Result of SUPREME(Super-dense real time monitoring Earthquake system for city gas supply) In "Tohoku Region Pacific Coast Earthquake"

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SUMMARY
The Great East Japan Earthquake did not damage any important facilities used by Tokyo Gas for city gas production and supply operations, but some low pressure pipelines with low earthquake resistance were damaged, forcing the company to suspend supplies of gas to about 30,000 homes to preserve safety. This report briefly describes initiatives taken by Tokyo Gas to provide prevention from earthquakes and its response to the Great East Japan Earthquake, which is centered on the super-dense real time monitoring earthquake system, SUPREME.

Keywords: The Great East Japan earthquake, earthquake countermeasure, SUPREME, Gas supply

1. INTRODUCTION

To ensure the continuity of Tokyo Gas operations in anticipation of large earthquakes, the company has taken advanced measures to ensure the continuity of its operations: enacting regulations, establishing the earthquake disaster prevention PDCA cycle by, for example, conducting annual integrated disaster prevention training with the participation of all employees, and at the same time, preparing earthquake disaster measures in three major categories: preventive measures, emergency measures, and restoration measures.
This report gives overviews of earthquake disaster prevention initiatives taken by Tokyo Gas and of its response to the Great East Japan Earthquake, which is centered on the super-dense real time monitoring earthquake system, SUPREME.

2. EARTHQUAKE DISASTER PREVENTION INITIATIVES TOKYO GAS

As stated above, Tokyo Gas has taken earthquake disaster prevention measures in three major categories: preventive measures, emergency measures, and restoration measures. This section discusses the specific contents of preventive measures and emergency measures which have absolutely minimized disaster damage.

2.1. Preventive measures

Tokyo Gas's basic policy is to takes preventive measures (equipment measures) for its LNG terminal and high pressure and medium pressure gas pipelines which support the core of city gas supply in our production and supply equipment, and to minimize damage caused by earthquakes.
LNG terminals and high pressure gas pipelines are designed and constructed under earthquake resistance design guidelines of the Japan Gas Association and in-house standards, with the target earthquake resistance of these standards defined as preventing leaks and maintaining their functions under level 2 earthquake motion(The Great Hanshin-Awaji Earthquake class). The earthquake resistance of existing equipment is also confirmed by design guidelines revised in response to the

Great Hanshin-Awaji Earthquake, and earthquake resistance measures are taken as necessary.
Medium pressure gas pipelines are, like high pressure gas pipelines, designed and constructed using welded steel pipes with superior strength and flexibility. By evaluating the earthquake resistance of the materials of existing medium pressure gas pipelines, and making individual detailed evaluations of non-earthquake resistant materials confirmed to be susceptible to leakage under level 2 earthquake motion, Tokyo Gas inspects the earthquake resistance considering the ground and the pipeline shape at each location where these materials are buried and implements earthquake resistance measures at locations they are found to be necessary.

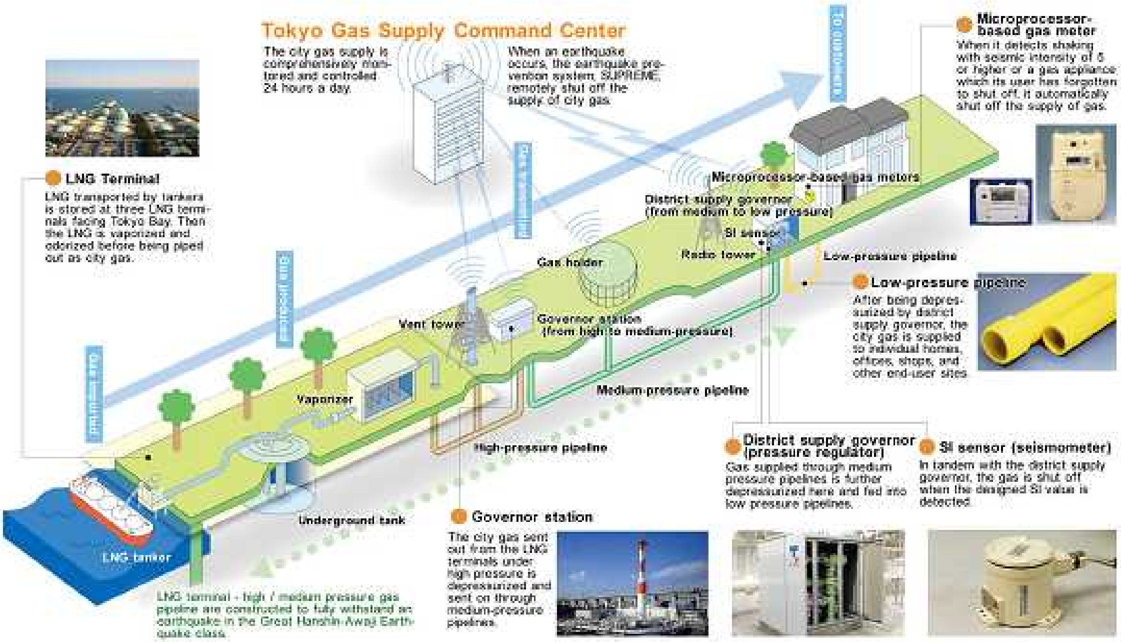

Figure 1. Outline of the City Gas Supply System and Earthquake Safety Measures

2.2. Emergency measures

As stated above, production and supply equipment of medium or high pressure is designed and constructed to maintain its functions under level 2 earthquake motion, but it is predicted that some low earthquake-resistant low pressure gas pipelines will be damaged by large scale earthquakes. And to prevent secondary damage, the supply of city gas must be promptly and reliably shut off in regions where damage is severe, so the following emergency measures are prepared.

2.2.1. Microprocessor-based gas meters

Microprocessor-based gas meters have been installed in the homes of all 10 million of our customers as equipment installed as close as possible to end users' premises in order to prevent secondary disasters. These microprocessor-based gas meters, which are also equipped with vibration sensors, automatically shut off the gas to ensure customers' safety when shaking in excess of 200gal (seismic intensity of about 5) has been detected.

2.2.2. Shut off supply to regions where damage is severe by SUPREME

A network of about 46,000km of low pressure gas pipelines sprawls across the Tokyo Gas supply area, and this pipeline network is divided into 140 blocks (districts). Because each block is physically isolated from adjoining blocks, it is possible to separately shut off the supply of gas only to districts where earthquake damage is severe.
Approximately 4,000 district supply governors, from which low pressure gas is transmitted, are all equipped with SI sensors so they continuously monitor the scale of earthquake vibrations. On the district supply governor, shut off valve which operate linked to the SI sensors are installed, and when an SI sensor has observed 40 to 60 kine, which corresponds to seismic intensity of weak 6, its district

supply governor automatically shut off, stopping the supply of city gas.
In blocks where damage is severe and in blocks where the Tokyo Gas supply shutoff criterion (where the SI value obtained by the judgment use seismograph is 60 kine or more) has been reached, supply must be stopped promptly, but if there is a district supply governor where the threshold value for automatic shut off within a block has not been reached, the supply of city gas continues. So in blocks where damage is severe, SUPREME permits shut off by a remote operation of all district supply governor in order to quickly shut off supply to such blocks.

2.2.3.Estimating damage to low pressure gas pipelines by SUPREME

SUPREME is equipped with a damage estimation equation prepared by performing factor analysis of past damage to low pressure gas pipelines caused by the Great Hanshin-Awaji Earthquake, of earthquake motion distribution/liquidation distribution, and of engineering geomorphologic classification and type of pipeline (Fig.2). The damage estimation equation is an approximation formula which statistically processes past damage, and it expresses the qualitative relationship-the larger the shaking, the more severe the damage-so it is appropriate to estimate the approximate number of damaged locations within an area with a large scale pipeline network.
SUPREME interpolates SI values for 50m meshes to calculate the number of damaged locations in each mesh in real time, based on SI values for 4,000 locations observed after disasters and data of geotechnical investigations (local site effects on ground motion) obtained in advance. SUPREME is also equipped with logic to calculate the PL value by the same process based on the observed SI values, to simultaneously estimate the risk of liquefaction (and to calculate damaged locations based on PL values and damage rate).
Finally, it estimates the number of damaged locations in each block and uses the results to decide to make a secondary emergency shut down decision and to enact restoration strategies.

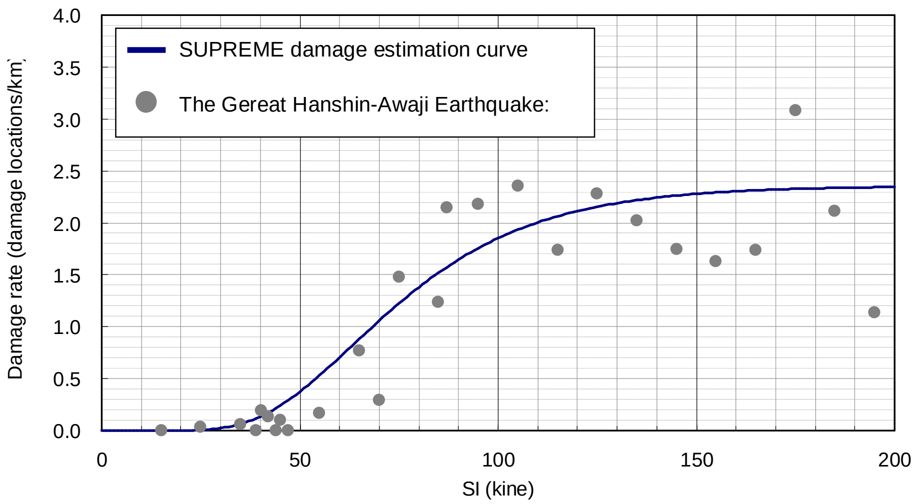

Figure 2. Damage Estimation Curve of SUPREME

3. RESPONSE TO THE GREAT EAST JAPAN EARTHQUAKE

3.1. Initial Measures Centered on SUPREME

When this earthquake struck at 2:46 p.m. on March 11, seismic intensity of strong 6 was recorded in Hitachi City in the Tokyo Gas supply area, and seismic intensity from weak 5 to strong 5 was observed in a wide range in the supply area, centered on the middle of Tokyo. At the same time as the earthquake occurred, the vibration sensor shut-off mechanisms on the microprocessor-based gas meters in users' homes activated, resulting in an estimated 3 million gas meters from among a total of about 10 million such meters automatically shutting off the gas, ensuring the safety of our customers.
At the same time, SUPREME, which is located in the Tokyo Gas supply command center in our head

office activated, collecting earthquake information from SI sensors installed on about 4,000 district supply governors and displaying the results of supply shutoff judgments in approximately five minutes (Fig.3). SUPREME quickly gathered enough information to enact policies guiding its initial response by, in addition to earthquake information, collecting gas supply pressure information, electric power failure information, and other detailed measured values for each district at the same time as it estimated damage to gas pipelines and evaluated the risk of liquefaction.

At fourteen of the approximately 4,000 district supply governors, shut off devices linked to SI sensors shut off transmission of low pressure gas to maintain safety. Because eleven of these were connected to surrounding district supply governors by gas pipelines, supply was continued by backup from adjoining district supply governors, but supply was stopped in districts supplied by three district supply governors with independent networks unconnected to gas pipelines. And in Hitachi City, maximum SI value of 70 kine was recorded, so supply to blocks was shut off based on supply shutdown criterion. Supply was shut off to a total of 30,596 homes: 30,008 throughout Hitachi City and 588 in the other three districts. However, the safety of customers was ensured and secondary disasters prevented by the rapid response led by SUPREME.

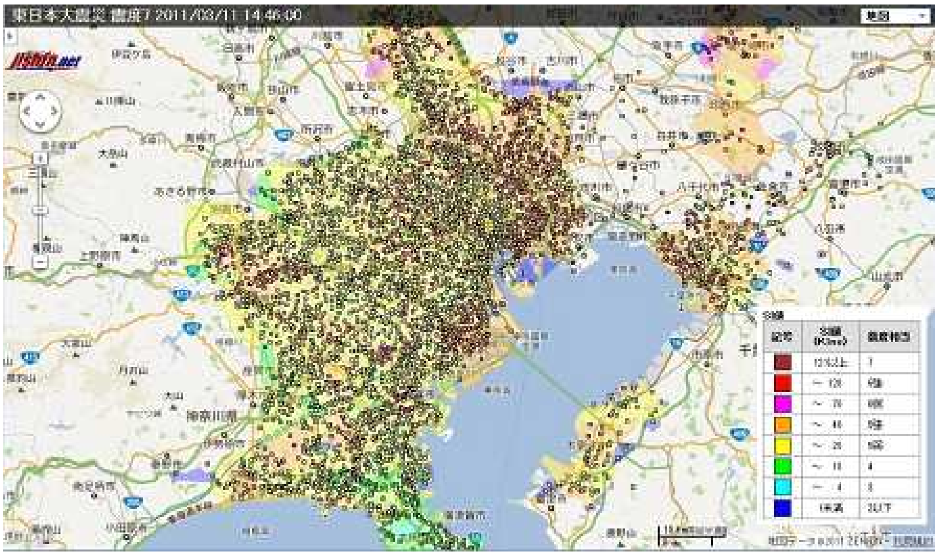

Figure 3. SI value observed by SI Sensors and Interpolated SI Values by 50m Meshes

3.2. State of damage to production and supply equipment

This earthquake did not damage important equipment which includes production equipment, gas holders, and high pressure and medium pressure gas pipelines. To protect these important classes of equipment, preventive measures described above were taken, and the effectiveness of these measures was fully confirmed by this earthquake.

Low pressure gas pipelines with low earthquake resistance, which partially survived, were damaged by the earthquake, but the number of cases of damage to gas pipelines buried under roadways is shown in Table 1, revealing that the total number of districts where supply continued and districts where supply was shut off was 230. According to damage estimations made by SUPREME (districts where supply continued) a total of 46 main pipelines and branch pipelines were damaged, a result which conforms closely with the 61 actual damaged locations, confirming the effectiveness of the damage estimation equation intended to macroscopically clarify damage.

Liquefaction damage centered on the Urayasu District (outside of the Tokyo Gas supply region), which was caused by this earthquake, also attracted considerable attention, but even in our supply region, liquefaction caused severe damage in the Mihama District of Chiba City. Supply to blocks was not shut off, but it was difficult to perform repair work because of sand flowing into the inside of gas pipelines. The liquefaction risk estimation function of SUPREME calculated the PL value in 50m mesh units, obtaining results shown in Fig.4, revealing trends generally similar to the actual state of damage on the scene, confirming the effectiveness of liquefaction estimation.

Table 1. State of Earthquake Damage by Equipment Category

Equipment category	Districts where gas supply continued	Districts where gas supply shut off: Hitachi City
LNG Terminal	No damage	No damage
High/medium pressure pipelines	No damage	No damage
Low pressure gas pipes		
Main pipeline (diameter≧100m)	***20***	15
Branch pipeline (diameter＜100mm)	***41***	9
Service pipeline	139	6
Total damage to low pressure pipelines*	200	30

*Covers pipes buried under roads; exclude pipes on customers' premises

Figure 4. Estimation of Risk of Liquefaction by SUPREME and Actual Liquefaction Damage

3.3. Restoration to region of 30,000 homes where supply was stopped

It was determined by the state of gas supply pressure after the earthquake that no gas pipelines were damaged in regions where single gas pressure regulators automatically shut down by vibration sensors cut off supply, one district in Yokohama, and 2 districts in Ibaraki Prefecture, and restoration was completed on March 11.

And to restore 30,008 homes in the Hitachi region, where seismic intensity of strong 6, or 70 kine was observed by Tokyo Gas SI sensors, and where supply by all lifelines including electricity and water were shut off, a total of 3,052 people including employees of Tokyo Gas, cooperating companies, and members of All Tokyo Gas took part in restoration work, first providing temporary supplies to hospitals and other priority supply customers, and succeeded in restoring the supply of gas to all customers approximately one week after the earthquake.

Past management manuals have applied only to regions where, anticipating large-scale earthquakes, gas pipeline damage would be severe, but in response to experience of the Niigata Chuetsu Earthquake and the Chuetsu Offshore Earthquake, a restoration manual was revised and prepared last year to permit a response to various degrees of damage. Our ability to complete restoration in a region where the supply to 30,000 users was cut off in only a week was a result of the application and skillful operation of this new manual.

The completion of restoration in the Hitachi Region was accompanied by the cancellation of the state of emergency, and completion of the response by Tokyo Gas to the Great East Japan Earthquake without any secondary disaster occurring.

4. FUTHER STRENGTHENING OF EARTHQUAKE PREVENTION MEASURES

Through its response to the Great East Japan Earthquake, Tokyo Gas confirmed the effectiveness of earthquake prevention measures based on the three types of measures—preventive measures, emergency measures, and restoration measures—and has shown that initial measures guided by SUPREME functioned particularly well. On the other hand, this response did reveal a number of problems, and regarding the overall earthquake phenomenon, also confirmed extensive damage exceeding past expectations in the form of giant tsunami and liquefaction.
To prepare for a giant earthquake which may occur tomorrow, Tokyo Gas will continue to improve its disaster prevention capability by tackling earthquake prevention measures even more resolutely, and will strive to maintain and increase the public's trust in its capabilities.

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