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DEVELOPMENT OF A PORTABLE REMOTE MONITORING SYSTEM FOR THIRD-PARTY DAMAGE

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ABSTRACT

The most important challenge we face is to protect gas pipelines from damage caused by third-party work. Toho Gas has developed a portable third-party damage remote monitoring system that can detect third-party damage to exposed gas pipes in real-time.

This system has adopted the vibration detection method as the basic technology that detects third-party contact in real time, but external noise measures were a major hurdle its development. The noteworthy point in this development approach is that the transmission of external noise vibration focused on the strong transmission to structures other than gas pipes. We have installed comparison sensors to detect noise on structures that support gas pipes and proposed a unique mechanism that cancels external noise vibrations by comparing the values obtained by the detection sensors and the comparison sensors. And because it is possible to freely vary the contact detection level value, slight contact such as touching it with the hands can be cancelled. This has achieved incorrect detection of 0% and contact detection of 100%.

As a result, it is a low cost system that is easily installed and is the world’s first acoustical detection system that can withstand practical use, because it can cancel noise without frequency analysis.

This paper describes the development history and configuration of this system.

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1. INTRODUCTION

Water supply and sewer pipe works, electrical and telephone cable works, and other public works projects are often executed around gas pipelines. Protecting pipelines from third-party work by taking measures to manage underground objects and to provide protection from third-party work is the most important challenge facing gas utility operators.

In Japan, few problems and accidents are caused by third-party work, thanks to a variety of preventive measures including coordination, visits to work sites, PR and so on. But because work itself is managed mainly by the other parties, the following are two important ways to prevent third-party damage.

- Discovering pipeline damage quickly to take action while the problem is still small.
- Constraining contractors performing third-party works so they will perform their work cautiously.

The Portable Third-Party Damage Remote Monitoring System was developed in order to quickly discover pipeline damage in real time and to increase constraints on contractors executing third-party work.

2. DEVELOPMENT OUTLINE

2.1 System concept

Figure 1 shows the concept of this system. When the system detects an abnormality that damages a gas pipeline caused by contact by heavy machinery or other effect of work executed by a third-party work contractor near gas pipelines, it immediately transmits a warning to the gas pipelines manager.

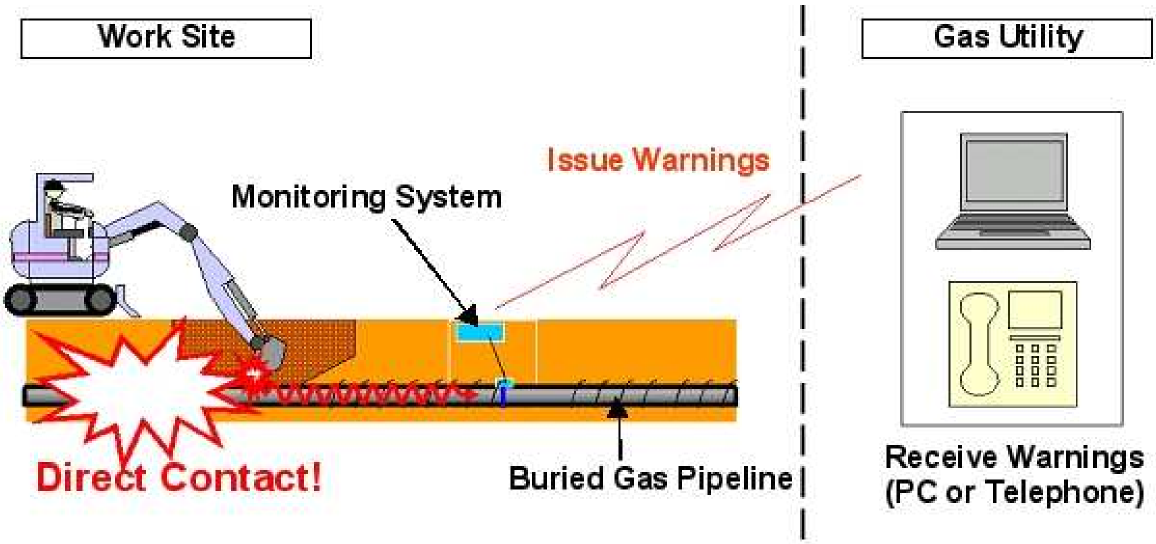


Figure 1: Concept of the Portable Third-Party Damage Remote Monitoring System

The following is the system operation procedure.

1) Preliminary arrangements concerning equipment installation with third-party work contractor. Notification of remote monitoring
2) Confirmation of the site (if necessary, excavation to check for buried objects). Installation of the system equipment at this time.
3) During the work period, remote monitoring of gas pipelines. If a warning is heard, managers rush to the work site.

4) After completion of the work, recovery of the system. Reinstallation of the recovered equipment at another work site.

Consequently, the equipment must satisfy the following specifications.

a) Reliable detection: It can reliably detect even slight deformation or damage to coating.
b) Measures to prevent false warnings: It can only detect impact directly on gas pipelines.
c) Immediate responsiveness: There is no time lag between detection and transmission of the warning.
d) Portability: Because it is repeatedly installed and recovered, it is easily handled, compact, and light.
e) Price: It is low priced equipment that does not require a major capital investment.

2.2 Progress of the development

Its basic technology that detects third-party work contact in real time is the vibration detection method. Efforts to apply the principle of directly detecting vibration (impact) that is transmitted by a gas pipe have a long history, both inside and outside of Japan. But because it also detects vibration and impact indirectly transmitted to gas pipelines, or in other words external noise, measures to improve the reliability of detection and to prevent false warnings is a major hurdle.

Pipelines that are monitored can be broadly categorized into two types according to the form of the work. In cases where water supply or sewer pipes or electrical cables are buried at locations where gas pipes have already been buried, the objects of monitoring are “buried gas pipelines”. And at the sites of subway construction, urban development projects, and river improvement works etc., “exposed gas pipelines” that are suspended or form pipe bridges are the objects of monitoring.

Problems with each gas pipelines type are clarified:

[Exposed Gas Pipelines]

・ External noise measures in the work site
・ Remote monitoring method

[Buried Gas Pipelines]

・ Damping of vibration caused by soil constraint
・ Installation method for buried pipelines
・ External noise measures in the work site
・ Remote monitoring method

When the object is a buried pipeline, there are challenges related to installation method etc. not faced when dealing with exposed pipes. Considering the degree of difficulty involved, priority was placed on developing the system for protecting exposed gas pipelines (steel pipe) (below called the “exposed system”).

3. DEVELOPMENT HISTORY

3.1 Outline of the exposed system

Vibration is produced in various ways at large-scale work sites. Many kinds of external noise are transmitted to exposed pipelines as vibration; chipping concrete, operation of cranes and other heavy equipment that transport materials, and large trucks traveling on the ground near gas pipelines. It is, therefore, difficult to distinguish direct impact on gas pipelines from other vibration simply by installing sensors directly on gas pipelines to detect vibration. At the start of the development, an attempt was made to remove external noise by performing frequency analysis of detected vibration, but it was found to be difficult to apply this method for both technological and cost reasons.

As a new development approach, we focused on the fact that the transmission of external noise includes powerful transmission to structures around gas pipelines. So in addition to sensors installed directly on gas pipelines (below called, “detection sensors”), sensors were simultaneously installed for comparison purposes on structures that support gas pipelines (below called, “comparison sensors"). A mechanism that can distinguish external noise by comparing vibrations detected by these two sensors has been proposed.

Figure 2 shows an outline of the exposed system.

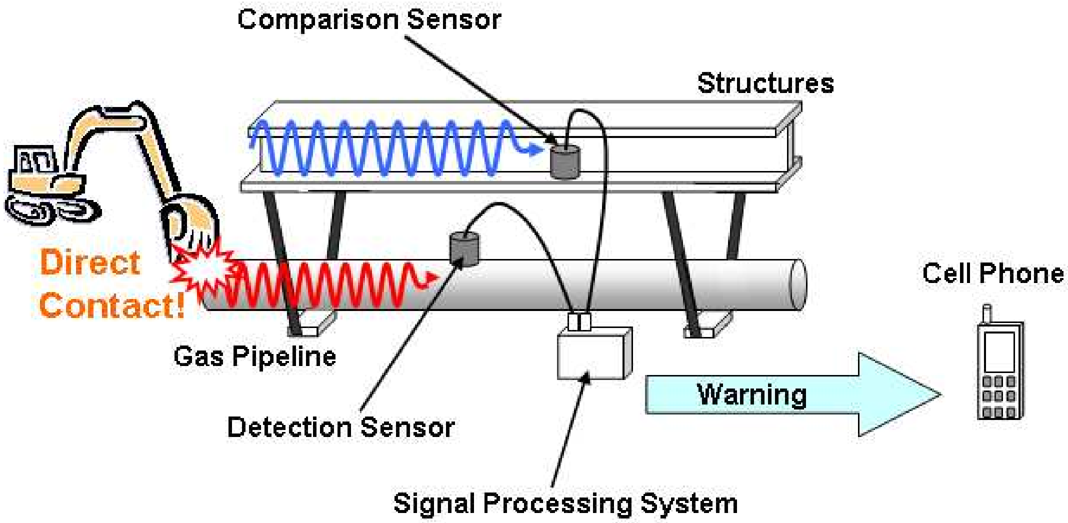


Figure 2: Outline of the Exposed System

3.2 Sensors and representing vibration as numerical values

A sensor on a structure is a vibration sensor that applies the piezoelectric effect and transmits the vibration to a vibration plate through its metal case.

The small signal produced by this sensor is amplified using an operational amplifier with an extremely small input bias current. Of the signals output from the operational amplifier, a filter is used to select only signals between approximately 10 and 10 kHz and their wave-forms are corrected in order to reliably obtain one cycle of continuous vibrations.

The signals from the detection sensor and the comparison sensor are separately processed. The two signals are input to A/D and computed by the CPU and the peak values of their respective wave-forms are always obtained.

3.3 External noise canceling mechanism

Although the use of a comparison sensor was proposed at the initial stage of the development, it was extremely difficult to construct specific cancel logic. Through repeated experimental trial and error using test pipes installed in a test field and an exposed gas pipeline at an actual subway construction site, vibration transmission data was collected.

As a result, it is possible to classify vibration produced at work sites broadly in the following three categories.

a) Noise of contact with gas pipelines = Third-party damage
b) Motor vehicle vibration of large trucks etc. from outside the work site (external noise)
c) Metal noise caused by heavy construction machinery inside the work site (external noise)

A law was derived by a comparison of values obtained from detection sensors and comparison sensors under these three types of vibration. It means that under contact noise that is applied directly to a gas pipeline, the values obtained by the detection sensor exceed those obtained by the comparison sensor, and inversely, under other types of vibration, the values obtained by the comparison sensor exceed those obtained by the detection sensor.

Figure 3 shows the logic of external noise cancel logic.

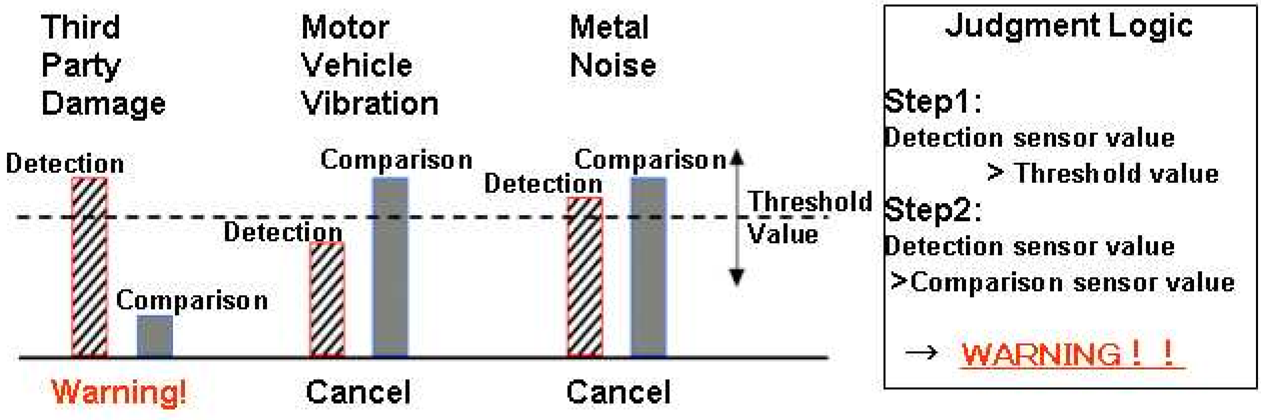


Figure 3: Logic of External Noise Canceling

This logic is based on two steps. Step one is a comparison of the detection sensor value with a fixed threshold value. The threshold value is the minimum impact force that could damage a gas pipe, and it is a value set empirically. This means that if the detection sensor value exceeds the threshold value, it can be assumed that the pipeline has been subject to vibration that is equal to or larger than the impact that damages gas pipelines. The second step is a comparison of the detection sensor level with the comparison sensor value. When the detection sensor value exceeds the comparison sensor value, the system judges that the vibration was caused by direct contact with the gas pipeline, and transmits a warning.

4. DEVELOPMENT ACHIEVEMENT

4.1 Exposed portable monitor system

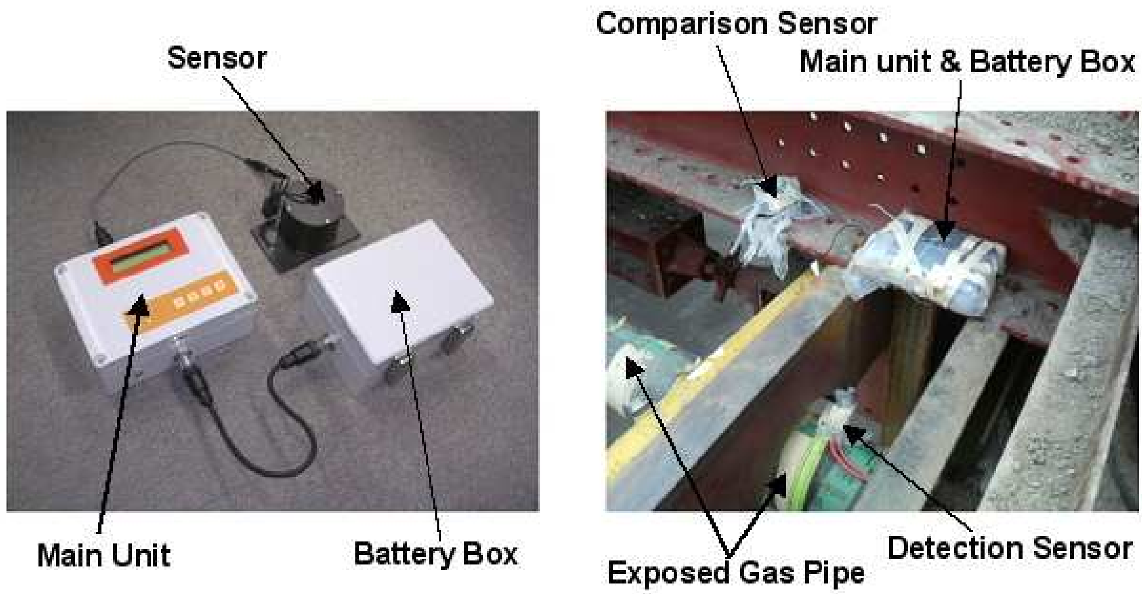
The system is divided into the main unit that process vibration signals that its sensors have detected and issues warnings, the battery box that supplies its power, and the sensors that detect vibrations.

The main unit assesses vibration according to its external noise cancel logic and when it senses gas pipeline contact noise (third-party damage) that exceeds the threshold value, it uses a PHS circuit to transmit a predetermined audible signal from its internal PHS transmitter as a warning to the cell phone or office phone of the gas pipeline monitor. The warnings are a “contact warning”, “battery power cutoff warning”, and “memory full warning”, and the audio varies according to which warning is issued. The main unit itself is equipped with a liquid crystal screen and four operating buttons, that can be used to perform necessary adjustment of the system: adjusting the sensitivity of the sensors and setting the threshold values for example. And it can refer to a record of warnings that have been issued.

The sensors are attached to gas pipelines or to H-steel and other structures by belts and vises. Soundproofing such as urethane is installed inside the sensor box to keep out superfluous vibration or noise.

An important feature of the system is that because the detection sensor and comparison sensor are used to cancel noise in this way without frequency analysis, it is simple to install and is inexpensive. As stipulated by the initial development goals, it is a portable system that one person can carry and install with ease, so it can be used repeatedly at different work sites. It also responds immediately when any problem has been detected.

Figure 4 shows the external appearance of the completed device and the view of its installation and Table 1 shows the specifications of the system.



(a) External appearance of the system (b) View of the system installation

Figure 4: Exposed Portable Monitor System

Dimensions	Main Unit: 175mm×125mm×75mm Battery Box: 175mm×125mm×75mm Sensor: [Diameter] 75mm, [Height] 55mm
Battery	Alkaline Batteries (size D)×4
Battery life	Approx. 1 month
Reaction time	Less than 10 sec (detect contact ~ issue warnings)
Detecting range	Approx. 1m~100m (coating steel pipe)
Memory	Max 99 (date/time/detect sensor values)
Warnings type	①Contact warning ②Battery power cutoff warning ③Memory full warning
Setting Tel. number	Max 5 (warnings to cell phone or office phone etc.)
Main Functions	・Remote monitoring (normal mode) ・Referring to a report warnings ・Adjusting date/time ・Setting threshold values ・Adjusting sensor sensitivity

Table 1: Specifications of the Exposed System

4.2 Work site application

The following is an example of a past trial operation of the system at work sites.

- Subway construction -- 1 spot
- River improvement works ---------------------------------- 4 spots
- Urban development projects ------------------------------- 2 spots

As a result, it achieved nearly “incorrect detection of 0% and contact detection of 100%” at every work site, showing it is a system that can handle practical use. Beginning in 2006, it will be installed and used for remote monitoring on exposed pipes at the locations of excavations executed as part of subway construction and large-scale urban development in supply districts.

4.3 Added functions (obtaining images)

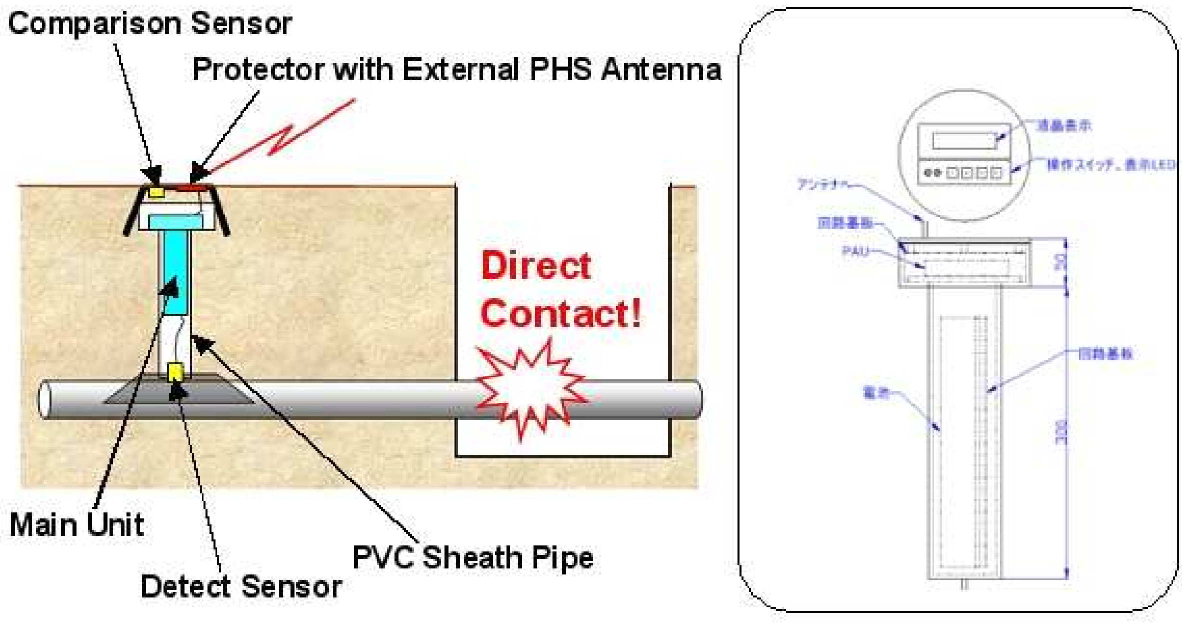
Development to add a function that obtains video images to the system has also been undertaken. When triggered by a warning signal, this function obtains an image of the state of contact so that conditions at the time of the warning can be confirmed later by viewing the image. This can also be counted on to provide a high level of constraint on contractors performing third-party work. Experiments using existing digital cameras are now being performed, and still images can be taken five seconds after detection.

It can be connected not only to a digital camera, but to an ordinary monitor camera, and its uses can be broadened to include fixed point monitoring using vibration sensors. It is also expected to be used to monitor elevated pipes on trunk lines that are one very important type of equipment, to provide protection not only from third-party work, but also from vandals or terrorists.

5. BURIED SYSTEM

Basic testing of the buried system using buried steel pipes in a test field has been performed to collect data. Because of damping of vibration caused by soil constraint, unlike exposed type, the application range is now shorter, at approximately 30m. But within this range, it achieves its development goal of being able to detect vibration transmitted in a gas pipeline (contact noise caused by heavy equipment etc.) without any problem.

A completed working model of a buried system is shown in Figure 5. It is installed vertically because the machinery is housed inside a buried PVC sheath pipe. Its PHS communication is performed through a special protector equipped with an external antenna.



(a) Outline of the completed working model (b) Outward form of main unit

Figure 5: Completed Working Model of the Buried System

The detection sensor is attached to the buried pipeline by a magnet. The comparison sensor is installed on the inside of the protector, where it compares vibration transmitted to the protector through the ground surface with vibration transmitted by the gas pipeline to distinguish external noise. This permits noise to be cancelled by the same logic as that employed by an exposed system.

6. CONCLUSION

Field testing of the exposed system is almost completed and it is at the full-scale introduction stage. Plans call for more systems to be introduced and for them to be used at a wider range of work sites.

But before buried systems are ready for practical application, a number of problems must be resolved. A prototype of a working system must be completed and tested in the field as quickly as possible. We intend to work to complete a system that can be installed at actual work sites as soon as possible.

In conclusion, we promise to continue development of various kinds in order to improve security to prevent future third-party work damage and other accidents.