Proceedings of Ninth World Conference on Earthquake Engineering
August 2-9, 1988, Tokyo-Kyoto, JAPAN (Vol.VII)

11-3-9

RESTORATION PLANNING SYSTEM FOR EARTHQUAKE DAMAGED CITY GAS PIPELINES

Takashi IWATA and Hiroyuki NAKANE

Pipeline Planning and Administration Department,
Tokyo Gas Co., Ltd., Tokyo, Japan

SUMMARY

Tokyo Gas Co. has been developing a computer software as one of its main earthquake countermeasures, to establish a reliable and efficient post-earthquake gas pipeline restoration planning in the event of a destructive earthquake in the Tokyo metropolitan area. The software is based on a simulation model, mainly derived from our experience in aiding restoration work of the Off-Miyagi in 1978. The software consists of two applications for pre- and post-earthquake use. The first one is called "Optimum restoration work planning system for a specific earthquake," and the second called "Actual restoration work control system". Through analysis of restoration work carried out in the recent Chiba-Ken-Toho-Oki Earthquake, the usefulness of these applications is being examined.

INTRODUCTION

The Tokyo metropolitan area, which is historically notorious for its frequent earthquakes has had no major earthquake since 1923, the Great Kanto. Thus, almost all of ground and underground facilities in the area have been constructed during the last 65 year period of geographic peace. In the event of a major earthquake in such a vast and little experienced city, various kinds of disasters including casualties by collapse of buildings and fires, etc. are expected. Besides these disasters the adverse effects brought about by the damage and malfunction of lifeline systems are considered to be a serious hazard to city life as well.

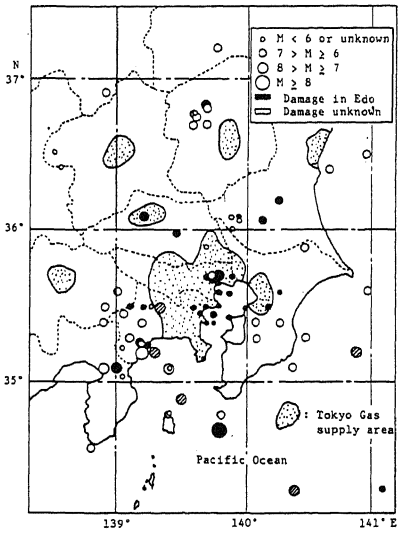

Fig. 1 Map of Kanto District Earthquakes

Among all lifeline systems, gas pipelines are expected to be the most vulnerale to earthquakes. In order to prevent a secondary disaster, gas supply to the districts devastated by an earthquake must be suspended immediately after major pipeline failures. Once the gas supply is stopped, consequent restoration work would take much time and labor, mainly due to repeated safety measures required in the recovery process, irrespective of the damage. A typical example can be found in the restoration work of the Miyagi-Ken-Oki Earthquake (1978). In the process of recovering lifelines, the restoration of the gas supply system entailed considerable delay when compared to the restoration of the water system which sustained more damage.

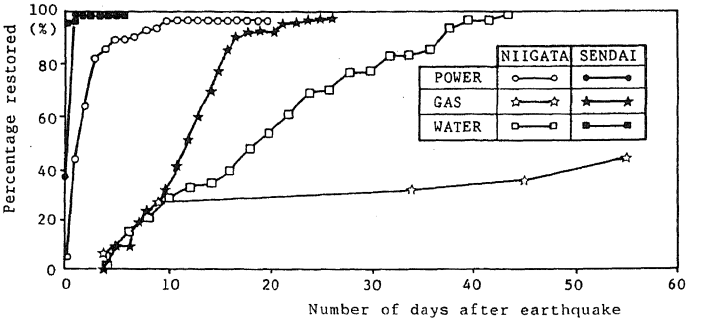

Fig. 2 Comparisons of the Restoration of Utilities after the Niigata and Miyagi-Ken-Oki Earthquakes[3]

This is the case with the Miyagi-Ken-Oki Earthquake, whose scale of damage can not be termed as "devastated" and it must be noted that the size of Sendai city is only one-twentieth of Tokyo (in population). So it could be easily imagined that a major earthquake in the Tokyo area could have by far more destructive effects. Under the situation mentioned above, Tokyo Gas Co., Ltd. has been developing restoration measures for alleviating the total adverse effects of possible future earthquakes.

SIMULATION MODEL

City Gas Supply Systems City gas is sent from the gas works to the high-pressure transmission pipelines (pressure equal to or greater than 10 kg/cm^2), or medium-pressure pipelines. District regulators are provided in the medium-pressure lines in order to supply gas to the low pressure network. The gas pressure is stepped down to less than 1 kg/cm^2 at the district regulators, and gas is then supplied to customers via low-pressure networks.

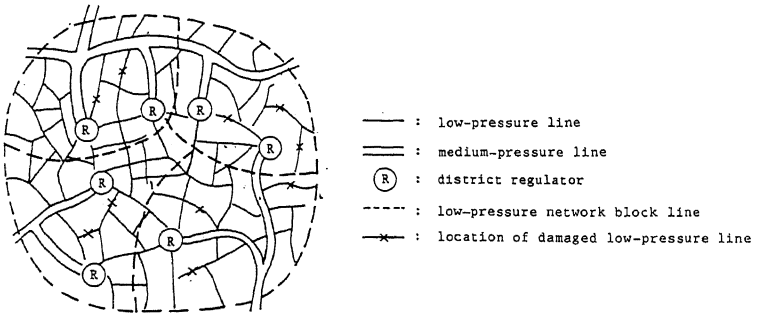

Fig. 3 Schematic Explanation of District Restoration Work

From past experience of gas pipeline damage by earthquakes and the functioning of our emergency response system, it can be summarized that restoration work mainly consists of repair of LP line damage and introduction of gas into MP networks from higher gas sources. Almost all gas customers are supplied from LP lines, gas of which is provided at the district regulators from MP lines. Therefore, before resumption of the district gas supply, restoration of MP lines must be completed up to the district regulators, as well as repairs of damaged sections of the district LP network.

Each district of the gas shutdown area -- not isolated in MP lines but in LP networks -- will have 10 to 30 district-regulators that are connected by an LP network. To facilitate the efficient location and repair of leaks, a subdivision of districts will be conducted according to population density and extent of damage. A subdivision, in which LP line repairs and resumption of gas supply are conducted is called an LP network block.

Restoration of MP Lines For the restoration of MP pipelines, regaining the serviceabilities of district regulators will be the direct objective and must be managed in connection with initiation of gas supply to the related LP network block. MP lines are restored in succession to the inspection or repair of higher gas sources such as HP lines and works. The restoration work progresses from upstream to downstream, in a tree-shaped pattern. Restoration includes injecting gas into the pipeline while confirming its safety through repeated pressure checks in each valve section from upstream to downstream. Repairs should be made if damage is discovered in the above process.

Restoration Process of LP Network Blocks Before restoration of an LP network block, Meter-Closing for all customers in the block must be completed, and all district governors must be operational. The sequence of restoration works in LP network blocks is shown in Fig. 4. In the model, each block is given such basic attributes as number of customers, length of LP pipelines, and expected number of damaged pipes.

Restoration Work Simulation Model The simulation model proceeds according to the MP and LP line restoration process shown above, with the limitation of the number of functional personnel involved in restoration work taken into account. In the simulation model, progress of restoration work is measured by the disposition of personnel, as is the case with actual restoration work. (Refer to Fig. 5.)

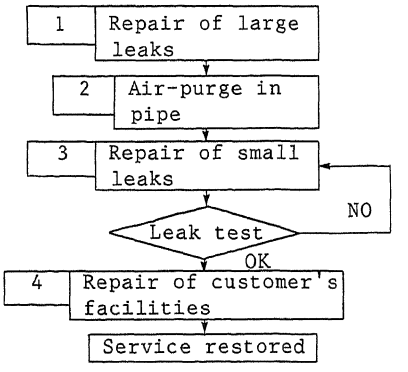

Fig. 4 Sequence of Restoration Work in Low-Pressure-Network Blocks

OPTIMUM RESTORATION WORK PLANNING SYSTEM

In the planning system, pipeline damage estimation is first of all conducted for each district in case of a target earthquake. In MP lines damage is estimated as network-link failures, while in LP lines as quantity of damage in LP blocks. Then emergency action is taken (suspension of gas supply), and resulting network serviceability is estimated. An optimum restoration plans are examined according to the case-study flow shown in Fig. 6.

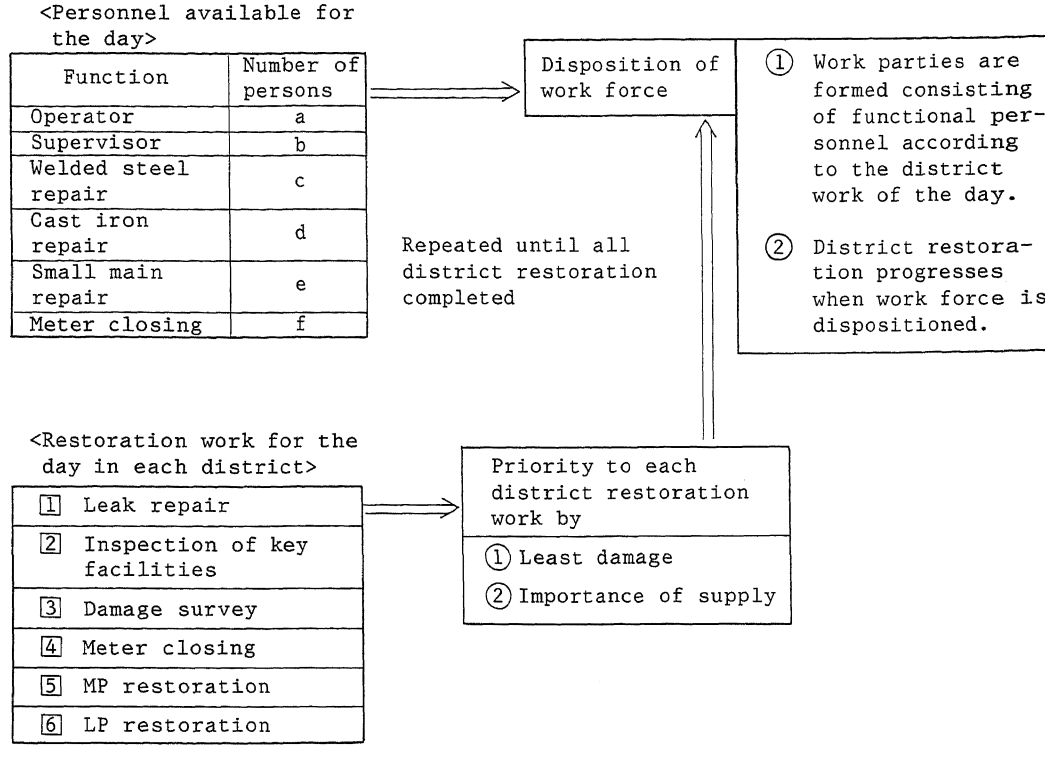

Fig. 5 Daily Personnel Disposition Model

Evaluation of each case study result is conducted by a measure shown in Fig. 7 (shaded area of "S")

Minimization of the shaded area, which represents opportunity loss of gas sales volume caused by the earthquake, is considered to be the most appropriate target for a case-study. Fig. 8 is used for identifying the lack of personnel by function, which will hinder the progress of restoration. If sufficient number of staff for each function can be allocated during the time requiring 100% involvement, there is a high possibility for the entire restoration period to be shortened.

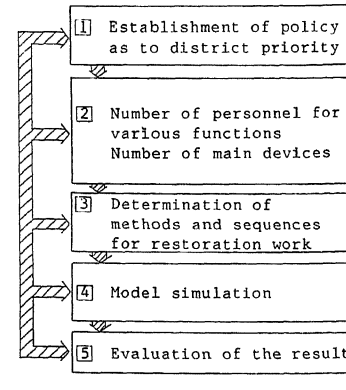

Fig. 6 Case-Study Flow for an Optimum Restoration Program

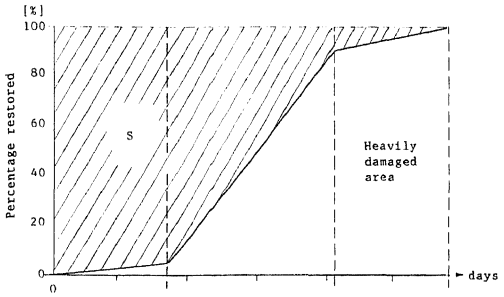

Fig. 7 Performance Graph for Evaluation of Simulation Cases (Restoration Activities)

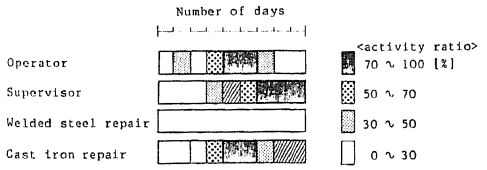

Fig. 8 Performance Graph for Evaluation of Simulation Cases (Daily Restoration Activities)

ACTUAL RESTORATION WORK CONTROL SYSTEM

Through the experience obtained from restoration work in the Miyagi-Ken-Oki and Nihonkai-Chubu Earthquakes, the system which controls daily restoration progress is considered to be highly helpful for making restoration periods shorter and the restoration itself more successful.

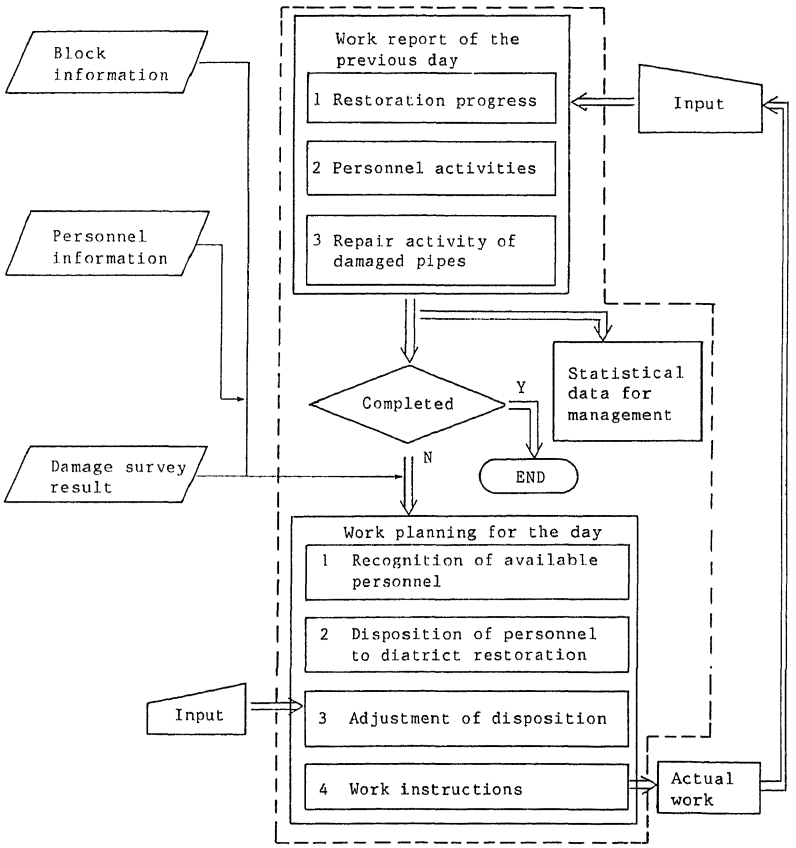

Fig. 9 Actual Restoration Work Control System

The system, called "Actual Restoration Work Control System," will help managers in charge of daily restoration planning -- many of whom got sick during past restoration activities due to overload -- to make more optimum and reliable restoration plans at reasonable time and labor.

CONCLUSION

In an analysis of the restoration work achieved in the recent Chiba-Ken-Toho-Oki earthquake (Dec. 1987), the usefulness of the above systems is examined. This restoration work was of a rather small scale, so that optimum restoration planning could be done without using a computer. Fig. 10 is a comparison of the actual restoration performance and the estimated one. The simulation result of our model shows good agreement with the actual which is considered to be near the optimum. Besides that, as a resolution of the practitioners' meeting (involved in the restoration), the data management information functions of the control system could be of great help in realizing an early and successful completion of the restoration work.

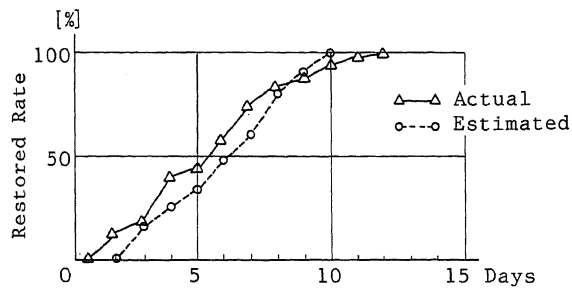

Fig. 10 Comparison of the Actual Restoration Rate and the Estimated (Chonan Area of Chiba-Ken-Toho-Oki Earthquake)

REFERENCES

1. Tokyo Metropolitan Disaster Prevention Congress "Report on the damage estimation of earthquakes in the 23 districts of Tokyo," the Metropolitan Government of Tokyo, (1978) [Japanese].
2. The Metropolitan Government of Tokyo, "Report of Basic Studies relating to the possible effects Tokyo by the Tokai," Tokyo Metropolitan Disaster Prevention Congress, (1983) [Japanese].
3. Katayama, T., "Emergency Operation of Rehabilitation of Water Supply System after Earthquakes," International Symposium on Lifeline Earthquake Engineering, ASME, (1983).
4. Japan Gas Association "The Miyagi-Ken-Oki Earthquake and City Gas Systems," Japan Gas Association, Tokyo, Apr., (1979) [Japanese].
5. Iwata, T., Saito, K., "Restoration Planning for Earthquake Damaged Gas Pipeline Network," International Symposium on Lifeline Earthquake Engineering, ASME, (1985).
6. Iwata, T., "Restoration Planning System for Earthquake-Damaged Gas Pipeline Network," presented at the U.S.- Taiwan-Japan Seminar/Workshop on Lifeline Earthquake Engineering, Taipei, Taiwan, Nov., (1985).
7. Kanto-Chuo Division (JGA) "The Chiba-Ken-Toho-Oki Earthquake and City Gas Systems," Kanto-Chuo Division (JGA), Tokyo, July, (1988) [Japanese].