THE DETECTION OF LEAKAGES IN OPEN RESERVOIRS BY THE RADIOISOTOPE SORPTION METHOD

INCT-2134/VI

INSTYTUT CHEMII I TECHNIKI JĄDROWEJ
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WARSZAWA 1992

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WYKRYWANIE PRZECIEKÓW W ZBIORNIKACH OTWARTYCH PRZY ZASTOSOWANIU SORPCYJNEJ METODY RADIOZNACZNIKOWEJ

ОПРЕДЕЛЕНИЕ СОРБЦИОННЫМ РАДИОИНДИКАТОРНЫМ МЕТОДОМ МЕСТА НЕГЕРМЕТИЧНОСТИ В ОТКРЫТЫХ НАТУРАЛЬНЫХ ВОДНЫХ БАССЕЙНАХ

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WARSZAWA 1992

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ABSTRACT

Location of leakages in large hydroengineering plants and industrial water reservoirs is of great importance from view-point of both safety and economy of their exploitation. Large variety of water reservoirs encountered in hydroengineering and industry calls for adaptation of investigation methods to their specific features. In the paper a number of methodological variants of known radiotracer technique developed at the Institute of Nuclear Chemistry and Technology (INCT) is presented. They are intended to detect and locate leakages in hydroengineering reservoirs and dams as well as large open industrial tanks. The radioisotopes Au-198 and In-113m being used for that purpose show excellent sorption characteristic on typical construction materials used to build such objects.

STRESZCZENIE

Lokalizacja nieszczelności w dużych obiektach hydrotechnicznych i zbiornikach przemysłowych ma istotne znaczenie zarówno z punktu widzenia bezpieczeństwa jak również ekonomiki ich eksploatacji. Duża rozmaitość typów zbiorników wodnych spotykanych w hydrotechnice i przemyśle wymaga przystosowania metodyki i techniki pomiarowej do specyficznych cech ich budowy. W publikacji przedstawiono szereg wariantów sorpcyjnej metody radioizotopowej, które zostały opracowane w Instytucie Chemii i Techniki Jądrowej. Obejmują one szeroki wachlarz rozwiązań począwszy od wykrywania i lokalizacji przecieków w zaporach i dużych sztucznych zbiornikach wodnych im towarzyszących aż do kontroli szczelności i lokalizacji przecieków w otwartych zbiornikach przemysłowych. Au-198 i In-113m wybrano jako znaczniki promieniotwórcze ze względu na ich doskonałą charakterystykę sorpcyjną na typowych materiałach konstrukcyjnych wykorzystywanych w budowie takich obiektów.

РЕЗЮМЕ

Локализация мест негерметичности в больших гидротехнических обьектах и промышленных водных бассейнах представляет большое значение так с точки зрения их безопасности как и экономии их эксплоатации. Большая разновидность типов водных бассейнов бстречаемых в гидротехнике и промышленности бынуждает каждый раз необходимость адаптирования методики и измерительной техники к специфическим чертам их строения.

В статье представлен ряд вариантов сорбционного радиоиндикаторного метода разработанного в Институте Ядерной Химии и Техники для определения негерметичностн гидротехнических обьектов.
Разработанная методика позваляет на определение и локализацию негерметического как в плотинах и больших сопутствующих им искусственных водных бассейнах так и в натуральных открытых промышленных бассейнах.

В качестве радиоиндикаторов выбраны радиоизотопы Au-198 и In-113м, в виду их хороших сорбционных свойств на типичных конструкционных материалах гидротехнических сооружений.

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1. INTRODUCTION

Water leaking from power and hydroengineering systems as well as from large industrial tanks and reservoirs presents a serious problem from view-point of both safety and economics. Any attempt to eliminate such leakages has to be preceded by precise location and estimation of a leakage occurred. Examination of a leaky structure after completion of repair work enables to ascertaining whether water-tightness has been restored and consequently to assess quality of repair work performed.

While solving the above problems the use of radioisotopes substantially facilitates and speeds up both location and relative comparison between leakages in question. Therefore a number of methods serving that purpose and based on the radiotracer technique have been developed and successfully implemented throughout the world [1-5]. Among them there are also the radiotracer sorption methods being developed at the INCT [6]. They are highly

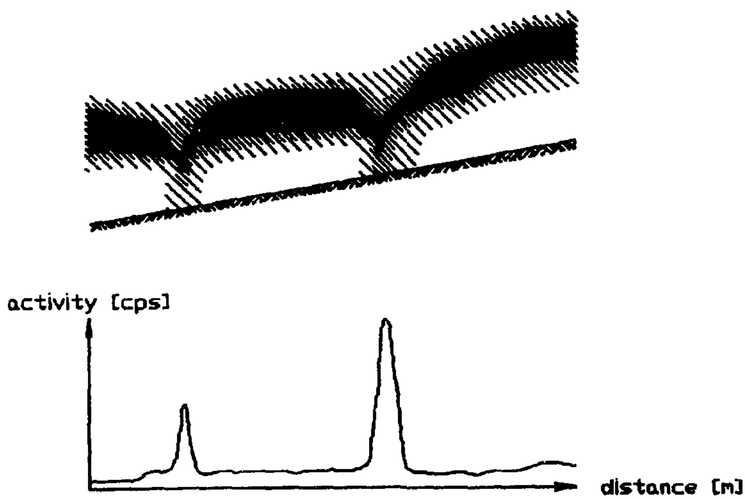

Fig. 1. Diagrammatic presentation of radiotracer smudge and corresponding distribution of bottom radioactivity caused by radiotracer adsorbed on bottom surface

useful in locating leakages occurring both in bottoms (or walls) of water tanks as well as in embankments and dams. The principles of these methods are shown in Fig. 1.

The methods consist, in general, in introduction into water of a radiotracer characterized by permanent sorption thereof on a material constituting bottom or watertight screen of a tank (reservoir) under examination. Water flow towards a leak entrains a tracer and its particles are deposited on surfaces surrounding a leak location. Radioactive spots formed thereby in areas where leakages take place are located thereafter by means of special detection apparatus. Among radioisotopes being tested for their suitability in such applications the following ones appeared to be most suitable because of their best sorption characteristic in respect to typical materials being used in construction of large water reservoirs, i.e. sand, concrete, asphaltic concrete etc. They are: In-113m obtained from the Sn/In generator in the form of $InCl_3$ solution and Au-198 in the form of colloidal solution of metallic gold. A radioactivity of 37-75 MBq (1-2 mCi) is quite sufficient to label 1 running meter (about 4 m^2) of examined section.

2. INVESTIGATION OF WATER RESERVOIRS AND DAMS OF ELECTRIC POWER AND HYDROTECHNICAL SYSTEMS

2.1. Location of reservoir bottom leakages

Experiments concerning location of bottom leakages were carried out at several points of the storage reservoir Przeczyce. Along selected cross-sections of the reservoir marked with anchored buoys In-113 m was

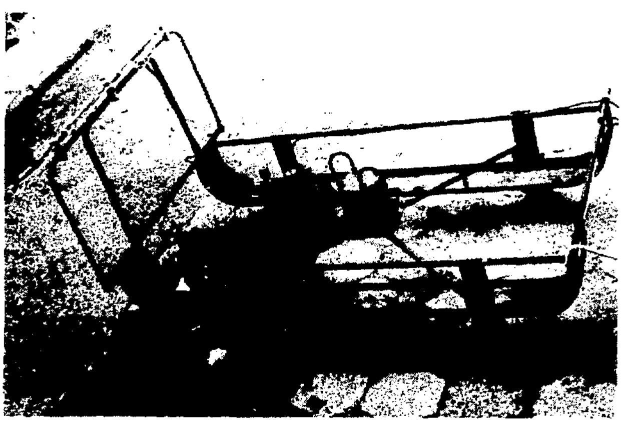

Fig.2. Radiotracer injection kit

continuously injected using a injecting sledge (Fig.2) moving over bottom surface as towed by a motorboat. The measurement cross-sections were selected by the reservoir management.

Initially dimensions of tracer cloud produced during a single passage of injecting sledge were 300 x 4 m. After lapse of predetermined time (in case of In-113m after about 1 h as its $t_{1/2}$ = 105 min) along the same cross-section a measuring sledge (Fig.3) was towed.

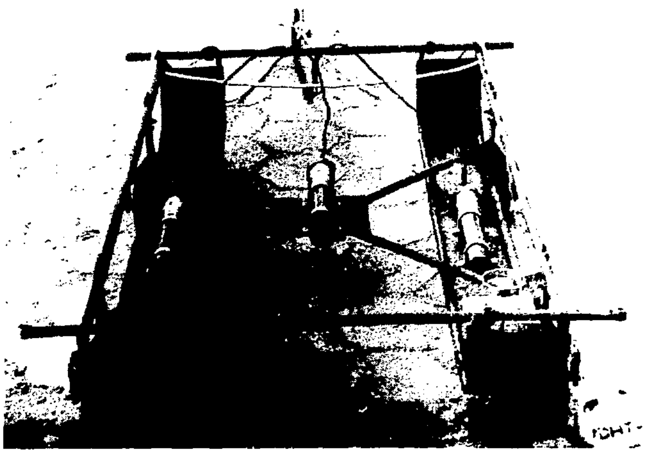

Fig.3. Leakage detection kit

The measuring sledge was provided with three scintillation probes connected to a counter and field-type recorder placed on the towing boat. Current position of the sledge was determined on the basis of position of a buoy thereabove. For determination of the buoy position two theodolites placed on the dam top were used. Constant radio-communication was maintained between crew of the boat and theodolite operators. Appearance of radioactivity peak on the recorder was immediately relayed to the theodolite operators by sending a corresponding radio signal and at that instant current buoy position (and consequently that of the sledge) was recorded as indicated by bearings taken by the two theodolites. Example of bottom activity spectra are shown in Fig.4. Distinctly sharp peaks are associated with leakages whereas a wide plateau is indicative of large bottom area showing increased filtration rate.

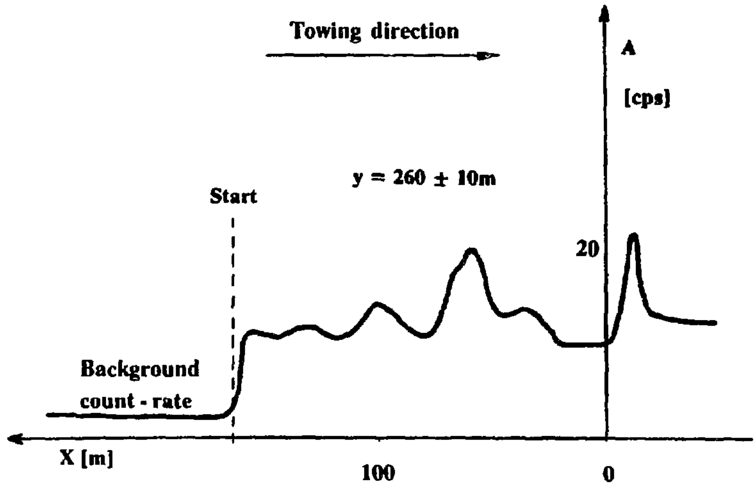

Fig. 4. Reservoir bottom radioactivity distribution curve

2.2. Location of leakages through shielding of dams and embankments

Field experiments were also carried out to determine leakages location in a portion of a dam at Wisła Czarne as well as to check for watertightness a shielding of upper reservoir of the Water-Power Plant Żarnowiec after repairs having previously been made. Radiotracers were In-113m and Au-198 respectively.

The same universal injection and measuring sledge equipped in wheels (shown already on Fig.2 and 3) has been used. The haulage was done by means of rope being wound onto a winch drum. At Wisła-Czarne the sledge were hauled along successive expansion joints of dam screen whereas at Żarnowiec along predetermined profiles marked every 2 m on the asphalt screen of reservoir. Sledge with measuring equipment were hauled at constant speeds. Haulage distance was marked on the radioactivity plot provided by the recorder every 2 m from the starting point. This made possible to locate a leakage with an accuracy of ±10 cm. Obtained radioactivity spectra (N) were normalized in respect to the background (N_t). Exemplary records of radioactivity distributions are shown in Fig.5.

The adopted graphical method of results presentation enables to make relative comparison of intensity of all leakages detected. On the basis

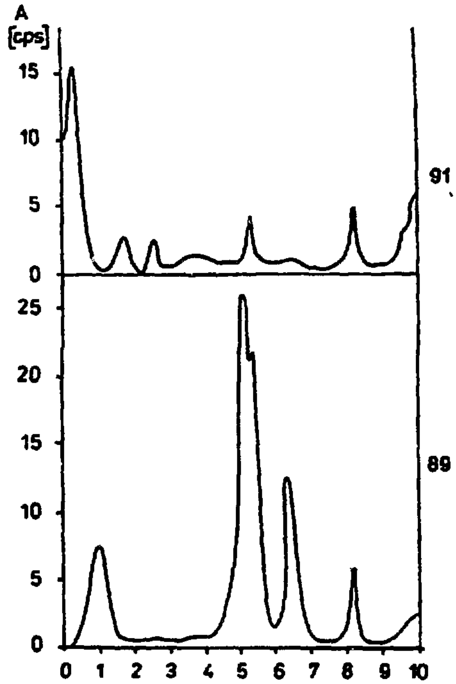

Fig.5. Normalized reservoir bottom radioactivity as a function of distance from bottom edge of the dam (upper reservoir of the Water - Power Plant at Żarnowiec) for profiles No 89 and 91

of acquired data a chart of leakages appearing within the examined area can be drawn with simultaneous indication of their relative intensities (Fig.6).

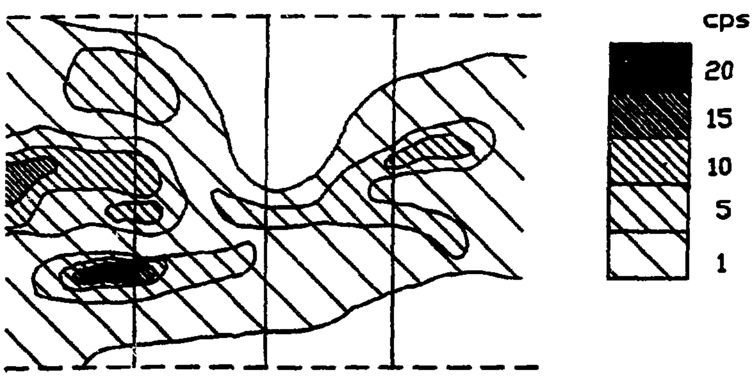

Fig.6. Chart of leakages drawn for portion of the bottom of upper reservoir at Żarnowiec

3. EXAMINATION OF LARGE OPEN INDUSTRIAL CONCRETE TANKS

The radiotracer leakage detection and location method has been used to examine an equalization tank of the sewage treatment plant at the Chemical Fibres Works "Elana" in Toruń. The examined tank was put out of operation as it was found that during its operation water emerges above ground surface next to the edge of that tank. Because of the necessity to examine for tightness all parts of the tank i.e. its bottom, overflow trough as well as sediment discharge funnel and pipe the examination was carried in two steps. First step included examination of sediment discharge pipe. It was done using a soluble radiotracer. During the second step, examination of the tank proper was carried out using the radiotracer surface sorption method.

The tank was prepared for examination as follows. Its interior was thoroughly cleaned, sediment scraper dismantled, overflow openings plugged and the whole tank filled with clean water up to a level reached by waste water during normal operation of the tank.

3.1. Examination with use of a soluble radiotracer

The work began with examination of the sediment discharge pipe for its tightness. A section of that pipe running just beneath the tank bottom required to be examined. To this and into inlet portion of the pipe (0.5 m downstream its inlet end) several milliliters of aqueous solution of radioactive KBr containing Br-82 isotope having radioactivity of ca. 3 GBq were injected.

Radiotracer movement within the discharge pipe was monitored by means of a scintillation probe connected to a counting and recording unit. Possible leakages would cause that tracer contained in water will be distinctly detectable at leaking locations. This enables not only to detect but also precisely locate a leakage occurred. But in this case tracer cloud within the pipe assumed axially symmetrical configuration and did not change the position of their center (maximum of activity) over plurality of measurements being made at predetermined intervals during 24 hours. This precludes any suspicion that the pipe is leaky.

3.2. Surface sorption method

The surface sorption method is based on principles being described earlier in relation to large hydrotechnical reservoirs.
The only exception is that the measuring equipment requires some modifications. In the examinations described here the radioisotope Au-198 in the form of radioactive colloidal gold aqueous solution was used for location of possible leakages. The radioactive gold was obtained by exposing to radiation in a nuclear reactor spectrally pure metallic gold $^{197}Au + ^{1}_{0}n \rightarrow ^{198}Au$, and subsequently transforming it, using chemical methods, into suspension of colloidal gold. The colloidal gold was obtained by dissolving metallic gold in aqua regia and reducing it subsequently by means of glucose in presence of gelatin. This process was carried out while maintaining appropriate physicochemical conditions (temperature and pH).

Radioactive solution of colloidal gold was introduced into the overflow trough and the tank interior making use of the existing movable service platform of the tank. Along the platform metering pumps were arranged, each provided with an injection hose opening within the tank about 0.5 m above its bottom. Deliveries of the metering pumps were so adjusted as to provide uniform distribution of tracer concentration along diameter of the tank.

During one complete turn of the platform the tracer solution was discharged through all hoses connected to the metering pumps. As far as the tank's discharge funnel is concerned the tracer was introduced in that area of the tank so as to obtain a tracer cloud centrally suspended within the funnel. After lapse of 12 hours from tracer introduction the radioactivity distribution measurements over surfaces of tank and trough bottoms were started. For that purpose a measuring system consisting of watertight scintillation probes, field radiometers and paper tape recorders was used.

The probes were suspended from the platform and moved therewith as immersed slightly above the bottom, monitoring thereby its whole surface. The funnel area was monitored from above thereof and a probe was moved above surface of the funnel. Separate radioactivity measurements were also made along all expansion joints of the tank bottom (two circumferential and eight radial ones).

As result of measurements being made the curves of radioactivity distribution over surface of the tank bottom as well as along all expansion joints have been obtained. These curves, in turn rendered possible to detect and locate three leakages in the bottom of overflow trough being situated adjacent to the place where the ground dumping has been found (Fig.7).

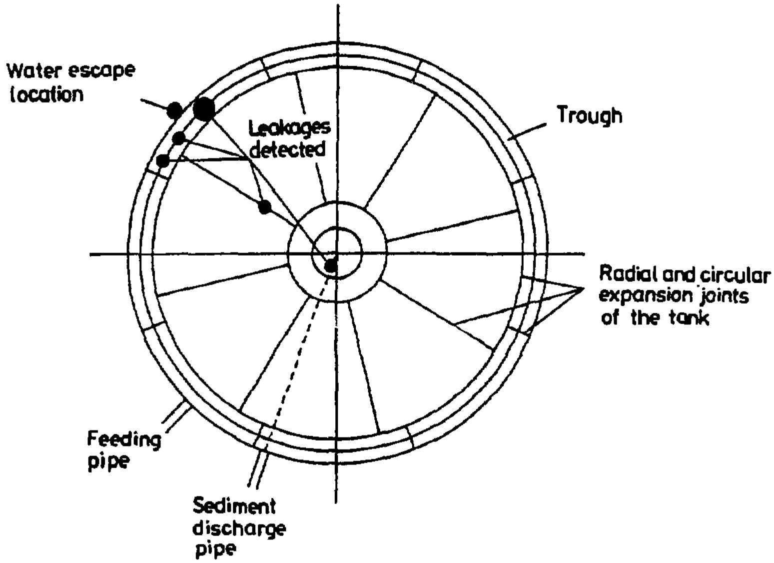

Fig.7. Diagrammatic view of examined tank

The examination of expansion joints rendered possible to detect small leakages also along the radial expansion joint No 3. Some spots of distinctly increased radioactivity were found also on the bottom of discharge funnel as well as around the sediment discharge pipe. It was, however difficult, to precisely locate leakages locations because of large amounts of deposits present in that area. The tracer being used is easily adsorbed on such deposits which makes difficult to interpret properly the results of measurements being made. Therefore it would be necessary to clean thoroughly the whole tank of such deposits before making the measurements.

4. EXAMINATION OF LININGS IN INDUSTRIAL TANKS

Industrial tanks (e.g. electroplating ones) need often linings against attack of strongly corrosive solutions. Checking of tightness of the linings as well as detection and location of small leakages therein are difficult especially if the lining is made of metal and there is a thick coat of other materials behind it, also using radiotracers with measuring their radiation intensity from outside of the tanks.

The method presented here [7] consists in filling of the tank examined with water, adding of several milliliters of radiotracer solution and homogenization (using e.g. a circulation pump) for about 1 h. Simultaneously the radiotracer adsorption from the solution upon the lining material, i.e. on its surface inside the tank, in pores and slits as well as on its reverse surface (from the side of coating) in the leak regions, takes place. Then the tank is emptied and its inner lining surface is washed for practically complete desorption of the radiotracer adsorbed thereon by pouring water from a faucet for a period of 15-20 min. The washing effectivity can be checked out by measuring of the radiation intensity from the checking swabs. Eventually scanning measurements of gamma radiation intensity distribution on the inner lining surface are carried out using portable detectors. The enhanced radiation originates from the radiotracer adsorbed fast in pores and slits as well as on the reverse surface of the lining in the leak regions and points to a leakage in a given place. We have found practically three kinds of leakages: points (orifices), segments (e.g. junctions) and area-type of the material consisting in pores. The detection of any leakage, even very small one, is possible by this method.

The method has been patented [8] and successfully applied for checking of tightness as well as for detection and location of leakages in the case of 5 mm lead lining in tanks for chromium electroplating of 1.5-12 m^3 volume. As a radiotracer In-113m ($T_{1/2}$=105 min) has been used from Sn-113/In-113m generator. A portion of the radiotracer of maximum 0.74 GBq (20 mCi) was sufficient for the search of these tanks in turn during the period within about 5 hours.

In Fig. 8 an exemplified scheme of leakages detected in one of the checked tanks for chromium electro-plating is presented. The searched linings were then repaired according to indications following from results of measurements and checked again. No leakage was detected thereafter and the baths worked well a long time giving significant economical effects.

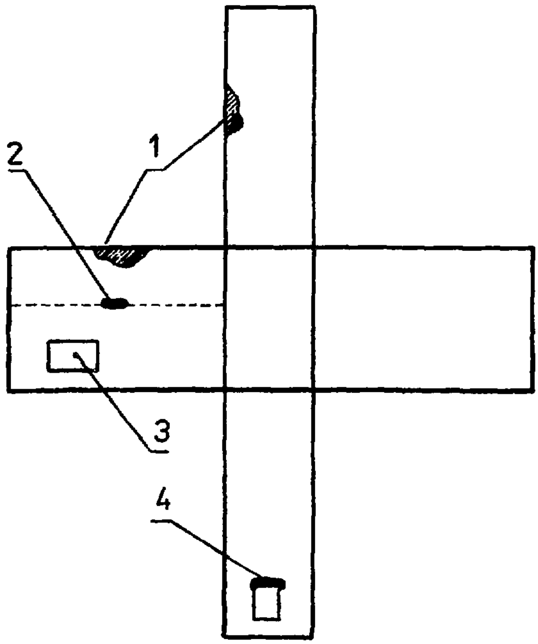

Fig.8. The scheme of leakages detected in lining at one of the checked electroplating tanks at Factory of Mechanized Longwall Lining in Tarnowskie Góry
1 - area-type leakage; 2,4 - segment (linear) leakages;
3 - point leakage; dotted line denotes a welding

The method enables to detect and localize quickly and surely leakages of any kind and size as well as to estimate the quantity of the leakage. The measurement is fully safe because it is carried out only with a very small part of the radiotracer introduced initially; moreover, the radiation disappears practically in one day and no decontamination is necessary. The method can be applied for detection and location of lining leakages in any tank to which an access from outside is difficult as well as for checking fitness of any tank without lining.

5. CONCLUSIONS

The use of radioisotopes for leak tightness checking purposes and for location of possible water leaks is a relatively new idea and in Poland did not yet found broader application. But expedience, however, of such examination and its high accuracy renders possible to locate quickly and accurately a leakage occurred, if any, and to check subsequently for quality of repair work performed. Practically there is no other method enabling to detect leakages by monitoring movements of a liquid in the tank under examination. The radiotracer method is, therefore, directly associated with physical phenomena occurring. Conventional method consisting in examination of quality of materials and their coatings are unable to give such precise information about exact location of a leakage as it is in the case of radiotracer method.

Ample experience gained till now in that field along with numerous variants of that method and apparatus being used therefore enable presently to make examination for leak tightness and locate leakages in facilities of various size and predestination.

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