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Original Paper

Practical Research on Leakage Control of Public Water Supply in a County in Northern China

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Abstract

Aiming at the prominent problems of the public water supply system in a county in northern China, such as unclear pipe network assets, low informatization level and inadequate leakage control measures, a comprehensive leakage control solution for water supply pipe networks was designed based on new-generation information technologies including GIS and IoT. The solution integrates pipe network census, district metering management, information software system development and management mechanism construction. Through the implementation of this solution, digital management of water supply pipe network assets, real-time perception of operational data and intelligent early warning were achieved. The leakage rate of the pipe network in the research area was stably controlled below 9%, which significantly improved the refined operation and intelligent management capacity of the local water supply enterprise. This research provides a referable technical path and practical paradigm for water supply leakage governance in similar small and medium-sized towns in China.

Keywords

Water supply pipe network leakage, District metering management, GIS, Intellectualization, Leakage control system

1. Introduction

1.1 Research Background

Leakage in water supply pipe networks directly causes water resource waste, increased operational costs and potential public safety risks *(Pawel & Dariusz, 2021)*. At present, numerous water supply companies in small and medium-sized towns in northern China are confronted with severe challenges in leakage control. Taking a county in Hebei Province as a case study, its water supply pipe network is a looped network with a total length of approximately 80 kilometers, the pipe diameters are mainly DN100 to DN600, and the main pipe materials are PE and UPVC. The core problems are as follows: (1) Unclear pipe network assets: The existing pipelines lack systematic and accurate data, and the management mainly relies on traditional drawings and written documents, which fails to support refined operation, maintenance and analysis of the pipe network. (2) Weak operational perception capability: There is a lack of monitoring equipment for flow, pressure and other key parameters at critical nodes of the pipe network, making it impossible to grasp the actual operational conditions of the network, and leading to delayed discovery and response to leakage incidents. (3) Backward management methods: Businesses such as pipe network inspection, maintenance and emergency repair are highly dependent on manual experience, without the support of information-based and intelligent management platforms, resulting in low management efficiency. (4) Absence of systematic leakage control strategies: A scientific district metering system and effective mechanisms for leakage assessment, location and control have not yet been established. Therefore, it is imperative to develop a systematic solution to improve the level of pipe network leakage management and realize effective control of leakage in water supply pipe networks.

1.2 Research Purposes and Significance

This study aims to design a feasible leakage control scheme for public water supply pipe networks in light of the current situation of urban water supply pipe networks, so as to effectively control pipe network leakage and upgrade the level of water supply management (*Li & Qian, 2025*). This research has direct practical significance for small and medium-sized towns in northern China to achieve the goals of water conservation and consumption reduction, ensure water supply safety, and enhance the operational efficiency of water supply enterprises.

2. Methods for Leakage Control of Water Supply Pipe Networks

2.1 Overall Governance Concept

The overall concept of this scheme is to take leakage control and reduction as the core, the application of information technologies as the support, and the construction of management systems as the starting point. Its technical framework can be summarized as “One Foundation, One Sensing System, One Software System, One Management Mechanism”:

One Foundation: Establish an accurate and dynamic GIS database for water supply pipe networks through a comprehensive pipe network census, forming the spatial data foundation for subsequent work.

One Sensing System: Construct a multi-level online monitoring network from water plants to main pipelines by deploying district metering facilities and instruments, so as to realize real-time perception of the operational status of the pipe network.

One Software System: Build a leakage management platform for water supply pipe networks to analyze, process and visually display the sensing data, thus realizing the intelligent management of the pipe network.

One Management Mechanism: Ensure the long-term and effective operation of the entire system by setting up professional teams and establishing corresponding performance appraisal and incentive mechanisms linked to leakage control effects.

2.2 Implementation Scheme for Leakage Control of Water Supply Pipe Networks

2.2.1 Pipe Network Census

The census covers the planar position and topographic data of underground water supply pipelines and their accessories within the urban area. Based on the results of underground pipeline surveys and various recorded information, digital water supply pipeline maps are compiled and drawn. Meanwhile, the collected data are processed, topologically checked and revised to form a set of accurate, complete and up-to-date pipeline data, which are then stored in the database and shared to ensure that the provided data files meet the requirements of pipe network district metering and the construction of software system databases.

Figure 1. Results of the Water Supply Pipe Network Census

2.2.2 Design of the District Metering System

District metering is the core technical measure for leakage control in this study. A total of 1 first-level metering management zone and 6 second-level pipe network metering zones were established in this scheme.

First-level zone: With the total water flow meter at the water plant outlet as the boundary, the difference between the total water supply and water sales in the entire central urban area (i.e., the water production-sales difference at the macro level) is assessed.

Second-level zones: The entire water supply area is divided into 6 independent second-level metering zones according to the pipe network topology, natural geographical boundaries and management requirements. By installing 19 flow meters on the boundary pipelines of each zone, independent metering of the inflow and outflow of each zone is realized. The zoning layout is shown in the following figure.

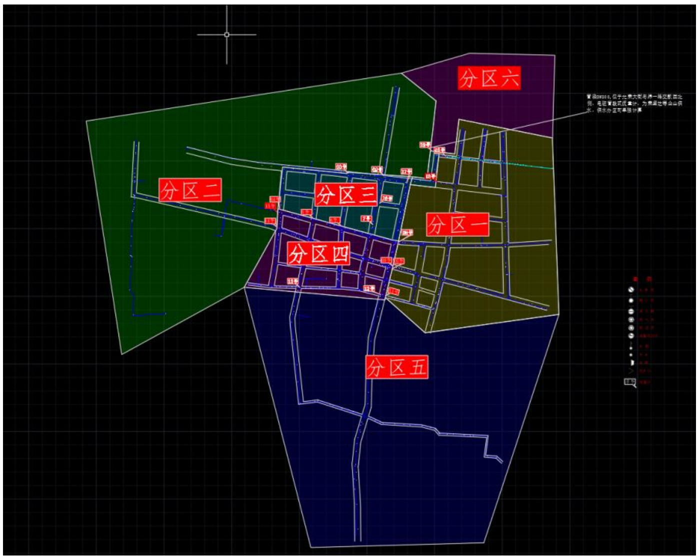

Figure 2. District Metering Layout of the Water Supply Pipe Network

The district metering relationship is shown in Table 1:

Table 1. District Metering Relationship Table

	Zone Name	Calculation Formula
1	Second-level Zone 1	No.01 + No.08 + No.09 + No.10 + No.11 + No.18
2	Second-level Zone 2	No.02 + No.03 + No.14 + No.15
3	Second-level Zone 3	Water plant output - No.01 - No.02 - No.03 - No.04 - No.05 - No.06 - No.07 - No.19 - (No.17 - No.16) - No.18
4	Second-level Zone 4	No.04 + No.05 + No.06 + No.07 + (No.17 - No.16) - No.08 - No.09 - No.10 - No.11 - No.12 - No.13 - No.14 - No.15
5	Second-level Zone 5	No.12 + No.13
6	Second-level Zone 6	No.19

2.2.3 Selection of Sensing Equipment

The selection of flow meters is critical to the reliability and economy of the district metering system. At present, flow meters are mainly classified into electromagnetic and ultrasonic types according to measurement principles, and into pipeline and insertion types according to installation methods. Electromagnetic pipeline flow meters are generally superior to insertion types in terms of metering accuracy and stability, but with higher costs. In terms of power supply and data transmission, there are two main modes: lithium battery power supply and external power supply. Lithium battery power supply ensures relatively stable data collection but has periodic maintenance requirements, while external power supply may lead to data loss due to unstable power supply.

The selection is made by comprehensively considering the metering scenarios, installation conditions and investment costs. The specific selection in this scheme is as follows: electromagnetic pipeline flow meters are adopted; the power supply modes are prioritized as municipal power supply, followed by solar power supply, and finally lithium battery power supply, with the quantities of 1, 4 and 15 respectively.

The main technical parameters of the electromagnetic flow meter are as follows: (1) Comply with the technical requirements of documents such as Verification Regulation of Electromagnetic Flowmeters (JJG1033); (2) Measurement mode: Bidirectional measurement; (3) Installation mode: Pipeline type; (4) Measured parameters: Flow rate and pressure; (5) Structure: Integrated type; (6) Accuracy class: 0.5; (7) Protection class: IP68; (8) Ambient temperature: -25°C～60°C, 5～90 %RH;(9) Power supply mode: Lithium battery (3.6V); solar power supply (3.6V lithium battery + DC 24V dual power supply); municipal power supply (AC 220V converted to DC 24V); (10) Liner: Rubber liner; (11) Electrodes: 316L stainless steel, 2～6 electrodes with built-in grounding electrode; (12) Rated pressure: GB PN10; (14) Communication mode: GPRS wireless remote transmission; (15) Power consumption: ≤1W.

2.2.4 Construction of the Information Software System

The software system is the key to exerting the performance of sensing equipment (*Andrés, David, & Alberto Jesus, 2022*). Its core is to build a leakage management platform for water supply pipe etworks, with functions including platform overview, large user management, district management, pipe network monitoring, and meter management. By deeply integrating static basic data (e.g., spatial attributes and asset ledgers of water supply pipe networks) with dynamic monitoring data (e.g., flow rate, pressure and operational status), the platform constructs a multi-dimensional and visual leakage analysis system for water supply pipe networks, realizing asset management, quantitative leakage accounting, dynamic early warning and efficient control of water supply pipe networks.

In terms of the hardware system, the existing large display screen in the central control room of the water plant is fully utilized, and servers, network and security equipment are configured to build a stable and reliable data center and operation environment.

Figure 3. Leakage Control Platform for the Water Supply Pipe Network

2.2.5 Construction of the Management Mechanism

In addition to engineering measures, this study specially emphasizes the integration of construction and management, and proposes to establish a long-term leakage control mechanism from the perspectives of manual supervision and technical protection. The local pipe network operation and maintenance department has set up professional teams for pipe network census, leakage detection and platform operation and maintenance, and established a performance appraisal and incentive mechanism linked to the effectiveness of leakage control. This mechanism stimulates employees' initiative and ensures that new technical means can be truly integrated into daily management work and continue to exert their effectiveness.

3. Conclusions

Through the comprehensive census of the water supply pipe network, this study constructed a set of national standard-compliant and high-precision spatial and attribute datasets for the water supply pipe network, which effectively solved the practical problems of incomplete data and insufficient data accuracy of the pipe network in the research area, and laid a solid data foundation for district metering and informatization construction of water supply pipe network leakage control. A pipe network district metering system of "1 first-level zone + 6 second-level zones" was constructed, and a leakage management platform for water supply pipe networks was built, realizing the deep integration of pipe network asset information, real-time monitoring data and business management processes. This practice has realized calculable water balance, evaluable regional leakage and predictable leakage risks of the pipe network. A long-term pipe network control mechanism was constructed through the combination of manual supervision and technical protection. The relevant achievements have effectively promoted the transformation of water supply pipe network management from "fuzzy perception" to "accurate visualization" and from "experience-based decision-making" to "data-driven decision-making", and comprehensively improved the level of refined leakage control and intelligent management of the regional water supply pipe network.

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