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Flexible Hose Lining Applies in the Complex Site of Extreme Long Length and Numerous Bends

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Abstract: Trenchless technologies apply to potable water pipeline was introduced to Taiwan in 1996. Most of them provide various pipe rehabilitation solutions for water mains. However, rehabilitation of small and medium diameters has always problems to pipeline utilities. In 2017, ISO-11295 introduced a new technology called "Lining with inserted hose" (flexible hose Sliplining) provide a good solution for small and medium dimeter rehabilitation Zhishan Road at Wai Shuangxi area in Shilin zone relies on the water supply from the Shuangxi Water Treatment Plant. Water source of Shuangxi is greatly affected by the dry season. Water supply jurisdiction lacks a backup mechanism, and the risk of water supply is relatively high. Therefore, to establish a backup water source for the Shuangxi Water Treatment Plant. Taipei Water Department intend to apply the water from the Huaxing Distributing Tank as the backup water source for the Shuangxi Water Treatment Plant. A 220mm diameter high-strength and flexible hose liner slip into the old Shuangxi raw water pipeline which path in the Jungle. Depending on the needs of the Shuangxi Water Treatment Plant, intermittently pressurized to improve the backup capacity of the water supply in the Shuangxi area and ensure the stability of the water supply. Case study describes a long length and multi-curved pulling project in the special surroundings of Jungle. Heavy machinery is impossible to approach and cannot provide any assistance, which is extremely difficult. Thanks for the anti-friction improvement facilities and following pulling strategies. The project finally completed. The project separated to two pulling sections that pass through an inverted siphons each, included a 52 meters elevation difference one. The sections lengths are 1,600M and 1,300M respectively, and connected the two sections by 120M open cut. The 1600M long length pulling is the longest single pulling case in the world by Lining with inserted hose.

Keywords: Trenchless Technologies, Pipeline Rehabilitation, Backup Water Source

I. Introduction

The Shuangxi Water Purification Plant supplies 2,000 m3 of water daily. Shuangxi raw pipe was constructed in 1954, total length is 3,545M. It is pipeline composed two 600mm RCP parallel pipes, connected with total 54 chambers and transport raw water gravitationally to a slow filtration plant. Following the completion of the Shuangxi Water Purification Plant in 1982, the old raw water pipelines were abandoned. Now a day, due to climate change, raw water intake to Shuangxi Water Treatment Plant can become highly turbid due to heavy rainstorms or become scarce during droughts. As a solution, Taipei Water Department planned to apply the clean water from the Huahxing Water Distribution tank as the backup water source for the Shuangxi Water Treatment Plant. A new flexible hose liner inserted into the raw water pipeline, pump the clean water from Huahxing Water Distribution tank to the Shuangxi Water Treatment Plant to ensure water supply Stability

II. Project execution

2.1 Project overview

The construction scope of Shuangxi Water Treatment Plant Backup Water Supply Pipe Turnkey Project required insertion a pipe which diameter should be over 220mmn into the old pipeline comprised two parallel § 600-mm reinforced concrete pipes (RCPs). Total insertion length is about 2,900M, plus open cut 120M to bury 300mm DIP at the middle cut-off section. The elevation of the entire line is gentle flat , but curvedly , except two inverted siphon sections with elevation differences, behind the National Palace Museum (up to 52 meters in elevation), and Jingque Stream (See fig.1.1)The raw water pipes were deployed on the multiple bends hillside. Due to the complex terrain, Only two access can carry tools and handy machine by man power. the deployment of large engineering equipment was difficult. Consequently, the project is more challenging than laying pipes in urban area. In this case, the contractor was responsible for reconnoitering the site and developing construction plans. (Figs. 2-1 -1& 2-1-2).

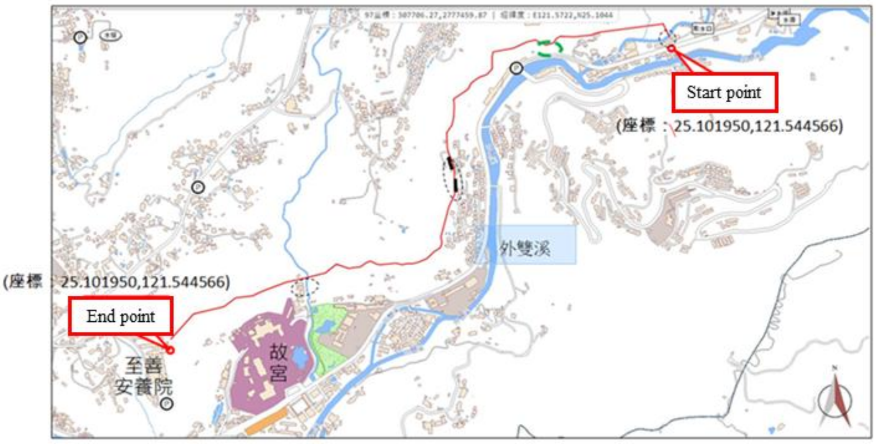
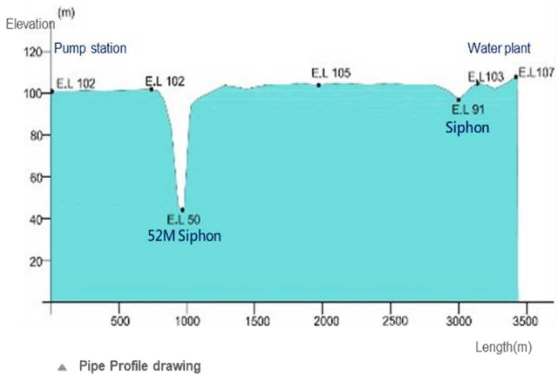


Fig. 2-1-1. Course of old pipeline



Main parameters	
Pipe Constructed	1954
Pipe Diameter	600 mm
Pipe Material	RCP
Chambers	54
Pipe Deactived	1987
Others	2 parallel pipes

Fig. 2-1-2. Pipeline profile and information

Fig. 2-1-3. Photos of ∮700-mm cast iron pipe, parallel ∮600-mm reinforced concrete pipes, and manholes

2.2 Project Planning

A diameter 224mm with thickness of 6.3 mm loose-fit flexible hose liner was selected. The liner pipe comprised a wear-resistant polyethylene (PE) outer shell, a middle layer made of high-strength aramid fiber, and a PE inner layer. The liner was flexible, lightweight, and tension-resistant flexible hose liner

Pulling work is arranged for two operation sections, which are 1,600M and 1,300M respectively. The middle cut-off section will apply 300mm DIP pipe by open cut. After the flexible liner is completed insertion process into existed pipe. Connecting DIP by using the connectors flanges (Fig. 2-2).

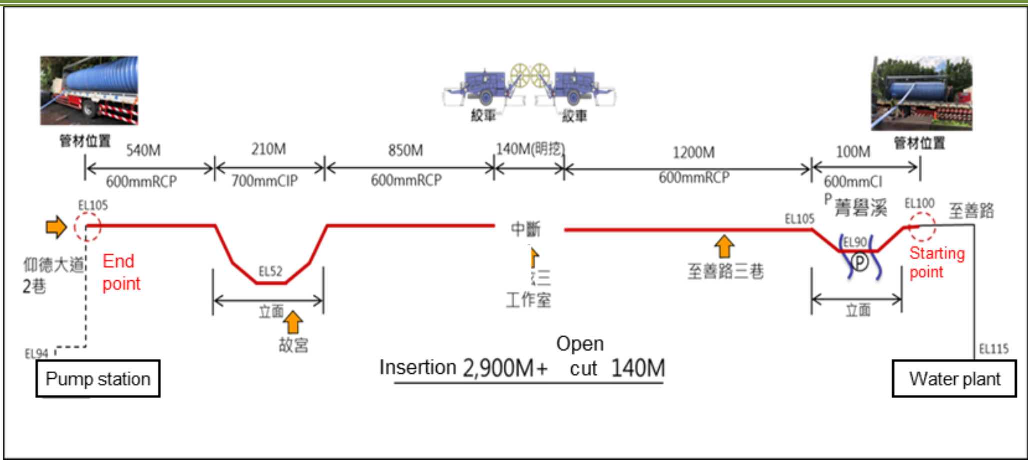


Fig. 2-2. Pipe length and winch placement.

2.3 Main design issues and countermeasures

The system supplier calculated maximum pulling force is 6.1 tons initially based on 0.5 friction coefficient and 1.3 safety factors. Therefore, a 10-ton pulling winch was arranged to meets the pulling force requirements. Wiping vegetable oil on the fold liner as lubrication material is necessary to reduce friction (Fig. 2.3)。

Fig.2.3 10-ton pulling winch and liner insertion

2.4 Fitting installation

Connectors are specially developed termination fittings which was bolt-connected to the flexible liner with connectors and mounted on the walls of a manhole chamber (Figs. 2-4-1 2-4-2 &2-4-3).

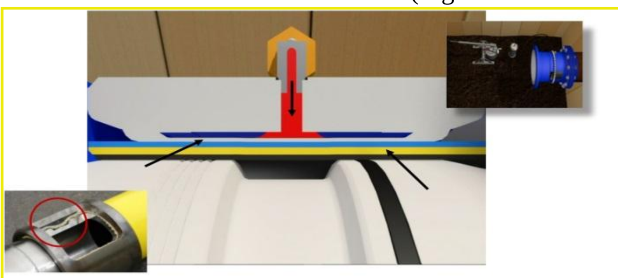


Fig.2-4-1 Connectors are specially developed termination fittings

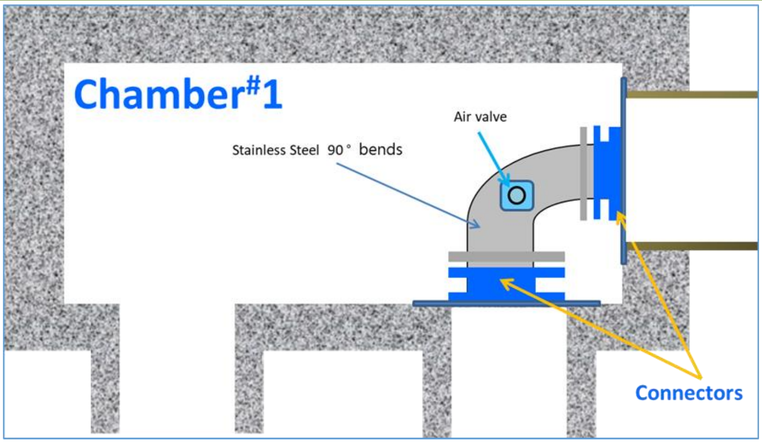


Fig. 2-4-2. Stainless-steel tube mounted on manhole walls.

Fig. 2-4-3. Short stainless-steel tube mounted to steel plates on manhole walls.

III. Challenges and Solution

The major challenges of this project included pulling a liner through the old pipeline for 1600 m, and addressing the friction caused by the bends encountered along the path. These challenges are discussed in the subsequent subsections.

3.1 Challenges: Long distance pulling and miscalculation pulling force

1. Requiring more powerful pulling capacity winch

Liner weigh is 4 kg/m. In section 1, Initially pulling force was estimated at 6.1 tons, but overlooked challenges such as mountainous terrain and curved pipes. The concrete raw water pipeline was buried along the curved of the mountain edge that created hundreds of bends, also chambers connected to the existed pipeline has a great curvature change (See fig 3-1-1 &3-1-2)。A site inspection revealed the presence of 93 bends and 25 manhole sites with a significant height difference Given these factors, a pulling force of over 16 tons was required.

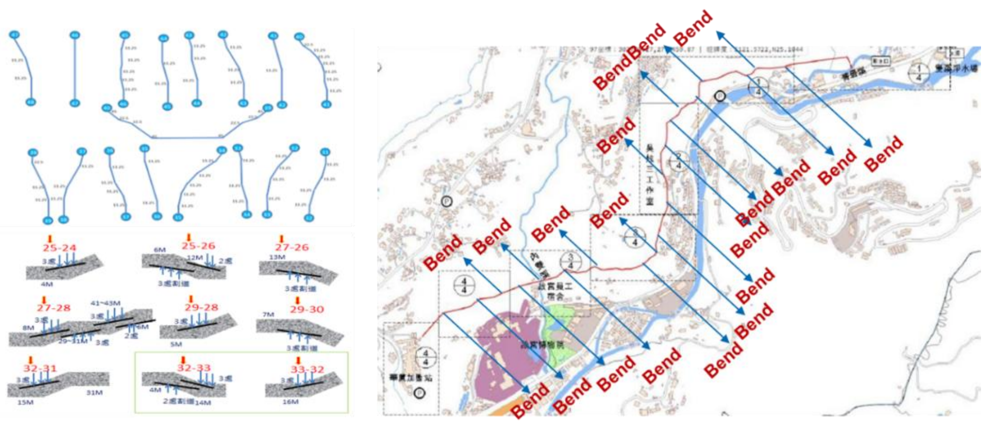


Fig. 3-1-1. Extreme Long Length,Numerous bends and manhole angles.

Fig. 3-1-2. Analysis of on-site pipe curvature.

2. Ensuring winch pulling force under maximum liner allowable stress

The winch should maintain under 8 tons and its pulling speed should keep under 5 m/min to meet the maximum design tensile strength of the liner.

3. Necessity of avoiding line wear

When a pipe is pulled over a long distance, it would experience scraping against uneven concrete surfaces and cause the cable block in the slot. Also this scraping causes considerable damage to the liner. Therefore, preventing pipe wear was a challenge in this project.

Fig. 3-1-3. Numerous bends cause slot on the RCP and scrap liner

4. Animal path access cannot apply construction machinery

The whole existed pipeline was located on the hillside, and heavy machinery cannot reach. Four 45° elbows located at two fixed blocks at the both sides of middle of the inverted siphon behind the hill of National Palace Museum caused the extra tensile load that did not expect from beginning. (Fig.3-2-1&3-2-2)

Fig. 3-2-1. Complex Terrain

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Fig. 3-2-2.4 extra 45° elbows at the siphon caused extra tensile load

Reconfirm the data of terrain, contour line. Re-measure the coordinate of GIS, also both sides angles of the chambers. Integrating the changes in the curvature of the entire pipeline. Finally, the estimated pulling force exceeds 16 tons, which has exceeded the limitation of pulling force. To consider the friction reduction is very necessary. Therefore, setup pulleys at the chambers to change to rotational friction when pulling. (See fig. 3-2-3)

While pulling, the winch cable and liner had to pass through bends, manholes, and inverted siphon pipes. At the bends, the liner pipe was exposed to axial tensile force and normal force. The action of these forces created considerable friction, necessitating a strong pulling force. To reduce friction, strategies were adopted as follows.

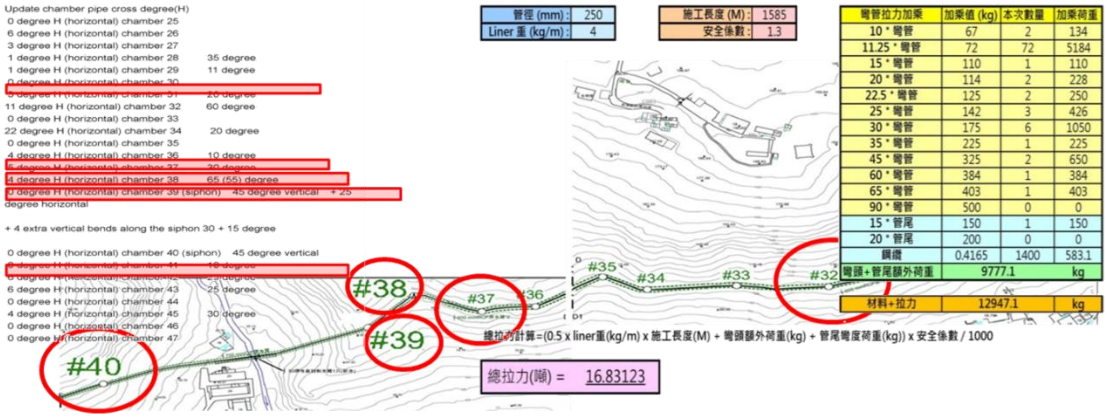

Fig. 3-2-3 Integrating the changes in the curvature pulling force exceeds the limitation of pulling force.

3.3 Solutions

1. Manhole rollers

(1) Rollers mounted on arch brackets (Fig. 3-3-1) were installed on the sidewall of manhole chambers to prevent the liner from scraping against the inner surface of the old pipeline.

(2) Roller sets (Fig. 3-3-2) were installed on the floor of manhole chambers to reduce the contact between the liner and the old pipeline.

(3) Rollers lined up in a curve (Fig. 3-3-3) were installed on the sidewall of manhole chambers to allow the line to pass a bend with minimum friction.

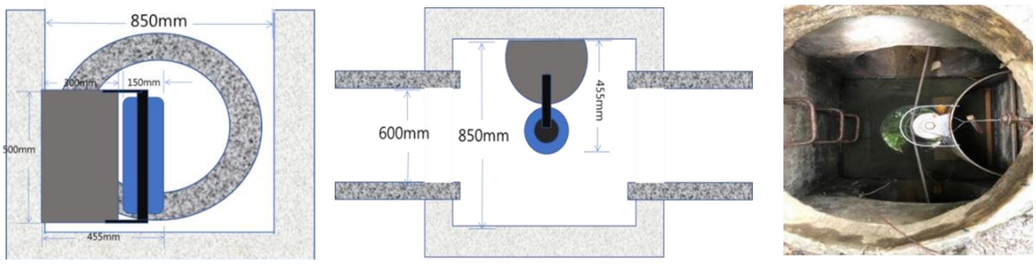

Fig. 3-3-1. Steel roller installed on sidewall of manhole chambers.

Fig. 3-3-2. Roller sets installed on the floor of manhole chambers

Fig. 3-3-3. Roller set comprising rollers lined up in a curve.

2. Rollers and friction pads

Simple rollers were installed at bends to facilitate the passage of the winch cable. Similarly, rollers or friction pads (or oil-absorbing sponges) were placed at bends for liner (Fig. 3-3-4).

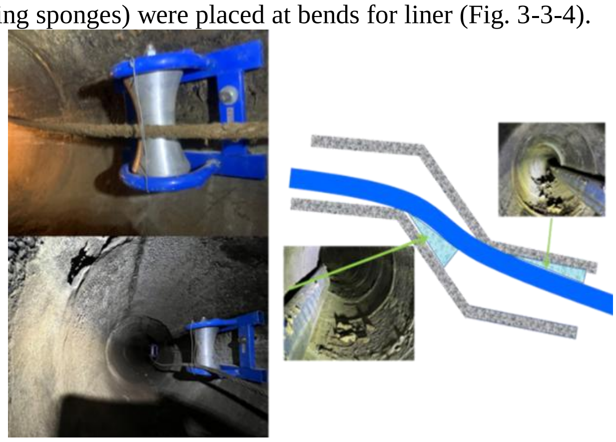

Fig. 3-3-4. Simple rollers and friction pads.

3. Duct tubes and rollers in inverted siphon pipes

In the manholes, a ∮300mm duct tube was installed to provide support to the liner pipe, thereby allowing the liner to enter the ∮700mm CIP at a 45° downward angle (Fig. 3-3-5 &3-3-6).

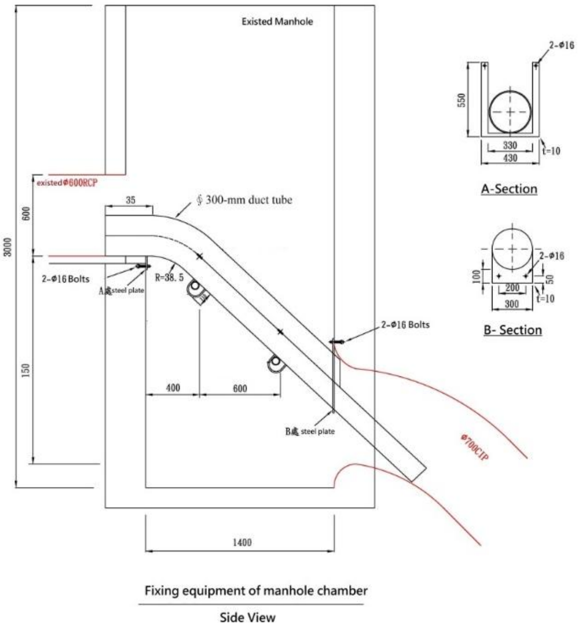

Fig. 3-3-5. ∮300mm duct tube connecting a horizontal section and a sloping section.

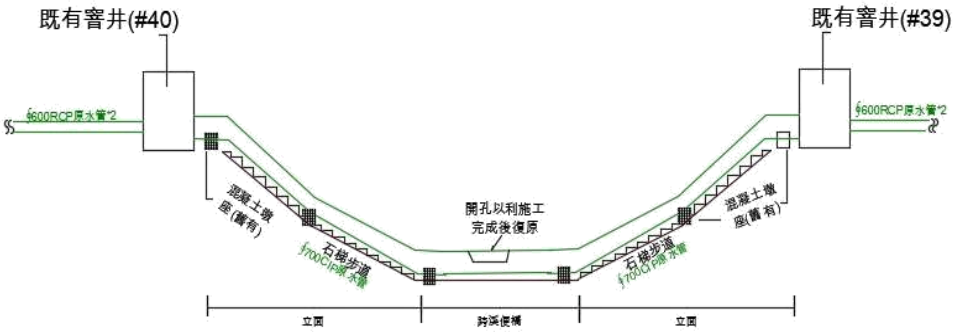

Fig 3-3-6. Extra rollers in inverted siphon pipes

4. Auxiliary winches

Applied portable winch at the several S cures points of chambers, and synchronous pull to provides auxiliary pulling force to release the stuck points. Finally, the main winch completes the task with a pulling force less than five ton (Fig. 3-3-7).

Fig. 3-3-7. Small portable winch used as an auxiliary winch.

5. Lubrication

To reduce friction, considerable amounts of cooking oil (oil-absorbing sponges) were used as a lubricant at the points where the liner entered the old pipeline (Fig. 3-3-8.).

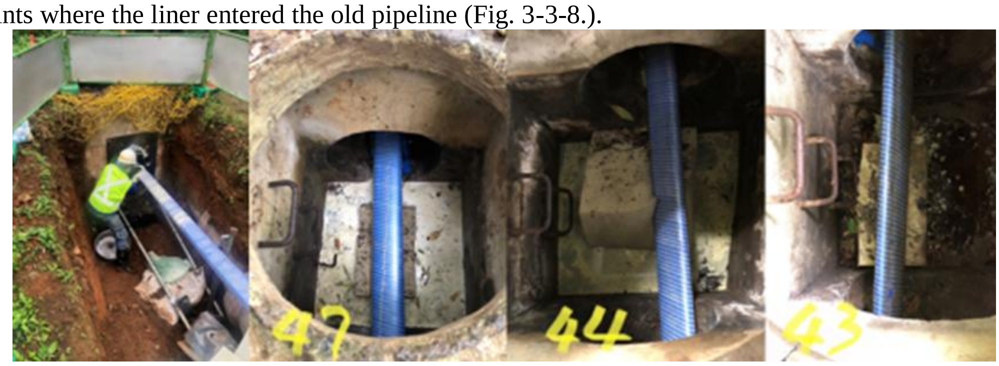

Fig. 3-3-8 Pipeline entrances and manholes lubricated using cooking oil.

IV. Conclusion And Suggestion

Completed in 270 days at a cost of US$1.3 million, this project involved slip-lining within 2900m sections with more than 150 bends, minimizing open cutting and environmental harm. Innovations such as roller installations, auxiliary winches, lubrication, and wear reduction measures are key to overcoming the challenges, setting a benchmark for countries that may encounter similar situations, and providing valuable experience for future engineering applications.

1. Considering the overall water supply backup capacity of the Shuangxi and Zhishan Road areas, the Taipei Water Department applied Shuangxi raw water pipes that had been out of service for many years to set up water pumping pipe to improve the water supply dispatching capacity of the Shuangxi Water Treatment plant to increase operational flexibility to reduce the water supply risk of Shuangxi, Zhishan Road area.
2. The high-strength flexible hose liner was applied for this project. Full pipeline working pressure can reach up to 16 kgf/cm2. The result completely meets the requirements after full-line pressure testing.
3. This project is a long-distance and multi-curved pipe slip-lining project. Worksite area is special and hard to dispatch. Heavy machinery cannot be applied to assist the construction. The condition made it extremely difficult. Finally, thanks to the friction reduction strategies and synchronous pulling by potable winch to release the stuck points, the task was successfully completed.
4. The high-strength flexible hose liner designed for pressure pipe applications and is not suitable for gravity flow applications. Therefore, full flow water supply from Shuangxi Water Treatment Plant gravity flow to Huahxing Distribution tank is not possible.

5. Flexible hose liner is designed as an independent structure liner for inner pressure only. However, the stiffness of the liner is not enough to keep round shape when liner is empty. Minimum 0.1-0.3 bar inner pressure is required to keep it re-rounded.

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