Analysis of modern methods and control devices of technological installations leakproofness and their classification

S.Sazhin

Dzerzhinsky Polytechnic Institute

Dzerzhinsk, Russia

Leakproofness, the property of goods that excludes penetration of gaseous and liquid matter through the covering is one of the main quality criterion of potted goods. The problems of leakproofness arise not only while producing and maintaining industrial goods of important setting but also in private life.

The progress of modern science and technology is closely connected with the diversity of sealing compounds. These are ships and land-based vehicles, unique large booster and thermonuclear machinery, microminiature electronic devices, refrigerating industrial plants and domestic refrigeration equipment, chemical production installations, underground cables and conduits, food package and a great number of other different installations, goods and systems.

The importance of sealing compounds, their high cost, economic losses in mass production output, the dependence of their working capacity on potting quality determine the significance of correct organized leakproofness control. Thus, State Standard 18353-79 refers leakproofness control to one of the main types of nondestructive check.

In comparison with other methods of nondestructive check, particularities of leakproofness control are connected with flaws location called leaks. Agreeably, leakproofness control technique is called leak detection technique. Leaks are found out by registration of trial matter flow.

The main leak detection methods are: mass-spectrometric, halogen, manometric, ion-plasmatic and others. They vary in sensitivity, conditions of test operation and other characteristics. According to the aggregative state of the used trial matter all the methods are divided into the groups of gaseous and liquid. Liquid methods, as a rule, don't require the use of special equipment. Gaseous trial matter can be revealed with the help of gas-analysis equipment. In some cases working matter is used as trial matter. At the same time proper leak detection method is selected that provides efficiency and handiness. For example, refrigerating industrial units and

plants including domestic refrigeration equipment are controlled by the halogen method with the use of halogen leak detectors that can register Freon leaks.

Analyzing the tendencies it is possible to mention further development of mass-spectrometric leak detection method [1]. It is explained by boundless opportunities of the method, such as super sensitivity, possibility to estimate the degree of a compound leakproofness with the use of different trial matter – helium, argon, hydrogen and other gases. Automated complexes controlling leakproofness of both desk-size and large enough goods have been and are still being created on the basis of this method. Automated mass-spectrometric leak detectors are produced on the basis of the method, the production is being implemented by the plant "Izmeritel" (St. Petersburg).

The example of such leak detectors is a device TI1-30 that can work both under countercurrent and direct current conditions (picture 1). Helium sensitivity is no less than $7 \cdot 10^{-12}$ m^3Pa/s. Response time is less than 1 s. Leak detectors of the type such as TI1-30 are characterized by high productivity owing to automatic control of setting-up procedures and the process of taking measurements.

Picture 1

At the last XVIII All-Russian conference "Nondestructive check and technical diagnostics" the specialists of the plant "Izmeritel" have pointed out in their report called "About new tendencies in working up helium mass-spectrometric leak detectors" that these leak detectors have one more advantage, that is the generality of their application starting with the tasks of the processes investigation and finishing with their use in field condition.

Speaking about foreign firms that successfully develop mass-spectrometric method of control it is necessary to mention the French company "Alcatel Vacuum Technology France" that for more than 35 years has been producing spilling facilities and helium (mass-spectrometric) leak detectors. The firm put the first portable helium leak detector on the market in 1965. It worked on the basis of a

diffusion pump and, according to modern criterion, guaranteed average sensitivity. Nowadays the models of the leak detectors produced by the firm are the most various on the world market. More than 10 000 leak detectors of the firm "ALCATEL" are successfully exploited all over the world.

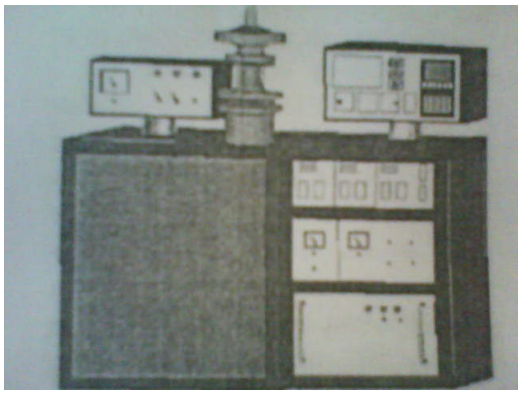
In the USA miniature portable devices having high detectability are being developed; they can quickly and safely determine even minor gas escape. The heart of the device is a sensor instantaneously determining the change of thermal gas conduction. When you switch the device on it is automatically calibrated against ambient air. A built-in ventilator sucks in air through a bleed to the chamber where the sensor is located. If the air sample composition alters, indications are shown on the screen and a beep is heard. When the leakage zone is found out a thin cone nozzle is put on instead of the bleed that can precisely determine the leak. The set includes a flexible checker for hard-to-reach places. Leak detectors are four batteries-operated: it provides 40 hours of work. The device switches off automatically in 5 minutes if it is not used in work. There is also a battery discharge indicator. The device is firm, light, safe. The sensing element doesn't decay in the course of time, it is tuned up and calibrated automatically.

The device GAS CHECK 3000 calibrated against helium belongs to these types of leak detectors. Another model GAS CHECK 5000is, an explosion-proof variant of a general purpose device, determines the escape of the following gases: acetylene, ammonia, argon, nitrogen, hydrogen, carbon monoxide, hydrocarbon sulfide, ethane, ethylene, Freon, hydrogen sulfide, hexafluoride, methane, neon, benzol, butane, xenon, nitrous oxide, helium, propane, carbonic acid, sulfurous anhydride. These are some performance attributes of leak detectors:

Reveals	Gas with the conductivity different from air
Actuation time	Less than a second with a short checker
Restoration time	About a second
Controlled leakage	From 0,0001 to 0,00001 ppm
Feeding	4 batteries of AA type
Service conditions	From 0^{o} C to 50^{o} C

It is necessary to mention one more tendency in the development of mass-spectrometric method, the function of which is to create high-production devices of leakproofness control of repetition work goods. The main component of such devices is a mass-spectrometric chamber that performs the function of a sensing element.

The example of a leakproofness control device is the plant MS Turbo-2 (picture 2), created at Dzerzhinsky Polytechnic Institute [3]. The device puts into action the countercurrent scheme of trial gas (helium) delivery to the mass-spectrometric analyzer (sensing element).



Picture 2

It makes it possible to conduct high-production tests under forevacuum pressure in the controlled goods (~ 10 kPa) and in the conditions of large gas loads.

All the operations in the plant are automated except for loading – unloading of the controlled goods. The productivity of the device of leakproofness control is to 100 items per hour, the threshold of sensitivity is $1 \cdot 10^{-10}$ m^3Pa/s.

Another **leakproofness control method** is called **supersonic** [2]. It has already gained wide application and is still being developed.

Every working equipment when finding flaws generates a wide spectrum of sounds. High-frequency supersonic components of these sounds by their nature have very small waves-length and at the same time they are narrow-directed, that is why it is easy to mark them out of the surrounding noise and precisely determine their source and location.

Supersonic transformers used for the disclosure of supersonic oscillation source are rather simple in use and are a good instrument of in-process measurement. They consist of a portable docking station with earphones, a measuring device, a sensitivity adjustment block and also, in the majority of cases, plug-in modules that are used in scan mode and contact method. The devices make it possible to carry out sensitivity tuning in the frequency range from 20 to 10 kilohertz.

Fields of supersonic method application are: localization of liquids and gases escape, inspection of steam separators, gates and valves hermiticity test, valves stems control, disclosure of sites of pressure and vacuum loss, boilers and condensers heat exchangers control, electrical equipment inspection, disclosure of

corona and internal discharge sites, enginery, check-up of bearings technical condition, bearings monitoring, compressors monitoring.

Sensitivity of tests made by acoustic leak detectors depends on air pressure in the unit under test, the used oscillation receiver and the type of flaw.

Leak detectors belong to the class of noncontact. They can detect leaks at a range of 0.5 – 1m from the unit.

Acoustic leak detectors are used for testing units where leakproofness isn't of great demand. Their threshold of sensitivity is $1 \cdot 10^{-2} – 1 \cdot 10^{2}$ $mm^3 \cdot MPa/s$.

As an example of industrial supersonic leak detectors it is possible to name IUK-2 and UZON that are used to establish the degree of leakproofness of the units that are under overpressure.

The firm "AKA" (Moscow) organized the issue of supersonic leak detectors such as "Ultracort" that are to determine supersonic acoustic signals, the source of which is pin holes (interstice) in conduits, vessels, etc. The minimal registered pressure is 0.1 Pa, equivalent to a hole 0.1 mm in diameter at a range of 200 mm.

Speaking about supersonic leak detectors that are characterized by high sensitivity and generality of functions it is necessary to mention such a leak detector as MAT-2KM [4]. It has a path of correlation processing. Threshold of sensitivity against electric port is 2 mkV. The leak detector is multi-purpose as to the field of application; moreover, it can determine leaks of different workspaces in locking arms.

Nowadays **semiconducting gas-perceptible sensors** are widely used [4]. The combination of high sensitivity, selectivity and promptitude predetermines their use for the creation of new, compact leak detectors built on the microelectronic basis.

Among the diversity of microelectronic sensing elements a particular place is occupied by sensors of chemistry of gases that are applied in different industries.

The production of microelectronic sensing elements is connected with the application of integrated chips technology. They are divided into sensors of the resistance type, electrochemical, on the basis of MIS structure, on the basis of Schottky barrier junction.

The most widely used are **resistance-type sensors**. In such sensors SnO_2, ZnO, F_2O_3 are used as sensitive material.

There are two variants of devices packaging. In the first one a layer of metal oxide is used with the deposited electrodes from noble metal (for example, platinum). In the second one the sensing element is made up by the method of thin- or thick film technology. Platinum contacts are deposited on an insulating base (pyroceramics, sapphire). A film of sensitive material in the form of the dope is applied from above that is later heat-treated. On the underside of the insulating base a thin-film resistance-type platinum heater is formed.

When such a sensor is put into the atmosphere containing hydrocarbons, carbon monoxide, hydrogen, ammonia and other gases, increase in sensor electrical production occurs that can be simply represented as aggregate of two conductors connected in parallel with each other (the layer of semiconducting oxide and heater).

On the basis of this variant of a sensor the gas sensor PS-1 has been developed. The sensor sensitivity is: against methane (CH_4) – 5 ppm, against carbon monoxide (CO) – 1 ppm, against propane (C_3H_8) – 1 ppm, against hydrogen (H_2) – 10^{-1} ppm.

Such portable leak detectors as PS are used to find leaks of foul and combustible gases from gas-supply systems.

Another type of sensor is organized on the basis of organic semiconductors. Phthalocyanine films are generally used as sensitive material; they are of high thermal and chemical resistance. These films are semiconductors of *p*-type, moreover, the mechanism of their conductivity is largely influenced by atmospheric oxygen. After vacuum processing films conductivity becomes of *n*-type, but under the influence of atmospheric oxygen it increases and turns into *p*-type conductivity again. Investigations proved that phthalocyanine films conductivity changes in the presence of the gases that have electron affinity larger than that of oxygen. These are halogens and halogenated gases and also NO_2. To reduce sensitive film impedance current-carrying electrodes usually have comb. The largest sensitivity of gas sensors is to NO_2 and it still increases when films are doped by heavy metals.

Leak detectors on the basis of microelectronic sensor with Schottky barrier junction have been created in order to control hydrogen leak [4].

Schottky diode has a structure metal-semiconductor. Dielectric spacer between metal and semiconductor is explained by impossibility to create gas-perceptible sensors on the structure Pd-Si because of palladium silicide formation on the boundary; it results in the loss of hydrogen sensitivity of such devices. To prevent

this effect tunnel-transparent layer of dielectric SiO_2 is grown on the surface of pure silicon before palladium spraying.

Analysis of literature dedicated to the methods of environmental, in particular, ambient air control, shows the increasing role of sensory methods of analysis in comparison with traditional physicochemical ones. It is also significant to note that more and more policies of environmental objects analysis based on sensory methods are being included, as the main ones, into the list of policies recommended by international and national departments of preservation of the environment.

Outward appearance of electronic sensor leak detector like TIF-5750A with the threshold of sensitivity 7 grams of leakage per year is shown at picture 3.

Picture 3

On the basis of sensor-based engineering achievements a number of firms in Japan, Germany, Russia and other countries have organized repetition work of compact gas analyzers, gas alarms and leak detectors.

The most striking results have been obtained by the firm RIKEN KEIKI (Japan) that produces modern sensing elements like HS-94 to hydrogen sulfide, OX-94 to oxygen, CO-94 to toxic gases.

Speaking about the Russian leak detectors with semiconductor sensing elements it is possible to mention the explosion-proof leak detector of combustible gas TIG-2 (NPO “Pure gas”, Moscow region).

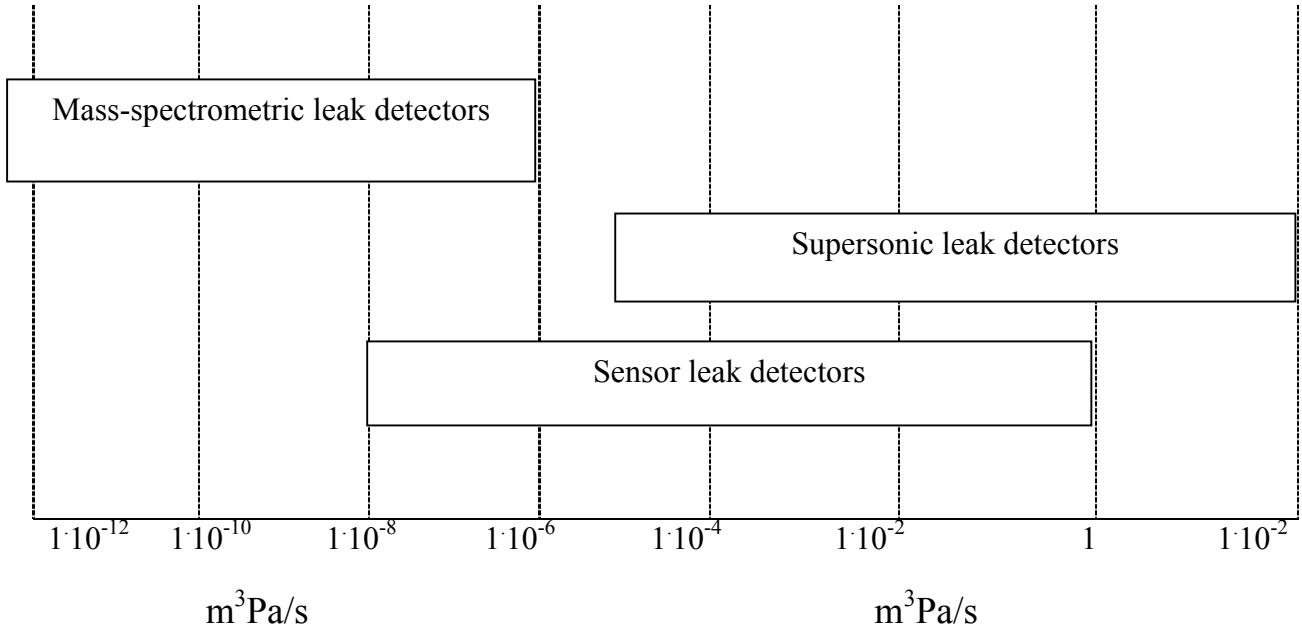
The specialists of the Russian scientific centre “Kurchatovsky Institute” have created semiconducting and optical sensors and, on their basis, leak detectors to determine methane, propane, benzine, hydrogen in the range from 0.005 volume percent to lower explosive limit. The sensor material is SnO_2, ZnO. Dimension of array is 2x0.5x0.3, restoration time is ~ 2seconds.

In Moscow State Forest University they have developed a multi-purpose gas-perceptible semiconducting sensor and an annunciator - leak detector to CO, CO_2, SO_2 and other gases with the threshold of sensitivity 0.5 MPC. The sensitive layer is made on the basis of SnO_2, ZnO.

In NIPTE at Nizhegorodsky State University an individual annunciator - leak detector of the type SOK-2 has been created; its purpose is to find out combustible and toxic gases and to provide personal security. The range of control is from 0.1-10 volume percent. Method of selection is gaseous-diffusion.

Thus, sensor leak detectors can with certainty be considered the most promising because of their tiny size, high gas sensitivity, possibility of multi-gaseous leak detecting device implementation.

To sum it up, let's give a classification of the examined leak detectors as to the threshold of sensitivity (picture 4). Taking this classification into consideration it is possible to define fields of application of the corresponding leak detectors. Thus, for example, directing the attention to mass-spectrometric leak detector threshold of sensitivity, we may say that the most preferable fields of their application are: leakproofness control of microelectronic engineering devices, control of the equipment of atomic energetics and missile building plants, etc. At the same time, sensor leak detectors being compact are and will be used when evaluating the equipment leakproofness degree in field and laboratory condition and in conditions of life.



The methods of leakproofness control examined in this report can be considered the most promising for the tasks of the leakproofness control of goods and industrial setting installations.

Literature:

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Annotation

In the report the most promising methods of leakproofness control of goods and installations are examined. The preferable fields of their application, the characteristics of leak detectors constructions based on the examined methods are stated. The ways of further development of the method are marked.