Efforts Aimed at Quick Incident Response at the Time of Earthquake
Introduction of Water Pressure Checking System via Communication Lines

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Abstract

The Tokyo Metropolitan Waterworks Bureau (TMWB) plays a role of water supply services, supporting about 13 million people's lives, urban activities and the capital’s central functions. Securing water supply in earthquake disaster is particularly very important. TMWB has the disaster recovery plan for various facilities including the capital’s central agencies (*1). It is specified that each one of the capital’s central agencies shall check the water supply pressure. If there is any damage such as decline of water pressure, water supply shall be restored within 3 days by appropriate countermeasures such as valve operation. On the other hand, the 2011 Earthquake off the Pacific Coast of Tohoku less directly affected water facilities due to the distance of 400 km between the epicenter and Tokyo. It took longer to check the water supply pressure because the staff got caught in an unexpected traffic congestion. Therefore, TMWB became the first water supplier in Japan to formulate and introduce a system which allows monitoring of water supply pressure while staying in the office in order to conduct recovery works quickly by identifying facilities with decreasing water supply pressure early on.

Keywords

Earthquake preparedness; communication lines; incident response; water supply pressure; monitoring

1. Introduction

Japan is one of the world’s most earthquake-prone countries and has experienced many major earthquakes such as the 2011 Earthquake off the Pacific Coast of Tohoku (Magnitude 9.0) in March, 2011 and the 2016 Kumamoto Earthquakes (Magnitude 7.3) in April, 2016.

The Headquarters for Earthquake Research Promotion suggests that the probability of a magnitude 7-level earthquake hitting Tokyo metropolitan area is estimated at 70% over the next 30 years.

Also, the Earthquake Division of the Tokyo Metropolitan Government's Disaster Prevention Council expects that, in the event of a magnitude 7.3 earthquake hitting directly underneath Tokyo, water suspension ratio becomes 60% or higher in some areas.

TMWB plays a role of providing water services, supporting about 13 million people's lives, urban activities and capital functions. Securing water supply in earthquake disaster is particularly very important.

2. Background and Purpose

The total length of water pipes owned by TMWB extends to about 27,000 km (which is equivalent to about two thirds of the equator). Particularly in central Tokyo, where the water pipes are networked like a finely-meshed pattern, alternative lines may be secured as a “back-up route” even if water leakage occurs in some parts of the area.

It is necessary to promptly ensure water services, especially for the capital's central agencies (*1), to recover the functions of the capital Tokyo at the time of a quake. Thus, if there is any damage such as decline of water pressure at these facilities after a disaster, water supply shall be restored within 3 days by appropriate countermeasures such as valve operation.

On the other hand, the 2011 Earthquake off the Pacific Coast of Tohoku less directly affected water facilities due to the distance of 400 km between the epicenter and Tokyo. It took longer to check the water pressure because the staff got caught in an unexpected traffic congestion.

Therefore, TMWB became the first water supplier in Japan to formulate and introduce a system which allows monitoring of water supply pressure while staying in the office in order to conduct recovery works quickly by identifying facilities with decreasing water supply pressure early on, determining the degree of emergency, and targeting the facilities to provide service to.

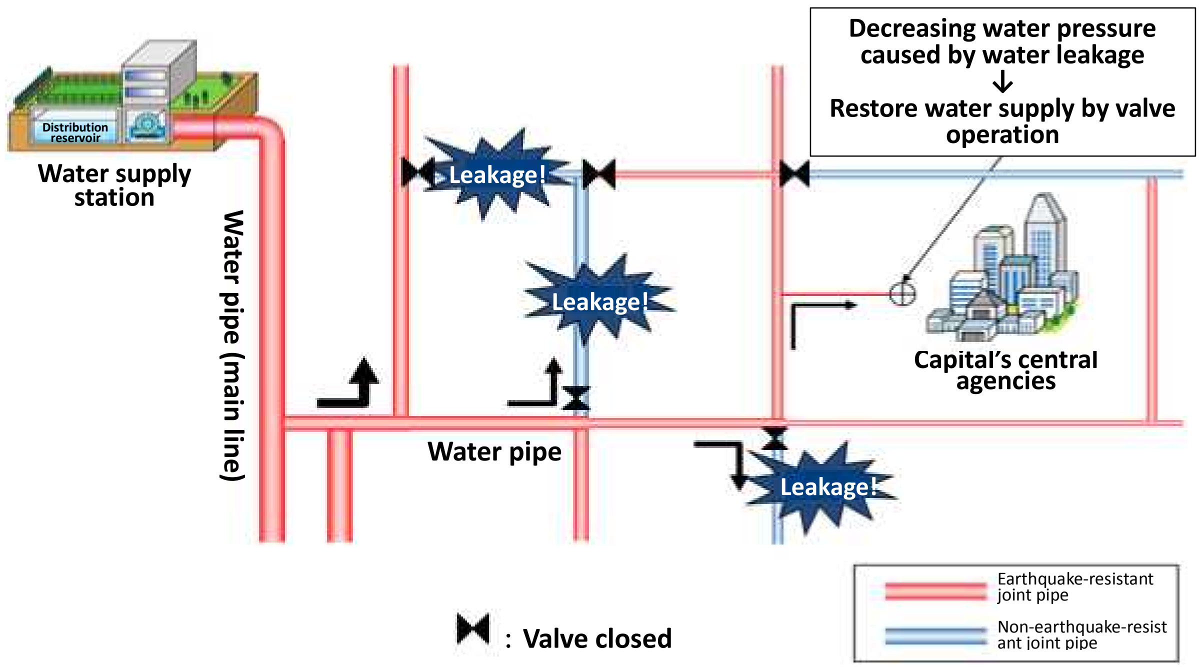


Figure 1 Image of water supply provided at the time of disaster

3. System Configuration

The system formulated in this project is constituted of "communication lines" which sends and receives the water supply pressure data, a "terminal unit" which measures water supply pressure on site, and the "data collection system" in the office which monitors the water supply pressure. Thus, this system allows the monitoring of the water supply pressure on site from the data collection system via communication lines.

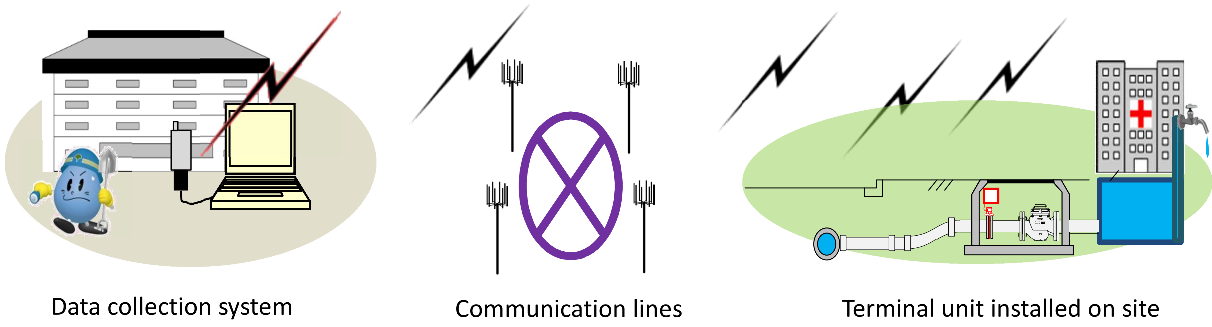


Fig. 2 Image of system configuration

3.1 Utilization of PHS Communication Lines (*2)

As for communication lines, TMWB has chosen to use PHS lines.

Reasons include the robustness of the PHS lines. In the current communications infrastructures in Japan, a communication link with PHS lines is easy to secure in urban areas at the time of disaster.

As proof of this, in fact, its communication was not controlled during the 2011 Earthquake off the Pacific Coast of Tohoku when the communication was restricted due to high concentration of access on mobile phone line.

Another reason is that with the PHS lines we can save more energy and call rates compared to using other mobile network systems. Another reason is that the PHS lines have low electromagnetic waves which may less affect medical devices at the target hospitals compared to using other mobile network systems.

3.2 Development of a Terminal Unit for Checking Pressure

TMWB aims to develop a terminal units that can be installed at the pipe joint which allows to measure water supply pressure in a feed-water pipe at the facility.

(1) Performance requirement of a terminal unit

a. It can measure water supply pressure at a point close to the facility.
b. It does not affect existing water supply pipes including water meters.
c. It works on cells which are easily changed.
d. It shall be water-proof to some extent.
e. It can do without daily check or maintenance.

(2) Configuration and specification of terminal units

The terminal device is composed of a pressure sensor and data conversion/transmission apparatus.

[Pressure Sensor]

A protective guard made of resin was attached to the pressure sensor, and a special fitting for measuring water pressure was sandwiched between the flanges in the upstream part of a meter (18 to 24 mm thick).

Also, the special fitting shall satisfy the requirements to be provided as part of the water supply pipe.

[Data conversion/transmission apparatus]

The data conversion/transmission apparatus shall be a box (201 mm wide × 151 mm high × 80 mm thick) with waterproof levels equivalent to IP 67 under the International Electrotechnical Commission (IEC) standard, accommodating the "communication line unit," the "pressure conversion unit" and "replaceable lithium batteries."

A battery life testing demonstrated that the batteries may be continuously used without replacement for ten years or more under the following operating conditions.

- The "communication line unit" is always kept on “standby”.
- To check the water supply pressure, it is received at least once a day via communication lines.

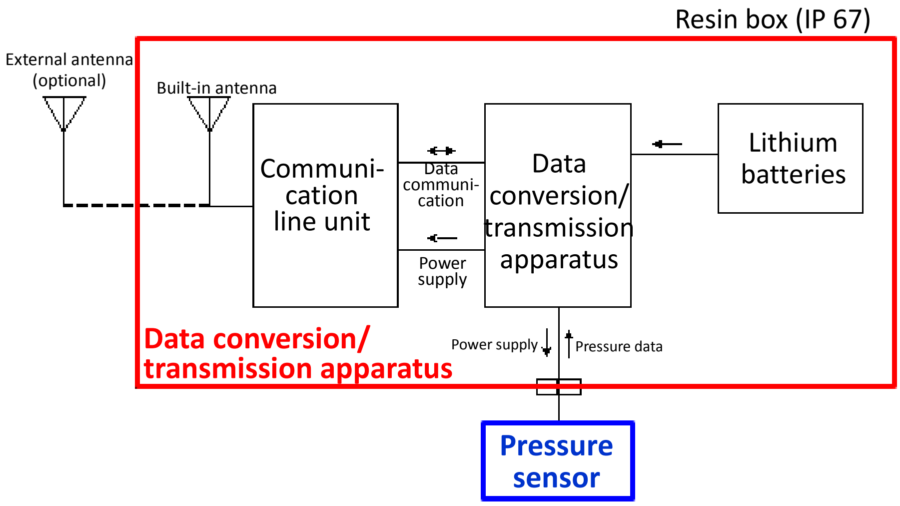


Figure 3 Configuration of terminal device
(Data conversion/transmission apparatus and pressure sensor)

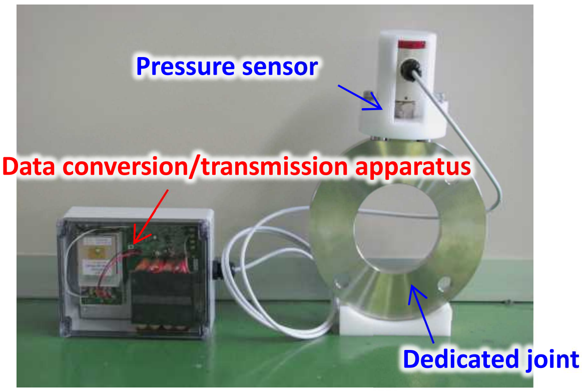


Figure 4 Terminal unit set

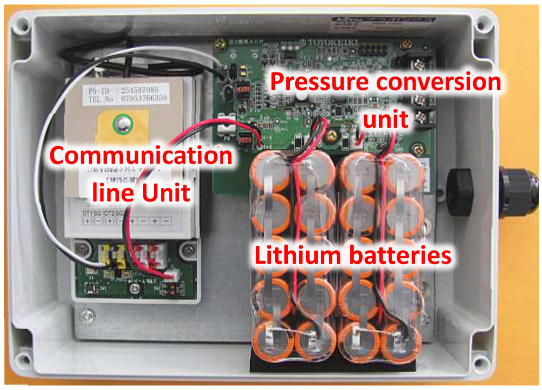


Figure 5 Data conversion/transmission apparatus

3.3 Development of the Data Collection System

A data collection system has been developed to collect data from terminal units via communication lines, which enables staff at one office to check the water supply pressure of many target facilities.

(1) [Performance Requirement of Data Collection System]

a. It can check the water pressure at any timing.

b. It can show the collected water pressure data, field intensity, and remaining battery on Excel sheets.

c. It has the scheduling function to collect data available at the present time on the day of the week.

(2) Configuration and specification of data collection system

The data collection system is composed of a personal computer on which dedicated software is installed, as well as a communication terminal unit.

[Software functions]

To satisfy the required performance, the software was developed with the following functions to:

・Function 1: Collect various water supply pressure values of the target facilities at a time. (Also available to collect data at intervals of 1 min to 60 min);

・Function 2: Measure the water supply pressure value, the battery remaining amount of the data conversion/transmission apparatus, and the electric field intensity at the same time, display the data on the screen and save it automatically in Excel; and

・ Function 3: Set up automatic collection schedule, as well as the normal pressure range per target facility.

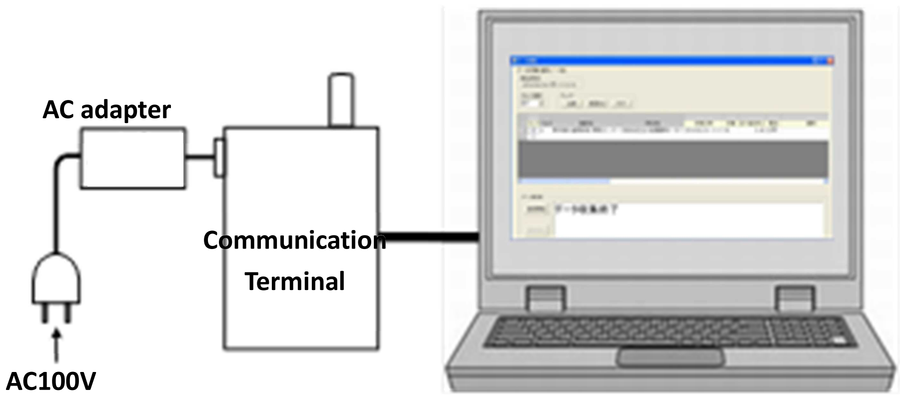


Figure 6　　Configuration of data collection system

Figure 7　　Data collection system: sample screen

4. Result of the Demonstration Test

Three disaster base hospitals distant from field offices were chosen and demonstration tests were executed there in order to validate the developed system.

(1) Installation of terminal units

After checking the electric field strength in the water meter BOX in advance in the premises of three sites, we installed the pressure sensor and the data conversion transmitter.

[Installation of pressure sensor]

The pressure sensor was installed so as to be sandwiched by the upstream flange portion of the water meter.

Figure 8　　Installation of pressure sensor

[Installation of data conversion/transmission apparatus]

As for the data conversion/transmission apparatus, we measured the electric field intensity in a water meter box using the PHS communication unit for about two weeks in advance, and installed it in the water meter box when the communication is stable.

Figure 9　Installed data conversion/transmission apparatus

(2) Result of the Demonstration Test

As a result of performing demonstration tests at three disaster hospitals for three months, we were able to construct what can satisfy the original performance required, with a satisfactory result from both of the terminal units and the data collection center.

[Communication success rate]

We checked communication on the hour (24 times a day) for 3 months after installation (6,549 times in total).

Initially there was no retry function, which led to failure sometimes due to the weak electric field and busy base station. However, all communication attempts succeeded after we added one retry function, achieving 100% of the communication success rate.

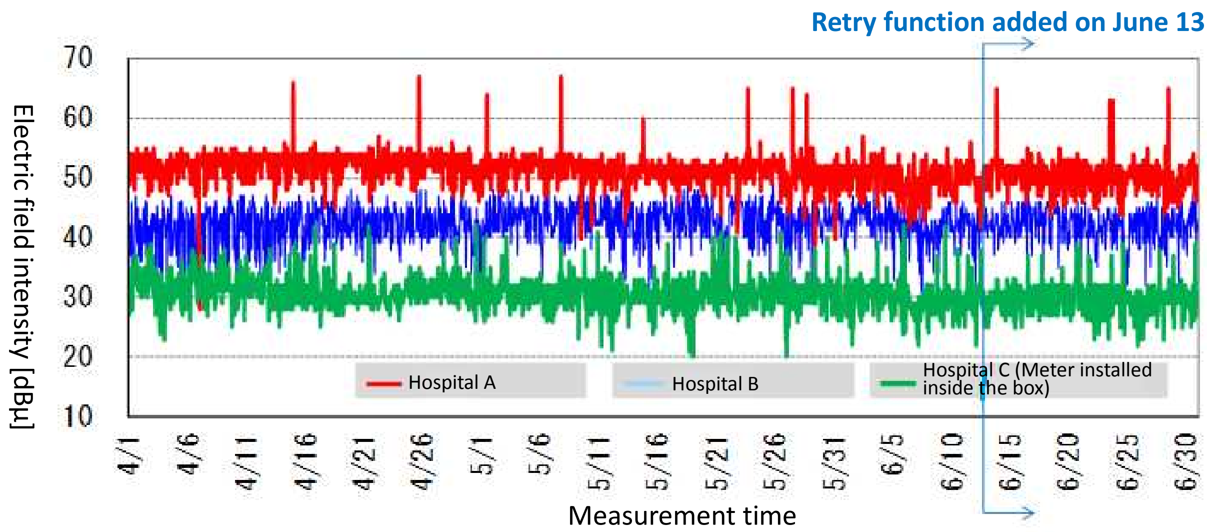


Figure 10　　Electric field intensity changes at 3 places

[Measured values of water supply pressure]

We reviewed whether the water supply pressure value measured on site using the pressure sensor was appropriate. As a result, it was confirmed that the water supply pressure values detected at the target facility were similar to the values measured at the neighboring fire hydrant, and were appropriate.

[Data collection function]

We reviewed whether the water supply pressure data communicated to the data collection system was correctly collected and stored via the terminal units installed. As a result, each communication was saved correctly in an Excel file.

	ﾌﾞﾛｯｸ	施設名	所在地	収集日時	収集	圧力値(MPa)	電池	備考
83	ﾃｽﾄ	Hospital B	江戸川区臨海町1-4-2	2014/02/04 00:00	OK	0.29	正常	
84	ﾃｽﾄ		江戸川区臨海町1-4-2	2014/02/04 01:00	OK	0.31	正常	
85	ﾃｽﾄ		江戸川区臨海町1-4-2	2014/02/04 02:00	OK	0.31	正常	
86	ﾃｽﾄ		江戸川区臨海町1-4-2	2014/02/04 03:00	OK	0.32	正常	PHS電波微弱/
87	ﾃｽﾄ		江戸川区臨海町1-4-2	2014/02/04 04:00	OK	0.32	正常	
88	ﾃｽﾄ		江戸川区臨海町1-4-2	2014/02/04 05:00	OK	0.31	正常	

Figure 11 Storage status of collected data

5. Conclusion

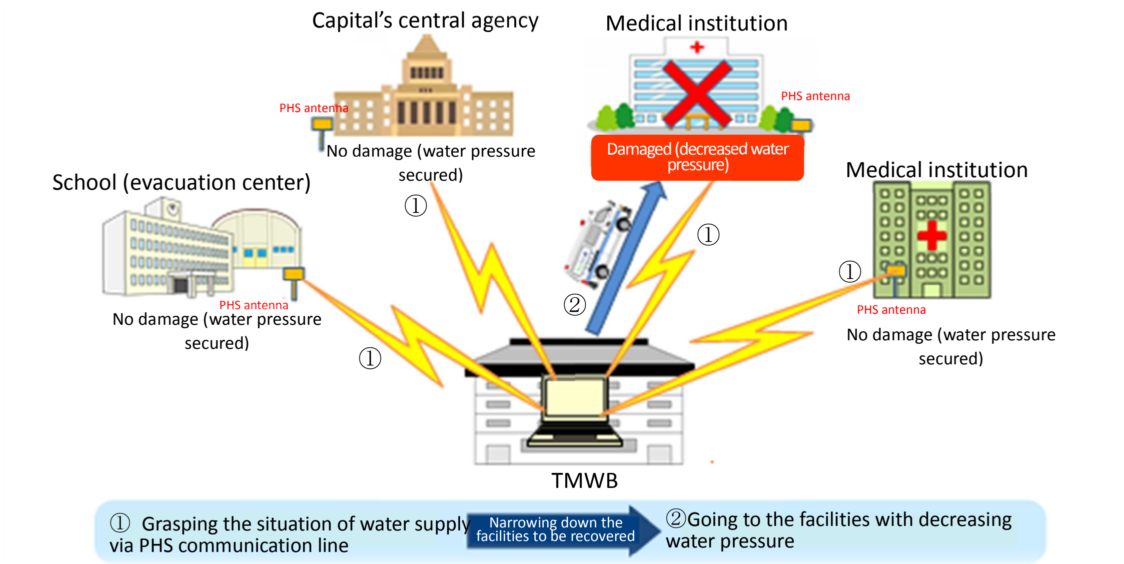
By adopting this system, water supply pressure in capital's central agencies can be monitored from the office. This will make it possible for us to identify facilities with decreasing water supply pressure early on and to quickly narrow down facilities to be investigated and recovered on a priority basis.

As a result of the measures, time needed to recover the damaged facilities will be shortened. For example, if 58 facilities (about half of the existing 115 facilities) are damaged, they will be recovered in 40 hours in the new system. It is shorter by 40 % than the estimated 63 hours under the conventional system, and water supply will be restored much quicker.

TMWB plans to implement this system to all of the 137 central capital institutions by the end of FY2017.

TMWB will further enhance emergency measures by introducing the system to more than 800 key facilities, including refugee centers and medical institutions, which give aid to and accommodate disaster victims.

Figure 12 Image of facilities targeted for accommodation



(*1) Central institutions of the government administration and economy, tertiary emergency medical facilities and core disaster hospitals which provide critical care for severely ill/injured patients

(*2) Wireless communication lines using the frequency of the 1.9 GHz band in Japan