# Leakage control methods for metal underground tanks and tanks placed on hardened soil with the use of radioactive tracers

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**Abstract.** Liquid fuel leakage control issues in underground tanks and tanks placed on hardened soil has been presented. Particularly the bottoms of the tanks were taken into account due to difficulties in physical access to them. Two ways of control have been presented. The first one refers to localization of the leakage from inside of the tank and is based on forced movement of the medium, and the second one refers to disclosure of leakage in closed end units, i.e. in those whose upper and bottom ends have no access. The second one is based on a groundwater technique. Three new examine techniques have been presented, all based on the forced flow of liquid movement: jacket, membrane and float techniques.

**Key words:** leakage control • radioactive tracers

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## Introduction

Metal tanks for liquids and gases are used in many sectors of industry and municipal services and its number is growing fast. New tanks (particularly underground tanks for fuels and aggressive liquids) already at the design stage are equipped with signalling and protections systems that signal, and in most case also locate, each leak. On the other hand, the tanks without such protections: large-size underground tanks, tanks placed on hardened soil, and older tanks in service for a dozen years, require a periodical tightness check.

A possible leakage of the tank bottom increases the contamination hazard that the environment, particularly the underground waters, will suffer from toxic substances leaking from the tanks to the soil during production, processing or storage. It is the responsibility of the maintenance service providers to cope with this problem, and also with the fire or explosion hazard and to find the ways of safe operation of the tanks [5].

One of the methods to achieve the correct operational conditions is to guarantee the tightness of the tanks and eliminate the hazard caused by a leakage. In technical terms, finding a solution to this problem is a very difficult task, and currently there are no absolutely reliable methods to control and locate the leakages. The difficulties are caused by a significantly large volume of the tanks, and by the fact that a leaking substance from a tank most often penetrates the soil undetected and if it does not appear on the surface, there is no evidence that a leak has actually taken place. It is particularly difficult to notice a leak in tanks where the medium turnover times are short, and when the medium evaporates quickly [1, 3, 5].

## Overview of the control methods based on radioactive tracers

This paper deals with the control of the tanks which have been in operation for a longer time. Consequently, a general rule that applies is that the controlled tanks shall be decommissioned for the duration of the check and suitably prepared for it [1, 4].

Preparation involves emptying of the tank from the medium, thorough rinsing and the removal of dirt and corrosion.

Depending on the chosen control method, in some cases it is also necessary to equip the tank with auxiliary tools, such as pumps and piping, to drill the holes in the tank's subbase, or to make a hydrological examination of groundwater in its vicinity [2].

### Underground tanks

In the case of underground tanks without concrete cover and totally covered with soil, the leakage control method is analogous to the method used for underground pipelines without cleanout chambers [2].

A radioactive substance with adequate physical and chemical parameters (in this case it is gaseous methyl bromide, $CH_3Br$, marked with radioactive bromine $^{82}Br$) and activity is introduced to the tank previously emptied from the stored medium. All connections to the tank are cut-off (plugged). Next, the compressed air or nitrogen is pumped into the tank to increase the pressure to a predefined control value. As the pressure is increased, the tracer is being mixed and distributed to some extent evenly over the checked facility. It is advisable to feed the radioactive tracer simultaneously with the control medium. If there is a leakage, an amount of the tracer escapes out of the tank and is adsorbed in the soil (overburden). The radiometric tests on the surface detect the possible leakage. In order to locate the leakage, the overburden must be gradually removed and controlled for radioactive contamination. Such a method unambiguously "leads" the investigator to the place in the tank where the leakage is located.

The underground tanks leakage control with radioactive tracers requires large total radioactivities, because the measurement of the radioactive tracer included in the leakage takes place through the overburden layer.

For the bromine $^{82}Br$ radioisotope, through a 100-centimetre soil layer one can locate the leak with the activity of minimum 1 mCi (37 MBq). For the large volume storage tanks, taking into account the limitations imposed by the Nuclear Regulatory Commission on the maximum activity used in an ABC generator (a device to convert the marked $^{82}Br$ potassium bromide to the gaseous methyl bromide) – 10 Ci (370 GBq), it is possible to locate only a leak with the flow rate which is too high from the employer's point of view.

The increase of the measurement sensitivity to locate the leaks with a flow rate below 1 $dm^3/h$, that is to the reliable radiometric measurement of the leak containing 0.1 mCi (3.7 MBq) is made it possible by the properties of the used tracer and the chemical compound in which it is dosed, i.e. methyl bromide desorption from the soil towards the overburden surface with a velocity from 10 cm/h for heavy soils to 15 cm/h for light soils.

Therefore, the radiometric measurements should a certain time (for a 100 cm overburden, after 8–10 h) after the test pressure is performed. From that moment, the measurement is realized as a measure of the continuously fed source with the radiation intensity decreasing exponentially (according to the decay curve of the bromine $^{82}Br$ radioisotope). The activity that can be measured is about 5 μCi (185 kBq). Depending on the geometry of the tank and the overburden thickness, the measurement takes maximum 100 h to be completed.

The method described above can be used for effective leakage control of the tanks buried no deeper than 10 m.

### On-ground tanks

From the point of view of accessibility, the on-ground storage tanks can be divided into tanks with access to the bottom from one side, and tanks without access. The radioactive control methods can be divided into those based on the forced flow of control medium and weak radiation sources application, and the methods in which high radioactivities are used.

Practically, only two methods (the drainage method and groundwater method) can be used for the leakage control of the on-ground tanks, and rather their bottoms to which there is no access from both sides (also from the inside) are tested. The tanks of the second type with access to the bottom can be controlled with the two above-mentioned methods, and additionally with the zone marking, membrane, jacket, and the float methods [5].

*Locating leakages with techniques based on forced flow of the medium and weak radiation sources*

In general, these methods involve accelerating of the liquid flow in the checked tank towards the leakage by using special covers or vessels. The methods can be used for the tightness control and leakage detection in the tanks emptied from the working medium, and filled with water for duration of the test to a level of minimum 100 cm. This height of the water column has been specified because very often small leakages manifest themselves in the tank only under pressure, and do not appear in non-pressure conditions.

### Jacket technique

This technique involves the tank bottom leakage control with a device consisting of the jacket, marking a liquid injection instrument and a gamma detector. The jacket (an organic glass plate with a dosing cylinder) forms with the tank bottom a flat vessel open at the perimeter. If there is no leakage under the jacket, the liquid in the zone is still, almost not moving. In such a condition, the introduced radioactive tracer does not change its position in the dosing cylinder. If the jacket is placed over leakage, the stream of liquid moves towards such leakage, and autogenous making-up of the water under the jacket causes the tracer in the cylinder to move. The smaller the distance between the jacket and the tank bottom and obviously the larger the leakage flow rate, the higher the speed of such movement. Measurement of the radiation intensity along the cylinder and on the jacket surface (with a collimated probe) allows to rather quickly define the tracer flow direction and consequently the existence and location of the leak. Various sizes of the jackets are used depending on the tank bottom size.

The jacket technique allows to detect and locate the leakages with flow rate no lower than 1 $dm^3$/h, and the used activities of the radioactive tracer – $^{82}Br$ are in the 1 μCi – 1 mCi range (37 kBq – 37 MBq).

## Membrane technique

The membrane technique is used to control the leakage and to locate the leakage zone.

The device consists of a circular, flexible membrane with a seal flange, a closed gamma radiation source – $^{60}Co$ with activity of about 6 μCi (250 kBq) fixed in the central zone of the membrane on an elastic string, and the body allowing to move the device on the bottom of the checked tank.

The device, placed on the bottom of the tank filled with water to about 1 m, forms with the tank bottom a closed vessel. Right after being placed on the bottom, the membrane will lift slightly, forming a spherical cap over the bottom. This is caused by the water pressure increase under the membrane as a result of seal flange distortion. If there is a leakage in the membrane-limited zone, the pressure under the membrane will decrease and it will settle causing a recorded movement of the gamma radiation source. The speed of the movement will be proportional to the leakage size, and by measuring the intensity of radiation emitted by the source the investigator can detect the leakage, estimate its flow rate and locate the leakage zone.

The membrane technique allows to detect and locate the leakages with a flow rate of minimum 0.5 $dm^3$/h.

## Float technique

The float technique is based on forcing the vertical liquid flow in the leakage zone. An open vessel is placed on the bottom of the tank and the connection between the vessel and the bottom is made tight with seal faces. A diameter 5 mm organic glass tube extends from the vessel to above the water level. The pipe has a tight float with a closed gamma radiation source ($^{137}Cs$ with activity of about 5 μCi – 200 kBq). In case of a leakage, the float in the pipe, goes down and its movement can be recorded by any measurement system with a collimated scintillation probe.

The float technique allows to detect and locate the leakages with a flow rate of minimum 0.05 $dm^3$/h.

### *Zone marking technique*

In the first step of zone marking technique application, the radioactive tracer is fed to the tank bottom zone through a special system of pipes. The tank was at first filled with water.

The tracer (a mixture of radioactive and non--radioactive potassium bromide or sodium chloride) was prepared and stored in an injection device on the bottom of the checked tank. The tracer solution must be denser than water (hence the mixture of radioactive and non-radioactive substance) and its temperature must be lower or equal to the water temperature. In such conditions, the tracer can remain in the bottom zone for a longer time, feeding the leakage zone and the leakage itself with a large amount of radioactive bromine $^{82}Br$ or sodium $^{24}Na$.

After 10–12 h from the introduction of the tracer, the tank should be quickly emptied. The emptying time should not exceed two days. With regard to detectability, the most advantageous method is to evacuate the water from the top of the tank because during the emptying procedure, the tracer is still being fed to the leakage. When the tank is empty, its bottom should be rinsed with a strong water jet.

Then, the tank bottom prepared and marked as above, should be tested with a special trolley-mounted collimated scintillation probe connected with any measuring instrument (RUST-3, DIDAC analyser, BASC radiometer) for areas with significantly increased radiation background identification. Practically, the search should be limited to the welded joints only as leakage in the base material is very unlikely.

When such places have been located, one of the methods described above or a traditional method (i.e. penetration or vacuum) can be used to confirm the existence of the leakage.

The activities used in this technique are high – up to 10 Ci (370 GBq) from bromine $^{82}Br$ and smaller by an order of magnitude for sodium $^{24}Na$; the leakages detected with this technique must not be below 0.5 $dm^3$/h.

This technique is not recommended due to high radioactivity hazard. In practice, it is used in the version for the location of the leakage zone without determining the leakage place, i.e. without measurements requiring the presence of people inside the tank.

For the location of leakage place, before tracer injection, it is necessary to make measuring channels in the form of piped boreholes under the tank bottom. During the measurement phase, the scintillation probes (preferably connected to a multichannel DIDAC analyser or a similar multiscaling system used). By recording the radiation intensity correlated with the probe location in the channel, the investigator can unambiguously locate the leakage zone.

In some tank designs it is possible to avoid drilling, and to use existing drainage channels for the measurements.

### *Groundwater technique*

Various tracers can be applied for leakage control with the groundwater technique. One can use the characteristic, chemical compounds easily detectable with specialized field chromatographs, colouring tracers and radioactive tracers.

This method allows only to confirm or exclude the leakage, and the possible location must be made with other methods mention above.

The only advantage of this method is that the tanks can be checked without stopping their normal use and people do not need to be inside.

The technique involves introduction of a control medium or a chosen tracer into the bottom-adjacent zone inside the tank, and then searching for it in specially made boreholes or natural, already existing accesses to the groundwater in the tank vicinity. To increase the effectiveness of the technique, it is recommended to raise the groundwater level by pumping water into the bottom-adjacent zone outside the tank.

Before starting the test, the investigator should know hydrologic features of the zone surrounding the tank. To estimate the leakage, it is also useful to know the adsorption properties of the soil surrounding the tank for the tracer used in the test.

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