# INTELLIGENT ROBOT WATCHDOG LOOKS FOR LEAKS

*(Acoustic and vibration technology works in oil refinery)*

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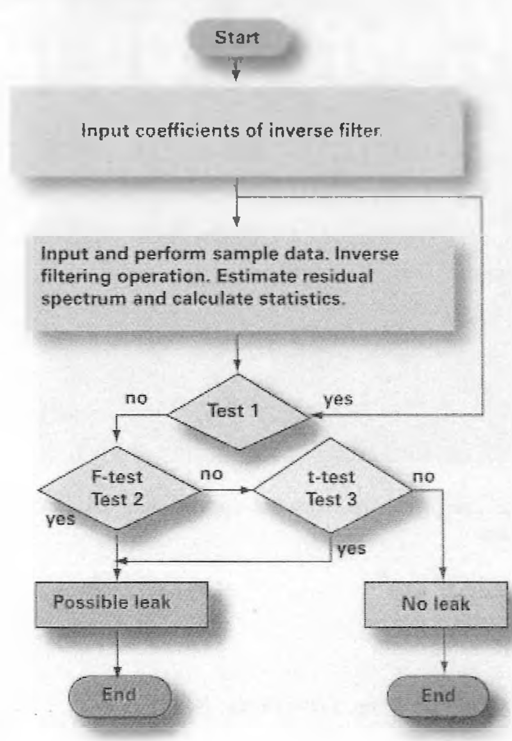
There is considerable demand for automated and reduced-manpower operation of plants in modern Japanese industries. Japan sees this as a trend of youthful new industrial employees not wanting to be plant operators.

An automated abnormal-signal segregation and extraction technique based on inverse filtered acoustic/vibration signals has proved effective for monitoring abnormal conditions in rotary machines, compressors, piping, and high-pressure vessels. Using pattern recognition techniques, an intelligent sensor system detects possible leakage of high-pressure gases in oil refineries. Leakage produces continuous sonic and ultrasonic tones.

In real plants, many sources other than leakage generate tones in the identical frequency band. The principle of this present method is to first reduce the sonic components from normal plant operation and then see what is left.
An inverse filter *whitens* any stationary signal. *Whiten* means characteristic peaks cancel from the spectrum of a signal by inverse filtering.

Leak detection flowchart




An abnormal condition's signal, which is not included in the ambient noise signal used to design the filter, does not flatten through the inverse filter and gives some amount of *colored* signal.

This robot watchdog monitors leakage of high-pressure gas in an oil refinery. We recently completed and tested a prototype.

**Principle of leak detection**

Besides generating tones in the identical frequency band, different sources also cause intermittent tones in the same band. Of the continuous tones, there is not only abnormal leakage but also normal leakage, as from a hydraulic pressure apparatus.

Intermittent sources such as a steam trap are akin to normal leakage in a plant. It is crucial for a real, workable leak detector to distinguish tones of possible abnormal leakage from those of normal leakage.

The principle of this method is to detect tones in the ultrasonic band, after reducing sonic components from the normal operation of plants using the inverse filter. That is, the ambient noise signals collect during normal process operating conditions, and an inverse filter evolves using that signal. Any signal that has the same statistical properties of the ambient noise under normal operations of the plants whitens as it passes through the inverse filter. If any abnormal signal, whose properties are different from the ambient noise signal, passes through the inverse filter, it leaves a residue. This residue is a colored signal.

**Steam trap intermittent**

Intermittent signals, like those generated during a steam trap action, also give such nonwhitened residual signals after inverse filtering and should be distinguished from real abnormal ones.

To classify such normal signals from abnormal ones, we have designed a pattern-recognizing sensor system, applying a statistical testing method using plural data sets sampled over a constant time interval. That is, the power spectrum of the residual signal is rather flat over the frequency band from 50 kilohertz (kHz) to 100 kHz when neither abnormal leakage signals nor intermittent signals exist. But it varies significantly when either of the two signals is present. If one calculates a set of power spectra from residual signals, the set corresponding to the intermittent signals varies more than the abnormal signals do.

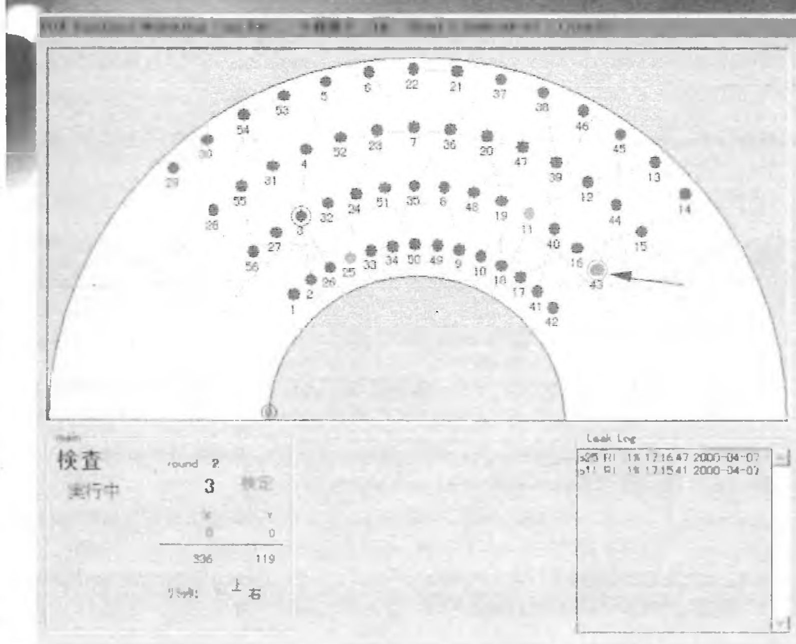
### Gimbals mounted watchdog

The pilot model watchdog robot detects a gas leakage from a hole with a diameter as small as 1.5 millimeters (mm) and pressure as low as 0.3 megapascal (44 pounds per square inch) from a distance of 50 meters (m). Its width, height, and depth are 690, 914, and 400 mm, respectively, and it weighs about 80 kilograms.

The main body of the robot is a scanning quarter-inch condenser microphone whose head is at the focal point of a 36.5-centimeters-long, sound-collecting hood. The hood mounts on two-axis gimbals.

**Dogged pursuit of a leak**

This display shows an array of 56 checkpoints in a coverage area. A blue circle denotes the point undergoing present checking action (#3). Pertinent data for that point is in the box at bottom left. A simulated leak source is at point #43. There is a red circle around this point indicating warning. A leak log is at the bottom right.




A computer controls the gimbals motion via a hydraulic pressure system. Each of the two rotation axes of the gimbals is equipped with a rotary encoder, which can determine the direction of the hood.

The gimbals system has a combination of a mechanical stopper and a limit switch for each axis, which prevents the robot from overrunning the predefined area. The hood aims itself by referring to the difference between the given direction and the rotational angles around the two axes.

The computer positioned in an instrumentation station 100 m distant collects the data sets and carries out data processing as well as the gimbals control.

### Hood collects sound

The robot sits on one of the middle decks of a continuous catalyst regeneration platform 27 m high. All of the signals between the robot and the computer are electronic and delivered via burstproof piping.

Control signals to the robot transform into hydraulic signals in a transition terminal box near the robot, which also adopts the burstproof structure. The sound-collecting hood can point in any direction using the rotational angles of respective gimbals' axes.

**The principle of this method is to detect tones in the ultrasonic band.**

The robot-mounted hood scans 56 points of a hexagonal lattice every 8 minutes. The robot monitors about 3,700 $m^2$ from a height of 5 m.

The signal from the condenser microphone in the hood feeds to the computer after sampling, is stored in memory, and is then used in the succeeding data processing. Ten data sets of 1,024 samples collect and profile each single direction. There is a half-second time interval between the successive data sets.

The robot has two operational control modes: the learning mode and the monitoring mode. In the learning mode, the robot makes an inverse filter and creates a set of reference data used in the monitoring mode for each point.

At each point, it collects the 10 data sets, the first of which helps in designing the inverse filter. All 10 data sets comprise the reference data for the statistical testing used in the monitoring mode. The results of this data processing are stored in computer memory.

In the monitoring mode, the robot also scans the 56 points. At each point it collects the same number of data sets as in the learning mode, and the inverse filter processes each of the data sets designed during the learning mode.

The statistical F- and t-tests use the results of all 10 data sets to judge possible leakage. If the testing indicates possible leakage, the same testing is carried out twice more by taking 10 new data sets for each point. If both tests indicate leakage, an alarm signal occurs.

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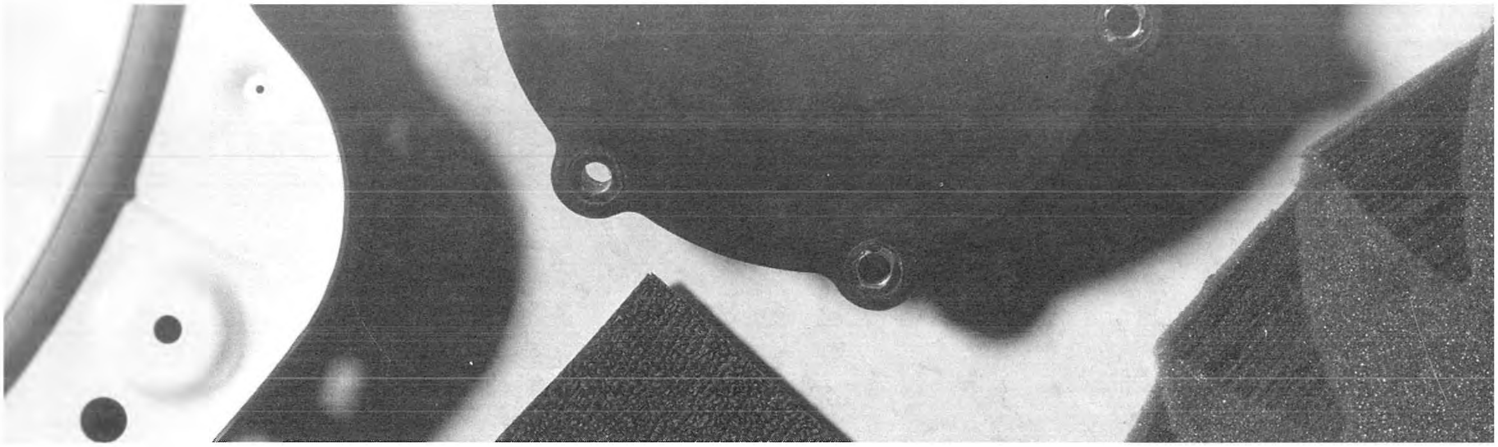

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