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LEAK TESTING UNDER WATER

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ABSTRACT

In some specific occasions there is a need to test tightness of pools or vessels that are permanently under water and they are not accessible from the outer side. The only possibility is in such a case testing from the pool from the waterside.
Q Techna has developed on the basis of the theoretical study and its experiences special method and equipment for leak testing of welds. The method is based on combined technique: bubble test and spectrometry with helium detection.
Calculation and work on field proved, that it is possible to detect with this method defects equivalent to the capillary of 0.01 mm in diameter.

***Keywords**:* Under water leak testing, Helium detection

1. Introduction

In some special occasions there is a need to test tightness of water filed vessels or pools (pits) that are permanently under water and they are not accessible from the outer side. The only possibility is in such a case testing from the pool from the waterside. In such a case is impossible to use "classic" helium leak detection and the only possibility is to use special methods with special equipment.
Q Techna designed and constructed a special equipment for leak testing, i.e., Helium Visual Testing System (HVTS), for leak testing of steel pits full of water, where is only a small gap between concrete structure and the steel vessel.

2. Basic principle, description of equipment and testing method

The testing method is a non-destructive method based on a combined technique – bubble observation and helium detection. We make use of the fact that fluids flow from the place of high pressure to the place of low pressure. Flow is a function of differential pressure (Δp), media and opening diameter.

The main element of HVTS is a vacuum box, which is submerged and fixed to the steel plate of the pool. For each specific geometry different box has to be constructed. Two examples are shown in figure 1. To assure Δp a special sealing system has to be used. It is necessary to establish at least 300 mbar Δp. In our case we use approximately 600 mbar Δp, i.e. 400 mbar absolute in the box.

The box has to be full of water. At first the pressure in the box at the bottom of the pool is by a water column higher than the atmospheric, and then it is reduced with a special pump. The pressure under the box is measured with a pressure gauge fixed on the box. Helium detector is also connected to the box with tubing and a special helium separator. This separator is watertight but allows helium permeability. In this way we detect the whole amount of helium penetrating through all defects covered by the box.

Helium is introduced in the gap between steel vessel and concrete, f. ex. through the drain system. Helium detector sensitivity in such circumstances is 10^{-7} mbar.l/s. To pinpoint the exact location of the leakage a special underwater remote camera has to be used – to observe bubbles.

This combined method has an advantage over the visual one, and is employed to exclude a human mistake to the highest degree possible.

Fig. 1: Boxes for HVT.

A theoretical study with a presumption there is a defect as a capillary has shown 290 mbar Δp is needed for a capillary with 10^{-2} mm in diameter. In fact capillary pressure (minimum Δp needed to assure flow in capillary) is (1):

$$p = \frac{4 \cdot \sigma}{d} \tag{1}$$

where is p [Pa] capillary pressure, σ [N/m] surface tension and d [m] capillary diameter. To calculate laminar flow through the defect Hagen-Poiseuille could be used:

$$q_V = \frac{\pi}{8} \cdot \left(\frac{d}{2}\right)^4 \cdot \frac{\Delta p}{\eta \cdot l} \tag{2}$$

where is q_V [m^3/s] capillary pressure, d [m] capillary diameter, Δp [Pa] differential pressure, η [Pa·s] dynamic viscosity and l [m] capillary length.
It was calculated that with HVTS in general a minimum leakage even less then 500 ml/year could be detected.

3. Method qualification

When new method is introduced it is mandatory to perform method qualification. The aim of the method qualification is:

- Confirmation of the physical principle,
- Method sensitivity verification,
- Verification, if the method is appropriate to detect theoretically calculated minimal defects.

In figure 2 laboratory equipment for method qualification is shown. Conditions of a real case have to be simulated. Equipment consists of a steel chamber, a vacuum pump, different capillaries (permeability between 2×10^{-1} to 1×10^{-3} mbar.l/s), a helium balloon, a permeable separator with a helium detector and an absolute pressure gauge. In the wall of the chamber there is a window to observe bubbles going out the capillary.

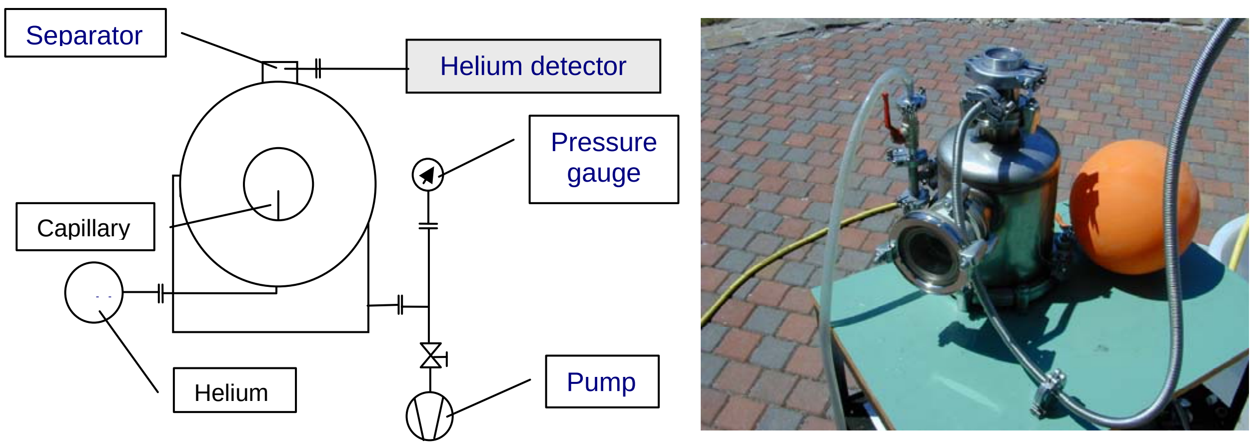

Fig. 2: Laboratory equipment for method qualification.

In figure 3 helium bubbles could be observed through the window coming out from the capillary. During the method qualification the chamber is full of water. The water pump establishes 700 mbar abs. The helium detector is set to zero. Through the calibrated capillary helium is introduced. Through the window bubbles could be observed and at the same time helium permeability is measured. No quantitative comparison between numbers of bubbles and helium permeability has been done yet.

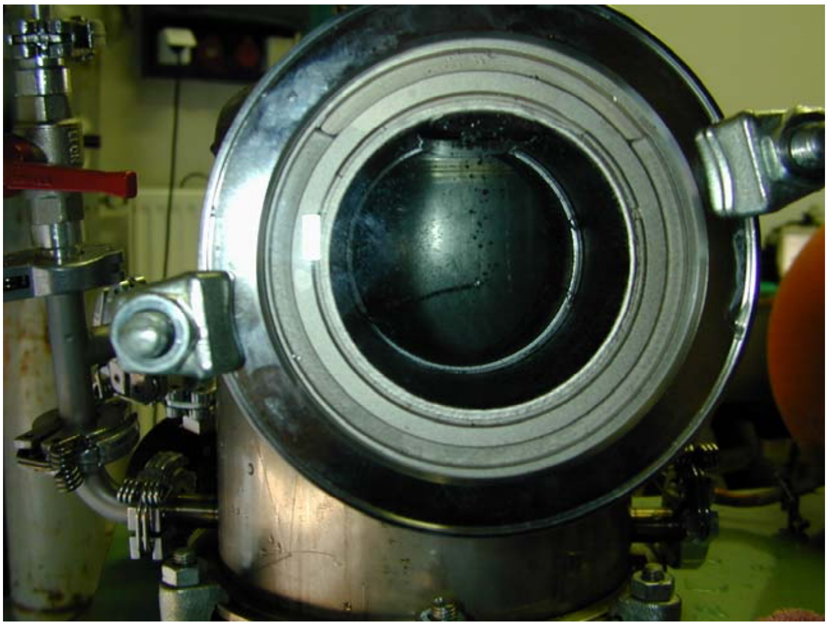

Fig. 3: Bubbles observed through the window
(pressure in the chamber 750 mbar abs, capillary diameter 0,01mm).

4. Equipment qualification

For our application the equipment qualification was performed for on-site work. It was necessary to assure conditions as similar as possible to the real one. A mock-up was manufactured in 1,5×1,5×1,5 m size. It is shown in figure 4.

Fig. 4: Mock-up with dimensions: 1,5×1,5×1,5 m.

Three vacuum boxes were constructed to match a very complex geometry of the pit in every aspect. The vacuum boxes were equipped with all necessary connections, a window and a mechanism for manipulation. It was also very important to assure appropriate sealing. For each box sealing was accomplished in a different manner.
The aim of the equipment qualification was:

- Sealing verification on a mock-up,
- Verification if necessary pressure could be established,
- Possibility to detect leakage visually and with a helium detector.

A capillary of 0,01 mm was used. Through the window bubbles were observed and in the same time helium permeability was measured. In figure 5 it is easy to see bubbles coming out of the capillary.

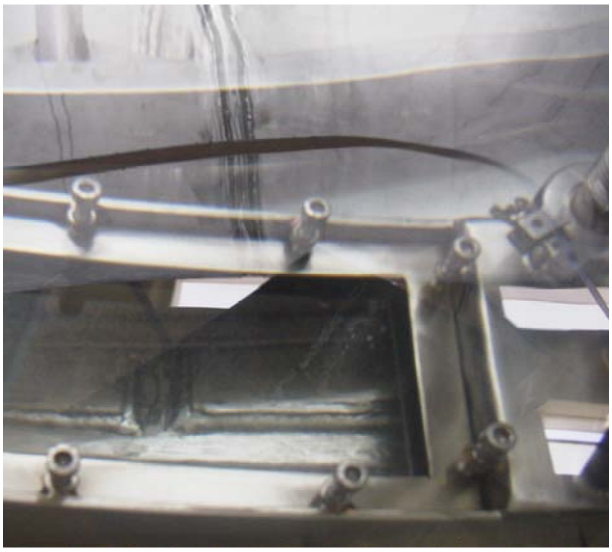

Fig. 5: Bubbles coming out from the capillary with a diameter of 0,01 mm.

Personnel for method and equipment qualification and of course the staff to perform on-site examination were appropriately trained and certified according to EN 473 [2] or SNT-TC-1A for visual and leak testing. Precondition for on-site testing was a qualified method and equipment.

5. On-site testing

All elements and all functions of HVTS were checked before the our actual project started. HVTS was fixed to a 16 m long extension - manipulation tool. The extension was fixed to the crane bridge. An under water camera independent from the vacuum box was used. The camera with a 25 mm focus was equipped with additional halogen light source. The camera and light were remote controlled. Every inspected position was digitally recorded. A camera control unit and a recording device are shown on figure 7.

Fig. 6: Camera control unit and a recording device.

Prior to the examination helium was introduced in the gap between steel vessel and concrete. On each position a vacuum box has been placed for 10 minutes. The pressure in the box was constantly between 400 in 500 mbar abs. However, the system was capable of achieving 125 mbar abs. The examined surface was observed and a helium detector was in function. At the end 1-minute film was recorded. Then the pressure in the box was equalized and the box was moved to another position.
During testing dissolved oxygen can present a certain visibility problem in water, but it is possible to solve the problem with an appropriate measures.
It is very difficult to test corners. A lot of experiments were done on a mock-up and a lot of small corrections on-site. From this point of view it is much easier to test transition floor-wall.

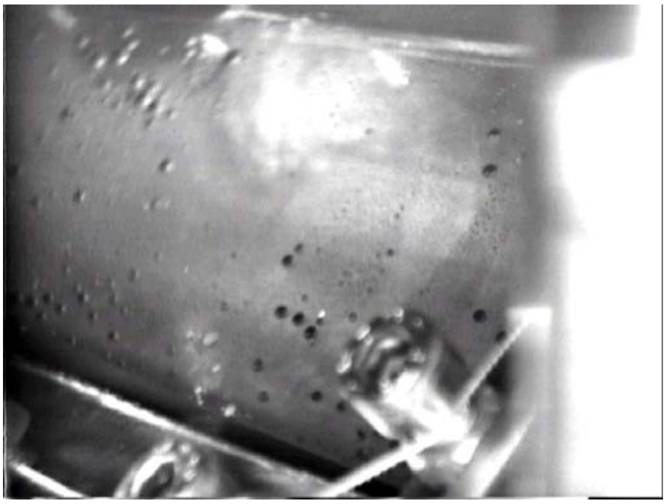

Fig. 7: An example of leakage.

6. Conclusions

Calculations and practical work have shown that HVTS is an appropriate method to detect leakages to capillary equivalence 1.10^{-2} mm. Holding time necessary to examine one location is 10 minutes. On-site the main problem is to seal a box on the test surface but with a carefully designed sealing system it is possible to test quite complex uneven surfaces.

7. References

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[2] EN 473:2000 - Non destructive testing - Qualification and certification of NDT personnel - General principles.