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Restoration work control system for earthquake damaged city gas pipelines

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ABSTRACT: There exists an excessive delay tendency in the restoration of gas pipelines devastated by major earthquakes because of the system's complex, multiphased restoration work procedures necessary for safety assurance. Another problem is that such restoration entails a vast amount of work, personnel versed in variegated jobs, and considerable time. Tokyo Gas has been developing software to support pipeline restoration to facilitate the early, safe resumption of gas supply. For efficient systematization of each restoration work plan and instruction, it is necessary to synchronize every task. These encompass pipe repairs and customer service to a unit area, which size must be adjusted according to the number of customers and the pipeline damage. Introduced to meet this need is the mapping system that enables arbitrary "polygon" area apportionment. According to the unit, the system issues work instructions for all filed operations, thus supporting successful completion of the restoration work.

1. INTRODUCTION

Tokyo is one of the largest cities in the world. In the central and peripheral area of the metropolis, complex lifeline networks that include those of Tokyo Gas are in place.

This region, which is one of the Tokyo Gas supply areas, experienced several large earthquakes in the past.

It takes much time and labor to restore the functions of gas pipelines after an earthquake. This is because there exists a great difference called "the difficulty in securing safety" between gas-network restoration operations and those of other lifelines such as electrical power and waterworks. If a major earthquake occurs, the supply of gas through gas pipelines will be halted where necessary to prevent secondary incidents. The gas remaining in medium-pressure lines will be emitted safely into the air. In the restoration work process, it is necessary to perform gas leakage tests to confirm pipeline integrity, safely replacing all air in the lines with city gas. In the case of low-pressure lines, rounds are made to each user, the gas-meter valves are turned off to disconnect the user's facilities from the mains, and then the above-mentioned operations are performed. After completion of repair and testing, gas supply is safely resumed. Guaranteeing absolute safety is both labor- and time-intensive.

Tokyo Gas is proceeding with diligent preparations to resume gas supply immediately if such an earthquake or other calamity occurs. In practical use for many years has been a forecasting system for damage to mains, a comprehensive restoration plan, and practical operational support. A new system has now been established that coordinates each operation within Tokyo Gas. The new system ensures that restoration operations can be effected more safely, precisely, and efficiently.

2. CHARACTERISTICS OF THE NEW SYSTEM

The new system consists of two principal parts.

① "Planning support system" for preparation of an optimal restoration plan

② "Work support system" to extract information in

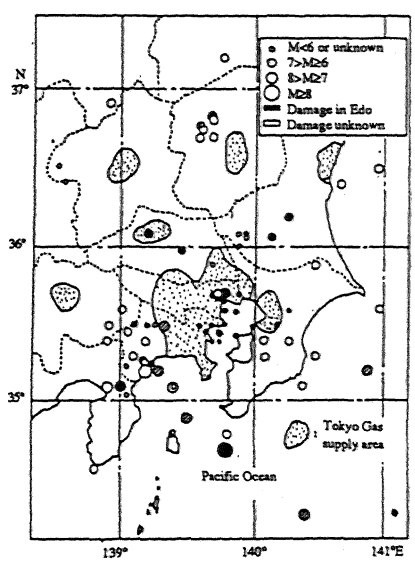


Figure 1 Map of Kanto District Earthquakes

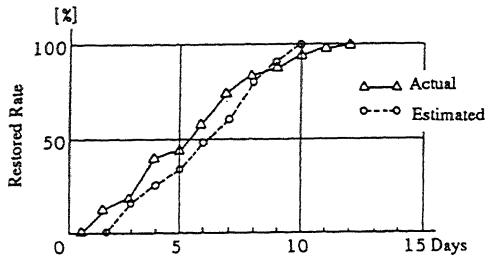


Figure 2 Comparison of the Actual Restoration Rate and the Estimated (Chonan Area of the Earthquake in the Eastern Sea off Chiba Prefecture)

the course of restoration work

The traditional system controls (a) estimation of seismic damage, (b) planning of low-pressure network (composition of restoration areas, worker apportionment, and prioritization), and (c) work progress. We would need, however, to take into consideration a certain extent of damage to the medium-pressure pipeline if the low-pressure network suffers damage that exceeds a prescribed level. Double would persist that customer service operations would be able to effect such a restoration. This system, therefore, has integrated the following improvements.

① To add restoration planning for the medium-pressure network

② To include customer service operations and personnel, such as for turning meter cocks off and on

③ To provide useful information for restoration by linking up with other data systems such as the mapping data base

④ To review personnel apportionment (ex.classification of skill levels) and other reforms

3. OUTLINE OF THE TRADITIONAL SYSTEM

(1) Restoration support system (pipeline version)

The system that we present here is based on the restoration support system (pipeline version). The system enables the following programs to be arranged on a graphic display: (a) estimation of damage to low-pressure gas pipeline, (b) formation of restoration areas, (c) restoration planning, and (d) work progress control and revision of plans.We have already confirmed the efficiency of this optimal simulation of restoration planning through review of data on the restoration procedures for the earthquake in the eastern sea of Chiba Prefecture.

(2) Mapping system

The mapping system (TUMSY: Total Utility Mapping SYstem) is a geographical data base indicating strata composition. It was developed specifically by Tokyo Gas Co. This system controls information on gas pipelines, roads, urban divisions, and building configuration in each hierarchical structure. It enables

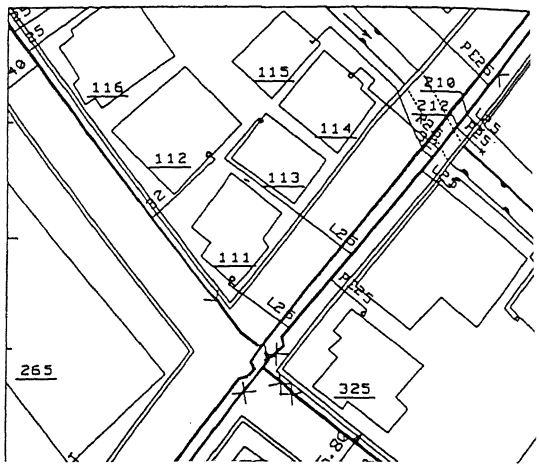


Figure 3 Example of Mapping Graphic Hard Copy

us to superimpose one graphic image upon another. This mapping system uses the same platform as that for the VAX-8800 host machine that operates the traditional restoration support system. That means that both data interchange with each other. The system also can link up with a customer control system by using customers' individual service pipe numbers as key numbers, and obtain customer information in an arbitrary polygon.

(3) Customer control system

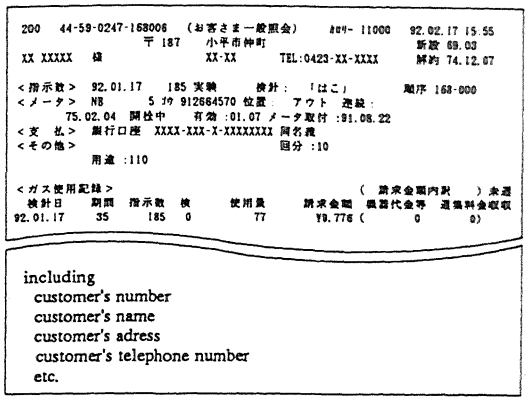
The customer control system controls the data on each customer of Tokyo Gas, whose totals come to approximately 7.5 million. The system covers a wide range of information including basic data such as addresses and names, gas use, and appliances.We can access the latest data because information is renewed daily in accordance with the company's business operations.

4. SYSTEM ARCHITECTURE

This system's architecture is illustrated on the "System Architecture Graph." The basic architecture hardly differs from that of the traditional restoration support system. The architecture, however, constitutes a facility data base that encompasses information such as the mapping system and customer control system. All data are operated on the color graphic display by selecting tablets (GUI). This enables us to avoid using keyboards except for inputting digital information. Information output from the system can also be rendered as hard copy or mounted on electrostatic plotters.

4-a Planning support system

The restoration work flow of city gas is illustrated on Figure 6 (next page). The work indicated by a broken line represents daily routine operations. The factors outlined below are necessary for modeling this work.



including
customer's number
customer's name
customer's adress
customer's telephone number
etc.

Figure 4 Example of Customer's Data

This system has a meshed area added to optimize the entire system and to make various data available.

(1) The generalized restoration process consists of closing meter cocks for all customers in the gas-suspended areas, repair work, purging air trapped in the pipeline, leakage testing, and opening the meter cocks to resume gas supply.

(2) The efficiency of the restoration process depends on the size of the gas-suspended area and the degree of damage to the pipelines. If the area is large, it should be subdivided into smaller districts whose number of customers does not exceed 10,000.

(3) The tasks involved in the restoration process (stated in [1]) comprise a critical-path relationship and should be conducted in series in the same restoration block. Because different types of work are involved, with different job functions, it is advisable to finish the entire restoration of each district in from three to five stages.

(4) Efficiency also depends on the rate of operation of each of the functioning personnel. Any of the restoration processes, if delayed, would deter resumption of gas supply. An appropriate number of skillful personnel utilized at the proper time would greatly influence the service resumption rate. Optimal manpower-utilization planning is thus essential.

(5) The total efficiency of the entire restoration process should be measured by the gas sales volume opportunity loss resulting from gas suspension.

4-b Work support system

Information offered

(1) Output of restoration area graph

The restoration area that forms the basic unit for restoration has been registered beforehand in the mapping data base. Accordingly, workers involved can easily access in graphic form the pipeline network information of their restoration areas. Subdivision (or combination) of restoration areas is often made at the planning stage. The mapping system, however, will flexibly deal with changes of restoration areas. We intend to use the same system to control information regarding the investigation results of earthquake damage.

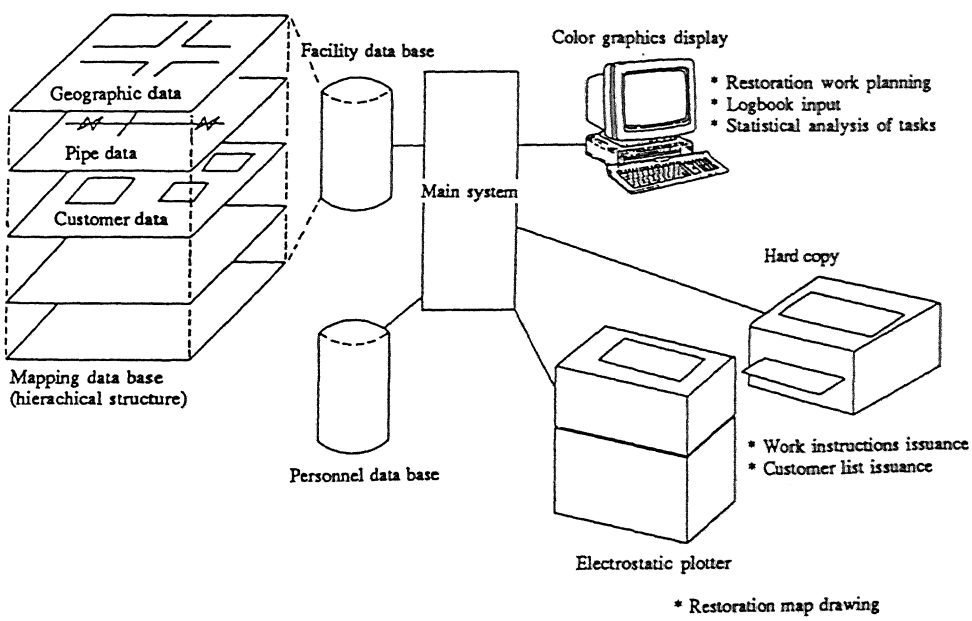


Figure 5 System Architecture Graph

(2) Checklist for confirming meter-cock closing

The location of gas-leak points through temporarily increasing gas pressure is prerequisite for detecting gas leakage to begin pipeline restoration. If customer gas outlets are left open in this case, a gush of raw gas could cause serious hazards. Such open gas valves would also make it impossible to confirm the completion of leakage repair when tightness is tested at the final restoration stage. The preceding work, therefore, should be completed to separate earthquake-damaged areas from the pipeline. Such work includes visiting each customer to close meter cocks, and detaching service pipes in the devastated residences from the adjoining pipeline. To confirm each closed meter cock, however, is no easy task. This is because in a large city such as Tokyo where houses are clustered, approximately 2,000 customers exist in a single restoration area. We must prepare complete checklists for customer services to allocate a large number of personnel to cover all damaged areas.To accomplish this, we compile customer lists in the restoration areas by means of our mapping and customer data systems. We apportion areas (groups of customers) of the restoration blocks on the mapping system's graphic screen. The system enables polygon apportionment by using tablets.We then extract service pipes existing in the areas designated in the polygon. The next step is to link the service pipe numbers and key numbers with the addresses and names of customers obtained from the customer data system. The final information is printed when work orders are issued and this constitutes the checklist used for making rounds of customers. This checklist will also be available for reopening meter cocks.

5. CONCLUSION

The restoration of a huge gas pipeline system devastated by a serious earthquake could suffer delays because of difficult safety assurance. Tokyo Gas has accordingly been developing software to systematize the control of manpower-allocation and work-progress in an effort to expedite the precise performance of complex and difficult restoration procedures. In the first system that has been put into practice, we estimate the extent of earthquake damage, systematize pipeline-repair work, and determine the efficiency of restoration in a case study. In this way we also assist the planning staff. In the new system, however, we expand the first system to include, besides the pipeline-repair system, systematization of customer services. This enables us to perform more efficient restoration procedures because consistent control has become available for the restoration planning and work progress. Linkage between the mapping data and customer data systems has also resulted in more exact work instructions and variegated information, such as customer lists.

A future problem is improvement of the accuracy of estimation for early-stage damage in a major earthquake. The present simulation estimates the extent of damage by putting ground conditions into macro instructions in accordance with the epicenter and scale (M-Δ), but highly accurate estimation is unavailable.Tokyo Gas selected some 300 sites in its service area and is developing a new system for on-line collection of earthquake acceleration and SI-value data. Earthquake damage estimation will become more accurate if it is based on these data. As the next target in our system development, we will connect the damage estimation system with the restoration support system to make the entire restoration system more practical.

REFERENCE

Iwata, T. and Saito, K.,(1985) Restoration Planning for Earthquake-Damaged Gas Pipeline Networks, International Symposium on Lifeline Earthquake Engineering, ASME.

Iwata, T., (1985) Restoration Planning System for Earthquake-Damaged Gas Pipeline Networks, U.S.-Taiwan-Japan Seminar/Workshop on Lifeline Earthquake Engineering, Taipei.

Iwata, T. and Nakane, H., (1988) Restoration Planning system for Earthquake-damaged City Gas Pipelines, Proceedings of Ninth World Conference on Earthquake-Engineering.

Japan Gas Association, (1979) The Miyagi-Ken-Oki Earthquake and City Gas Systems, Japan Gas Association, Tokyo, Apr. [Japanese].

Kanto-Chuo Division (JGA), (1988) The Chiba-Ken-Toho-Oki Earthquake and City Gas Systems, Kanto-Chuo Division (JGA), [Japanese].

Katayama, T., (1983) Emergency Operation of Rehabilitation of Water Supply Systems after Earthquakes, International Symposium on Lifeline Earthquake Engineering, ASME.

Metropolitan Government of Tokyo, (1978) Report on the damage estimation of earthquakes in the 23 districts of Tokyo, Tokyo Metropolitan Disaster Prevention Congress [Japanese].

Metropolitan Government of Tokyo, (1983) Report on Basic Studies relating to the possible effects on Tokyo of the Tokai Earthquake, Tokyo Metropolitan Disaster Prevention Congress [Japanese].

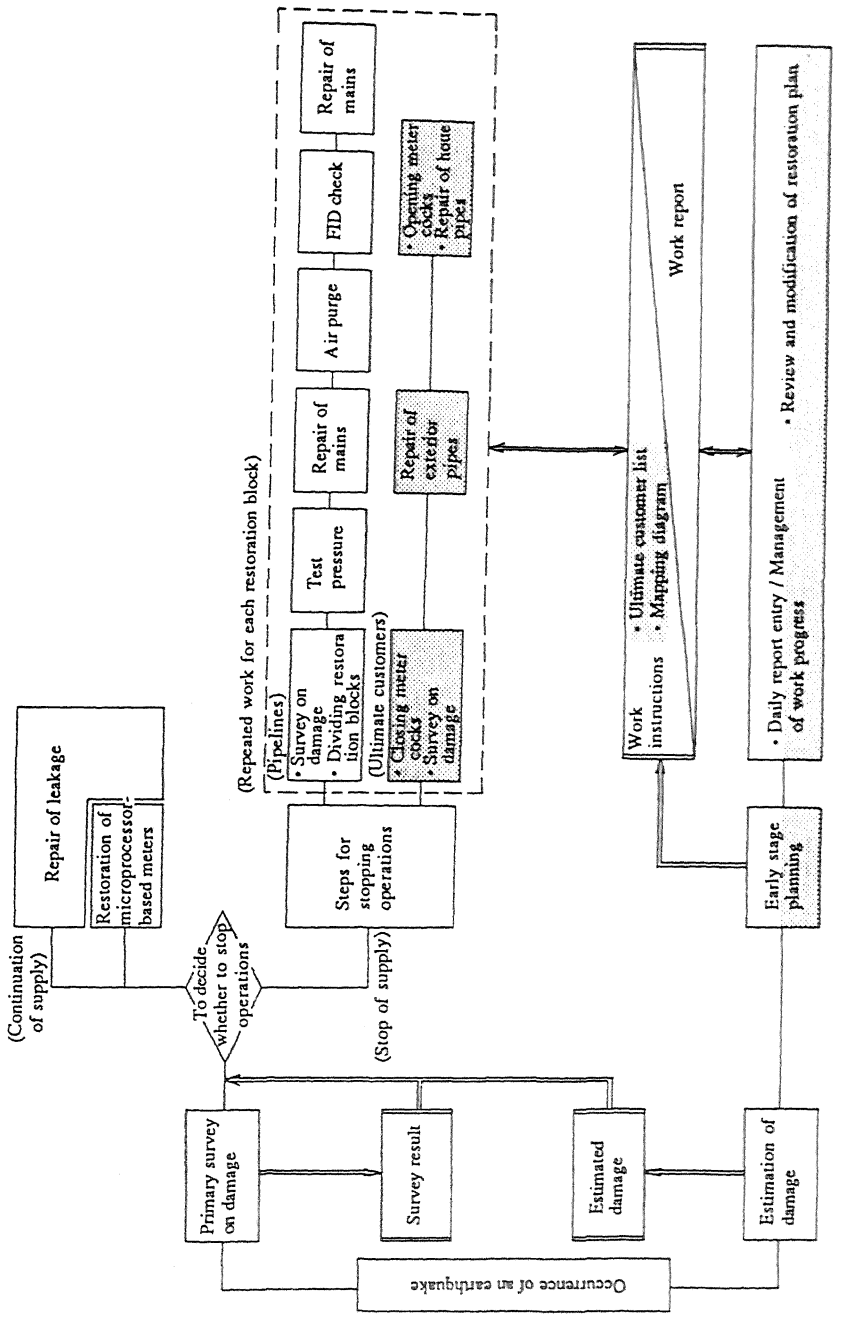


Figure 6 Flow of Restoration Works