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DEVELOPMENT OF SURER DENSE REALTIME DISASTER MITIGATION SYSTEM FOR URBAN GAS SUPPLY NETWORK

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ABSTRACT: To cope with earthquake related secondary disasters, the new real-time disaster mitigation system for a city gas network has been developed by Tokyo Gas Company since 1998 for the purpose of realization of dense real-time seismic motion monitoring, quick gas supply shut-off, prompt emergency response and efficient restoration work. In 2001, Tokyo Gas successfully started the operation of SUPREME, which employs 3,800 new SI sensors and remote control devices at all the district regulator stations in its service area (3100km^2). SUPREME can observe the status of 3,800 district regulators and shut them off remotely, if necessary. The remote shut-off using SUPREME can realize quick gas supply shut-off and effectively reduce gas leakage risk during earthquakes.

Key Words: SUPREME, dense real-time seismic monitoring, new SI sensor, 3800 district regulator, remote shut-off

INTRODUCTION

Urban gas supply is one of the important sources of energy, which support many aspects of life. As compared with other energy sources, gas is more vulnerable to earthquake risk. Since it is flammable, a possible leakage due to damages in pipes and other facilities may lead to significant fires and, in the worst case, explosions. The conventional emergency measure to avoid gas-related hazards has been shutting-down of gas supply.

Table 1[1] reveals the detailed feature of damages related to gas supply networks during the Kobe earthquake in 1995. It was thus demonstrated that there is a need to initiate the emergency measures more quickly. Without knowing the situation of gas supply network, it was difficult to make a decision immediately after a quake whether the gas supply should be suspended or not. Consequently, efforts were initiated to develop a real-time system to mitigate earthquake-induced damages in gas supply networks which aimed collecting information quickly and, if necessary, carrying out emergency measures.

Table 1 Damage to gas supply network during Kobe earthquake

Number of leakage	106 in trunk pipes with medium pressure 26,459 in service pipes of low pressure, consisting of 5,190 under road pavement, 6,184 in connection to customer, and 15,085 in customers' pipe.
Time until shut-down	about 15 hours
Number of shut-down	859,000
Days until recovery	85 days

The Tokyo Gas understood the need of a real-time system in 1980's. The first version of such a system was named SIGNAL[2] for which the development efforts started in 1986 and its service started in June, 1994; seven months prior to the Kobe earthquake. Recently a new compact seismograph was developed. Being called "New SI Sensor,[3]" this device houses an electronic circuit which determines the SI value more precisely, detects the onset of liquefaction, and transmits the whole time history of seismic acceleration to the head quarter. Consequently, a new safety system called SUPREME (SUPer-dense REaltime Monitoring of Earthquake) was developed which makes use of 3,800 of new SI sensors[3].

SEISMIC SAFETY MEASURE IN URBAN GAS INDUSTRY

This company has a service area of 3,100 km^2 in and around Tokyo where there are 10 million customers (as of March 2004). Fig.1 illustrates the structure of the gas supply network in which pipelines are classified into for groups. "Regulators" in Fig.1 are the facilities to lower the gas pressure. 3800 district regulators reduce the pressure from the medium level to the lowest.

The basic philosophy is that gas facilities should maintain their serviceability without damage during strong earthquakes. Consequently, the trunk pipelines with high and medium pressures have received high standards of seismic safety.

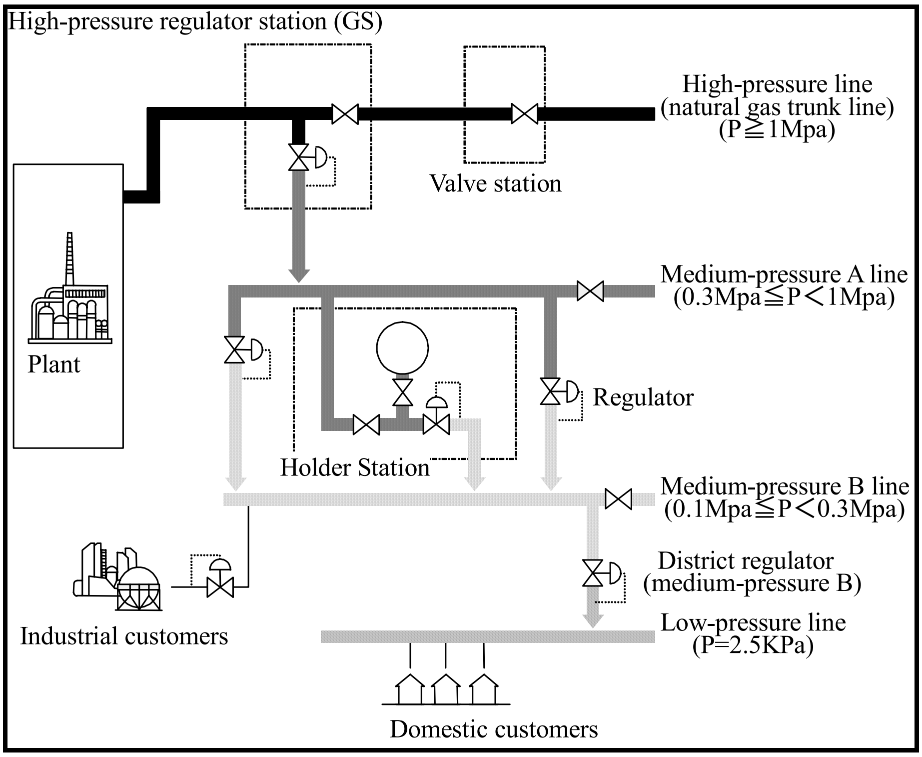

Fig.1 Schematic diagram of pipeline network of Tokyo Gas Company.

In contrast to trunk pipes, those with lower gas pressure are prone to earthquake hazards. In particular, 21,000 damages were reported in small pipes during the Kobe earthquake. Although improvement of seismic resistance of those small pipes is desired, it is not practically possible to date due to the following reasons, such as the total length of pipeline is too enormous for any immediate action to be taken, and those pipes in the land of customers are customers' property which the gas company cannot control. Consequently, it is very likely that those pipelines will cause many leakage problems during a big earthquake. To still avoid significant problems induced by leakage, it seems reasonable to stop gas supply automatically by sensing the intensity of earthquake motion.

The idea of safety as mentioned above is made real by the SI sensor. A district regulator which at normal time reduces the level of gas pressure from the medium one to the lowest. This facility is equipped with an SI sensor that monitors the seismic spectrum intensity which was originally proposed by Housner[4] and takes a value similar to the maximum velocity of ground motion;

$$SI = \frac{1}{2.4}\int_{0.1}^{2.5} SvdT \qquad (1)$$

in which *Sv* is the relative velocity response spectrum with 20% damping of the observed earthquake motion at a natural period of *T*. To date, a district regulator stops the gas supply if the monitored SI value exceeds 30 to 40 cm/sec to avoid secondary disasters caused by gas leaks. Here, it is the reason to set the SI value as 30 to 40 cm/sec that the damage of low pressure gas pipes and houses usually start to occur if SI values exceeds 30 cm/sec. The newly introduced SUPREME system will function based on these achievements so far made.

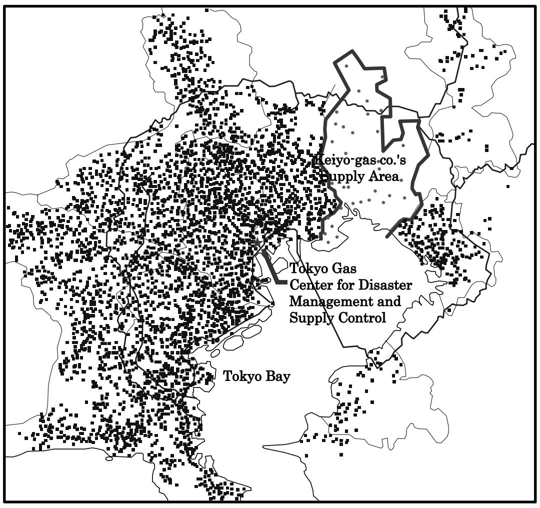

Fig.2 Locations of monitoring stations in SUPREME

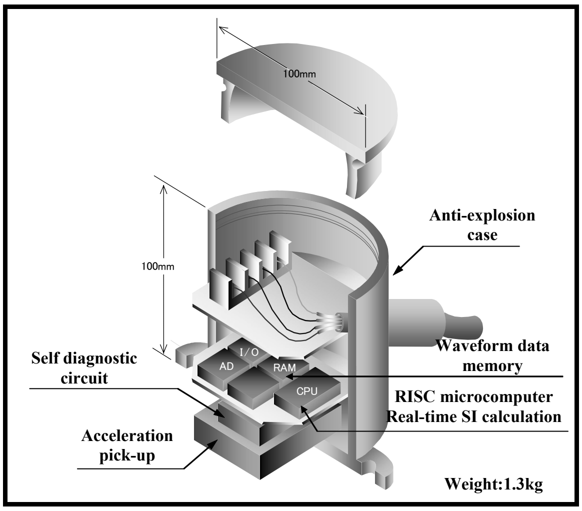

Fig. 3 Sketch of new SI sensor.

SUPER DENSE REALTIME MONITORING BY SUPREME SYSTEM

The SUPREME system as shown in Fig.4 is characterized by the use of the New SI sensor. This sensor together with monitoring device for gas pressure, and shut-down action of gas valves are installed at all the 3,800 district regulator stations. Since the total service area is 3,100 km^2, there is, on average, one monitoring station per every 0.9 km^2. Moreover, there are 20 liquefaction sensors which monitor the subsurface pore water pressure and detect liquefaction directly [5]. Table.2 indicates the number of data sources in the system.

As of March, 2004, 3,000 district regulator stations have received New SI sensors, while all the 3,800 stations will be equipped with the sensor until 2006. The communication between those sensors and the head quarter where the decision of shut-down is made by a computer relies on two kinds of channels. The one is a company-owned wireless and 332 stations are connected to this. The remaining 3,500 stations rely on the ordinary telephone network. Although the ordinary network is less reliable upon seismic emergency, the cost-performance analysis made this feasible. A special provision against telecommunication congestion is made by getting a special privilege from the telephone company. Accordingly, it is aimed that the control center at the head quarter can receive 80% of needed information within 20 minutes after a quake. This rate of response was facilitated by developing a new data-communication unit (called DCX).

Table 2 Number of data collected by SUPREME (as of March 2004).

Type of data	through wireless	through telephone network
SI and acceleration	332 including 300 district regulator stations	3,000 New SI sensors
Onset of liquefaction	20 liquefaction sensors and 300 New SI sensors	3,000 New SI sensors
Gas pressure, flow, and shut-down	300	all the 3,800 district regulator stations

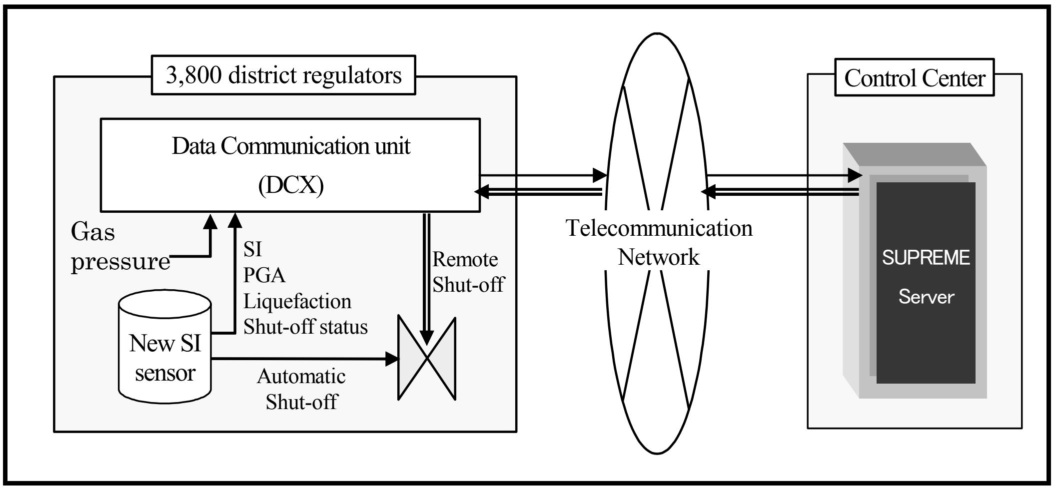

Fig.4 Illustration of SUPREME system.

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