An Analysis on Optimization of Living and Fire Water Supply Systems of Small High-Rise Residential Blocks

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Abstract: With the rapid growth of our population, the demand for housing quality of urban residents has been gradually raised. Due to the shortage of traditional multi-storey residential and high-rise residential, it is difficult to achieve a balance between quality and quantity of housing. As a result, a new type of residential building, small high-rise residential building, came into being. The so-called small high-rise residential generally refers to buildings of 7 to 11 layers, including unit buildings and tower buildings. In view of the problems existing in the water supply system of the small high-rise residential blocks, this paper presents a new system, namely a combined system of living and fire water supply. This system can be, according to the available pressure of municipal pipeline network, divided into three types, and has been optimized in order to fully utilize the municipal pipeline network pressure.

1. Introduction
Housing is one of the most important necessities in people's lives. People’s standard of living reflects the economic and social development of a country. Small high-rise residential buildings have the following characteristics: First, small-sized high-rise residential buildings. They are close in design to multi-layer buildings, and have large spacing, good ventilation and lighting conditions. In particular, some excellent examples of small high-rise buildings are optimized in the allocation of water, electricity, hot and cold water, and allow therefore comfortable living conditions and high security levels. Second, many small high-rises have a good vision and beautiful scenery, which are difficult to achieve for traditional high-rise buildings. According to a survey, single small high-rises are most welcomed by real estate developers and buyers in large and medium-sized cities, and this type of residential building social, economic and ecological demands of residents. In recent years, with the dramatic development of the real estate industry, the idea of small high-rises blossomed across the country, especially in the southern part of China.

Due to the growing volume of real estate sales, the number of new buildings is increasing. Past experience has shown that part of the norms and standards may not apply in certain situations. Besides, complicated design of water pipeline in residential blocks, different pipeline length and head loss all make it necessary to carry out research and optimization for living water supply and fire water supply system design in such special residential blocks.
2 Traditional Water Supply Design in Residential Blocks

2.1 High Water Tank System
The high water system composes of underground cistern, centrifugal pump and high water tank. The key to set partition water tank, which stores water, adjusts water level stabilizes water pressure, at the proper location. High water tank is fed by the centrifugal pump installed in the basement. This system is commonly used in the relatively early years.

This system has four patterns: parallel mode, series mode, break-pressure cistern mode and pressure reducing valve mode. The parallel mode is shown in Fig. 1, and series mode in fig. 2.

2.2 Variable-Frequency Pump System
Frequency control pump system changes its speed during water supply process to maintain an effective working condition of the pump. Its biggest advantage is that, without the high water tank, secondary pollution is prevented. Also, it saves construction area, increases economic efficiency, and enables a
neater design of the building. The disadvantage is the need for more expensive frequency control motor device.

This system has two patterns, series mode and pressure reducing valve mode. The later is more suitable for small high-rise.

2.3 Air Pressure Tank System
This system has two patterns: series mode and pressure reducing valve mode. As shown in Fig. 6 and 7.
2.4 Pipeline Overlay System
Pipeline overlay water supply system, also known as non-negative pressure water supply system, is a new system developed in recent years. It is particularly suitable for small high-rises. It is invented based on variable-frequency speed-control equipment, and features high energy efficiency, hygienic operation, easy installation, easy maintenance and so on. Pipeline overlay water supply system composes mainly of steady-flow compensator, water pump and intelligent control system. The water supply mode is shown in Fig. 8.

![Fig. 8 Pipeline Overlay Water Supply System](image)

2.5 Fire Water Supply System of Temporary High Pressure
Fig. 9: one-time water supply system of indoor hydrant. Fig. 10: separate water supply system of indoor hydrant. Fig. 11: series mode of fire hydrant water supply system.

![Fig. 9: one-time water supply system.](image)  ![Fig. 10: separate water supply system.](image)
2.6 Traditional combined living and fire water supply system
There are two main types of combined living and fire water supply, one is with a roof water tank, as shown in Fig. 12, the other without one, as shown in Fig. 13.
3. Improved Combined Living and Fire Water Supply System

a. When the municipal pipeline network pressure $P$ is greater than 0.5MPa, it meets the needs of living water and fire hydrant water supply system in small high-rises without any additional pressure pumps and storage tanks, therefore a design of direct water supply can be used. The system is suitable for constant pressure fire water supply system, usually does not need roof fire water tank. See Fig. 14.

Fig. 14  Direct water supply system

Fig. 12 combined system with roof water tank Fig. 13 combined system without roof water tank
b. When P is between 0.1 and 0.5MPa, a centralized pump room water supply system can be used. In order to prevent the pressure of the outdoor pipe network from rising too high, the covered radius of the centralized water supply pump room should not exceed 150m. Here, two pump rooms can be used for water supply. The pipeline is connected to each other. See Fig. 15.

Fig. 15 Two-partition system

c. When P is less than 0.1MPa, if the level of the partition system is kept, then, due to low pressure level, the energy efficiency is low and a considerable part of outdoor pipes are wasted. So it is better to supply pressurized water to the residents, and set a shared cistern for indoor and outdoor fire and living water. The outdoor pipelines are connected to fire hydrants, and one set of pump adapter, which is connected to the outdoor municipal fire water pipeline network, are shared by several buildings. See Fig. 16.

Fig.16  The whole pressurizing water supply system

In order to prevent misuse of water for fire protection, the use of fire pumps should be decided based on different water pumps and fire pumps. There are normally three designs for cistern outlet:

a. Air duct mode. See Fig. 17
4. Project Overview

A small high-rise residential block, with a total area of 140,000 square meters, includes 20 small high-rise residential buildings, which all have 10 layers. The municipal pipe network pressure is about 0.1 MPa. A conventional method is shown in Fig. 20, the improved living and fire water supply system is shown in Fig. 21.
Fig. 20  Conventional method

Fig. 21  Improved combined system
5 Optimization of Water Supply System

5.1 Comprehensive Assessment Model
This model has four levels. On the top is Objective Level A, and then Criterion Level B, Sub-criterion Level C and Plan Level D. See Fig. 22

![Comprehensive assessment model](image)

Fig. 22 Comprehensive assessment model

5.2 Structure Judgment Matrix and Result Analysis

① Relative Weight of Criterion Level B and Objective Level A

|     | A       | B1   | B2   | B3   | W      |
|-----|---------|------|------|------|--------|
| B1  | 1.0     | 1.0  | 3.0  | 0.4298|
| B2  | 1.0     | 1.0  | 3.0  | 0.4298|
| B3  | 1/3     | 1/3  | 1.0  | 0.1438|

② Relative Weight of Sub-criterion Level C and Criterion Level B

|     | B1  | C1  | C2  | C3  | C4  | W    |
|-----|-----|-----|-----|-----|-----|------|
| C1  | 1.0 | 1/5 | 1/3 | 1.0 |     | 0.097|
| C2  | 5.0 | 1.0 | 3.0 | 5.0 |     | 0.568|
| C3  | 3.0 | 1/3 | 1.0 | 3.0 |     | 0.239|
| C4  | 1.0 | 1/5 | 1/3 | 1.0 |     | 0.094|
### Table 3  C5-C8 and B2 Relative Weight

| B2 | C5 | C6 | C7 | C8 | W    |
|----|----|----|----|----|------|
| C5 | 1.0| 3.0| 5.0| 1/3| 0.265|
| C6 | 1/3| 1.0| 3.0| 1/5| 0.124|
| C7 | 3.0| 1/3| 1.0| 1/9| 0.054|
| C8 | 1.0| 5.0| 9.0| 1.0| 0.585|

### Table 4  C9-C11 and B3 Relative Weight

| B3 | C9 | C10 | C11 | W    |
|----|----|-----|-----|------|
| C9 | 1.0| 1.0 | 1/3 | 0.4395|
| C10| 1/3| 1/3 | 3.0 | 0.4395|
| C11| 1/3| 1/3 | 1.0 | 0.1455|

③Total ordering of Sub-criterion Level C and Objective Level A

### Table 5  Total ordering of Level C and Level A

| B | C | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C total ordering |
|---|---|----|----|----|----|----|----|----|----|----|-----|-----|-----------------|
| C1 | 0.4298 | 0.4298 | 0.1438 | 0.1438 | 0.0438 | 0.0613 | 0.0488 | 0.0214 | 0.0488 | 0.0220 | 0.0412 | 0.1068 | 0.0421 |
| C2 | 0.5584 | - | - | 0.2395 | - | - | 0.0412 | - | - | - | - | - | - |
| C3 | 0.0966 | - | - | - | - | - | - | - | - | - | - | - | - |
| C4 | 0.2495 | - | - | - | - | - | - | - | - | - | - | - | - |
| C5 | 0.124 | - | - | 0.249 | - | 0.0488 | - | 0.0214 | - | 0.0488 | - | 0.1068 | - | 0.0421 |
| C6 | 0.264 | - | - | 0.249 | - | 0.0488 | - | 0.0214 | - | 0.0488 | - | 0.1068 | - | 0.0421 |
| C7 | 0.054 | - | - | 0.249 | - | 0.0488 | - | 0.0214 | - | 0.0488 | - | 0.1068 | - | 0.0421 |
| C8 | 1.0 | - | - | 0.249 | - | 0.0488 | - | 0.0214 | - | 0.0488 | - | 0.1068 | - | 0.0421 |
| C9 | 1.0 | 1.0 | 1/3 | 0.4395 | 0.4395 | 0.1438 | 0.0438 | 0.0613 | 0.0488 | 0.0220 | 0.0412 | 0.1068 | 0.0421 |
| C10| 1/3 | 1/3 | 3.0 | 0.4395 | 0.4395 | 0.1438 | 0.0438 | 0.0613 | 0.0488 | 0.0220 | 0.0412 | 0.1068 | 0.0421 |
| C11| 1/3 | 1/3 | 1.0 | 0.1438 | 0.0438 | 0.0613 | 0.0488 | 0.0220 | 0.0412 | 0.1068 | 0.0421 |

④Relative Weight of Plan Level D and Objective Level A

### Table 6  Level D and Level A Relative Weight

| C: | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 |
|----|----|----|----|----|----|----|----|----|----|-----|-----|
| D: | 0.042 | 0.239 | 0.106 | 0.042 | 0.109 | 0.048 | 0.022 | 0.249 | 0.061 | 0.062 | 0.020 |
| D1 | 0.125 | 0.500 | 0.382 | 0.666 | 0.520 | 0.833 | 0.857 | 0.820 | 0.820 | 0.5799 |
| D2 | 0.167 | 0.875 | 0.500 | 0.166 | 0.333 | 0.750 | 0.533 | 0.167 | 0.167 | 0.220 | 0.220 |

It can be seen from the combination weight that Plan D1 is better than Plan D2. Therefore, for water supply system of small high-rise residential blocks, D1 is the ideal plan.

### 6 Conclusion

This paper proposes a new design concept for small high-rise residential blocks indoor and outdoor combined living and fire water supply system that ensures water safety at the same time. Studies have shown that simple system design can reduce the use of outdoor pipelines, and that the number of equipment required, and initial investment that comes with that, can be cut down when using shared variable-frequency pumps for living and fire water supply. The combined system can improve the use of fire hydrant water and reduce the number of equipment to make system more stable. And since the fire...
pump is steadily in operation, the fire safety level is improved and thus creating better living conditions.

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