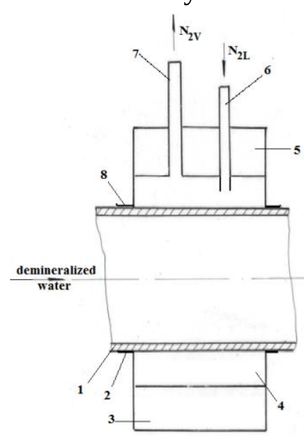

Figure 3 *Ice plugging device (experimental model)*

The variant adopted has a single outlet nozzle for nitrogen steam (7) and the liquid nitrogen supply equipped to carry out through nozzle (6), at the upper half sleeve (8) level.

The liquid Nitrogen transfer from the liquid Nitrogen tank to the central nozzle is performed using a special joint, pressure hose with outer seal metallic clamp. The liquid nitrogen supply available is a Dewar vessel.

The experimental tests

For temperature measurement of the outer wall in the ice plugging device area, direct on the tube, have been placed the surface temperature plugs thermocouple made of Fe-Constantan, as following: upstream and downstream ice plug device, at the end of half-clamps: in upper/ lower position (four thermocouples), at nitrogen vapours outlet, at liquid nitrogen chamber inlet and in water supply – drain vessel.

The data measurement and their on-line recording performed every time with a high level digital data acquisition and processing system.

One test performed for an initial flow rate of 6.1 l/min. on test section. After about two minutes from liquid nitrogen injection (0.7 bars) towards freezing device noted the circuit attended by vapours draining, **Figure 4**. The N_2 drained vapours column signalized starting the ice plugging storage process inside of the test tube.

Figure 4 *The process starting*

After 40 minutes, noted the ice deposits (on the tube) both ice plugging device upstream and downstream. In the test section, the water flow rate decreased at 4.8 l/min.

The temperatures recorded on the outer tube walls, in the monitoring area decreased as follows: at sleeve inlet, down – 19°C, up – 10°C and at outlet, down – 37°C and up – 16°C in condition of water temperature increasing with 1.1°C (from 17.4°C to 18.5°C).

After 80 minutes, the water flow rate in the test section decreased at 3.8 l/min., and the temperatures recorded on the outer tube wall lowered forward, in the monitoring area.

After 100 minutes, the water flow rate in the test section decreased less than 2.5 l/min., and the temperatures recorded on the outer tube wall lowered reaching the values: at sleeve inlet, down – 55°C, up – 22°C and at outlet, down, – 76°C and up – 32°C in condition of water temperature increasing at 20.6 °C.

After 350 minutes, the experiment has closed down due to depletion of the liquid nitrogen volume of the Dewar vessel. The temperatures on the outer tube wall, in the monitoring area, reached to the following values: at sleeve inlet, down – 73°C, up – 35°C and at outlet, down, – 97°C and up –52°C in condition of water temperature reached 22.9°C and carried on flowing in the test section.

Proceed to dismantling of the upstream section from test section, in parallel with pipeline draining and then, to remove it for viewing of ice plug deposits, **Figure 5**.

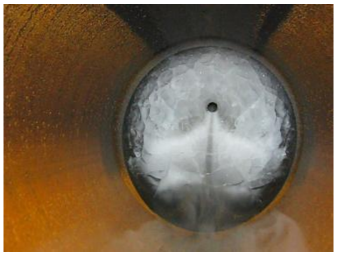

Figure 5 *The ice layer deposit*

The remained hole in the ice had an equivalent diameter of ~ 14 mm. An imaginary section through the test tube longitudinal axis, in correct scale of direct measured sizes versus the plane face of the connecting flange of test section, is shown in the **Figure 6.**

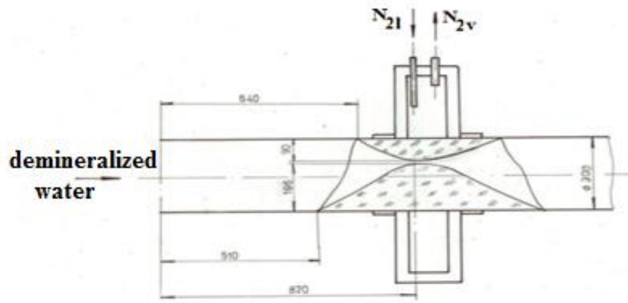

Figure 6 *The apparent cross section through the longitudinal axis of the testing pipe*

Decreasing in time of the wall temperature at freezing (ice plugging) device inlet/outlet for this test is shown in the **Figure 7**. There we see the evolution in time of the water temperature.

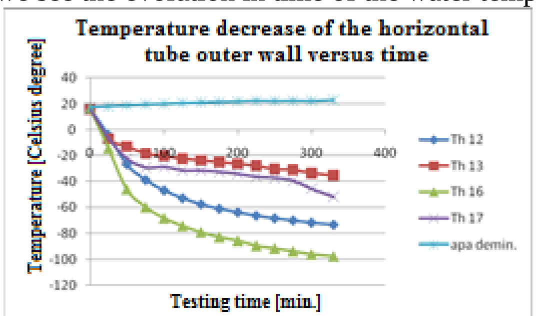

Figure 7 *The temperature variation of the outer pipe wall versus time*

Another test has carried out for an initial flow rate on the test section lower with ~ 16.5%, of 5.1 l/min. After about two minutes from the liquid nitrogen injection (0.6 bars) to the ice plugging device, this time the N_2 vapours column showed up at device outlet pipe, also.

After 40 minutes, noted the ice deposits (on the tube) around device. The water flow rate, in the test section, decreased at 4.8 l/min. The temperatures recorded on the outer tube wall, in the monitoring area, lowered as follows: at sleeve inlet, down – 16°C, up – 26°C and at outlet, down – 28°C and up – 19°C in condition of water temperature increasing with 1.8°C (from 14.6°C to 16.4°C).

After 90 minutes, the water flow rate in the test section decreased just at ~ 4.40 l/min. and the measured temperatures on the outer tube wall, before and after device, reached in this moment the values: at sleeve inlet, down – 46°C (Th 12), up – 37°C (Th 13) and at outlet, down – 64°C (TH 16) and up – 33°C (Th 17), the water temperature increasing forward with 1.5°C reaching to 17.9°C.

After two hours from the test starting the flow rate in the test section remained the same ~ 4.40 l/min. The measured temperatures on the outer tube wall, before and after device, were: at sleeve inlet, down – 54°C (Th 12), up – 39°C (Th 13) and outlet, down – 74°C (Th 16) and up – 29°C (Th 17), the water temperature increasing with 0.7°C, from 14.6°C to 18.6°C.

After 325 minutes the experiment has closed down due to depletion of the liquid nitrogen volume of the Dewar vessel. The temperatures on the outer tube wall, in the monitoring area, reached to the following values: at sleeve inlet, down – 73°C, up – 36°C and at outlet, down, – 97°C and up –53°C in condition of water temperature reached 19.6°C. The water flow rate in the test section didn't lower under 2.5 l/min.

Proceed to dismantling of the upstream section from test section, in parallel with pipeline draining and then, to remove it for viewing of ice plug deposits, **Figure 8**.

Figure 8 *The ice deposit*

The remained hole in the ice had an equivalent diameter of ~ 44 mm. An imaginary section through the test tube longitudinal axis, in correct scale of direct measured sizes versus the plane face of the connecting flange of test section, is shown in the **Figure no.9**.

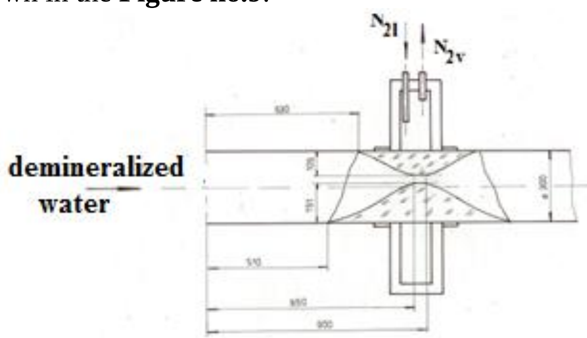

Figure 9 *The apparent cross section through the longitudinal axis of the testing pipe*

Decreasing in time of the wall temperature at freezing (ice plugging) device inlet/outlet for this test is shown in the **Figure 10**. There we see the evolution in time of the water temperature, also.

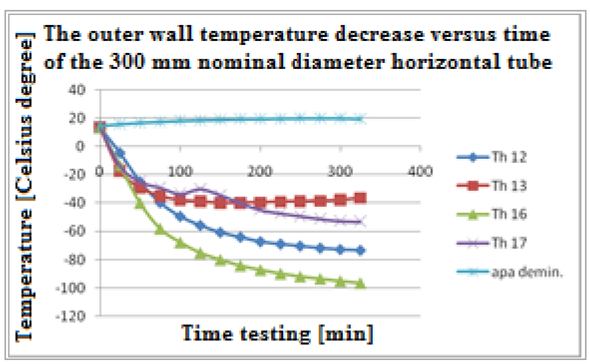

Figure 10 *The temperature variation of the outer pipe wall versus time*

Decreasing of the flow rate value on the test section, during test, is mainly due to local hydraulic resistance increasing, by subsequent ice layers into testing tube, in the influence area of the ice plugging device, the water flowing in the loop being instantaneously take up by the existing by-pass.

The results

The two tests carried out in the same conditions from geometric point of view. None of them hasn't completed with ice plug. The water temperature variation during each test was away different. For the first test the water temperature in the test section was ~5°C greater than the second test temperature, during all test time, **Figure 11**.

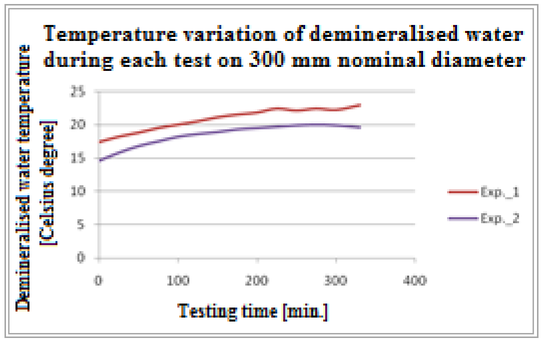

Figure 11 *The water temperature variation*

Decreasing in time of the wall temperature at the inlet/outlet in/out ice plugging device for the two tests is plotted in the **Figure 12**. If decreasing of the temperatures measured upstream (downstream) on the outer tube wall for the bottom area of the cross flowing section are taking place for each, aproximately at the same way, the diference between the temperatures measured upstream (downstream) at the top is obvious for each case.

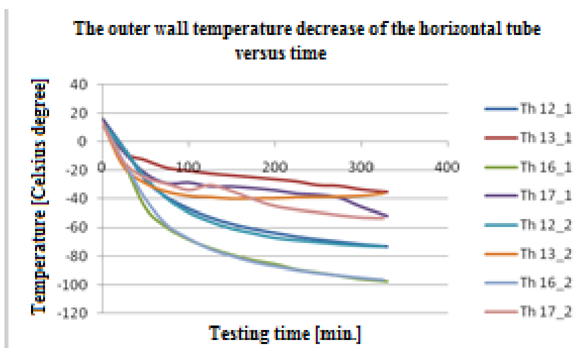

Figure 12 *The temperature variation of the outer pipe wall*

The temperatures measured upstream and downstream on the outer pipe wall, at the top side is obvious different both in time and along of the influence area of the plugging device. Thus, for the second test, upstream, the temperature of the pipe wall decrease relative quickly around the value of – 40°C during first 100 minutes, then is maintaining almost constant for the next 175 minutes of the test and finally, at 325 minutes to increase slowly at about – 36°C. In case of the first test, the temperature of the pipe wall is decreasing slowly all-time to a value similar to those reached at the end, in the second test. Downstream, there is a difference for the second half of the test time and between the much reduced limits as value.

Although the water temperature level in the test section in the second test maintained with about 5°C lower all test time, the circulating water temperature being lower, the ice deposits thickness in the influence area of the freezing device was lower. The difference between the equivalent diameters of the holes remained in the ice was of about 30 mm.

The ice deposits shape was different along of the influence are, also. Thus, in the first test from the begining created a restraint like a diaphragm that then evolved endlong while, in the second test, first created a larger diameter passage way that evolved radial in time much slower. During the tests anlyzed, each flow rate variation correspond to restraint formed in the ice, **Figure 13**.

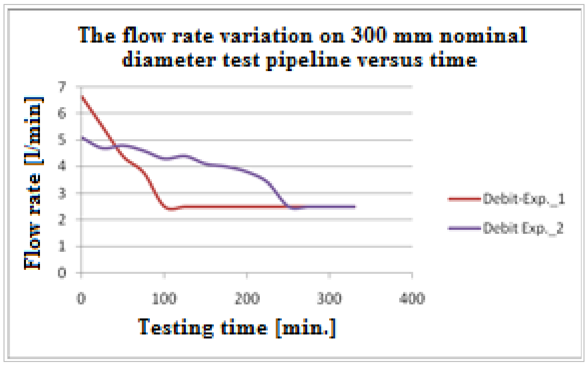

Figure 13 *The flow rate variation*

Conclusions

- none of the two tests didn't complete with ice plug;
- although, the conditions of the second test were more favourable to ice plugging, we could say that the liquid nitrogen injection way in the device led to this result;
- we note that in both cases, a thermal balance is reaching, from this moment the flow rate is maintaining constant or decreasing insignificant in time;
- we consider that the flow rates from ice plugging process starting were oversized;
- increasing of the ice layer depth leads to a better thermal insulation between the circulating water and liquid nitrogen torus, slowing down the ice deposit depth evolution;
- the more evenly ice deposit evolved on the tube inner on the device influence length, the more visible is decreasing the primary plugging chances of the tube, becoming dependent on the available liquid nitrogen amount.

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