# Water supply network modeling and pipe burst analysis based on WaterGEMS

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**Abstract.** In recent years, the water supply task of urban water supply pipe network is more and more heavy, and leakage accidents of pipe network often occur, among which the most serious leakage accident is pipe burst accident. To solve this problem, this study uses WaterGEMS software to establish the topological structure of water supply pipe network, adopts the water supply pipe network model and computer technology to carry out dynamic analysis on pipe burst accident of pipe network, and uses golden section method to predict the water leakage caused by pipe burst accident state.

**Keywords:** WaterGEMS, Golden section method, Micro model of pipe network, Tube-burst accident.

## 1 Introduction

Under the current information management system, there are still many water companies whose management and technology are not enough scientific, and informationized, exposing many problems that need to be solved [1]. Based on the pipe burst accident, this study uses WaterGEMS software to build the topological structure of water supply pipe network, sort out and simplify the topological relationship, and establish the micro model of water supply pipe network. Combined with computer technology, dynamic analysis of pipe burst accident in pipe network is carried out, and golden section method is used to predict the water leakage caused by pipe burst accident.

## 2 Establishment of location model of burst pipe

### 2.1 Establish the pipe network topology

The water supply pipe network of a high-tech zone in a city is more than 300 kilometers, with daily water supply of 200,000 tons. At present, there is a water plant in the area for water supply operation. A total of 6 pumps are set up to supply water at constant pressure in turn, and 3 to 4 pumps are usually open. The sorted GIS data was imported into

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WaterGEMS software, and the basic topological structure of water supply pipe network was established and sorted out. The sorted pipe network topology of a certain area is shown in Fig.1.:

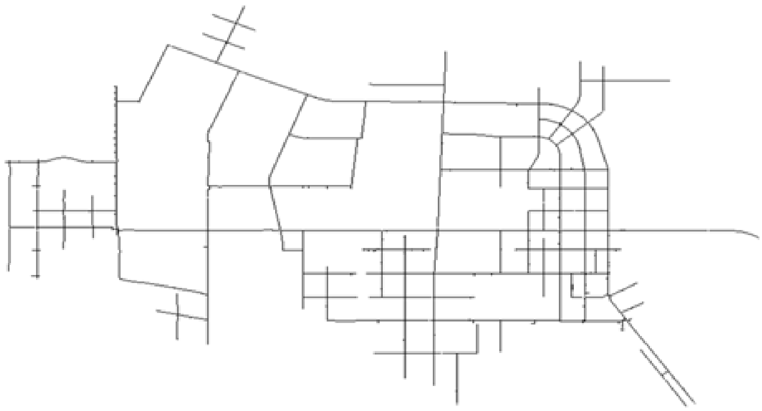

**Fig. 1.** Pipe network topology diagram.

## 2.2 Urban water supply network node flow distribution

WaterGEMS is used for pipe network modeling, and the collected basic data information of water supply pipe network is imported into the established model through GIS data interface [2], so as to allocate the amount of water used by users. The topological relationship between the established model software and users is shown in Fig. 2.:

**Fig. 2.** Topological structure diagram of water users and pipe network.

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## 2.3 Establish the mathematical model of pipe network

The flow of the nodes is distributed to the nodes of the hydraulic model of the water supply pipe network, and then the continuity equation of the pipe network, the energy equation of the water supply pipe network and the adjustment equation of the pipe network modeling are established to model and simulate the pipe segment.

When the adjustment equation is used for hydraulic calculation in modeling software, the relevant basic equations should be established in the established model first, and then the hydraulic modeling software should be used to verify and solve the established model equations [3]. By simulating the operation condition of water supply pipe network in a high-tech zone of a city, the node pressure, flow rate of pipe section, flow rate of pipe section and head loss [4] can be calculated, as shown in the figure below:

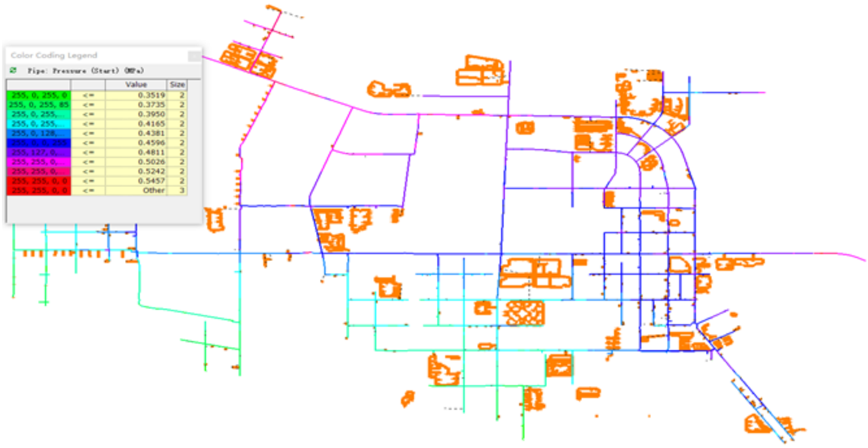


**Fig. 3.** The simulated results of hydraulic calculations of hydraulic model.

| | ID | Label | Length (Scaled) (m) | Start Node | Stop Node | Hazen-Williams C | Flow (L/s) | Velocity (m/s) | Headloss (m) |
|---|---|---|---|---|---|---|---|---|---|
| 49103: 8108 | 49103 | 8108 | 17.742 | M-519 | J-3749 | 110.0 | 88.89564 | 1.26 | 0.16521 |
| 49256: 8582 | 49256 | 8582 | 21.950 | J-3916 | J-3914 | 110.0 | 8.45501 | 1.08 | 0.44718 |
| 49277: 9830 | 49277 | 9830 | 22.517 | J-128 | J-127 | 110.0 | 31.95272 | 1.02 | 0.19811 |
| 50612: 11137 | 50612 | 11137 | 49.811 | J-2372 | J-445 | 110.0 | 477.61201 | 0.95 | 0.08943 |
| 51649: 11138 | 51649 | 11138 | 74.198 | J-2373 | J-2372 | 110.0 | 477.61201 | 0.95 | 0.12196 |
| 45726: 11366 | 45726 | 11366 | 0.481 | J-550 | M-822 | 110.0 | 7.41563 | 0.94 | 0.02989 |
| 48443: 11365 | 48443 | 11365 | 4.048 | M-822 | J-2047 | 110.0 | 7.41561 | 0.94 | 0.08312 |
| 48204: 11607 | 48204 | 11607 | 2.295 | J-399 | M-1247 | 110.0 | 250.34307 | 0.89 | 0.02372 |
| 49234: 11608 | 49234 | 11608 | 21.235 | M-1247 | J-404 | 110.0 | 250.34301 | 0.89 | 0.05473 |
| 50507: 11612 | 50507 | 11612 | 47.808 | J-2168 | J-405 | 110.0 | 250.34300 | 0.89 | 0.09823 |
| 50681: 11611 | 50681 | 11611 | 50.890 | J-404 | J-2168 | 110.0 | 250.34300 | 0.89 | 0.10329 |
| 48524: 8250 | 48524 | 8250 | 5.008 | J-273 | M-1185 | 110.0 | 248.68124 | 0.88 | 0.02779 |
| 49810: 11631 | 49810 | 11631 | 37.229 | M-1185 | J-409 | 110.0 | 248.68124 | 0.88 | 0.07990 |
| 46309: 6160 | 46309 | 6160 | 1.037 | J-2772 | M-98 | 110.0 | 6.89513 | 0.88 | 0.03315 |
| 47173: 6161 | 47173 | 6161 | 1.404 | M-98 | J-2773 | 110.0 | 6.89511 | 0.88 | 0.03795 |
| 49281: 11614 | 49281 | 11614 | 22.668 | J-405 | J-406 | 110.0 | 247.93241 | 0.88 | 0.05603 |
| 51296: 11618 | 51296 | 11618 | 62.268 | J-406 | J-2171 | 110.0 | 247.93238 | 0.88 | 0.11971 |
| 51101: 11619 | 51101 | 11619 | 58.154 | J-2171 | J-407 | 110.0 | 247.47546 | 0.88 | 0.11272 |
| 50373: 11639 | 50373 | 11639 | 45.267 | J-2180 | J-410 | 110.0 | 247.31222 | 0.87 | 0.09194 |
| 51207: 11635 | 51207 | 11635 | 60.307 | J-409 | J-2180 | 110.0 | 247.31222 | 0.87 | 0.11603 |
| 51097: 11622 | 51097 | 11622 | 57.991 | J-407 | J-2172 | 110.0 | 247.23471 | 0.87 | 0.11224 |
| 50878: 11623 | 50878 | 11623 | 54.436 | J-2172 | J-408 | 110.0 | 247.23192 | 0.87 | 0.10656 |
| 48990: 11628 | 48990 | 11628 | 14.242 | J-408 | J-2175 | 110.0 | 246.89186 | 0.87 | 0.04214 |
| 49083: 11630 | 49083 | 11630 | 16.948 | J-2176 | J-274 | 110.0 | 246.89186 | 0.87 | 0.04647 |
| 50162: 11629 | 50162 | 11629 | 42.207 | J-2175 | J-2176 | 110.0 | 246.89186 | 0.87 | 0.08677 |
| 48705: 11640 | 48705 | 11640 | 7.046 | J-410 | J-411 | 110.0 | 246.35408 | 0.87 | 0.03053 |
| 51054: 11644 | 51054 | 11644 | 57.155 | J-411 | J-2245 | 110.0 | 246.34897 | 0.87 | 0.11017 |
| 51130: 11778 | 51130 | 11778 | 58.741 | J-2245 | J-412 | 110.0 | 246.34897 | 0.87 | 0.11268 |
| 48750: 11408 | 48750 | 11408 | 7.812 | J-412 | J-413 | 110.0 | 246.19944 | 0.87 | 0.03170 |
| 49742: 10912 | 49742 | 10912 | 35.570 | J-413 | J-2187 | 110.0 | 246.19942 | 0.87 | 0.07577 |
| 50127: 10913 | 50127 | 10913 | 41.709 | J-2187 | J-534 | 110.0 | 245.45511 | 0.87 | 0.08504 |
| 47231: 7408 | 47231 | 7408 | 1.430 | J-3363 | M-296 | 110.0 | 6.74255 | 0.86 | 0.03666 |
| 47537: 8707 | 47537 | 8707 | 1.564 | J-571 | J-3363 | 110.0 | 6.74255 | 0.86 | 0.03834 |
| 46924: 7409 | 46924 | 7409 | 1.314 | M-296 | J-3364 | 110.0 | 6.74252 | 0.86 | 0.03522 |
| 48818: 8251 | 48818 | 8251 | 9.724 | M-1186 | J-273 | 110.0 | 241.78890 | 0.86 | 0.03356 |
| 48014: 8254 | 48014 | 8254 | 1.988 | J-274 | J-1613 | 110.0 | 241.78887 | 0.86 | 0.02167 |
| 48085: 8252 | 48085 | 8252 | 2.071 | J-1612 | M-1186 | 110.0 | 241.78887 | 0.86 | 0.02180 |
| 49238: 8253 | 49238 | 8253 | 21.344 | J-1613 | J-1612 | 110.0 | 241.78887 | 0.86 | 0.05138 |

**Fig. 4.** Water supply network hydraulic model pipeline simulation data table of the city.

### 2.4 Location of pipe burst accident point

It is found that the pressure drop in the area of pipe burst accident is greater than that in other areas by simulating the distribution of pipe burst accident and the variation of pipe pressure in the area of pipe burst accident. In addition, when the pipe burst occurs, due to the huge pressure difference between the inside and outside of the pipe, the ejected water will rub against the pipe wall to produce vibration and impact with the surrounding soil to produce sound waves, namely leakage signals [5].

Due to time delay and large amount of water leakage, the traditional acoustic positioning method is usually combined with the mean square error statistical index to evaluate the location of pipe network accident, and the mean absolute error statistical index and mean relative error statistical index are used as auxiliary indexes to determine.

### 2.5 Estimation of water loss

According to the city water supply in the zone, the water leakage of a golden interval step by step is determined, and the calculated leakage of water is used as the water supply network simulated calculation of the leakage of water at the time of the accident. Meanwhile the pressure value of the pressure measuring point and pressure measuring point of the pressure value of the mean square error at the time of accident in the pipe network under the actual working conditions are calculated, until the calculated accuracy meets the required range of mean square deviation.

### 2.6 The example analysis

The average daily water supply of the water plant in the high-tech zone of a city is 200,000 $m^3/d$. It is assumed that the accident occurred at the node position of -J-3606 in the fourth zone at 3:00 PM, and the leakage flow of water is 22L/s. According to the water supply capacity under normal working conditions, the interval of water leakage can be estimated as (0.01, 190) (unit L/s, the same below), according to the formula (1) and (2).

$$x3=x1+0.382\times(x2-x1) \tag{1}$$

$$x4=x1+0.618\times(x2-x1) \tag{2}$$

The formula can be used to calculate the water leakage at the golden section point as 72.586L/s and 117.424L/s respectively. Then, the mean relative error, mean absolute error and mean square error of the four working conditions are compared, and the results are shown in Table 1.:

**Table 1.** Leakage interval (0.01,190) comparison table of leakage loss error.

| Leakage flow | 0.01L/s | 72.586L/s | 117.424L/s | 190L/s |
|---|---|---|---|---|
| Mean relative error | 1.181 | 1.016 | 2.469 | 4.989 |
| Mean absolute error | 4.079 | 3.782 | 9.724 | 21.894 |
| Mean square error | 1.193 | 1.031 | 2.483 | 4.992 |

Determine the two numbers in the data with smaller mean square error, as a new leakage interval. According to the golden point formula, compare the error of leakage water again, make the above comparison, continuously shorten the leakage area, and list of all pressure testing points in the accident area and mean square error of points of the simulating condition point and the actual condition point at the time of pipe explosion accidents according to the calculated value of each point shown in Table 2.:

It can be seen from Table 2. that the mean square deviation of pressure monitoring points of No.4 and No.7 is 1.04 and 1.03 respectively, which are close to and minimum. According to the principle of leak location: When pipe somewhere tube-burst accident occurs suddenly, the pressure value around the leakage point drops sharply, causing a pressure difference of the pipeline inside and outside, which can determine the actual location of the pipe explosion accident between 4 and 7. Taking No. 4 and No. 7 as the accident area, at this time the golden section method can be used to determine again, with leakage of water set (0.01, 40.818) as the initial range of leakage water quantity, and then calculate again. By comparing the mean square error, it can be concluded that the mean square error is the smallest when the leakage water quantity is 21.547L/s, indicating that the actual leakage water quantity is 21.547L/s when the pipe bursting accident occurs.

**Table 2.** Comparison table of mean square variance corresponding to detonating accidents at every monitoring point in an accident area.

| The serial number | Position of monitoring point | Mean square error |
|---|---|---|
| 1 | High-tech Zone Management Committee | 1.07 |
| 2 | Hongsen Industrial Co., LTD | 1.26 |
| 3 | Changming middle school | 1.42 |
| 4 | Taigu Coca-Cola Beverage Co. LTD | 1.04 |
| 5 | Fairview State Property Development Co. LTD | 1.24 |
| 6 | XX University | 1.34 |
| 7 | Hongyu Cigarette Machine Accessories Co., LTD | 1.03 |
| 8 | Watch table of Cuilinyuan | 1.16 |
| 9 | Shiqi measurement and Control Technology Co., LTD | 1.53 |
| 10 | Zhengxing Technology Company Limited | 1.19 |
| 11 | Second hydrant on Yulan street and Shinan Road north | 1.23 |
| 12 | Yuanda Biopharmaceutical Co. LTD | 1.19 |
| 13 | Fairview State Property Development Co. LTD 2 | 2.62 |
| 14 | XX University Experimental Primary School | 2.60 |

From the analysis of the above model, it can be seen that the red represents the suspicious accident point, and the purple mark represents the actual accident spot. Therefore, the model through the use of positioning the accident point can greatly reduce the range of pipe explosion accident, and by using golden section method to find the water leakage can be accurate in the event of a tube-burst accident.

## 3 Conclusion

WaterGEMS is used to establish the topological structure of the urban water supply pipe network, and then the hydraulic calculation of the water supply pipe network is carried out according to the established micro model, and the water leakage corresponding to each working point is calculated by using the golden section method, and then comparing the mean square error of the simulated data and the actual data at each working point, leakage water generated can be accurately in the event of pipe explosion accident. The results show that this method can effectively solve the problems encountered in the actual operation of water supply network and has good practical significance.

**Fig. 5.** Explosion accident points analyzed by pipe burst Location model and the actual explosion accident point.

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