润新阀之應用

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First Edition

Application of Runxin Valve



WENZHOU RUNXIN MANUFACTURING MACHINE CO.,LTD

Preface

In recent years, with the rapid development of China's economy, industrial, agricultural and daily life water consumption have been increasing, so the accompanying demand for water treatment equipment has also been increasing. However, the control valve which is core part for filtration and softening water treatment system were imported before 2003. They were automatically controlled or manually controlled by multiple valves. That greatly increased the cost and operational difficulty of water treatment equipment. And to a certain extent hindered the popularization of water treatment equipment.

The research on automatic control valves for water treatment systems began in the United States in the 1960s, mainly using rubber piston structure and cam structure, and its sealing parts are rubber and plastic. Runxin company developed control valve with ceramic hermetic head faces sealing structure for water treatment system firstly in 2003. It uses high flatness ceramic sealing disk as the sealing part, which has the characteristics of good sealing performance, long life time, convenient positioning, etc. The mature production technology has made it have many advantages, such as good interchangeability and high cost performance. Through continuous series development and production, control valves have been formed a full range, such as water treatment capacity 1-50m^3/h, time clock type and meter type, manual and automatic, LED or LCD and indicator light display, etc.

The control valve for water treatment systems with ceramic flat sealing structure is completely different from the structure of similar foreign products. Therefore, it has its unique features in functions, characteristics and applications, etc. In order to enable the majority of users to fully understand Runxin valve, better use Runxin valve, to maximize its use value, and help users solve problems in the water treatment process to the greatest extent, based on the actual application cases in recent years collected, summarized the on-site problems encountered by users, and after referring to relevant technical materials, we compiled the book " Application of Runxin Valve ".

With the introduction of more and more series of Runxin valves in market, various matching products are becoming more and more abundant. The ceramic core ball valve is just one example of the perfect application of ceramic sealing technology. It can not only provide supporting facilities for Runxin valve, but also can be widely used in many fields such as feeding water treatment, sewage treatment, food engineering, solar energy, petroleum, chemical industry, metallurgy, light industry, papermaking and so on. Therefore, we introduce the ceramic core ball valve as a separate chapter, so that more friends can understand it in depth.

There are nine chapters in this book, mainly including: Overview of Runxin Valve, Multi-functional Flow Control Valve for Water Treatment Systems,Application of Runxin Filter Valve,

Application of Runxin Softener Valve, Application of Runxin Valve in Demineralization Water Treatment, Application of Runxin Valve in Special Water Treatment System, Application of Runxin Valves in Residential Water Treatment System, Maintenance of Runxin Multi-functional Flow Control Valves, and Runxin Ceramic Ball Valve. This book is mainly written by Zhou Ying, Wu Xiaorong, Liu Ying, Yuan Hailin, Ye Maogan, Wu Xianshui, Wang Guirong, etc. The application cases in the book are from Shenyang Jieming Water Treatment Equipment Co., Ltd., Qingdao Dimei Thermoelectric Device Co., Ltd., Shijiazhuang Losun Water Treatment Equipment Co., Ltd., Beijing Tongchuang Fulai Technology Development Co., Ltd., Tianjin Huaju Water Treatment Equipment Trading Co., Ltd., Cleanpure Water Treatment Co. , Ltd., Sichuan Haidelun Mechanical & Electrical Co. , Ltd., WATER WAREHOUSE PROD. SERV. TRAT. AG. EFL. LTDA (from Brazil), EURO-CLEAR KFT.(from Hungary), and other agents of Runxin valve. We do our sincerely appreciation for your support.

The design calculations in the book refer to relevant water treatment books, standards and specifications, and some excerpts are not authorized by the owner of the book. We do our sincerely apologize. The application example is the installation situation on the customer's site, without the authorization of the user. We do our sincerely apologize.

There are some shortcomings in the book due to our limited knowledge and we sincerely appreciate if readers and experts can give their criticisms, point out mistakes and make corrections.

Editor

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1. Overview of Runxin valve

1.1 Introduction of Runxin valve

"Runxin valve" refers to the general name of various control valves produced by Wenzhou Runxin Manufacturing Machine Co., Ltd. (abbreviated as Runxin company). Runxin company was established in the year of 2000. In the early stage, Runxin mainly produced water mixing valve, floating ball valve, check valve, ceramic core faucet, corner valve, shut-off valve and other valves for solar water heaters. In 2003, Runxin started to develop multi-functional flow control valve for water treatment systems. In 2010, Runxin applied multi-functional flow control valve to civil terminal water treatment product, and developed whole house water filter, residential softener, prefilter and other series of products. In 2013, Runxin started to produce ceramic core ball valve.

According to product application characteristics, Runxin valves are mainly divided into: water mixing valve and floating ball valve for solar water heaters, ceramic core faucet, multi-functional flow control valve for water treatment systems, ceramic core ball valve, ceramic core check valve, etc. Among them, the multi-functional flow control valve for water treatment systems is divided into filter valve, softener valve, desalination valve, etc. The softener valve can be divided into different types according to the number of tank of the water softener controlled by single valve, the way of starting regeneration, the flow direction of regenerated liquid, and the control method (see 2.2 for details).

The water mixing valve and floating ball valve for solar water heaters, ceramic core faucet, ceramic core check valve, their applications are simpler, and more common in market, no more detailed introduction. This book mainly introduces the applications of multi-functional flow control valve and ceramic core ball valve for water treatment systems.

1.2 Features of Runxin valve

1.2.1 Structural characteristics of Runxin valve

Runxin valve, whether multi-functional flow control valve, control valve for solar water heaters, check valve, faucet, etc., all adopt the patented technology of hermetic head faces sealing structure.

Multi-functional flow control valve for water treatment systems and control valve for solar water heaters whice require multi-channel control, replacing the traditional multi-valve manual operation with one-valve integrated control. Its main patented technology is to integrate the functions required by each flow channel on the hermetic head faces sealing disks, there are two (or more than two) high flatness ceramic disks with multiple through holes or blind holes all contact with the plane of composite material disk. The fixed disk is fixed, and the moving disk rotates at the same center according to the program, corresponding to the relative channel of the

valve body, generating multiple water passages required in advance design, so as to realize the function of controlling water passage at each station.

1.2.2 Design concept of Runxin valve

Runxin valve always follows the design concept of "less cutting, no cutting", which is mainly reflected in the following aspects:

(1) The control valve body is generally designed and manufactured in a "less cutting, no cutting" method, there are mainly two kinds of plastic valve body and metal valve body. Plastic valve body is made of high-quality engineering plastic injection molding, common materials are: POM, PP, ABS, PPO, UPVC, etc. The metal valve body is formed by medium temperature wax mold casting, common materials are stainless steel 304, 316, 316L, etc.

(2) The rubber parts that play the role of flexible sealing are formed at one time with a mold.

(3) The valve core for sealing key components is made of high-strength, high-precision grinding and polishing ceramic.

1.2.3 Key component (ceramic component) performance

(1) Processing

The ceramic material used in Runxin valve is corundum ceramic, with Al_2O_3 containing exceeding 95%.

The ceramic part is sintered at 1680℃ super high temperature after grouting or dry pressing in mould.

Using diamond grinding paste, double-sided grinding technology is used for grinding and polishing to make a high-precision optical mirror surface.

(2) Product performance

High hardness, up to HRA85 or above, so it is resistant to particle impurities and wear resistance.

After the flat valve core is grinded and polished, the flatness can reach 0.0003mm, the parallelism is 0.02mm, and the sealing performance is good when fitting. In the case of high flatness bonding, the actual sealing surface can seal gas and liquid well within 1mm.

The ball core and valve seat of the ceramic core ball valve are coarsely and finely grinded by diamond, and then the core and valve seat are grinded in pairs, so that the ball roundness is controlled within 0.0006mm. Through the hard sealing between the ball and the valve seat to realize sealing gas and liquid.

Al_2O_3 has a stable chemical structure, so it has strong corrosion resistance to acid, alkali, salt, etc.

1.3 Features of control valve for water treatment systems

1.3.1 Replacing multiple valves with one valve

Compared with traditional filter and softener with multiple ordinary valves, replacing multiple ordinary valves with a multi-functional flow control valve has the following advantages:

(1) Convenient pipeline connection

Traditional filter needs to install five valves to realize the functions of filtration, backwash and fast rinse. Water softener needs to install at least seven valves with an injector or brine pump, to realize the functions of softening, backwash, brine draw & slow rinse, brine refill and fast rinse. The anion and cation exchanger and the mixed bed system even need to install eleven valves and two injectors to achieve various functions. The pipeline connection composed of multiple valves is complicated and there are many leakage points.

Runxin multi-functional flow control valve is equivalent to integrating the functions of multiple straight-through valves into one valve. When installing, only need to connect the multi-functional flow control valve to the tank, and then connect the inlet and outlet pipelines. Convenient connection, less leakage points.

(2) Easy maintenance

Due to fewer connecting pipelines and fewer leakage points, when problems occur with the multi-functional flow control valve, it can be solved by directly replacing the corresponding accessories of the control valve.

(3) Easy to realize automation

The water treatment system controlled by multiple valves requires multiple valves to switch between opening and closing. The opening and closing time is long, so it is easy to have internal water mixing. To achieve automation, each valve needs to be controlled separately, and more complicated programming is required. If uses multi-functional flow control valve, only need one valve, and the corresponding function can be realized by setting in program.

1.3.2 Performance characteristics of Runxin valve

(1) Hermetic head faces sealing material and structure

The moving disk and fixed disk of the multi-functional flow control valve adopt highly-fitting hermetic head faces sealing disk. In order to prevent the disks from seizing due to intermolecular gravity, the moving disk and fixed disk are made of different materials. Among them, the moving disk is made of corundum ceramic which is sintered by super high temperature of 1680℃, and the hardness can reach HRA≥85°. The fixed disk is made of high-strength composite material, which has good corrosion resistance and can withstand low concentrations of acid and alkali. Therefore, Runxin control valve can be used for anion and cation resin beds that adopt acid and alkali for regeneration.

For softener valve, due to the great difference of flow rate between service and regeneration steps, if the inlet water pressure is high, it will cause excessive pressure on the sealing face,

which will increase the torque and wear of the sealing face. Therefore, it adopts a design similar to the partial balance structure in the mechanical sealing, so that the pressure on the sealing face is partially unloaded, and does not increase significantly with the increase of the inlet water pressure, thereby avoiding the wear of the sealing face.

(2) Can be operated with pressure

Runxin valve adopts hermetic head faces sealing technology. Because two high-flatness sealing disks are attached to each other and rotated, when switching the working positions, it can be operated with pressure.

Some control valves on the market use springs to press plastic parts against rubber, the rubber parts and plastics are sealed by water pressure and spring pressure. When switching the position, in order to prevent the rubber from being damaged or rushed out, this type of control valve needs to close the inlet valve, that is, it cannot be operated with pressure.

(3) Raw water bypass optional

Soft water cannot be produced during the regeneration process of the water softener. Therefore, for boiler and other water equipment with strict requirements on the hardness of the feed water, a suitable soft water storage tank must be installed, so that the water softener can provide the boiler with qualified feed water during the regeneration, or use one in service one standby water treatment system. However, some water equipment, especially civil water treatment system, usually does not have strict requirements on the hardness of the feed water, and short-term use of hard water has little effect. So usually there is no soft water storage tank, and a control valve with raw water bypass can be selected, to ensure no water interruption.

GB/T 18300 "Specification for Automatic Control Sodium Ion Exchanger" stipulates: for water softeners used in boiler, no hard water should flow from the outlet of the exchanger during the regeneration process. Therefore, Runxin industrial softener valves have no raw water bypass structure (the so-called raw water bypass means that the control valve automatically blocks the water outlet pipeline of the equipment during regeneration or rinse, and no untreated raw water enters the system).It is used in water treatment system with no strict water hardness requirements. To avoid water interrupted during regeneration, a control valve with a raw water bypass structure can be adopted.

1.4 Application of Runxin valve

Runxin valve has complete specifications and types, which can be used in various water treatment systems. The common filter and softener valve can not only be used for filtration and softening in boilers and various industrial equipments, but also for water treatment such as desalination, deaeration, and iron removal, as well as civil water treatment equipments. Ball valve can be used in various types liquid flow control of fluid pipes.

1.4.1 Application of Runxin filter valve and softener valve

As the core component of filter and softener for water treatment systems, Runxin filter and softener valves have many applications. Among them, the most widely used is the softening of industrial boiler feed water. If the calcium and magnesium ions in the water enter the boiler, it is easy to form hard scale on the high-temperature heating surface. The heat transfer of scale is very poor. After the boiler is scaled, it will not only significantly reduce the output and thermal efficiency of the boiler, waste a lot of fuel, but also cause corrosion under the scale. In worse situation, it will block the furnace tube or cause metal overtemperature, and deformation, bulge, even the safety accident of the pipe burst will be caused. Therefore, in order to ensure boiler safety, energy saving, and economic operation, boiler feed water must be softening treated. According to the GB/T 1576 "Water Quality for Industrial Boilers " standard: steam boilers or steam-water dual-purpose boilers with rated steam pressure ≤ 2.5MPa, and the feed water is softened, the feed water hardness is required to be ≤ 0.03mmol/L, 3.8MPa＞rated steam pressure＞2.5MPa steam boiler, the feed water hardness is required ≤ 0.005mmol/L, and the feed water must be softened or desalinated. If the feed water of the hot water boiler is softened, the feed water hardness should be ≤ 0.6mmol/L.

For heat exchange equipment prone to fouling, water for industrial equipment such as circulating cooling system, and the pretreatment of reverse osmosis membrane also needs filtration and softening treatment. In addition, some washing industry, breeding industry and other industries, if the water hardness is high, also need softening treatment. Using soft water to wash clothes, bed sheets, table cloths, etc., not only reduces the amount of detergent, but also makes the cloth soft after washing. Some flowers and plants in the breeding industry need to be irrigated with soft or pure water to make the flowers more colorful and growth is more ideal. At present, water softeners are also widely used in civil daily life, such as household electric boilers, water heaters, floor heating and other devices. The use of soft water can avoid pipe scaling, save electricity, and extend the service life of heating devices. Long-term use of high hardness water, not only easy to make boil kettle and other appliance scaling, but also easy to make the skin rough after washing a face and taking a bath, drinking taste is poor, some may even cause stones, and affect health. Therefore, daily life water in areas with higher hardness also needs to be softened. For reverse osmosis desalination treatment system, it is usually necessary to install two grades of deep filtration (quartz sand filtration + activated carbon filtration) and softening treatment before it, to avoid impurities such as particulate matter, organic matter, residual chlorine, calcium and magnesium ions in the water from polluting and damaging the surface of the reverse osmosis membrane, prevent membrane pore blockage caused by scaling and affect desalination rate, and extend the service life of RO membrane.

Natural circulation steam boilers with relatively high pressure, various forced circulation steam boilers and large hot water boilers need to strictly control the hardness of softened water, while small steam boilers and steam-water dual-purpose boilers with lower pressure, small and medium-sized hot water boilers, ordinary industrial equipment, civil and residential water treatment, etc., the requirements of the water hardness is often not too strict. You can choose the appropriate control valve to configure the water softener according to the actual situation.

At present, the maximum water treatment capacity of a single filter valve and softener valve can reach 50m^3/h, and the hardness of raw water treated by a single water softener can reach 10mmol/L. By configuring a series and parallel system of multiple filters and softeners, the water treatment capacity can reach more than 200m^3/h, the maximum raw water hardness can reach 20mmol/L. And through the interlocking configuration in the system, the filter tank or softening tank can be automatically controlled to be rinsed or regenerated in turn to ensure the orderly operation of the system and the qualified water quality.

1.4.2 Usage and application of control valve for special water treatment

1.4.2.1 Desalination treatment

Power plant boiler feed water, and laboratory, electroplating plant, integrated circuit manufacturing, pharmaceutical preparations, biochemistry, drinking water, cosmetics and other industries that have special requirements, all need pure water or ultrapure water. The general method for producing pure water and ultrapure water by ion exchange technology is as follows:

(1) First grade desalination to produce pure water: a cation exchanger (abbreviated as cation bed) and anion exchanger (abbreviated as anion bed) work in series as an anion and cation exchanger desalination system. The cation bed is filled with H^+ type cation resin, the anion exchange resin is filled in the anion bed. During service, all cations in the water entering the cation bed are exchanged and removed by H^+, and the outlet water is acidic; after entering the anion bed, all anions are exchanged and removed by OH^-, the H^+ and OH^- are neutralized, and the final outlet water is desalinated water. When resin exhausted, the cation exchange resin is usually regenerated with hydrochloric acid (using H^+), and the anion exchange resin is regenerated with sodium hydroxide (using OH^-).

(2) Mixed bed desalination to produce ultrapure water: the cation exchange resin and anion exchange resin are mixed uniformly in the same tank at a ratio of 1:2 (abbreviated as mixed bed), the service and regeneration are automatically controlled by control valve. After mixing the anion and cation exchange resins, it is equivalent to the formation of countless anion and cation exchangers in the tank, which makes the removal of anions and cations in the water more sufficiently, and the outlet water conductivity is lower than that of the first grade desalination system, so it is called ultrapure water. During the regeneration of the mixed bed, it is necessary to separate the anion and cation exchange resins, and then through the control valve to absorb

alkali and acid for regeneration. But the regeneration effect of the mixed bed is not as good as that of the first grade desalination system, and it is difficult to recover the original exchange capacity of the resin if it is exhausted deeply. Therefore, the general mixed bed inlet water usually adopts the first grade desalination water (conductivity ≤ 20μs/cm), and the mixed bed desalination is also called second grade desalination. When the water conductivity ≥ 0.5μs/cm, the regeneration should be carried out.

At present, the maximum flow rate of the mixed bed desalination system composed of Runxin control valve is $4m^3/h$. If a higher flow rate desalination system is required, a mixed bed system composed of Runxin ceramic core ball valves can be used, which can reach $50m^3/h$.

1.4.2.2 Iron and manganese removal filtration treatment

Groundwater containing iron and manganese is widely distributed, and iron and manganese often exist in the form of divalent iron and manganese with higher solubility in groundwater. Due to the dissolved oxygen in surface water, iron and manganese mainly exist in water-insoluble $Fe(OH)_3$ and MnO_2 states. Therefore, the groundwater containing ferrous ions, the water just extracted from the well has no color, and becomes brownish-red turbid water after being stored for a period of time, mainly because the Fe^{2+} in the water is oxidized to Fe^{3+}. The Fe^{3+} can promote the growth of iron bacteria in the pipe network, forming a viscous film in the pipe network, causing corrosion of metal pipes. It is easy to stain clothes and utensils, pollute the water for living and production. Manganese also can stain utensils and clothes, can form the covered thing on the inner wall of the water pipe, which will flow out with the water, and form black precipitate. If manganese is contained in drinking water, long-term intake will cause harm to human body.

Common methods for removing iron and manganese are: after air or ozone aeration, manganese sand or special low-density iron and manganese removal filter media or iron and manganese removal resin are used to remove. The iron and manganese removal system composed of Runxin filter valve, aeration tank and filter tank filled with manganese sand. After aeration, the iron and manganese will be removed by manganese sand catalytic oxidation and filtered. It needs to do backwash regularly to prevent manganese sand from hardening. A system composed of Runxin softener valve and special low-density iron and manganese removal filter media, after adjusting the PH value of the raw water and then aerating, the iron and manganese are removed by the filter media. When reaching a certain removal rate, it needs to enter alkaline washing regeneration to restore the effect of iron and manganese removal. The design can be designed according to the softening system.

For the iron and manganese removal system using manganese sand as the filter media, Runxin filter valve can be used, and the single valve rinse flow rate can reach $60m^3/h$. The system adopts a special low-density filter media for removing iron and manganese, Runxin

softener valve can be used, and the single valve service flow rate can reach 20m^3/h. For systems that use resin after ozone oxidation, softener valve can be used.

1.4.2.3 Deaeration treatment

Oxygen corrosion refers to the destruction of metal materials under the electrochemical action of dissolved oxygen in water. Oxygen corrosion is the most common form of corrosion in boiler systems. If the boiler feed water is not treated with deaeration or the deaeration is improper, the dissolved oxygen will enter the boiler system in whole or in part, causing oxygen corrosion in the feed water pipeline, water tank, economizer, steam drum, steam pipeline and condensate system. This kind of corrosion causes serious damage to the strength of metal components.

The common methods of deaeration include vacuum deaeration, thermal deaeration, chemical deaeration and sponge iron deaeration. The sponge iron deaeration system controlled by Runxin valve uses the reaction of sponge iron and oxygen in the water to achieve the purpose of deaeration. After the sponge iron reacts with the dissolved oxygen to a certain extent, the sponge iron needs to be washed to elute the resulting iron oxide and prevent the sponge iron from hardening. Due to the sponge iron is heavy, it needs high backwash flow rate to clean it, but the service flow rate during deaeration cannot be high. The backwash flow rate and the service flow rate are at least 4 times difference, which is difficult to achieve with common control valve. The deaeration system composed of Runxin deaeration control valve divides the filter chamber into left and right chambers. During service, the left and right chambers are fed with water simultaneously. When the left and right chambers are rinsed separately, the rinse flow rate can be doubled to achieve a better cleaning effect. A ball valve can also be used to achieve rinse.

At present, the maximum flow rate of Runxin deaeration control valve is 4m^3/h, which can achieve 12m^3/h by interlocking. If ceramic core ball valves are adopted, a deaeration system of more than 50m^3/h can be formed.

1.4.2.4 Fluorine removal treatment

In many areas, the groundwater contains a certain amount of fluorine, the general content is 0.4mg/L ~ 0.5mg/L, but the high fluorine area can reach 10mg/L or even higher. The trace fluorine in the human body is an important component of teeth and bones, but if the human body takes in excessive fluorine, it will cause fluorosis, which will have a greater impact on human health. Therefore, the national standard GB 5749-2015 "Standards for Drinking Water Quality" stipulates that the fluorine content of drinking water shall not exceed 1.0 mg/L, and fluorine removal is required if it exceeds 1.0 mg/L.

Currently, the more effective fluorine removal method is to use the fluorine removal filter media to adsorb and remove. That is, the fluorine-containing raw water flows through the fluorine removal filter media layer at a certain flow rate, and the fluoride ion is trapped by the fluoride

filter media to make the outlet water become low fluorine or no fluoride water. When the fluorine in the media becomes saturated and the fluorine content in the outlet water is ≥1.0mg/L, the media becomes invalid, and the regeneration reagent is required to perform forced up-flow regeneration of the media layer to restore the fluorine removal capability of the filter media.

1.4.3 Usage and application of ball valve

Runxin ceramic core ball valve is a hard sealing ball valve, which is mainly used to cut off, distribute and change the flow direction of the media in the pipeline. It only needs to rotate 90 degrees and a small torque can be closed tightly. Due to the use of ceramic ball and ceramic valve seat, it has the significant characteristics of low torque, corrosion resistance, wear resistance, zero leakage, and long life time, etc. By selecting different rubber sealing materials, it can be widely used in water, steam, oil, organic acid, inorganic acid, solvent, alkali, chemical and other media. In the water treatment system, through different ball valve combination, it can form a filtration system, a softening system, and a mixed bed desalination system, etc.

At present, the specifications of Runxin ceramic core ball valves have been produced in batches from DN15 to DN80, and the maximum can reach DN200.

2. Multi-functional flow control valve for water treatment systems

2.1 Basic principle of multi-functional flow control valve

Multi-functional flow control valve, also called multi-way valve, refers to a valve that can realize three or more flow channels and three or more control functions. Common multi-functional flow control valves used in water treatment systems, according to different paths, can be divided into three-position five-way valve (filter valve), five-position six-way valve (softener valve, ion exchange desalination valve), etc.

Runxin multi-functional flow control valve controls the flow channel based on the principle of hermetic head faces. It consists of two (or more than two) high flatness ceramic disks with multiple through holes or blind holes are attached the fixed disk. By rotating the moving disk, the moving disk and the fixed disk are rotated at the same center. When the moving disk rotates to a certain set position, the flow channel corresponding to the through hole of the valve body opens, and the sealing of the corresponding blind hole blocks the fluid. So that the water treatment equipment performs a certain function operation. After the completion of this function, continues to follow the water treatment equipment operation procedure to make the moving disk rotate to the next position, and to perform the next function operation. This is carried out in sequence to put the water treatment equipment into normal operation.

For example, as shown in Figure 2-1, the multi-functional filter valve is integrated with filter, backwash, and fast rinse channels, which can realize the functions required by the filter.

Figure 2-2 is a multi-channel valve, which can realize that the water entering from the inlet and flowing out from other ports according to the function requirements.

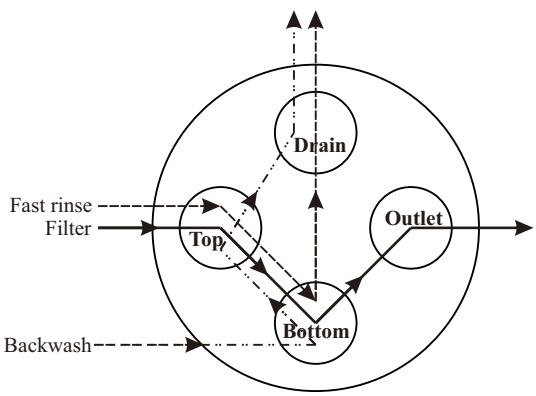


Figure 2-1Filtration channels

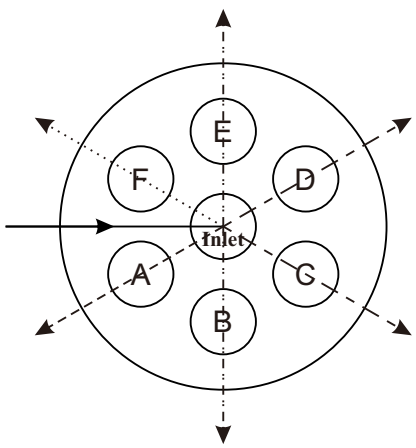


Figure 2-2 Multi-channel valve

For automatic valves, the station conversion is generally driven by motor. The signal to drive the motor, the filter valve usually uses the pressure difference or time signal. The softener valve and the desalination valve usually use the time signal, meter signal or other signals that the control valve can receive (such as the water hardness signal of water softener, the outlet water conductivity signal of desalination ion exchanger, etc.). For the water softener, when the service time reaches the program setting time or the water treatment capacity reaches the set cycle water

treatment capacity or the hardness of the outlet water is unqualified, the automatic control valve will start regeneration according to the set program. The motor is controlled by the program to drive the moving disk to rotate, then to perform functions such as backwash, brine draw & slow rinse, brine refill and fast rinse. For the filter valve, its working principle is basically the same as the softener valve's, except that it only has functions such as filter, backwash and fast rinse, without the functions of brine draw & slow rinse and brine refill.

2.1.1 Principle of control valve with single valve core

Figure 2-3 shows a schematic diagram of the moving and fixed disks of a commonly used softener valve. The fixed disk is fixed on the valve body, and the valve body is provided with water inlet and outlet, drain, brine line connector, the connector of top and bottom strainers, which are corresponding to the through hole on the fixed disk. The moving disk has a through hole that is always connected with the water inlet, and there are two blind holes' diversions, which are attached to the fixed disk through rotation to form different flow channels, thereby forming service, backwash, brine draw & slow rinse, brine refill and fast rinse stations respectively.

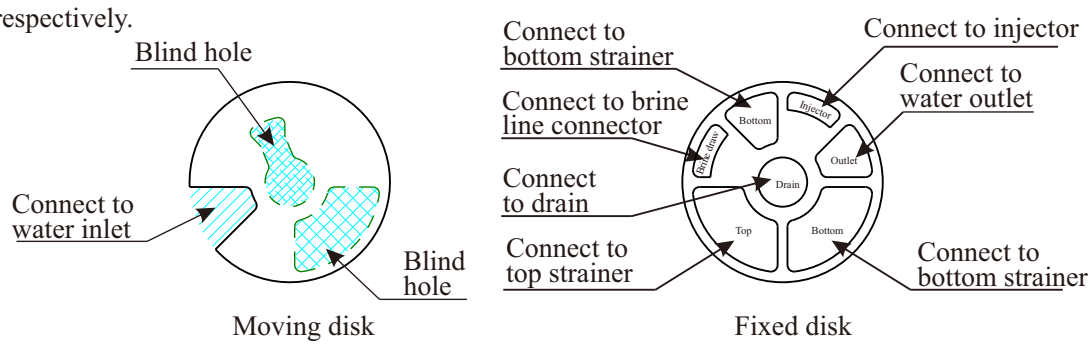


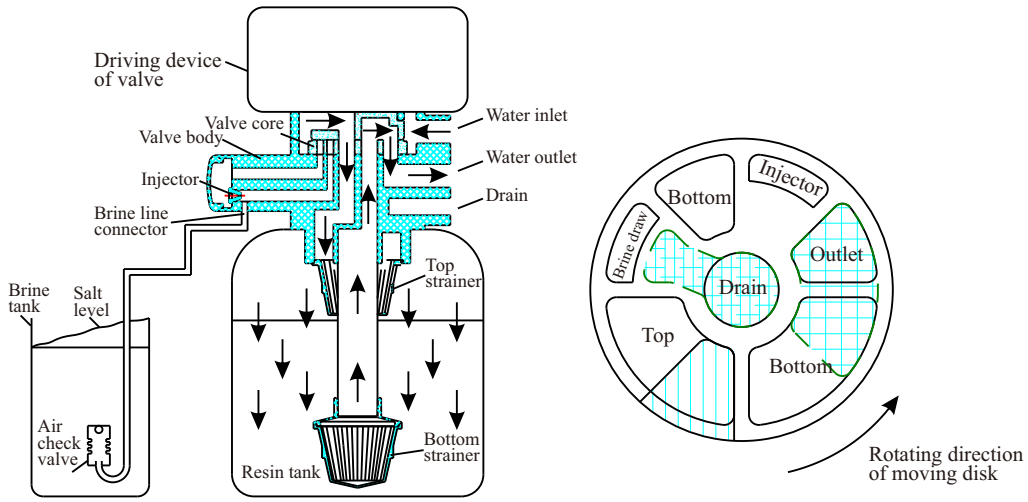
Figure 2-3 Moving disk and fixed disk diagram of 63604

The above-mentioned moving disk and fixed disk is just an example. Depending on the required function or the layout of each interface, each interface of the fixed disk can be divided into five equal parts, six equal parts, seven equal parts or even ten equal parts or not equal parts. The moving disk can be designed according to the position of the hole of the fixed disk, and there are many different structures of moving disk and fixed disk.

Taking the softener valve as an example, the flow direction of the liquid flow in the service and regeneration process and the working position in the softener valve are described below:

2.1.1.1 Service position (making soft water)

In service, the moving disk and the fixed disk form a bonded state as shown in Figure 2-4. At this time, raw water goes through the through hole of the moving disk, enters the fixed disk, valve body and top strainer. After being softened by the resin, it returns to the fixed disk from the bottom strainer and the riser pipe, flows through the blind hole's diversion of the moving disk, and finally flows out from the water outlet. When the service time or cycle water treatment capacity reaches the set value, it will stop service and enter the regeneration process.



a) Liquid flow direction during service b) Diagram of moving disk and fixed disk during service

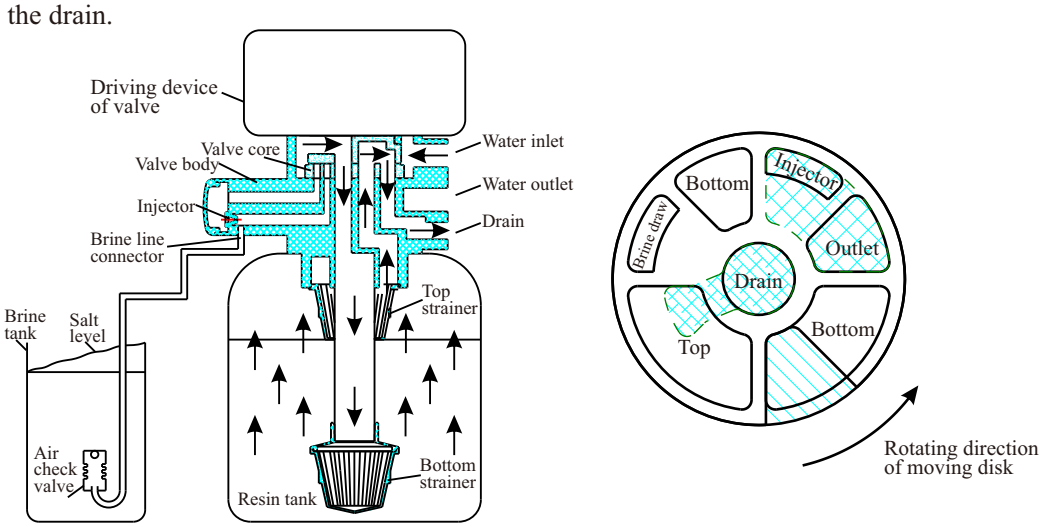
Figure 2-4 Diagram of service position

2.1.1.2 Regeneration process

The steps of down-flow regeneration process are: Backwash→ Brine draw & slow rinse→ Brine refill → Fast rinse, after water qualified goes to service.

(1) Backwash position

After stopping service, turn the handle or program controls motor to drive the moving disk to rotate, and stop when it forms a state with the fixed disk as shown in Figure 2-5. Raw water goes through the through hole of the moving disk, enters the fixed disk, valve body and riser pipe, flows out from the bottom strainer, and cleans up the resin layer upwards. The waste water passes through the top strainer and valve body, and through the blind hole's diversion of moving disk to the drain.



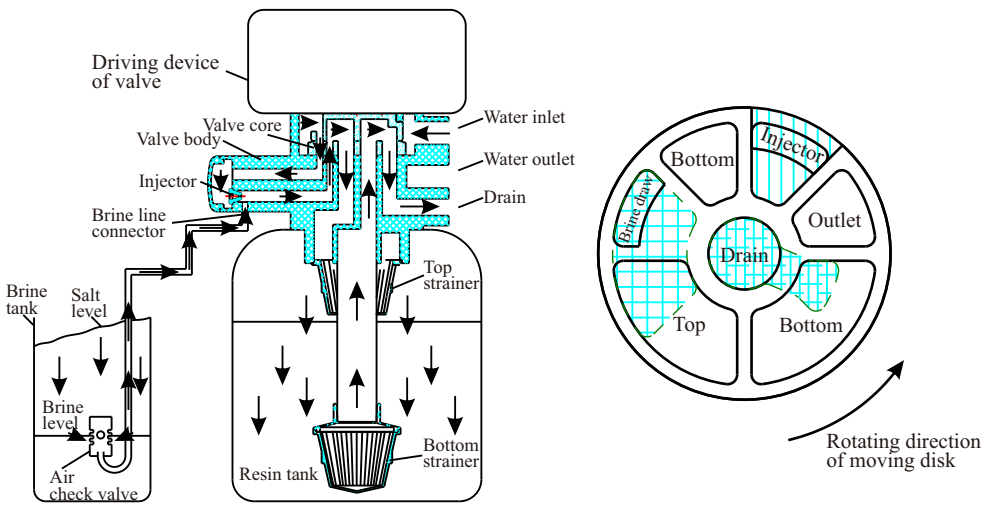
a) Liquid flow direction during backwash b) Diagram of moving disk and fixed disk during backwash

Figure 2-5 Diagram of backwash position

(2) Brine draw & slow rinse position

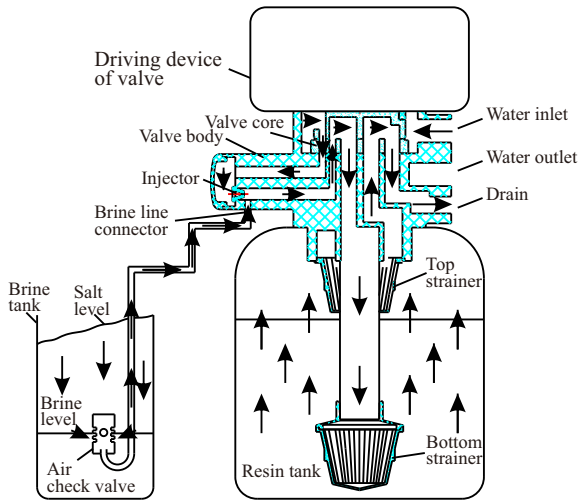
Brine draw: after the backwash is completed, turn the handle or the program to control the motor to rotate, and driving the moving disk to rotate, and forms a state with the fixed disk as shown in Figure 2-6. Raw water goes through the through hole of the moving disk, enters the fixed disk, and flows through the injector. When negative pressure is generated at the nozzle outlet, the saturated brine in brine tank is sucked and mixed with the inlet water (part of products use the soft water which is from the soft water tank or produced by another tank as the inlet water for regeneration, and mixed with the softened water) to be diluted to a certain concentration of salt solution, from top strainer, and flows into the resin layer downwards, to restore the exchange capacity of resin. The waste water returns from bottom strainer and riser pipe to the fixed disk, through the blind hole's diversion of the moving disk and is discharged from the drain.

Slow rinse: after the brine is sucked from brine tank, the inlet water continues to clean the resin in same station, liquid flow direction and flow rate as brine draw. Meanwhile, the brine remaining in the resin tank will be used to continue to ion exchange with resin. Since the slow rinse state and the brine draw state is basically the same, the two are usually set to the same step, but after brine in the brine tank is sucked up, the air check valve installed in the brine tank is shut down to block the brine line connector to prevent air sucked to resin tank.



a) Liquid flow direction during brine draw & slow rinse by down-flow regeneration

b) Diagram of moving disk and fixed disk during brine draw & slow rinse by down-flow regeneration

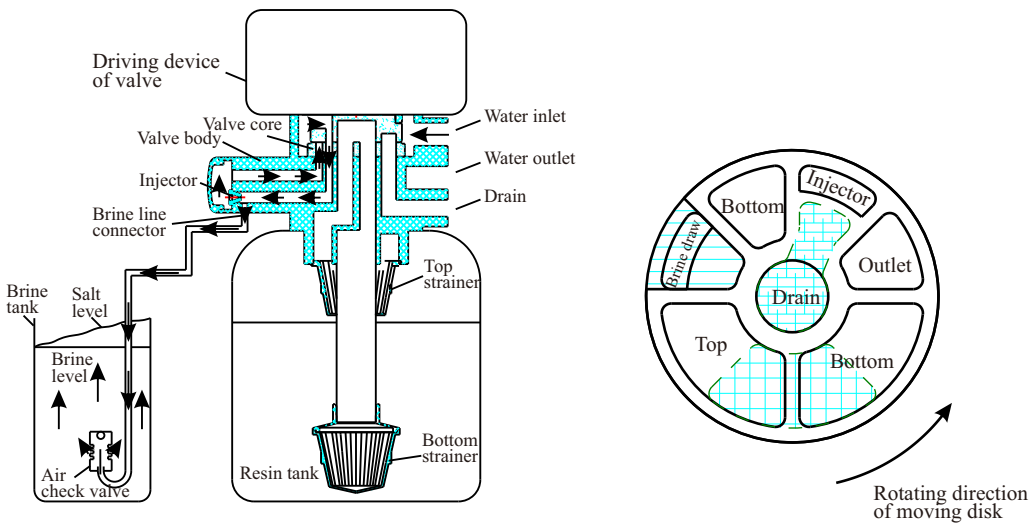


c) Liquid flow direction during brine draw & slow rinse by up-flow regeneration

Figure 2-6 Diagram of brine draw & slow rinse position

(3) Brine refill position

After brine draw & slow rinse is completed, turn the handle or the program controls motor to rotate the moving disk, and forms a state with the fixed disk as shown in Figure 2-7, raw water goes through the through hole of the moving disk, enters the fixed disk, and after passing through the injector, it will fill brine to brine tank through the brine line connector, to make the liquid level in the brine tank reach the set height for brine draw in next regeneration.

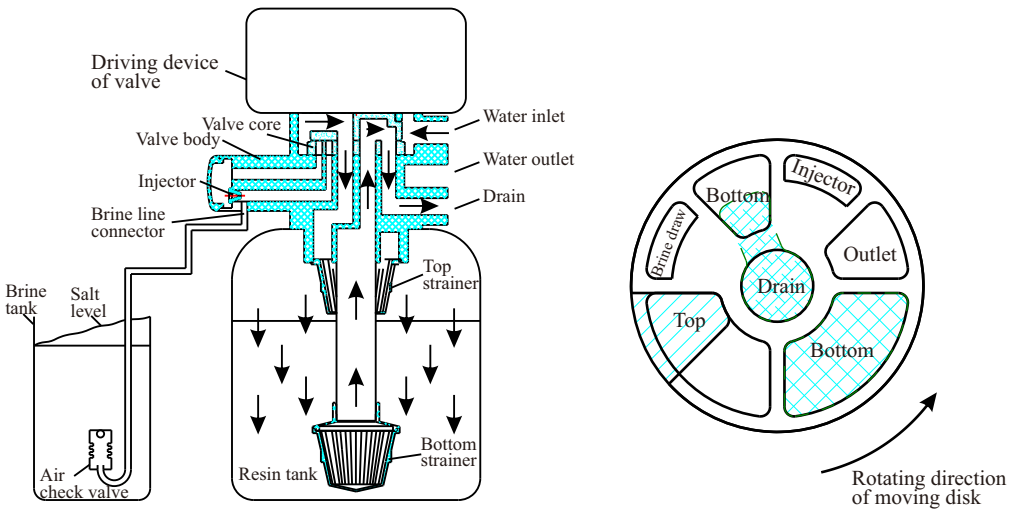


a) Liquid flow direction during brine refill b) Diagram of moving disk and fixed disk during brine refill

Figure 2-7 Diagram of brine refill position

(4) Fast rinse position

After the brine refill is completed, turn the handle or program controls motor to rotate the moving disk, and forms a state with the fixed disk as shown in Figure 2-8, raw water goes through the through hole of the moving disk, enters the fixed disk, valve body and top strainer. After cleaning the resin layer downwards, returns to the fixed disk from the bottom strainer and riser pipe, and flows from the blind hole's diversion of the moving disk to the drain.



a) Liquid flow direction during fast rinse b) Diagram of moving disk and fixed disk during fast rinse

Figure 2-8 Diagram of fast rinse position

The regeneration process of up-flow regeneration is basically the same as down-flow regeneration, only up-flow regeneration does not need backwash in each regeneration. Its flow direction of brine draw is opposite to the down-flow. The sucked brine firstly enters to riser pipe, and then through bottom strainer to resin layer upwards. After the resin is regenerated, enters the valve body and fixed disk through the top strainer, and flows through the moving disk's diversion to the drain, as shown in Figure 2-6 Figure C.

2.1.2 Principle of control valve with double valve cores

The moving disk and fixed disk of the control valve need to arrange multiple through holes on the same plat, to connect with the top strainer, bottom strainer, inlet, outlet, drain, and the inlet and outlet of injector. Therefore, the higher the water treatment flow rate, the larger the required through hole, and the larger the diameter of the moving disk and fixed disk. Generally, for a control valve with flow rate of $10m^3/h$, the diameter of the moving disk and fixed disk is about 100mm. When the diameter exceeds 100mm, the sintering yield of the ceramic disk will be greatly reduced. In order to ensure product quality, for the control valve with flow rate higher than $10m^3/h$, two valve cores are designed to achieve the required functions, one controls the water inlet (hereinafter called the water inlet valve core), and the other controls the water outlet (hereafter called the outlet valve core).

Figures 2-9 to 2-12 are diagrams of the fixed disk of the outlet valve core, the fixed disk of the inlet valve core, the moving disk of the outlet valve core, and the moving disk of the inlet valve core, respectively. On the fixed disk of the water inlet valve core, there are through holes connected with the top strainer, bottom strainer and the injector inlet. On the fixed disk of the water outlet valve core, it is provided through holes connected with the top strainer, bottom strainer, outlet and drain. The holes on the valve body are connected with the corresponding through-holes of the fixed disk, the top and bottom strainers interfaces of the inlet valve core are connected with the top and bottom strainers interfaces of the outlet valve core through the corresponding process holes on the valve body. As required, the outlet of injector is connected with the top strainer during down-flow regeneration, and connected with the bottom strainer during up-flow regeneration.

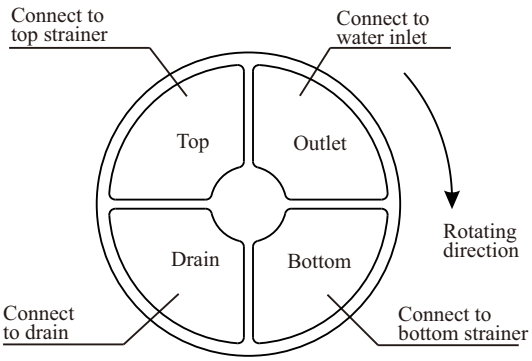


Figure 2-9 Fixed disk of outlet valve

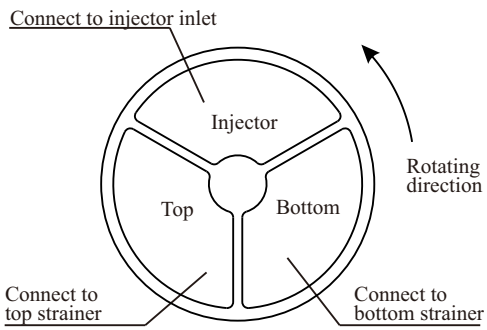


Figure 2-10 Fixed disk of inlet valve

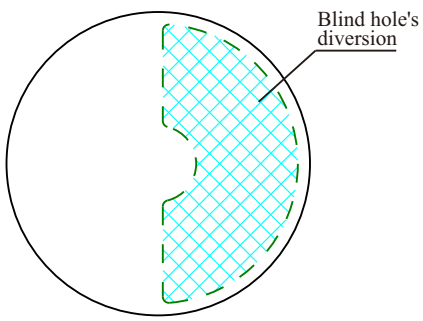


Figure 2-11 Moving disk of outlet valve

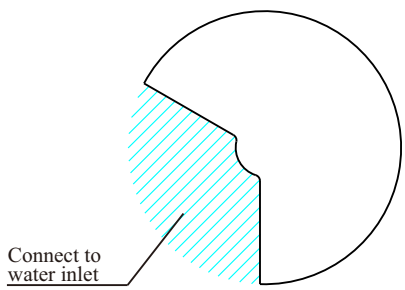
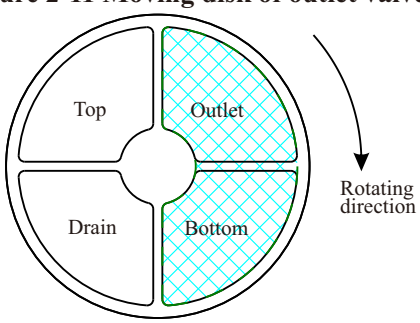
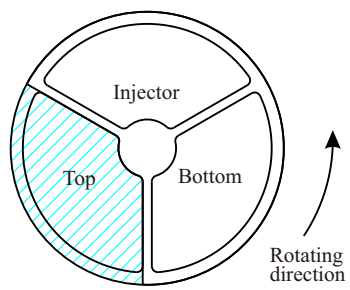


Figure 2-12 Moving disk of inlet valve



a. Outlet valve core



b. Inlet valve core

Figure 2-13 Diagram of moving disk and fixed disk of inlet valve (outlet valve) during service position

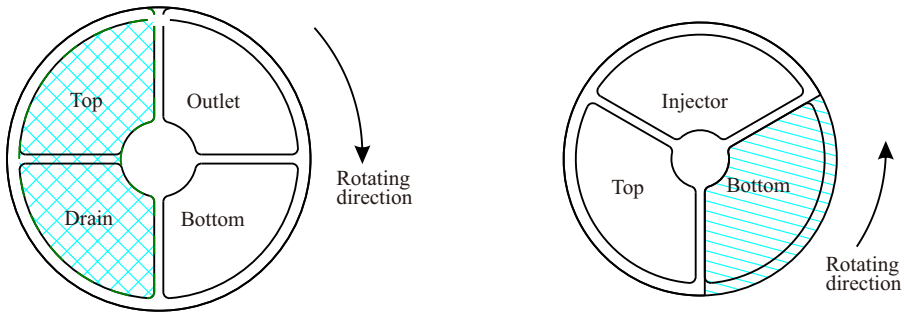


Figure 2-14 Diagram of moving disk and fixed disk of inlet valve (outlet valve) during backwash position

(1) Service position (making soft water)

During service, the moving disk and fixed disk form a state as shown in Figure 2-13. At this time, raw water enters the inlet valve core, and passes through the through hole of inlet valve core moving disk, the inlet valve core fixed disk, valve body, top strainer, enters the resin tank. After being softened by resin, the soft water through the bottom strainer to the riser pipe, and enters the fixed disk of the outlet valve core, then flows out from the blind hole's diversion of the outlet valve core moving disk to the outlet.

(2) Backwash position

When the service time or flow rate reaches the programmed value, the program controls the motor to rotate the moving disks of the water inlet valve core and the water outlet valve core, so that the moving disks and fixed disks of the two sets of valve cores form a state as shown in Figure 2-14. At this time, raw water enters the inlet valve core, through the through hole of inlet valve core moving disk to the inlet valve core fixed disk, valve body and riser pipe, and flows out from the bottom strainer, flushes the resin layer upwards, then passes through the top strainer, valve body to enter the outlet valve core fixed disk, and flows out from the blind hole's diversion of the outlet valve core moving disk to the drain.

(3) The fast rinse of the control valve can also be achieved through similar operations. The brine draw and brine refill need to be realized by installing a small electronic ball valve on brine line connector of valve body.

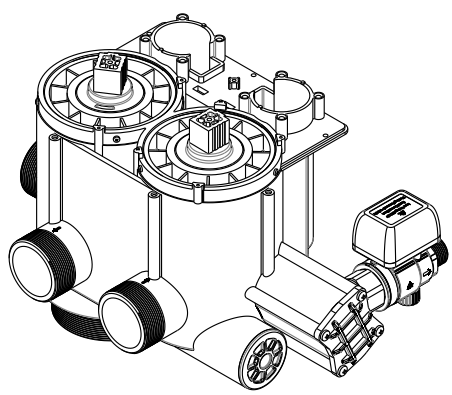


Figure 2-15 Structure diagram of control valve with double valve cores

2.1.3 Principle of piston control valve

When the water treatment flow rate of control valve is higher than 20m^3/h, if use a flat ceramic valve core, the diameter of the moving disk and fixed disk will reach 200mm or more, which is difficult to achieve with ceramic sealing disks. In order to solve this problem, the design uses a distribution valve to control four tee piston valves, to realize the functions required for the service and regeneration of the water treatment equipment. The distribution valve is used to drive the piston valve to achieve the corresponding flow channel, and the flow rate is realized by the tee piston valve.

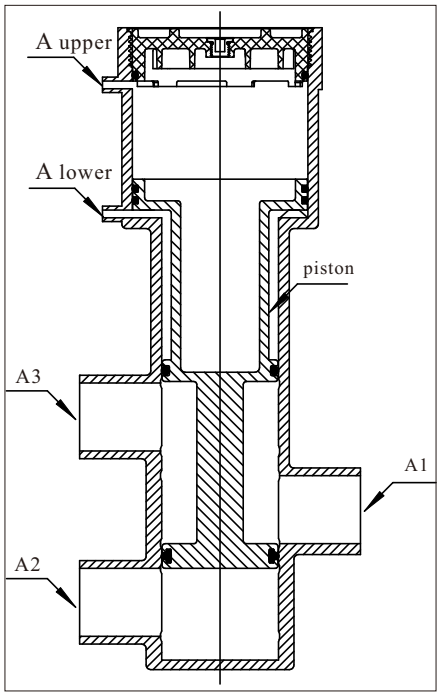
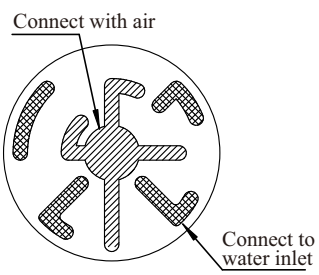
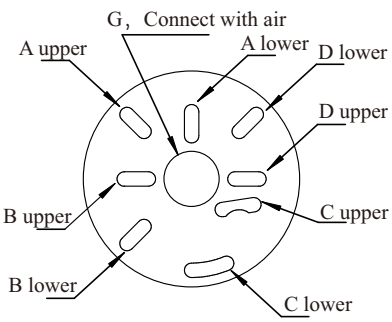


Figure 2-16 Structure diagram of the tee piston valve

Figure 2-16 shows the structure diagram of the four pieces of tee piston valves A, B, C, and D of the 63650. The four pieces of tee piston valves are driven by a distribution valve. Figure 2-17 and Figure 2-18 show the diagrams of the moving disk and fixed disk of the 63650 distribution valve, and Figure 2-19 is the diagram of the 63650 distribution valve in service position. There are four through holes and one blind hole on the moving disk; a through hole G is installed in the center of the fixed disk to connect with air. The fixed disk is provided with eight through holes, such as A upper, A lower, B upper, B lower, C upper, C lower, D upper, D lower, respectively connect with the upper/lower chambers of the tee piston valves A, B, C, and D. The tee piston valve is controlled by a motor-driven distribution valve. According to the program setting, the four pistons are in different positions during service, backwash, brine draw & slow rinse, fast rinse and brine refill to the brine tank at the beginning of service, to realize the functions of each step. A1, A2, and A3 are the three connectors of the tee piston valve A respectively.





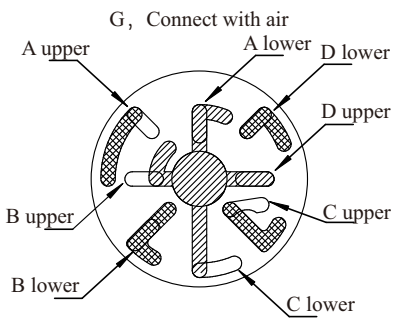


Figure 2-17 Diagram of moving disk Figure 2-18 Diagram of fixed disk Figure 2-19 Diagram of moving disk/fixed disk in service position

(1) Service position (making soft water)

In service position, as shown in Figure 2-19, the distribution valve controls four pieces of tee piston valves to realize A piston downwards, B piston upwards, C piston downwards, D piston upwards, then it can form passage as Figure 2-20

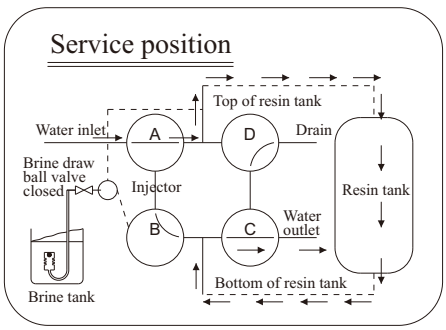


Figure 2-20 Flow chart in service position

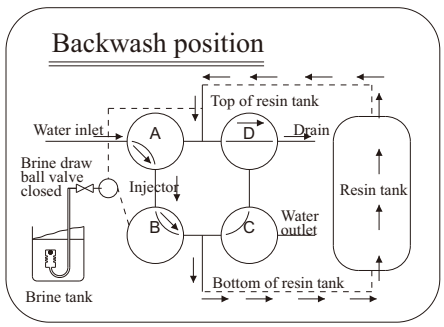


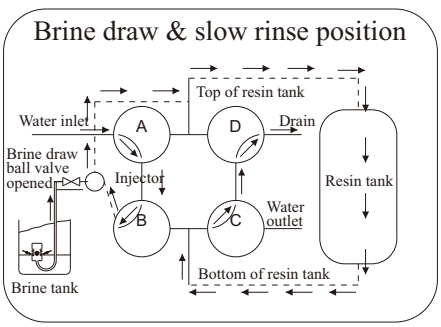
Figure 2-21 Flow chart in backwash position

(2) Backwash position

In backwash position, through different angles of moving and fixed disks located respectively, distribution valve controls four pieces of tee piston valves to realize A piston upwards, B piston upwards, C piston upwards, D piston downwards, then it can form passage as Figure2-21.

(3) Brine draw & slow rinse position

In brine draw & slow rinse position, through different angles of moving and fixed disks located respectively, distribution valve controls four pieces of tee piston valves to realize A piston upwards, B piston downwards, C piston upwards, D piston upwards, meanwhile, brine draw ball valve will be opened, then it can form passage as Figure 2-22. When brine draw finished, the ball valve will be turned off and enters into slow rinse status.



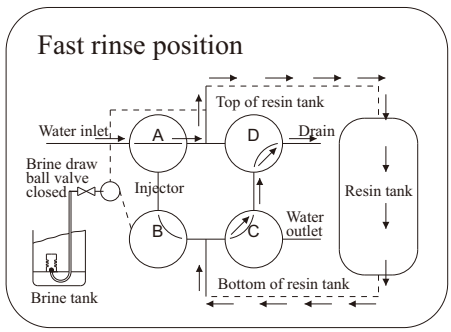


Figure 2-22 Flow chart in brine draw & slow rinse position

Figure 2-23 Flow chart in fast rinse position

(4) Fast rinse position

In fast rinse position, through different angles of moving and fixed disks located respectively, distribution valve controls four pieces of tee piston valves to realize A piston downwards, B piston upwards, C piston upwards, D piston upwards, then it can form passage as Figure 2-23.

(5) Brine refill position

After the fast rinse is completed, it will return service position again. In the same time, the electrical ball valve will be opened, a small part of hard water fills into brine tank though injector. The electrical ball valve will be turned off when the set brine refill time reached.

The 63650 softener valve takes raw water pressure into four pieces of tee piston valves through the distribution valve. The area of bearing pressure on the top and bottom of piston is different which forms pressure difference and result in piston moves in or out in chamber. In order to make the piston form a certain pressure difference, there is a diaphragm pump matched with control valve to make inlet pressure≥0.2MPa≥inlet pressure of main valve (meantime, ensure the fixed disk is connected to the drain G).

When the piston control valve used as a filtration system, distribution valve controls pistons to achieve the functions such as service, backwash and fast rinse.

2.2 Classification and nomenclature of multi-functional flow control valve

2.2.1 Classified by control method

The multi-functional flow control valve can be divided into manual control, semi-automatic control, fully automatic control, WIFI control, etc.

(1) Manual control

Manual control refers to the functions required for the service, rinse and regeneration of water treatment equipment through manual operation, that is, when the equipment is in service, regeneration or rinse, manually turn the valve to the corresponding station and stay at each station for the corresponding time, manually move to the next station.

(2) Semi-automatic control

Semi-automatic control means to start regeneration or rinse manually, and the subsequent process is automatically completed by the set program.

(3) Fully automatic control

Fully automatic control refers to a control valve will start regeneration or rinse automatically according to the time or meter set in the program or the input command received, and the subsequent processes fully automatically complete according to the program.

The fully automatic control valve according to the display mode is divided into: LED display, LCD display, indicator light display, etc.

(4) WIFI control

WIFI control refers to the control valve can be remotely controlled the valve to service, start regeneration or rinse through the mobile phone APP, and automatically complete various operations according to the set program.

2.2.2 Automatic control valve classified by regeneration method

According to the different methods of service ends and starting regeneration, automatic control valves can be divided into time clock type control valve, meter type control valve and online monitoring control valve.

(1) Time clock type control valve

Time clock type control valve refers to a control valve that starts rinse or regeneration by setting a fixed operating time, divided into two types: by days and by hours. For control valves by days, the shortest automatic regeneration interval is once a day. If it requires two or more regenerations in a day, it needs to regenerate manually. For control valves by hours, the minimum automatic regeneration interval is one hour, and it can be automatically regenerated multiple times in a day. However, the water softener should not be regenerated frequently. Generally, the regeneration should not exceed twice a day. The filter system can be rinsed once every two hours at most depending on the water quality.

The disadvantage of the time clock type control valve is: as long as the filter or water softener is in the service position, the control valve will continue to count the time even if there is no actual water used after rinse or regeneration, the control valve will start rinse or regeneration at the set time. Sometimes this will cause waste, or if the water supply demand fluctuates greatly, when the water demand increases sharply, it is easy to cause the unqualified water output. Therefore, for intermittently operating boilers or other industrial water equipment, if the water using time is irregular and the water softener stops and starts frequently, it is better to use meter type control valve instead of time clock type control valve.

(2) Meter type control valve

Meter type control valve refers to a control valve that starts rinse or regeneration by setting the cycle water treatment capacity. In service, the flow meter in the control valve measures the amount of water flowing. When the service water treatment capacity reaches the set value, it will automatically rinse or regenerate. Therefore, the regeneration setting of the meter type control valve is more reasonable than the time clock type control valve, whether it is continuous or intermittent service, whether the water consumption is stable or not, it all can be applied.

According to the time of starting regeneration, the meter type control valve can be divided into the meter immediate type and meter delayed type.

a) Meter immediate type: when the water treatment capacity reaches the set value, rinse or regeneration is will start immediately.

b) Meter delayed type: when the cycle water treatment capacity reaches the set value, it does not rinse or regenerate immediately, but delayed until to the set time. This is more suitable for some working conditions where the water supply is shortage, the water pressure is unstable and needs to be adjusted to a certain period of time for rinse or regeneration.

(3) Online monitoring control valve

The online monitoring control valve detects the corresponding parameters of the water treatment system online. When the detected parameters exceed the set value, it sends a signal to control the valve to automatically start rinse or regeneration. For filters, the pressure drop at the water inlet and outlet or the turbidity of the outlet water can be detected. For water softener, can detect the outlet water hardness. For anion and cation exchange desalination systems, can detect the water conductivity, etc.

Online monitoring control valve can not only ensure the quality of water, but also avoid the waste of rinse or regeneration in advance, so it is an ideal control valve. At present, because it is difficult to achieve accurate quantitative control for the automatic detection of water hardness, online monitoring control valves are not widely used in water softeners. Even if they are widely used in the future, manual regular inspection and calibration are required.

2.2.3 Multi-functional flow control valve classified by application

According to different applications, multi-functional flow control valve can be divided into filter valve, softener valve, control valve for special water treatment, etc.

(1) Filter valve

The filter valve refers to the multi-functional flow control valve used in the filtration system, with three main functions: service (filtering), backwash and fast rinse. With the popularization and application of household filters, some household filter valve products also have a closing function, that is, after receiving a signal (such as a signal generated by water leakage), the control valve can be closed to cut off the water.

(2) Softener valve

The softener valve refers to the multi-functional flow control valve which reduces the water hardness by using ion exchange resin. Its main functions include service, backwash, brine draw & slow rinse, brine refill and fast rinse, etc. According to the different regeneration methods, the functional sequence will be slightly different.

(3) Control valve for special water treatment

The control valve for special water treatment include the control valve for iron and manganese removal by aeration (filter valve), the control valve for deaeration by sponge iron, and the control valve for fluorine removal by special filter media.

2.2.4 Softener valve classified by flow direction in service and regeneration

According to the different liquid flow directions in service and regeneration, the softener valve can be divided into down-flow regeneration, up-flow regeneration, down/up-flow regeneration, and control valve for floating bed.

(1) Down-flow regeneration control valve

Down-flow regeneration control valve means that the brine flow direction in regeneration is

consistent with the water flow direction in service, and both flow from top to bottom. The down-flow regeneration steps are simple and easy to control, so the down-flow regeneration softener valve is the most widely used.

(2) Up-flow regeneration control valve

Up-flow regeneration control valve means that the brine flow direction in regeneration is opposite to the water flow direction in service. Generally, it refers to water flow direction of the control valve is from top to bottom in service, and water flow direction of brine draw & slow rinse is from bottom to top.

Up-flow regeneration has the advantages of saving salt and water, and its condition is to avoid resin disorder. In order to prevent the resin disordered in backwash, after the inlet water is filtered, it is not necessary to perform backwash every time when the turbidity is very low. Runxin up-flow regeneration softener valve can set the interval backwash times according to the turbidity of the inlet water, to achieve multiple cycles and backwash once. For example, if you set backwash once in 4 cycles, then the first 3 cycles of regeneration has no backwash, directly brine draw & slow rinse, when starting the fourth cycle of regeneration, performs backwash, and then brine draw & slow rinse again.

(3) Down/up-flow regeneration control valve

The down/up-flow regeneration control valve means that the control valve has both down-flow and up-flow regeneration functions in one valve, which can be set by the program according to actual needs. Mainly used in civil softening systems.

(4) Control valve for floating bed

Control valve for floating bed means the water flow direction is from bottom to top in service, and makes the resin floating during service. The resin settle down during regeneration, and the water flow direction is from top to bottom in brine draw & slow rinse.

For the characteristics, advantages and disadvantages of down-flow regeneration, up-flow regeneration and floating bed, refers to 4.1.3.2.

2.2.5 Automatic control valve classified by the number of exchange tank

According to the number of exchange tanks controlled by control valve, automatic control valves include single valve with single tank, single valve with double tanks and single valve with triple tanks, etc., among which single valve with single tank and single valve with triple tanks are mainly used for softening system, and all are softener valves.

(1) Single valve with single tank control valve: as shown in Figure 2-24 and Figure 2-25, one control valve only controls one water treatment tank. As there is no water available during rinse or regeneration, the water softener configured with a single valve with single tank control valve is only suitable for equipment with stable water consumption and intermittent service. For equipment that needs continuous service, two single valve with single tank softeners can be configured to operate in parallel, making regeneration separately to achieve continuous water

supply. The water storage tank can also be configured to solve the water usage problem during the regeneration of the softener.

The single valve with single tank softener valve can be divided into raw water bypass and no raw water bypass in regeneration. The raw water avaliable in regeneration is to avoid water shortage of water equipment. In regeneration, the inlet water will flow directly out of the softener through the bypass, that is, the outlet water in regeneration is unsoftened raw water, which is suitable for low requirements for softened water, allowing to use hard water for a short time, not suitable for boilers and other equipment that have strict requirements on the hardness of softened water. GB/T 18300 "Specification for Automatic Sodium Ion Exchange" stipulates that: for water softeners used in boilers, hard water should not flow out of the exchanger outlet during regeneration. Therefore, if the water softener used in the boiler is equipped with a softener valve, that is raw water available in regeneration, it is necessary to add a solenoid valve at the water outlet, to prevent the hard water from the exchanger outlet entering the soft water tank during regeneration. The water softener which has raw water available in regeneration is mainly used in civil or water treatment systems that do not require high water quality.

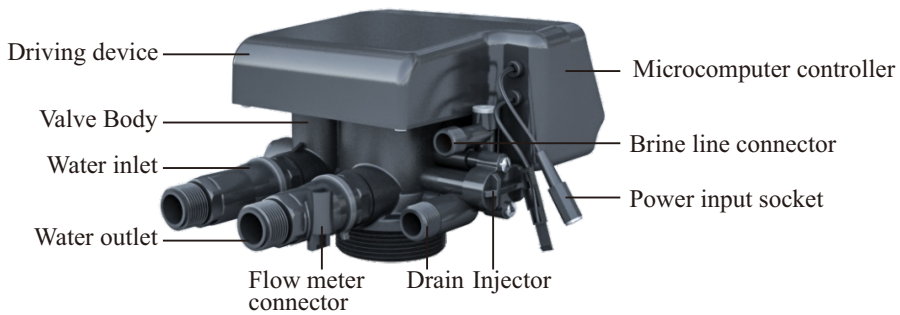


Figure 2-24 Single valve with single tank automatic control valve

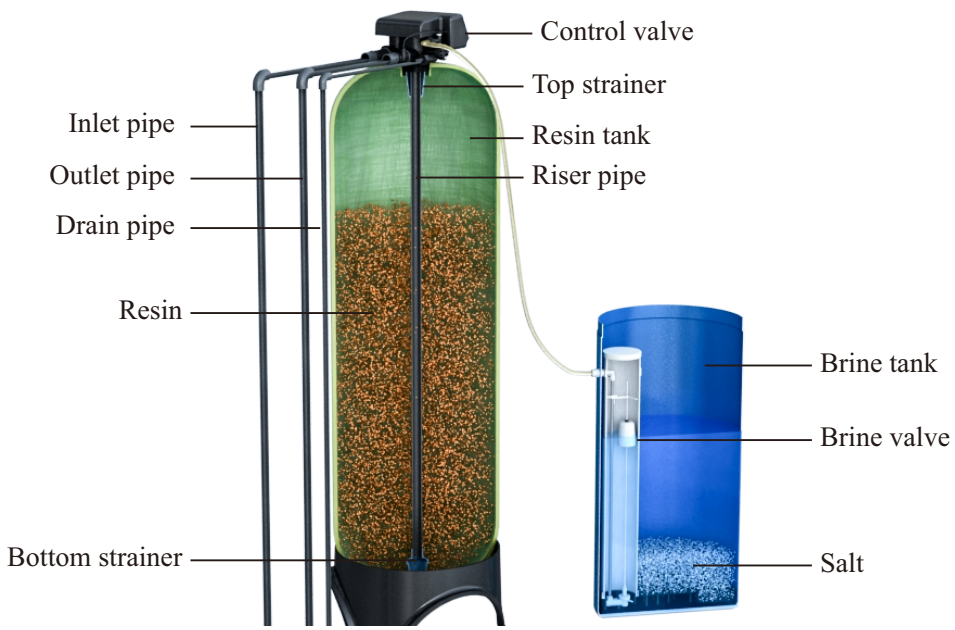


Figure 2-25 Single valve with single tank automatic control water softener

(2) Single valve with double tanks control valve: as shown in Figure 2-26 and Figure 2-27, it is mainly used for softening system. Two exchange tanks are controlled by a control valve, one of which is in service, and the other is in regeneration or standby state. The single valve with double tanks water softener can continuously soften water and is suitable for water equipment that needs continuous operation without any interruption.

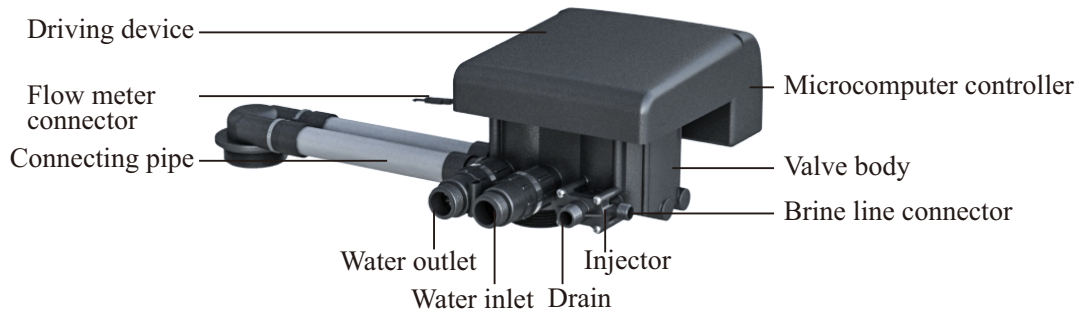


Figure 2-26 Single valve with double tanks automatic control valve

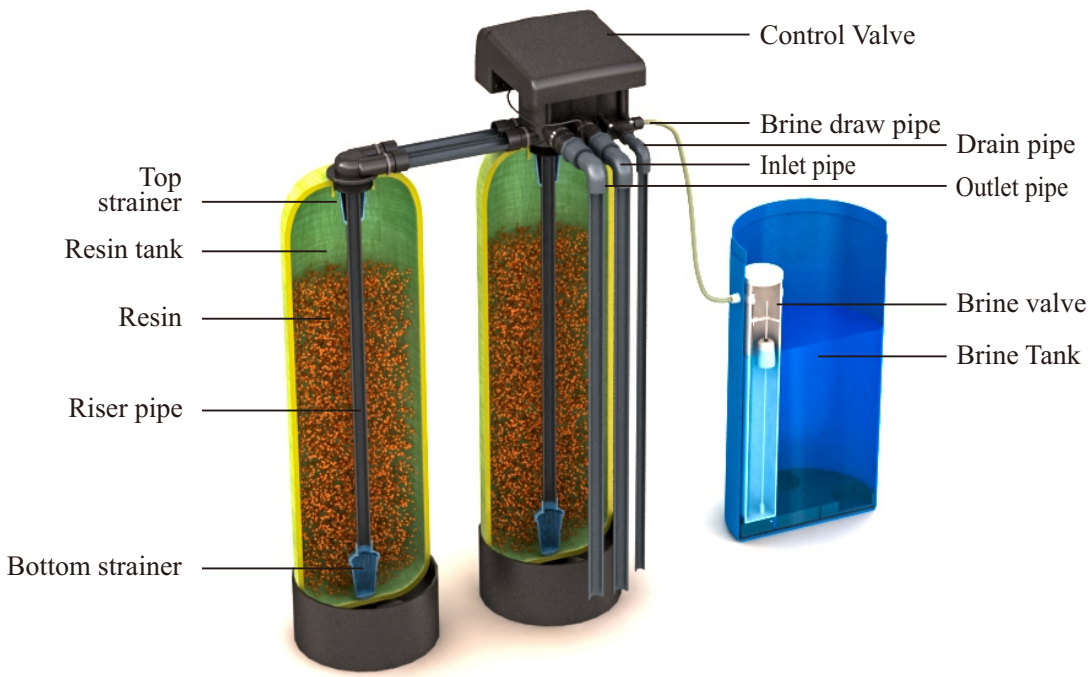


Figure 2-27 Single valve with double tanks automatic control water softener

(3) Single valve with triple tanks control valve: as shown in Figure 2-28 and Figure 2-29, it is used for high hardness (more than 10mmol/L) water treatment systems that require second grade softening, that is, one control valve controls the service and regeneration of three exchange tanks, two exchange tanks are working in series, and the other exchange tank is in regeneration or standby state. The second grade exchange tanks in series, when the first grade tank exhausted, the second grade exchange tank is automatically switched to the first grade. The standby exchange tank is connected in series to the second grade, and the exhausted exchange tank is

regenerated then standby. In this way, the whole system always has two exchange tanks working in series, and the regenerated tank is used as the second grade to ensure the outlet water quality.

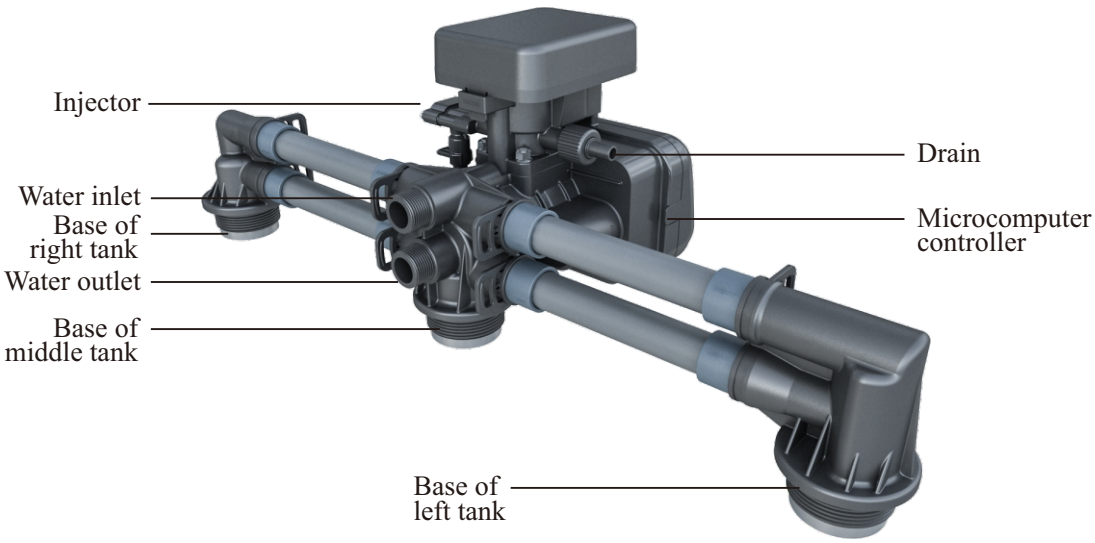
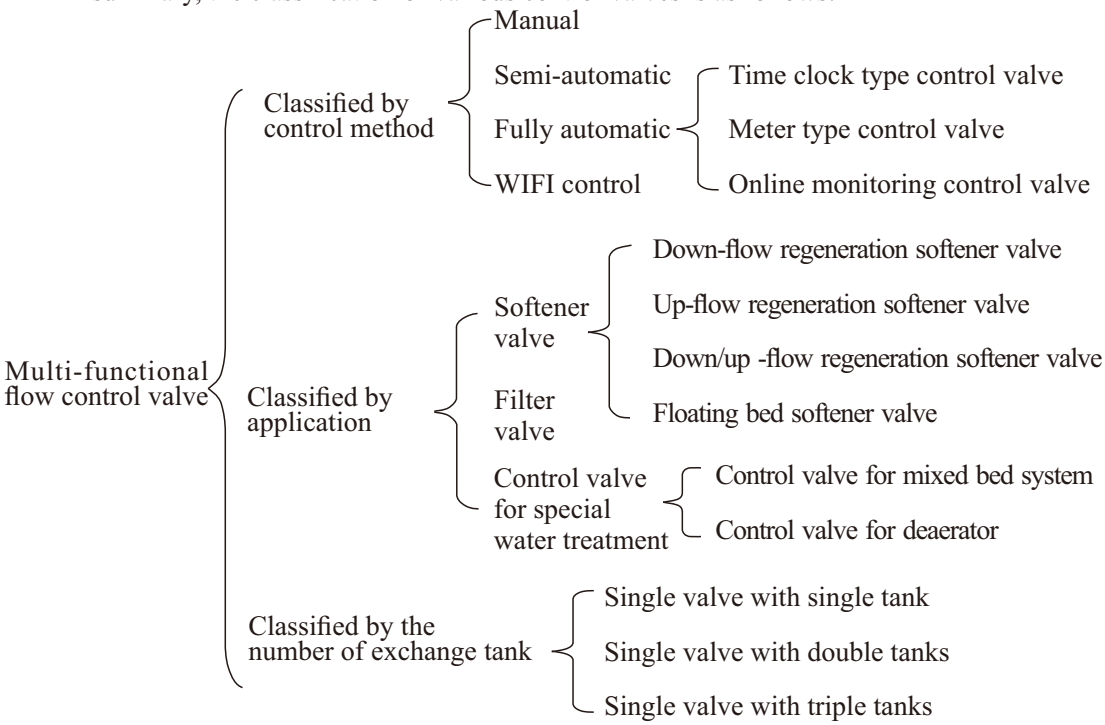


Figure 2-28 Single valve with triple tanks automatic control valve



Figure 2-29 Single valve with triple tanks automatic control water softener

In summary, the classification of various control valves is as follows:



2.2.6 Nomenclature regulation of multi-functional flow control valve

For the convenience of use, according to application, control method, handle or regeneration type, Runxin valves are classified and coded as shown in Tables 2-1, 2-2, and 2-3 :

Table 2-1 Classification and code of control valve by application

Code	1	4	5	6	7	8	9
Application	Special application	Spare part	Filter	Softener ， down-flow regeneration	Softener ， up-flow regeneration	Softener ， down/up -flow regeneration	Floating bed

Table 2-2 Classification and code of control valve by control method

Code	0	1	2	3	4	5	6
Control method	Semi -automatic	Manual control	Automatic control , LCD display	Automatic control , LED display	Automatic control ， indicator light display	Automatic control , digital tube display	Automatic control , WIFI control

Table 2-3 Classification and code of control valve by regeneration type

Code	0	1	2	5	6	7
Regenerati on type	No control type	Manual control , metal handle	Manual control ， plastic handle	Automatic control , time clock type	Automatic control , meter type	Automatic control , online monitoring type

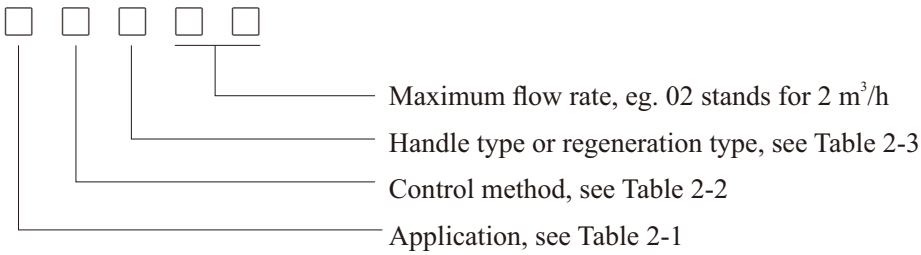
Table 2-4 Classification and code of special application control valve

Code	11	13	15	17	18
Special application	Control valve for fluoride removal	Control valve for deaerator	Control valve for mixed bed system	Single valve with double tanks	Single valve with triple tanks

Table 2-5 Classification and code of spare part

Code	41	42	43	44	45	46	47	48
Spare part	Bypass valve	Tee valve	Brine valve	Online monitoring device	Disk filter	Controller	Disinfection device	Salt shortage alarm device

Runxin valves are named according to below table. Its model number consists of 5 digits.



Note:

The code beginning with 1 or 4 are control valves for special application or spare parts. The meaning of the second digit is different from that in Table 2-2. The meaning of the first two digits is shown in Table 2-4 and Table 2-5.

Examples:

For 53610 control valve, 5 means filter valve, 3 means LED display automatic control, 6 means meter type, 10 means water treatment capacity is $10m^3/h$, that is, 53610 means meter type automatic filter valve with water treatment capacity of $10m^3/h$.

For 62504 control valve, 6 means down-flow regeneration softener, 2 means LCD display automatic control valve, 5 means time clock type, 04 means water treatment capacity is $4m^3/h$, that is, 62504 means time clock type down-flow regeneration softener valve with water treatment capacity of $4m^3/h$.

For 17610 control valve, 17 means single valve with double tanks, 6 means meter type automatic softener valve, 10 means water treatment capacity is $10m^3/h$, that is, 17610 means single valve with double tanks meter type automatic softener valve with water treatment capacity of $10m^3/h$.

2.3 PCB connector of automatic control valve

2.3.1 Main function connector

(1) Signal output connector

There is signal output connector on main control board which is used for controlling external wiring. The middle one is common (COM), two beside ones are normal close (NC) and normal open (NO).

It can be used to control the inlet booster pump, deep well pump (when deep well water supply), inlet solenoid valve, outlet solenoid valve, etc. For the application wiring diagram, see "2.4.2 Application of each connector of control valve".

(2) Interlock connector

There are two connectors on the main board of the industrial automatic control valve, one is interlock input, the other is interlock output. Main function: for a series, parallel or series-parallel system composed of multiple water softeners or filters, interlock ensures the orderly operation of the system, and separate rinse or regeneration. Even if there are two or more tanks that need to be rinsed or regenerated, due to the effect of interlock, the system only activates one control valve to rinse or regenerate according to the program setting, avoiding several valves to start regeneration or rinse at the same time.

(3) Remote handling connector

This connector can receive external active signals, voltage DC5 ~ 24V, used to control the valve. For example, it can receive the signal from PLC and the signal from conductivity meter. When the signal is received, the program controls valve to enter the next station. If the control valve is in service position, when the remote handling connector receives a signal, the control valve enters the backwash position. When the control valve is in the brine draw & slow rinse position, if it receives a signal, the control valve enters the next station.

(4) RS-485 connector

RS-485 is the remote communication connector, which realizes the collection and control of field data of the control valve remotely. Used in conjunction with PLC and other upper computers, the control valve can be operated remotely.

(5) Other connectors

Due to the different requirements in different countries, for residential control valves, some products are also equipped with salt shortage alarm connector that can receive the salt shortage signal, disinfection connector which in regeneration position, electrolyzes brine to generate hypochlorous acid to disinfect the resin in tank. These connectors are mainly a single function and will not be described in detail.

2.3.2 Function application of each connector of control valve

The function application of connectors on the control board of Runxin control valve is shown in Table 2-6, and the output signal status of the signal output connector is shown in Table 2-7.

Table 2-6 Function application of connectors of control board

Function	Application	Explanation
Signal output connector b-01	Outlet solenoid valve or electronic ball valve	If system strictly requires no hard water flow from outlet or controlling the liquid level in water tank.
	Inlet pump.	Increase pressure for regeneration or rinse. Use the liquid level controller to control inlet pump to ensure there is water in tank.
Signal output connector b-02/pressure relief connector	Inlet solenoid valve or electronic ball valve, or bypass pressure relief.	When inlet pressure is high, it needs to close water inlet when valve is rotating to protect motor.

Interlock connector	To ensure only one control valve regeneration or rinse in system.	Use in RO pretreatment, water supply together but regeneration in turn, second grade ion exchange equipment, etc.
Remote handling connector	Receive signal to make the control valve rotate to next position.	It is used for online monitoring system, PC connection, and realizes automatic or remote control of valve.
RS-485 connector	Real-time data transmission.	Connects with PLC, computer, etc., communicates with the control valve in real time

Table 2-7 Signal output

Position	Set：b-01			Position	Set：b-02	
	COM and NO	COM and NC			COM and NO	COM and NC
Service position	No connected	Connected		Each working position	No connected	Connected
Other position	Connected	No connected		Motor switching position	Connected	No connected

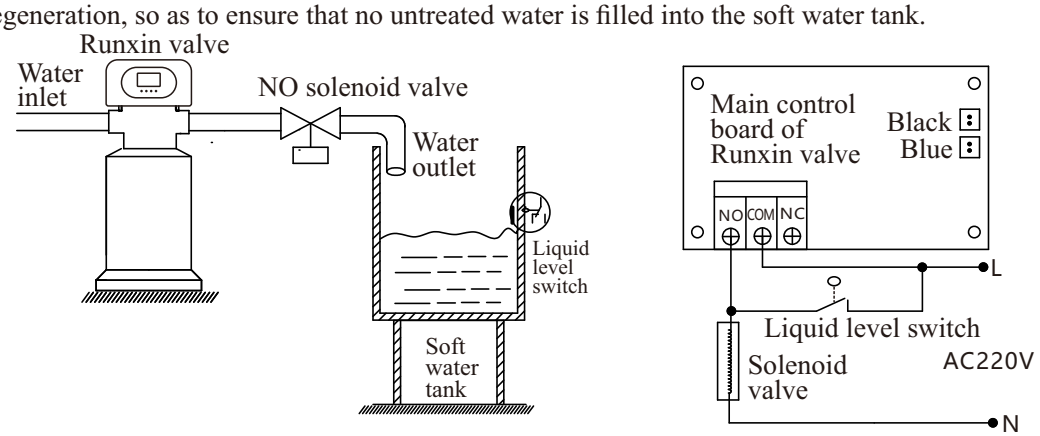
2.3.3 Function application of signal output

2.3.3.1 Control solenoid valve or electronic ball valve（Set b-01）

The liquid level of the water tank can be controlled by controlling the outlet solenoid valve. For water softeners used in boiler or other application which strictly require to control the outlet water hardness, during the regeneration process, it is necessary to ensure there is no hard water flowing out from the outlet. A solenoid valve can be installed on the outlet. The wiring method is shown in Figure 2-30. Its main functions are:

a) When the control valve is in service position, if soft water tank is short of water, the solenoid valve is open to supply soft water to the tank, but if water tank has enough water, solenoid valve is closed, so no soft water supplied.

b) When the control valve is in the regeneration process of backwash, brine draw & slow rinse, brine refill and fast rinse, NO and COM port is connected, the solenoid valve is closed, and cut off the outlet waterway. That is, no water comes out from the outlet when softener in regeneration, so as to ensure that no untreated water is filled into the soft water tank.



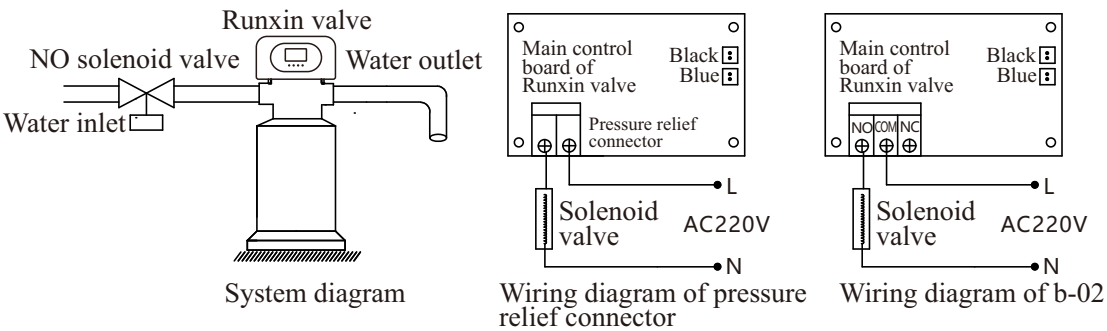
System diagram　　System wiring diagram

Figure 2-30 Wiring diagram of controlling outlet solenoid valve

2.3.3.2 Control solenoid valve or electronic ball valve on inlet (Set b-02)

(1) Pressure relief during working position switching: when the inlet pressure exceeds 0.6MPa, install a solenoid valve on inlet. Control mode is b-02. Pressure relieved when valve switching position. The wiring is shown in Figure 2-31.

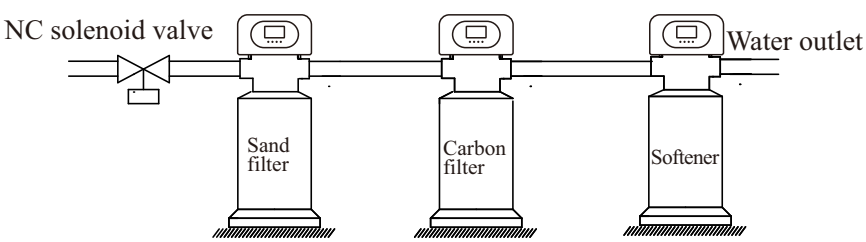
Its main function is: when inlet pressure is high, install a solenoid valve on inlet to ensure valve switching properly. When valve is exactly in position of service, backwash, brine draw & slow rinse, brine refill and fast rinse, solenoid valve is open. When valve is switching, solenoid valve is closed, no water flow into valve to ensure valve switching properly under no pressure state. It can prevent the problem of internal water mixing and water hammer of the control valve in the process of station switching.



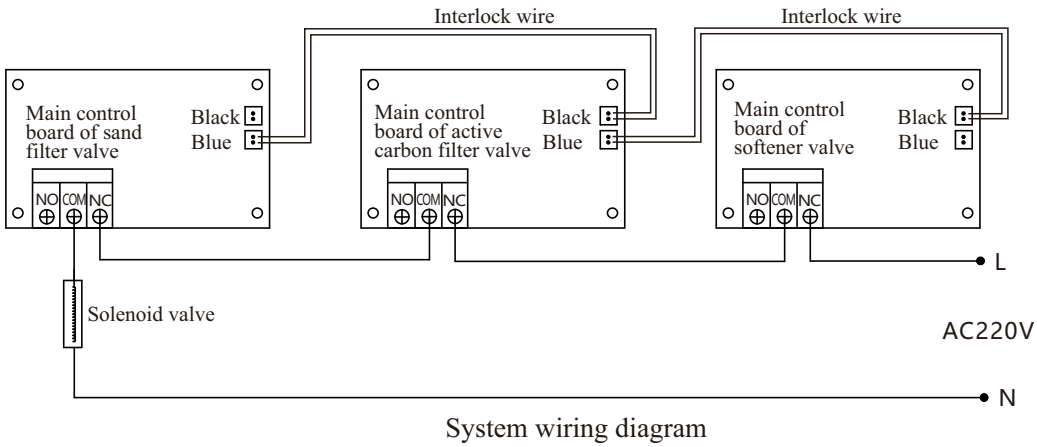
System diagram　　Wiring diagram of pressure relief connector　　Wiring diagram of b-02

Figure 2-31 Wiring diagram for controlling inlet solenoid valve

(2) Control in series system: when multiple water treatment equipments form a series system, such as multi-grade filtration, reverse osmosis pretreatment or second grade softening treatment, the interlock wire can be connected, when multi-grade series equipment is used in parallel, only allow one control valve for rinse or regeneration without affecting the normal operation of other equipment. When using multi-grade series interlocking, the inlet solenoid valve wiring is shown in Figure 2-32.



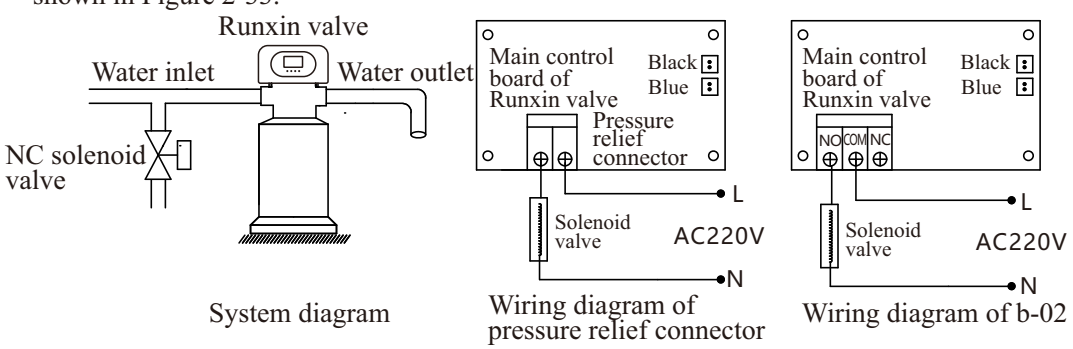
System diagram



System wiring diagram

Figure 2-32 Wiring diagram of interlock for controlling inlet solenoid valve for multi-grade series

(3) Bypass pressure relief: in systems that use inlet booster pump or a well water supply, when the valve rotates, the valve switching may cause the flow rate to change, increasing or decreasing the pressure in the system, which requires higher pressure resistance of the system. By installing a solenoid valve on the inlet pipe to connect with the drain or to the original water tank, when the valve rotates, the pressure relief solenoid valve opens and discharges to the drain or backflow to the original water tank, to prevent the sudden shut-off of the valve when it rotates, resulting in a sudden rise in inlet pressure and causing damage to the system. The wiring is shown in Figure 2-33.



System diagram

Wiring diagram of pressure relief connector

Wiring diagram of b-02

Figure 2-33 Wiring diagram of pressure relief connector

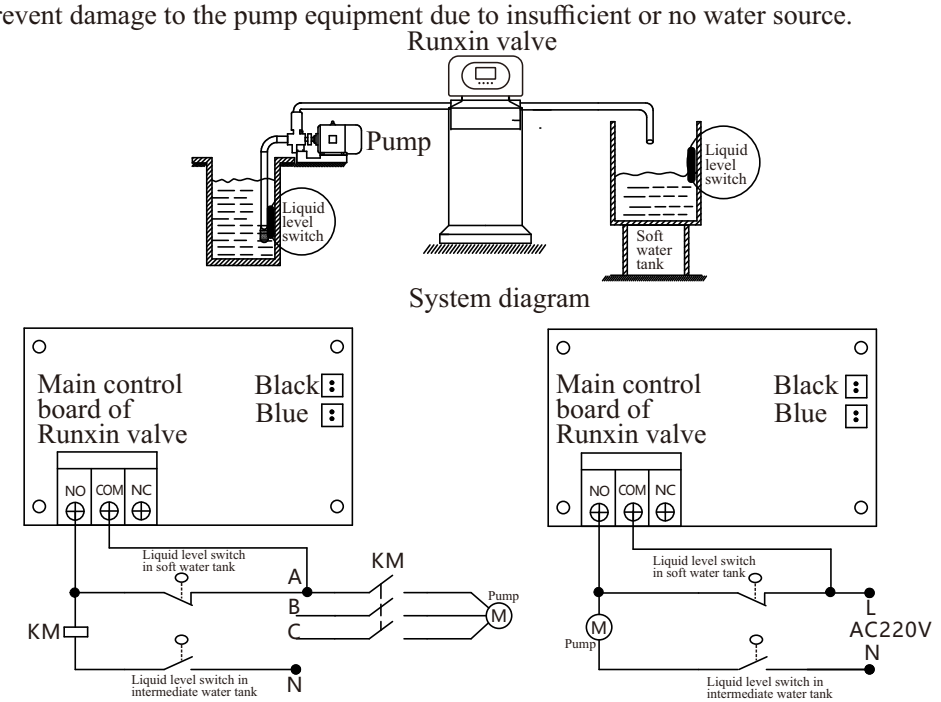
2.3.3.3 Liquid level switch controls inlet pump (Two-phase motor or three-phase motor) (Set b-01)

For the system with underground water or intermediate water tank, the opening and closing of the inlet pump can be controlled by the liquid level switch of the water tank and the control valve. The wiring is shown in Figure 2-34. The single-phase pump adopts two-phase motor, and the three-phase pump adopts three-phase motor and AC contactor. The main functions are:

(1) When control valve in service position, if water tank is short of water, start the water pump; if water tank has enough water, the liquid level switch is closed, so pump doesn't work.

(2) When filter valve is in backwash, fast rinse or the softener valve is at the position of each step of regeneration, regardless of the water level of the water tank, the water pump is in normal working condition to ensure that the water inlet is supplied with water as required during water rinse or regeneration.

(3) The liquid level switch is installed in the well (or intermediate water tank, etc.), which can prevent damage to the pump equipment due to insufficient or no water source.

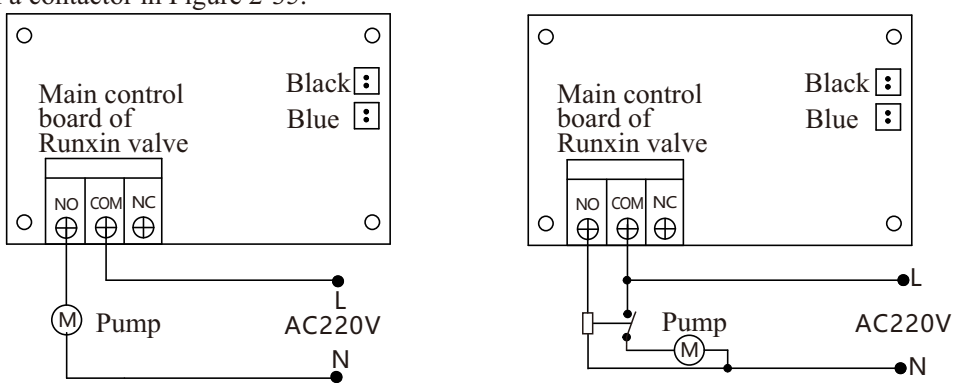


Wiring diagram of three-phase pump system Wiring diagram of single-phase pump system

Figure 2-34 Wiring diagram of the inlet pump controlled by liquid level switch

2.3.3.4 Control inlet booster pump (Set b-01 or b-02)

If inlet water pressure is less than 0.15MPa, which makes backwash or brine draw difficult, a booster pump is suggested to be installed on inlet. And set the control mode to b-01. The wiring is shown in Figure 2-35. If the booster pump current is bigger than 5A, system needs to install a contactor in Figure 2-35.



Wiring diagram of pump current less than 5A Wiring diagram of pump current bigger than 5A

Figure 2-35 Wiring diagram of inlet boost pump

The main function is: install a booster pump at the inlet of water softener or filter. When the inlet pressure is low, the signal output connector can control the booster pump to turn on in the regeneration or rinse position, increase the inlet pressure to ensure brine draw or rinse effect.

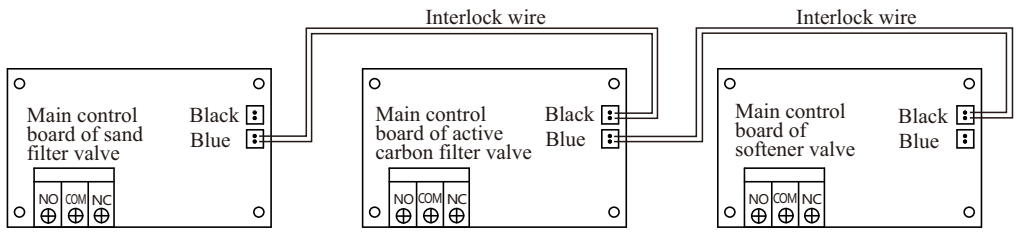
2.3.4 Function application of interlock

If the water treatment system requires a series system consisting of multiple filters or multi-grade water softeners, or a parallel system consisting of multiple filters or water softeners, and a series system consisting of water softeners and reverse osmosis equipment, etc. By connecting the interlock wire, the series, parallel or series-parallel system composed of multiple water treatment control valves can start service, rinse and regeneration in orderly, avoiding the bad effect of multiple control valves starting rinse or regeneration simultaneously.

When the interlock wire is connected, only the CN8 (black) of the previous valve and the CN7 (blue) of the latter valve need to be connected. When multiple systems are interlocked, the interlock wire is disconnected, it is automatically divided into two interlock systems, its wiring is shown in Figure 2-36, and its main functions are:

(1) When used in a parallel system composed of n sets of water treatment equipment, only one valve can be regenerated or rinsed, and (n-1) equipment is supplying water or suspending, that is, realizing the function of working simultaneously but regeneration separately.

(2) When used in a water treatment system with multiple equipment in series (such as a second grade softening treatment or reverse osmosis pretreatment system), only one valve can be used for regeneration or rinse to ensure that there is water in each stage of the system during regeneration or rinse.

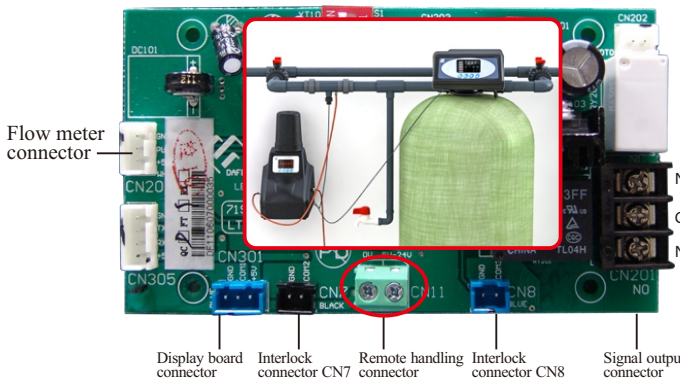


System wiring diagram

Figure 2-36 Wiring diagram of interlock

2.3.5 Function application of remote handling connector

When the control valve is used for ion exchange desalination to produce pure water or other online monitoring system or connected to the PC (as shown in Figure 2-37), when the conductivity or other parameters reach the set value or the PC sends a signal, the system needs regeneration, the signal wire can be transmitted to the remote handling connector on the main board of the valve body, to make the valve immediately regeneration. This connector is equivalent to pressing the manual button after receiving the signal. The wiring is shown in Figure 2-38:



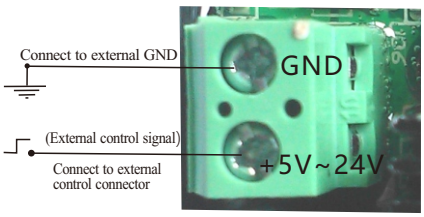


Figure 2-37 Online monitoring remote handling **Figure 2-38 Wiring diagram of remote handling connector**

Extended function: if need to use PLC to control the softener valve, you can set each time parameter of the softener valve to the maximum value. When regeneration is needed, the PLC will send a signal to the softener valve to enter the backwash position. If the backwash time on PLC is set to 20 minutes, when the time is up (the time set by the softener valve has not yet arrived), the PLC can send a signal to control the softener valve to finish backwash and enter the next program, and so on.

2.4 Application of each connector in water treatment system

2.4.1 Multiple water treatment equipments to realize working simultaneously but regeneration separately

For multiple water treatment equipments, more than one equipment need to supply water at the same time, and to avoid simultaneously rinse or regeneration, it can be realized by connecting multiple valves to interlock wires. The wiring is shown in Figure 2-36:

2.4.2 Use a single flow meter to realize double (multiple) tanks working simultaneously but regeneration separately and in sequence

For water treatment system equipped with a meter type valve and one (or more) time clock type valve, they can be interlocked, and the operation cycle of the time clock type valve can be set to the maximum value, and the signal output connector of the meter type valve is connected with the remote handling connector of the time clock type valve, to realize working simultaneously but regeneration separately and in sequence. The wiring is shown in Figure 2-39.

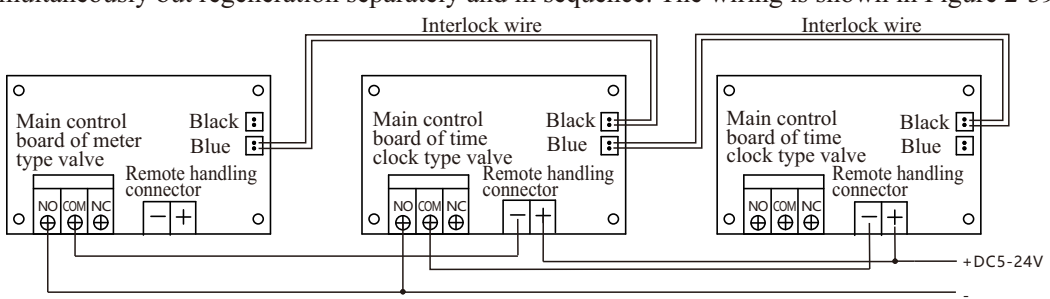


Figure 2-39 Wiring diagram of working simultaneously but regeneration separately and in sequence

Application note: when the meter type valve in regeneration, the signal output connector outputs a signal and sends it to the remote handling connector of the time clock type valve. If the remote handling connector of the time clock type valve receives the signal, also need to regenerate. Because the system has been interlocked, when the meter type valve is regenerating, the time clock type valve ready to be regenerated enters the waiting position. After the meter type valve completes regeneration, the time clock type valve starts regeneration. Similarly, control the next time clock type valve after the previous control valve completeing regeneration, then into the regeneration sequence, and so on, to achieve the purpose of working simultaneously but regeneration separately and in sequence.

This connection can be applied to the anion cation system.

2.4.3 One in service one standby softening system

Two 63510, 63515 or 63520 valves and a 42020 tee valve can form a one in service one standby water supply system. The control valves need to be interlocked and connected with the tee valve. The wiring diagram is shown in 2-40.

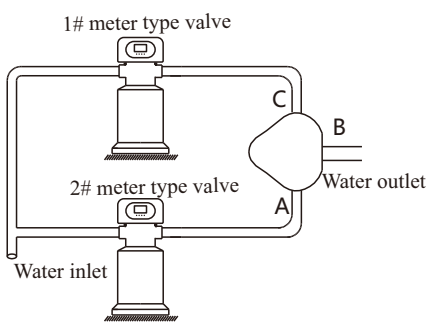
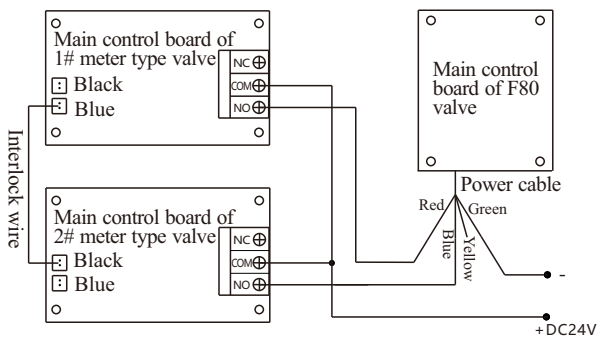


Diagram of one in service one standby system



Wiring diagram of one in service one standby system

Figure 2-40 One in service one standby system composed of two valves and two tanks

Application note: as shown in the left Figure 2-40, when the 1# control valve is in service, the tee valve is in the state of connecting with C and B, and the 2# valve is in regeneration or standby after regeneration. When the water treatment capacity or service time of 1# control valve reaches the set value, the control valve will enter the regeneration, and the tee valve is controlled to switch to the connection state of A and B. (Because 1# and 2# are interlocked, when 1# enters the regeneration, 2# will definitely be in service, and vice versa), which realizes the function of one in service one standby.

2.4.4 Reverse osmosis (RO) system pretreatment

For water supply systems that use second grade filtration (quartz sand filtration + activated carbon filtration), softening pretreatment and then reverse osmosis (RO) treatment, the opening and closing of the pump can be controlled by the liquid level switch of the storage tank and the control valve. The control mode of Runxin valve is set to b-01, the pre-pretreatment control valves are interlocked, the signal output connector is connected to the inlet booster pump,

high pressure pump and water tank level switch are shown in Figure 2-41. Its main functions are:

a) When the liquid level of the water tank is low, the inlet booster pump and high pressure pump are opened.

b) When the water tank is full, the booster pump and high-pressure pump are closed.

c) When the control valve in regeneration, the booster pump is opened and the high pressure pump is closed at the same time.

d) Check valve function: when the pretreatment water supply is insufficient, and there is no low pressure switch protection or low pressure switch failure, it prevents the high pressure pump from generating negative pressure in the front system and avoids the pretreatment tank from being sucked deformed.

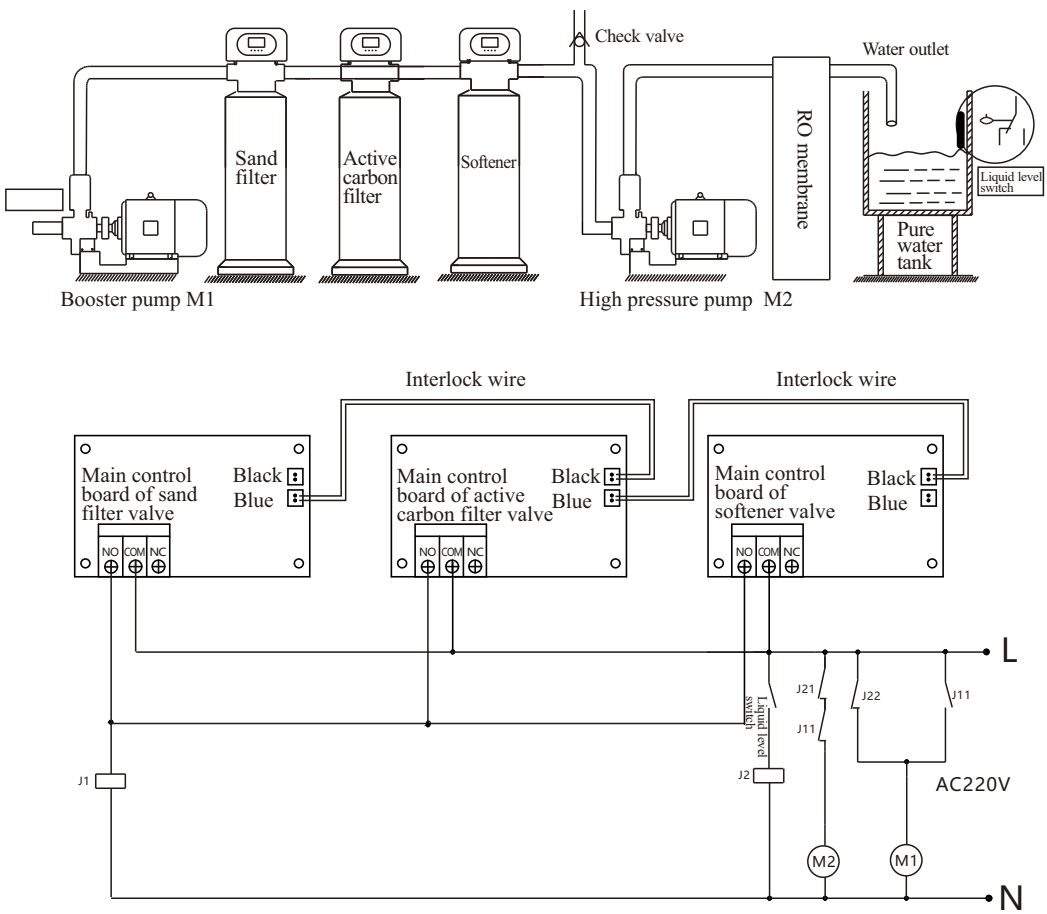


Figure 2-41 Wiring diagram of pretreatment and RO system

3. Application of Runxin filter valve

Generally, natural water often contains more suspended solids and colloidal substances. Although most of the suspended solids and colloidal substances can be removed after coagulation treatment, it is still inevitable that a few tiny suspended particles will remain. It needs to be further removed by filtration to meet the subsequent ion exchange treatment, membrane treatment and other requirements for inlet water. Especially for reverse osmosis membrane treatment systems, even the water seems to be relatively clear, it also needs to be processed by precision filtration treatment before entering the reverse osmosis device which can avoid membrane blocking and ensure normal operation.

3.1 Function and principle of filtration

The selection of filter system and filter media usually needs to be determined according to factors such as the inlet water quality, the subsequent water treatment process requirements for inlet water, and the amount of treated water. Generally, the main function of filtration is cut off pollution, which is to more thoroughly remove impurities such as suspended solids and colloids in water through a suitable filter layer. The most commonly used filtration method is granular filter media filtration, because the equipment of this method is relatively simple, and when the filter layer exhausted, it is easy to use backwash to restore its filtration ability. The filtration principle is generally considered to be the combined result of surface adsorption and mechanical retention: firstly, when water starts to enter the filter layer from the top, part of the suspended solids in water is retained by the surface of the filter layer due to adsorption and mechanical retention. At this time, the suspended solids will overlap and bridge each other, so after a period of time, it seems that an additional filter membrane is formed on the surface of the filter layer. In the subsequent filtration, this filter membrane will play the main role of filtration. This filtration process is called thin membrane filtration. In the actual filtration operation, the filtration function is not only the surface of the filter layer. In fact, when the water flow enters the middle of the filter layer, it will also play the role of interception of suspended solids and colloidal substances due to the adsorption and coagulation results.

3.2 Common filtration equipment and system

The traditional common filtration equipment is mainly the filtration equipment with granular media as the filter media. According to the structure of the equipment, the liquid flow direction and the different configuration of filter media, there are many classifications. The following is a brief introduction of several commonly used filtration equipment and systems.

3.2.1Pressure filter

The commonly used pressure filters mainly include single-flow filter and dual-flow filter.

3.2.1.1 Single-flow filter

(1) Structure

Ordinary single-flow filter is also called mechanical filter, this filter is usually a closed vertical cylindrical container filled with suitable filter media, and equipped with water inlet device, water distribution system, and some are also equipped with entering compressed air device. There are various necessary pipes, valves and instruments outside the filter.

In the single-flow filter, a certain space should be left between the inlet device and the filter layer for the expansion of the filter layer during backwash. This space is always filled with water during service, which can promote the uniform flow of water. Therefore, the water inlet device of this type of filter is generally relatively simple.

The water distribution system is an important component in the filter. Its function is to ensure that the water flow is equally distributed in the filter layer, and prevent the filter media from leaking. There are many types of water distribution systems, currently commonly used are: drain cap type, branch pipe slit type and filter cloth type (perforated plate clamped press cloth or branch pipe coated press cloth), etc.

(2) Use

The service flow velocity of ordinary single-flow filter is generally 8m/h ~ 10m/h. When the pressure drop (that is, the pressure difference between inlet and outlet) of the water flow filter layer increases to a certain value, the service shall be stopped and backwash shall be carried out. At this time, the water in the filter should be discharged to the upper edge of the filter layer, and then compressed air of a certain strength is sent from the lower part [Different filter media require different compressed air strength. The heavier the filter media, the bigger the strength required. Generally, the compressed air backwash strength of quartz sand filter media is (18 ~ 25) L/(m^2·s)]. After stirring and blowing for 3min ~ 5min, while continuing to supply compressed air, backwash water should be fed into the filter, the strength of backwash water should make the filter layer expand by 10% to 15%. After the backwash water is fed for 2min to 3min, stop the compressed air and continue to backwash with water for 1min to 2min. At this time, the strength of the backwash water should be increased to make the expansion rate of the filter layer reach 40%-50%. Finally, make fast rinse until the outlet water is qualified, and then start the filtration service.

The turbidity of the outlet water should be monitored during the service of the filter. However, the service end point of the single-flow filter is usually not judged based on the turbidity change of the outlet water, but determined by adjusting the appropriate pressure drop. This is because the filter media distributed fine at the top and coarse at the bottom for the single-flow filter. As water flows through the filter layer, more and more suspended impurities are

trapped on the surface of the filter layer, which is equivalent to forming a denser and denser filter membrane. The filter membrane reduces the turbidity of the outlet water and increases the pressure drop of the water flow. If the filter has been servicing until the pressure drop exceeds a certain limit value, this filter membrane will suddenly break. At this time, a large amount of suspended impurities on the surface layer will be quickly distributed throughout the filter media layer, causing the turbidity of the outlet water to deteriorate quickly, and it is difficult to backwash the polluted filter media layer, which affects the subsequent filtering effect. Therefore, the single-flow filter should determine the end point of service for backwash before the turbidity increases (that is, before the pressure drop reaches the limit). For example, a mechanical filter is loaded with a quartz sand filter media with particle size of 0.6mm to 1.2mm, and the height of filter layer is about 0.7m. When the backwash is just completed, the pressure drop of the water flowing through the filter layer is about 4.9kPa. When the maximum service pressure drop is about 40kPa, the turbidity of the outlet water starts to increase significantly, so the filter cannot be serviced to this limit value. Generally, it services until the pressure drop reaches 20kPa ~ 30kPa, backwash should be carried out.

3.2.1.2 Dual-flow pressure filter

The appearance of the dual-flow pressure filter is similar to the single-flow filter. The difference is that the intermediate water distribution device is added. In service, the water is fed in from the upper and lower channels respectively. After filtered, the water is discharged from the middle. The total height of the filter media of the dual-flow filter is 2m ~ 2.4m, and the intermediate water distribution device is generally located in the filter layer 0.6m ~ 0.7m from the surface of the filter media. When quartz sand is used as the filter media, the particle size should be 0.4mm ~ 1.5mm, the average particle size should be controlled at 0.8mm ~ 0.9mm, and the uneven coefficient K_{80} should be 2.5 ~ 3. Although the filter media distribution of the dual-flow filter is still fine at the top and coarse at the bottom, since most of the water flows from bottom to top encounters the large particle filter media first, and then the gradually finer filter layer, the whole filter layer can be fully utilized through this "reverse particle size filtration". In addition, when the water inflows from the upper part flows downwards through the small particle filter media on the surface, although the head of water loses quickly and the water flow is gradually reduced, but it can prevent the filter layer from expanding when the lower water flows upwards, making the filtration process more stable.

When the dual-flow filter is in service, the upper and lower inlets account for about 50% respectively at the beginning, but as the filtration goes on, the resistance of the upper filter layer increases, the water flow rate gradually decreases, and the proportion of the lower water flow rate increases. To the end of the service, the lower water flow rate accounted for about 80% of

the outlet water flow rate. Compared with the ordinary single-flow filter, the dual-flow filter has the advantages of large output and longer service cycle, but the cleaning operation and maintenance are more complicated, and the turbidity of the outlet water is not as low as the single-flow filter.

The cleaning method after the failure of the dual-flow filter is as follows: firstly, blow wash with compressed air for 5-10 minutes, then use clean water to enter from the middle, and rinse the upper filter layer upwards. Then turn off the compressed air, feed water from the middle and bottom at the same time, discharge from the upper part, rinse the entire filter layer, and control the backwash intensity (16-18) L/(m^2·s) for a time of 10min-15min. Finally, stop backwash, clean in the service direction, and start the filtration service when the outlet water is qualified.

3.2.1.3 Multi-layer media filter

Ordinary single-flow filter, under the washing of backwash water, the filter media is naturally arranged according to "upper fine and lower coarse". So this kind of filter mainly uses the filter membrane function on the surface of the filter layer to filter, and the lower filter media mostly fails to exert its filtering effect. Therefore, its average filtration ability is low, the service cycle is short, and the head loss of the filter layer increases rapidly. In order to improve this situation, for single-flow filters, multi-layer media filter are designed. Most of the multi-layer media filter currently in use are double-layer or triple-layer filter.

(1) Double-layer filter

Its structure is the same as ordinary filters, except that two different filter media are layered in the filter bed. The upper layer is the filter media with small relative density and large particle size, and the lower layer is the filter media with large relative density and small particle size. Usually used: the upper layer is anthracite (relative density 1.5~1.8), and the lower layer is quartz sand (relative density about 2.6). Because of their large difference in relative density, even if the particle size of anthracite is large, they can still be on top of the smaller quartz sand after backwash. In this way, the particles of the whole filter layer can form a "fine at the top and coarse at the bottom" arrangement, which is very beneficial to filtration.

Whether the double-layer filter can achieve good service effect, the key is whether the two filter media can be separated well in backwash. In order not to mix the two filter media in backwash, the particle size of the two filter media must be appropriately selected. Practice has been showed that when the relative density of anthracite is 1.5, the ratio of the maximum coal particle size to the minimum quartz sand particle size should not be bigger than 3.2. In practical application, it is difficult to achieve complete immiscible layer of two filter media, and it is generally required to control the thickness of the mixed layer to be less than 10 cm.

The ordinary quartz sand filter can be directly changed to a double-layer filter. At this time, the minimum particles with a height of 200mm ~ 300mm in the upper layer can be taken away,

so that the particle size of the remaining quartz sand surface layer is 0.65mm ~ 0.75mm,and then the anthracite filter media with a particle size of 1.0mm ~ 1.25mm can be loaded. In this way, most of the suspended solids in the water will penetrate into the pores between the anthracite particles during filtration and be intercepted, and the remaining can be retained by the lower layer of quartz sand.

(2) Triple-layer filter

The principle and structure of the triple-layer filter bed is similar to the double-layer bed, which is equivalent to adding a layer of filter media with higher relative density and smaller particles under the double-layer filter bed. The high density filter media commonly used are: garnet, magnetite or ilmenite, etc. Their chemical properties are stable. The density of garnet is 4.2g/cm^3, and the density of magnetite is (4.7 ~ 4.8)g /cm^3.

The particle size range of the triple-layer filter is generally: the upper layer of anthracite is 0.8mm~ 2.0mm, the lower layer of high-density filter media is 0.25mm~0.5mm, the middle layer of quartz sand can be determined according to the conditions of the upper and lower filter media, and no obvious mixing is required. The thickness proportion of each layer of filter media in the total thickness can be determined according to the inlet water quality, generally: the lower filter media accounts for about 5%~10%, the middle filter media accounts for about 25%~35%, the upper filter media accounts for about accounted for 60%~ 65%.

Although the double-layer filter has a higher filtration ability and flow rate (usually 12m/h~16m/h) than the single-layer filter, but due to the larger particle size of the lower quartz sand, in order to prevent suspended solids from passing through the filter layer, the filtration speed still cannot be too high. In the triple-layer filter, because the particle size of the filter media is arranged from top to bottom, from large to small, and the lower filter media has small particle size and large surface area, the filtration ability of the filter layer can be fully utilized. So the filtration rate can even be increased to more than 30m/h, which can still effectively prevent the penetration of suspended solids. Therefore, the advantages of this type of filter are high filtration rate, large filtration ability, long filtration cycle, good outlet water quality, and strong adaptability to water sources with high turbidity and large turbidity fluctuations. Its water flow resistance is equivalent to the ordinary filter.

3.2.1.4 Variable pore filter

The variable pore filter is also specially designed on the basis of the single-flow filter. Its main feature is that the filter layer in the filter is fully mixed with two different particle size filter media. The filter media ratio is: coarse filter sand with particle size of 1.2mm~2.8mm, accounting for about 96% of the total volume of the filter layer, about 4% is fine filter sand with particle size of 0.5mm~1.0mm, and the total height of the filter layer after mixing is 1.5m-2m.

In the variable pore filter layer, the fine filter media is evenly mixed in the pore center of the coarse filter media, so that the porosity of the whole filter layer is greatly reduced. In this way, when the water flows through the filter layer, the channel becomes tortuous and long, which is beneficial to intercept the suspended solids.

The operating experience shows that whether the variable pore filter is operating well, the key factor is if the backwash effect is good or not, and if the small particle size filter media can be fully mixed in the large particle size filter media and distributed evenly. The general backwash process is as follows: first backwash with water for 2 minutes, then scrub with air and backwash with water for another 2 minutes, finally, backwash with water for 2 minutes, the backwash intensity is (15-16)L/(s·m^2). After the backwash is completed, compressed air is required to mix the large and small filter media thoroughly before it can be put into operation. In the variable pore filter, the main process is osmotic filtration. In the case of good backwash, it has the advantages of small filter layer resistance, large filtration ability, and high filtration rate.

3.2.2 Fiber filter

The fiber filter is named after the use of fiber material as the filter media. At present, the main applications that have been applied are capsule extrusion fiber filter and floating fiber hydraulic regulating density filter. The main structure of the fiber filter is basically the same as the single-flow pressure filter. The internal filter media is a synthetic fiber with a certain density, and the water is filtered through the filter layer upwards. Among them, the capsule extrusion fiber filter is the fiber filter layer with several impermeable capsules. In filtration, the capsule filled with water expands and compacts the fiber bending, so that the water can be filtered as it passes through. When washing, remove the water in the capsule, relax the fiber, and use compressed air for water and air wash to clean the fiber filter layer.

Fiber filter media is usually filament made of polypropylene fibers, which have the advantages of high tensile strength, good chemical stability, low water absorption, large surface area, small water flow resistance, and easy cleaning. It is an ideal filter media. Practice has proved that the fiber filter is a relatively efficient filter, its characteristics are:

a) High operating flow rate and large filtration capability. When the water flow velocity is 30m/h, the filtration capability is 4.9kg/m^2. When the water flow velocity is 50m/h, the filtration capability is 2.3kg/m^2. Its filtration capability is 5-10 times higher than that of sand filter.

b) The outlet water quality is better. Fiber filtration can be used for both clarification filtration and contact filtration. When the inlet water is treated by coagulation, the turbidity of the outlet water can be ≤ 1NTU.

c) Low head loss and low operating pressure. The average filtration pressure difference during operation is 0.02MPa ~ 0.06MPa, generally the maximum does not exceed 0.2MPa.

3.2.3 Activated carbon adsorption filtration

Although the turbidity of the filtered water can be reduced to a lower level, some organic matter and free chlorine are often remained. It will affect the service life of the ion exchange resin or reverse osmosis membrane greatly, so it should be removed as much as possible. Using the ordinary pressure filter with activated carbon as the filter media, it can better remove the free chlorine and reduce the organic content in water. Because activated carbon is expensive and easily broken when washed with strong water, the main function of its filtration is not to intercept pollution, but to reduce the content of free chlorine and organic matter in water through adsorption. In order to ensure its adsorption effect and avoid a large amount of suspended solids and colloidal substances from polluting the activated carbon, it is usually necessary to set up a sand filter before the activated carbon filter to reduce the turbidity of the water, then enters the activated carbon filter.

Activated carbon is a kind of adsorbent with strong adsorption capacity, and its filtration effect is mainly based on physical adsorption. It is usually made of fruit shell charcoal (such as coconut shell, walnut shell, apricot kernel), coal, charcoal, etc., which are processed through activation treatment such as chemical treatment or high-temperature roasting. After activation treatment, the surface and the interior of activated carbon formed innumerable interconnected capillary channels, with pore size ranging from 1nm to 100nm, so it has a large adsorption specific surface area, generally up to $500m^2/g \sim 1500\ m^2/g$. The activated carbon used for adsorption and filtration is usually made into particles with particle size of 1 mm~4 mm, which can be selected according to needs when used.

Activated carbon filtration can more effectively remove free chlorine in water. In this process, in addition to the physical adsorption of Cl_2 by activated carbon, the surface of activated carbon also has a certain catalytic effect, which can promote the hydrolysis of free chlorine Cl_2 and accelerate the production of new ecological oxygen [O]. The new ecological oxygen can react with the carbon or other easily oxidized components in the activated carbon to further promote the removal of free chlorine.

Although the adsorption and filtration with activated carbon can reduce the content of organic matter in water, but because of various types of organic matter in water and the big difference in molecular size, so the adsorption capacity of activated carbon is different. Usually the adsorption effect is related to the activation characteristics of activated carbon and the

composition of organic matter in water. For example, among activated carbon made from fruit shells, coconut shell activated carbon is the best in terms of conventional adsorption index, but for the adsorption of organic matter in natural water, activated carbon made from walnut shell or apricot kernel is better. In addition, experiments have shown that the general activated carbon has a better adsorption and removal effect on organic matter with a molecular weight of 500~3000, while it is difficult to remove organic matter with a molecular weight of less than 500 or more than 3000. Generally, the adsorption rate of organic matter in general water by activated carbon filtration is about 20%~80%.

In operation, when the activated carbon is polluted by suspended solids or colloids and affects the adsorption and filtration, it can be cleaned by backwash. But if the adsorption performance of activated carbon has disappeared, it should be regenerated or replaced with a new one. The methods of activated carbon regeneration treatment generally include: ① Steam cleaning. ② High temperature roasting to decompose and volatilize the adsorbed organic matter. ③ Soaking in a appropriate solution, such as NaOH or NaCl solution, to desorb the adsorbed impurities. ④ Extract with organic solvents. However, these regeneration technologies are still immature so far, and need further research and exploration.

Activated carbon filtration is often used for precise filtration when the water quality requirement is high. Because activated carbon is expensive and difficult to regenerate after adsorption is saturated, the main purpose of activated carbon filtration is not to intercept pollution, but to adsorb free chlorine and part of organic matter and a small amount of fine impurities. Activated carbon filtration is usually set after ordinary mechanical filtration, so that the turbidity of the inlet water is not too high, and the service life of the activated carbon can be prolonged.

3.3 Selection of filter media

The material used as the filter media should have the following conditions: stable chemical properties, and does not affect the quality of outlet water, good mechanical strength, not broken in use, proper particle size and good uniformity. In addition, it should be cheap and easy to obtain. Commonly used filter media for filtration are quartz sand, anthracite, marble, etc.

3.3.1 Chemical stability of filter media

In order to test the chemical stability of the filter media, under certain conditions, the filter media can be separately soaked in neutral solution (NaCl solution with concentration of 500mg/L can be used), acid solution (the aqueous solution with pH ≈ 2 can be made by HCl), and alkaline solution(the aqueous solution with pH ≈ 12 can be made by NaOH) for about 24 hours, to observe the contamination of the aqueous solution. If it is used for boiler water treatment, the hardness of the water before and after soaking should be measured. If the hardness

of the water increases significantly after soaking, it indicates that the filter media is easy to dissolve calcium or magnesium. In general, quartz sand is suitable for neutral and acidic water, but cannot be used for alkaline water treated with lime, because SiO_2 will dissolve in alkaline solution. When lime is treated, anthracite or semi-burned dolomite can be used as filter media.

3.3.2 Particle size and non-uniformity coefficient of filter media

(1) Particle size

There are two ways to express the particle size of the filter media: average particle size d_{50} refers to the sieve pore diameter which 50% (measured by mass) of the filter media can pass. The effective particle size d_{10} means the sieve pore diameter which 10% (measured by mass) of filter media can pass.

Different filter media and different filtration conditions have different requirements for the particle size of the filter media. It should be selected according to the specific conditions when using it, and it should not be too large or too small. When the particle size is too large, the fine suspended solids is easy to pass through the filter layer, and it is difficult to loosen the filter layer sufficiently during backwash, resulting in incomplete backwash, which leads to the formation of hard blocks of sediment and filter media, and uneven water flow, the outlet water quality is reduced and the filter will exhaust quickly. If the particle size is too small, the water flow resistance will be large, and the water head loss in the filter layer during filtration will also increase quickly, thus shortening the filtration cycle and increasing the consumption of backwash water.

(2) Non-uniformity coefficient

The uniformity of the filter media particle size is usually expressed by the non-uniformity coefficient K_{80}, it refers to the ratio between the sieve pore diameter (d_{80}) which 80% (measured by mass) of the filter media can pass and the sieve pore diameter (d_{10}) which 10% (measured by mass) of the filter media can pass, namely: $K_{80}=d_{80}/d_{10}$.

The size of the filter media particles is uneven, there are two undesirable consequences: one is to make the backwash operation difficult, if the backwash intensity is too large, it will bring out tiny particles, and the backwash intensity is too small, it cannot loosen the lower filter layer; second, it is easy to worsen the filtration situation. Uneven particle size usually means that there are fine filter particles, which tend to be concentrated on the filter layer. As a result, the dirt is accumulated on the surface of the filter layer and the head loss increases rapidly, the filtration cycle becomes shorter.

Generally, when using quartz sand or marble as the filter media, the effective particle size can be 0.35mm, and the non-uniformity coefficient should not be bigger than 2. When anthracite is used, the effective particle size can be 0.6mm, and the non-uniformity coefficient should not be bigger than 3.

3.4 Factor of filtration service

The general service condition of filtration equipment is: in service, the water flows through the filter layer from top to bottom to remove suspended solids in the water. When the head loss (also called pressure drop) of the water flowing through the filter layer reaches the allowable value or the turbidity of the outlet water begins to exceed the allowable value, in order to restore its filtration ability, it is necessary to use fast water to backwash from bottom to top to remove the sludge trapped and the powder generated by the fragmentation of the filter media in the filter layer during service. After the backwash, use water again to wash from top to bottom until the turbidity of the outlet water is qualified, and then put into the next cycle of filtration service. Therefore, the filtration operation is a periodic cycle, consisting of three steps of service filtration, backwash and fast rinse. The actual service time between two backwashes is called the filtration cycle.

The service effect of filtration is usually evaluated from two aspects: one is the outlet water quality, which is often expressed by turbidity. The other is the filtration capability of the filter layer, also known as the sludge capacity. It refers to, under the condition that the outlet water quality of filtration equipment is qualified, the quality of sludge that can be retained by a unit volume of filter media in the whole filter cycle.

There are many factors that affect the filtration effect, mainly including filtering velocity, backwash and water flow uniformity, which are described below.

3.4.1 Filtering velocity

The filtering velocity (V) in filtration can be calculated by the following formula:

$$v = Q/S \quad m/h \qquad (3—1)$$

In the formula, Q—Outlet flow rate of filter, m^3/h.

S—Sectional area of filtration, m^2

From this formula, it can be seen that the filtering velocity doesn't mean the velocity that water pass through the holes between filter media, it is the velocity that water pass through the filter tank under the assumption that the filtering media doesn't occupy the space. It is the relative data that indicate the speed of water flow in the filter tank.

The filtration process is a process in which the filter layer is gradually saturated with suspended solids in water from top to bottom. Therefore, the filtering velocity not only affects the transport of suspended solids to the surface of the filter media, but also has a hydraulic shear effect on the suspended solids that has been intercepted or adsorbed by the filter media. If the filtering velocity is too fast, the hydraulic shearing effect is bigger than the adsorption effect, which will increase the turbidity of the outlet water, increase the head loss, and shorten the filtration cycle. If the filtering velocity is too slow, it means that the output per unit area of the filter is reduced. If want to achieve a certain output, the filtration area must be increased, making the

equipment bulky and increasing investment. Therefore, the optimal filtering velocity of the filter should be determined by debugging according to the media characteristics and the inlet/outlet water quality. The maximum filter velocity is depending on the diameter of media. The smaller diameter is, the lower velocity will be. The service filtering velocity of common filters can be referred to Table 3-1.

Table 3-1 Filtering velocity of filter

Filter type		Filtering velocity m/h
		Filtering velocity after coagulation clarification
Fine quartz sand or fine sand		6～8
Single -layer filter media	Single -flow	8～10
	Dual -flow	15～18
Double -layer filter media		12～16
Triple-layer filter media		20～30
Varivoid pore filtration		18～20
Fiber filtration		20～40
Activated carbon filtration		When mainly adsorbing organic ： 5～10
		When mainly adsorbing free residual chlorine ： ≤20

3.4.2 Backwash

The filtration effect in service can be monitored by measuring the turbidity of the outlet water. However, this index cannot indicate the progress of the filter layer filtration, because in the filtration service, the turbidity of the outlet water is irregular. When the turbidity of the outlet water increases significantly, the filter layer is often seriously polluted. It will be difficult to clean the filter layer by backwash at this time. Therefore, the actual monitoring index to determine whether the filter needs backwash in service is not the turbidity, but the pressure drop of the water flowing through the filter layer. This is because the head loss changes significantly in the filtration service, and the pressure measurement is also relatively simple.

When the filter services until the pressure drop reaches a certain value, it should stop service and start backwash. It is avoid that the filter conducts backwash when pressure drop is high. The reason is: when the pressure drop is high, to achieve a certain output, the inlet water pressure must be increased, which will easily cause the filter layer to break, and a large number of water will pass through the filter membrane crack, destroy the filtration effect, and make the outlet water unqualified quickly. In actual service, the pressure drop of the filter should be controlled much lower than the pressure drop when the filter layer is broken. In this way, it can avoid that the filter layer is too polluted, making the backwash difficult to be thorough, and causing adverse consequences such as agglomeration of the filter material.

The backwash flow rate can be expressed by "backwash intensity", and its unit is L/(m^2·s), indicating the backwash water volume(L) that water passes through per square meter of filtering section per second. The backwash intensity should be properly controlled, not only to loosen the filter layer sufficiently, so that the particles can collide and rub against each other, and at the same time wash away the sludge and tiny media powder, but not to take away the normal filter media particles. The most suitable backwash intensity should be obtained through experiments, because it is related to many factors such as the particle size and density of the filter media particles and water temperature, and it is difficult to estimate. Generally speaking, the backwash intensity of quartz sand is (13 ~ 16) L/(m^2·s), the washing time is 10min ~ 15min, and the air scrubbing time is 3min ~ 5min. While anthracite has a low density, the backwash intensity is (10 ~ 12) L/(m^2·s), backwash time is 5min ~ 10min. Activated carbon backwash intensity is (7 ~ 10) L/(m^2·s), backwash time is 20min ~ 30min. The filter material gradation and backwash intensity of various filters can refer to Table 3-2.

In backwash, the rapid upwards flow of water will loosen the filter media particles and expand the filter layer. The ratio of the increased height of the filter layer after expansion to the height before expansion is called the filter layer expansion rate, which is an index used to measure the backwash intensity. The expansion rate of the general filter layer should be 25%~50%.

In order to improve the backwash effect and reduce the water used for backwash, some filtration equipment is also equipped with compressed air pipes to agitate the filter media with compressed air.

Table 3-2 Filter media gradation and backwash intensity

Filter type	Filter media			Backwash intensity L/(m^2·s)			Remark
	Type	Particle size mm	Height of layer mm	Water backwash	Air and water mixed washing		
					Air	Water	
Pressure type fine sand filter	Quartz sand	0.3～0.5	600～800	10～12	27～33	—	Air scrubbing 3～5 min Washing by water lasts for 10～15 min
Pressure type single-layer media filter	Quartz sand	0.5～1.2	1200	13～16	20	—	Air scrubbing 3～5 min Lasts for 5 ～10 min
	Anthracite	0.5～1.2	800	10～12	10	—	Lasts for 5 ～10 min
Pressure type double -layer media filter	Anthracite	0.8～1.8	400	13～16	10～15	8～10	Lasts for 5～10 min
	Quartz sand	0.5～1.2	800				

Pressure type triple-layer media filter	Anthracite	0.8～1.6	450～600	16～18	—	—	Lasts for 5 ～10 min Do not use air scrubbing
	Quartz sand	0.5～0.8	230				
	Heavy mineral	0.25～0.5	70				
Pressure type fiber filter	Polypropylene fiber bundle	—	1200～1300	—	60	Wash upwards 3～5 Wash downwards 6～10	Lasts for 20 ～60 min
Activated carbon filter	Activated carbon	0.8～1.6	1500～2000	7～10	—	—	Lasts for 20 ～30 min Do not use air scrubbing

Note：1. The backwash intensity listed in the table is the parameter when the backwash water temperature is 20℃. When the water temperature increases or decreases by 1℃, the backwash intensity needs to be increased or decreased by 1% accordingl y. The backwash intensity should be adjusted appropriately according to the changes in water temperature and water quality throughout the year.

2. Suitable backwash expansion rate of filter media: 45% for single-layer filter media of quartz sand, 50% for double-layer filter media, and 55% for triple -layer filter media.

3. When alternate backwash with water and compressed air is used, the backwash intensity of water should be reduced.

4.The relative density of the filter media: anthracite 1.4～1.6, quartz sand 2.6 ～2.65, heavy mineral 4.7～5.0.

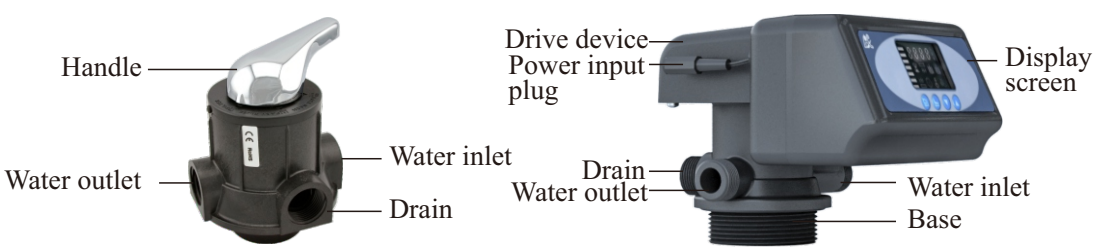
3.4.3 Uniformity of water flow

In the process of filtration or backwash, the filtration equipment requires uniform water flow distribution along each part of the filter layer section, otherwise, it will affect its maximum performance.

In filtration equipment, the water distribution system (or drainage system) has the greatest impact on the uniformity of water flow. The water distribution system refers to a device installed under the filter layer, collects filtered water in filtration, and sends backwash water in backwash. In order to make the water flow uniform, the design of the water distribution system must be reasonable.

3.5 Application of Runxin valve in filtration system

Runxin filter valve is easy to install and operate. Its appearance is shown in Figure 3-1. The manual filter valve can complete all steps of the filter by turning the handle. The automatic filter valve can complete all operations automatically. The application is briefly introduced as follows.



A. Manual filter valve b. Automatic filter valve

Figure 3-1 Appearance of Runxin filter valve

3.5.1 The moving and fixed disks of filter valve and its liquid flow direction in each position

The steps of filter operation and rinse process are: service to failure→ backwash→ fast rinse→ service. The commonly used filter valve moving and fixed disks, the liquid flow direction of each position and the valve body position are shown as follows:

(1) Moving and fixed disks: as shown in Figure 3-2, the moving disk uses a through hole, which is always connected to the inlet, and a blind hole is used for flow diversion. The fixed disk uses a sealing disk with multiple through holes, its different through holes connect with the corresponding connectors of the valve body (such as top strainer, bottom strainer, inlet, outlet, drain, etc.).

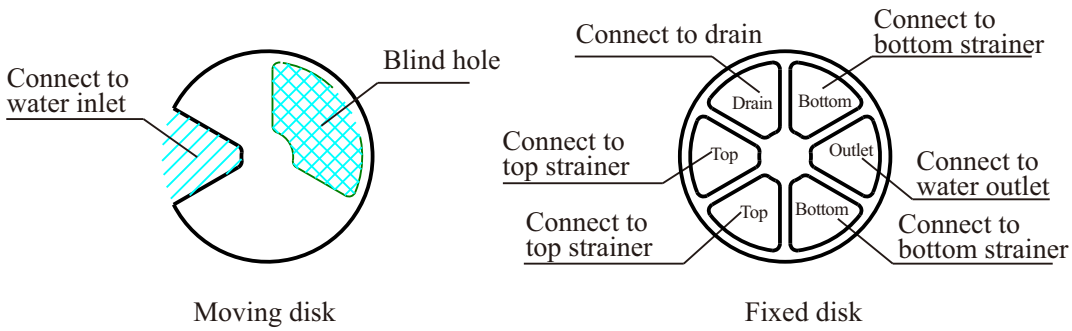


Figure 3-2 Diagram of moving and fixed disk of common filter valve

(2) Service: as shown in Figure 3-3, in service position, the moving and fixed disks form a fitting diagram as shown in Figure 3-3, and the inlet water enters top strainer from the inlet of the control valve, and flows downwards the filter layer, the filtered water flows out through the bottom strainer and the riser pipe to the outlet.

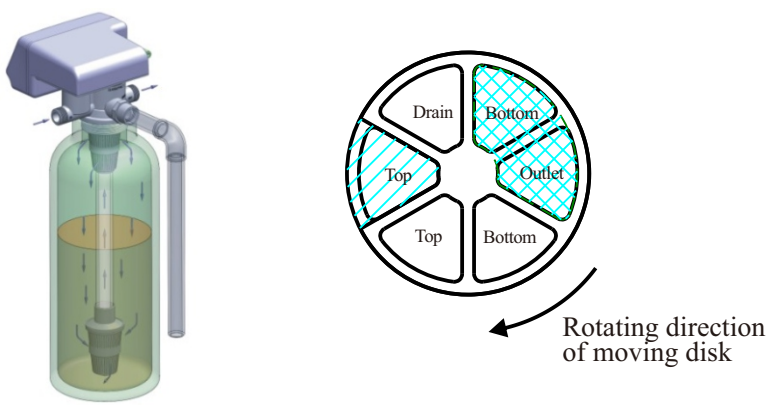


Figure 3-3 Service position and diagram of moving/fixed disks

(3) Backwash: when the filter services until the pressure drop reaches the set value or the turbidity of the outlet water increases, stop the service, start backwash, and manually or by program control to make the moving disk rotate to the state shown in Figure 3-4. At this time, the inlet water enters the bottom strainer from the inlet of the control valve through the riser pipe,

cleaning the filter layer from bottom to top, and at the same time loosens the filter layer and discharges the trapped dirt through the top strainer to the drain.

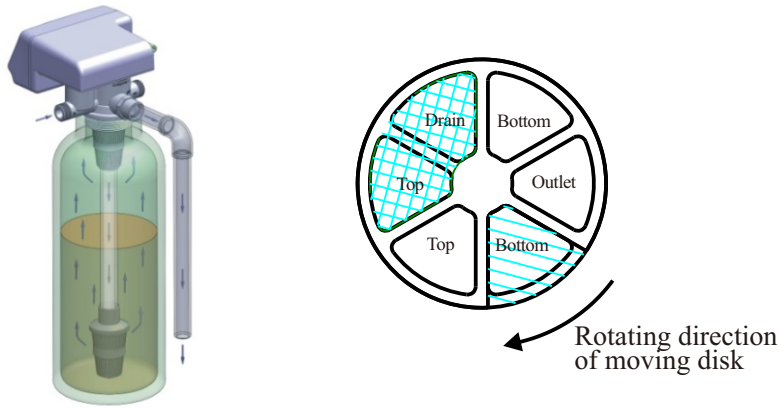


Figure 3-4 Backwash position and diagram of moving / fixed disks

(4) Fast rinse: after the backwash is completed, manually or by program control to rotate the moving disk to the state shown in Figure 3-5. At this time, the inlet water enters the top strainer from inlet of the control valve, and passes through the filter layer from top to bottom, the waste cleaning liquid is discharged through the bottom strainer, the riser pipe to the drain.

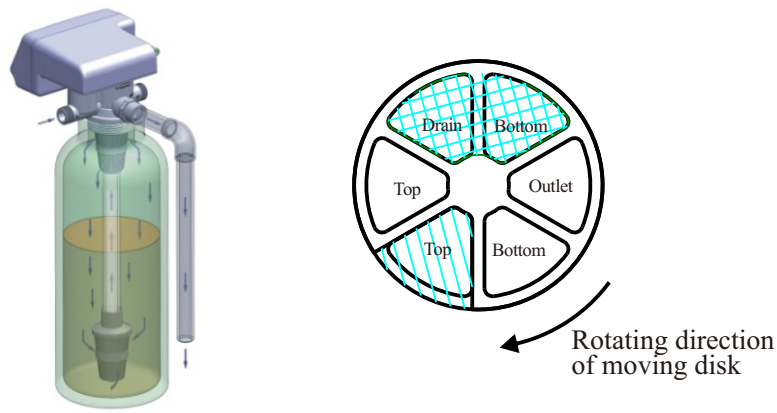


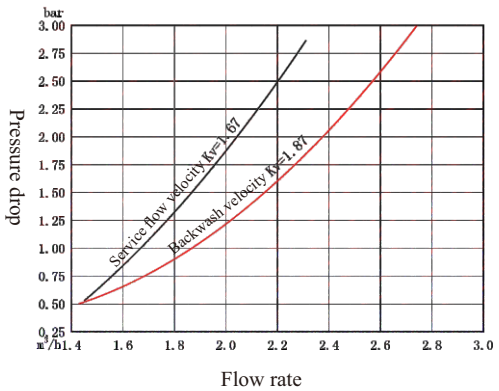
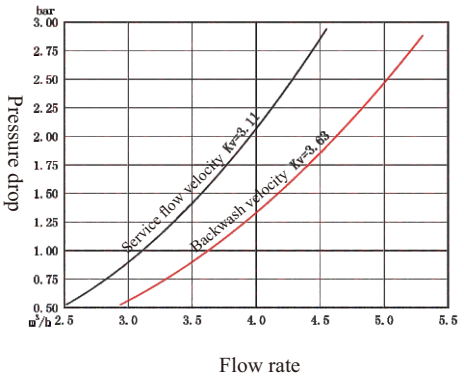
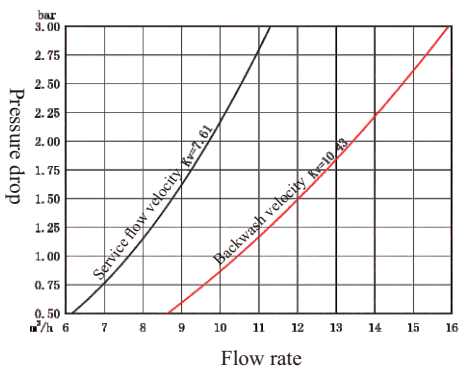
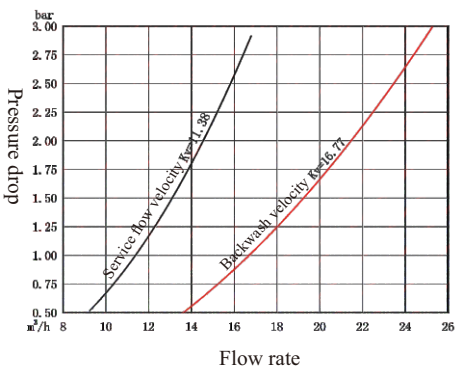
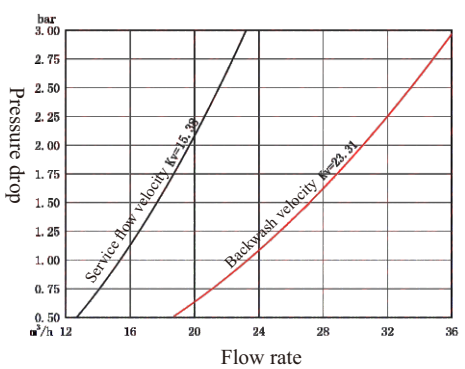
Figure 3-5 Fast rinse position and diagram of moving/fixed disks

3.5.2 Selection of filter valve

The selection of filter valve is related to many factors such as water quality, water flow rate, tank size, material of filter media and particle size. Generally speaking, the service flow rate is relatively low, and the backwash flow rate is much higher. Therefore, when selecting the control valve, should be paid attention to: in addition to adapting to the matching filter, to meet the requirements of the service flow, the flow performance curve corresponding to the pressure drop and the flow velocity should also be considered , select the control valve that meets the requirements of the service and backwash intensity, rather than only be selected based on the water treatment capacity of system and the maximum water treatment capacity of control valve.

The flow performance curve of commonly used Runxin automatic filter valve is shown in Table 3-3.

Table 3-3 Flow curve of commonly used Runxin filter valve

<table>
<tr><td>Model:53502</td><td>Model:53504</td></tr>
<tr><td> 
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<tr><td>Model:53510</td><td>Model:53515</td></tr>
<tr><td> 
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<tr><td>Model:53520</td><td></td></tr>
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In Table 3-3, the flow curve is based on the pressure drop between the inlet and outlet as the ordinate, and the flow rate through the outlet or drain as the abscissa. The point on the curve represents the flow value that can be reached under such a pressure drop. The continuous water output of the control valve is generally the flow of the outlet when the pressure drop is 0.1MPa. When multiple devices are connected in series, this should be selected. The peak water output is generally the flow rate of the outlet when the pressure drop is 0.175MPa. When a single device is used independently, it can be selected according to this. The backwash flow rate of the control valve is the flow rate of the drain when the pressure difference is 0.175MPa.

The K_v value of service and backwash indicates the flow rate at which the pressure drop is 0.1MPa when the control valve is in service or backwash position.

3.5.3 Application example

A company needs to set up an activated carbon filtration system with flow rate of $10m^3/h$. How should it be configured?

Scheme discussion: ①According to the filtering velocity in Table 3-1, select the service flow velocity of the activated carbon filter to be 10m/h, then:

According to the formula Q=v×S, the sectional area of the filter media in the filter tank is: $S=Q/v=10m^3/h \div (10m/h) =1m^2$

According to the formula $S=3.14\times D^2/4$, the inner diameter of the tank is calculated: $D^2=4S/3.14=1.27$, $D\approx1.13m$

On the basis of the production specifications of commonly used filter tanks, the tank configuration can select the tank body with a diameter of 1.2m and a height of 2.4m.

②According to the backwash intensity table of the filter in Table 3-2, the backwash intensity of the activated carbon filter was selected as $7L/ (m^2\cdot s)$, which was converted into the backwash velocity as: $7L / (m^2\cdot s) \times 3600/1000= 25.2m/h$

Then the backwash flow rate is: $Q=v\times S=25.2\times3.14 \times (1.15/2)^2\approx26.2m^3/h$

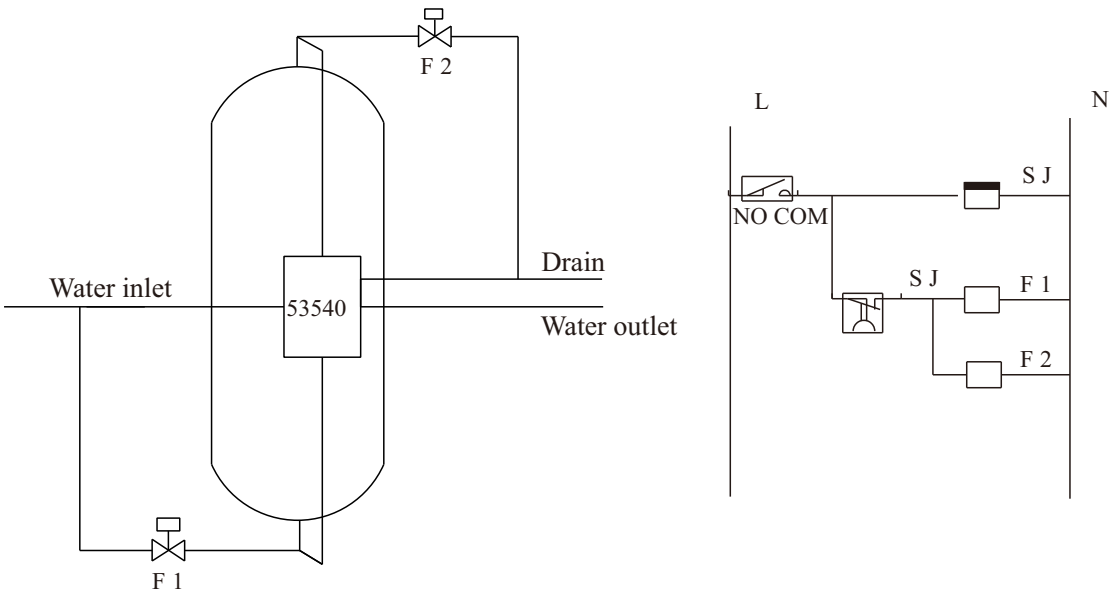
③ According to the flow curve table of the control valve, when the pressure drop is 0.175MPa, the backwash flow of the 53520 can reach $29m^3$, so the control valve 53520 can be selected.

Since the filter backwash flow rate is usually much bigger than the service flow rate, in order to make the control valve meet the service flow rate, and keep that there is enough backwash flow rate to ensure the backwash effect, the following two methods to increase the backwash flow rate are provided :

Method 1: add bypass valve to increase the backwash flow

This method is for side-mounted control valves, as shown in Figure 3-6: by adding valves (F1 and F2) between the inlet and the bottom strainer, and between the top strainer and the drain,these two valves are closed in the service and backwash position. In the backwash position,

valves F1 and F2 are controlled to open through the signal output connector of the 53540 valve, so that part of the raw water enters directly from the bottom of the tank to backwash the filter material, and then discharges the water from the top strainer on the tank through the F2 to the drain, which can achieve the purpose of enhancing the backwash intensity of the system. The wiring of the control signal is shown in Figure 3-6.



(a) Diagram of bypass valve setting (b) Wiring diagram of electronic circuit

Figure 3-6 Diagram of the device and electronic circuit for adding bypass valve to increase the backwash flow rate

The parameters of 53540 control valve are required to be set as: b-01; NO and COM are the signal output connection points of 53540; F1 and F2 are normally closed valves; SJ is the time relay, since F1 and F2 valves only need to be opened in backwash, closed in fast rinse and service, so set SJ time to be consistent with backwash time.

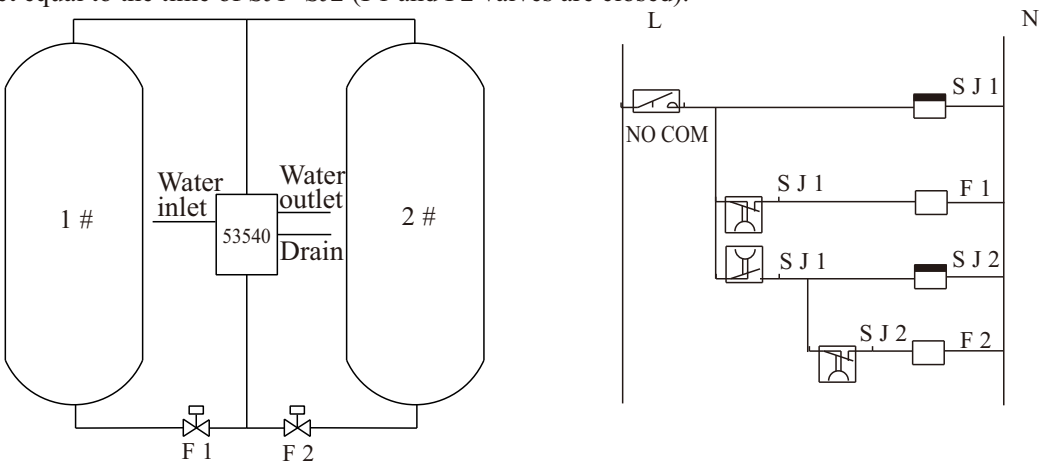
Method 2: single valve with double tanks service in parallel, backwash respectively

For the side-mounted control system, one valve is used to control two tanks. The two tanks operate in parallel in service, and they are rinsed separately in backwash, so that the service flow rate is only half of the backwash flow rate.

As shown in Figure 3-7: a 53540 automatic control valve is equipped with two tanks, and the two tanks supply water simultaneously when service. F1 and F2 are normally open valves. When backwash, first close the F2 valve and backwash the 1# tank, after completed, close the F1 valve, and then open the F2 to backwash 2# tank, so that the backwash flow rate is 2 times of the service flow rate. The wiring of the control signal is shown in Figure 3-7.

The parameter setting of 53540 control valve is: b-01; NO and COM are the signal output connection points of 53540; SJ1 and SJ2 are time relays, which control the closing time of F1

and F2 valves and the backwash time of the two tanks respectively; The backwash time of 53540 is set equal to the time of SJ1+SJ2 (F1 and F2 valves are closed).



(a) Diagram of device and valve (b)Wiring diagram of electronic circuit

Figure 3-7 Diagram of the device and electronic circuit of single valve with double tanks service in parallel, backwash respectively

3.6 Application case

3.6.1 Application of filter valve in purification and filtration treatment system

(1) Background

A customer in Shijiazhuang, Hebei, uses groundwater as the source of water used in daily life. Because the groundwater often contains sand and other particulate matter, it has a bigger impact on daily life, and can easily cause damage to water heaters, faucets, shower nozzles and other water equipment. Therefore, when groundwater is used as daily used water, it needs to be filtered to remove particulate impurities to make it clear and transparent.

(2) Project overview

In order to meet the daily water consumption and water quality requirements of users, it is necessary to configure a stainless steel filter tank with a water flow rate of $8m^3/h$, using multi-layer quartz sand filtration, which adopts multi-layer quartz sand filtration and is designed according to the service flow velocity of 10m/h and the backwash intensity of $10L/m^2 \cdot s$. Since the service flow rate is $8m^3/h$, the backwash flow rate is about $28m^3/h$. Check the flow curve table of the control valve, when pressure drop is 0.175MPa, the backwash flow of the 53520 control valve is $29m^3/h$, which can meet the requirements.

(3) Filter configuration

The filter system adopts Runxin 53520 automatic control filter valve, and is equipped with a stainless steel tank with the diameter of 1m and the height of 2.2m. The tank is filled with coarse sand with the particle size of 2~4 mm and the thickness of 100 mm as the supporting layer to

make the water distribution uniform. The middle part is filled with quartz sand with the particle size of 1 ~ 2mm as the second supporting layer; the upper part is filled with 0.6 ~ 1.2mm quartz sand for filtration.

System process flow: well water→ pump towerless variety-frequency for water supplying→ filter→ clean water tank.

The equipment installation is shown in Figure 3-8.



Figure 3-8 Diagram of filter installation

(4) Running effectiveness

Average turbidity of raw water: 10NTU; outlet water turbidity of filter: ≤5NTU

The system has been put into use since 2014, and the service of the system has been stable. The turbidity of the outlet water meets the user's requirements, and the automatic timed backwash has good effect.

3.6.2 Application of control valve in activated carbon filtration system

(1) Background

In order to protect the environment, industrial sewage should be treated to meet the standard before it can be discharged. A music metal product factory in Tianjin, the production sewage generated during the production process, its chroma and suspended solids exceed the maximum allowable discharge concentration of the urban drainage system in the national mandatory standard GB 8978 "Integrated Wastewater Discharge Standard", so sewage treatment is needed to achieve the first-level emission standard of chroma <50mg/L and suspended solids <70mg/L, and meet the emission standards for fixed-point detection of river channels designated by the Environmental Protection Agency.

(2) Project overview

Due to the chroma and suspended solids of the production sewage exceed the standard severely, flocculation is added in the sedimentation tank to precipitate and solidify, then the water is extracted by water pump, and the suspended solids are removed by fiber filtration;

activated carbon is used to filter and decolor; resin is used to reduce water hardness, and the treatment flow rate is required to be 50m^3/h.

Two sets of Runxin 53540 automatic filter valves are used, matched with filter tanks with the diameter of 1.8m and the height of 2.8m, filled with activated carbon, and two sets are in parallel, so as to realize the water treatment capacity of each set is 25m^3/h, and the water treatment capacity of two sets is 50m^3/h. Meanwhile, configure the ball valve as shown in Figure 3-6 to increase the backwash flow rate. Then two sets of Runxin 63650 automatic control softener valves matched with resin tanks with the diameter of 1.5m and the height of 2.4m are filled with sodium ion exchange resin for softening.

The sewage treatment process is: sewage to be treated→ sewage tank (medicated flocculation sedimentation)→variety-frequency water pump→ fiber filter→ activated carbon filter→ water softener→ water tank. The process is shown in Figure 3-9.

(3) Running effectiveness

The system has been in use since 2015 and has been servicing steadily, with good turbidity reduction and decolorization effects, and it meets the emission standards for fixed-point detection of river channels designated by the Environmental Protection Agency.

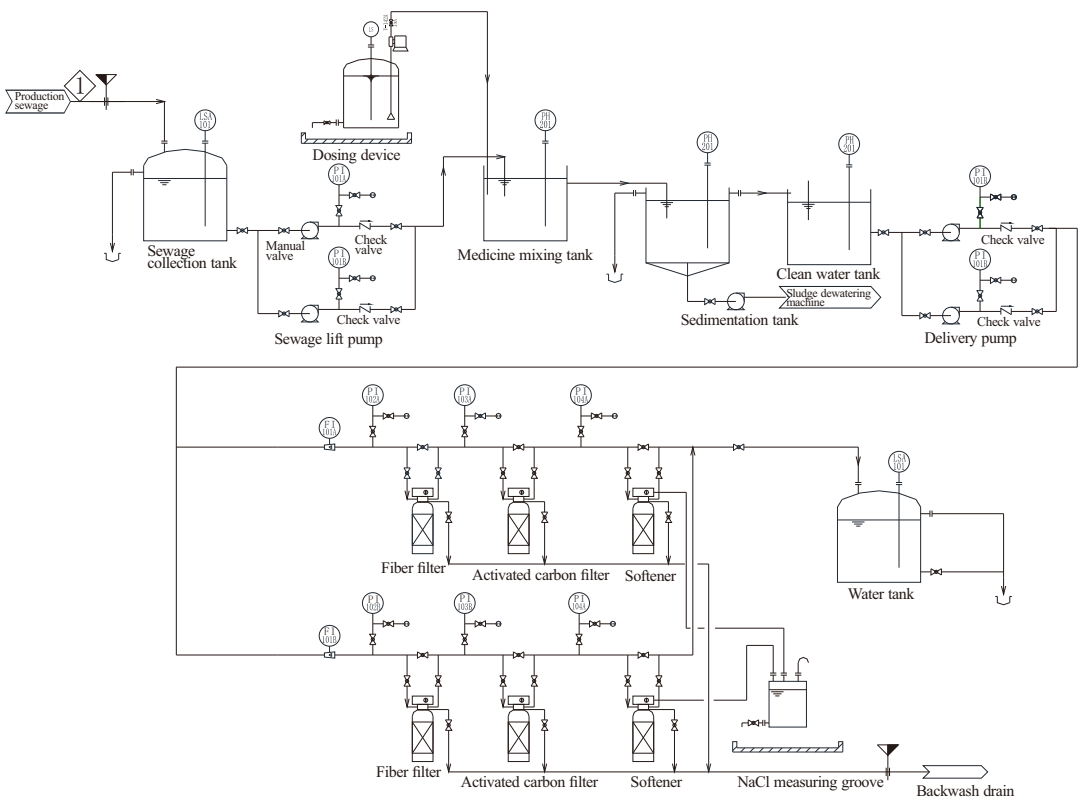


Figure 3-9 Process flow chart of control valve for sewage treatment

3.6.3 Application of control valve in multi-grade filtration system

(1) Background

An airport in Yunnan, because it is far from the city, the tap water is not delivered. Groundwater is used as the water source, and after treatment, it is used as safe drinking water for airport staff, crew members and passengers.

(2) Project overview

According to test, the quality of local groundwater is easy to change with different seasons. Sometimes the turbidity is high, reaching or even exceeding 20NTU, the hardness is about 40mg/L (calculated as $CaCO_3$), there is a certain unpleasant smell, and it cannot meet the standard of drinking water. Due to the large number of airport personnel and passengers, the treated water volume needs 25m^3/h.

This project is mainly to remove turbidity and unpleasant smell, etc. The design uses quartz sand filter to reduce turbidity; uses activated carbon filter to remove unpleasant smell; uses precision filter to remove tiny impurities; uses ultraviolet sterilizer to disinfect and sterilize, so as to meet the standard requirements of drinking water.

The project design uses three sets of sand and carbon filtration systems to service in parallel. Through the interlock connectors, the three sets of systems can supply water simultaneously and rinse separately, to ensure the daily water supply meets the requirements. Each sand and carbon filtration system is composed of a filter with quartz sand and a filter with activated carbon in series, and each set flow rate is 9m^3/h. Each filter adopts Runxin 53518 automatic control valve, matched with a stainless steel filter tank with the diameter of 1m and the height of 2.4m. PLC is used to collect the pressure drop signal of the inlet and outlet water, and send a signal to the control valve to realize automatic rinse when rinse is needed.

The technological process of the system is: raw water→ quartz sand filter→ activated carbon filter→ precision filter→ ultraviolet sterilizer→ microporous filter→ outlet water. The equipment installation is shown in Figure 3-10.



Figure 3-10 Installation of control valve in multi-grade filtration system

(3) Running effectiveness

The system has been put into use since 2017 and has been servicing stably. The quality of the outlet water is clear and no unpleasant smell, which is superior to the standards for drinking water quality.

4. Application of Runxin softener valve

The softener valve is an automatic control device for the water softener, and the key component of the automatic water softener. Water softener, also known as sodium ion exchanger, is a water treatment equipment to remove or reduce calcium and magnesium ions in water and other hardness substances. It is widely used in boilers, heat exchange equipment, water heaters and other equipment that need to soften water, as well as water treatment for civil life, aquaculture, washing industry and so on.

4.1Introduction of water softener

4.1.1 Structure of automatic water softener

4.1.1.1 Main composition and function of water softener

The automatic water softeners are usually composed of automatic control valve (also called softener valve), resin tank and brine tank. The automatic water softener generally has two types of top-mounted and side-mounted. The composition is shown in Figure 4-1 and Figure 4-2. The main functions of each component are:

a) Control valve: automatically control the water softener for service and the whole process of regeneration after resin exhausted. There are many types and models of control valves, see Table 2.2 for details.

b) Resin tank: a tank used to fill sodium ion exchange resin.

c) Resin: the water softener generally uses strong acid sodium cation exchange resin, usually 001×7.

d) Brine tank: a tank filled with salt and brine. When the resin is exhausted, brine is used to regenerate the ion exchange resin.

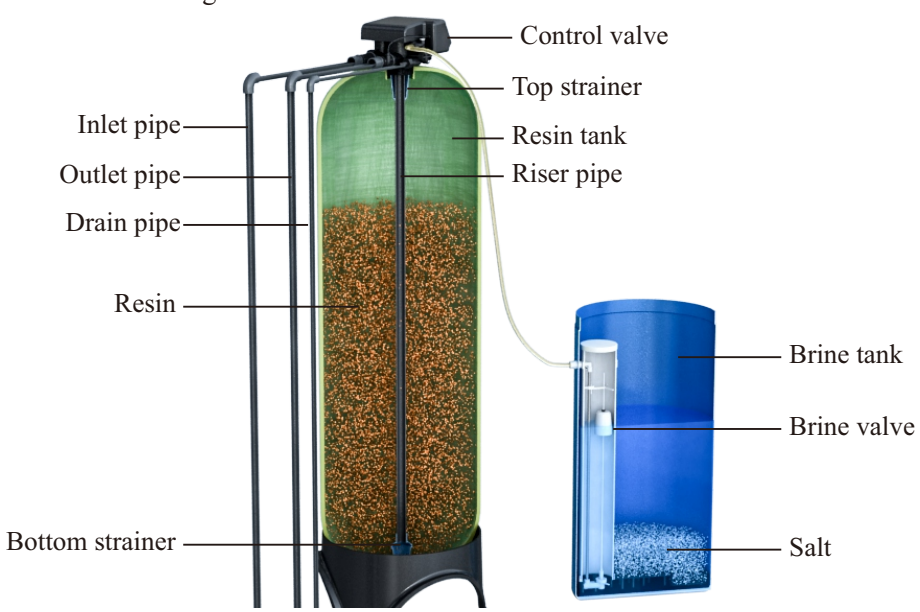


Figure 4-1 Single valve top-mounted automatic water softener

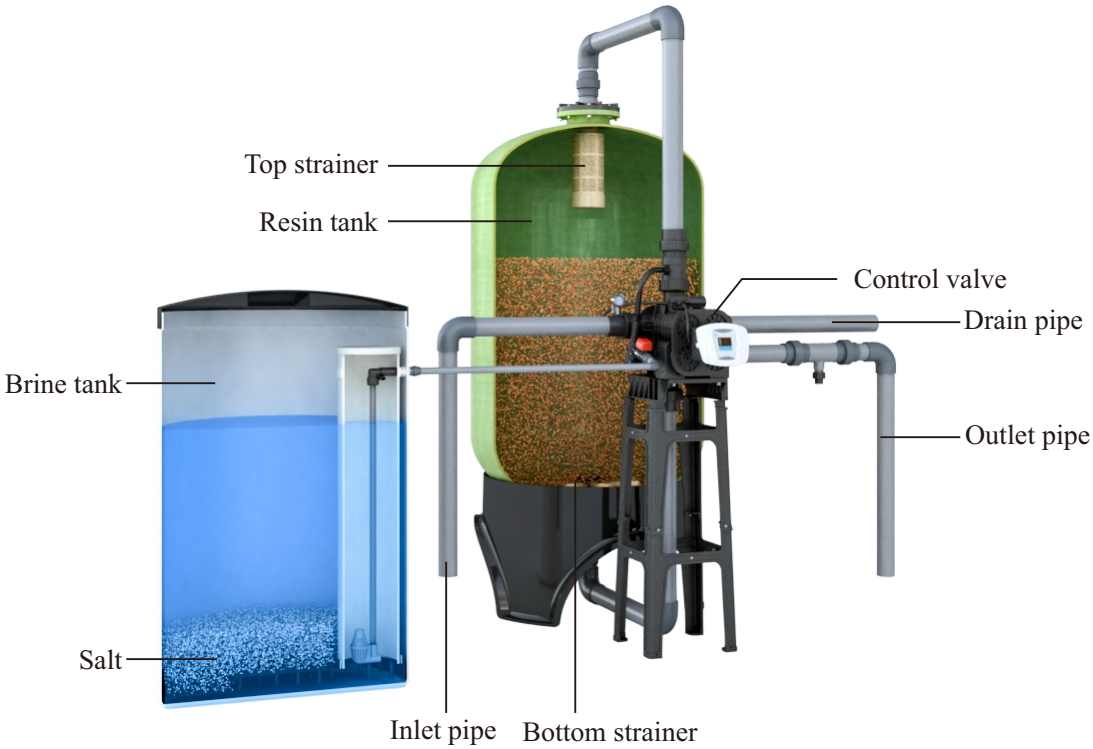


Figure 4-2 Single valve side-mounted automatic water softener

4.1.1.2 Resin tank

The resin tank is equipped with riser pipe, top and bottom strainers, and is equipped with Na^+ exchange resin. The basic requirements are as follows:

(1) Tank quality

The tank of the automatic water softener is usually made of glass fiber reinforced plastic, and a few are made of stainless steel or other materials. If it is made of carbon steel, its inner surface should have an anti-corrosion coating or lining.

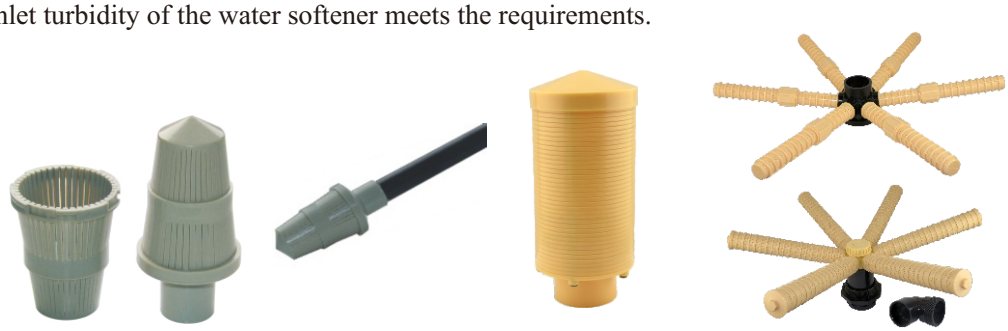
Quality requirements for glass fiber reinforced plastic tanks: the inner surface should be flat and smooth, and the tank should not contain cracks, layers, pinholes, impurities and bubbles, etc., which will affect the performance. The opening plane should be perpendicular to the axis without burrs and other obvious defects.

(2) Riser pipe and strainer

In the middle of the resin tank is the riser pipe, which is used for water outflow or backwash water inflow, and brine inflow for up-flow regeneration. Both ends of the riser pipe are equipped with top and bottom strainers to ensure uniform water distribution, no bias current, and avoid resin leakage. Generally, for resin tank with smaller diameter, the strainer is usually a large water cap, and some use laminated strainers; big diameter resin tank should be equipped with multi-claw strainer (see Figure 4-3) to make the water distribution more equally. The gap size of strainer should be appropriate, not only to avoid leakage of resin, but also not to affect the flow

of water. The gap size of strainer should not be too small, generally slightly smaller than the resin particles. If the gap size is too small, the suspended impurities and broken resin cannot be washed out during backwash, which will easily cause the suspended solids in the resin layer to accumulate and pollute the resin, which will affect the regeneration effect and reduce the exchange capacity of resin; if the gap is too large, when the backwash intensity is large, it is easily to cause resin rush out and loss.

In order to avoid the accumulation of excessive suspended solids and colloidal impurities on the resin surface during service, which will affect the regeneration effect and reduce the resin exchange capacity, it is generally required that the water softener inlet turbidity ≤ 5NTU. If the raw water has high turbidity, a filter should be installed before the water softener to ensure that the inlet turbidity of the water softener meets the requirements.



a. Small diameter strainer of resin tank b. Big diameter strainer of resin tank

Figure 4-3 Strainer of automatic water softener

(3) Resin filling

When filling the resin tank with Na^+ exchange resin, take care to prevent the resin from entering the riser pipe (when filling the resin, the nozzle of the riser pipe can be temporarily wrapped with plastic cloth or plugged with a plug or use a special funnel to block the riser pipe nozzle). The height of the resin layer should be determined according to the tank size, raw water quality and outlet water quality requirements. For general boilers or other industrial equipment to treat with water, the height of the resin layer should not be less than 800mm, and there should be retained 40%-50% backwash expansion space above the resin layer; the height of the resin layer of the floating bed should not be less than 1200mm, and the filling height of the resin should account for about 90% of the height of the tank, and retain about 10% of the water cushion space, which can not only make the layer not disordered during regeneration, but also meet the expansion of the resin during regeneration. In general, the higher the inlet water hardness, the higher the height of the resin layer, and the higher the resin tank configured.

4.1.1.3 Brine tank

The material of the brine tank for the water softener is usually plastic, with salt isolating board, brine well, liquid level controller, air check valve and other devices (see Figure 4-4). The brine

tank should be covered, and its effective volume should be within the specified salt concentration range, at least to meet the amount of one regeneration, and convenient for salt adding operation. Under normal circumstances, there should always be solid salt in the brine tank, so that the brine is in saturated or supersaturated state. The requirements for brine tank components are:

(1) Brine filtration

In order to avoid solid impurities in the salt solution blocking the injector and affecting the regeneration effect, the brine tank should have a good filtration device, which is generally achieved through multiple filtrations such as salt isolating board and brine well.

(2) Salt isolating board

The salt isolating board is the partition board with many fine holes and a certain distance from the bottom of the brine tank. The regeneration salt is placed on the salt isolating board, and the dissolved saturated brine passes through the salt isolating board and enters the brine well. In addition to filtering, the salt isolating board can also promote the uniformity of brine concentration. Because when the brine tank is refilled (refilling water after regeneration), the water is injected into the brine tank from the bottom of the salt isolating board through the brine pipe and brine well. The density of brine after the salt is dissolved on the salt isolating board is higher than the water, which is easy to flow down. Thus forming convection, which can promote the uniform concentration of saturated brine. Some water softener brine tanks are not equipped with the salt isolating board, and the solid salt sinks at the bottom of the brine tank, because the salt solution is not easy to flow, after several regenerations, the brine concentration around the brine well is easy to be low, affecting the regeneration effect.

(3) Air check valve and liquid level controller

In order to prevent air being sucked into the resin tank after the brine suction is completed, an air check valve should be installed in the brine well of the brine tank. The air check valve is equipped with a check ball. When there is brine in the brine tank, the ball floats; when the brine is sucked up, the ball falls, blocking the brine nozzle to prevent air from entering the resin layer. If the brine pipe is not equipped with an air check valve, the brine in the brine tank will continue to be sucked after it is completed, it will easily cause air sucked to the resin layer and form many small bubbles, which will cause water distribution unequally, and affect the quality of water produced during regeneration and service.

The liquid level controller is actually a small float valve, which is generally installed on the stem of the air check valve and can be adjusted up and down as needed. Some water softeners do not have a liquid level controller, and the brine level is mainly determined by the refill time of the brine tank. Since the injection speed of the filling water is related to the inlet water pressure, the water softener without liquid level controller sometimes has difficulty in controlling the brine level to the appropriate height under the unstable inlet pressure.





(a) Internal device of brine tank (b) Air check valve (c) Check valve with liquid level controller

Figure 4-4 Device in the brine tank of automatic water softener

4.1.2 Basic principles of softening treatment

4.1.2.1 Hardness (YD) and alkalinity (JD) in water

Hardness usually refers to the content of calcium and magnesium ions (Ca^{2+}, Mg^{2+}) in water. It is an important technical indicator to measure whether boiler and other heating equipment is easy to cause scaling. The main function of water softener is to remove or reduce calcium and magnesium ions in water. Generally, the water containing hardness is called hard water, and the water removing hardness is called softened water or soft water.

Calcium and magnesium ions are the main cations in natural water and exist in almost all natural water. Usually people call the total content of calcium hardness and magnesium hardness in water as "total hardness", among which calcium hardness includes: calcium bicarbonate, calcium carbonate, calcium sulfate, calcium chloride, etc.; magnesium hardness includes: magnesium bicarbonate, magnesium carbonate, magnesium sulfate, magnesium chloride, etc. In addition, the hardness can be divided into carbonate hardness and non-carbonate hardness according to the type of anion.

(1) Carbonate hardness

The salt concentration of calcium and magnesium ions with bicarbonate or carbonate in water is called carbonate hardness. The carbonate hardness in natural water is usually dominated by bicarbonate, so natural water is neutral. Carbonate hardness will occur the following decomposition reactions and form precipitation in high-temperature water. If the precipitation precipitates on the heated surface, it will form water scale. If it precipitates in the boiler water, it will form water slag. The water slag can be removed by boiler sewage discharge, but if it is not discharged timely, the water slag will also be converted into scale.

$$Ca(HCO_3)_2 \rightarrow CaCO_3\downarrow + H_2O + CO_2\uparrow$$

$$Mg(HCO_3)_2 \rightarrow MgCO_3\downarrow + H_2O + CO_2\uparrow$$

$$MgCO_3 + H_2O \rightarrow Mg(OH)_2\downarrow + CO_2\uparrow$$

(2) Non-carbonate hardness

It refers to the water in addition to carbonate, the salt content composed of calcium and magnesium ions and other anions (such as sulfate, chloride, silicate, etc.). After the water containing non-carbonate hardness enters the boiler, as the boiler evaporates and concentrates, the ion concentration continues to increase, and the solubility and solubility of calcium sulfate and silicate in the water will decrease with the increase of temperature. When the concentration of ions is greater than the solubility, precipitation will be precipitated and water scale will form on the heating surface.

(3) Alkalinity

Alkalinity refers to the amount of substances that can accept hydrogen ions (H^+) in water. The alkalinity in water is mainly composed of OH^-, CO_3^{2-}, HCO_3^- and other small amounts of weak acid salts. In natural water, the alkalinity mostly exists in the form of HCO_3^-, only a very small amount of natural water, if the alkalinity is high, there will be a small amount of CO_3^{2-}; HCO_3^- will be decomposed into CO_3^{2-} after heating in the pot water, and will be further hydrolyzed to form OH^-. Therefore, the alkalinity in boiler water mostly exists in the form of CO_3^{2-} and OH^-.

Carbonate hardness not only constitutes the alkalinity but also a part of the hardness. If the water containing carbonate hardness enters the boiler, the alkalinity in the boiler water will be reduced due to the formation of carbonate scale or slag; if use of softened water as the boiler feed water, because the softened water only removes the hardness and retains the alkalinity, as the boiler evaporates and concentrates, the alkalinity in the boiler water will increase. Therefore, when the alkalinity of boiler water is too high, it needs to be softened-alkali reduction treatment.

(4) Relationship between hardness and alkalinity

The hardness and alkalinity of natural water have the following three conditions:

a) Hardness is bigger than alkalinity: in this kind of water, Ca^{2+} and Mg^{2+} first form carbonate hardness with HCO_3^-, and the remaining Ca^{2+} and Mg^{2+} form non-carbonate hardness with SO_4^{2-}, Cl^- and other anions. This is the case with most natural water;

b) Hardness equals to alkalinity: in this kind of water, all Ca^{2+} and Mg^{2+} form carbonate hardness with HCO_3^-. At this time, there is neither non-carbonate hardness nor residual alkalinity, which is rarely seen in natural water;

c) Alkalinity is bigger than hardness: this kind of water is called alkaline water. Ca^{2+} and Mg^{2+} all form carbonate hardness with HCO_3^-, while the remaining HCO_3^- forms sodium potassium alkalinity with Na^+ and K^+, also known as negative hardness. The water has almost no non-carbonate hardness, and is called negative hard water or alkaline water. Only a few areas have this natural water.

(5) Measurement unit of hardness and alkalinity

There are three commonly used measurement units of hardness and alkalinity, which are described as follows:

a) Expressed in millimoles/liter (mmol/L)

The GB/T 1576 "Water Quality for Industrial Boilers" standard stipulates that the hardness and alkalinity in the boiler water quality index are all measured in mmol/L, and it is stipulated that the monovalent ions is the basic unit of hardness, that is, the basic units of hardness are: $1/2Ca^{2+}$, $1/2Mg^{2+}$, the basic units of alkalinity are: OH^-, $1/2CO_3^{2-}$, HCO_3^-. In this book, the water hardness, alkalinity, resin working exchange capacity, etc. all involve the concept of mole, all take univalent ion as the basic unit. Special attention should be paid to the calculation of related processes.

b) Expressed by "German hardness" (°dH)

This is a unit of measurement used specifically to indicate hardness previously. Its definition is: when the concentration of hardness ions in water sample is equivalent to 10 mg/L CaO, it is called 1 German hardness (1°dH).

Since the molar mass of 1/2CaO is 28g/mol, so:

$$1\text{mmol/L}\ (1/2Ca^{2+},\ 1/2Mg^{2+}) = 2.8\ ^\circ\text{dH}$$

c) Expressed in mg/L of $CaCO_3$ (ppm)

Many water quality analysis data use this unit to express the hardness content, and its definition is: when the ion concentration of hardness in the water sample is equivalent to 1mg/L$CaCO_3$, it is 1ppm hardness.

Since the molar mass of $1/2CaCO_3$ is 50g/mol, 1mmol/L hardness is equivalent to 50mg/L $CaCO_3$ or 50ppm $CaCO_3$.

The conversion relationship of the above three units can be expressed as:

$$1\text{mmol/L}\ (1/2\ Ca^{2+},\ 1/2Mg^{2+}) = 2.8\ ^\circ\text{dH} = 50\text{ppm}\ (CaCO_3)$$

4.1.2.2 Main chemical performance of cation exchange resin

The working principle of the water softener is mainly to use cation exchange resin to remove the hardness, so that the water can be softened or softened-alkali reduction treatment. Therefore, the chemical performance of the resin has a great influence on the effect of ion exchange treatment.

(1) Selectivity of cation exchange resin

The ion exchange resin has different exchange ability for various ions in the solution. For the same kind of ion exchange resin, some ions are easy to be adsorbed and exchanged by the resin, but it is difficult to replace them; while other ions are more difficult to be exchanged by adsorption, but are easier to be replaced. This performance of resin is called the selectivity of ion exchange resin.

There are many factors that affect the selectivity of ion exchange resin, such as the kind, property and solution concentration of ion exchange resin. Since the softening treatment needs to remove cations such as Ca^{2+} and Mg^{2+}, cation exchange resin is required. According to the properties of the active groups that play an exchange role in resin, cation exchange resin can be divided into two categories: strong acid cation exchange resin and weak acid cation exchange resin. Their selective order rules for various cations are as follows:

a) The selective order of strong acid cation exchange resin for common cations is:

$$Fe^{3+} > Al^{3+} > Ca^{2+} > Mg^{2+} > K^{+} \approx NH_4^{+} > Na^{+} > H^{+}$$

b) The selective order of weak acid cation exchange resin for common cations is:

$$H^{+} > Fe^{3+} > Al^{3+} > Ca^{2+} > Mg^{2+} > K^{+} \approx NH_4^{+} > Na^{+}$$

According to the selectivity of the cation exchange resin can know:

① Fe^{3+} and Al^{3+} are easily exchanged and adsorbed by the resin, but not easily replaced. If the resin is contaminated by the adsorption of iron and aluminum ions, it will significantly affect its exchange capacity for other ions. This phenomenon is called resin "poisoning". In order to maintain the exchange capacity of the resin, it is necessary to avoid the contamination of the resin by iron and aluminum ions. If it is contaminated, it needs to use acid for cleaning to restore.

② In the dilute solution, the selectivity of the resin to Ca^{2+} and Mg^{2+} is better than Na^{+}, so when the water softener is in service, the Ca^{2+} and Mg^{2+} in the inlet water are easily exchanged with the Na^{+} in the resin, but when the resin is regenerated with brine after exhausted, it is necessary to increase the brine concentration (increase the Na^{+} content) in order to replace Ca^{2+} and Mg^{2+} from the resin.

③ The weak acidic cation exchange resin is the easiest to exchange and adsorb H^{+}. Therefore, it is easy to regenerate the weak acidic cation exchange resin with acid after it exhausted, usually only use a lower concentration of acid solution can make the resin get better regeneration. Because the weak acid cation exchange resin has a weak ability to adsorb Na^{+}, it is difficult to be regenerated by brine, so the softening treatment usually uses strong acid cation exchange resin; for desalination treatment, strong acid cation exchange resin is also needed to remove Na^{+}; and for raw water with high hardness and high alkalinity, when hydrogen-sodium ion exchange is used to soften and reduce alkalinity, the hydrogen ion exchanger adopts weak acid cation exchange resin, which has the advantages of large exchange capacity, low acid consumption, low waste acid concentration and easy treatment.

In addition, the above selectivity order is only applicable to water with low salt content. For example, in a solution with high salt content, the selectivity order will be somewhat different, and some low-valent ions will have priority over high-valent ions. For example, when the sodium ion exchanger is regenerated, in a certain concentration of salt solution, sometimes the exchange and adsorption of Na^{+} by the resin will take precedence over Ca^{2+} and Mg^{2+}.

(2) Resin exchange capacity

The exchange capacity is a technical index that indicates the number of ions that the resin can exchange. There are two commonly used measurement units: one is mass unit notation, which usually refers to the amount of ions that can be exchanged by the unit mass of dry ion exchange resin, commonly expressed in mmol/g; the other is the volume unit notation, which usually refers to the amount of ions that can be exchanged by the unit volume wet ion exchange resin, commonly expressed in mol/m^3. In practical application, the exchange capacity is usually expressed in the following two ways:

a) Total exchange capacity: indicates the total amount of active groups in a certain amount of ion exchange resin, reflecting the amount of ions that can be exchanged when all exchange groups in the resin are fully functional. The total exchange capacity of strong acid cation exchange resin is generally≥4.2 mmol/g. However, in actual work, the exchange groups in the resin cannot all play a role, so the total exchange capacity reflects the amount of ions that can be exchanged theoretically.

b) Working exchange capacity: working exchange capacity refers to the amount of ions that the resin can exchange under working state, which is generally expressed in volume units. In actual work, this is a very important and practical index. Due to many factors affecting the working exchange capacity, even the same ion exchange resin may have different working exchange capacities in different water softeners. Generally, the factors that affect the exchange capacity of resin mainly include the following aspects:

① Particle size of resin. For the same resin with the same volume, the smaller the particles, the larger the specific surface area and the larger the exchange capacity. However, if the particles are too small, the pressure loss of the water flow through the resin layer will be large, which will affect the output of the water softener.

② The height of the resin layer. The higher the resin layer, the higher the utilization rate and the larger the working exchange capacity. Therefore, the resin layer height of industrial water softeners is generally not less than 0.8m.

③ Quality of inlet water. Under the same flow rate, if the salt content, hardness and Na^+ content of the inlet water increase, the working exchange capacity will decrease.

④ Structure of water softener. Whether the water distribution of the water softener is uniform, the ratio of the inner diameter of the resin tank to the height of the resin layer, and the regeneration method all have a certain impact on the working exchange capacity.

⑤ Operating conditions. The main reason is that the flow rate and temperature have a greater impact on the working exchange capacity: the flow rate is too high, the exchange capacity decreases; increasing the temperature can speed up the ion exchange rate, thereby increasing the working exchange capacity.Therefore, in the process of soft water service and

regeneration, it is advantageous to appropriately control the flow rate and increase the temperature.

⑥ Acidity and alkalinity of the solution. The acidity and alkalinity of the solution have a greater impact on the resin exchange process. For example: for cation exchange resin, when the pH value of the solution decreases, the activity of the acid groups of the resin will decrease, and its working exchange capacity will also decrease; but for anion exchange resins, when the pH value of the solution decreases, it can accelerate the dissociation of basic groups in the resin, thereby increasing its working exchange capacity. In desalination system, anion exchange is usually placed after hydrogen ion exchange. One of the reasons is to improve the working exchange capacity of the anion resin.

⑦ Degree of regeneration. The degree of resin regeneration has a great influence on the working exchange capacity. The more fully regenerated, the larger the working exchange capacity. However, in practice, it is not economical to consume too much regeneration reagent in order to fully regenerate the resin. In general, a suitable regeneration reagent consumption should be selected, which can make the resin get better regeneration without consuming too much regeneration reagent.

⑧ Resin quality. Poor quality of the resin itself, or pollution by suspended solids and organic during service, "poisoning" by Fe^{3+} or oxidation by free chlorine, etc., will greatly reduce the working exchange capacity of the resin.

(3) Reversibility of ion exchange reaction

The softener makes soft water by using the exchange effect of Na^+ exchange resin to remove calcium and magnesium ions, and the ion exchange reaction of the resin is reversible. When the water containing hardness passes through the Na^+ exchange resin, the Ca^{2+}, Mg^{2+} in the water start the exchange reaction with Na^+ in the resin, so that the outlet water is softened. If R represents the ion exchange group in the resin, RNa represents the sodium resin, and R_2Ca (R_2Mg) represents the exhausted resin, the reaction formula of the softening water production process is:

$$2RNa + Ca^{2+}\ (Mg^{2+}) \rightarrow R_2Ca\ (R_2Mg) + 2Na^+$$

Effective resin Inlet water (hard water) Exhausted resin Outlet water (soft water)

When the ion exchange resin exhausted, in order to restore its exchange capacity, it needs to be regenerated with regeneration reagent. The most commonly used regeneration reagent for water softener is brine (sodium chloride solution), that is, the Na^+ ionized from NaCl is used to treat the exhausted resin, and the reversibility of the ion exchange reaction is used to exchange the Na^+ in brine with the Ca^{2+} and Mg^{2+} in the resin, so as to restore the softening capacity of the resin, the reaction formula can be expressed as:

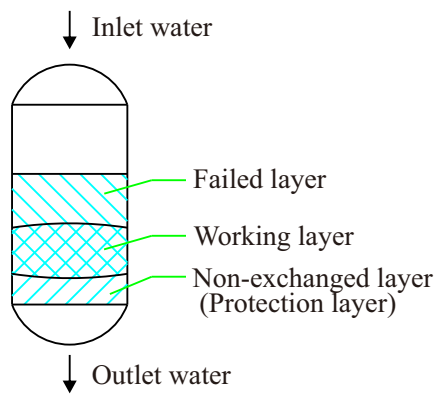
$$2Na^{+} + R_2Ca\ (R_2Mg) \rightarrow 2RNa + Ca^{2+}\ (Mg^{2+})$$

Brine Exhausted resin Effective resin Wastewater discharge

These two reactions are essentially the result of chemical equilibrium shift in the positive and negative directions in the reversible reaction. It can be seen that the reversibility of the ion exchange reaction is the basis that the ion exchange resin can be exchanged and regenerated for repeated use, and it is also the working principle of the water softener.

4.1.2.3 Service of water softener

Generally, when the water softener is in service, the water flows through the resin layer downwards, the Ca^{2+} and Mg^{2+} in the water exchange reaction with the Na^{+} in the sodium resin, and the outlet water is softened; when the upper layer of resin contacted by the water flow is exhausted, it continues to enter the next layer of resin for ion exchange, so that the exchange working layer continues to move down. As shown in Figure 4-5, the entire resin layer in the exchanger can be divided into three areas. The upper part is the failed layer. In this layer, due to the previous service, the Na type resins are all transformed into Ca^{2+} and Mg^{2+} types, losing the ability to continue to soften, and no change occurs when the water passes through this layer; the layer below it is the exchange layer, also known as the working layer. When the water passes through this layer, the Ca^{2+} and Mg^{2+} in the water exchange reaction with the Na^{+} in the effective resin. Therefore, there are both Na type, Ca type and Mg type resins in this layer; below the working layer is the effective resin layer that has not yet undergone the exchange reaction. With the service of the exchanger, the area of the failed layer continues to increase, the working layer continues to move down, and the non-exchanged area decreases accordingly. When the working layer moves down to the bottom of the resin layer, the outlet water will have hardness due to the penetration of Ca^{2+} and Mg^{2+}. Therefore, in order to ensure that the outlet water is qualified, the bottom layer should retain a certain amount of Na type resin for protection. Before the working layer reaches the bottom, it should be regenerated.



1.Failed layer 2. Working layer 3.Non-exchanged layer (Protection layer)

Figure 4-5 Working condition of resin in water softener

From the above analysis shows that, in fact, when the water softener services to failure, part of the resin in the working layer or protection layer is still sodium type and does not fully play the role of ion exchange. Therefore, the smaller their proportion in the entire resin layer, the higher the resin utilization rate. This is also the reason that increasing the height of the resin layer can improve the water treatment capacity by the water softener. In addition, in the service of the water softener, the effect of the thickness of the ion exchange working layer on the working exchange capacity is also obvious. There are many factors that affect the thickness of the working layer, mainly including:

a) Service flow rate: the faster the flow rate of water through the resin layer, the thicker the working layer, and the lower the resin utilization rate;

b) Raw water quality: the higher the hardness of the raw water, the thicker the working layer;

c) Water flow temperature and resin particles: the lower the water flow temperature, the larger the resin particles, the slower the exchange reaction speed, and the thicker the working layer.

In actual service, when the hardness of the raw water increases and the temperature decreases in winter, the service flow rate can be appropriately reduced to prevent the working layer and protection layer from becoming thicker, so as to maintain the working exchange capacity and outlet water quality.

4.1.3 Resin regeneration

The regeneration of resin is a key process of the using of softener. The regeneration degree of resin will affect outlet water quality and water treatment capacity greatly. Under the condition of good quality of resin and keeping salt in brine tank always, whether can ensure regeneration process is reasonably controlled and make an effective regeneration for resin is an important basis for evaluating the performance of the softener valve.

4.1.3.1 Regeneration process and requirement

Water softener works in service until outlet water hardness is disqualified, it needs to regenerate. The regeneration process of water softener is: Backwash→ Brine draw→ Slow rinse (ion exchange and rinse) →Brine refill→ Fast rinse→ until outlet water hardness qualified then go to service. The purpose and requirement of each process:

a) Backwash: Clean resin adversely to remove the suspended solids, sludge and other impurity things on the surface of resin which are intercepted during service process, and the broken resin, meanwhile to loose the resin layers which are pressed tightly during service. The backwash intensity should be well controlled. If the backwash intensity is too low, the impurity things in resin layers can not be cleaned sufficiently, so that the resin surface will be blocked by suspended solids or other colloidal substance easily which will affect ion exchange.If it is too

high, the complete resin may be flushed out which result in loss of resin. The backwash time should be determined by inlet water turbidity or resin polluted degree, generally speaking, it needs about 10min~15min.

b) Brine draw: It means by sucking brine to regenerate resin. Na^+ in brine will exchange with Ca^{2+} and Mg^{2+} in invalid resin to make resin recover softening capability. Automatic water softener is using inlet water pressure, sucking brine from brine tank through injector and dilute brine to be a certain concentration to regenerate resin in resin tank. The flow rate of brine draw should be slow to ensure there is sufficient contact time between brine and resin. If the flow rate is too high, there may be some brine flushed out without ion exchanged with resin, for up-flow regeneration, it may cause resin layers disorder which influences regeneration effect. But that not means the lower flow rate the better. Because ion exchange of resin is a reversible reaction. The exchanged Ca^{2+} and Mg^{2+} will be back to resin if they are not flushed out promptly. So if flow rate of brine draw is too low or in soak, it may influence regeneration degree and lower working efficiency. The brine draw time is related to resin volume, brine concentration, flow rate, etc. It will be explained in process calculation in detail.

c) Slow rinse: It is also named ion exchange and rinse. After brine draw, it cleans with same water flow direction and a little bit higher flow rate than brine draw. It helps to better ion exchange, flushed out wasted liquid to improve regeneration degree. Usually slow rinse time is close to brine draw time, but for up-flow regeneration water softener, if it uses inlet water for slow rinse, the slow rinse time should be shortened to prevent the calcium and magnesium ions in inlet water exchanged with bottom part of resin which influences outlet water quality. Additionally, the brine draw and slow rinse are in same working position for majority of softener valves, the time is combined, so the actual slow rinse time is the residual time after brine draw.

d) Brine refill: After brine is sucked from brine tank, it needs to refill certain water to brine tank to satisfy next regeneration required brine height, and make solid salt to dissolve until to be saturated brine. (It needs manually refill water to brine tank in initial time use.)

e) Fast rinse: It cleans with same water flow direction and flow rate as service, flushes out the regeneration liquid until outlet water is qualified, then make softener to service.

4.1.3.2 Down-flow regeneration and up-flow regeneration

When water softener's resin exhausted, it needs to regenerate. According to the different direction of brine draw, there are two regeneration ways which are down-flow regeneration and up-flow regeneration.

(1) Down-flow regeneration

The brine draw direction same as service direction, it is named down-flow regeneration. Usually the flow direction of down-flow regeneration is from top to bottom. As the brine contact with fully exhausted resin on top of resin tank firstly, when brine flows downwards to resin

protection layer which is at bottom part of resin tank, not only low concentration of Na^+ in exchanged brine, but also containing big quantity of Ca^{2+} and Mg^{2+}, based on ion exchange reversible principle, this is not good for regeneration. So the bottom part of resin can not be regenerated sufficiently, but also resin in protection layer will be polluted by ion exchanged Ca^{2+} and Mg^{2+}, which will affect outlet water quality. In order to improve resin regeneration degree, it needs to consume more salt for regeneration, so the salt consumption is often relatively large in down-flow regeneration.

Working process of down-flow regeneration softener valve sets: (Service to resin exhausted) →Backwash→ Brine draw and slow rinse→ Brine refill→ Fast rinse→ until outlet water hardness qualified then go to service. Because of easy regeneration process and well controlled, down-flow regeneration softener valve is most widely used.

(2) Up-flow regeneration

The brine draw direction opposite to service direction, it is named up-flow regeneration or convective regeneration. There are two common up-flow regeneration ways. One is service flow direction from top to bottom, brine draw from bottom to top, which is named fixed bed up-flow regeneration process. The other one is service flow direction from bottom to top, resin floats compactly at top part of resin tank by water flow kinetic energy. During regeneration, resin goes down, brine flows from top to bottom, it is named floating bed process. Floating bed is suited for continuous working, but not for stop and start working frequently.

During up-flow regeneration, brine contact with resin in protection layer which is less degree of exhausted firstly, when flows to resin layer which is high degree of exhausted, there is high concentration of ion exchanged Ca^{2+} and Mg^{2+}, but it is flushed out fast, which helps to better regenerate. As the resin in protection layer (close to outlet water part) has sufficient regeneration for up-flow regeneration, so even though the resin in surface layer (close to water inlet part) has less good regeneration effect, it will not influence outlet water quality.

The ideal up-flow regeneration comparing to down-flow regeneration, it has advantages of high degree of regeneration, good quality of outlet water, low consumption ratio of regeneration regent, high capacity of working exchange, etc. For down-flow regeneration, it also has advantages of simple device and pipeline, convenient regeneration mode, easily automatic controlling, etc. Additionally, to achieve advanced performance of up-flow regeneration, there are two preconditions: one is resin layers can not be disordered (during backwash and regeneration process, water upwards, if water flow is high which may mix invalid resin layer and protection layer. It is named resin layers disordered). The other one is slow rinse after brine draw is better to use soft water. If use high hardness inlet water for slow rinse, it may make resin in protection layer at bottom invalid which will influence outlet water quality. In order to prevent backwash make resin layers disordered, some softener adopts interval backwash times,which

means couple of services with one backwash, and uses soft water for brine draw and slow rinse, but it needs more complicated pipelines and controllers, so it is more common to adopt down-flow regeneration in automatic softener.

Working process of up-flow regeneration softener valve is similar to down-flow regeneration's, it sets: (Service to resin exhausted) →Backwash(some softener valves can set couple of services with one backwash)→Brine draw and slow rinse→ Brine refill→ Fast rinse→ until outlet water hardness qualified then go to service. The water flow direction of brine draw and slow rinse is opposed to service's. In order to prevent resin disordered, the flow rate of brine draw and slow rinse should be lower than down-flow regeneration's (it should be controlled 2m/h ~ 4m/h).

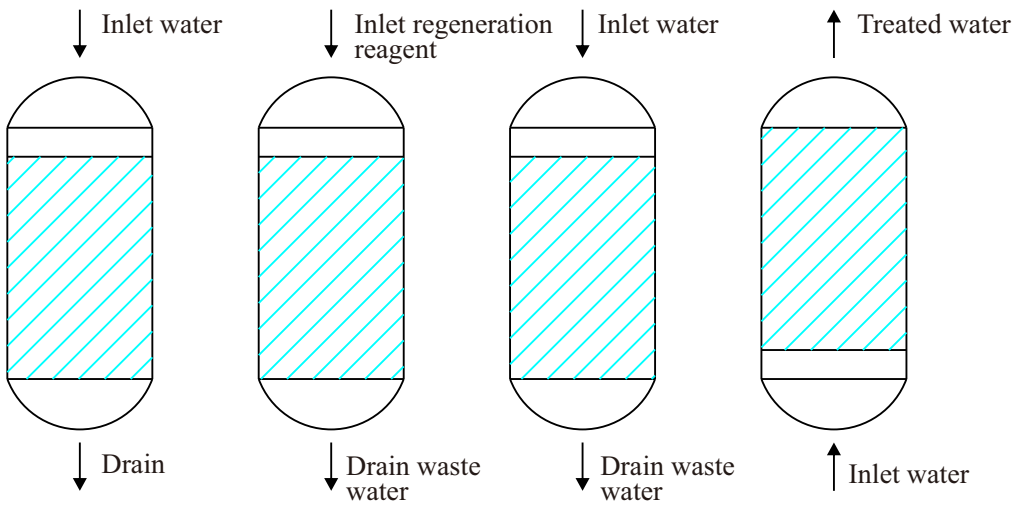
Currently, some up-flow regeneration softeners adopt fully tank resin which means resin filled height up to 90% ~ 95% of resin tank, there are only few free space as expansion space for regeneration. Regeneration process can reduce backwash steps, set: (Service to resin exhausted) →Brine draw and slow rinse→ Brine refill→ Fast rinse→ until outlet water hardness qualified then go to service. Even though the flow direction of brine draw and slow rinse is upwards, but there is less free space for resin flow, and reduce backwash steps, so it can prevent resin disordered. Its flow rate of brine draw and slow rinse can be set same as down-flow regeneration(4m/h ~ 6m/h), it can loose resin layers which can shorten regeneration time, improve regeneration efficiency and increase water treatment capacity. But it has high requirement on water inlet turbidity. A filter needs to be equipped before softener and ensure inlet water turbidity for softener less than 2NTU, water should be equally distributed. Additionally, inlet water pressure can not be high, or else it will make resin layers pressed tightly, not easily be loosed and not good for ion exchange, it may also influence regeneration efficiency and outlet water quality. If necessary, take out of resin from resin tank to clean after working for some time to prevent resin layers pressed tightly. This is the disadvantage for up-flow regeneration.

(3) Floating bed

Floating bed is up-flow regeneration, but its service flow direction is opposite to fixed bed up-flow regeneration's. In service position, water flow upwards, lift up resin. Resin will settle down during regeneration position. Brine and rinse water downwards through resin layers. So working process of floating bed softener valve sets: (Service to resin exhausted) →Settling bed(static or few drain to settle down resin)→Brine draw and slow rinse→ Brine refill→ Resin floated and down-flow rinse(lift up resin and clean upwards)→ until outlet water hardness qualified then go to service. Additionally, it is better to use soft water for brine draw and slow rinse, or else the top resin will be easily invalid which may influence outlet water quality. Runxin floating bed with single valve and single tank, uses water pump to take soft water from soft

water tank for brine draw, slow rinse and brine refill. Floating bed with single valve and double tanks, uses soft water from service tank for brine draw, slow rinse and brine refill for the other regeneration tank, which can make better regeneration effect.

Water flow direction of floating bed as Figure 4-6:



(a) Settling bed; (b) Brine draw; (c) Ion exchange and rinse; (d) Resin floated, down-flow rinse and service

Figure 4-6 Water flow direction of floating bed in regeneration

When floating bed is invalid, stops service, then starts regeneration after resin settling bed. There are two kinds of settling bed:

a) Settling bed by drain: When it stops service, drain at bottom shortly to make resin falling down tidily. Pay attention that drain time usually less than 1 minute to prevent water level in resin tank lower than resin layer. This kind of settling bed is fast and less disturbance for resin layers, it is suitable for high water level floating bed.

b) Settling bed by gravity: When it stops service, resin settles down naturally with its gravity, usually takes 2 minutes to 3 minutes. This kind of settling bed is slow, it is suitable for the floating bed with low water level and do not set drain to settle bed of softener valve.

Floating bed requires top and bottom strainers water distribution equally, uses high flow rate during start and service to lift up resin (usually take 20m/h ~ 30m/h for resin floated, the service flow rate can be increased to 20m/h ~ 60m/h). If the water distribution is unequal or with low flow rate, resin layers will be loosed and messy which may affect outlet water quality. So inlet water pressure will be considered when configure softener valve.

Advantage and limitation of floating bed

a) Advantage of floating bed

① High service flow rate and water treatment capacity: Floating bed allows high service flow rate, so under the same volume exchanger circumstance, outlet water capacity for floating bed is larger than fixed bed.

② Low consumption ratio of regeneration reagent, good outlet water quality: Consumption ratio of regeneration reagent for floating bed is 1.1 ~ 1.4, regeneration reagent utilization ratio is 70% ~ 90%. As its high utilization ratio, less waste water drained, it reduces pollution to environment. Meanwhile, it adopts soft water for regeneration, resin in protection layer keeps good regeneration degree, so it has a good quality of outlet water and has a good adaptation for inlet water hardness content.

③ The device is simple structure, easy operation, less processes during regeneration, as regeneration reagent flow downwards, so no worry about resin disordered during regeneration.

b) Limitation of floating bed

① The impurity things in resin can not be easily cleaned, it needs to take out the resin from tank to clean: The resin filling capacity up to about 90% of the tank volume in floating bed, no enough backwash space, so it can not flush out the impurity things or broken resin during regeneration, so floating bed has a high requirement on inlet water turbidity, and needs to deliver resin to specific extracorporeal cleaning tank to clean in a certain period.

② Not suitable for application which service starts and stops frequently: floating bed is better used to continuous work after resin floated, until to resin exhausted, settling bed and regeneration. The advantages of floating bed will be reflected sufficiently in this way. If service stops or starts frequently, resin will be disordered in resin floated or settling bed at different levels, which will affect outlet water quality (it is not big influence for the application where is not strict requirement on outlet water hardness). Additionally, floating bed requires the inlet water have a certain pressure and stable enough, if it is low inlet water pressure, the exchanger can not be resin floated well, it will influence outlet water quality greatly.

4.1.3.4 Factors affected regeneration effectiveness

There are many factors affected regeneration effectiveness of water softener, main factors are as following.

(1) Regeneration way

As described above, if it can guarantee resin not be disordered and use soft water for brine draw and slow rinse, the up-flow regeneration has better regeneration effectiveness than down-flow regeneration.

(2) Salt consumption in regeneration

Generally speaking, salt consumption is a key factor for regeneration degree of water softener. It is directly related to recover of resin exchange capability and economy. If there is short of salt or brine is unsaturated, regeneration degree is low, it will affect working exchange capacity, shorten water treatment capacity, exchanger water consumption will increase, sometimes it will influence outlet water quality. If increase consumption ratio of regeneration

reagent properly, it can improve resin regeneration degree, but after improve to a certain level, the regeneration degree can not be improved obviously. If increase more, it makes waste of salt. So it is not an economic choice to use too much of regeneration regent.

(3) Inlet water pressure

During regeneration of automatic water softener, it uses inlet water pressure to make brine draw from brine tank through injector and dilute to be a certain concentration, flow to resin tank to regenerate resin. Inlet water pressure should meet the demand of softener valve designed. If pressure is low, it affects the brine draw, which makes brine concentration low and influence regeneration effectiveness. So if inlet pressure is too low, it needs to equip with booster pump. If inlet pressure is unstable, then stabilized equipment and pressure gauge are necessary to guarantee brine draw flow rate and volume stable for better regeneration effectiveness.

(4) Brine concentration and injector matching

In a certain range, increase brine concentration properly, it can improve regeneration degree. But after to a certain level, if continues to increase brine concentration, instead of improving regeneration effectiveness, the exchange capacity is affected by the compression of the high concentration of brine on the resin group. Meanwhile, when salt consumption is fixed, the higher brine concentration, the smaller brine volume. It has less contact time with resin and affect regeneration degree. For down-flow regeneration, the brine concentration diluted through injector is controlled in 6% ~ 10%, for up-flow regeneration, it is 5% ~ 8%. To make sure the brine concentration controlled in a proper range, there are three conditions: First one is brine concentration in brine tank should be saturated or over saturated (there is always solid grain salt in brine tank). Second one is matching with proper injector. Third one is inlet pressure for brine draw meet the demand.

(5) Flow rate for brine draw and slow rinse

The flow rate of brine draw and slow rinse which passes through resin layers is an important factor for regeneration degree of water softener. To keep a proper flow rate, it actually keeps a certain contact time between regeneration regent and resin to make sure the ion exchange is well processed and the brine is used maximally.

During regeneration, it is very important to control a certain flow rate. If flow rate is too fast, there is no enough contact time between brine and resin, ion exchange can not be processed sufficiently, but the brine has been flushed out of exchanger, it influences regeneration effectiveness and also wastes salt. For up-flow regeneration, if low rate is too fast, resin will be easily disordered. During regeneration in down-flow regeneration and floating bed up-flow, brine flows downwards, resin will not be disordered, the flow rate of brine draw and slow rinse is controlled in 4m/h ~ 6m/h. For up-flow regeneration, as brine flows upwards, the flow rate is controlled in 2m/h ~ 4m/h to prevent resin disordered.

(6) Brine level in brine tank

Under normal circumstance, water softener will draw all of brine in brine tank in each of regeneration, so each salt consumption mainly depends on brine level after brine refill, it is not related to how much of solid salt remained in brine tank. If brine level is not enough, it draws less brine which will reduce regeneration effectiveness and influence water treatment capacity. If brine level is too high, it makes longer time for brine draw, it not only makes waste of salt, but also shorten slow rinse time. So during water softener trial running, it should control brine level at a proper height by setting brine valve in brine tank or brine refill time, which can guarantee there is enough brine for each regeneration, proper brine draw time and no waste of salt.

(7) Brine draw time

If brine draw time is short, it makes there is not enough contact time between brine and resin, which will influence regeneration effectiveness easily. In order to make sure ion exchange processed completely, the contact time between regeneration reagent and resin is no less than 30 minutes. But brine draw time can not be too long, as the flow channel and flow rate are the same for “brine draw” and “slow rinse” (which is exchange rinse), usually automatic controller sets them as one working position. If brine level is high, it takes longer time for brine draw and shorten slow rinse time, which makes waste regeneration liquid not be flushed out completely in fast rinse position, and chloride ion content in outlet water in service position is high, sometimes water hardness is also too high.

(8) Regeneration salt

The purity of sodium chloride in regeneration salt has influenced regeneration degree of resin and outlet water quality greatly. If there are much of impurity things in salt, especially with much of calcium and magnesium ion, it will reduce regeneration degree and influence outlet water quality. Additionally, if inlet water has high hardness, it is better to use soft water for regeneration (including brine refill), or else if use high hardness water for brine dissolving and brine draw, it rises calcium and magnesium ion content in brine which will influence regeneration effectiveness.

For automatic water softener, it is better to use the specific small round or grain industrial salt for regeneration, but not refined salt or iodized salt. Because when refined salt is saturated, it may be blocked easily and forms “salt bridge” which makes salt can not be dissolved sufficiently, the brine is unsaturated and influences regeneration effectiveness. When inlet water pressure is high, the refined salt may be sucked to brine pipeline and injector which makes them blocked and can not suck brine. The iodized salt will oxidize the resin which affects the resin service life.

(9) Temperature

The temperature has a great influence on ion exchange speed. The lower temperature, the

slower reaction. So when water temperature is low in winter, it needs to reduce flow rate of regeneration and service accordingly.

(10) Inlet water hardness

For most of water softener, it uses inlet water for brine refill. If inlet water has high hardness, the hardness in brine is increased which influences regeneration effectiveness. Additionally, for up-flow regeneration water softener, inlet water flows upwards through bottom strainer in slow rinse position, if inlet water has high hardness, it makes resin in protection layer at bottom invalid, inlet water hardness out of standard at the beginning of service or lengthen fast rinse time. So if inlet water has high hardness, it is better to use soft water for regeneration process (including brine draw, slow rinse and brine refill).

4.2 The classification and selection of water softener system

The type and performance of automatic water softener device and system mainly depends on the characteristics of softener valve. Depending on the combination of water softener and different tanks' quantity controlled by softener valve, there are multi-types of systems, such as single valve with single tank, single valve with double tanks, single valve with triple tanks working in series, multi-valves with multi-tanks working in parallel, etc.

4.2.1 Single valve with single tank water softener system

It has one softener valve controlling one resin tank, which is the simplest water softener system. When water softener is in regeneration, there is no soft water available, so single valve with single tank system is only suitable for the boiler and other equipment with stable water consumption and intermittent service. For the application which requires soft water available without any interruption, it needs to equip with water softener which flow rate is higher than application required, and match a soft water tank which can supply soft water at least 2 hours (for example, if the water consumption of device is $4m^3/h$, then it needs to match a soft water tank at least $8m^3$), to make sure there is enough soft water in soft water tank available during water softener in regeneration. Or it can match two sets of single valve with single tank water softeners, alternate their regeneration time to achieve supplying soft water without any interruption.

Additionally, single valve with single tank water softener has two types which are raw water bypass and no raw water bypass during regeneration. Raw water bypass during regeneration can achieve soft water available without interruption. Raw water bypass to outlet of water softener directly in regeneration process, which means the outlet water is hard water at this moment, it is suitable for the application that do not have high requirement on soft water and allow to use hard water in a short time, but not suitable for the application which has high requirement on water hardness, such as boiler system. GB/T 18300 “Specification for Automatic Control Sodium Ion Exchange” specified: for the water softener used in boiler system, it is not allowed to have hard

water pass to outlet during regeneration process. So for boiler system, it should use softener valve which does not have raw water bypass during regeneration. If the used valve has raw water bypass, it needs to equipped with solenoid valve to prevent hard water go to soft water tank, which results in water hardness out of standard and makes scaling in boiler system.

4.2.2 Single valve with double tanks water softener system

It has one softener valve controlling two resin tanks, one resin tank is in service, the other is in regeneration or standby. One valve with double tanks can allow supplying soft water continuously, and is used in application which requires soft water available without interruption, such as boiler system. In this system, it only has one brine tank, which can save floor space and procurement cost comparing two sets of water softeners.

When adopts single valve with double tanks water softener, if inlet water hardness is not high and long time of service, the resin tank may standby for quite a long time. When it switches to service, the outlet water of beginning running may be out of standard. In order to solve this problem, this valve usually delay fast rinse, which means after brine refill, this tank will be standby, until before switching to service, it starts to fast rinse to make sure outlet water is qualified at the beginning of running.

4.2.3 Single valve with triple tanks working in series water softener system

Single valve with triple tanks working in series water softener system is mainly used in application which has high hardness in raw water (hardness higher than 6mmol/L) or has strict requirement on outlet water hardness (requires outlet water hardness lower than 0.01mmol/L), needs to equip with second grade softener to make outlet water hardness meet the demand. Generally speaking, second grade softener needs to have two sets of softener working in series. If system requires soft water available without any interruption, it needs to equip with two sets series common softeners, that is to install 4 sets of water softeners, thereinto 2 sets working in series, 2 sets regeneration or standby, it is low-usage of the devices. Runxin develops a valve with working in series on triple tanks, which has one softener valve controlling tree tanks, alternates two tanks working in series, one regeneration and standby. It is not only high-usage of the devices, but also saves the procurement cost of system. The mode of single valve with triple tanks working in series is: one softener valve controls three tanks automatically (name three tanks as A, B and C), when A and B work in series (A's outlet water go into B for secondary softening), C is in regeneration or standby. When the outlet water hardness of first grade A reaches a certain number, it stops working, meanwhile, C starts service (at this moment, B turns to first grade softening, its outlet water go into C for secondary softening), A starts to regenerate then standby. A, B and C tank work as first and second grade softening and regeneration in turn, which can ensure outlet water hardness qualified and also improve the resin efficiency. Please pay attention that it can not wait to have high hardness on outlet water of first

grade softener then start regeneration, the first reason is that if first grade softener has high hardness on outlet, it can make water hardness on second grade softener out of standard easily. Second reason is that making resin exhausted fully, it is hard to regenerate resin sufficiently, if it is as second grade softener after regeneration, it can make outlet water disqualified.

4.2.4 Multi-valves with multi-tanks water softener system

Multi-valves with multi-tanks water softener system can achieve multi-tanks working simultaneously but regeneration separately.

When water treatment capacity is higher than 50m^3/h, the system can equip with several sets of softener valves and tanks working in series or parallel, which designs several sets of softeners working in parallel to achieve total capacity met the demand, by using interlock function which controlled by microcomputer to control only one tank in regeneration to ensure the water quality and capacity meet the demand.

As single valve with single tank can not supply water continuously, for the application which requires soft water supply without any interruption, it usually adopts two sets of single valve with single tank water softener systems, with interlock to working in parallel, to achieve two sets systems working simultaneously but regeneration separately. For the high water treatment capacity system, it also can equip with multi-tanks in series. For example, a system requires capacity 100m^3/h and continuously supplying soft water, it can match 3 sets of capacity 50m^3/h single valve with single tank softener systems, it needs 2 sets of these systems in service and use interlock function to guarantee outlet water capacity. Considering of 2 hours for regeneration, it is not suggested to adopt more than 4 sets of single valve with single tank systems working in series, to prevent one set in regeneration, the other set may need to regenerate also.

4.3 Calculation water of softener process

4.3.1 Set service period

It is very important to set service period correctly and adjust it accordingly. If set improperly, resin may be exhausted but not regenerate timely, it will result in outlet water hardness out of standard. Or if resin is not exhausted but regenerate in advance, it will waste of salt and water for regeneration. Even though there are default parameters of controller set in factory, and supplier will make a trial running when new device is installed on site and set each parameter accordingly, but ender user also needs to adjust the parameters according the changing of raw water quality, requirement on outlet water quality, water consumption, etc. Additionally, during device service, operator needs to take water to test regularly to check if outlet water hardness is qualified. When it is disqualified, it needs to check the reason, adjust parameters, replace resin or repair water softener.

(1) Calculation of water softener water treatment capacity

The water treatment capacity for water softener can be calculated based on filled resin volume and the total hardness removed, as formula (4-1). For meter type water softener, it can calculate the capacity by this formula.

$$Q = \frac{V_R \times E}{YD \times K} \qquad (4\text{-}1)$$

In this formula: Q──Soft water capacity treated in softener service, t or m^3.

V_R──Resin volume in resin tank, m^3. ($V_R = \pi \times R^2 \times h_R$, thereinto R is radius of internal of resin tank, m. h_R is resin filled height, m.)

E──Resin working exchange capacity, mol/m^3. Usually for new sodium resin, it takes $1000mol/m^3$ ~ $1200mol/m^3$, for old one, it takes $800mol/m^3$ ~ $1000mol/m^3$ to calculate.

K ──Security factor which is used for guarantee the latter part of outlet water hardness qualified, usually takes 1.1~1.8 (When the raw water hardness is larger or the flow rate is higher, take the larger value of K; otherwise, take the smaller value.).

YD──Inlet water average total hardness, mmol/L (Remark: hardness elementary unit is $1/2Ca^{2+}$, $1/2Mg^{2+}$).

(2) Calculation of time clock type water softener service time

Time clock type automatic softener service time (day or hour) is calculated according to water treatment capacity and soft water used per day. It usually calculates service days by formula (4-2), service hours by formula (4-3).

$$d = \frac{V_R \times E}{YD \times K \times Q_t \times T} = \frac{Q}{Q_t \times T} \quad (\text{day, takes round-off number}) \qquad (4\text{-}2)$$

$$t = \frac{V_R \times E}{YD \times K \times Q_t} = \frac{Q}{Q_t} \quad (\text{hour}) \qquad (4\text{-}3)$$

In this formula: d ──Service days after regeneration, d.

Q_t──Softener water treatment capacity within a unit of time (if it used for feeding boiler, it is similar to evaporation capacity), t/h.

T──Softener service time (hour) or boiler service hour per day, h/d.

t ──Service time after regeneration (by hour), h.

The other symbols are same as in formula (4-1).

For example 4-1 An automatic water softener, single valve with duplex tanks, meter type, there are 250L resin filled in each resin tank, inlet water average hardness is 4.0mmol/L, if resin working exchange capacity is $1000mol/m^3$, security factor 1.4, how much water treatment capacity to be set for this water softener properly?

Answer:

$$Q = \frac{V_R \times E}{YD \times K} = \frac{0.25 \times 1000}{4.0 \times 1.4} \approx 44.6\ m^3$$

As there is no decimal point for set capacity, in order to prevent outlet water hardness out of standard, so here it is properly to set water treatment capacity as $44m^3$.

For example 4-2 An oil burning boiler which evaporation capacity is 2t/h, the matched automatic water softener filled $0.15m^3$ resin, boiler is running about 10 hours per day, if raw water hardness is 2.6mmol/L, how many days set for this softener service then regeneration?

Answer:

$$d = \frac{V_R \times E}{YD \times K \times Q_d \times T} = \frac{0.15 \times 1000}{2.6 \times 1.2 \times 2 \times 10} = 2.4$$

In order to make sure boiler running safety, prevent outlet water hardness out of standard, according to calculation, it takes 2 days which means regeneration in every 2 days.

4.3.2 Calculation of regeneration process

4.3.2.1 Estimation of salt consumption for each regeneration

The salt filled in brine tank of water softener usually can be used for couple times of regenerations, but no need to fill in each regeneration. But it still needs to estimate salt consumption (m_z) for each regeneration according to formula (4-4), so that to estimate brine draw time, and evaluate the reasonability of actual salt consumption.

$$m_z = \frac{V_R \times E \times k \times M}{1000 \times \varepsilon} \tag{4-4}$$

In this formula: m_z——Salt weight consumed in one regeneration, kg.

V_R ——Resin volume filled in resin tank, m^3.

E——Resin working exchange capacity, mol/m^3. Usually for sodium resin, it takes $800mol/m^3$ ~ $1200mol/m^3$. It takes $1000mol/m^3$ to calculate.

k ——Consumption ratio of regeneration reagent. For sodium resin, up-flow regeneration, it takes 1.2 ~ 1.7, for down-flow regeneration, it takes 1.8 ~ 2.2.

M—— Molar mass of regeneration reagent, when use salt to regenerate, NaCl is 58.5.

ε——Regeneration reagent purity, the NaCl content in common table salt or industrial salt is 95% ~ 98%..

4.3.2.2 Calculation of brine level needed in brine tank

Under the condition of always having solid salt in brine tank and sufficient brine draw time set, the salt consumption for automatic water softener mainly depends on the brine level in the tank. Under normal temperature, the saturated brine concentration is 26.3%, so 1kg of salt dissolving to saturated brine needs 2.8L of water, so the water refilled to brine tank for dissolving salt, the brine level can be calculated according to formula (4-5).

$$H = \frac{2.8 \times m_{cz} \times 10^{-3}}{\pi \times R_Y^{\ 2}} \tag{4-5}$$

In this formula: H——Brine level after automatic water softener brine refilled, m.

m_{cz}——The amount of sodium chloride in salt for one regeneration ($m_{cz}=m_z\times\varepsilon$), kg.

R_Y ——Radius of internal of brine tank, m.

4.3.2.3 Estimation of brine draw time in regeneration

When salt weight consumed per one regeneration and regeneration flow rate are confirmed, the brine draw time can be estimated as formula (4-6) in theory. The brine draw of automatic water softener is processed by injector sucking saturated brine and diluted into resin tank, so the actual brine draw flow rate, brine concentration after diluted and volume are related to softener valve matched, injector size, inlet pressure, etc. For Runxin softener valve, there are information of selecting proper softener valve and injector depending on the size of resin tank diameter in the user manual. It can check brine volume and flow rate, so to calculate brine draw time.

$$t=\frac{60\times V_z}{S\times v}\ \text{min} \tag{4-6}$$

$$\text{Thereinto:}V_z=\frac{m_{cz}}{C\times\rho\times10^3}\ \text{m}^3$$

In this formula: t ——Brine draw time, min.

V_Z——Brine volume after diluted entering into resin tank, m^3.

S——Sectional area of resin layer, m^2.

ν——Regeneartion liquid (brine) flow rate, m/h.

m_{cz}——Sodium chloride weight consumed in one regeneration ($m_{cz}=m_z\times\varepsilon$), kg.

C——Brine concentration after diluted entering into resin tank, % (usually 6% ~ 8%).

ρ——Brine density after diluted entering into resin tank (if number＜1.06, it can be ignored).

For example 4-3: A set of down-flow regeneration water softener, radius of internal of resin tank is 0.5m, resin filled height is 1.4m, through the matched softener valve and injector, it can be checked from the manual, the brine concentration is controlled by 6% during regeneration, brine flow rate for entering into resin tank is 5 m/h. Question: How much kilogram of industrial salt consumed which sodium chloride containing is 96% in one regeneration? If radius of internal of resin tank is 0.3m, what is brine level refilled in brine tank after regeneration? How long should brine draw time be set?

Answer:

① Resin volume in this water softener： $V_R=3.14\times0.25^2\times1.4\approx0.27\ m^3$

For down-flow regeneration, consumption ratio of regeneration regent takes 2, resin working exchange capacity takes 1000mol/m^3, salt consumed in one regeneration:

$$m_z=\frac{V_R\times E\times k\times M}{1000\times\varepsilon}=\frac{0.27\times1000\times2\times58.5}{1000\times96\%}\approx33\text{kg}$$

② Sodium chloride weight consumed per one regeneration $m_{cz}=33\times96\%\approx32$ kg, brine level filled in brine tank.

$$H=\frac{2.8\times m_{cz}\times10^{-3}}{\pi\times R_Y^{\ 2}}=\frac{2.8\times32}{3.14\times0.2^2\times1000}\approx0.72\ \text{m}$$

③ Sectional area of resin layer in resin tank $S=3.14\times(0.5/2)^2\approx0.2m^2$, brine draw time in regeneration:

$$t=\frac{60\times m_{cz}}{S\times v\times C\times1000}=\frac{60\times32}{0.2\times5\times6\%\times1000}=32\ \text{min}$$

4.3.2.4 Main performance index of water softener

According to GB/T 18300 "Specification for Automatic Control Sodium Ion Exchange" regulation, the main performance index of water softener refers to table 4-1.

Table 4-1 Main performance parameters of water softener

Connecting system		Service flow rate [a] m/h	Backwash flow rate m/h	Brine draw and slow rinse flow rate m/h	Fast rinse flow rate m/h	Regeneration liquid concentration [b] %	Salt consumption g/mol	Working exchange capacity [c]/-(mol/m^3)
First grade sodium	Down-flow regeneration	20～30	10～20	4～8	15～20	6～10	≤120	≥800
	Up-flow regeneration	20～30	10～20	2～4	15～20	5～8	≤100	≥900
	Floating bed	30～50	—	2～5	15～20 [d]	5～8	≤100	≥900
Second grade sodium		≤60	10～20	4～8	20～30	5～8	—	—

1.For water softener used in industrial softening equipment, the brine draw time should be no less than 30 minutes.

2.At the end of regeneration, the chlorine ion in outlet water should be no 1.1 times higher than in inlet water.

[a] Water softener for industrial application, it only can work at upper limit maximum value in a short period, but not for long time. Water softener for residential application, the flow rate is more flexible, but should not influence the ender user's requirement for water quality.

[b] Regeneration liquid concentration means the brine concentration after the brine diluted through injector entering into ion exchange resin layer under normal temperature.

[c] Means sodium ion exchange resin working exchange capacity. Weak acidic cation resin working exchange capacity ≥1800 mol/m^3.

4.3.3. Injector design and selection

For automatic softener valve, the injector is usually integrated. When design a system, according to the matched resin tank diameter, considering of injector suck and injection ratio, make the regeneration flow rate and brine concentration of water softener comply with GB/T 18300 "Specification for Automatic Control Sodium Ion Exchange".

According to regeneration liquid concentration requirement in table 4-1, for up-flow regeneration water softener, when design injector, its suck and injection ratio (which is the ratio of sucked brine volume and water entering into injector volume) should be controlled between 1:4.3 to 1:2.3. For down-flow regeneration, the ratio should be between 1:3.4 to 1:1.6.

By regeneration liquid flow rate and matched tank diameter (inner diameter) value, it can calculate the total injector outlet volume (which is the sum of injector inlet volume and sucked saturated brine volume, it is also the diluted brine volume). So the suck and injection ratio of injector is decided when design the softener, selecting proper injector for different diameter of tank is decided when select the model, which is decided when configure the water softener.

For example: matching resin tank with diameter 400mm, when adopt down-flow regeneration, the regeneration liquid flow rate after diluted is $Q=v\times S=(4\sim 8)\times 3.14\times 0.2^2=(0.5\sim 1.0)m^3/h$.

In order to make sure the brine draw and flow rate of regeneration for variety diameter of resin tank all comply with requirement, there are different Runxin valves and relative injectors for matching variety diameter of tank for optional in softening system. During actual selection, one size of injector can be matched for different models of control valves (as the flow channels of control valve are different, the water resistance will be different, so the total injector draw rate, slow rinse and brine refill flow rate will be different also), according to raw water quality, inlet pressure, actual water treatment capacity required, and other factors may cause matching different control valves for the same diameter of resin tank. It needs to have trial running and verification for the system configuration.

4.3.4 Economy evaluation of water softening running

Under normal working condition of water softener, usually evaluates a water softener's economy performance by salt consumption or ratio, working exchange capacity, etc.

4.3.4.1 Regeneration salt consumption and ratio

To recover exchange capacity of 1mol of ion exchange resin, the consumed weight (g) of regeneration reagent is named reagent consumed weight. If uses salt for regeneration, it is named salt consumption. In theory, to recover softening capacity of 1mol of sodium resin, it needs 58.5g of NaCl. But in actual application, the salt consumption is usually higher than the theoretical value. The proportion of actual salt consumption to molar mass of regeneration reagent (which is theoretical value) is named reagent ratio. For down-flow regeneration water softener, the reagent ratio should not be higher than 2.5, for up-flow regeneration, not higher than 2, or else, the water softener does not have a good economy performance. It needs to check the reason. The actual salt consumption (g/mol) and ratio can be calculated according to formula (4-7) and (4-8) accordingly.

$$\text{Salt consumption}=\frac{m_{cz}}{Q(YD-YD_C)} \approx \frac{m_{cz}}{QxYD} \quad g/mol \tag{4-7}$$

$$\text{Regeneration reagent ratio}=\frac{\text{Reagent consumed weight}}{\text{Reagent molar mass}}=\frac{\text{Salt consumption}}{58.5} \tag{4-8}$$

In this formula: m_{cz} ——Sodium chloride weight consumed in one regeneration (take 100% NaCl to calculate), g.

Q——Water treatment capacity of water softener, m^3.

YD——Raw water average hardness, mmol/L.

YD_C——The residual hardness in softened water, when it is much smaller than raw water hardness, it can be ignored.

58.5——Molar mass of NaCl, g/mol.

When the salt consumption and ratio of water softener is high, it can check the reasons from following aspects, then adjust and improve it.

a) Check if there is too much water filled in brine tank which result in sucking too much salt?

b) Check if water treatment capacity is set too low, which means system will regenerate before resin exhausted?

c) Check if resin polluted or poisoned which will reduce its exchange performance?

d) Check if resin flushed out which result in insufficient height of resin layer, and under the same salt consumption, the water treatment capacity reduced?

4.3.4.2 Working exchange capacity

Working exchange capacity means the ion exchange quantity of resin during its working. For new resin, the exchange capacity usually is more than 1000mol/m^3, but for automatic softening system in industrial application, in order to guarantee outlet water qualified in service, its capacity set will be more conservative, which result in making some discount of exchange capacity. Additionally, when resin is used, it may be polluted or not good regeneration, it will also affect exchange capacity. It needs to check the reason and improve it. For an automatic softening system, if its actual exchange capacity is less than 500 mol/m^3 (for manual softening system, less than 800 mol/m^3), it is not good economy performance, it needs to check the reason and improve it. The actual working exchange capacity E (mol/m^3) of sodium resin can be calculated according to formula (4-9).

$$E=\frac{Q(YD-YD_C)}{V_R} \approx \frac{Q.YD}{V_R} \tag{4-9}$$

In this formula: Q——Water softener water treatment capacity, t or m^3.

YD——Inlet water average hardness, mmol/L.

YD_C——The outlet water hardness in sodium exchanger, mmol/L (if this value is very small, it can be ignored).

V_R——Resin volume in resin tank, m^3.

When resin working exchange capacity is reduced obviously, it can check the reason from following aspects, and improve it.

a) Check if resin regeneration comply with requirement (such as if there is enough salt in brine tank, if brine level is appropriated. If inlet water pressure, brine concentration, flow rate comply with requirement)?

b) Check if resin is polluted or poisoned ?

c) Check if there is enough resin bed height ?

d) Check if service flow rate is too fast ?

e) Check if water treatment capacity is set too low, which makes regenerate before resin exhausted, so there is some resin not be used sufficiently?

For example 4-4: A meter type water softener, resin filled $0.5m^3$, it feeds softened water for steam boiler system, average inlet water hardness is 3.6mmol/L, it requires outlet water hardness less than 0.03mmol/L, set softener water treatment capacity of 90t, it can make sure outlet water is qualified. Fill salt with 200 kg (NaCl containing 96%) into the brine tank every time, after regeneration 3 times, there is no solid salt in brine tank, it needs to fill salt again, how is economy performance for this water softener?

Answer:

(1) This softener actual salt consumption = (200÷3×1000)×96%÷(90×3.6)≈198 g/mol

Actual regeneration reagent ratio = 198÷58.5≈3.4

(2) Actual working exchange capacity: E = 90×3.6÷0.5 = 648 mol/m^3

This water softener has high reagent ratio, it needs to check reason. As its working exchange capacity comply with requirement, and outlet water before regeneration is qualified, it means resin and water treatment capacity set correctly, the reason may fill too much water in brine tank which result in higher slat consumption, it needs to check and adjust brine liquid level controller and brine draw time, then retest it.

There will be using different units for calculation at some areas, the common units are:

1mmol/L ($1/2Ca^{2+}$, $1/2Mg^{2+}$) = 50PPM (takes $CaCO_3$ for calculation)

1mmol/L ($1/2Ca^{2+}$, $1/2Mg^{2+}$) = 2.92grain/gallon

1grain/gallon = 17.1PPM (takes $CaCO_3$ for calculation)

$1m^3$ = 264gallon (US gallon) = 220gallon (UK gallon)

1kg = 2.2pounds

1PPM = 1mg/L.

4.4 Softening and alkalinity reduction processes

For the application which raw water contents high alkalinity, if it only adopts sodium exchanger for softening in boiler water supply system, as sodium exchange to remove calcium and magnesium hardness, the remaining alkalinity in water will increase as boiler water evaporation which makes it concentrated. The high alkalinity not only affects steam quality, but also makes alkaline corrosion for metal. If it improves boiler sewage discharge rate to reduce boiler alkalinity, it is not energy saving and emission reduction. Therefore, if use high alkalinity water (alkalinity＞2.5mmol/L) for boiler water supply, it needs softening and alkalinity reduction processes. For industrial boiler softening and alkalinity reduction processes, there are main three ways: partial softening, hydrogen-sodium ion exchange and ammonium-sodium exchange.

4.4.1 Partial softening

For partial softening, there are two kinds of circumstances: the first one is for high hardness water application, adopts the first grade softening to remove the majority of calcium and magnesium ions to make low hardness water, the second one is for high hardness and high alkalinity water application, one part of water after softening to remove hardness, then mix with raw water in a certain percentage, to make the mixed water hardness lower than alkalinity 1mmol/L ~ 2mmol/L.

Partial softening process is suitable for natural circulation steam boiler which rated evaporation capacity ≤4t/h and rated steam pressure ≤1.0MPa, steam and water two-way optional boiler and hot water boiler which rated power ≤4.2MW. These boilers working pressure and thermal load are low, after partial softening, the residual calcium and magnesium ions enter into boiler, they will make reaction with alkaline substance, the reaction thing will be drained out of boiler system. Through partial softening process (fill proper amount of antisludging agent in boiler if necessary), boiler water meet the demand of boiler internal water treatment standard in GB/T 1576 “Water Quality for Industrial Boilers”, it can prevent scaling inside of boiler, also prevent high alkalinity in boiler water, reduce sewage discharge and thermal losses, it also can lower water treatment cost.

4.4.2 Hydrogen-sodium ion exchange

Hydrogen-sodium ion exchange process is taking one part of raw water ion exchanged with H^+ resin and making water acidic, the other part of raw water ion exchanged with Na^+ resin to remove hardness, and making water alkaline. When mix these two kinds of water to neutralize, it can remove hardness and reduce alkalinity of water. So under normal circumstance of boiler evaporation, concentration and reasonable swage discharge, boiler alkalinity can comply with the standard. H-Na ion exchange system has two processes of H^+ exchange and Na^+ exchange.

There are many types of operating ways. Here introduce some common ways.

4.4.2.1 H-Na ion exchange process with weak acid H^+ exchange resin

(1) Softening and alkalinity reduction principle of H-Na exchange ion process with weak acid H^+ exchange resin

It is a good way to reduce alkalinity in water by using weak acid H^+ exchange resin, it has advantages of no strong acid generated, high exchange capacity, easy regeneration, simple control, etc. Because weak acid resin is hardly ion exchanged with strong acid anion salts, such as SO_4^{2-}, Cl^-, etc. It usually reacts with weak acid salts. So after ion exchanged, it will not generate strong acid, and the exchange capability for weak acid H^+ resin exchange Na^+ is weak, there will be still part of $NaHCO_3$ in outlet water. So the main function of weak acid H^+ exchanger is to remove carbonate hardness (calcium bicarbonate and magnesium bicarbonate) in water. The reaction is expressed as:

$$R(-COOH)_2 + \left.\begin{matrix} Ca \\ Mg \\ Na_2 \end{matrix}\right\}(HCO_3)_2 \rightarrow R(-COO)_2\left\{\begin{matrix} Ca \\ Mg \\ Na_2 \end{matrix}\right. + 2H_2CO_3$$

Weak acid H^+ resin Inlet water Exhausted resin Outlet water

$$H_2CO_3 \rightarrow H_2O + CO_2$$

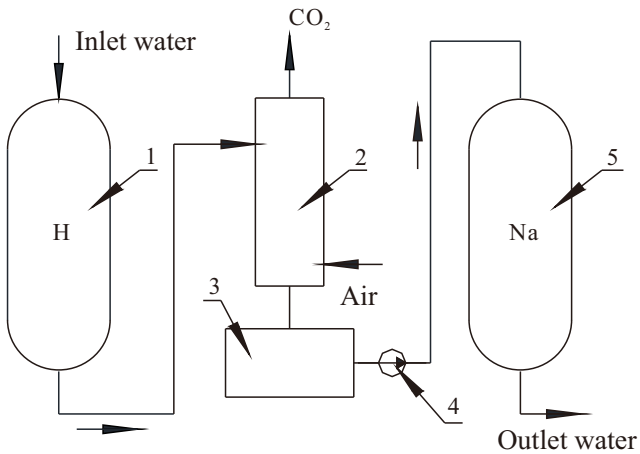
CO_2 in outlet water of H^+ exchanger can be removed by decarbonator, then enter into Na^+ exchanger to remove non-carbonate hardness to reduce alkalinity and hardness. Moreover, the exchange capacity of weak acid H^+ exchange resin (means the capacity of removing carbonate hardness) is almost 2 times of strong acid cation resin, and even if resin exhausted, it is easily to regenerate by alkali, low consumption of acid, usually consumption ratio of regeneration reagent is about 1.1, low concentration of discharged acid which is easily to be dealt with. Although the price of weak resin is higher, it is generally economical and relatively safe due to the low operating cost.

(2) System of H-Na ion exchange process with weak acid H^+ exchange resin

H-Na ion exchange system with weak acid H^+ exchange resin and strong acid Na^+ exchange resin is as Figure 4-7. Raw water enters into weak acid H^+ exchanger to remove carbonate hardness, the carbon dioxide generated will be removed by decarbonator, then exchanges in Na^+ exchanger to remove non-carbonate hardness.

The outlet water of H-Na ion exchange system is processed by Na^+ exchanger, so it is no need to control outlet water of H^+ exchanger strictly, as long as its outlet water hardness reduction number is similar to inlet water alkalinity. The water quality is mainly controlled by the outlet water hardness of Na^+ exchanger. In order to make H^+ exchanger and Na^+ exchanger exhausted and regenerated simultaneously, the filled resin ratio of weak acid H^+ exchange resin

and strong acid Na^+ exchange resin is depending on the ratio of carbonate hardness(means raw water alkalinity) and non-carbonate hardness(the difference value between total hardness and alkalinity in raw water). Meanwhile, it should keep a certain alkalinity in system outlet water. Generally speaking, for industrial boiler system, the alkalinity remained is controlled in 0.4 mmol/L ~ 1.0 mmol/L.



1.Weak acid H^+ exchanger 2.Decarbonator 3. Middle water tank 4. Water pump 5. Na^+ exchanger

Figure 4-7 Diagram of System of H-Na ion exchange process with weak acid H^+ exchange resin

For automatic control exchanger, when making design, the water treatment capacity can be set according to formula (4-1), service time set according to formula (4-2) or (4-3). But it needs to adjust hardness in formula: for weak acid H^+ exchanger, YD is carbonate hardness (means raw water alkalinity), for Na^+ exchanger, YD is non-carbonate hardness (means the difference value between total hardness and alkalinity in raw water). Working exchange capacity E: Na^+ exchange resin is still calculated as 1000mol/m^3, weak acid H^+ exchange resin is calculated as 1800mol/m^3 ~ 2000mol/m^3. If there is a big difference of two exchangers' capacity, it is not good for automatic controlling, so it needs adjust the size and filled resin volume of two exchangers, and also keep a certain alkalinity in finial outlet water.

4.4.2.2. H-Na ion exchange process with strong acid cation exchange resin

(1) Softening and alkalinity reduction principle of H-Na ion exchange process with strong acid cation resin

Strong cation resin after regenerated with acid becomes H^+ exchange resin (RH). Raw water is treated by H^+ exchange resin, all cation in water is exchanged by H^+, the reaction is expressed as:

$$2RH + \begin{Bmatrix} Ca \\ Mg \\ Na_2 \end{Bmatrix} \begin{Bmatrix} (HCO_3)_2 \\ SO_4 \\ Cl_2 \end{Bmatrix} \rightarrow R_2 \begin{Bmatrix} Ca \\ Mg \\ Na_2 \end{Bmatrix} + \begin{Bmatrix} 2H_2CO_3 \\ H_2SO_4 \\ 2HCl \end{Bmatrix}$$

H^+ resin Inlet water Exhausted resin Acidic outlet water

From the above formula, it is known that after exchanged by H^+, all strong acid anion in raw water with H^+ generate strong acid, so the outlet water is strong acidic. As the exchange capacity of cation exchange resin to sodium is weaker than to calcium and magnesium ions, when H^+ exchange resin is exhausted, Na^+ content in outlet water is increasing firstly. When H^+ exchanger takes the Na^+ content controlling in outlet water as the end of service, the acid in outlet water is similar to the amount of strong acid anion in raw water. But if the H^+ exchanger outlet water Na^+ content increases (sodium leakage) and not regenerates, but still works until outlet water hardness out of standard (hardness leakage), then starts to regenerate, which means exchanger takes the hardness controlling in outlet water as the end of service. From the period of sodium leakage to hardness leakage, the acid in outlet water will decrease.

Raw water goes through Na^+ exchanger, all cation in water is exchanged by Na^+, the reaction is expressed as:

$$2RNa + \begin{matrix} Ca \\ Mg \end{matrix} \left\{ \begin{matrix} (HCO_3)_2 \\ SO_4 \\ Cl_2 \end{matrix} \right. \rightarrow R_2 \left\{ \begin{matrix} Ca \\ Mg \end{matrix} \right. + \left\{ \begin{matrix} 2NaHCO_3 \\ Na_2SO_4 \\ 2NaCl \end{matrix} \right.$$

Na^+ resin Inlet water Exhausted resin Outlet water

From the formula, it is know that raw water after exchanged by Na^+, the hardness is removed but not alkalinity, which means the outlet water is alkaline water.

Mix the acidic water treated by H^+ exchanger with alkaline water treated by Na^+ exchanger, they make neutral reaction, the reaction formula is expressed as:

$$2NaHCO_3 + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O + 2CO_2\uparrow$$

$$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2\uparrow$$

After neutralization, the generated CO_2 can be removed by decarbonator.

(2) Common systems of H-Na ion exchange process with strong acid resin

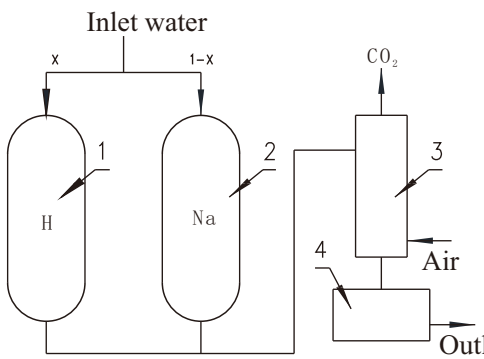
Common systems of H-Na ion exchange process with strong acid resin are two kinds which are in series system and parallel system.

a) Parallel H-Na ion exchange system

The system is designed as Figure 4-8. Raw water is divided into two parts, enters to H^+ exchanger and Na^+ exchanger separately. Then mix two outlet water, after neutralization, the generated CO_2 can be removed by decarbonator. It needs to instruct that when use parallel H-Na ion exchange system, H^+ exchanger takes the Na^+ content controlling in outlet water as the end of service. If it takes the hardness leakage as the end of service, although it can increase water treatment capacity, but if the Na^+ content of outlet water increased in H^+ exchanger, the alkalinity of mixed outlet water will increase accordingly, it needs to increase the outlet water ratio of H^+ exchanger, and when H^+ exchanger finishes regeneration, it also needs to reduce the ratio, or else the alkalinity of mixed outlet water is too low, sometimes even the outlet water becomes

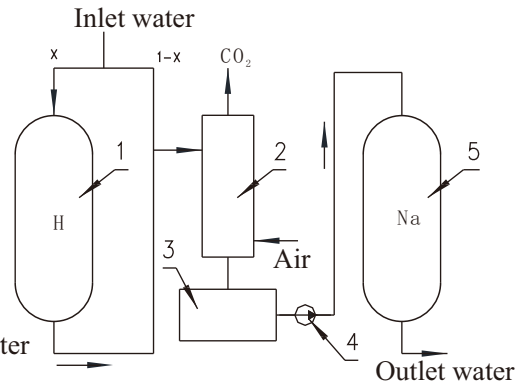
acidic water which will influence the running safety of boiler system. That is to say, if H^+ exchanger takes the hardness content controlling in outlet water as the end of service, it needs to adjust two outlet water ratio frequently which is not easy to control.

For automatic H^+ exchanger, if it takes the Na^+ increasing in outlet water as the end of service, it can measure the outlet water conductivity to make exchanger regeneration automatically. Under the condition of stable inlet water conductivity, if Na^+ content in outlet water is increased, it means H^+ decreased, at this moment, outlet water conductivity will decrease obviously, it can make exchanger to start regeneration.



1. H^+ exchanger 2. Na^+ changer
3.Decarbonator 4.Water tank

Figure 4-8 Parallel H-Na ion exchange system



1. H^+ exchanger 2. Decarbonator 3. Water tank
4.Pump 5.Na^+ changer

Figure 4-9 In series H-Na ion exchange system

b) In series H-Na ion exchange system

System design is as Figure 4-9. In this system, raw water is also divided into two parts, one part enters to H^+ exchanger, the other part mixes with the outlet water of H^+ exchanger. In this way, the acidic substance in outlet water of H^+ exchanger makes neutralization reaction with carbonates in raw water, the generated CO_2 can be removed by decarbonator. The decarbonized water enters to water tank, then takes to Na^+ exchanger by water pump. In series system, the decarbonator should be installed before Na^+ exchanger, or else the water containing CO_2 goes through Na^+ exchanger, it will generate $NaHCO_3$, which will increase the alkalinity of soft water again.

(3) Comparison of parallel and in series H-Na ion exchange system

In terms of device, there is only a part of raw water entering into Na^+ exchanger for parallel system, but in series system, all treated water will enter into Na^+ exchanger finally, so under the condition of output same capacity, parallel system needs smaller volume of Na^+ exchanger, and in series system needs bigger one. So parallel system is more compact and less investment.

In terms of service, in series system does not need to control strictly and adjust two outlet water capacity ratio, because even though the mixed outlet water of H^+ exchanged water and raw water is acidic, it will enter into Na^+ exchanger (all H^+ are exchanged to Na^+), the final outlet

water will not be acidic. So the in series system is more safety and reliable, the H^+ exchanger capacity can be used sufficiently. If H^+ exchanger takes the hardness leakage as the end of service for parallel system, it has to adjust timely and control two exchangers' outlet water capacity ratio strictly to ensure the soft water after mixed with a certain alkalinity.

(4) Treated water capacity ratio of H-Na ion exchange

When use H-Na ion exchange, it should adjust the two ion exchangers' outlet water capacity ratio properly according to raw water quality, which can ensure the alkalinity of mixed water is 0.4 mmol/L ~ 1.2mmol/L.

Set X as the portion of outlet water capacity of H^+ exchanger with total outlet water's, then (1-X) is: the portion of outlet water capacity of Na^+ exchanger in parallel system, or the portion of water not go through H^+ exchanger in series system.

After treated by H-Na ion exchange, it still needs to retain a certain alkalinity in mixed soft water, so no matter for parallel or in series system, after two outlet water mixed, it should comply to formula (4-10):

$$(1 - X)\,JD - XSD = JD_C \tag{4-10}$$

After collection, it is:

$$X = \frac{JD - JD_C}{JD + SD} \times 100\% \tag{4-11}$$

In the formula： JD——Alkalinity of raw water, mmol/L(HCO_3^-)

JD_C——Retained alkalinity in outlet water after H-Na ion exchange system treated, mmol/L(HCO_3^-)

SD ——Acid of outlet water of H^+ exchanger, mmol/L (H^+). If it takes Na^+ content controlling in outlet water as the end of service, it is the total containing of strong acid anion in raw water. If it takes hardness content controlling in outlet water as the end of service, it is the non-carbonate hardness in raw water.

This shows, the outlet water capacity ratio of H^+ exchanger and Na^+ exchanger, based on the differences of the end of service for H^+ exchanger, it will be divided into two circumstances:

a) If H^+ exchanger takes the Na^+ increasing in outlet water as the end of service, the ratio is calculated based on formula (4-11).

b) If H^+ exchanger takes the hardness leakage as the end of service, at this moment, the acid of outlet water is equivalent to the amount of the non-carbonate hardness in raw water, raw water alkalinity is equivalent to carbonate hardness. So the sum of these two is the total hardness of raw water (YD), and it uses formula (4-12), but not (4-11):

$$X = \frac{JD - JD_C}{YD} \times 100\% \tag{4-12}$$

For example 4-5: A industrial boiler system, raw water quality is: hardness＝5.6 mmol/L, alkalinity＝4.8 mmol/L, adopts parallel H-Na ion exchange system. It requires there is alkalinity about 1.0 mmol/L in treated soft water, total water capacity is 20t/h. when H^+ exchanger takes the Na^+ content controlling as the end of service, the average acid in outlet water is 2.3 mmol/L. When H^+ exchanger takes the Na^+ content controlling as the end of service or two exchangers take the outlet water hardness content controlling as the end of service, what is the water treatment capacity ratio will be for H^+ exchanger and Na^+ exchanger?

Answer: ① Water treatment capacity ratio when H^+ exchanger takes the Na^+ content controlling as the end of service:

$$X = \frac{JD - JD_C}{JD + SD} \times 100\% = \frac{4.8 - 1.0}{4.8 + 2.3} \times 100\% = 53.5\%$$

It means when H^+ exchanger takes the Na^+ content controlling as the end of service, two exchangers water treatment capacity will be:

H^+ exchanger water treatment capacity＝53.5%×20=10.7 t/h;

Na^+ exchanger water treatment capacity＝20 - 10.7＝9.3 t/h。

② Water treatment capacity ratio when H^+ exchanger takes the hardness content controlling as the end of service:

$$X = \frac{JD - JD_C}{YD} \times 100\% = \frac{4.8 - 1.0}{5.6} \times 100\% \approx 68\%$$

It means when outlet water Na^+ content increasing for H^+ exchanger, as the outlet water alkalinity decreased, H^+ exchanger water treatment capacity increases to: 68%×20≈13.6t/h. Na^+ exchanger water treatment capacity decreases to: 20 - 13.6＝6.4t/h. But when H^+ exchanger finishes regeneration, water treatment capacity should be adjusted back to 10.7t/h, which is not easy to control.

4.4.3 Ammonium-sodium ion exchange

4.4.3.1 Softening and alkalinity reduction principle of ammonium-sodium ion exchange

Cation exchange resin after regenerated with ammonium salt will become NH_4^+ type (RNH_4). After raw water is treated by NH_4^+ type exchanger, all cation in water is exchanged by NH_4^+, the reaction is expressed as:

$$\left.\begin{matrix} Ca \\ 2RNH_4 + Mg \\ 2Na \end{matrix}\right\} \left\{\begin{matrix} (HCO_3)_2 \\ SO_4 \\ 2Cl \end{matrix}\right. \rightarrow R_2 \left\{\begin{matrix} Ca \\ Mg \\ Na_2 \end{matrix}\right. + \left\{\begin{matrix} 2NH_4HCO_3 \\ (NH_4)_2SO_4 \\ 2NH_4Cl \end{matrix}\right.$$

Ammonium resin　Inlet water　Exhausted resin　Outlet water

Ammonium bicarbonate (NH_4HCO_3) generated after reaction, it is decomposed after heated in boiler water:

$$NH_4HCO_3 \rightarrow NH_3\uparrow + CO_2\uparrow + H_2O$$

So NH_4^+ exchange has function of softening and alkalinity reduction, but also can reduce salt partly, meanwhile, after NH_3 enters into steam system, it can neutralize CO_2, make passivation on surface of steel.

Ammonium chloride (NH_4Cl) and ammonium sulfate [$(NH_4)_2SO_4$] generated after reaction, can also be decomposed after heated in boiler water and generate strong acid:

$$NH_4Cl \rightarrow NH_3\uparrow + Hcl$$

$$(NH_4)_2SO_4 \rightarrow 2NH_3\uparrow + H_2SO_4$$

The other part of raw water after goes through Na^+ exchanger, the sodium bicarbonate ($NaHCO_3$) in soft water enters into boiler, it is decomposed after heated in boiler water, and generates alkali:

$$2\ NaHCO_3 \rightarrow Na_2CO_3\uparrow + CO_2\uparrow + H_2O$$

$$Na_2CO_3 + H_2O \rightarrow 2NaOH + Co_2\uparrow$$

The acid and alkali generated in above formula make neutralization reaction in boiler water:

$$H^+ + OH^- \rightarrow H_2O$$

$$2H^+ + CO_3^- \rightarrow H_2O + CO_2\uparrow$$

So the principle of NH_4−Na ion exchange is almost the same as H−Na ion exchange, the differences are as following:

(1) The alkalinity and salt reduction effect of NH_4−Na ion exchange is showed only after soft water decomposed after heated in boiler. But not like H−Na ion exchange, the alkalinity is reduced before soft water going to boiler.

(2) The water after exchanged by NH_4^+, only after heated, it shows strong acid, and not use acid to regenerate, so there is no need for strict acid preventing treatment for water treatment device and pipeline. But NH_4Cl and $(NH_4)_2SO_4$ is acidic in water, so it should make acid preventing treatment for NH_4^+ exchanger and pipeline.

(3) The water after exchanged by NH_4^+ will not decompose CO_2 before water heated, so NH_4−Na ion exchange system does not need decarbonator.

(4) The ammonia generated after the NH_4^+ exchanged water is heated, enters the steam system together with steam, which can neutralize CO_2 and have a certain anti-corrosion effect on the steam pipeline, but makes corrosion for brass parts in thermal system or heat exchange equipment. Additionally, if steam contact with heated substance directly, it may influence the product quality. So it is better to remove oxygen, ammonia, carbon dioxide by thermodynamic deaerator for soft water treated by NH_4−Na ion exchange before entering into boiler.

4.4.3.2 NH_4 - Na ion exchange system and notice

(1) For NH_4 - Na ion exchange system, it usually uses parallel system, but not in series or mixed resin system. As cation exchange resin is more easily to select NH_4^+ rather than Na^+, if it uses in series system, when water goes through NH_4^+ exchanger, then enters into Na^+ exchanger, the NH_4^+ will be exchanged by Na^+ again, which makes water alkalinity increased again. If uses mixed resin system, ammonium salt and sodium salt will make regeneration with resin together, if NH_4^+ resin takes the majority percentage after regeneration, it may result in boiler water alkalinity not enough or even become acid, which influences boiler running safety. If NH_4^+ resin takes less percentage, then water alkalinity is higher which is not easy to control and difficult to adjust.

(2) When NH_4^+ exchanger regenerates, usually uses 5% ~ 8% of NH_4Cl as regeneration reagent. If uses $(NH_4)_2SO_4$ as reagent, its concentration should not exceed 3%, to prevent $CaSO_4$ precipitation generated during regeneration, which covers on surface of resin particle to reduce its exchange capability. The regeneration reagent consumption for NH_4^+ exchanger calculated refers to formula (4-4). When reagent is NH_4Cl, the molar mass is 53.50.

(3) NH_4^+ exchanger and Na^+ exchanger both take the hardness content controlling in outlet water as the end of service, thereinto, strong acid anion ammonium salt content (it will be strong acid ammonium salt after heated) in outlet water of NH_4^+ exchanger is same as hardness of non-carbonate. So the percentage X of NH_4^+ exchanger water treatment capacity to the total water treatment is also calculated according to formula (4-12), then proportion of Na^+ exchanger water treatment capacity represents 1-X. As the strong acid performance of strong acid anion ammonium salt can not be expressed sufficiently at normal temperature, it can not estimate whether the water treatment capacity ratio is appropriate by retained alkalinity after mixing the outlet water of two exchangers, but according to the practical monitoring boiler water alkalinity to estimate and adjust. When uses formula (4-12) to calculate NH_4^+ exchanger water treatment capacity ratio, it is better to keep alkalinity JD_C with 1.0 mmol/L ~ 1.2mmol/L.

4.5 Practical application of Runxin softener valve

Runxin softener valve is suitable for softening water treatment with all types of water quality in variety application. Runxin valve has been widely used in the world, here we share some of typical applications for reference.

4.5.1 Application of softening water treatment in boiler feeding system

If there is calcium and magnesium or other hardness substances in boiler feeding water, it is easy to cause scaling and corrosion under scale on heated surface, it does not only decrease heat transfer performance, waste fuel, but also destroys the heated metal surface and influences boiler

running safety. So the water feeding to boiler system has to be softened, and controls softened water hardness strictly to guarantee the water hardness complying with the boiler standard, and to prevent water scaling in boiler system.

4.5.1.1 Parallel boiler feeding water treatment system

(1) Background

A transnational food company set a factory in South Africa, the water feeding to boiler, its hardness should be ≤0.5mg/L (0.01mmol/L), water flow rate should reach 120m^3/h. Raw water is tap water, the average hardness is about 60mg/L (1.2mmol/L), even though the raw water hardness is not high, but it controls outlet water hardness strictly. So the water feeding to boiler needs to be softened deeply. The steam is used for food manufacturing, so the water softener needs to fill food-grade resin. Operator will test outlet water hardness on each shift.

(2) Project overview

System flow rate requires 120m^3/h, single water softener can not reach such high flow rate, so it designs couple sets of softener systems in parallel (as Figure 4-10): match 4 sets of resin tanks with diameter of 1.2m and height of 1.8m, use 63640 softener valve, fill 1000 liter of food-grade resin in tank. Flow chart for softening water treatment system is: tap water→ softener→ water for using. Softener valves have interlocked, to achieve working simultaneously but regeneration separately, which can guarantee enough water supply for boiler, and improve softener utilization.



Figure 4-10 Softening water treatment system with working in parallel but regeneration separately

(3) Running effectiveness

This system has been put into use since 2017 and working well. It can not only meet the demand for boiler system, but also guarantee the outlet water qualified. Its outlet water hardness is always 0mg/L, customer is very satisfied.

4.5.1.2 Filtration-softening in series water treatment system

(1) Background

A transnational company set a beverage factory in a country in Africa, the feeding water hardness supplied to steam boiler should be less than 0.03mmol/L, water treatment capacity is 30m^3/h. Raw water is tap water, but its water quality is unstable and with high turbidity, the

hardness in raw water is fluctuating, the maximal reaching to 450mg/L (9mmol/L) which is over the standard of feeding water hardness for common single softener (the standard requires no higher than 6.5mmol/L). In order to guarantee the softened water complying with the boiler standard and prevent scaling in boiler, avoid polluting ion exchange resin and affecting the softening effect by high turbidity raw water, it uses filtration-softening in series system when designed the system. Operator will test the turbidity of filtered water and hardness of softened water manually.

(2) Project overview

As raw water is bad quality, not only has high hardness, but also has suspended solids, grainy sand, etc. So designed flow chart of water treatment system is: disk filter → active carbon filter → softener → water tank. System installation is as Figure 4-11.

The first step of water filtration system is disk filter, uses Runxin 45040 disk prefilter, mainly used to remove suspended solids and grainy impurity things. The second step of filtration equips metal tank with diameter of 2m and height of 2.2m, uses Runxin 53540 time clock type control valve, takes active carbon as media, filling height is 1m, mainly to remove residual chlorine and reduce organics, which can prevent oxidation and pollution of ion exchange resin, and lengthen resin life time. Meanwhile, system equips ball valve as Figure 3-6, to increase backwash flow rate.

As the raw water hardness can be changed greatly on the site of factory located, in order to guarantee the softener outlet water hardness always qualified, even though raw water hardness reaching up to 9mmol/L, system uses the higher resin tank to increase the resin filling height to solve this problem. So this softening system equips two sets of water softeners, with metal tanks diameter of 2m, height of 2.2m, filling 4000L of sodium resin, using Runxin 63650 softener valves.

The active carbon filter valve and softener valve have interlocked to prevent them backwash and regeneration simultaneously. For the condition of unstable of tap water supply or electricity service, system controls filter to start backwash by time, softener regeneration by delayed according to the water supply condition.



Figure 4-11 Filtration-softening in series water treatment system

(3) Running effectiveness

This system was installed and started to running from November of 2015, till now, it is proofed to work reliable and stable. During past five years, there was no error or outlet water hardness out of standard happened.

4.5.1.3 Floating bed used in softening water treatment of heating network heat exchange station

(1) Background

Heat exchange station is a secondary heating network heat exchange station, which transforms the primary heat from boiler heating network to supply hot water and heating water for end user. It means hot water (or steam) enters from the side inlet of primary heating network to plate heat exchanger, after heat exchanged, flow out from the side outlet of primary heat pipeline. The secondary heating network water is filtered to remove sediment, through secondary cyclic water pump, goes to plate heat exchanger for heat exchanging, which will supply hot water for heating, air conditioner or daily used to meet end user's demand. So the hot water and heating water supplied by heating network has to be softened.

A concentrated heat supplying heat exchange station in a city in North of China, raw water is deep well water, average hardness is 8.5mmol/L, turbidity less than 5NTU, it requires flow rate of softening system no less than 19m^3/h, outlet water hardness less than 0.03mmol/L, and adopts central controlling, outlet water hardness monitory automatically, water tank full of water shut down automatically, brine concentration monitory automatically, cyclic brine dissolve automatically alarm, etc.

(2) Project overview

The average raw water hardness is up to 8.5mmol/L in this heat exchange station, which is out of maximal standard of single fixed bed water softener inlet hardness (standard requires no higher than 6.5mmol/L), and this heat exchange station requires to control softened outlet water hardness strictly, the common single fixed bed water softener can not meet the demand, if it equips secondary sodium softener, it increases the cost. So the system adopts the floating bed softening system with increased height of resin layer.

Although the raw water turbidity is less than 5NTU in this heat exchange station, which meets the inlet water requirement for fixed bed, as the resin is almost filled fully in resin tank for floating bed, there is no backwash space to clean the resin, if inlet water turbidity is high, it may pollute resin, which will influence floating bed system water capacity and quality greatly, so it requires the inlet water turbidity no higher than 2NTU for floating bed. In order to meet the turbidity requirement of floating bed inlet water, it needs to install an ultrafilter before softener system.

This softener system equips 2 sets of floating bed resin tanks with diameter of φ700×2300mm, sodium resin filled up to the level about 10cm lower than top strainer, single tank flow rate is 20m^3/h, use Runxin 93620 control valve for floating bed. It equips Runxin 42020 electronic three-way ball valve to realize one in service one standby. To guarantee the floating resin not disordered during service process, it adopts variable-frequency water pump to

supply water for floating bed, it can make inlet water pressure stable to guarantee outlet water hardness less than 0.03mmol/L. Additionally, in order to improve regeneration effectiveness and outlet water hardness qualified fastly, system uses soft water for brine draw, slow rinse and upwards down rinse. For example, when system detects 1# tank outlet water is disqualified or water treatment capacity reaches to the set value, by switching of 42020 electronic three-way ball valve, 2# tank turns to service, 1# tank starts regeneration, 93620 softener valve controls ball valve open, regeneration pump turns on automatically, sucks soft water for 1# tank regeneration. When 1# tank finishes regeneration, ball valve will be closed, regeneration pump shut down, 1# tank is in standby.

There is a Runxin 44310 hardness monitory online device equipped on outlet of softener system to monitor hardness automatically. If the outlet water hardness is out of standard (higher than 0.03mmol/L), monitory device will send a signal to PLC controller, controller will send a signal to 93620 control valve remote handling connector to start regeneration automatically. There is a density online monitory device installed in brine tank to monitor brine density. When the brine density is less than 1.2g/cm^3 (means the brine is unsaturated), it will send a signal to PLC controller and start brine dissolving system.

There is an electronic valve on system outlet, and connect with liquid level controller in soft water tank. When the soft water tank is at high level, electronic valve on outlet is closed automatically. When it is at low level, electronic valve is opened to allow fill soft water to tank.

By setting central controller, it can automatically control the opening or closing of water supply system with non-negative pressure and variable-frequency, filtration system, floating bed system, hardness online monitory device, brine density online monitory device, liquid level controller in soft water tank, regeneration pump. For softening system, it mainly uses internal dry contact signal on 93620 control valve to control 42020 electronic three-way ball valve switching and regeneration pump opening or closing, and sends signal to PLC controller, outputs remote signals of two control valves' service and regeneration. It uses internal dry contact signal on 44310 hardness online monitory device, when it detects outlet water hardness is disqualified, it will send a signal to PLC automatically and a remote alarm signal to 93620 control valve to make it regenerate, and will make 42020 electronic valve switching to start standby tank to service.

The entire water treatment system configuration and automatic controller wiring of the heat exchange station refers to Figure 4-12. The floating bed softening water treatment system refers to Figure 4-13.

(3) Running effectiveness

This system was installed and started to running from October of 2018, till now, it works in a good condition and outlet water qualified. In comparison, if uses common fixed bed softening system to remove high hardness, it needs second grade softening, flow rate is 20m^3/h, equipped with 4pcs resin tanks (2sets× 2pcs in series second grade softening, one in service one standby)

or 3pcs resin tanks (alternate 2 tanks working in series, 1 tank regeneration). But for floating bed system, only needs 2 tanks, with less investment, high water treatment capacity, save 20% of water regeneration used which reduces waste water discharge by 20%, save salt and water. System uses online monitory devices, automatic service and regeneration, it can not only guarantee outlet water quality, but also save labor cost to operate and detect water quality.

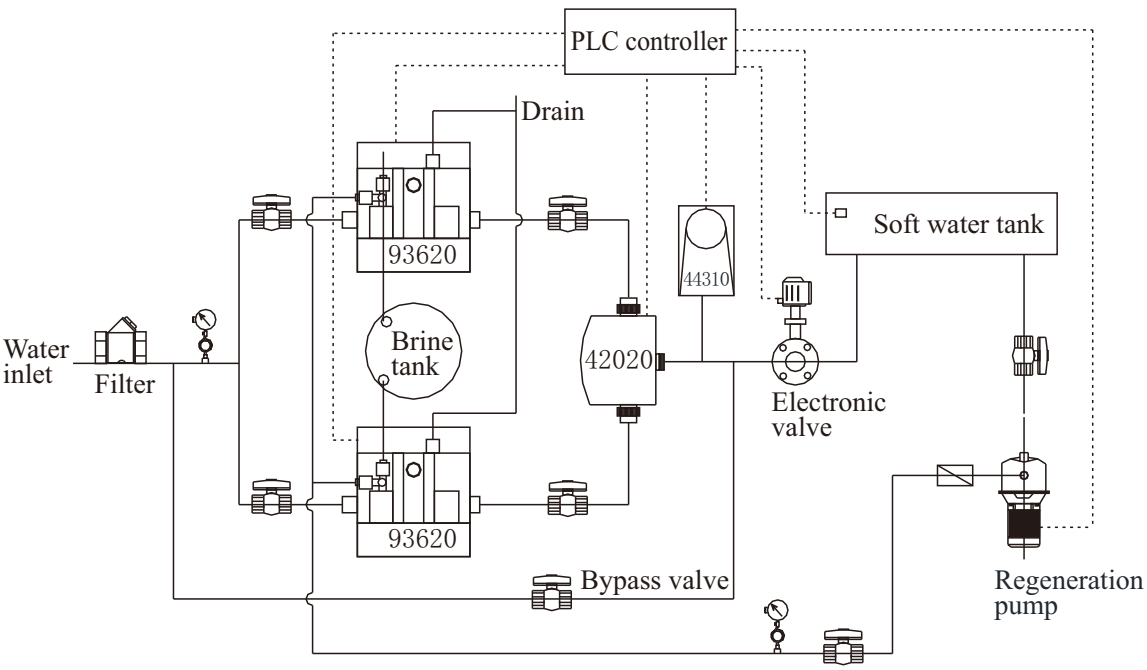


Figure 4-12 Water treatment system configuration and automatic controller wiring of the heat exchange station



Figure 4-13 Floating bed softening water treatment system

4.5.2. Runxin valve used in hydrogen-sodium ion exchange softening and alkalinity reduction processes system

4.5.2.1 The necessity of hydrogen-sodium ion exchange softening and alkalinity reduction processes

If used raw water with high hardness and alkalinity for boiler system, if only make softening, even though the hardness is removed, but there is still high alkalinity inside of water, after the water enter into boiler, along with evaporation which makes it concentrated, the alkalinity will increase sharply, which not only increases the boiler swage discharge, wastes fuel, lower thermal efficiency, but also increases feed water capacity, influences steam quality greatly, even causes priming accident and boiler metal alkaline corrosion. So for raw water with high hardness and alkalinity, it is necessary to make softening and alkalinity reduction processes to achieve it at proper level.

4.5.2.2 Typical case of hydrogen-sodium ion exchange softening and alkalinity reduction processes

(1) Background

A chemical company in Northeast of China equips with 2 sets steam boiler systems with rated working pressure of 1.6MPa and evaporation of 35m^3/h, one of them works continuously 24 hours, the other is mainly standby. When it needs high flow rate, these two sets boiler systems will work simultaneously. It takes underground water as raw water, raw water quality test results: average hardness is 6.2mmol/L, average alkalinity is 5.9mmol/L. It belongs to high hardness and alkalinity water, so it needs to make softening and alkalinity reduction processes. In considering of variety aspects, decides to adopt hydrogen-sodium ion exchange to make softening and alkalinity reduction. In order to prevent scaling in boiler system, improve steam quality, lower swage discharge ratio, it requires the outlet water hardness <0.03 mmol/L, alkalinity $\leq$0.9mmol/L, swage discharge ratio no higher than 5% (boiler water evaporation no less than 20 times), boiler alkalinity need comply with GB/T 1576 “Water Quality for Industrial Boilers” (which means after boiler evaporation 20 times, the alkalinity $\leq$24.0 mmol/L).

(2) Project overview

In considering of raw water which takes from underground with high hardness and alkalinity, but also may contain sand and other impurity things, so it adopts disk prefilter to remove sediment to guarantee inlet water turbidity of ion exchanger less than 5NTU.

For hydrogen ion exchange resin, comparing to strong acidic H^+ resin, weak H^+ resin has advantages: high exchange capacity, no strong acid in outlet water, easy control for system outlet water quality, low acid consumption, low concentration of wasted acid, low cost of treatment of wasted acid, etc. The comparison of resin filled volume, acid consumption during regeneration for two types of resin as following:

a) Filled resin volume

In order to make H^+ exchanger and Na^+ exchanger exhausted and regeneration simultaneously, the percentage of H^+ exchange resin and Na^+ exchange resin is calculated based on the percentage of raw water carbonate hardness (which is raw water alkalinity) and non-carbonate hardness (which is difference value between total hardness and alkalinity in raw water) and remain alkalinity. It has already been tested raw water total hardness was 6.2mmol/L, alkalinity was 5.9mmol/L, so raw water carbonate hardness=alkalinity=5.9mmol/L, non-carbonate hardness=total hardness-alkalinity=6.2-5.9=0.3mmol/L, it requires system outlet water alkalinity ≤0.9 mmol/L after treated, so H^+ exchanger removes carbonate hardness of 5.9-0.9=5mmol/L, Na^+ exchanger removes hardness of 6.2-5=1.2mmol/L. The weak acid cation resin working exchange capacity is 1800 ~ 2000mol/m^3, strong acid cation resin capacity is 800 ~ 1200mol/m^3, boiler evaporation is 35m^3/h, in considering of loss of boiler swage discharge, boiler feed water takes 38m^3/h for calculation, working for 24 hours, one regeneration in 24 hours, can calculate weak acid H^+ exchanger filled resin volume $V_{weak\ H}$, strong acid H^+ exchanger filled resin volume $V_{strong\ H}$ and Na^+ exchanger filled resin volume V_{Na} as following:

$$V_{weak\ H} = \frac{Q \times YD \times k}{E} = \frac{38 \times 24 \times 5 \times 1.05}{1800} \approx 2.8m^3$$

$$V_{strong\ H} = \frac{Q \times YD \times k}{E} = \frac{38 \times 24 \times 5 \times 1.5}{1000} \approx 6.8m^3$$

In this formula: $V_{Na} = \frac{Q \times YD \times k}{E} = \frac{38 \times 24 \times 1.2 \times 1.45}{1000} \approx 1.6m^3$

Q——Exchanger water treatment capacity, one regeneration in 24 hours, m^3.

YD——Removed hardness, mmol/L.

k ——Security factor which is used for guarantee the outlet water hardness qualified, for weak acid H^+ exchange resin, takes 1~1.2, strong acid cation resin (includes H^+ exchanger and Na^+ exchanger), takes 1.2 ~ 1.8.

E——Resin working exchange capacity, mol/m^3.

From the calculation, as weak acid H^+ exchange resin exchange capacity is much higher than strong acid H^+ exchange resin, it only needs to fill 2.8m^3 of weak acid H^+ exchange resin, but if use strong acid H^+ exchange resin, it needs to fill 6.8m^3.

b) Calculation of H^+ exchanger acid consumption in one regeneration

Calculation of filled resin volume according to the above formula, for down-flow regeneration water softener, use weak acid H^+ exchange resin and strong acid H^+ exchange resin, the acid consumption for one regeneration is calculated as following:

$$m_{Z\ weak\ acid} = \frac{V_R \times E \times k \times M}{1000 \times \varepsilon} = \frac{2.8 \times 1800 \times 1 \times 36.5}{1000 \times 30\%} \approx 613kg$$

$$m_{Z\ strong\ acid} = \frac{V_R \times E \times k \times M}{1000 \times \varepsilon} = \frac{6.8 \times 1000 \times 2 \times 36.5}{1000 \times 30\%} \approx 1655\ kg$$

In this formula:

m_z——Strong acid quantity consumed in one regeneration, kg.

V_R ——Resin volume filled in resin tank, m^3.

E ——Resin working exchange capacity, for strong acid H^+ exchange resin, takes 1000mol/m^3 for calculation, for weak acid H^+ exchange resin, takes 1800mol/m^3.

k ——Regeneration reagent consumption ratio. For strong acid H^+ exchange resin, up-flow regeneration, it takes 1.2 ~ 1.8, down-flow regeneration, it takes 2 ~ 3.5. For weak acid H^+ exchange resin, it usually takes 1.0 ~ 1.1.

M——Molar mass of regeneration reagent, when uses acid to regenerate, HCl is 36.5.

ε——Purity of regeneration reagent. For industrial application, strong hydrochloric acid (HCl) purity is 30% ~ 33%.

From the calculation, even though the price of weak acid cation resin is higher than strong acid resin's, its filled resin volume and acid consumed are much less, and for regeneration acid concentration, weak acid resin concentration only needs 1.5% ~ 2%HCl, but for strong acid resin needs 3% ~ 4%HCl. So if use weak acid cation resin, the total cost of investment, regeneration and waste liquid treatment are much less, and less environmental pressure.

From analysis and comparison, this system adopts weak acid H^+ exchange resin to remove carbonate hardness, uses decarbonator to remove CO_2 which caused after carbonate hardness ion exchanged by H^+ exchanger, so as to reduce alkalinity. Then enter into Na^+ exchanger filled with strong acid cation resin to remove non-carbonate hardness and residual carbonate hardness. The treatment flow chart is: raw water→ raw water pump→ disk prefilter→ weak acid H^+ exchanger→ decarbonator→ decarbonate water tank→ middle water pump→ Na^+ exchanger→ soft water tank→ pump for feeding boiler→ enter into boiler. The waste acid of weak acid H^+ exchanger is drained to cesspit in chemical company and treated unified.

(3) System configuration

Based on above calculation, considering of exchanger backwash expansion height and resin tank specification, the designed hydrogen-sodium ion exchange softening and alkalinity reduction processes system is: H^+ exchange resin tank adopts two tanks, diameter is 1.5m, height is 2.4m, filled 2.8m^3 weak acid H^+ exchange resin. Na^+ exchange resin tank adopts two tanks, diameter is 1.2m, height I is 2.2m, filled 1.6m^3 Na^+ exchange resin. Equip a hydrochloric acid tank for regeneration of H^+ exchanger, a brine tank for regeneration of Na^+ exchanger, tank

diameter is 1.5m, height is 1.2m. Use Runxin 63640 meter type control valves which are acid corrosion resistance to set up two sets of double valves on double tanks H^+ exchanger system and Na^+ exchanger system, which can achieve one in service one standby or two in service in parallel (but regeneration separately), flow rate is up to $38m^3/h$ ~ $76m^3/h$.

As the outlet water of H-Na ion exchanger will be treated by Na^+ exchanger finally, there is not necessary to control the outlet water quality of weak acid H^+ exchanger strictly, as long as the hardness reduction in outlet water is similar to alkalinity in inlet water. The water quality is mainly controlled by the outlet water hardness of Na^+ exchanger as the end of service. So need to equip Runxin 44310 hardness online monitory device on outlet of Na^+ exchanger to monitor outlet hardness online. When outlet water hardness is higher than 0.03mmol/L, the device will send a warning signal to control the system automatically (only need people to retest regularly).

Two sets of weak acid H^+ exchangers and Na^+ exchangers adopt Runxin valves with interlock cable to make system having at least one set in service status to make sure there is always feeding qualified water for boiler system. Additionally, in order to reduce device energy consumption, guarantee feed water pressure, raw water pump and decarbonator pump use variable-frequency control.

System devices as Figure 4-14, 4-15:





Figure 4-14 Hydrogen-sodium ion exchange softening and alkalinity reduction system

Figure 4-15 Decarbonator and decarbonator water tank in hydrogen-sodium softening and alkalinity reduction system

(4) Running effectiveness

This hydrogen-sodium ion exchange softening and alkalinity reduction system has been used for one year, system running, regeneration and monitory can achieve automatically controlling. By retest of outlet water quality weekly, its outlet water hardness and alkalinity are all complying with requirement, boiler feeding water and quality meet national standard, boiler sewage discharge ratio and thermal efficiency meet energy saving requirement, steam quality is guaranteed, achieve customer's good feedback.

4.5.3 Application of softening system which controls outlet water hardness strictly

For some company, they require big quantity of soft water when manufacture their product, and needs to control water hardness strictly, or else it may affect their product quality, so they need to equip water softening system. Here are several typical cases.

4.5.3.1 Water softening treatment in wine making company

(1) Background

Water is not only a necessary raw material for making wine, but also water quality may influence wine quality greatly. For a wine making company, water turbidity and hardness have to meet quality management requirements to guarantee make good quality wine.

A Chinese wine making company, takes raw water from underground, average turbidity is 10NTU, average hardness is 8mmol/L. For water used wine making, it requires turbidity less than 1NTU, hardness less than 0.03mmol/L, flow rate is 200m^3/h.

(2) Project overview and system configuration

As raw water with high turbidity, before softening, it needs to reduce turbidity. It adopts multi-media filter to reduce raw water turbidity from higher than 10NTU to lower than 1NTU, then through sodium ion exchanger to soften water.

The flow rate of feeding water system requires 200m^3/h, single filter and softener can not achieve such high flow rate, so it designs 8 sets systems in parallel with 8 sets filters and 8 sets softeners, with interlock cable to achieve working simultaneously but regeneration separately, flow rate up to 200 ~ 250m^3/h.

Multi-media filter has three types of media, the top part media with smaller grain, the bottom part with bigger grain, to improve the filtering efficiency and outlet water quality. Filled media in each filter: porcelain sand with grain size of 2-3mm at bottom layer (take about 5% of total media volume), biological ceramsite with grain size of 1-2mm at middle layer (take about 35% of total media volume), biological ceramsite with grain size of 0.5-1mm at top layer (take about 60% of total media volume). Filter tank has the diameter of 1.5m, height of 2.4m. Filter media layer height is 1.5m, adopts Runxin 53540 automatic filter valve.

As raw water with high hardness, it adopts higher resin tank with filling more resin to guarantee outlet water hardness qualified. Resin tank diameter of each water softener is 1.5m, height is 2.4m, fill 2200L sodium resin, adopts Runxin 63640 automatic softener valve, brine tank diameter is 1.5m, height is 1.5m. Each one set of softener matched with one filter in series as a system, there are total eight sets systems, by interlock cable, automatic control to allow only one set system in regeneration, the other systems in service in parallel, even though this system is exhausted, but it will still work and wait until the other system finish the regeneration, then it starts to regenerate.

As the system regeneration frequently, considering it not convenient to fill salt in brine tank for such big system, so it uses a big salt dissolve pool, it can allow to fill one truck's salt for dissolving. By using regeneration pump to take measureable saturated brine to each brine tank, which can ensure the brine concentration and homogeneity, to achieve filling salt automatically and saving labor. Additionally, matches a soft water pool with 100m^3 for emergency used in case of system error.

The treatment flow chart is: raw water→ raw water pump feed water→ multi-media filter→ water softener→ soft water pool→ water for using. System device as Figure 4-16.



Figure 4-16 Eight sets of filtering-softening parallel water treatment systems

(3) Running effectiveness

After treated by multi-media filter, raw water turbidity is reduced from 10NTU to less than 1NTU. When the filter achieves the set service time or the pressure drop between inlet and outlet more than 0.05MPa, the system will start backwash automatically. Raw water hardness is 8mmol/L, after treated, water hardness is no higher than 0.03mmol/L. Since the system has been put into use in 2010, it works well all the time..

4.5.3.2 Water softening treatment for black carbon manufacturing

(1) Background

It needs a lot of soft water for making black carbon. A black carbon manufacturer in Shandong province in China, it requires water hardness for manufacturing ≤0.03 mmoI/L. Adopt deep well water as raw water, hardness is 5mmol/L, customer himself prepares 500m^3 half-ground water pool in reserve, softening flow rate is 60 ~ 80m^3/h.

(2) Project overview and system configuration

As raw water with high hardness, and flow rate requires 60 ~ 80m^3/h, it adopts several sets systems in parallel when designs. Uses 3 sets of φ1200×2400mm resin tanks, each tank filling

001×7 type resin 1500L, Runxin 63640 automatic softener valve is matched, through interlock cable, three tanks working in parallel and simultaneously, but regeneration separately.

In order to make convenient and save salt, it adopts concentrated salt dissolving and feeding brine (23-26% pure and saturated brine, it is fed by specific liquid vehicle regularly. There is a level automatic reminding warning light in brine storage tank, can be remotely monitored), equips a $10m^3$ PE brine storage tank (installed higher) to feed saturated brine to the brine tanks of three sets softeners automatically. Equips three pieces of brine tanks, installs a Runxin electronic ball valve of Q931015C-25 for each brine tank for brine refilling. When softener valve finishes regeneration, through signal controller, there is a signal sent by 63640 control valve, it can control to open the matched electronic ball valve to brine refill. When brine filled to set level, the ball valve will be shut down automatically. It can guarantee the brine concentration and regeneration salt consumed volume. Set the brine refill time of each 63640 softener valve to be 0 to remove brine refill process.

The treatment flow chart is: raw water storage pool→ raw water pump (one in service one standby, constant pressure and variety-frequency control) → softening parallel system (three tanks in parallel, working simultaneously, but regeneration separately) → electronic valve→ soft water tank. Softening system includes exchange tank (three sets), control valve (three sets), brine tank (three sets), brine storage tank (three sets are used in combination) and pipelines, etc. The practical devices refer to Figure 4-17.



Figure 4-17 Installation diagram of softening system

(3) Running effectiveness

By using interlock function and internal dry contact signal of 63640 control valve, it achieves

three sets of water softeners regeneration interlocked (three valves working simultaneously, but regeneration separately). When three sets are all in service, flow rate is more than 90m^3/h. When one of them in regeneration, the other two sets flow rate is 60m^3/h. The outlet water hardness is qualified and meets manufacturing demand. The system has been put into use since 2015 and working well.

4.5.4 Application of softening system which does not control outlet water hardness strictly

Using high hardness water, it may influence manufacturing and daily life greatly. So it still need to soften water, but no need to control hardness strictly, only need to reduce hardness to a certain level. GB/T 18300 "Specification for Automatic Control Sodium Ion Exchange" states automatic softener service flow rate is 20m/h ~ 30m/h, because if service flow rate is high, the ion exchange may not be sufficient which results in outlet water hardness disqualified. It is mainly for boiler system or other application which requires to control outlet water hardness strictly. But for the application which no need strictly control hardness, it can increase service flow rate properly. Under the condition that outlet water hardness met demand, it can equip a smaller resin tank to reduce cost. Here are several softening treatment cases for reference.

4.5.4.1 Water for cleaning airfield runway

(1) Background

If there is any oil dirty thing on airfield runway, it may cause airplane wheel accident, exceed the meter set range. So when monitory on airfield runway detects the data out of standard, it needs to do pressure spray wash timely. It also needs to add medicine in cleaning water, if there is hardness, it will lower the medicine effect and increase the quantity of medicine, and there is sediment to block pipeline and sprayer. So it needs to use soft water for cleaning airfield runway. Additionally, it usually freezes in snow time in winter, the oil thing in ice becomes the biggest barrier when cleaning, so it usually uses 60℃ warm soft water for better cleaning.

Softening treatment system in a airfield runway in North of China, raw water from underground, average hardness is 6.8mmol/L, it adopts towerless variety-frequency for water supply, it requires outlet water hardness less than 0.6mmol/L, flow rate is 100m^3/h.

(2) Project overview and system configuration

Considering of cleaning airfield runway, it needs to clean quickly and cleanly, consumes big quantity of water, and non-fixed time for cleaning, so softening system adopts four sets of water softeners, Runxin 63640 automatic softener valves is matched, by interlock cable to achieve working simultaneous, but regeneration separately. Each softener equips resin tank with diameter of 1.5m, height of 2.4m, filling 001×7 sodium exchange resin 2.5 m^3, uses brine tank with diameter of 1.5m, height of 1.5m. System flow rate is 70m^3/h ~ 100m^3/h.

The treatment flow chart is: raw water→ towerless variety-frequency for water supply→ softening system→ plate type glass fibre reinforced plastic water tank→ water for spray cleaning. Device configuration refers to Figure 4-19.



Figure 4-19 Four sets interlocked water softeners working in parallel

(3) Running effectiveness

The system outlet water hardness is less than 0.6mmol/L which can meet demand for airfield runway cleaning. The system has been put into use since 2012 and working well.

4.5.4.2 Softening water treated for baby indoor swimming pool

(1) Background

Baby swimming in warm water can help to improve blood circulation, increase vital capacity, raise immune system, etc. Currently there are many baby indoor swimming pools, baby SPA established in each city, which is specially used for 0 ~ 12 months baby swimming, bathing and touching. As baby's skin is very sensitive, the water has to been softened.

A baby swimming pool used city water as raw water, hardness is 5.5mmol/L, it requires the outlet water hardness after treated less than 0.6mmol/L, flow rate more than 15m^3/h.

(2) Project overview and system configuration

Softening water system adopts two sets of water softeners, each resin tank with diameter of 0.9m, height of 2m, each tank filling 001×7 sodium exchange resin 750L, uses brine tank with diameter of 0.9m, height of 1.2m, uses Runxin 63618 automatic softener valve to achieve double valves on double tanks system, by interlock cable to realize working simultaneously, but regeneration separately, flow rate is 15 ~ 20m^3/h. Considering of high flow rate instantaneous, equips with food grade 304 stainless steel soft water tank to make sure no water interruption during operation time. Softening system and device refer to Figure 4-20.

Softening treatment flow chart is: raw water→ booster pump→ water softener→ 304 SS soft water tank→ swimming pool pipeline.

(3) Running effectiveness

The system has been put into use since 2017. System outlet water hardness is less than 0.6mmol/L which meet the demand for baby swimming. The system has been working well.



Figure 4-20 Softening system for baby indoor swimming pool

4.5.4.3 Softening water treatment for laundry industry

(1) Background

There are big quantities of bed sheet, quilt cover, towel, tablecloth, clothing need to be cleaned in hotel. If use high hardness water for laundry, the calcium and magnesium ions will react with detergent, which not only reduce cleaning effect, increase detergent consumed amount, but also the sediment will diffuse into fiber to make it stiff and oxidized, which will form yellow “stain”. If use soft water for cleaning, even though use the common detergent, it can also make clothing soft and non-discolouring. So laundry place of enterprises and hotels need to use soft water for laundry.

A laundry company in Shandong province in China, specifically makes laundry for customer's clothing in hotel. Raw water uses well water, which is muddy and with some big grain sediment, average hardness is 16mmol/L. It requires outlet water after filtered and softened, the flow rate more than $4m^3/h$, hardness $<$ 1mmol/L.

(2) Project overview and system configuration

As it is using well water with sediment, if sediment is not removed, it will pollute resin and block strainers, and may destroy the sealing surface of control valve, so it needs to use filter to remove sediment and reduce turbidity. It designs to adopt quartz sand + anthracite double media filter + ultrafilter with 5 cores 40inch filter element and accuracy of 5 microns, flow rate is $7.5m^3/h$.

As the raw water hardness up to 16mmol/L, the common single fixed bed softener can not remove such high hardness to meet the demand. So it adopts floating bed softener, by increasing resin layer to improve softening effectiveness and flow rate. So it equips two sets of floating bed resin tanks (diameter of 0.5m, height of 1.8m), inlet water goes through ultrafilter first, so there is no need backwash in softening regeneration. The resin is filled up to 8cm lower than top strainer, uses Runxin 17606 one valve on double tanks control valve for floating bed system, one in service one standby, outlet water flow rate is $4m^3/h$ ~ $6m^3/h$.

The treatment flow chart is: raw water→ raw water pump→ double media filter and ultrafilter→ floating bed softener→ soft water pool→ water for using.

The device configuration refers to Figure 4-21.



Figure 4-21 One in service one standby floating bed softener

(3) Running effectiveness

Raw water after filtered by double media filter and ultrafilter, removed sediment and other impurity things, so the turbidity is less than 2NTU, then enter into floating bed system for softening, which can reduce the pollution for resin greatly. In this way, even no backwash, the floating bed system still can service normally. It adopts the height increased resin tank, and resin filled up to 8cm lower than top strainer to increase resin layer height, even though raw water hardness is 16mmol/L, but the treated water hardness complies with demand. The system has been put into use since 2017 and working well.

4.5.4.4 Softening water treatment for seafood processing

(1) Background

There is requirement for water used for seafood processing. The water hardness may influence seafood quality and taste. A seafood company in Dalian, they require the water hardness

used for processing edible seaweed to be controlled about 2.8mmol/L. It adopts underground water as raw water, average hardness is 8.9mmol/L, turbidity less than 5NTU, minimal flow rate is $6m^3/h$.

(2) Project overview and system configuration

As water hardness should be controlled around 2.8mmol/L, underground water hardness is 8.9mmol/L, the outlet water hardness for softener is low, it is getting larger when reaching resin exhausted, so it is hard to control the hardness to be 2.8mmol/L. It adopts partial softening treatment which equips a softener to soften part of water to a certain hardness, then mix the softened water with raw water in a certain percentage to make the outlet water hardness at (2.8±0.2)mmol/L for using.

Softener resin tank with diameter of 0.6m, height of 1.9m, filled 350L resin, uses Runxin 63610 automatic softener valve. After adjusting, softener flow rate is $5m^3/h$, outlet water hardness is 0.1mmol/L ~ 0.3mmol/L, mix with $2.2m^3/h$ of raw water which hardness is 8.9mmol/L, it can make the final outlet water hardness at (2.8±0.2)mmol/L.

The treatment flow chart is: raw water→ raw water pump (variety-frequency control) → water softener→ soft water tank (mix with some raw water in a certain percentage) → water for using. The pipeline system for filling raw water to the soft water tank is equipped with a Runxin electronic ball valve with flow control, which can automatically control raw water mixing when softener in service, during softener in regeneration, ball valve stops filling raw water to the soft water tank automatically.

(3) Running effectiveness

The system has been put into use since 2014 and working well. It can provide water which meet demand.

5. Application of Runxin valve in demineralization water treatment

The purpose of demineralization water treatment is to remove various mineral salts from water to produce the pure water or ultra-pure water. Demineralization water treatment is widely used in boiler feed water treatment of medium pressure and above, electronics industry, pharmaceutical industry, purified water industry, cosmetics production and beauty industry, and production of testing water in laboratory of various industries, etc.

The current methods of demineralization water treatment mainly include: ion exchange primary demineralization treatment (making pure water), primary demineralization treatment + mixed bed (making ultra-pure water), reverse osmosis (RO) + mixed bed, reverse osmosis +electrodeionization (EDI) whole membrane treatment, etc. Among them, ion exchange demineralization treatment is using cation and anion resins to remove mineral salts through ion exchange reaction, which belongs to chemical demineralization. Reverse osmosis and electrodeionization whole membrane treatment are based on physical demineralization, which has rapidly developed in recent years.

5.1 Ion exchange demineralization treatment

The process of ion exchange demineralization is to use H^+ type cation resin to exchange various cations in water to H^+, and OH^- type anion resin is used to exchange various anions in water to OH^-. Then H^+ and OH^- combine to form H_2O. After such an exchange treatment, almost all the salts in the water can be removed, so it is called ion exchange demineralization treatment or chemical demineralization treatment.

5.1.1 Principle of ion exchange demineralization

When water passes through the H^+ type resin in the cation exchanger (hereinafter referred to as the cation bed), various cations in the water are exchanged by the H^+ in the resin and then remain on the resin, and H^+ goes to the water. For example, R represents the resin, and its ion exchange reaction can be comprehensively expressed by the following formula:

$$2RH + \begin{matrix} Ca \\ Mg \\ Na_2 \end{matrix}\Bigg\}\begin{matrix} Cl_2 \\ SO_4 \\ (HCO_3)_2 \\ (HSiO_3)_2 \end{matrix} \rightarrow R_2\Bigg\{\begin{matrix} Ca \\ Mg \\ Na_2 \end{matrix} + \begin{matrix} 2HCl \\ H_2SO_4 \\ 2H_2CO_3 \\ 2H_2SiO_3 \end{matrix}$$

H type resin Inlet water of cation bed Invalid resin Outlet water of cation bed

From the above reaction, it can be seen that the outlet water of cation bed contains strong acids such as H_2SO_4 and HCl, corresponding to the anions in the inlet water, as well as weak acids such as H_2CO_3 and H_2SiO_3, so it is acidic. Among them, H_2CO_3 becomes CO_2 in acidic water, which is removed by the decarbonator, and then enters the anion exchanger (hereinafter referred to as the anion bed). At this time, various anions in the water are exchanged and absorbed

by the OH^- resin, and the OH^- on the resin is replaced into the water and combined with H^+ in the water to form H_2O. The exchange reaction can be represented by the following formula:

$$2ROH + \begin{cases} 2HCl \\ H_2SO_4 \\ 2H_2CO_3 \\ 2H_2SiO_3 \end{cases} \rightarrow R_2 \begin{cases} Cl_2 \\ SO_4 \\ (HCO_3)_2 \\ (HSiO_3)_2 \end{cases} + 2H_2O$$

OH type resin Inlet water of anion bed Invalid resin Outlet water of anion bed

For the demineralization water treated by the primary demineralization system, various anions and cations are basically removed, and only a small amount of sodium ions and silicon dioxide remain in the water (usually controlled below 100μg/L). The conductivity of the outlet water can reach 5μS/cm or less, which can meet the needs of boiler feed water in thermal power plants (below high pressure), and the requirements of general industries for pure water. For the high-pressure (and above) boilers or electronic industries that have high requirement, they need ultra-pure water (conductivity $\leqslant$ 0.2μS/cm; $SiO_2 \leqslant$ 20μg/L). The mixed bed treatment needs to be added after the primary demineralization treatment to further remove the residual anions and cations in the water.

5.1.2 Common ion exchange demineralization system

5.1.2.1 Primary composite bed demineralization system

Among the ion exchange demineralization treatment systems, the simplest one is the primary composite bed demineralization system. As shown in Figure 5-1, the form in which the H type and OH type resins are filled in two exchangers is called a composite bed. It is customary to call the cation bed for the exchanger equipped with H type resin; the exchanger equipped with OH type resin is called the anion bed; the exchanger that mixes H type resin and OH type resin together is called a mixed bed.

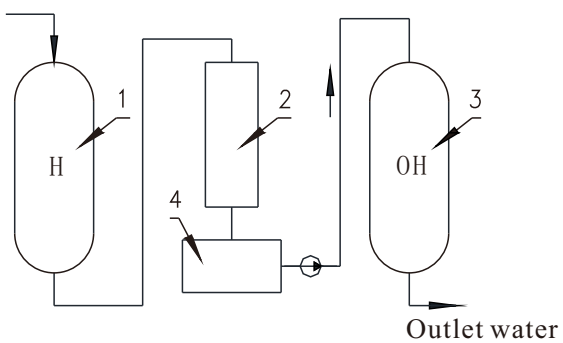


Figure 5-1 Primary composite bed demineralization system

1-Strong acid H type exchanger 2-Decarbonator 3-Strong base OH exchanger 4-Middle water tank

In ion-exchange demineralization systems, the cation bed is usually first and the anion bed is second. This order can usually not be reversed. The main reasons are as follows:

(1) If anion bed is first, after calcium, magnesium, iron and other salt substances in water are

exchanged by OH type anion resin, $Mg(OH)_2$, $Ca(OH)_2$, $Fe(OH)_3$ and other sediment will be precipitated during service and adhere to the resin surface, blocking and polluting the resin, so that the exchange reaction can't proceed normally.

(2) When cation bed is first, the acidic water after cation exchange enters the anion bed, H^+ can neutralize with OH^- immediately, which is beneficial to the dissociation of the basic groups of the anion resin, can increase the exchange capacity of the anion resin, and be good for anion exchange reaction.

(3) Silicon removal is one of the difficulties in the demineralization treatment. If the Na^+ in the water is not removed, the removal of silicon will be more difficult and will accelerate the invalidation of the anion bed.

(4) The chemical stability and anti-pollution ability of the cation resin is better than anion resin, and the price is much cheaper than the anion resin. The cation bed can protect the anion resin when it is in first.

In the primary composite bed demineralization system, the cation bed is filled with strong acid cation exchange resin, and the anion bed is filled with strong base anion exchange resin. For the demineralization treatment of raw water with high salt content, a weak type exchanger can be installed before the strong exchanger, because the weak type resin is featured with large exchange capacity and easy regeneration. However, because the weak cation exchange resin has a weak ability to exchange sodium ions, and the weak anion resin has a weak ability to exchange carbonates, and can hardly remove silicon, it is necessary to set up a strong bed after the weak bed to remove sodium ions and silicon dioxide in the water.

Usually, the cation exchange resin is regenerated with hydrochloric acid after invalidation, and the anion exchange resin is regenerated with sodium hydroxide after invalidation. In order to facilitate the neutralization treatment of the waste liquid, it is advisable to design the anion and cation exchanger and resin to be invalid simultaneously and regenerate at the same time. Since the exchange capacity of anion exchange resin is usually much smaller than that of cation exchange resin (see Table 5-1), the configuration of the anion bed should usually be larger than the cation bed, or the anion exchanger should be set as a combination of weak anion bed and strong anion bed.

In addition, ion exchange resins often get deteriorated and polluted due to the influence of oxidizing substances (such as free residual chlorine) and heavy metal ions (such as Fe^{3+}) in the water. It has proved that when the feed water contains 0.5mg/L free residual chlorine (Cl_2), the resin will be significantly deteriorated after only 4-6 months of service. Deteriorated resin is featured with lighter color, larger volume and decreased exchange capacity. If the raw water with high Fe^{3+}content, or with poor anti-corrosion measures of the ion exchange system and pipeline, it is easy to lead resin be "poisoned", which will cause the exchange capacity to drop

sharply. At this time, even if 10% HCl is used for regeneration capacity recovery of resin, it can only get a temporary improvement. After a few cycles of service, the exchange capacity will drop sharply. Therefore, when using ion exchange demineralization treatment, special attention should be paid to the equipment and piping system that must have good anti-corrosion measures.

Table 5-1 Exchange capacity of several commonly used ion exchange resins

Resin Model	Type	Total exchange capacity mmol/g	Working exchange capacity mol/m^3	Ionic form	Main application
001×7	Strong acid cation resin	≥4.2	1100～1500	Na^+	Hard water softening, cation removal in demineralization treatment, wastewater treatment
D001	Macroporous strong acid cation resin	≥4.0	1100～1400	Na^+	
111	Weak acid cation resin	≥12.0	2000～2500	H^+	Hard water softening, cation removal in demineralization treatment
D111	Macroporous weak acid cation resin	≥9.0	1800～2200	H^+	Water treatment, wastewater treatment of electroplating containing nickel and copper
201×4	Strong base type I anion resin	≥3.5	350～450	Cl^-	Anion removal in demineralization treatment
D201	Macroporous strong base type I anion resin	≥3.0	450～500	Cl^-	Anion removal in demineralization treatment
303×2	Weak base anion resin	≥5.0	800～1000	Cl^-	Anion removal in demineralization treatment
D301	Macroporous weak base anion resin	≥4.0	1000～1200	Free amine	Anion removal in demineralization treatment
D311	Macroreticular weak base anion resin	≥6.5		Free amine	Demineralization treatment, brackish water desalination

5.1.2.2 Selection of ion exchange resin

The selective sequence of anion and cation exchange resins is generally as follows:

(1) The selectivity sequence of strong acid cation exchange resin for common cations is:

$$Fe^{3+} > Al^{3+} > Ca^{2+} > Mg^{2+} > K^+ \approx NH_4^+ > Na^+ > H^+$$

(2) The selectivity sequence of weak acid cation exchange resin for common cations is:

$$H^+ > Fe^{3+} > Al^{3+} > Ca^{2+} > Mg^{2+} > K^+ \approx NH_4^+ > Na^+$$

(3) The selectivity sequence of strong base anion exchange resin for common anions is:

$$SO_4^{2-} > NO_3^- > Cl^- > OH^- > HCO_3^- > HSiO_3^-$$

(4) The selectivity sequence of weak base anion exchange resin for common anions is:

$$OH^- > SO_4^{2-} > NO_3^- > Cl^- > HCO_3^-$$

It can be seen from the above rule that the strong acid cation exchange resin H^+ ranks last, indicating that it is not easy to regenerate, and the concentration of regenerant needs to be increased to allow the resin to be effectively regenerated; The H^+ of the weakly acid cation exchange resin and the OH^- of the weak base anion exchange resin are ranked first, indicating that the weak resin is easy to regenerate; However, the ability of weak acid cation resin to exchange Na^+ is weak, and the ability of weak base anion resin to exchange HCO_3^- is very weak, and it cannot exchange $HSiO_3^-$. It can be seen that setting a weak resin can reduce the consumption of the regenerant, but if users want to remove Na^+ and $HSiO_3^-$ in the water, users must use strong acid cation exchange resin and strong base anion exchange resin. In addition, it can be seen that Na^+ and $HSiO_3^-$ are always exchanged last. Therefore, for H^+ exchange resins, the Na^+ presented at the outlet water is usually considered as the end of the cation bed service control, while for strongly base OH^- exchange resins, the $HSiO_3^-$ presented at the outlet water is considered as the end of the anion bed service control.

5.1.2.3 Various common ion exchange demineralization systems

In addition to the simple primary composite bed demineralization system, it also can make up a suitable demineralization system by configuring different ion exchange equipment and resins according to the raw water quality and the requirements for the quality of the feed water to achieve the required demineralization effect and good economy. Besides, in order to avoid the pollution of suspended solids, colloidal substances, organic matter, free residual chlorine, etc., and to ensure the service life of the ion exchange resin, it is usually necessary to install a quartz sand (or fiber, multi-media) filter and an activated carbon filter before the ion exchanger. The configuration and applicability of common ion exchange demineralization systems is shown as below:

(1) Quartz sand (or fiber) filter→Activated carbon filter→Strong cation bed→Decarbonator (middle water tank)→Strong anion bed →Water tank of primary demineralization.

This simplest primary demineralization system is suitable for raw water with low alkalinity, salinity and silicon content, as well as treatments that do not require high quality of demineralized water.

(2) Quartz sand (or fiber) filte→Activated carbon filter→Strong cation bed→Decarbonator (middle water tank)→Weak anion bed→Strong anion bed→Water tank of primary demineralization.

The system connects a weak anion bed in series before the strong anion bed, which is suitable for raw water with high salt or silicon content but with low alkalinity. It mainly takes

advantage of the large exchange capacity and easy regeneration of the weak anion resin. The weak anion resin removes most of the strong acid anions in the water during service, which can significantly promote the strong anion resin to better remove silicate ions and ensure that the silicon content of the treated water is qualified. During regeneration, only a low concentration of base solution is required to make the weak anion resin better regenerated. Therefore, the addition of a weak anion bed in the system cannot only ensure the quality of the outlet water (especially the quality of silicon removal), but also improve the cost-performance of system operation.

(3) Quartz sand (or fiber) filter→Activated carbon filter→Weak cation bed→Strong cation bed→Decarbonator (middle water tank)→Strong anion bed →Water tank of primary demineralization.

The system is equipped with a weak cation bed before the strong cation bed, which is suitable for raw water with high carbonate hardness and alkalinity but with low silicon content. It also mainly utilizes the characteristics of large exchange capacity of weak cation resin and easy regeneration. The weak acid cation exchange resin is used to remove carbonate cations, and the regeneration waste liquid discharges from the strong cation bed is used to regenerate the weak acid cation exchange resin, reducing the consumption of regeneration acid.

(4) Quartz sand (or fiber) filter→Activated carbon filter→Weak cation bed→Strong cation bed →Decarbonator (middle water tank)→Weak anion bed→Strong anion bed→Water tank of primary demineralization.

This system is suitable for the raw water with high alkalinity and salt content. It is equipped with weak acid cation exchange resin and weak base anion exchange resin, which can improve ion exchange demineralization capacity and reduce the consumption of regenerant.

(5) Quartz sand (or fiber) filter→Activated carbon filter→Strong cation bed→Decarbonator (middle water tank)→Strong anion bed→Water tank of primary demineralization→Mixed bed →Water tank of secondary demineralization.

This system is suitable for demineralization treatment that requires high water quality (outlet water conductivity $\leqslant 0.2\mu s/cm$)

(6) Quartz sand (or fiber) filter→Activated carbon filter→Weak cation bed→Strong cation bed→Decarbonator (middle water tank)→Weak anion bed→Strong anion bed→Water tank of primary demineralization→Mixed bed→Water tank of secondary demineralization.

This system is suitable for demineralization treatment that treats raw water with high alkalinity, salinity and silicon content, and has high requirements for desalinated water quality. However, at present, reverse osmosis + mixed bed treatment is more adopted for treating this kind raw water.

5.1.2.4 Two-bed and double-chamber bed

In some demineralization systems, weak acid cation resin and strong acid cation resin, or weak base anion resin and strong base anion resin are filled in the same exchanger, that is, two-bed or double-chamber bed exchanger. The two-bed exchanger utilizes the lower density of weak acid (or weak base) than strong acid (or strong base) resin, so that the weak resin is on top of the strong resin, and the water pass through from top to bottom during service. So, the weak resin is exchanged first, and then strong resin. When regenerating, the regeneration solution flows from bottom to top, regenerating the strong resin first, and then regenerating the weak resin. The double-chamber exchanger is divided into upper and lower chambers by porous partitions in the exchanger, and the weak resin and the strong resin are separately filled to form a double-chamber bed or a double-chamber floating bed (strong resin is in the upper chamber, the weak resin is in the lower chamber. Water flows from bottom to top during service, and the regeneration solution flows from top to bottom during regeneration).

The advantages of two-bed and double-chamber bed: without additional equipment, it can take advantage of the large exchange capacity and easy regeneration of the weak resin and achieve the effect of improving the efficiency of the exchanger and reducing the consumption of regenerant. Especially for the two-bed cation exchanger, it has obvious advantages.

For two-bed and double-chamber bed anion exchanger, although they have the above advantages, they also have obvious disadvantages, which are easy to cause colloidal silicon pollution of the resin. This is because when the strong anion resin and the weak anion resin are regenerated in the same exchanger, the regeneration waste liquid discharges from the strong anion resin contains higher silicon compounds. When it flows through the weak anion resin, the weak anion resin is easy to adsorb OH^- which will reduce the pH value in the regeneration solution. So that it is easy for the silicon compound to form colloidal silicic acid and precipitate in the resin. Especially when the temperature is low, it is easy to make cleaning difficult after regeneration. And because the resin is polluted by colloidal silicon, the silicon content of the outlet water will be too high, which affects the quality of demineralized water and the water treatment capacity. In order to prevent colloidal silicon pollution, the following measures can be taken:

a) Step-by-step regeneration: firstly use 1% NaOH regeneration solution to regenerate the resin at a faster flow velocity, so that the resin is initially regenerated. At this time, the amount of silicic acid exchanged is not much, but the weak anion resin can be initially regenerated and the resin layer is alkaline. Then use 3% ~ 4% NaOH to regenerate at a lower flow velocity, so as to avoid the sediment of colloidal silicic acid due to the decrease of pH value.

b) Properly increase the temperature of the regeneration solution. The temperature of the NaOH regeneration solution can be increased to about 50℃ by adding a heater or making the regeneration solution with condensed water to improve the regeneration effect.

5.1.3 Decarbonator

5.1.3.1 Purpose of installing the decarbonator

In the demineralization system, a decarbonator is generally installed after the cation bed. After the raw water is exchanged with H^+, the carbonate in the water is basically converted into carbonic acid, and is easily decomposed into water and carbon dioxide. When the pH value of the water is lower than 4.3, almost all the carbonic acid compounds in the water exist in the form of free CO_2, which can be easily removed by a decarbonator.

The purposes of installing the decarbonator are: on the one hand, as carbonic acid in acidic water basically exists as CO_2, it can be removed by a decarbonator; on the other hand, the removal of CO_2 can relieve the burdens of anion bed and improve the silicon removal effect. If there is no decarbonator or the carbon removal effect is poor, the CO_2 in the water will be converted into HCO_3^- after entering the anion bed, which needs to be removed by the anion exchange resin. It not only affects the effect of the anion resin for removing silicon, but also decrease the water treatment capacity, increases the consumption of the reagenerant and reduces the outlet water quality. Therefore, in order to ensure that the decarbonator can achieve a good decarbonization effect, the CO_2 measurement of the intermediate water tank should be carried out regularly, the decarbonator should be regularly maintained, and the invalid media should be replaced in time.

5.1.3.2 Decarbonator and working principle

The free CO_2 in water can be regarded as a gas dissolved in water, and its solubility in water conforms to the law of gas dissolution (that is, the amount of gas that is dissolved in water is directly proportional to the partial pressure of that gas above the water). Therefore, the free CO_2 in the water can be removed, as long as the partial pressure of CO_2 in the gas on the water surface is reduced,. The decarbonator is designed according to this principle.

In various ion exchange water treatment systems, the most commonly used decarbonator is the air-blowing decarbonator. Its structure is shown in Figure 5-2.

The working principle of the air-blowing decarbonator is: the CO_2 dissolved in the water is in contact with the air that is blown in the reverse direction. Because the CO_2 content in the air is very small (about 0.03% of the atmospheric pressure), according to the law of gas dissolution, the CO_2 will continue to escape until its partial pressure is balanced. Through the air-blowing decarbonator, the CO_2 content in the water can generally be reduced to less than 5mg/L.

The air-blowing decarbonator is a cylindrical device, and the cylinder is usually made of metal or plastic. If made of metal, anti-corrosion measures should be taken on the inner surface. The packing filled in the cylinder is generally: porcelain ring, stainless steel Ω ring or honeycomb grid, etc. During service, water pass through from the upper part of the column, sprinkle through the water distribution device, flows through the packing layer, and enters the intermediate water

tank from the lower part. The function of the air-blowing decarbonator is to continuously feed in fresh air from the lower part, while continuously releasing the air containing CO_2 from the upper part. The function of the filler is to disperse the water flow, so that the blown air and water have a very large contact surface area, and CO_2 can easily escape from the water and be taken away immediately.

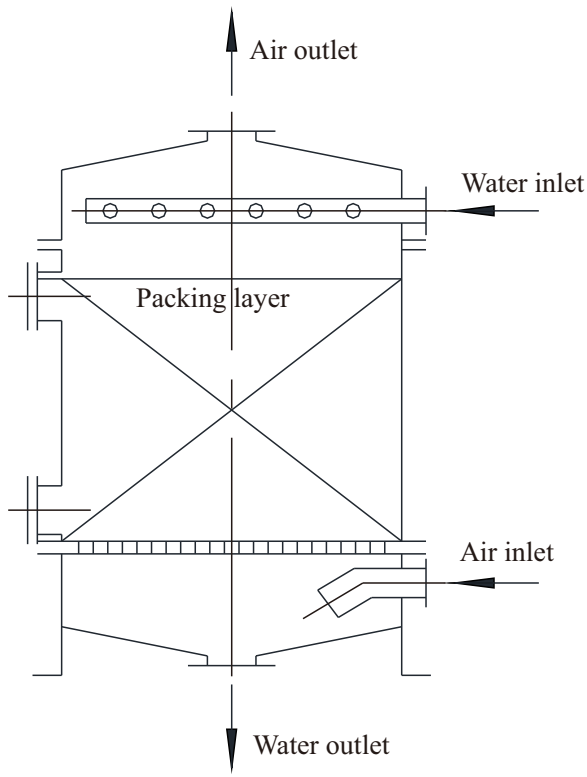


Figure 5-1 Structure of air-blowing decarbonator

5.1.3.3 Factors affecting the carbon dioxide removal effect of the decarbonator

The main factors that affect the CO_2 removal effect of the decarbonator are as follows:

a) pH value: When the temperature is constant, the relative amount of various carbonic acid compounds in the water is related to the pH value. The lower the pH value, the easier the carbonic acid compounds exist in the form of free CO_2, which is more beneficial for CO_2 removal.

b) Temperature: the higher the temperature is, the lower the solubility of CO_2 in water is, and the better the CO_2 removal effect can realize.

c) Device structure: in the air-blowing decarbonator, the larger the contact area of water and air and the longer the contact time, the better the CO_2 removal effect.

5.1.4 Service of the primary demineralization system

5.1.4.1 Service control of cation exchanger (cation bed)

The selective sequence of cation exchange resins for cations shows that when water containing Ca^{2+}, Mg^{2+}, Na^{+} ions passes through the cation bed, the H ion exchange resin will first exchange and adsorb Ca^{2+}, followed by Mg^{2+}, and then exchange and adsorb Na^{+}. In addition, the continue entering Ca^{2+} and Mg^{2+} will also replace the Na^{+} that has been absorbed by the resin. Therefore, when the entire bed is close to invalid, the Na^{+} content in the outlet water of the cation bed increases first (when the Na^{+} content in the outlet water exceeds the limit, it is called sodium leakage). For this reason, the Na^{+} content of the outlet water is usually measured to control the end of the service of the strong acid cation exchanger. In order to remove the salts in the water, when there is a leakage of Na^{+} , the strong cation bed should stop service and start regeneration.

(1) Service of weak acid cation exchanger (weak cation bed)

Weak acid cation exchange resins generally can only remove carbonate hardness, and are difficult to exchange with other salt cations. If RL represents weak acid cation exchange resin, the exchange reaction in the weak cation bed can be expressed as follows:

$$2R_LH + \begin{cases} Ca(HCO_3)_2 \\ Mg(HCO_3)_2 \end{cases} \rightarrow R_{L2} \begin{cases} Ca \\ Mg \end{cases} + 2CO_2 + 2H_2O$$

Usually, the weak cation bed and the strong cation bed service in series and regenerate simultaneously. Therefore, there is no need to strictly control the outlet water quality of the weak cation bed. But by measuring the conductivity and acidity of the outlet water of the weak cation bed, the salt content of the outlet water of the strong cation bed can be judged, and the water treatment capacity and working exchange capacity can be estimated.

Since the weak acid cation exchange resin is very easy to regenerate, the strong cation bed and weak cation bed are usually connected in series to regenerate. That is, after regeneration solution discharged from the strong cation bed, it continues to flow into the weak cation bed to regenerate the weak cation resin. This can reduce the consumption of regenerant, reduce the discharge of regeneration waste liquid, reduce the cost of sewage treatment, and relieve the pressure on environmental protection.

(2) Service of strong acid cation exchanger (strong cation bed)

After the water is treated with strong acid H^{+} exchange, Ca^{2+} and Mg^{2+} are completely removed, Na^{+} is basically removed, and almost all cations in the water are replaced by H^{+}, so the cation bed outlet water is acidic. In normal service, the acidity of the outlet water of cation bed is related to the salt content of the inlet water. Generally, the higher the salt content of the raw water, the greater the acidity of the outlet water and the greater the conductivity; If the salt content of the inlet water is stable, the acidity and conductivity of the outlet water will also remain stable. Until the strong cation bed starts to leak sodium, the exchanger will be invalidated and the acidity and conductivity of the outlet water decreases accordingly. Therefore, when the

quality of the raw water is stable and the conductivity of the inlet water of the exchanger does not change much, it can be initially judged whether the cation bed is invalid according to the conductivity of the outlet water or the acidity of the outlet water, which is beneficial for the automatic controller to start regeneration by monitoring the conductivity online. However, if the salt content (conductivity) of the inlet water fluctuates greatly, it is difficult to accurately judge whether the cation bed is really invalid based on the changes in the conductivity and acidity of the outlet water. Because the conductivity and acidity of the cation bed outlet water will change with the salt content of the inlet water, and it can't accurately reflect the residual amount of salt cations in the water. Therefore, in the case of frequent changes in the conductivity of the inlet water, it is necessary to measure the Na^+ content of the outlet water to judge the invalidation degree of the cation bed. For the primary composite bed demineralization system, the end point of the strong cation bed is generally controlled as: $Na^+ \leqslant 100\mu g/L$ (if measured with a pNa meter, it should be controlled to be $pNa \geqslant 5.36$)

5.1.4.2 Service control of anion exchanger (anion bed)

According to the selective sequence of anion exchange resins for anions, weak base anion exchange resins and strong base anion exchange resins have strong exchange and adsorption capacity for strong acid radical anions, while their adsorption capacity for weak acid anions (such as HCO_3^-) is relatively weak, and the worst absorption capacity is for $HSiO_3^-$. Especially when the water contains a lot of NaOH, the effect of removing silicon is often incomplete, and the weak base anion resin can hardly remove silicon. Therefore, in the primary demineralization system, the anion exchanger is usually arranged after the strong acid H type cation exchanger and the decarbonator. This is not only because the removal of HCO_3^- can relieve the burden on the anion bed, but also the H^+ in the water can immediately neutralize the OH^- produced by the anion exchange, which can improve the ionization ability of the active group in the anion exchange resin and is beneficial to the removal of silicon.

(1) Service of weak base anion exchanger (weak anion bed)

Weak base anion exchange resin has strong exchange capacity for SO_4^{2-}, NO_3^-, Cl^- and other strong acid group anion, and has the advantages of large exchange capacity and easy regeneration. However, it has weak exchange capacity for weak acid group anion HCO_3^-. For the weaker acid group anion $HSiO_3^-$, it cannot be exchanged. The exchange sorption process can only be carried out in acidic solution. Therefore, the weak anion bed should be installed after the strong cation bed and the decarbonator, and a strong anion bed must be installed after it.

When the weak anion bed and the strong anion bed service in series and regenerate at the same time, it is mainly to control the outlet water quality of the strong anion bed. Generally, the outlet water quality of the weak anion bed does not need to be strictly controlled. The conductivity and Cl^- of the weak anion bed are usually measured for judging the invalidation

degree of weak anion resin, predicting the water treatment capacity of strong anion bed, and estimating the resin's working exchange capacity. When the weak anion bed and the strong anion bed are regenerated separately, the weak anion bed should monitor and control the Cl^- in the outlet water. When the Cl^- content increases, the weak anion bed should start regeneration.

(2) Service of strong base anion exchanger (strong anion bed)

In the operation of the primary demineralization system, when the anion bed and the cation bed invalidate at the same time, the pH value of the outlet water from the anion bed generally does not change much, but the conductivity and silicon content will rise quickly. In actual situation, sometimes the anion bed and the cation bed do not invalidate at the same time, and the index of outlet water quality of the anion bed is also different. For example, when the anion bed is invalidated and the cation bed is not, the pH value of the outlet water from the anion bed will drop (sometimes even it is acidic), the silicon content will rise, and the conductivity will often decrease first and then rise quickly. Conversely, if the anion bed is not invalidated and the cation bed is invalidated, the pH, conductivity and Na^+ content of the outlet water will increase. At the same time, the increase of the NaOH content in the anion bed will affect the resin's silicon removal effect, resulting in the silicon content in the outlet water will also rise fast. Therefore, the cation bed and the anion bed should be monitored separately and regenerated in time when they are invalidated.

When the primary demineralization system is service normally, the outlet water from the anion bed contains trace amounts of Na_2SiO_3, so the pH value is mostly between 7 ~ 9, the conductivity is (0.5-5) μS/cm, and the silicon content (calculated as SiO_2) is generally <50μg/L. The end point of service is generally controlled as SiO_2<100μg/L.

For industries that do not require strictly on silicon content in water, the primary demineralization treatment system can judge the end of service by monitoring the conductivity of the outlet water from the anion bed. But for boiler feed water treatment of power plant that requires strict control of silicon content, the control of the end of the anion bed service should be determined by measuring SiO_2 content, rather than simply measuring the conductivity to replace the measurement of SiO_2. Because the conductivity of SiO_2 is extremely weak, even if the silicon content exceeds the standard, the impact on the conductivity is very small. Only when the content of other anions in the outlet water increases, the conductivity will increase significantly. At this time, the SiO_2 content in the outlet water is usually already serious exceeding. In addition, if the cation bed fails to start regeneration in time, the conductivity of the outlet water from the anion bed will increase, and the high Na^+ content in the inlet water of the anion bed will accelerate the invalidation and reduce the water production capacity of the anion bed.

When the ion exchange demineralization system is service, if the water flow velocity is too

fast (>40m/h) or too slow (⩽ 2m/h), the outlet water quality will decrease and the conductivity will increase. When the standby exchanger is put into service again, the quality of the outlet water at the beginning is often unqualified, and it needs fast rinse firstly until the outlet water's qualified.

(3) Measures to improve the silicon removal effect of anion exchange

In order to prevent the formation of silicate scale in thermal systems (such as boilers and steam turbines, etc.), power station boilers must strictly control the silicon content in the feed water. However, due to the relatively poor ability of anion exchange resin to absorb silicon, various measures need to be taken to improve the silicon removal effect. The main measures are summarized as follows:

a) Improve the carbon dioxide removal effect of the decarbonator and relieve the burden of the anion bed;

b) Set up weak anion exchanger to remove most of the strong anions in the water before entering the strong anion bed, which can prevent the strong acid anion from displacing the silicic acid compound from the resin, which can significantly improve the silicon removal effect of the strong anion resin;

c) Try to control the sodium ion content of the cation bed to avoid excessive Na^+ content from affecting the silicon removal effect;

d) Improve the the degree of regeneration of the anion exchange resin by appropriately increasing the temperature of the regeneration solution, two-step regeneration and other measures.

5.1.5 Exchanger regeneration of demineralization system

5.1.5.1 The consumption of regenerant and concentration of regeneration solution

In the primary demineralization system, after the cation bed and anion bed being invalidated, the regeneration steps and operation methods are basically same as the regeneration of the sodium ion exchanger, except that the regeneration system, regenerant and the concentration of regeneration solution used are different.

(1) Commonly used regeneration solution and concentration: regenerate strong cation exchange resin by 3% ~ 4% HCl; regenerate strong anion exchange resin by 2% ~ 3% NaOH.

(2) The amount of regenerant (m_z) for one time regeneration can be estimated according to formula (5-1):

$$m_z = \frac{V_R \times E \times k \times M}{10^3 \times \varepsilon} \quad (5\text{-}1)$$

In the formula: m_z—the amount of regenerant for one time regeneration, kg;

V_R —The filling volume of resin in the exchanger, m^3;

($V_R = \pi \times R^2 \times h_R$, R is the radius of the inner wall of the exchanger, m; h_R is the filling height of the resin, m)

E—The working exchange capacity of the resin, generally the strong acid cation exchange resin is (800 ~ 1200) mol/m^3, the strong base anion exchange resin is (300 ~ 450)mol/m^3, the weak base anion exchange resin is (600 ~1000)mol/m^3. If system adopts automatic regeneration, it needs to be multiplied by a factor of 0.6 ~ 0.9

k—The specific consumption of regenerant. For strong ion exchange resin, generally take 1.2 ~ 1.8 for up-flow regeneration; take 2 ~ 3.5 for down-flow regeneration; if weak ion exchange resin is regenerated separately, generally take only 1.0 ~ 1.1;

M—The molar mass of the regenerant, HCl is 36.5, NaOH is 40;

ε—The purity of the regenerant, the general concentrated hydrochloric acid (HCl) and concentrated alkali (NaOH) used in industries is about 30% to 33%.

Note: The purity of the purchased concentrated acid and concentrated alkali should be sampled. Generally, standard solutions should be used for acid and alkali titration, instead of just measuring the density with a densitometer to judge its concentration. In addition, when necessary, the Na^+ in the acid and the Cl^- in the alkali should be detected to prevent the counter ion content in the regenerant from being too high and affecting the regeneration effect.

5.1.5.2 Regeneration solution flow velocity and regeneration time

When the ion exchange resin for demineralization treatment is regenerated with acid or alkali, the flow velocity of the regeneration solution is similar to that of softening treatment. Generally, the flow velocity for down-flow regeneration is 4m/h ~ 6m/h; for up-flow regeneration without top pressure, the flow velocity should be controlled at 2m /h ~ 4m/h. The diameter of the ion exchanger for the demineralization treatment of boiler feed water treatment of power plant is usually relatively large. When it is up-flow regeneration, top pressure generated by the compressed air is generally required to prevent chaotic layers. In the case of having top pressure, the flow velocity of the regeneration solution is controlled at 4m/h to 8m/h. For the time calculation of adding the regeneration solution, please refer to the relevant process calculation of the water softener.

Example 5-1 A up-flow regeneration anion exchanger with a diameter of 2m requires filling resin with 2m height. The bulk density of the 201×4 resin used is 0.7g/mL, the working exchange capacity is 400mol/m^3, the specific consumption of regenerant is 1.6, the concentration of the regeneration solution is 3% (density is 1.03), and the flow velocity of the regeneration solution is controlled to 3m/h.

Questions:

① How much 201×4 resin should be filled in the exchanger?

② How much 30% sodium hydroxide is needed for one time regeneration?

③ How long does it take to add the regeneration solution during regeneration.

Answer:

① The amount of resin needs to be filled: $m = V_R \cdot \rho = 3.14 \times (2/2)^2 \times 2 \times 0.7 = 6.28 \times 0.7 \approx 4.4$ t

② The amount of sodium hydroxide needed for one regeneration:

$$m = \frac{V_R \cdot E \cdot k \cdot M}{10^3 \varepsilon} = \frac{6.28 \times 400 \times 1.6 \times 40}{10^3 \times 30\%} \approx 536 kg$$

③ Diluted into 3% regeneration solution by injector, the volume is:

$$V_Z = \frac{m_{cz}}{C \cdot \rho \cdot 10^3} = \frac{536 \times 30\%}{3\% \times 1.03 \times 1000} = 5.2 \text{ m}^3$$

④ Time for adding the regeneration solution:

$$t = \frac{60 \cdot V_Z}{S \cdot v} = \frac{60 \times 5.2}{3.14 \times 1^2 \times 3} \approx 33 \text{ min}$$

5.1.5.3 Regeneration of weak resin

For ion exchangers equipped with weak resin, in order to reduce the consumption of regenerant, usually it will take advantages of weak resin that has the feature of easy regeneration, and regenerate strong resin bed and weak resin bed in series. That is, the regeneration waste liquid discharged from the strong resin bed is used to regenerate weak resin. But for the weak anion bed, if the regeneration waste liquid discharged from the strong anion bed contains a higher concentration of silicic acid compound, it is easy to cause the silicon pollution of the resin when the weak anion resin is regenerated. Therefore, when the weak anion bed and the strong anion bed are regenerated in series, in order to prevent silicon pollution, a two-step regeneration method can be used. That is: firstly, use 1% NaOH regeneration solution to regenerate at a fast flow velocity, so that the resin is initially regenerated; secondly, regenerate with 3% ~ 4% NaOH at a low flow velocity. It is also possible to make sequential regeneration with the same regeneration solution. At the beginning, only regenerate the strong anion resin (at this time, the discharged regeneration waste liquid contains high silicon content and needs to be discharged); secondly, add the regeneration solution and regenerate the strong anion bed and the weak anion bed in series. At this time, the silicon content in the regeneration waste liquid discharged from the strong anion bed has been reduced and can be flowed into the weak anion bed to regenerate the weak anion resin. In addition, the strong anion bed and the weak anion bed can also be regenerated separately. The 1.5% to 2.5% NaOH is usually as regeneration solution for regenerating the weak anion resin .

5.1.6 Calculation of the water treatment capacity

5.1.6.1 Calculation of the water treatment capacity for the primary composite bed ion exchanger

(1) The water treatment capacity of cation bed can be calculated according to formula (5-2)

$$Q=\frac{E\times V_R\times\delta}{JD+SD_C} \quad (5\text{-}2)$$

In the formula:

Q—— Water treatment capacity, m^3;

E——Working exchange capacity of resin, mol/m^3, please refer to Table 5-1;

V_R——Filling volume of resin in the exchanger, m^3;

δ ——For exchangers regenerated by the automatic controller, in order to ensure the qualified outlet water in the later period of service, the formula keeps a coefficient which is generally 0.6 to 0.9 (the inlet water conductivity is higher, and the smaller value is adopted; otherwise, the larger value is adopted);

JD——Average alkalinity of inlet water of cation bed, mmol/L;

SD_C——Average acidity of outlet water of cation bed, mmol/L;

(2) The water treatment capacity of anion bed can be calculated according to formula (5-3):

$$Q=\frac{E\times V_R\times\delta}{SD_J+SiO_2+CO_2} \quad (5\text{-}3)$$

In the formula:

SD_J——Average acidity of inlet water of anion bed, mmol/L;

CO_2——The average content of CO_2 in the inlet water of anion bed, mmol/L. If the carbon removal effect is good, the residual CO_2 is very small and can be ignored;

SiO_2——The average content of silica in the inlet water of anion exchanger, mmol/L;

The meaning of other symbols is the same as formula (5-2).

5.1.6.2 Calculation of water treatment capacity of weak cation bed—strong cation bed series system

(1) The water treatment capacity of weak cation bed can be calculated according to formula (5-4):

$$Q=\frac{E\times V_{Rr}\times\delta}{YD_T\text{-}\alpha)} \quad (5\text{-}4)$$

In the formula:

YD_T——The average carbonate hardness in the inlet water (in general, means the inlet water's alkalinity), mmol/L;

V_{Rr}——Volume of weak acid resin, $m^{3;}$

α——The residual carbonate hardness in the outlet water of the weak cation bed, mmol/L.When the α value is difficult to determine, it can also be selected according to Table 5-2;

The meaning of other symbols is the same as formula (5-2).

Table 5-2 α value reference data

Inlet water quality	Hardness ÷ alkalinity	1.0～1.4		1.5～2.0	
	YD_T（mmol/L）	＜2	＞2	＜3	＞3
α value（mmol/L）		0.15～0.2	0.2～0.3	0.1～0.2	0.3～0.4

(2) The water treatment capacity of strong cation bed which is connected with weak cation bed in series can be calculated according to formula (5-5):

$$Q=\frac{E\times V_{Rq}\times\delta}{SD_C+\alpha} \tag{5-5}$$

In the formula:

V_{Rq}——Volume of strong acid cation resin, m^3;

SD_C——The average acidity of the outlet water from the strong cation bed, mmol/L;

The meaning of other symbols is the same as formula (5-4).

5.1.6.3 In the weak anion bed-strong anion bed series system, the calculation of the water treatment capacity of weak and strong resin

(1) The water treatment capacity of weak anion bed can be calculated according to formula (5-6):

$$Q=\frac{E\times V_{R,r}\times\delta}{SD-\beta} \tag{5-6}$$

In the formula:

$V_{R,r}$——Volume of weak anion resin, m^3;

SD——The average acidity of the inlet water from the weak anion bed, mmol/L;

β——The average residual amount of strong acid anions in the outlet water of the weak anion bed, mmol/L. The β value is similar to the average acidity of the outlet water from the weak anion bed, and it can be approximatly calculated by the average chloride ion content of the outlet water when there is no acidity (in mmol/L);

The meaning of other symbols is the same as formula (5-2).

(2) The water treatment capacity of strong anion bed which is connected with weak anion bed in series can be calculated according to formula (5-7):

$$Q=\frac{E\times V_{R,q}\times\delta}{CO_2+SiO_2+\beta} \tag{5-7}$$

In the formula:

$V_{R,q}$——Volume of strong acid anion resin, m^3;

The meaning of other symbols is the same as formula (5-2) and (5-6).

5.1.7Automatic control of regeneration for the primary demineralization system

5.1.7.1 Online monitoring of conductivity

The conductivity is the easiest to measure among the various water quality indexes of demineralization system. The online conductivity monitoring is not only relatively cheap, but also the measured data is relatively stable and reliable. However, although conductivity can reflect the change of ion concentration in water, different ions have different effects on conductivity. Therefore, if users want to judge the content of a certain ion (such as Na^+ in the cation bed) by conductivity, it is needed to understand the corresponding relationship.

(1) The influence of ionic components in water on the conductivity measurement

The principle of conductivity measurement is mainly based on the electrolyte (acid, alkali, salt) dissolved in water, and ionized into conductive cations and anions. Its conductivity is expressed by conductivity. By measuring the conductivity of the aqueous solution, the ion concentration in the water can usually be reflected. However, different ions perform various conductivity because of different charges and different directional migration speeds when conducting. Therefore, for an aqueous solution with the same electrolyte concentration, if the electrolyte ion composition is different, the measured conductivity is not the same. The molar conductivity λ_0 ($S\cdot cm^2/mol$) of some common ions in an infinitely diluted aqueous solution is shown in Table 5-3 (at 25℃).

Table 5-3 The molar conductivity of some common ions in an infinitely diluted aqueous solution at 25℃

Cation	H^+	Na^+	$1/2Mg^{2+}$	$1/2Ca^{2+}$	$1/2Fe^{2+}$	$1/3Fe^{3+}$
$\lambda_0^+(S\cdot cm^2/mol)$	349.7	50.1	53.1	59.5	53.5	68.5
Anion	OH^-	Cl^-	HCO_3^-	$1/2CO_3^{2-}$	$1/2SO_4^{2-}$	$C_2H_5COO^-$
$\lambda_0^-(S\cdot cm^2/mol)$	199	76.3	44.5	72	79.8	31

Generally speaking, the higher the conductivity coefficient of the ion, the stronger the conductivity and the greater the measured conductivity value. It can be seen from the table that the conductivity of most cations is not much different, only H^+ conductivity is several times larger than other cations; the difference in conductivity of anions is larger than that of cations, the conductivity of OH^- is lower than that of H^+, but it is also 2-6 times larger than other anions; the conductivity of organic salt ions is often small. Therefore, for the sample water with the same salt ion concentration, if the pH difference is large, the measured value of conductivity will be very different. Usually acidic water is the largest, alkaline water is the second, and neutral water is the smallest.

(2) Conductivity change of inlet water and out water of cation bed

For ion exchange demineralization system, various cations are exchanged into H^+ after the

cation bed treatment, and the outlet water is acidic. Therefore, the conductivity of the outlet water of cation bed is significantly higher than that of the inlet water, and its increase is proportional to the salt content of the inlet water (especially the non-carbonate content). The higher the non-carbonate content, the more significant increase of the conductivity of the outlet water. However, if the salt content of the inlet water does not change much during service, the conductivity of the outlet water will remain basically stable until the resin begins to invalidate. The Na^+ content in the outlet water increases and the H^+ content decreases, and the conductivity decreases significantly. When this situation reaches to a certain extent, it means the cation bed needs regeneration. However, if the conductivity of inlet water changes greatly, for example, the salt content of raw water in some areas is easy to change with the seasonal climate, dry season and wet season, etc. If it is not adjusted in time, when the salt content of raw water increases, the conductivity and acidity of the outlet water of cation bed increase correspondingly, but the Na^+ content may exceed the standard and cause the outlet water of final cation bed to be unqualified. When the salt content of the raw water decreases, the conductivity of the outlet water of cation bed decreases. However, in this situation, the resin actually is not invalidated. Regenerate in advance causes waste of acid and water. Therefore, when the conductivity of the raw water changes greatly, it is difficult to reflect the actual resin invalidation only by the conductivity of the outlet water, and it is necessary to monitor the Na^+ content of the outlet water to correctly judge whether regeneration is required. In order to understand the change of the conductivity of the inlet water in time, an online conductivity meter should also be installed at the inlet of the cation bed, so as to correctly judge and adjust the water treatment capacity in time, ensuring the quality of the outlet water.

(3) Conductivity change of inlet water and out water of anion bed

After the CO_2 in the outlet water of the cation bed is removed by the decarbonator, and the main ions in the water are hydrogen ions, trace sodium ions, strong acid anions, silicate ions and residual bicarbonate ions. After anion exchange, all strong acid anions and carbonate ions are removed, and silicate ions are basically removed. At the same time, OH^- and H^+ are neutralized. When the resin of the anion bed has not been invalidated, no matter how high the conductivity of the inlet water is, it will not affect the conductivity of the outlet water. As long as the Na^+ content in the outlet water of the cation bed is qualified, the outlet water's conductivity of the anion bed can remain basically stable (<10μS/cm), and the change of the inlet water's conductivity mainly affects the water treatment capacity. When the anion bed invalidates, as the silicate ions ($HSiO_3^-$) are the most difficult to be exchanged, so the silicate content in the outlet water will be increased firstly. Since silicate ions are weak dielectrics and have poor conductivity, their content changes have little effect on conductivity. Until the Cl^- in the outlet water of the anion bed increases, the conductivity will increase significantly. Therefore, for pure water production with less strict silicate

requirements, or where mixed bed treatment is required later, online monitoring of the conductivity of the outlet water can be used to start the regeneration of the anion bed; however, for the boiler feed water treatment for power plant that needs strict control of the silicon content of outlet water, it is necessary to simultaneously use an online silicate monitor to measure SiO_2 and start regeneration. In addition, it should be noted that if the Na^+ in the outlet water of the cation bed is not strictly controlled, the anion bed resin does not invalidate, the NaOH contained in the outlet water will be alkaline, which will also cause the conductivity of the outlet water to increase significantly. Therefore, the anion bed also needs to monitor the pH value for correctly judgement.

5.1.7.2 Start setting of regeneration

The automatic start of regeneration of ion exchanger in the demineralization system can also be achieved by setting water treatment capacity or online monitoring of the conductivity of the outlet water. But it is not like the softening treatment, which can be simply set by only measuring the hardness of the inlet and outlet water. The change in the outlet water quality of demineralization system not only can be affected by many factors, but also requires specific instruments for measuring the quality indexes of outlet water. No matter it adopts setting water treatment capacity or online monitoring, or a combination of the two, after the demineralization system is installed, it should be tested in advance through several cycles of operation. Then it can be put into service after ensuring it is reliable. When the water quality changes significantly, it needs to be adjusted in time.

From the above-mentioned calculation formula of water treatment capacity, it can be seen that starting the regeneration by setting the water treatment capacity, it is necessary to measure the alkalinity (carbonate hardness), silicon content and acidity of the outlet water of cation bed during the testing stage. If the regeneration is started by online monitoring, it is recommended to install a conductivity meter at the inlet and outlet of the cation bed and the anion bed; the outlet of the anion bed should also be equipped with a pH meter, so that the cation bed and anion bed can be correctly judged whether they are invalidated when the conductivity of the outlet water from the anion bed increases significantly. Also, it can prevent the outlet water from being acidic or alkaline and causing harm; for those with strict requirements on silicon content, an online silicate monitor should be set at the outlet of the anion bed to start the regeneration of the anion bed. Due to the different ion composition contained in different source waters, the correlation values between the acidity, Na^+ content and conductivity of the outlet water of cation bed are different. Therefore, it is necessary to measure various water quality indexes at the inlet and outlet of each exchanger during testing stage, confirming the corresponding relationship between the conductivity of the outlet water of cation bed and the Na^+ content, and determining the conductivity setting value for starting regeneration; the anion bed can start regeneration when

the conductivity of outlet water exceed the standard. However, at the same time, a pH meter with reminder function should be installed at the outlet. When the pH value of the outlet water of the anion bed is less than 6.5, it is likely that the invalidation of the cation bed causes the conductivity to increase. Of course, it's best to make the cation bed and anion bed as much as possible to be simultaneously invalidated and regenerated when make system design and resin selection.

5.2 Service and regeneration of mixed bed

5.2.1 Overview of mixed bed treatment

Mixed bed is an abbreviation of a fine demineralization device that mixes anion and cation exchange resins in the same exchanger. Since the H type resin and OH type resin in the mixed bed are uniformly mixed during service, it is equivalent to the formation of tens of thousands of composite bed anion and cation exchange reactions, and the H^+ produced by cation exchange and OH^- produced by anion exchange are immediately generate H_2O, which basically eliminates the influence of counter ions and can proceed the exchange reaction very thoroughly. Therefore, the outlet water quality can reach high purity.

When the resins of the mixed bed are invalidated, it is needed to separate and regenerate the anion and cation exchange resins; after regeneration and cleaning, then mix two resins uniformly. If necessary, the resin can be mixed more evenly by compressed air, and then put into service. In order to better separate the cation resin and the anion resin in the mixed bed during regeneration, and can be evenly mixed without layering during service, the specific density of the selected cation resin and anion resin should be appropriate. The specific density difference should be controlled within 15%-20% (note that it is not the bulk density).

Usually the mixed bed is installed after the strong anion bed of primary ion exchange or after the reverse osmosis treatment. The remaining cations and anions in the demineralized water after the primary ion exchange demineralization treatment are mainly sodium ions and silicate ions. Therefore, the resins filled in the mixed bed must be a strong acid cation exchange resin and a strong base anion exchange resin. Since the exchange capacity of the cation resin is usually at least twice larger than that of the anion resin, the ratio of the cation resin to the anion resin in the mixed bed is usually 1:2. But for the mixed bed used for condensate polishing treatment, it mainly for removing the metal cations and has very few anions, so the ratio of cation resin to anion resin is generally 2:1.

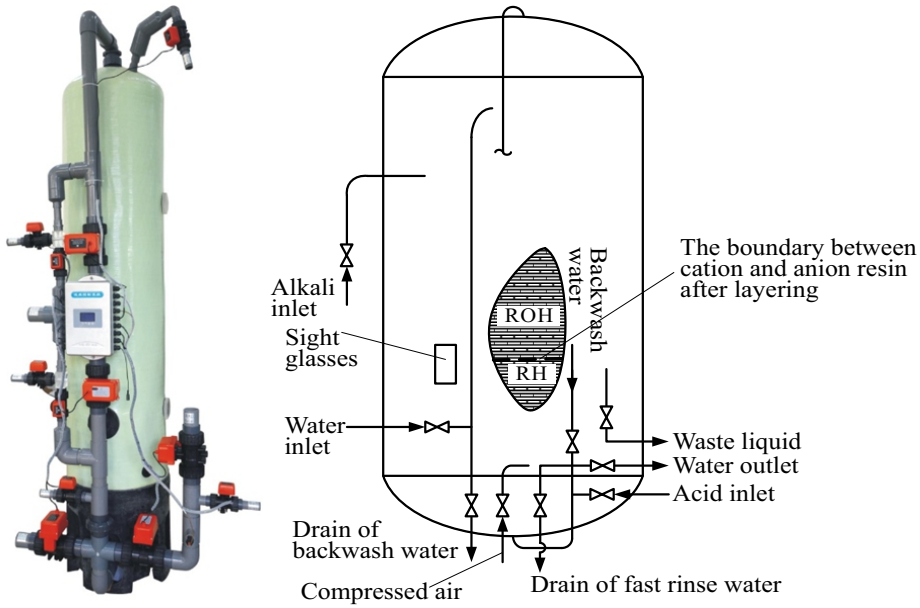


Figure 5-3 Diagram of mixed bed device and piping system

5.2.2 Device structure of mixed bed

The device and piping system of the mixed bed are shown in Figure 5-3.The tank of the device is similar to the pressure filter, which is a cylindrical closed container. The tank is often equipped with an upper water inlet device, a lower water distribution device and a compressed air device. For the mixed bed that is regenerated inside the tank, there is also an upper alkali inlet device, a lower acid inlet device, a middle water distribution and waste discharge device. The tank of the mixed bed is usually equipped with three sight glasses, the upper, middle and the lower one. The lower one is set at the boundary between the cation and anion resins to observe the resin layering during regeneration. The middle one is used to observe the layer height of the anion resin and the condition of the mixed resin during service. The upper one observes the swelling condition of the resin during backwash layering.

5.2.3 Regeneration and service methods of mixed bed

The regeneration of a mixed bed is quite different from the regeneration of a single-layer resin. The main regeneration and service methods are briefly introduced as follows:

(1) Backwash layering

After the mixed bed is invalidated, the cation and anion resins must be separated before regeneration, and the degree of separation is the primary key to the regeneration effect. At present, the more commonly used method is to adopt hydraulic sieving to separate the cation and anion resins. This method is to suspend the resin by backwash hydraulic power to make the resin layer reach a certain expansion rate. Based on the specific density difference of the cation and anion resins, the higher density cation resin settles quickly, and falls to the lower layer first; the lower density anion resin settles slowly and falls on the upper layer, thus achieving the purpose of layering.

Attention should be paid to the backwash operation: at the beginning of the backwash, the flow velocity should be small. After the resin layer is loosened, gradually increase the flow velocity to about 20m/h to make the expansion rate of the entire resin layer reach more than 50%. The backwash time is generally 10minutes ~20minutes

In addition, it should be noted that whether the cation and anion resins can be clearly layered, it is not only related to the difference in specific density of the resin and the flow velocity of the backwash water, but also related to the invalidation degree of the resin. If the degree of resin invalidation is large, the resin is easy to layer. Otherwise, it will be not easy. This is because after the resin absorbs different ions, its density will increase. Especially for the specific density of the invalidated anion resin (such as SO_4^{2-} type) is close to the non- invalidated cation resin (H type), resulting in difficulty in layering. In addition, H type resins and OH^- type resins sometimes adhere to each other (clumping), which can also cause difficulties in layering. In order to make the layering easier, users can add an appropriate amount of NaOH regeneration solution before layering to regenerate the anion resin into OH type and the cation resin into Na type, thereby increasing the density difference between the two resins and eliminating the viscosity of the resin.

(2) Regeneration

There are two main methods for regeneration of mixed bed: inside regeneration and outside regeneration. The latter method has been seldom used at present. The following mainly introduces inside regeneration.

Inside regeneration is the regeneration of resin happens in the exchanger. According to the different steps of acid drawing, alkali drawing and cleaning, it can be divided into two-step treatment method and synchronous treatment method.

a) Two-step treatment method: Most mixed bed adopts a two-step treatment method by letting alkali and acid pass through the anion and cation resin layer separately. The process is shown in Figure 5-4, the specific operation method is:

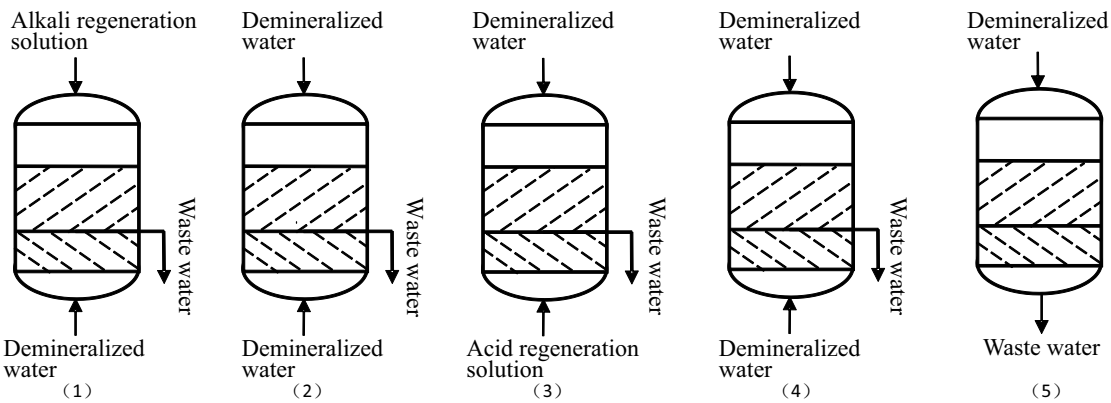
① Anion resin draw alkali: after the backwash and layering are completed, drain the water in the exchanger to about 10cm above the surface of the resin, and draw 2% to 4% NaOH regenerating solution from the upper part to regenerate the anion resin. At the same time, make the demineralized water flows from the bottom to the cation resin to reduce the possibility of contamination of cation resin. And the regeneration waste liquid is discharged from the middle drain which is at the boundary between the anion and the cation resin.

② Rinse after drawing alkali: after the alkali regeneration solution has been drawn, make the demineralized water to pass through the resin layer at the same flow direction and flow velocity as mentioned above, washing resin until the alkalinity of the discharged water drops below (OH^-) 0.5mmol/L;

③ Cation resin draw acid: 3% to 5% acid regeneration solution (usually HCl) is fed from the bottom to regenerate the cation resin. At the same time, a small amount of demineralized water is fed from the top to clean the anion resin, preventing the acid from passing the anion resin layer. The regeneration waste liquid is still discharged from the middle drain which is at the boundary between the anion and the cation resin;

④ Rinse after drawing acid: after the acid regeneration solution has been drawn, make the demineralized water pass through the resin layer at the same flow direction and flow rate as step ③, washing resin until the acidity of the discharged water drops below (H^+) 0.5mmol/L;

⑤ Overall fast rinse: feed demineralized water from the top, and drain from the bottom, washing the resin until the conductivity of the outlet water is less than 1.5μS/cm. In the cleaning process, sometimes in order to avoid blind area, a short-time backwash of 2min to 3min can also be performed to improve the cleaning effect.



(1)-Anion resin draw alkali (2)-Rinse after drawing alkali (3)-Cation resin draw acid

(4)-Rinse after drawing acid (5)-Overall fast rinse

Figure 5-4 Working process of the inside regeneration of mixed-bed

b) Synchronous treatment method: during regeneration, the alkali enters the anion resin layer from the top, at the same time, the acid enters the cation resin layer from the bottom and the regeneration waste liquid is discharged from the boundary between the anion and the cation resin. The regeneration time depends on the regeneration time of the anion resin, and the rinse process is the same as the two-step method. The advantage of this method is that the regeneration time is short, but the disadvantage is that it is not easy to control. A well-designed regeneration system and precise operation are required in order to achieve a satisfactory regeneration effect.

Inside regeneration should avoid acid and alkali polluting the outlet water during service. The design should pay attention to the isolation of acid, alkali and outlet water. For example, two valves should be installed on the acid inlet pipe which is connected with the outlet pipe. In addition,

the filling volume of the anion and cation resins should ensure the boundary at middle drain port. Otherwise, after layering, if the anion resin is lower than the middle drain port or the cation resin is higher than the middle drain port, this part of the resin will not be regenerated, thereby affecting the working exchange capacity.

The specific consumption of regenerant in mixed bed regeneration, generally cation resin is 2 times of the theoretical volume, and anion resin is 3 times of the theoretical volume.

(3) Mixing anion and cation resin

After the resin is regenerated and cleaned, the layered resin must be remixed uniformly before being put into service. In order to better mix the resins evenly, the compressed air can enter from the bottom for stirring and mixing. The compressed air should be purified to prevent the oil impurities in the compressed air from polluting the resin. While mixing, the pressure of the compressed air is 0.1MPa ~ 0.15MPa, flow rate is (2.5~3.0) $m^3/(m^2 \cdot s)$, the mixing time is depends on whether the resin is mixed evenly, generally it takes 0.5min ~ 1.0min, too long mixing time is easy to wear resin.

In some mixed beds, after the resin is mixed, the ratio of anion and cation resin in the lower layer is often close to the expected ratio, while there is a large difference in the upper layer resin. The reason is mostly due to the delayed drainage or insufficient drainage speed after the resin is mixed. As a result, the resin layered again during the settlement process. In order to mix the resin uniformly as a whole, in addition to feeding appropriate compressed air and keeping it for a certain period of time, when the compressed air is turned off, a sufficient drainage speed should be used to force the resin to settle quickly. At the same time, water can be fed from the top to accelerate the resin settlement to avoid re-layer.

(4) Fast rinse

The mixed resin layer needs fast rinse with demineralized water before it is put into service. Generally, the flow velocity of fast rinse is 10m/h ~ 20m/h, and it can be put into service only after outlet water is qualified. In the early stage of fast rinse, if the discharged water is turbid, it can be drained into the sewage. When the discharged water become clear, then it can be recycled.

(5) Service

During fast rinse, when the conductivity of the outlet water of mixed bed is $\leqslant 0.2\mu S/cm$ and the silicon content is $\leqslant 20\mu g/L$, it can be switched to service status. The operation method is the same as that of the ordinary fixed bed, but higher flow velocity than the single-layer bed can be used.

For the mixed bed, within a certain range, the height of the resin layer and the flow velocity have little effect on the conductivity of the outlet water. But when the height of the resin layer is too low (such as lower than 0.6m), increasing the flow velocity will significantly affect the outlet

water quality. If the flow velocity of the mixed bed is too slow, the thick boundary water film is formed on the surface of the resin particles, which affects the ion exchange rate and reduces the quality of the outlet water; while the flow velocity is too fast, the ions will be carried out by the water flow before the ions can diffuse into the resin for exchange, resulting the conductivity of the outlet water is increased. Furthermore, excessively fast flow velocity increases the thickness of the protective layer and reduces the working exchange capacity of the resin. Therefore, the general mixed bed service flow velocity is 40m/h ~ 60m/h.

The outlet water quality of the mixed bed is relatively stable, and the conductivity can usually reach below 0.1μS/cm. Under normal situation, the quality of the inlet water and the degree of resin regeneration have little effect on the conductivity of the outlet water, but it has a significant impact on the water treatment capacity. Since the resin regeneration degree in the mixed bed is not high and the exchange capacity utilization rate is low, in order to ensure a certain water treatment capacity, the conductivity and silicon content of the inlet water should not be too high. Generally, the quality of the inlet water of the mixed bed should be controlled as: conductivity $\leqslant$ 10μS/cm, silicon content $\leqslant$ 100μg/L.

Intermittent service has little effect on the outlet water quality of the mixed bed. Like the single bed, when the exchanger is put into service after being stopped, the conductivity of the outlet water will often be unqualified at the beginning, and a short period of fast rinse is required to make the outlet water qualified. However, it usually only takes 3min to 5min of fast rinse for the mixed bed to make the outlet water be qualified, while the single-layer bed usually takes more than 10min.

The end point of the mixed bed service is more obvious. When the exchanger is invalidated, the conductivity of the outlet water rises faster. Therefore, it is easier to start regeneration in time through online monitoring of the conductivity, which is convenient for automatic control.

5.3 Demineralization treatment of reverse osmosis

5.3.1 Overview of reverse osmosis membrane treatment

Reverse osmosis membrane treatment is a demineralization treatment technology developed in the 20th century. In recent years, with the continuous development of membrane treatment technology and the substantial reduction in membrane prices, reverse osmosis demineralization treatment has become more and more popular. It is widely used in many water treatment systems fields, such as seawater demineralization, boilers, electronics, pharmaceuticals, medical treatment, laboratory testing, and drinking water, etc.

Reverse osmosis is mainly used to remove inorganic salts dissolved in water and greatly reduce the salt content in water. The reverse osmosis treatment device (also called RO device) not only has a high degree of automation and small volume,but also is environmental and

basically pollution-free.

Compared with the traditional ion exchange demineralization treatment, the one-time investment cost of the reverse osmosis device is higher, but the daily operating cost is relatively low. Especially for raw water with high salt content (conductivity higher than 500μS/cm), the operating cost performance is better than anion and cation exchange demineralization treatment, and it has strong applicability to water, and the outlet water quality is stable and can relieve environmental pressure.

The reverse osmosis water treatment device is shown in Figure 5-5, which usually includes: ultrafilter, high pressure pump, reverse osmosis membrane element and membrane shell, instrument and connecting pipeline, electrical control device and cable, etc. In addition, there also should be installed with pretreatment device, reverse osmosis scale inhibitor dosing device, chemical cleaning device and so on. Reverse osmosis membrane is the core part of reverse osmosis device and the key to ensure demineralization effect.



Figure 5-5 Reverse osmosis device

Attention: different from ion exchange demineralization, the purity (conductivity) of outlet water of reverse osmosis is greatly related to the salt content of the inlet water and the water production rate (also known as the raw water recovery rate). When the water production rate is constant, the higher the salt content of the inlet water, the higher the conductivity and hardness of the outlet water; reduce the water production rate and the outlet water quality will be improved. But the water production efficiency will be reduced, the energy consumption will

increase, and it may still not meet the qualified requirements. Therefore, the reverse osmosis outlet water usually cannot fully meet the boiler feed water requirements. For industrial boilers, further softening treatment is required. For power station boilers or other fields that need ultra-pure water, further ion exhanges mixed bed treatment or advanced electrodeionization is required.

Under in normal situation, the desalination rate of the reverse osmosis device (that is, the percentage of the amount of removed salt and the salt content in the inlet water) is 95% to 98%, which can be calculated according to formula 5-8:

$$\eta\ \% = \frac{S_J - S_C}{S_J} \times 100\% \qquad (5\text{-}8)$$

In the formula:

η%—desalination rate,% ;

S_J—Salt content (or conductivity) of inlet water, mg/L (μS/cm);

S_C—Salt content (or conductivity) of outlet water, mg/L (μS/cm);

Example: an enterprise in Sichuan of China is equipped with a steam boiler (model SZS55-1.25-Q), which requires the conductivity of feed water is ⩽ 20μS/cm and hardness is ⩽ 0.03mmol/L. The average conductivity of raw water is 836μS/cm and the average hardness is 4.8mmol /L. Besides, the desalination rate of the newly installed RO secondary treatment device is required to reach 98%.

Question: can the outlet water quality meet the boiler feed water requirement?

Answer: based on the formula 5-8, when the desalination rate is 98%, it could be calculated that the outlet water conductivity is 16.7μS/cm and hardness is 0.096mmol/L. Although the conductivity of the outlet water meets the water requirements, the hardness exceeds the standard and does not meet Chinese national standards; even if the water production rate is reduced, the outlet water quality can be improved, but it is difficult to meet the qualified standards. Furthermore, the desalination rate of the RO device will gradually decrease after a period of operation, and the water quality of the raw water will also fluctuate, so the hardness of the feed water is difficult to meet the standard, and it is easy to cause boiler scaling.

The solution is to install a water softener before the RO device to greatly reduce the hardness of the inlet water of reverse osmosis, which can prevent the formation of scale on the reverse osmosis membrane, extend the service life of the membrane, and ensure that the hardness of outlet water meets the requirement of the boiler feed water standard.

In order to save investment costs, many users combine reverse osmosis treatment with ion exchange treatment, which not only reduces investment costs, but also ensures that the product water quality meets the requirements of boiler feed water or other pure or ultra-pure water production. Common and typical combined demineralization treatment systems are:

(1) Sand filter or multi-media filter→activated carbon filter→sodium ion exchange→ reverse osmosis→demineralization water tank (suitable for producing pure water or soft water with low salt content produced from the raw water with high salt content);

(2) Sand filter or multi-media filter→activated carbon filter→weak acid H^+ ion exchange→ decarbonator→middle water tank→reverse osmosis→demineralization water tank (suitable for producing pure water or soft water from raw water with high salt content and carbonate hardness or producing soft water with low salt content);

(3) Clean water→sand filter or multi-media filter→activated carbon filter or ultrafiltration→two-stage series reverse osmosis→demineralization water tank (suitable for producing pure water from the raw water with high salt content, and scale inhibitor is required before reverse osmosis);

(4) Clean water→sand filter or multi-media filter→activated carbon filter or ultrafiltration→two-stage series reverse osmosis→anion and cation exchange mixed bed→ demineralization water tank (suitable for producing ultrapure water, and scale inhibitor is required before reverse osmosis);

(5) Clean water→sand filter or multi-media filter→activated carbon filter or ultrafiltration→weak acid H^+ ion exchange→decarbonator→middle water tank→two-stage series reverse osmosis→anion and cation exchange mixed bed→demineralization water tank (suitable for producing super water from raw water with high salt content and carbonate hardness).

For the two-stage reverse osmosis system, the concentrated water discharged from the second stage can be returned to be the inlet water for first-stage.

5.3.2 Membrane pollution and prevention

In the process of membrane treatment, membrane pollution is a very common problem. The so-called membrane pollution usually refers to the phenomenon that macromolecular solute in the treated liquid has physical and chemical interaction or mechanical interaction with membrane, and adsorbs and precipitates on the membrane surface or in the membrane pore, which makes the membrane pore smaller or blocked, resulting in the decrease of the water permeability or separation capacity of the membrane.

5.3.2.1 The form of membrane pollution

Membrane pollution is mainly in the form of covering pollution of membrane surface and blocking pollution of membrane pore. The pollution layer on the membrane surface is roughly a two-layer structure, the upper layer is a loose layer with larger particles, and the fine layer with a small particle size is close to the membrane surface. Generally, the pollution of the loose layer

is not enough to cause a big impact on the membrane performance. It can be washed away under the action of hydrodynamic shear stress during backwash. The fine layer on the membrane surface has a greater impact on the normal performance of the membrane. Because of this pollution layer, a large number of membrane pores will be covered, and the long-term interaction between the particles and other impurities in the layer can easily gel into a filter cake, increasing the water permeability resistance. Membrane pore clogging means that fine particles enter the membrane pores, or the membrane pores become smaller or completely blocked due to the adsorption of proteins and other impurities on the inner wall of the membrane pores. This phenomenon is generally an irreversible process and will cause seriously damage of the membrane performance.

5.3.2.2 Common pollutants

Common pollutants can be roughly divided into the following types:

(1) Colloid pollution: the colloid mainly exists in the surface water, especially with the change of seasons, the colloid and suspended matter such as clay and silt in the water are evenly distributed in the water, which is extremely harmful to the filter membrane. Because during the process of membrane treatment, a large number of colloidal particles rush to the surface of the membrane along with the water flowing through the membrane. After long-term continuous operation, the particles trapped by the membrane easily form a gel layer. Some particles equal to or smaller than the pore size of the membrane will even penetrate into the membrane pores, block the water channel and cause irreversible deterioration.

(2) Organic matter pollution: some of the organic matter in the water is found in natural water, such as humic acid and tannic acid, and some are artificially added during the water treatment process, such as surfactants, detergents, polymer flocculants, etc. These substances are also easy to be adsorbed on the surface of the membrane and damage the performance of the membrane.

(3) Microbial pollution: microbial pollution is also a risk factor for the safe operation of membranes. Some nutrients are trapped by the membrane and accumulate on the surface of the membrane, and bacteria multiply rapidly in this environment. Live bacteria together with their excretion materials form microbial mucus and tightly adhere to the membrane surface. These mucus combine with other sediments to form a complex covering layer was created, which not only affect the water permeability of the membrane, but also cause irreversible damage to the membrane.

(4) Scaling: when the raw water is concentrated to a certain extent in the membrane element, the insoluble salts and easily scaling substances contained in the concentrated water side will be precipitated due to super saturation and deposited on the membrane surface or in the concentrated water channel. This phenomenon is called "scaling", which can easily cause blockage of membrane pores and affect water flux.

5.3.2.3 Prevention of membrane pollution

In order to prevent membrane pollution, a pretreatment device must be installed before the RO device. Generally, a multi-media or quartz sand filter is required to remove suspended impurities and colloidal substances in the raw water; an activated carbon filter is installed to remove organic matter and residual chlorine; a sodium ion exchanger is installed to remove or reduce the hardness and prevent membrane from scaling (some use scale inhibitors to prevent from scaling); microfiltration or ultrafiltration can remove colloidal substances and microorganisms thoroughly, but the investment cost is relatively high, and the filter membrane is easy to be blocked by particles or gel substances similar to the membrane pore size. Therefore, in the membrane treatment system, it is necessary to add a suitable bactericide and regularly chemically clean the membrane surface.

5.4 Application of Runxin automatic control valve in demineralization system

5.4.1 Application of Runxin valve in ion exchange demineralization system

The material of Runxin automatic control valve has acid and alkali resistance, so it is suitable for the demineralization treatment of anion and cation exchangers. Runxin's softener valve can be applied to anion and cation exchangers, and in actual application, the valve draw alkali or acid instead of brine. For the mixed bed (anion and cation exchange resins are in the same resin tank in proportion) which is for producing the ultrapure water, the suitable models of Runxin control valve are 15702 and 15704, and they have two built-in injectors to draw acid and alkali or wash acid and alkali respectively.

5.4.2 Application of Runxin valve in pretreatment system of reverse osmosis device

The common pretreatment system of the reverse osmosis device is: sand filter or multi-media filter→activated carbon filter→sodium ion exchange→reverse osmosis. If the hardness and alkalinity of the raw water are relatively high, the pretreatment system can be set to: sand filter or multi-media filter→activated carbon filter→weak acid H^+ ion exchange→ decarbonator→reverse osmosis. This pretreatment system can take advantage of weak acid resin which has the features of large exchange capacity for carbonate hardness and easy regeneration, to remove the carbonate hardness and avoid membrane scaling. The suitable automatic control valve is the same as that valve used in the normal filtration and softening system.

5.4.3 Application case of Runxin valve used in the demineralization system

5.4.3.1 The application of Runxin valve in drinking water demineralization system

(1) Project background

In many European countries, large factories, gas stations, expressway service areas, and other places where people are crowded, need to provide a lot of drinking water. But these places, generally are located in remote areas, which are far from cities. It is difficult to supply tap water,

so mainly groundwater is used for drinking water after treatment. But the quality of groundwater is more complex, and water quality after simple treatment is often difficult to meet the drinking water requirements. Therefore, it needs reverse osmosis treatment.

(2) Project introduction

WATER WAREHOUSE from Brazil provides the drinking water system for workers who build management and charging systems at a gas station and customers who pass by for refueling. The raw water is groundwater, and the indexes of average water quality after measurement are: TDS is 1500mg/L, hardness is 300ppm (6mmol/L), iron content is 4ppm ~ 5ppm, manganese content is 0 ~ 2ppm, chloride content is 450mg/L. The groundwater belongs to brackish water with high salt content and high hardness.

It is required to produce the clear drinking water with below indexes: TDS ⩽ 80mg/L, hardness ⩽ 30ppm (0.6mmol/L), chloride content ⩽ 30mg/L, and water flow rate is 0.5m^3/h. Based on above requirements, RO system is designed to reduce salt and hardness.

Considering that the iron and manganese content of groundwater exceeds the standard, it is easy to cause pollution to the RO membrane. During the pretreatment, the raw water is added with chlorine and sodium hydroxide, and then treated by the iron and manganese removal device, then filtered by activated carbon, and softened by the resin before entering the reverse osmosis system. The system adopts two sets of 53502 automatic filter valves, equipped with iron and manganese removal device, and activated carbon filters. One set of 63502 automatic softener valve is equipped with a resin tank with a diameter of 0.4m and a height of 1.65m to make up a pretreatment system. The working process for whole water treatment system is: Well water→ Water pump→ Add chlorine and Sodium hydroxide→ Iron and manganese removal→ Activated carbon filtration→ Softener→ RO machine→ Drinking water tank→ Booster pump→ Disinfection→ Drinking point. The layout of system is shown as Figure 5-6, and installation is shown as Figure 5-7:

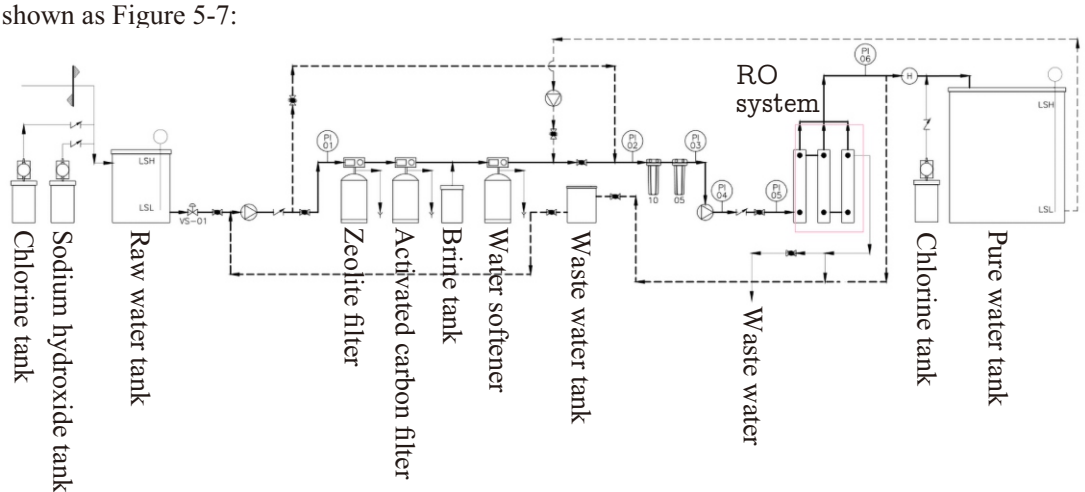


Figure 5-6 Diagram of drinking water treatment system



Figure 5-7 Pretreatment system of RO device

(3) Operation condition

Since the installation and usage of the system in early 2017, the system has been operating stably, producing qualified water and having good automation control.

5.4.3.2 The application of Runxin valve in demineralization system for plant cultivation

With the development of society and technological progress, pure water from reverse osmosis demineralization system has been widely used in the fields of drinking, chemical, food processing, pharmacy, breeding, and planting. Because the reverse osmosis membrane is easily polluted by impurities, especially when the inlet water turbidity and hardness are high, it will damage the membrane surface and block the membrane pore channels, which significantly affects the desalination rate and water production rate of the reverse osmosis treatment. Therefore, for a complete set of reverse osmosis device, the prefiltration and anti-scale pretreatment cannot be ignored. Use Runxin automatic control valve in the prefiltration and softening treatment of reverse osmosis demineralization device, which can guarantee the long-term stable operation of the system. The following introduces the application case of Runxin automatic control valve in the pretreatment of reverse osmosis system.

(1) Project background

In a rare mushroom planting industrial park in Guiyang city of Guizhou province, the raw water is municipal tap water with an average salt content of 286mg/L and an average hardness of 4.4mmol/L. Due to the high salt content (conductivity) in the water, which will affect the quality and growth of the plant, a two-stage reverse osmosis demineralization device (RO device) is designed to reduce the salt content (conductivity) of the raw water to meet the requirement on the irrigation water for rare mushroom. Due to the high hardness of raw water, the pores is easily blocked because of the surface of the reverse osmosis membrane scaling. In order to prevent the

reverse osmosis membrane from being damaged, extend the service life of the membrane, and ensure the desalination rate and water production rate of the RO device, below pretreatment systems should be installed before the RO device: quartz sand filter (sand filter for short) and activated carbon filter (carbon filter for short) for secondary filtration, requiring outlet water turbidity <1.0NTU; water softener is applied to control outlet water hardness ⩽0.06mmol/L.

(2) Project introduction and device configuration

a) Sand filter configuration: 400×1650 FRP tank, filled with 200kg (10-20 mesh) quartz sand, with Runxin 51106 filter valve.

b) Carbon filter configuration: 400×1650 FRP tank, filled with 75kg nutshell activated carbon, with Runxin 51106 filter valve.

c) Water softener configuration: 400×1650 FRP tank, filled with 150L sodium ion exchange resin, equipped with 200L brine tank, with Runxin 63604 meter type automatic softener valve.

The system is maintained by a specialized person to regularly monitor the outlet water quality indicators. The softener valve is set to A-02 (meter immediate type) to ensure the soft water supply to the RO device. At the same time, the signal output mode of softener valve is set to b-01: when the water softener is regenerated, the signal is output, and the RO device stops running; after the regeneration is finished, the RO device automatically restart operation. It can prevent damage to the high-pressure pump caused by the shortage of water supply when the water softener is regenerated.

The process flow of the water treatment system is: municipal water supply→raw water tank→raw water pump→sand filter→carbon filter→water softener →RO device→pure water tank→booster pump→irrigation place. The equipment installation is shown in Figure 5-8.



Figure 5-8 Sand filter-carbon filter-softening pretreatment and RO system

(3) Operation effect

The water produced by the system has been tested and fully meets the usage standards. Since the installation and operation in early 2019, the system has been operating stably, producing qualified water and having good automation control. Customer have appreciated it.

5.4.3.3 Application of Runxin valve in ultrapure water production system

(1) Project background

A pharmaceutical company in Inner Mongolia of China, requires ultrapure water for production. The raw water is groundwater, the indexes of water quality after measurement are: turbidity is 8NTU-9NTU, conductivity is 1100μs/cm ~ 1200μs/cm, hardness is 4mmol/L ~ 5.5mmol/L. It is required to produce ultrapure water with conductivity ⩽ 0.3μs/cm, and the water production capacity requires $8m^3/h$ ~ $12m^3/h$. Based on above requirements, the system adopts two-stage reverse osmosis + electrodeionization(EDI)demineralization treatment, and is equipped with the pretreatment of quartz sand filter and activated carbon filter, so as to meet the inlet water requirements of the reverse osmosis device.

(2) Project introduction

Since the turbidity and hardness of the raw water are not very high, the RO inlet water of the reverse osmosis device is from the water after being treated by quartz sand filtration and activated carbon filtration, add scale inhibitor to prevent RO membrane from scaling. The pure water after the two-stage reverse osmosis treatment enters EDI deep demineralization treatment to produce ultrapure water. The pretreatment system is equipped with one quartz sand filter and one activated carbon filter. The matching tank has a diameter of 1.5m and a height of 2.4m. Both filters adopt Runxin 53530 time type automatic filter control valve. The process flow diagram is shown in Figure 5-9, and the equipment installation is shown in Figure 5-10.

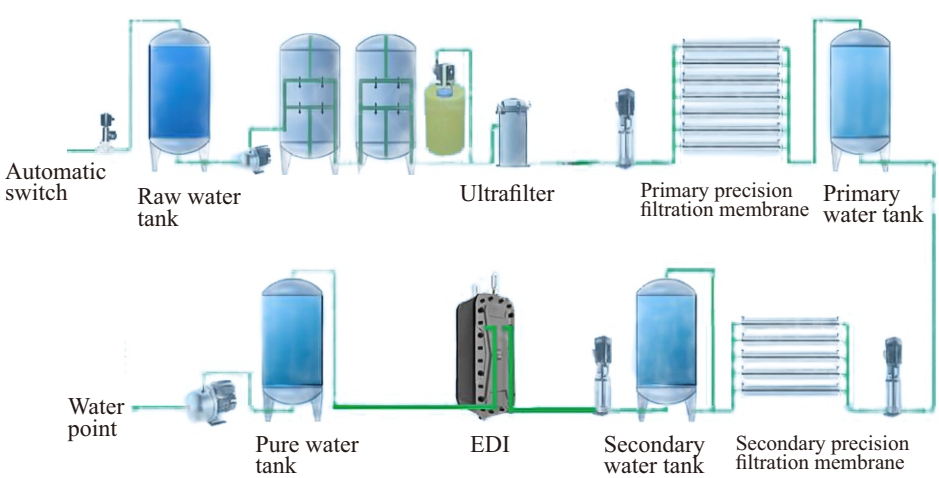


Figure 5-9 Process flow diagram of filter and two-stage reverse osmosis



Figure 5-10 Filter and two-stage reverse osmosis system

The process flow of the water treatment system is: raw water tank→raw water pump→ multi-media filter→activated carbon filter→add scale inhibitor→ultrafilter→high pressure pump→two-stage series reverse osmosis device→middle water tank→inlet water pump of EDI→EDI demineralization→ultrapure water tank→water supply pump→terminal filter→ ultraviolet sterilization→water for pharmaceutical.

(3) Operation effect

Since the installation and usage of the system in early 2018, the system has been operating stably, producing qualified water and having good automation control.

5.4.3.4 Application of Runxin valve in demineralization system for boiler feed water

(1) Project background

In a brewery in Xichang city of Sichuan province, there is an original coal-fired boiler with an evaporation capacity of 6m^3/h. The feed water is softened by an automatic control sodium ion exchanger. In order to adapt to the new national environmental protection policy, the original coal-fired boiler is eliminated and replaced by an electric heating boiler with the same evaporation capacity. As electric heating boilers have higher requirements on the quality of feed water, the original softening treatment can no longer meet the boiler feed water requirements and needs to be updated. For this reason, after being softened, the feed water needs to be treated by the two-stage reverse osmosis treatment. The raw water is municipal tap water, and the indexes of average water quality after measurement are flowing: pH value is 7.2, hardness is 1.8mmol/L, total alkalinity is 0.9mmol/L. It is required to produce the water with below indexes: hardness $<$ 0.03mmol/L, conductivity $\leqslant$ 5μS/cm, water flow rate is 10m^3/h.

(2) Project introduction

In order to prevent RO membrane pollution and extend the service life of the membrane, a quartz sand filter is equipped to remove suspended impurities and reduce turbidity. An activated carbon filter is used to remove residual chlorine and organic matter. The suitable FRP tank for the filter system is 1.5m in diameter and 2.2m in height, respectively filled with quartz sand and activated carbon. The filter systems adopt 53530 automatic control filter valves. Keep the original automatic water softener to reduce the hardness. After being filtered and softened, the treated water enters the high-pressure pump after treated by the ultrafilter, and then enters the demineralized water tank after being processed by the two-stage RO device, and finally is pumped to the deaerator to supply boiler feed water.

The process flow of the water treatment system is: municipal tap water→raw water tank → raw water pump→multi-media filter→activated carbon filter→water softener→ultrafilter→two-stage series reverse osmosis system→demineralized water tank. The equipment installation is shown in Figure 5-11.

(3) Operation effect

Since the installation and usage of the system in early 2018, the system has been operating stably, producing qualified water and having good automation control.



Figure 5-11 RO system and pretreatment device

5.4.3.5 Application of Runxin valve in mixed bed

(1) Project background

In the production process of metallic silver powder, it is necessary to repeatedly clean with deionized water in the precipitation tank and filter, to obtain high-purity silver powder. If the cleaning is not thorough, impurities will be left after and cause silver powder agglomerate when dry. Deionized water for cleaning generally requires a resistivity of 15MΩ.cm or more.

(2) Project introduction

A company requires deionized water with a water consumption of 10m^3/h and resistivity is ⩾15MΩ.cm during the cleaning process. The water source is from municipal tap water. The system adopts activated carbon filter+ softening treatment + reverse osmosis treatment + mixed bed ion exchange system to produce deionized water. The mixed bed ion exchange system is equipped with three special FRP tanks with a diameter of 300mm and a height of 2000mm. The tank is filled with strong acid cation resin and strong base anion resin in a ratio of 1:2. Three Runxin 15704 mixed bed control valves are used, forming three sets of mixed bed ion exchange system to supply water in parallel. The system installation is shown in Figure 5-12. The mixed bed is designed to service with an average flow rate of 50m/h (generally is 40~60m/h), backwash layering flow velocity of 10m/h, regeneration flow velocity of 5m/h. The system online monitors the outlet water quality through a resistivity meter. When the resistivity of the outlet water exceeds the value, the mixed bed control valve starts regeneration automatically. Runxin mixed bed control valve adopts ceramic hermetic sealing structure which is acid and alkali resistance, and synchronous regeneration method is adopted when the anion and cation resin is regenerated which makes regeneration effect better. The control valve is equipped with acid and alkali drawing injector, which can draw the acid and alkali respectively and synchronously regenerate cation resin and anion resin.

The process flow of the water treatment system is: raw water→ activated carbon filter→ softening system→reverse osmosis system→middle water tank→booster pump→mixed bed ion exchange system→deionized water tank.

(3) Operation effect

After the raw water is deionized by the system, the outlet water resistivity is ＞15MΩ.cm, and can be up to 17.6MΩ.cm. It runs for 8 hours a day and regenerates once every half a month. The deionization effect is good, the operation intensity of workers is low, and the operation cost is low.



Figure 5-12 Mixed bed treatment system

6. Application of Runxin valve in special water treatment system

The special water treatment mentioned in this chapter mainly refers: removing iron, manganese, dissolved oxygen, fluorine, arsenic, nitrate and nitrite, copper, lead, zinc, nickel and other heavy metal ions in the water.

6.1 Application of Runxin valve in iron and manganese removal system

6.1.1 The impact of iron and manganese water on life

Groundwater containing iron and manganese is widely distributed. Iron and manganese can coexist in groundwater and often exist in the form of ferrous iron and manganous manganese with higher solubility. Due to the high content of dissolved oxygen in surface water, iron and manganese are mainly deposited in the water in the form of insoluble Fe $(OH)_3$ and MnO_2. Ferrous iron and manganous manganese are relatively stable in the anoxic groundwater, but once exposed to air, they are easily oxidized into Fe_2O_3 and MnO_2 that are hard to be dissolved in the water. Therefore, for groundwater with a high content of ferrous ions, it is often seen that the colorless groundwater that has just been pumped from the well will gradually turn into a turbid brownish red after a period of time. The higher the iron content is, the darker the color is. The reason is the ferrous Fe in the water is oxidized to Fe_2O_3.

It is difficult to detect if the iron content in the water is <0.3mg/L; when it is more than 0.3mg/L, it is easy to make clothes and utensils colored and yellow; when the iron content is greater than 0.5mg/L, the water will turn yellow and the chromaticity can be more than 30 degrees; when it reaches 1.0mg/L, there will be an obvious rust odor. Iron ions are also easy to promote the growth of iron bacteria in the pipe network, forming a viscous film in the pipe network, causing pollution to domestic and production water and damage to the pipeline. In addition, when water with high iron content enters the boiler and heat exchange equipment, it is easy to form iron oxide scale and under-deposit corrosion; when raw water with high iron content enters the ion exchanger, it is easy to make the resin poisoned.

When the manganese content in the water is $>$ 0.1mg/L, the drinking water will have an unpleasant taste, and make the utensils and washings colored; if the manganous compound in the solution is oxidized, it will form the sediment and cause scaling; when the content of manganese in the water reaches 0.2mg/L, a layer of coating will be formed on the inner wall of the water pipe and will flow out with the water, causing black sediment.

Manganese is one of the trace elements which are necessary for the human body, animals and plants, but excessive intake of manganese can cause poisoning, and long-term exposure to manganese compounds can also cause manganese poisoning. Early manifestations include fatigue, weakness, dizziness, headache, insomnia, weakness of the lower limbs, etc. Severe

poisoning can also cause speech disorders, slurred speech, difficulty in speaking, and incoherent speech. The manganese will make the water color, smelly, and taste, affecting the quality of industrial products such as textiles, papermaking, brewing, and food, causing pollution to household appliances, and making clothes have blackish or light gray stains.

Therefore, the water that is rich in iron and manganese ions will cause greater harm to human life, industrial and agricultural production, and it needs to be treated before put into use.

6.1.2 Common water treatment processes for removing iron and manganese

6.1.2.1 Iron removal

Ferrous iron in groundwater is unstable and aeration method is often used to remove it. Ferrous iron in groundwater usually exists in the form of bicarbonate Fe $(HCO_3)_2$. Generally, groundwater is pumped into the aeration tank through a water pump, and compressed air is introduced into the water through pipeline or aeration tank or air is mixed into the pipeline by injector. So, the oxygen in the air and water can be fully mixed to achieve the purpose of oxidizing ferrous iron to ferric iron. Then filter through manganese sand or other iron and manganese removing filter media to remove the iron oxide sediments.

Natural manganese sand (the main component is manganese dioxide) is a good catalyst for the oxidation of ferrous iron to ferric iron. When the pH value is greater than 5.50 (generally, the pH value of the raw water should be maintained at 6.5 to 7.0 to obtain a better treatment effect), it can accelerate the oxidation of ferrous iron to ferric iron. The chemical reaction equation is as follows:

$$4Fe^{2+} + O_2 + 8OH^- + 2H_2O \rightarrow 4Fe(OH)_3\downarrow$$

During the oxidation process, enough dissolved oxygen must be maintained in the water to oxidize the ferrous iron to ferric iron. In addition, after hydrolysis, it will be the colloidal ferric hydroxide sediments that are brown floc. The iron can be removed by filtration through a manganese sand filter.

6.1.2.2 Manganese removal

Manganese removal by oxidation is basically same as iron removal. After aeration, when the raw water passes through the manganese sand filter media, under the action of the manganese active filter membrane on the surface of the manganese sand filter media, Mn^{2+} in the water is oxidized by dissolved oxygen to MnO_2, and is adsorbed on the surface of the filter media, making the filter membrane be renewed. The process is also an autocatalytic reaction. The reaction formula is:

$$2Mn^{2+} + O_2 + 4OH^- \rightarrow 2MnO_2\downarrow + 2H_2O$$

When the manganous salt in water is filtered, the following chemical reaction may also occur due to MnO adsorption:

$$MnO_2 \cdot H_2O + Mn^{2+} + 2OH^- \rightarrow MnO_2 \cdot MnO \cdot H_2O + H_2O$$

Effective manganese sand　　Invalid manganese sand

After the manganese sand is combined with Mn^{2+} to generate manganese sesquioxide, it loses its manganese removal function. It needs to add oxidant for regeneration and re-oxidize $MnO_2 \cdot MnO$ to MnO_2. In general, the method is adding chlorine (Cl_2) to the water to restore the manganese removal function of the manganese sand. The reaction formula is:

$$MnO_2 \cdot MnO \cdot H_2O + 2H_2O + Cl_2 \rightarrow 2MnO_2 \cdot H_2O + 2HCl$$

The removal of manganese is more difficult than the removal of iron. When iron and manganese coexist, iron has the negative effect on the removal of manganese. In the filter layer, the removal of iron must be completed before manganese removal. Therefore, in order to realize a stable manganese removal effect, the concentration of Fe^{2+} should not exceed 2mg/L.

6.1.2.3 Removal method when iron and manganese coexist

(1) When the iron and manganese content in the raw water is high (iron content exceeds 5mg/L and the manganese content exceeds 1.5mg/L), if the manganese sand is simultaneously used for treatment, the iron is easier to be oxidized than manganese and manganous manganese is more difficult to be oxidized to tetravalent manganese. Therefore, it is generally necessary to adopt secondary filtration. That is, remove iron first, making the concentration of Fe^{2+} below 2mg/L, and then remove manganese. The process is:

Groundwater→deep well pump (variable frequency pump)→aeration→primary filtration (remove iron)→secondary filtration (remove manganese)

（2）When the iron and manganese content in the raw water is low (iron content is less than 5mg/L and the manganese content is less than 1.5mg/L), it can adopt one filtration. The process is:

Groundwater→deep well pump (variable frequency pump)→aeration→filtration (remove iron and manganese)

6.1.3 Iron and manganese removal filter media

At present, the common filter media for removing iron and manganese in China includes manganese sand, SS filter media, synthetic molecular sieve "JM-3" filter media, which is mainly realized by the principle of chemical reaction and adsorption.

Manganese sand is mainly used to remove manganese by using the manganese active filter membrane MnO_2 on the surface; SS filter media is a porous particle filter media containing silicon, iron and aluminum, which has good filtration, adsorption and flocculation precipitation effects; JM-3 type filter media is a lattice tetrahedron of silicon, aluminum, and oxygen, which can realize the function by adsorption and ion exchange.

The silicon in the JM-3 iron and manganese removal filter media is exchanged with

aluminum. Aluminum is trivalent and silicon is tetravalent. It lacks a charge and needs to be supplemented by positively charged ions. When the water contacts with the JM-3 filter media, the positively charged ions in the water can supplement the short charge in the JM-3 filter media, so that it can be absorbed by the filter material to achieve the purpose of water filtration. It can effectively remove most of the inorganic salts and some organic substances in the water with a removal rate of 70% to 90%. Especially for the treatment of toxicological substances such as fluorine, arsenic, mercury, lead, cadmium, selenium, molybdenum, iron, manganese, zinc, calcium, magnesium, etc., the effect is remarkable.

The JM series filter media is a porous material, containing many pores, with a pore diameter between 0.5 and 1.6 nanometers, and has a large specific surface area (generally (500-1000) m^2/g). In the production, it is activated by physical and chemical methods to achieve the purpose of removing ions, so it can be regenerated and reused. The material is strong, acid and alkali resistant, high temperature resistant, and its service life can reach decades.

The comparison of common iron and manganese removal filter media is shown in Table 6-1.

Table 6-1 Comparison of common filter media for iron and manganese removal

Item	Manganese sand	JM-3 type filter media	SS filter media
Bulk density	(1.8～3.2)kg/cm³	(0.9～1.1)kg/cm³	(0.5～0.8)kg/cm³
Composition	Natural manganese ore (compound that contain manganese)	Synthetic materials	Synthetic materials
Principle of manganese removal	Adsorption and retention	Chemical reaction, adsorption and retention	Adsorption and retention
Service life	Average two years	＞10years	Average two years
How to remove iron and manganese	Remove iron first, then remove manganese. Add alkali to increase the pH value of the water after aeration and removing manganese; add acid to adjust the pH value of the outlet water to below 8.2.	After aeration, the water enters the filter layer (down flow), and the iron and manganese are adsorbed and retained. The iron content of the outlet can reach<0.3mg/L and the manganese content can reach<0.1mg/L.	Remove iron first, then remove manganese. Add alkali to increase the pH value of the water after aeration and removing manganese;
Regeneration way	Use the water that contain iron and manganese to backwash, add chlorine or ozone or other oxidizing substances in the water to regenerate manganese sand filter media	Use 2.5% dilute base solution to make the media is soaked by dynamic and static way for about 3 hours to restore iron and manganese removal ability.	Use the water that contain iron and manganese to backwash
Filtration flow velocity	8.0m/h Downstream, flow velocity 8.0m/h		
Filter media replacement cycle	Replace within 1 ~ 2 years	No need to replace within 10 years	Replace within 1 ~ 2 years
Backwash times/water consumption	Runs for 4 -8 hours to backwash once, with high water consumption.	Running one cycle to backwash once, low water consumption and water saving.	Runs for 4-8 hours to backwash once, with high water consumption.
Tank material and service life	Using carbon steel tanks, the average service life is 8 years; surface anti-corrosion treatment should be done every year.	The tank body is FRP structure, and the average service life is more than 20 years. It is a green material.	The tank body is a FRP wire-wound structure or a carbon steel tank body.
Comparison of regeneration reagent consumption	Relatively high	Low	Relatively high
Conclusion	It can remove iron and manganese. It is difficult to operate and manage, and the operation cost is high. The overall cost is too high, and the outlet water quality of system is unstable.	The iron and manganese removal process is simple, easy to manage, and low operating cost. The overall cost is low, and the outlet water quality of system is stable.	It can remove iron and manganese. It is difficult to operate and manage, and the operation cost is high. The overall cost is too high, and the outlet water quality of system is unstable.

6.1.4 Common methods of oxidizing ferrous ion and manganous manganese

According to the content of iron and manganese and the situation of the project, the common methods to oxidize ferrous ion and manganous manganese are aeration method and ozone oxidation method.

6.1.4.1 Aeration method

Common aeration methods are divided into drop aeration method and injector aeration method. Their characteristics are as follows:

(1) Drop aeration method: the groundwater is pumped up through a deep well pump and directly dropped from a height to the pool. During the water falls from a height, the water contacts with the air, thereby increasing the dissolved oxygen in the water. This method is not sufficiently aeration, and is mainly used in groundwater with low iron and manganese content.

(2) Injector aeration method: in the process of pumping groundwater up through a deep well pump, an injector is added on the water pipeline. The water passes through the main pipe of the injector to generate negative pressure to suck and mix the air, and finally enter the pool. The dissolving oxygen capacity of this method is higher than that of the drop aeration method.

6.1.4.2 Ozone oxidation method

(1) The principle of the ozone oxidation method: by installing an ozone generator in the filter system, ozone is used to promote the oxidation of ferrous iron and manganese, and then removed by the filter material. Some households in the United States which are far away from cities often use the ozone oxidation method, considering it is difficult to install tap water pipes, the groundwater contains high iron and manganese and the place is limited. The oxidation-reduction reaction of oxidizing iron and manganese ions are:

$$6Fe^{2+} + O_3 + 8OH^- + 7H_2O \rightarrow 6Fe(OH)_3\downarrow + 4H^+$$

$$3Mn^{2+} + O_3 + 2OH^- + H_2O \rightarrow 3MnO_2\downarrow + 4H^+$$

(2) The main equipment and process of ozone oxidation

The equipment is composed of an aeration tank and a filter tank. The ozone generated by the ozone generator enters the aeration tank. The filter tank is filled with a special filter media for removing iron and manganese, and the Runxin softener valve is used for automatic control. The water treatment process is:

a) Service: the water flows into the aeration tank first and is oxidized by ozone aeration. Then enters the filter tank, and it is filtered through a special iron and manganese filter media, removing the oxidized iron and manganese colloidal precipitate. When the system reaches the set water treatment capacity or cycle, the backwash is required to remove the sediment in the filter tank and aeration tank, and the backwash is started through program control.

b) Backwash: the water flows from the bottom of the filter tank, washing and loosening the filter layer from bottom to top. The iron and manganese colloidal sediment trapped in the filter

layer during filtration are drained out to the bottom of the aeration tank; continue to rinse from bottom to top, discharging the sediment in the bottom of aeration tank together with the residual exhaust air in the upper part from the control valve. When the iron content is less than 10mg/L, it can be backwashed directly with raw water. When the iron content is greater than 10mg/L, it needs to be backwashed with the treated water.

c) Feed ozone: after the backwash is completed, the control valve will switch to the brine draw status (at the same time the ozone generator is activated), so that ozone enters the aeration tank. When the ozone volume in the tank reaches a certain amount, the control valve will switch to the fast rinse status.

d) Fast rinse: the water enters the aeration tank for aeration and oxidation, and then flows into the filter tank to rinse the filter media from top to bottom. After the fast rinse is finished, switch to service status.

An automatic softener valve is suggested to remove iron and manganese by ozone oxidation. As there is no brine tank and no need to brine refill, the brine refill time of the softener valve should be set to 0. when the softener valve switches to the brine draw status, the ozone generator should start and feed the ozone into the aeration tank. The installation diagram is shown in Figure 6-1, the right tank is an aeration tank, and the left tank is filled with filter media.

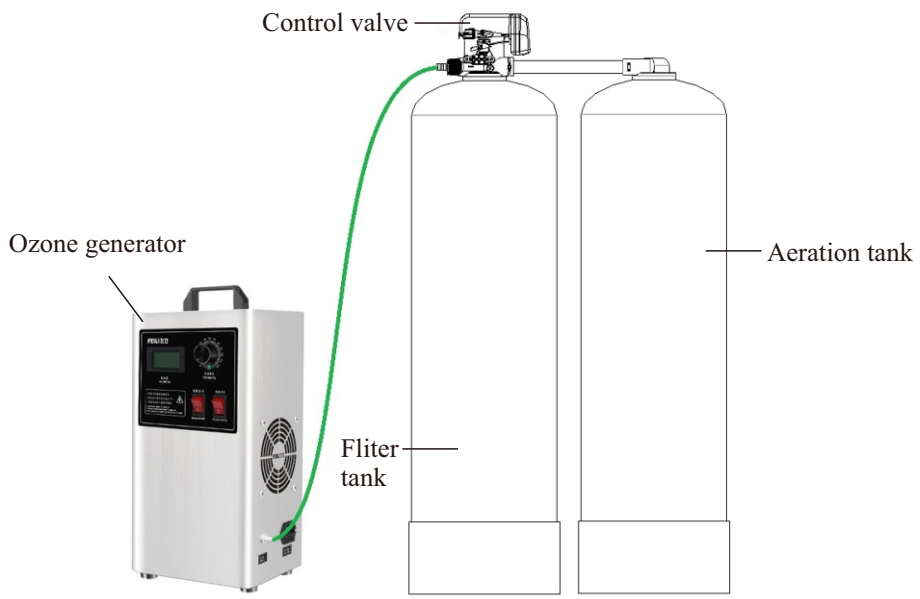


Figure 6-1 Iron and manganese removal system with ozone

6.1.5 Iron and manganese removal system actual application

Considering the particularity of the process of removing iron and manganese and the particularity of the filter media, attention should be paid when selecting the filter control valve. The side-mounted filter valve should be selected, and the control valve should be selected to meet the system requirement on "backwash flow rate".

6.1.5.1 Runxin automatic control valve used in the iron and manganese removal system

6.1.5.1.1 Rural drinking water renovation——waterworks adopt aeration filtration to remove iron and manganese

(1) Project background

Many waterworks in northern China use groundwater as a source of water supply. However, in some areas, the iron and manganese content in groundwater is relatively high, and it must be treated before it can be supplied to the user's home.

In a town in northwestern Jilin, a waterworks has a daily water supply of 1200m^3, and its water source is groundwater. China national standards require that the iron content of tap water is less than 0.3mg/L and the manganese content is less than 0.1mg/L. However, the iron content in the local groundwater is 1.0mg/L, manganese content is 0.4mg/L, the total bacterial count exceeds the standard, which does not meet the national water quality standards for centralized water supply. The water needs to treated before it can be supplied to the residents.

(2) Project introduction

Considering the iron and manganese content of the raw water does not exceed too much, the iron and manganese are designed to be removed by SS filter media after aeration. The system uses a water pump to pump the well water to the water tank. After being aerated by a blower, it flows into the iron and manganese removal filter system. The system is equipped with a filter tank with a diameter of 1.5m and a height of 2.2m (filled with SS filter media), matched with Runxin valve 53540. The filtered water is sterilized by a chlorine dioxide generator, then enters the water purification tank, and is supplied to each water point by a water pump.

The water treatment process used in the iron and manganese removal system is shown in Figure 6-2. The process is: well water→pump to well water tank→aerated by a blower at the same time→raw water pump→iron and manganese removal filter→sterilization (chlorine dioxide generator)→water purification tank. The filter system device is shown in Figure 6-3.

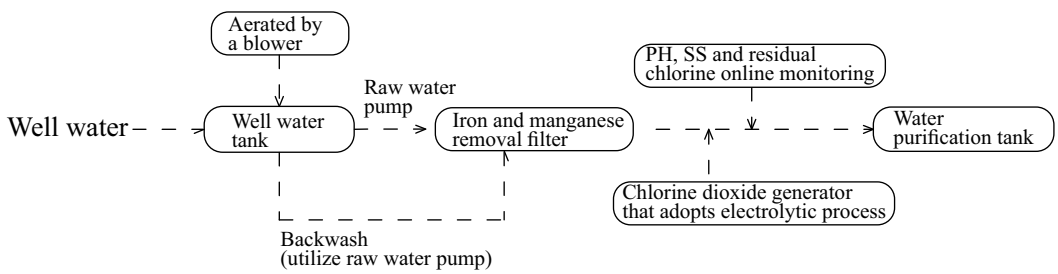


Figure 6-2 Aeration and filtration treatment process for iron and manganese removal in the waterworks



Figure 6-3 Iron and manganese removal device and system

(3) Operation effect

After the well water is aerated, Fe^{2+} is oxidized to Fe^{3+}, and Mn^{2+} is oxidized to MnO_2, which is removed after adsorption and filtration by SS filter media. The iron content in the outlet water of the system is less than 0.3mg/L and the manganese content is less than 0.1mg/L; sterilization is performed by chlorine dioxide generator. The iron and manganese content and the total bacterial count in the water supply meet the national standards. The system has been operating well since it was put into use in 2018.

6.1.5.1.2 Manganese removal in wastewater treatment of factory

(1) Project background

Some metal processing plants have high iron and manganese content in the wastewater produced during the production. Under normal situation, it is usually discharged into the sewage station for treatment, but this will waste a lot of water resources. A stainless-steel company in Qingdao of China mainly produces cold-rolled sheets. The manganese content of the wastewater produced during the production is as high as 1.5mg/L ~ 2.5mg/L, exceeding the discharge standard which requires the manganese content should not greater than 0.1mg/L. And some metal impurity particles are contained in the wastewater, and they also need to be processed before they can be reused. The flow rate is required to be $6m^3/h$, and need continuous water supply.

(2) Project introduction

In order to reduce the manganese content from 1.5mg/L ~ 2.5mg/L to below 0.1mg/L, manganese sand treatment is followed after aeration treatment. In order to ensure continuous

water supply, the manganese removal filter adopts one in service one standby way.

As the wastewater contains metal impurity particles, sedimentation and grid network are used to remove the wastewater. The wastewater is discharged into the sedimentation tank. The sedimentation tank is built with grid network, and the particulate impurities are trapped on one side. After the sedimentation and preliminary filtration, the wastewater enters the collection tank and feed compressed air to aerate at the same time; use a self-priming booster pump to pressurize the wastewater to pass through a bag filter, then enter the manganese sand filter, and the treated clean water flows into the pool. The filtration system uses two φ900×2200mm carbon steel filter tanks (lined with rubber), filled with 1.2 tons of manganese sand, and adopts Runxin 53520 automatic control valves and a three-way valve, forming a one in service one standby system.

The process of the wastewater treatment system is: wastewater→wastewater sedimentation tank→grid network→wastewater collection tank (aeration with compressed air)→self-priming booster pump (start and stop according to the liquid level of the pool)→bag filter→electric three-way valve (switch during service, backwash and fast rinse status)→manganese sand filter (one in service one standby)→electric three-way valve (one in service one standby)→ reserve water tank. The system is shown in Figure 6-4.

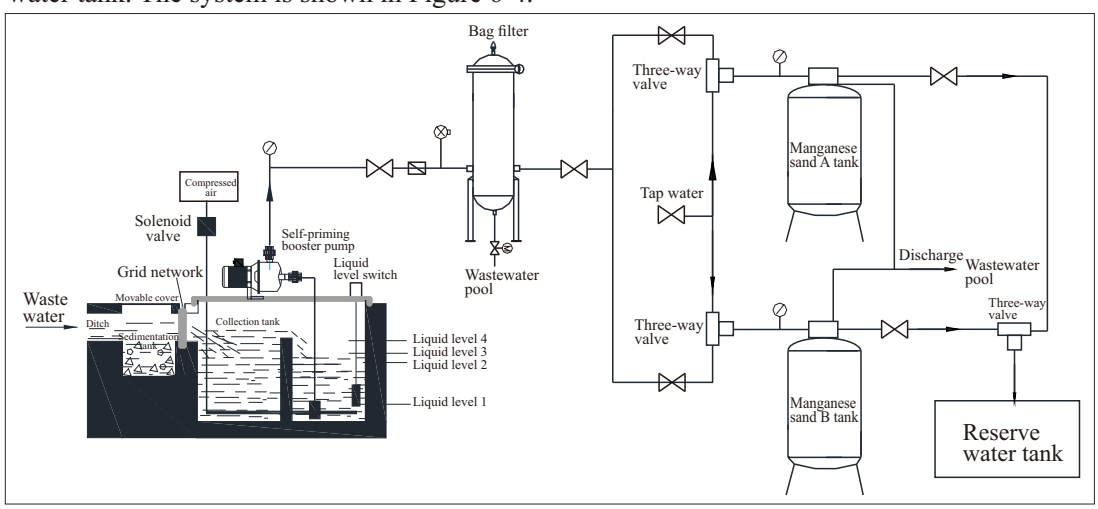


Figure 6-4 Manganese removal treatment system for wastewater

(3) System and device requirements

① The setting of the sedimentation tank and grid network is shown in Figure 6-5.

② Before the wastewater collection tank, dig a concrete sedimentation tank with a depth of 0.5m and a side length of 1.2m underground to settle the large particles of impurities in the water to the bottom of the pool. The overflow is installed with a plug-in grid network (filter mesh with 18 mesh, the accuracy is 830 microns), which can realize regular online manual removal of impurities at the bottom of the sedimentation tank and cleaning the grid network without stopping the machine.

③ Wastewater collection tank size: length × width × height is about 2m×2m×2.5m, the middle is separated, the inside is connected with aeration pipe. The compressed air device open and close according to the liquid level, and it is closed when the liquid level is low.

④ In order to ensure continuous water supply, two self-priming booster pumps are set up, which are turned on according to the liquid level of the pool. When the liquid level of the pool reaches the high level, two pumps will start at the same time; when the liquid level is lower than the high level and higher than the low level, a single unit will start; when the liquid level is lower than the low level, the two pumps will stop.

⑤ Two manganese and sand filters makes up one in service one standby system which adopt the tap water for backwash. When the filter tank A reaches the preset service cycle, the outlet water is automatically switched from tank A to tank B through Runxin 53520 control valve and three-way valve. Then tank A starts backwash, and after the fast rinse, it turns to the service status. The equipment is shown in Figure 6-6.

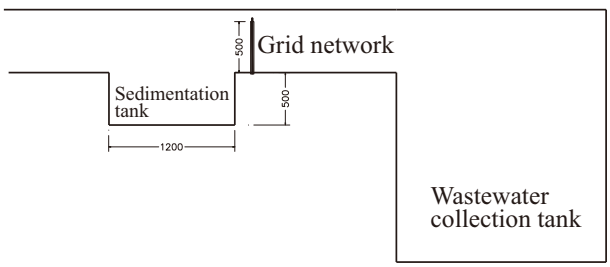


Figure 6-5The setting of the sedimentation tank and grid network



Figure 6-6 Manganese sand filter system

(4) Operation effect

The wastewater treatment system was put into use in June 2017 and has been operating normally for 24 hours each day. The reuse of reclaimed water after wastewater treatment has good economic and social benefits.

6.1.5.2 Runxin electronic ceramic ball valve used in the iron and manganese removal system

In the special water treatment system, when a single multi-functional flow control valve can't meet the user's demands for different water treatment methods and water treatment capacity, a control system composed of multiple electronic ceramic ball valves and ball valve controllers can be used to automatic control the removal of iron and manganese, meeting the user's requirements for water treatment capacity and water supply.

The multi-valve control process consists of one controller and multiple electronic ceramic ball valves. Electric ceramic ball valves are installed at different points in the same system, and different process is completed in different opening and closing sequences of ball valves at different times. Thereby complete oxidation, filtration, regeneration, backwash, fast rinse and other process which are required for iron and manganese removal, forming a dynamic chain of iron and manganese removal processes to achieve the purpose of reducing iron and manganese content and purifying water. The following is a case of using this system to remove iron for the feed water used in a central heating boiler in a city.

(1) Project background

The groundwater system of the Liaohe River Basin in northern China is rich in iron and manganese, and the quality of groundwater is not ideal. However, due to insufficient surface water, groundwater is still used for water supply in this area. As the feed water of the heating boiler, in order to prevent the heating boiler from scaling and corrosion, the feed water must be treated with iron and manganese removal. A largest thermal heating company in a certain area is responsible for heating services for 60% of the local heating area. One of the heating projects needs to use two 100t/h hot water boilers to supply heating for an area where it is located. Groundwater is used as the source water. The average iron content in the water is 29.5mg/L and the manganese content is 3.5mg/L. In order to prevent iron-manganese oxide scaling from depositing on the heated surface, and to avoid resin being polluted by iron during softening treatment, the iron and manganese removal treatment must be carried out first, and then followed by the water softening treatment.

(2) Project introduction

According to the GB/T 1576 "Industrial Boiler Water Quality" standard, the iron content of the feed water for hot water boiler should not exceed 0.3mg/L. The iron content in the raw water is as high as 29.5mg/L, which is seriously exceeding the standard. In order to make the iron removal treatment meet the requirements of the standard, the iron removal and manganese removal treatment should be carried out after sufficient aeration.

This project uses JM-3 filter media to remove iron and manganese at the same time. During service, in order to meet the requirements of feed water for boiler, firstly adjust the pH value of the inlet water to 8.5, and then fully aerate the water through an aeration device (oil-free air

compressor) to oxidize the ferrous iron and manganous manganese into ferric iron and tetravalent manganese, and then pass the filter device filled with JM-3 filter media to remove iron and manganese. When the water treatment capacity reaches the set value, 2.5% NaOH solution needs to be used to regenerate the filter media to restore the treatment effect. During regeneration, the 2.5% NaOH solution with 0.8 times the volume of the filter media is pumped into the filter media through the regeneration pump, and then returned to the regeneration liquid tank. After cycling for three hours, turn off the regeneration pump and soak for three hours. Wash out the regeneration liquid in the tank with raw water until the PH value of the outlet water is less than 8.5, then the iron and manganese oxide deposits stored in the filter media can be removed, so as to realize the repeated use of the filter media.

Due to the high iron content in the groundwater, the system is designed to filter at a lower flow velocity, and the service flow velocity is generally controlled to be 8m/h; the system is equipped with a set of FRP tanks with a diameter of 1.8m and a height of 2.85m, filled with JM-3 filter media. An automatic control system is formed by multiple Runxin DN50 ball valves and special ball valve controllers to realize the removal of iron and manganese to meet water supply. The water treatment system equipment installation is shown in Figure 6-7, and the system process is as follows:

Groundwater→Variable frequency pump→PH adjustment device→Aeration device (oil-free air compressor)→Iron and manganese removal equipment (with regeneration device)→ Water purification tank→Variable frequency pump→User



Figure 6-7 Iron and manganese removal system and device

The installation diagram of the iron and manganese removal system which adopts ball valves is as follows:

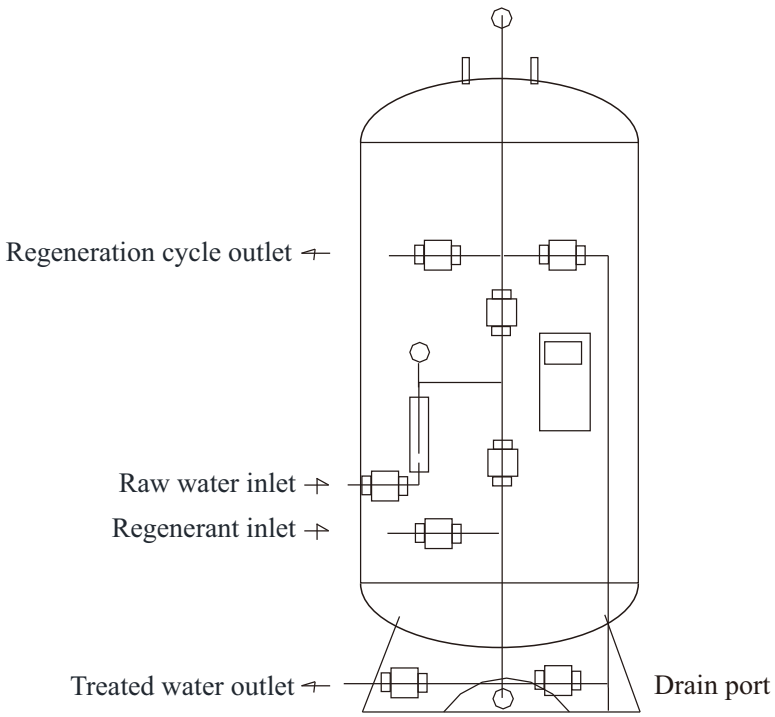


Figure 6-8 Installation of iron and manganese removal system

(3) Operation effect

After the groundwater is aerated, the colloidal oxides formed by the oxidation of the ferrous iron and manganous manganese are removed by JM-3 filter media adsorption and chemical reaction. After testing, the treated outlet water iron content is <0.1mg/L, manganese content is <0.05mg/L, and the water in the storage tank is clear, colorless and tasteless. Since the filter media can be regenerated by NaOH in time to restore the effect of removing iron and manganese, it has a long service life (average is more than 10 years). The operating cost is low, which is different from the manganese sand that needs to be replaced regularly. The system was put into use in 2011 and has been still operating normally.

6.2 Application of Runxin valve in deoxygenation system at room temperature

6.2.1 The influence of dissolved oxygen in water on boiler

The corrosion of boiler metal is mainly divided into oxygen corrosion, acid corrosion or alkaline corrosion and under-deposit corrosion. Acid corrosion and alkaline corrosion could be avoided by controlling the PH value and alkalinity of feed water and boiler water, under-deposit corrosion could be avoided by controlling the hardness of the feed water to prevent boiler from scaling, or cleaning and descaling the scaled boiler. At present, the most common corrosion of boilers is oxygen corrosion. It will make the metal wall thinner, significantly reduce the boiler pressure-bearing capacity, easily cause damage and affect safe operation of boiler once the metal surface is corroded by oxygen. In addition to shutting down the boiler for maintenance, deoxidizing feed water during operation is also an effective method to prevent boiler oxygen corrosion. In GB/T1576 standard "Water Quality for Industrial Boilers", the regulation of dissolved oxygen content in boiler water is shown as table 6-2:

Table 6-2 Dissolved oxygen standard of boiler feed water under different pressure conditions

Unit:mg/L

Nominal steam pressure (MPa)	Steam boiler				Hot water boiler	
	p≤1.0	1.0＜p≤1.6	1.6＜p≤2.5	2.5＜p≤3.8	Feed water	Boiler water
Dissolved oxygen	≤0.10	≤0.050			≤0.10	≤0.50

6.2.2 Common methods of boiler feed water deoxygenation

(1) Thermal deoxygenation

It adopts Henry's law that the solubility of a gas in the liquid phase is proportional to the equilibrium partial pressure of that gas at the vapor-liquid interface. In the open equipment, the water is heated to the boiling point to make the water boil. The pressure of the water vapor on the water surface is equal to the external pressure, and the partial pressure of other gases is zero. At this time, all the gas dissolved in the water will escape, thereby removing the dissolved oxygen in the water. Thermal deoxygenation is usually applied to steam boilers. Hot water boiler are generally not suitable for thermal deoxygenation due to insufficient deoxygenation temperature, it usually adopts chemical deoxygenation or normal temperature sponge iron deoxygenation.

(2) Vacuum deoxygenation

The working principle of vacuum deoxygenation is similar to thermal deoxygenation. The dissolved oxygen, carbon dioxide and other gases in water can be removed by taking advantage

of the fact that the solubility of gas in the boiling state of water is close to zero. Since the boiling point of water is related to pressure, at room temperature, vacuum can be used to make it boil. That is, when the water temperature is stable, the lower the pressure (that is, the higher the vacuum), the less the residual oxygen and carbon dioxide content in the water.

(3) Chemical deoxygenation

It removes oxygen by adding chemicals to water and reacting with dissolved oxygen. Due to the addition of chemicals, the salt content of feed water is increased, and the deoxidization reaction is slow and the effect is limited. It is usually used as an auxiliary deoxidization method.

Commonly used agents for chemical deoxygenation of boilers mainly include hydrazine (auxiliary deoxygenation of power plant boilers) and sodium sulfite (only for industrial boilers).

(4) Sponge iron deoxygenation at room temperature

The filtration type deoxygenation at room temperature is a kind of chemical deoxygenation. It adopts active sponge iron (Direct Reduced Iron) to remove dissolved oxygen in water. The main component of sponge iron is iron. Its porous internal structure provides a specific surface area of 50,000-100,000 times that of ordinary iron filings. Because of its large surface area, the dissolved oxygen in water can react with iron while water which contains oxygen passing through this special sponge iron filter media, so that the oxygen content of the water is less than 0.05mg/L due to the consumption of oxygen. Its chemical reaction formula is:

$$2Fe + 2H_2O + O_2 \rightarrow 2Fe(OH)_2\downarrow$$

$$4Fe(OH)_2 + 2H_2O + O_2 \rightarrow 4Fe(OH)_3\downarrow$$

The $Fe(OH)_2$ and $Fe(OH)_3$ which are produced by the reaction are water-insoluble soft floccule. When they accumulate to a certain extent, they can be washed away from the filter media by backwash and recover to the original filtering capacity. The consumption of sponge iron is very low. Depending on the amount and quality of the treated water, it is generally replenished once every 3 to 6 months.

6.2.3 Application cases of Runxin valve used in deoxygenation system at room temperature

Thermal deoxygenation, vacuum deoxygenation and chemical deoxygenation can directly treat the water by heating, vacuuming, and adding oxygen removal chemicals, do not need the control valves. So, the following are only examples of Runxin valve application in sponge iron deoxygenation at room temperature.

(1) Project background

Most of the northern China heating stations use groundwater as boiler feed water. Generally, the oxygen proportion of groundwater is not high, but the hardness is high. Therefore, it is necessary to remove or reduce the hardness by softener. During the softening process, oxygen in the air is easy to dissolve in water. Therefore, in order to prevent the boiler from oxygen corrosion, it is also necessary to carry out deoxygenation treatment. A heating station in Hebei

province of China, use deep well water as raw water. After softening, the dissolved oxygen content in the water is about 8.5mg/L. It is required that the dissolved oxygen content in the feed water for the boiler should be less than 0.1mg/L through deoxygenation.

(2) Project introduction

The project adopts sponge iron deoxygenation at room temperature. It is equipped with two sets of FRP tanks with diameter of 1.6m and height of 2.6m, and the tanks are filled with sponge iron. Adopting Runxin 53530 filter valve to form two sets of sponge iron deoxygenation systems for water supply in parallel. The design average flow velocity is 12m/h (generally 8m/h~15m/h), backwash according to set service days, and equip it with ball valve, as Figure 3-6 shows, to enlarge backwash flow rate, and interlock with interlock wire to prevent two filters from rinsing together. The deoxygenated water enters a sealed water tank and is used as boiler supplemental water.

The working process for this system is: raw water tank→ raw water pump→ softening treatment system→ sponge iron deoxygenation filter→ deoxygenation sealed water tank→ boiler feed water. See Figure 6-9 for sponge iron deoxygenation filter device:



Figure 6-9 Sponge iron deoxygenation filter device equipped with automatic filter valve

(3) Operation effect

After being deoxidized by sponge iron, the oxygen content of soft water is lower than 0.05mg/L, the effect of oxygen deoxygenation is good and the operation cost is low by adding sponge iron every half a year.

In practical use, according to the size of the system, Runxin electronic ball valve and special ball valve controller are also optional to be used to form an automatic sponge iron deoxygenation system. The tank is composed of left and right chambers. During operation, the left and right chambers are running at the same time. When rinsing, the left and right chambers

are rinsing separately, so as to improve the backwashing strength. The installation diagram is shown as Figure 6-10:

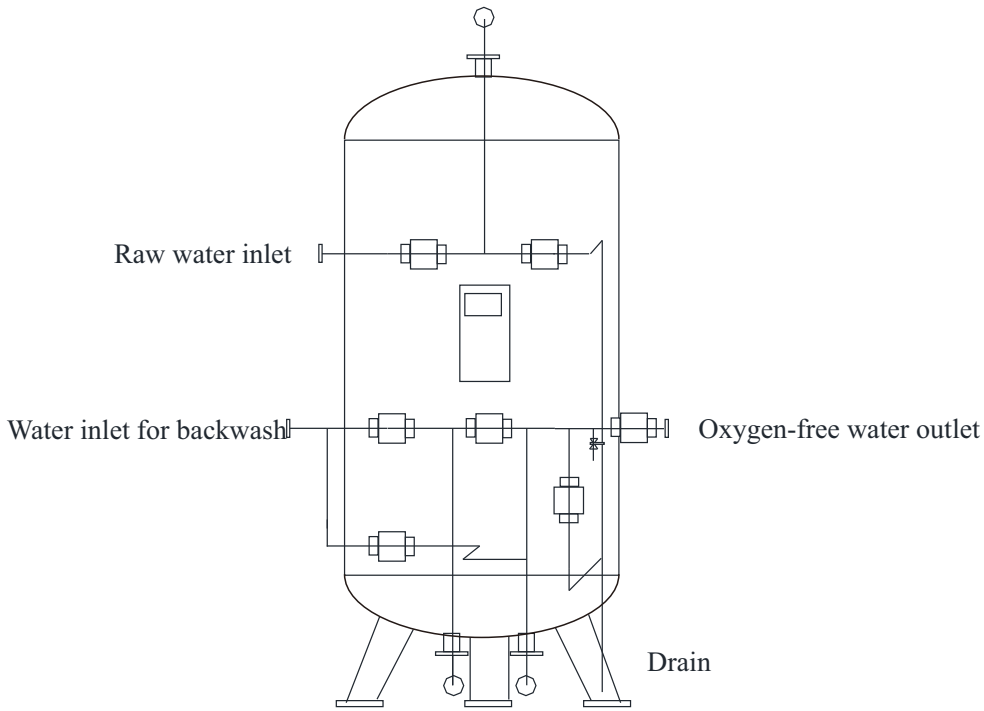


Figure 6-10 Installation diagram of sponge iron deoxygenation filter device equipped with ball valve

6.3 Application of Runxin valve in defluorination system

6.3.1 Harm of fluorinated water

Fluorine has a high chemical activity, which mainly exists in the form of CaF_2, $Ca_{10}F_2(PO_4)_6$ and Na_3AlF_6. After the groundwater comes into contact with these minerals, it will dissolve fluorine compounds, so that the groundwater contains a certain amount of fluorine, which can generally reach 0.4mg/L～0.5mg/L, and even reach 10mg/L or higher.

Fluorine has important physiological functions to the human body, and it's an important component of teeth and bones. In normal situation, fluorine content of teeth is 200ppm～600ppm, the fluorine content of adults' teeth is 11mg/100g, but it is only 6mg/100g for people suffering from dental caries. The main symptoms of chronic fluorosis are dental fluorosis (yellow teeth) and skeletal fluorosis. As shown in Figure 6-11, the surface of teeth with dental fluorosis loses luster and some have yellow, brown, or black pigmentation. In severe cases, there may be flaky or large defects, and the enamel is damaged and lost.

At the early stage of skeletal fluorosis, patients have pain and fatigue in limbs, spinal skeleton and all joints of the whole body, serious can cause limb dysfunction, the whole body bone and joint deformation, and even paralysis.



Dental fluorosis patient Skeletal fluorosis patient

Figure 6-11 Dental fluorosis and skeletal fluorosis

Considering comprehensively, when the fluorine content in drinking water is less than 1.0mg/L, it has less impact on the human body and the anti-caries effect of fluorine. Therefore, the Chinese national standard GB5749-2015 "Standards for Drinking Water Quality" stipulates that the fluorine content in drinking water shall not exceed 1.0mg/L.

6.3.2 Common methods of defluorination

(1) Fluorine-removal agent adsorption method: it is a more commonly used method for fluorine removal. The fluorine-containing water is filtered through the fluorine removal agent at a certain filtration rate, and the water from the filter candle can meet the requirements of the fluorine content of drinking water. The common fluorine-removal agents include $Ca_3(PO_4)_2$, Bone Char, activated Al_2O_3, ASA and so on. The former two have poor mechanical strength and require strong base/acid for regeneration, which is inconvenient to use. Activated Al_2O_3 has good performance, and no necessary to regenerate with strong base/acid, but it will increase the aluminum content of the outlet water. For drinking water, it is not suggested to use aluminum-containing fluorine-removal agent, because when adopting aluminum-containing fluorine-removal agent to treat fluorinated water, although the fluorine content can reach the standard, the aluminum content in the filtered water is likely to exceed the standard. The harm of excessive aluminum may be more serious than the harm to human health caused by excessive fluorine.

(2) Desalination fluorine-removal: common methods like electrodialysis, reverse osmosis and ion exchange can remove fluorine and desalt at the same time. But the process is more complicated, and the equipment investment is also higher. For water with high salt and fluorine content, these methods often have more wastewater.

(3) JM-1 type fluorine removal filtering media filtration treatment: JM-1 type fluorine removal filtering material is a kind of porous substance with pore size 0.5nm ~ 1.6nm, has large specific surface area. It adopts adsorption and ion exchange to remove fluoride. There is no active aluminum in JM-1 type fluorine removal filtering media, defluorination chemical reaction formula is as below:

F (fluorinated water) +R (fluorine removal filtering material) →FR (retentate) + H_2O

For the raw water with fluorine content is≤20mg/L, primary (single tank) defluorination treatment is generally adopted; if the fluorion content in raw water is＞20mg/L, two-stage (double tanks) or multi-stage(multi tanks) series fluorine removal system shall be adopted to make the high fluorine-containing water pass through one defluorination system to reach the fluorine removal standard. JM-1 type fluorine removal filtering material can be reused through regeneration, and its service life can reach 10 years.

(4) Other defluorination methods: the lowest cost method is to use sulfuric acid, lime flocculation or precipitation to remove fluorine, but the efficiency is low, and the treatment process also has an impact on the environment, so it is rarely used. In areas where electricity costs are low, distillation method can be considered, that is, to produce distilled water from fluorinated water.

6.3.3 Runxin valve application in defluorination system

(1) Project background

Taonan of Jilin Province is located in the remote area of Northwest China, with a population of more than 10,000. There is no tap water supply, so it can only rely on the small-scale centralized water plant to solve the drinking water problem. However, the local surface water resources are poor, and the fluorine content of underground water is more than 4mg/L, which seriously exceeds the requirement that the fluorine content of drinking water should not be larger than 1.0mg/L specified in GB5749-2006 "Standards for Drinking Water Quality". If the daily domestic water consumption is 80L -100L per day, it needs to treat 82t-100t water every day. If the daily water supply is 2.5h, the required water treatment flow is 32.8t/h-40t/h.

(2) Project introduction

This project adopts JM-1 type fluorine removal filtering material, matches with FRP tank with a diameter of 1.8m and a height of 2.85m. The tank is filled with JM-1 filter material with a height of 2m, equipped with several Runxin DN50 manual ball valves to form a defluorination system. The water treatment system for each system is $10m^3/h$, it adopts 4 systems working in series to achieve water supply demand $40m^3/h$.

As there is mud and sand in underground water, so it is necessary to remove the mud and sand before defluorination; then adjust the PH value of the raw water to 6.5, and then the raw water passes through the JM-1 filter to remove fluorine, the water flows from top to bottom. The low fluorinated water, whose fluorine is mostly/totally removed, will enter filtered water tank and is sent to users by pump and pipe. If the fluorine content exceeds 1.0mg/L, it means that the filter material is saturated with adsorption, and a special regenerant is needed to regenerate the filter material to achieve repeated use of the filter material. The equipment installation is shown as Figure 6-12. The working process of the system operation is:



Figure 6-12 Water supply and defluorination system in Taonan of Jilin Province

(3) Operation effect

The fluorine content in the outlet water of the system is less than 0.25mg/L, which is lower than the requirement that the fluorine content in drinking water cannot exceed 1.0mg/L, which is issued in GB5749-2006 "Standards for Drinking Water Quality". And the outlet water is produced very stable since 2011.

6.3.4 Selection principles for the application of Runxin control valves in the defluorination process

(1) Runxin manual ceramic ball valve needs to be combined into a side-mounted manual controlling system, adopting the defluorination process of "down-flow filtration, up-flow regeneration";

(2) Runxin electronic ceramic ball valve needs to be combined into a side-mounted automatic controlling system, adopting the defluorination process of "down-flow filtration, up-flow regeneration";

(3) Runxin side-mounted multi-functional flow control valve adopts "down-flow filtration, up-flow regeneration" automatic control valve. Figure 6-13 Runxin valve application in defluorination equipment:



Defluorination system composed of ball valves



Defluorination system composed of control valves

Figure 6-13 Runxin ceramic ball valve and control valve application in defluorination water treatment system

6.4 Application of Runxin valve in other special water treatment systems

6.4.1 Application of Runxin valve in the purification system for removing nitrate and nitrite

6.4.1.1 Influence of nitrate and nitrite on human health

Nitrate and nitrite are widely present in water, soil, and plants in the natural environment. Intake of large amounts of nitrate can induce methemoglobinemia. The clinical manifestations are hypoxic symptoms, such as cyanosis of lips and nails, and purple spots on the skin. In severe cases, it can cause death. Nitrite is a recognized carcinogen and has a great impact on human health.

GB5749-2006 " Standards for Drinking Water Quality" stipulates that the nitrate content (calculated by nitrogen (N)) cannot exceed 10mg/L. Small centralized water supply, decentralized water supply and individual areas with restricted groundwater sources can be relaxed to 20mg /L. The nitrite content should be less than 1mg/L.

6.4.1.2 Removal method

At present, the method of removing nitrate and nitrite mainly adopts [-$N(CH_3)_3OH$] anion exchange resin for ion exchange removal. When the resin is invalid, use industrial salt (NaCl) to regenerate the resin to recover the nitrate and nitrite removal ability.

But it should be noted that the exchange flow velocity varies from different resins, when using anion exchange resins to remove nitrate and nitrite, a lower exchange flow velocity should be used. Therefore, when selecting equipment models, pay attention to the service flow rate at low exchange flow velocity.

The working process of nitrate and nitrite removal is: groundwater→ variable frequency pump→ multi-media filter→ nitrate removal ion exchanger→ ultrafilter→ storage water tank→ water supply pump→ users

The ion exchange reaction formula of nitrate, nitrite and resin is as follows:

$$NO_3^- + NO_2^- + 2RN(CH_3)_3CL = RN(CH_3)_3NO_3 + RN(CH_3)_3NO_2 + 2CL^-$$

nitrate nitrite valid resin invalid resin invalid resin outlet water

6.4.1.3 Actual application

(1) Project background

A residential community in Yuhong District of Shenyang in China used self-provided underground well water for domestic water for residents. After using it for a period of time, it was found that the residents had hypoxic symptoms, such as cyanosis of lips and nails, and purple spots on the skin. The water samples were sent to the CDC for test, and it was found that the nitrate content (calculated by nitrogen) in the water was 27.5mg/L, which exceeded the national standard by 2.75 times and must be treated before use.

(2) Project introduction

The community has a total of 7,000 residents, and the average daily water consumption is about 560m^3. Since the community also provide water for the catering service industry, the total daily water consumption is about 600m^3. Based on the 15 hours as average daily service time of water treatment equipment, the designed system flow rate is 40m^3/h. The ion exchange and regeneration of nitrate removal is similar to softening, they both adopt industrial salt for regeneration, but the service flow velocity is relatively lower. This system is equipped with FRP tank with a diameter of 1.0m and a height of 2.4m, the tank is filled with 1600L I type strong base anion exchange resin, this system also use Runxin 63620 control valve and install a ball valve at outlet so as to adjust the water output to reach the design flow rate. It is equipped with two sets of ion exchange devices, one in service and one standby. The equipment installation is shown as Figure 6-14. The operation effect is good, and the nitrate content of the outlet water reaches the standard requirements.



Figure 6-14 Ion exchange devices for nitrate removal

6.4.2 Application of Runxin valve in arsenic removal

6.4.2.1 Influence of arsenic on human body

Arsenic and its compounds are very toxic. When the human body consumes too much arsenic, it will cause arsenic poisoning. Among them, arsenic trioxide, also known as arsenic, can be poisoned by oral of 5mg-50mg, and death by 60mg-100mg. Long-term consumption of arsenic-containing water or food can also accumulate arsenic in the human body and affect health.

After arsenic invades the human body, in addition to being excreted in urine, digestive tract, saliva, and breast, it mainly accumulates in osteoporosis, liver, kidney, spleen, muscles, hair, nails and other parts. Arsenic easily acts on the nervous system, and stimulates hematopoiesis. If a small amount of arsenic invades the human body for a long time, it can stimulate the formation of red blood cells. Long term exposure to arsenic can easily damage human cells and capillaries, aggravate organ damage and induce malignant tumor. Therefore, Chinese national standards stipulate that the maximum limit of arsenic in food is not more than 0.7mg/kg and that of fresh milk is not more than 0.2mg/kg. GB5749 "Standards for Drinking Water Quality" stipulates that the limit of arsenic in drinking water is 0.01mg/L, and the limit of small-scale centralized water supply and decentralized water supply is 0.05mg/L.

6.4.2.2 Methods of arsenic removal

The methods of arsenic removal include RO, JM-2 filter media adsorption etc. The cost of RO equipment is relatively higher, generally speaking, where arsenic is contained in the water source, water resources are relatively rare. However, the arsenic removal by RO will produce a large waste of water, and at the later stage of use, the cost is high and there will be a little bit troublesome for maintenance. JM-2 filter media is a kind of a special arsenic removal filter media, which can remove arsenic via adsorption and ion exchange.

6.4.2.3 Actual application cases

(1) Project background

A nursing home in Xinmin City, Shenyang of China, is located in a remote place, which is unable to be provided municipal tap water. There is no surface water nearby, and there is only groundwater for domestic water usage. After testing, the arsenic content of the groundwater is 0.12mg/L, which exceeds the limit of 0.01mg/L stipulated in the national standard GB/T 5749-2006 "Standards for Drinking Water Quality". Therefore, it can only be used after arsenic removal treatment. Since the groundwater is relatively turbid, it is necessary to perform a multi-media filtration process to remove sediment before arsenic removal.

(2) Project introduction

There is total 260 people in the nursing home, the daily water consumption is 15.6m^3. According to the average daily work of 8 hours, it is equipped with an 8m^3 filtered water tank

emergency usage. Therefore, the arsenic removal water treatment equipment is designed with a treatment capacity of $2m^3/h$.

While using JM-2 filter media for arsenic removal, a lower exchange flow velocity should be set, generally 4m/h. In addition, the pH value of the raw water should be adjusted to 8.5 ~ 9.0. It is equipped with FRP tank with a diameter of 1.0m and with a height of 2.4m, the tank is filled with JM-2 filter media especially for arsenic removal. Optionally equipped with DN25 ball valve and ball valve controller. Install the ball valve at the outlet to adjust the water output to reach the design flow rate. In the early stage of operation, the arsenic content of the outlet water is sampled and tested every 2 hours; when the water treatment capacity is approaching to set value, the arsenic content of the outlet water is detected once every 1 hour; if the arsenic content of the outlet water exceeds standard, it indicates that the filter media is saturated with adsorption, and a special regenerant is required to regenerate the filter media for the repeated usage of filter media. The system installation is shown as Figure 6-15, this system has been running well since it was installed and put into use, and the arsenic content of outlet water has reached the standard requirements. The working process of the water treatment system is as follows:

Arsenic-containing groundwater→ variable frequency pump→ mud-removal filter→ pH value adjustment device→ arsenic removal equipment (with regeneration device) → filtered water tank→water point

For special water treatment system, such as defluorination, arsenic removal, heavy metal removal, and nitrate removal, users can select different diameter of electronic ball valve and ball valve controller to form a controlling system according to the water output. The installation of special water treatment system controlled by ball valve is shown as Figure 6-16:



Figure 6-15 Arsenic removal system controlled by manual ball valve

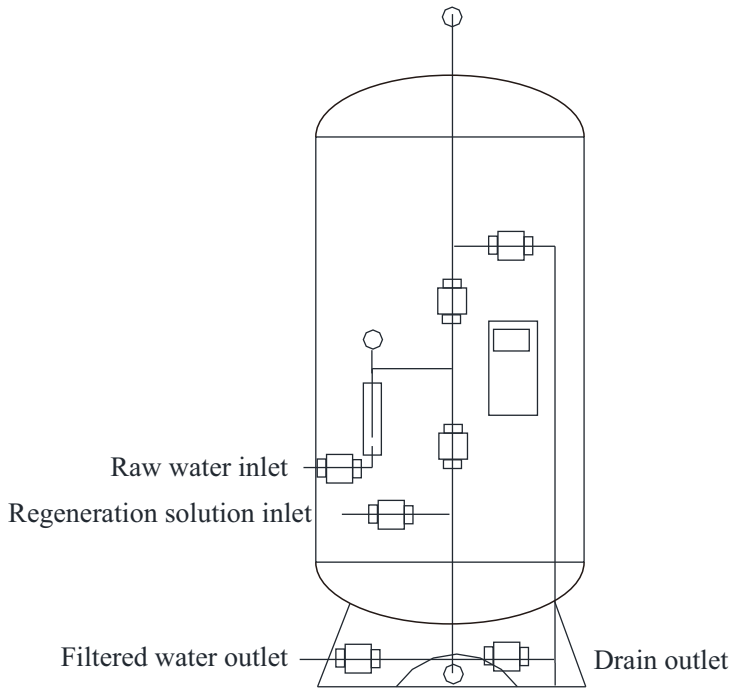


Figure 6-16 The installation of special water treatment system for defluorination, arsenic / heavy metal / nitrate removal

6.4.3 Application of Runxin valve in boron removal system

(1) Project background

Poultry farms are generally located in remote areas far away from the city, and tap water is difficult to reach, so they usually use the nearby surface water or groundwater. In order to ensure that the poultry products meet the standards and prevent the harmful substances in meat and eggs from exceeding the standard, it is usually necessary to sterilize the drinking water of poultry.

A poultry farm in Hungary uses groundwater as the source of water. The content of boron in the groundwater is high, which usually exists in the form of H_3BO_3 and H_3BO^{2-} in the water. It can be used as drinking water for poultry after the content is reduced. In addition, there may still have some bacteria in the groundwater, in order to prevent the bacteria from causing infectious diseases to poultry, it is necessary to carry out sterilization treatment first and remove the residual gas in the groundwater. Therefore, chlorine sterilization and reverse osmosis (RO membrane) treatment are used to remove boron. The poultry production of the company is large, and the daily water demand is about $10m^3/h$.

(2) Project introduction

In this project, the deep well pump is used to pump groundwater, chlorine generator is used to add chlorine to the pipeline regularly for sterilization. Three FRP tanks with a diameter of 0.9m

and with a height of 2.4m are configured. The tanks are filled with activated carbon, and Runxin 53520 control valves are used to form three sets of activated carbon filtration systems to remove impurities and residual chlorine; in order to prevent RO membrane from scaling, the softener treatment systems are installed before RO device. 63610 Runxin valves, and resin tanks with diameter of 0.6m and height of 1.8m filled with Na^+ ion exchange resin are used to form three sets of softening system to reduce the hardness of feed water; then use RO membrane to remove the impurities in the water, the treated water will enter a 10m³ water storage tank, a liquid level controller is installed to control the level of water, and the water will be sent to each water point by booster pump. In the RO system, CIP system is equipped to prevent the outlet water from being polluted by microorganisms and bacteria. The equipment installation is shown as Figure 6-17, and the water treatment working process is as follows:

Groundwater→ deep well pump→ sterilization (equipped with chlorine generator) →activated carbon filter→ softener→ adjust PH value→ RO system (equipped with CIP system) → water storage tank→ booster pump →water point



Figure 6-17 The installation of boron removal system

7. Application of Runxin valve in residential water treatment

With the rapid development of industrial and agricultural production and urbanization, and the continuous growth of urban population, the contradiction between the demand for domestic water and the shortage of excellent water resources is becoming more and more serious. In some areas, not only the hardness (calcium and magnesium content) is very high, but also there are a variety of organic compound, heavy metal ions, industrial wastewater and detergent or pesticide residues and other harmful pollutants to human body, which makes the tap water treatment more and more difficult, and more sterilization and disinfectants need to be added. In addition, with the construction of high-rise buildings in the city, the pollution problem of secondary water supply has emerged; the old pipeline in the city is also easy to lead to the pollution of water supply for residents. In north part of China, the deeper the groundwater is dug, the higher the content of hardness and other impurities in the water will be. However, people's requirement for domestic water, especially drinking water is higher and higher. Therefore, people pay more attention to the advanced treatment of urban tap water or centralized water supply.

Runlucky whole house water purification treatment system which is independently developed and produced by Runxin, it could comprehensively treat various impurities in the water, the series products include: disk prefilter with intelligent leakage protection function, whole house water filter with intelligent leakage protection function, residential water purifier, residential softener, shower softener, RO and Spring filter and so on.

7.1 Application of Runxin filter in whole house water filter system

7.1.1 Prefilter

Due to the aging or maintenance of the water pipeline, there may be some impurities such as mud, sand, rust and so on when the water is transported from the water plant to the families. So, it is necessary to further treat the tap water in order to ensure the safety of domestic water and protect household water appliances. Some developed countries also put forward higher requirements for water supply system. For example, the German government stipulated in 1988 legislation (DIN 1988) that all constructed buildings must be equipped with protective impurity filters in the water supply system.

Therefore, prefilter is the first preliminary filter equipment. It is mainly installed at the back end of the water meter in the domestic water pipeline, which is the first water purification guard in the home. It is mainly used to filter the granular or flocculent impurities such as sediment, rust and so on in the secondary pollution of the tap water supply system. It is a reliable impurity filtering device. The main function is preventing the harm which caused by the impurities produced in the water supply system of cities and residential areas, and playing a positive role on

pre-protection of hidden pipe, faucet, plumbing, water heaters, boilers, central air conditioners, washing machines, dishwashers, coffee machines and other water appliances (like water purifiers, pure water machines, water softeners).



Figure 7-1 Disk prefilter

In current market, most of common prefilter for residential use mainly adopts stainless steel filter cartridge, which can be washed manually regularly to remove the impurities intercepted by the filter net. As they adopt down-flow rinse, it's hard to clean out the impurities stuck in the filter net, and floccule is difficult to remove, which is easy to adhere to the filter net, resulting in the flow rate becoming smaller and smaller.

In industrial water treatment, there is a kind of filter which use disk as filter core. Generally, the filter barrier is composed of high-quality engineering plastic disk with evenly distributed grooves. It cleans impurities by loosening disks and filter by repressing the disks. Theoretically, it could be used for unlimited times.

Household filtration system need prefilter featured with various functions, easy operation, easy maintenance and installation. In order to make prefilter cleaning automatically and free of maintenance, Runlucky prefilter takes the advantage of hermetic head faces structure, integrate the ceramic valve core with disk filter core (as Figure 7-1 shows). The motor controls the rotation of valve core, so that the filtration and backwash can be achieved by the switching of water flow channel. During backwash, disk filter core will automatically loosen and rotate under the water pressure, so that the impurities can be easily washed away; in addition, the prefilter has bypass function to achieving continuous water supply during backwash.

7.1.2 Whole house water filter

7.1.2.1 Effect of domestic water on human health

People knows a lot about the influence on human health caused by harmful substance in the drinking water, but we usually ignore the harm of chemical substances in domestic water which contact with skin through bathing and other ways. Some studies have shown that there are some toxic and harmful chemicals (such as toluene, ethylbenzene, styrene, etc.) in clear and transparent water, which are easy to be absorbed by human skin. For example, if there is trichloro ethylene in shower water, because of its volatility in hot water, people are easier to inhale the chemical during bath than to swallow it directly. Table 7-1 is the comparison between the absorption rate of certain chemicals by the skin of adults and children and the absorption rate of oral inhalation. These absorption rates can be considered similar to the absorption of other common chemicals in drinking water.

Table 7-1 Average absorption rate of certain chemicals by the skin and oral inhalation

	Exposure time	Absorption rate of skin	Absorption rate of oral inhalation	Water consumption
Adults bath	15min	63%	27%	2L
Baby bath	15min	40%	60%	1L
Kids swimming	1h	88%	12%	1L
Total average		64%	33%	

Above data shows that skin's absorption rate of some chemicals is amazing, so people should pay special attention to swimming and bath. In fact, the amount of volatile chemicals in hot water inhaled by breath is 6-80 times more than that from the mouth.

Therefore, it is not enough to just pay attention to the quality of drinking water. In order to ensure the health of whole family, it is necessary to install a water treatment equipment to filter all domestic water and can automatically backwash, that is, the whole house water filter.

7.1.2.2 The classifications of whole house water filter

There are two types of common whole house water filter on the market: one is the whole house water filter with ultrafiltration membrane structure; the other is the whole house water filter using the activated carbon as the filter media.

Whole house water filter with ultrafiltration membrane structure mainly use ultrafiltration membrane as filtering element to remove impurities and bacteria larger than 0.1μm in water, but cannot remove residual chlorine and other odors in water. It mainly discharges the retained impurities through the drain via fast rinse, but the impurities intercepted in the membrane hole cannot be washed out, and floccule are also difficult to be washed out.

Whole house water filter which uses activated carbon as the filter media, can achieve filtration by adsorption function of activated carbon. This type of whole house water filter can be equipped with a control valve with backwash function to backwash the filter media, regularly to prevent secondary pollution and prolong the service life of the filter media.

7.1.2.3 Whole house water filter with activated carbon

Generally speaking, the main concern of urban tap water is residual chlorine, organics, THM'S and plumbum. Among them, residual chlorine is a disinfectant added by waterworks to prevent bacteria produced in water transportation, which can only be removed when end users use it. Figure 7-2 shows various models of activated carbon filters, which can significantly and effectively reduce these major pollutants.



Figure 7--2 Various models of whole house water filters with activated carbon

Whole house water filters with activated carbon mainly uses activated carbon, quartz sand and other filter media to absorb residual chlorine, heavy metals, viruses, organics, pesticides, algae and other harmful substances in water, and filter out rust, solid suspended solids and other impurities. It can effectively solve the secondary pollution caused by disinfection, aging of pipeline, secondary water supply and other reasons in the process of water transportation and can safely protect the family water safety.

After adsorption of organics, algae and other impurities by activated carbon, impurities need to be cleaned out in time to prevent pollution again. Some experts pointed out that "in order to solve the problem of microorganism and its reproduction generated by adsorption devices such as activated carbon and membrane treatment, the device is needed to be set up to backwash regularly." Therefore, the key of the whole house water filter is: first, it depends on the effects of filtration, the turbidity of outlet water and the removal of residual chlorine is mainly related to the quality of activated carbon; **second, it must have the function of backwash. The ideal equipment should be able to automatically and regularly backwash the filter element and filter media, which can not only avoid the secondary pollution(such as pollutant accumulation and bacterial breeding caused by long-term use), but also greatly prolong the service life of filter element and filter media and reduce the maintenance cost during the use.**

Runlucky whole water filter with activated carbon has following functions:

a) Deodorization: remove the odor caused by phenol and organics;

b) Decolorization: remove the chromaticity caused by the iron, manganese, plant decomposition matters or organics;

c) Dechlorination: remove the residual chlorine and odor caused by adding disinfectant in tap water;

d) Removal of TOC: it can remove 10% ~ 60% of organics, such as pesticides, chlorinated hydrocarbons, etc.

e) Removal of heavy metals: it can remove mercury, chromium, plumbum and other heavy metal ions;

f) Remove synthetic detergent and synthetic dyestuff, etc.;

g) Remove viruses, radioactive substances, mutagenic substances, etc.

7.2 Application of Runxin softener valve in residential water softening system

7.2.1 Advantages of soft water

There are high content of calcium and magnesium ions in natural water (called hard water). When people wash face, hair, bath and wash clothes, calcium and magnesium ions are easy to react with soap, shampoo, shower gel, laundry detergent and other washing products, forming insoluble particles or floccules, blocking the pores of people or hardening clothes; if hard water is used for boiling water or cooking food, it not only affects the taste, but also easily causes the formation of scale in the kettle and steamer; if it is used for heating equipment such as water heaters and wall-hung boiler, it is easier to scale, affect heat transfer, and increase electricity or gas consumption. So, it is necessary to soften the domestic water. There are following advantages of using soft water:

a) Clean and soften skin and hair better. “Bath with soft water makes skin and hair better." Bathing with soft water can completely remove the dirt from the skin, scalp and hair, delay skin aging, and make the skin without tension after cleaning, with delicate luster and smooth hair. Therefore, beauty salons generally use soft water.

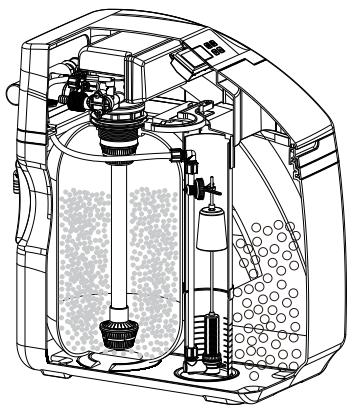
b) Avoid heating equipment and cooking utensils from scaling. The use of soft water can prevent the scaling of wall-hung boiler, water heater, steamer and kettle, prevent the heating pipes from burning due to scaling, greatly reduce the maintenance times of the equipment, prolong the service life of the water heater by more than one time, reduce the gas or electricity charges for heating equipment or cooking utensils by 29% - 32%, and the water pipes installed in the walls will not scale or block.

c) Improve the washing effect of home life. The use of soft water can make the laundry soft and clean, with the color as new, and can significantly reduce the amount of laundry detergent; washing dishes and porcelain are as bright as new, without water stains, and reduce the amount of detergent; no yellowing, no scaling, no peculiar smell of toilets, sinks, bathtubs; the small holes of the shower nozzle do not form white scale, and the water flows smoothly.

7.2.2 The structure and classifications of residential softener

Residential softener is mainly composed of resin tank (filled with resin), control valve, brine valve and brine tank. According to different appearance, residential softener is divided to

integrated type of residential softener and split type of residential softener (as Figure 7-3 and Figure 7-4 shows). Integrated type of residential softener means that the resin tank and the brine tank are placed in a same cabinet, which occupies a small area and is more beautiful. Split type of residential softener means resin tank and the brine tank are divided into two parts. Generally, the residential softener with large water treatment capacity adopts the split type softener.



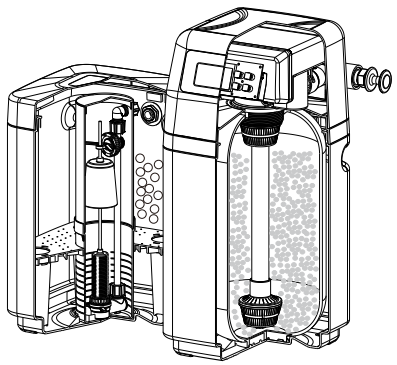


Figure 7-3 Integrated type of residential softener **Figure 7-4 Split type of residential softener**

7.2.3 Special functions of residential softener

The special function of Runlucky residential softener is mainly reflected in the control valve, which has different special functions according to the different control valves. The following alternative functions are commonly used:

(1) Brine dry mode

The resin tank of integrated type of residential softener is put in the brine tank. In service status, there is a large amount of brine in the brine tank, and the resin tank will be soaked in the brine all the time, which will have negative effect on resin tank and brine, and may cause pollution and pollute the resin during brine draw process.

Brine dry mode means in service status, the softener will keep brine tank always dry to prevent resin tank from being soaked in the brine tank all the time and avoid the resin tank or brine from deterioration; when the volume or time reaches set value, brine refill starts 4 hours earlier before service finished. After brine refill, it will take 4 hours to dissolve the salt, then the softener goes to regeneration. In this way, during the service of the softener, the brine tank is basically dry, so it is called brine dry mode.

(2) Salt shortage alarm function

When the residential softener reaches the set water treatment capacity, the invalid resin should be regenerated, so it is necessary to add salt regularly. However, due to the lack of special personnel for management of residential softeners and long cycle of adding salt (sometimes it may be more than one month), users may forget to add salt, resulting in the resin cannot be effectively regenerated and outlet water cannot meet the softening requirements.

In order to keep the brine tank always filled with salt and ensure that the resin can be effectively regenerated, Runxin has developed a control valve with a salt shortage alarm function, which can alarm when the brine tank is short of salt to remind users to add salt. Currently, there are several ways to alarm for salt shortage:

a) Specific gravity method: periodically detect the specific gravity of the brine in tank. When it is lower than the set value, it can alarm to remind the user to add salt. But it is only suitable for residential softener without brine dry mode.

b) Reflection and refraction method: illuminate the brine tank through a light-emitting lamp, determine whether there is salt in the brine tank by the difference between the reflection or refraction of solid salt and water, and give an alarm when salt shortage is measured.

(3) Chlorine disinfection

After using the resin for a period of time, it is easy to generate the bacteria. Parts of European countries require regular disinfection of resin tank. Disinfection is realized by installing a disinfection device on brine line connector, and it can generate chlorine to disinfect resin tank by electrolyzing the saturated solution of sodium chloride under brine draw status.

(4) Vacation mode

The resin is easy to invalid and generate bacteria if the residential softener doesn't work for a long time, which may cause resin broken when it is used again. Vacation mode means before a long-term business trip or vacation, softener will draw brine into resin tank to soak the resin, and then turn off the valve. After the vacation, turn on the valve to clean the brine, and then it can be put into use normally.

(5) Brine refill with soft water

Common residential softeners usually adopt raw water for brine refill. But if the hardness of raw water is high, the content of calcium and magnesium in salt water will increase, affecting the regeneration effect; in addition, when there is iron and manganese in the water, the brine tank will be colored, which will easily cause pollution to brine tank. In order to solve this problem, some control valve is developed to brine refill with soft water. That is, using soft water to dissolve the salt in brine tank, which can not only improve regeneration efficiency, but also avoid coloring of the brine tank.

(6) Raw water bypass during regeneration

It is specified in GB/T 18300 "Specification for Automatic Sodium Exchange" that hard water should not flow out from the outlet of the exchanger during the regeneration process for the industrial water treatment equipments (such as boilers). This is mainly to prevent the increase of hardness of raw water, which will make the heating equipment (such as boilers) being scaled, resulting in the reduction of heating efficiency or safety risks. Generally, it takes 1~2 hours to regenerate. For industrial softener equipment, there is usually a soft water tank for

providing enough soft water to the boilers during regeneration. But for residential softeners, they are usually not equipped with soft water tank. If there is no water flows out during regeneration, it will interrupt the water supply of the water equipment and affect the users. Although some users set the residential softener to regenerate at night, but there may be a need for temporary water usage. Therefore, residential softener is equipped with control valve with the function of raw water bypassing during regeneration, so that the raw water can flow out from the outlet for the users' urgent need.

(7) Raw water mixing

The hardness of domestic water is not the lower the better. For example, the hardness in drinking water is too low to be harmful to human body. Therefore, some European countries, such as Italy, Belgium, require the hardness of outlet water should be controlled within 50 ~ 90mg/L (calculated by $CaCO_3$). After regeneration, the outlet water hardness of residential softener is usually lower than 30mg/L. In order to meet demand, users can mix partial raw water with the soft water, making hardness of outlet water can be adjusted to 50 ~ 90mg/L. This is the hard water mixing function.

(8) WIFI function

With rapid development of IOT, some household appliances, including residential softener, could be operated by phone. Once the residential softener is connected with WIFI, users could enquiry the working condition and set parameters via phone anytime. This function could be used to improve after-sales service.

7.3 Application cases of Runlucky whole house water treatment system

7.3.1 The application of residential softener

Residential softener could be widely applied to wall-mounted boiler, water heater, washing machine, floor heating, hot water boiler, HVAC (central air conditioner), heat exchange station of central heating and so on.

(1) Applied in heating boiler

Located in a military training camp in Kashgar, Xinjiang province of China, the hardness of local raw water is 415mg/L (calculated by $CaCO_3$). Heating and bathing water is needed in winter. In order to avoid the scaling problem of heating boiler, raw water needs to be softened.

Because there are not so many people and it has equipped with a large water tank, a set of residential softener is used to supply water to the heating boiler. The hardness of outlet water reaches the standard requirement, effectively prevent the boiler from scaling, and reduce the energy consumption of boiler. The installation refers to Figure 7-5.

(2) Applied in wall-mounted water heater

For the decorated family, as the water softening treatment was not considered in the early

stage, so the pipeline is not reserved. In order to prolong the service life of gas water heater, and have a better experience of bathing, it is suggested to install a wall-mounted residential softener to provide the soft water for water heater and shower. The installation refers to 7-6.





Figure 7-5 Residential softener for heating boilerFigure 7-6 Wall-mounted residential softener for shower

7.3.2 Typical application cases of whole house water treatment system

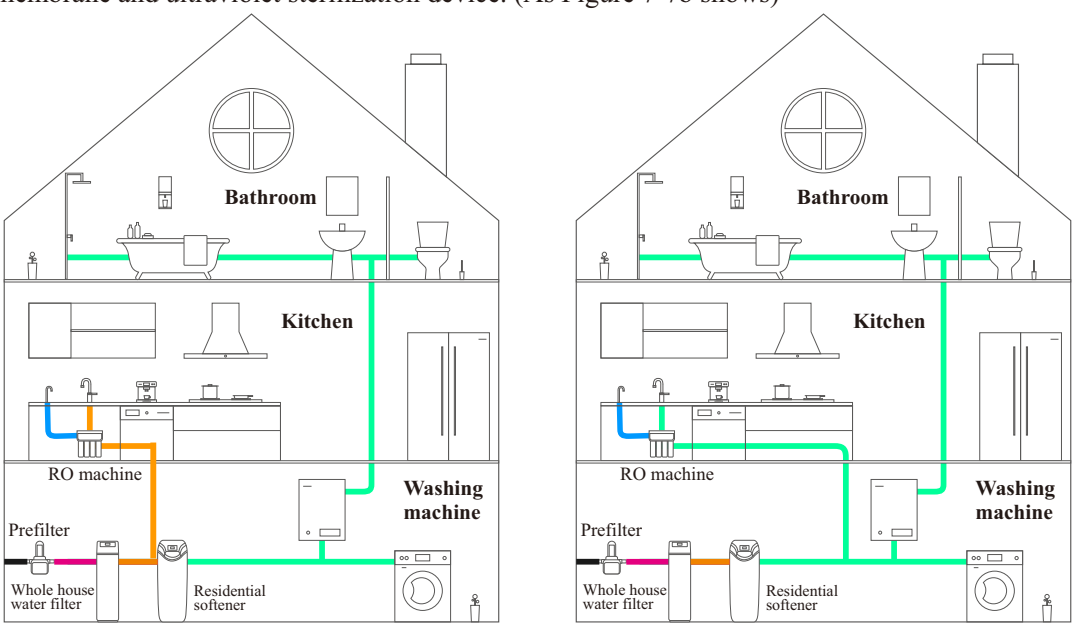
Prefilter+ adsorption filtration+ softening and RO

Domestic water comes from surface water, such as river, lake and reservoir, and the quality of surface water varies greatly in different areas. Compared with groundwater, the hardness of surface water is not very high. But because of the aquatic organisms, algae and breeding industry, the organics content in water is very high, and the water quality is easily affected by rainy and dry season; and there are some heavy metal ions, chemicals, viruses and bacteria that affect human health when the surface water is polluted. Although most impurities have been removed from municipal tap water after treatment, it is inevitable that there will still be residues, and a certain amount of fungicides should be added. In some coastal cities, whenever the spring tide comes, seawater is easy to pour back, which will significantly lead to deterioration of water quality and have a great impact on people's domestic water.

In this case, the whole house water treatment system is applied to a family in a southern city of China, annual variation range of local tap water quality is: hardness is 125mg/L ~ 175mg/L (calculated by $CaCO_3$); alkalinity is 1.5mmol/L ~ 2.2mmol/L; conductivity is 180μs/cm ~ 300μs/cm. User hopes to equip with a whole house water treatment system, with a total flow rate of about 20m^3/month (about 700L per day). According to the local water quality and usage, the whole house water treatment system is designed as: install a prefilter at the main pipe of tap water to remove large particles of impurities and floccules (such as mud, rust and so on); then equip with a activated carbon filter. It adopts 53502 Runxin filter valve, a filter tank with a diameter

of 250mm and with a height of 890mm, filled with 12kgs of activated carbon. Water treatment capacity is around 1500L/h. The outlet of the filter is divided into two channels, one of which is directly connected to the kitchen for cooking and soup making; the other is equipped with a R150 integrated automatic residential softener, which is used for floor heating circulation system (floor heating area is about 160m^2), water heater, bathing, laundry, etc. The water output is 1500L/h; Then install an RO in kitchen, used for drinking water, with 2L/min output (daily water treatment capacity is 700L). The whole house water treatment system installation is shown as Figure 7-7a, and performs good. Due to the high degree of automation of the water treatment system (except users need regularly to add the salt to residential softener by manual), it is convenient to use and the outlet water quality meets the requirements of customers when follow the requirements of the operation manual to do the operation and maintenance after installation

If the hardness of raw water is high (calculated by $CaCO_3$, exceeds 300mg/L), the water for kitchen also needs to be softened, and RO is suggested to replaced by reverse osmosis membrane and ultraviolet sterilization device. (As Figure 7-7b shows)



a. Whole house water treatment system for low hardness of raw water

b. Whole house water treatment system for high hardness of raw water

Figure 7-7 Whole house water treatment system in a residential house

8. Maintenance of Runxin multi-functional flow control valve

8.1 Installation of Runxin valve

8.1.1 Service conditions

Service conditions of Runxin valve and water softener should comply with below requirements, shown as table 8-1.

Table 8-1 Service conditions of Runxin valve and water softener

Items		Requirement
Working conditions	Water pressure	0.2MPa～0.6MPa
	Water temperature	5℃～50℃
Working environment	Environment temperature	5℃～50℃
	Relative humidity	≤95%（at 25℃）
	Electrical facility	AC100～240V/50Hz ～60Hz
Inlet water quality	Water turbidity	Down flow＜5FTU; Up flow＜2FTU; Floating bed ＜2FTU; Filter＜20FTU
	Water hardness	First Grade Na+ ＜6.5mmol/L; Second Grade Na+ ＜10mmol/L
	Free chlorine	＜0.1mg/L
	$Iron^{2+}$	＜0.3mg/L
	CODMn	＜2mg/L（O_2）

Notice: In the above table, First Grade Na^+ represents First Grade Na^+ Exchanger. Second Grade Na^+ represents Second Grade Na^+ Exchanger.

8.1.2 Installation requirement

The installation steps are carried out according to the specified requirements, and the built-in functions shall be connected as needed. The installation location and environmental requirements of the equipment are as follows:

a) It should be arranged in order according to the process, reduce the noise interference to the main operation area;

b) A certain space shall be reserved to facilitate the operation and maintenance of the equipment;

c) Equipment shall be installed indoors. If the equipment is installed outdoors, the operation part of control valve, meter, sampling device, valves etc. should be arranged in a centralized way, and measures for rain, frost, and sun protection should be taken.

d) Acid and alkali storage tanks can be arranged outdoors, alkali storage tanks in cold areas should be arranged indoors, acid and alkali storage tanks should be close to the wastewater neutralization tank.

e) The shorter the distance between the filter (or water softener) and the drain, the better;

f) Brine tank should be located close to softener;

g) Do not place the equipment in the environment with acid and alkali, strong magnetic field and strong vibration, so as to avoid the failure of electronic control system;

h) Do not install equipment and devices, drainage outlets, overflow pipe fittings, etc. in the environment below 5 ℃ or above 50 ℃;

I) Install the system in the place where with minimum loss in case of water leakage.

8.1.3 Installation notice

8.1.3.1 Pipeline requirements

a) The base thread for control valve includes 2.5-8NPSM and 4-8UN (they are both US standard). The tank thread must meet the corresponding valve thread standard.

b) Do not use too much force when installing the pipe joints, so as to prevent thread slipping or cracking of contact surface

c) When installing pipelines, make sure that the pipeline is straight and not subject to force on the valve joints.

d) When installing the control valve with side-mounted connector to match the tank with top and bottom openings, please pay attention to the direction of the side-mounted connector. "TOP" port connects to the top opening of the tank, and "BOTTOM" port connects to the bottom opening of the tank.

e) Drain outlet should lower than control valve.

f) If the water pressure of raw water is low, it may affect rinsing or regeneration, it needs to install a booster pump at inlet.

8.1.3.2 Installation notices of softener valve

a) When installing automatic softener valve, if users have strict requirement on hardness of outlet water, a solenoid valve could be installed at the outlet to close the outlet during regeneration and prevent raw water from flowing out and entering the water system.

b) When installing systems with 63504, 63502, 73504, 73502, 63510 softener valves, if the outlet pipe or water tank is higher than the control valve, a liquid level controller must be installed in the brine tank or a check valve should be installed at outlet so as to prevent the water in the outlet pipe or water tank flowing back into the brine tank while backwash.

c) Brine tank should be located as close as possible to the resin tank, and its connection length should not exceed 2m to avoid abnormal brine draw caused by too long brine draw pipeline.

8.1.3.3 The installation notices of 63540 and 63550 piston control valve

a) Inlet water turbidity < 20FTU

Excessive water turbidity may cause the piston to not work smoothly and easily scratch the piston. If the turbidity of the inlet water exceeds the standard, a filter device must be installed at the inlet.

b) Requirement for drain outlet

Drain outlet should lower than control valve, for 63540 and 63550 series softener valves, the distance between drain outlet and control valve should not exceed 5m; for 53530 and 53550 series filter valves, the distance between drain outlet and control valve should not exceed 3m.

c) Requirement for brine draw pipeline

There should be no more than 4 pipe elbows from the brine ball valve to the brine valve in the brine tank, and there should be an animated connection for the convenience of detecting the brine valve during the usage.

d) Installation requirement for flow meter

While installing the flow meter of 63540 and 63550 series softener valves, the straight distance of pipeline in front of the flow meter should be 10 times of the pipeline diameter, and the straight distance of pipeline behind the flow meter should be 5 times of the pipeline diameter.

8.2 Common system trouble cases

8.2.1 Reduction of water treatment capacity

(1) Injector is not matched

A supplier of residential softeners reports that the residential softeners they assembled have gradually reduced the water treatment capacity periodically during usage.

We have learned from that the supplier of the residential softener purchased the standard softener control valve from Runxin for assembling in the residential softener. When softener valve with Runxin's standard configuration used in a water softener with a flow rate of $2m^3/h$, it is generally matched tank with a diameter of 250mm and a height of 1350mm, and standard configuration is 5# injector and flow control. But for residential softener, usually its resin tank diameter is 250mm or 200mm and height is 890mm or 430mm. In this situation, if the residential softener is also equipped with 5# injector, because the actual resin tank height is lower and the resin filling volume is smaller, so in order to control the regeneration salt consumption, the supplier shorten the brine refill time to reduce the amount of brine, then the brine draw process of injector will be finished quickly. Therefore the contact time between the

resin and the brine is greatly shortened, and some are even less than half of the standard requirement, resulting in insufficient regeneration of the resin. It reduces the water treatment capacity or make the outlet water be unqualified.

Therefore, while selecting softener valve model, it is not only necessary to consider the diameter of the resin tank, but also the height of the resin tank and the filled volume of resin. For residential softeners with a larger tank diameter but a lower height, a smaller injector can be selected to extend the contact time between the brine and the resin and improve the regeneration effect of the resin.

(2) Resin is poisoned or polluted by organics

A wool processing plant, located in Wuxi, Jiangsu province of China, takes river water as raw water which enters water softener after flocculation precipitation, and softened water is used to clean wool. After a period of usage, the hardness of the outlet water does not meet the standard in the later stage of service. That is, the water treatment capacity is gradually reduced.

After inspection, the turbidity of inlet water is a little bit high. It is mainly due to the high organics content in river water. Also, the water level of the river gradually decreases because of the reduction of rainfall, the turbidity of the river water becomes higher and higher, and the flocculation precipitation effect is not ideal, so that the turbidity of outlet water increased. After open the resin tank for inspection, it is found that the resin is wrapped by a large amount of flocculated organic matter (as shown in Figure 8-3), resulting in less and less effective resin that can play a role in exchange, and leading to the decrease of water treatment capacity.

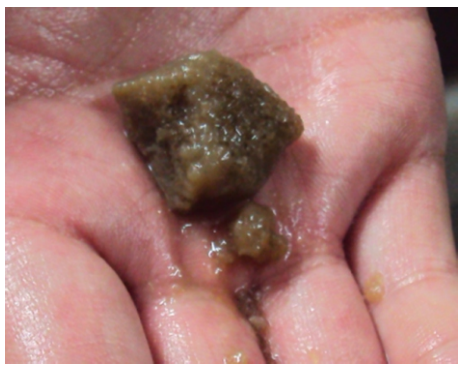


Figure 8-3 Resin is polluted by organics

Solution: wash or replace resin, improve flocculation precipitation, and add a filter in front of the residential softener to keep the inlet water turbidity qualified. If the turbidity of the feed water still can't meet the requirements after the precipitation and filtration of the raw water during the dry period, tap water should be used as the raw water for water softener.

(3) Turbine of flow meter is stuck

According to the feedback from a water softener user, a set of softening system configuration is as follows: using 63618 control valve, a resin tank with a diameter of 0.9m and a height of 2.1m, filled with 900L of resin; the raw water is groundwater with an average hardness of 9.6mmol/L, and the water softener's inlet pressure is 0.3MPa. During usage, the water treatment capacity is getting smaller and smaller, and the peak flow rate displayed on the controller decreases, but the actual water output is normal.

After inspection and comparison, it is found that the water flow rate displayed on the control valve is lower than the actual water flow rate at the outlet of the water softener. The water inlet flow rate meets the requirements, but the peak water flow rate is getting smaller and smaller. It is judged that it may be caused by the flow meter trouble. After disassembling the flow meter, it is found that the turbine is stuck and worn seriously due to the high turbidity of the inlet water, and it couldn't rotate smoothly (as shown in Figure 8-4), resulting in inaccurate measurement, which means that the flow rate displayed on the controller is less than the actual water output. And when the actual water output reaches the set value, regeneration should be started. But the water treatment capacity measured by the controller has not reached the set value and cannot be regenerated in time. After replacing a set of flow meter, the water treatment capacity is displayed normally.



Figure 8-4 Turbine of flow meter is stuck

Notice: it is required that the inlet water turbidity should less than 5FTU. When this value is exceeded, a coagulation sedimentation or filter should be added in front of softener.

8.2.2 The outlet water hardness of softener failed to meet the requirement

(1) Riser pipe is broken down

Some customers report that: when the softener is put into operation after regeneration, the hardness of outlet water has always exceeded the standard. After disassemble the softener for maintenance, it is founded that riser pipe is scratched by the particles, impurities and welding slag, which causes leakage and part of raw water enter outlet without being softened, resulting in unqualified outlet water. After further inspection, it is found that because the water inlet pipe is welded by iron pipes, the welding slag in the pipeline is not cleaned up during installation, so that the inlet raw water contains relatively hard welding slag and small particles of impurities. During operation, particulate impurities or welding slag enters the top strainer, and after a period of use, slow brine draw happens during regeneration.

(2) O-ring of riser pipe is broken down

A user in Changsha, Hunan Province of China, reports that the outlet water of a new softening system equipped with 63610 control valve is unqualified at once when it is put into use. After inspection, the O-ring of riser pipe is broken, but this problem wasn't solved even after replacing a new O-ring. After careful check, the mouth of the riser pipe hasn't been chamfered, the O-ring of riser pipe is scratched by the sharp edge while installing the valve. It results in the mouth of riser pipe not being sealed, and part of raw water without being softened is mixed with outlet water, so that the hardness of water exceeds the standard. After chamfering the riser pipe, and changing a new O-ring, this problem is solved.

(3) Brine tank is too small

As Figure 8-5 shows, installed in the Jilin of China, there are two sets of softening systems which is equipped with 63640 control valves and matched with resin tank with a diameter of 1000mm and a height of 2400mm. Two systems supply the water in parallel for boiler equipment by interlock. They use a 300L brine tank while regeneration. Customer reports that the hardness of outlet water always exceeds the standard.

The technicians check on the spot and find that the equipped brine tank is too small. Calculating based on 120g salt consumption per liter of resin regeneration, 1250L resin regeneration requires 150Kg of salt, which is dissolved into 420L saturated brine. The volume of the brine tank generally refers to the volume when the water is full, the actual brine volume also needs to remove the volume of solid particle salt and the distance from the overflow of tank to the top. Therefore, the general brine tank has only 2/3 of the volume to hold saturated brine. The exceeding hardness of raw water in this case is caused by the too small brine tank, the brine tank can actually contain less than 200L of saturated brine, resulting in insufficient brine draw during resin regeneration, and part of the resin is not effectively regenerated. Generally, a water softener with a resin volume of 1250L needs to be equipped with a brine tank with the volume above 800L. Two sets of softeners running in parallel can share one brine tank if they regenerate respectively. However, if regeneration is required at the same time, an independent brine tank is required for each.



Figure 8-5 Equipped brine tank is too small

8.2.3 Softener fails to draw brine or draw brine slowly

(1) Brine pipeline is too long

As Figure 8-6 shows, the brine pipeline of 63618 valve in the middle is too long (more than 3m), resulting the control valve fails to draw brine. However, the 63618 control valve on the right draws brine normally (the brine tank is on the right).



Figure 8-6 The brine pipeline is too long

(2) Brine pipeline is blocked

As Figure 8-7 shows, the softening water treatment system which is installed in a in an oil company in Yan'an of China. The user reports that brine draw is slow during regeneration, and the brine had not been absorbed by half after the set brine draw time of 70 minutes. Open the brine draw device to check and find that the strainer is used as the brine valve. But due to too many impurities in the salt, the strainer as the brine valve is seriously blocked, resulting in a slow brine draw speed.



Figure 8-7 Brine pipeline is blocked

(3) Top strainer is blocked

As Figure 8-8 shows, a softener with 17610 control valve installed in Shanghai of China is founded that the valve fails to draw brine during regeneration. After check, the top strainer is blocked by suspended impurities and broken resin. As this valve is an up-flow regeneration valve, this valve fails to draw brine once the top strainer is blocked. Drain the broken resin by backwash (temporarily remove the top strainer), then the valve could draw brine normally.



Figure 8-8 The strainer is blocked

(4) Injector is blocked

A customer uses 63510 control valve for softening water treatment system for boiler feed water. After a period of usage, the valve fails to draw brine during regeneration.

According to the item 11 in Table 2 of 8.2.1 of this chapter, open the brine draw device and it is found that the injector is blocked by sand (as shown in Figure 8-9). Further inspection reveals that the bottom strainer of the sand filtration system before the water softener is damaged, the filter material leaked, and quartz sand entered the softening water treatment system, blocking the nozzle of the injector, resulting in failure of brine draw. After cleaning, the brine draw function works normally.



Figure 8-9 Injector is blocked

8.2.4 Piston valve drains continuously (mainly for 63540 and 63550 softener valve)

(1) Back pressure in drain pipeline

A purification water treatment system installed in a waterworks in Guatemalan (as shown in Figure 8-10), adopts 12 sets of 53530 filter valve working in parallel, and it requires flow rate of 250m^3/h; the waste water in the rinse process is discharged to the second floor (upper floor) for reuse, and it is found that there is water leakage during the service of the filter.

After receiving users' feedback, the technicians check and analyze that as the water need be drained to the second floor during filter backwashing, so there is the back pressure generate in the drain outlet. While the drain outlet of the distribution valve is connected with the drain of the main pipeline, and the back pressure in the drain outlet of the distribution valve leads to the failure of the piston to operate smoothly.

Solution: separate the drain outlet of distribution valve from the drain outlet connection of the main pipe (as shown in Figure 8-16), not connecting with the main drain pipe. Drain it directly

into the recycling pool on the first floor, and seal the main drain port with a plug. After the above improvements, the piston moves smoothly, and the water leakage problem is solved.

The drain pipe is upward, and the drain pipe of the distribution valve is connected with the main drain pipe, resulting in back pressure in the drain pipe of the distribution valve



Figure 8-10 Back pressure in the drain pipe of softening water treatment system

(2) Overlong drain pipeline

As Figure 8-11 shows, installed in a sewage treatment plant in Tianjin of China, there are three filtration systems composed of six sets of 53530 automatic control valves. One quartz sand tank and one activated carbon tank make up one filtration system, and three filtration systems are working in parallel. Taking tap water as the raw water, the inlet pressure is 0.15Mpa.



Figure 8-11 Overlong drain pipeline

After installation, it is found that the drain outlet of the filtration system always drains water, and the pressure gauge on the activated carbon filter in each group of filtration systems shows no pressure.

After inspection, it is found that the water inlet pressure of the system is lower than 0.2MPa, and the drain pipeline is too long (more than 15m), which results in the back pressure in the drain outlet of the distribution valve, which makes it difficult for the piston to move smoothly and cannot normally change the working position, so that the drain outlet continuously drain water.

Solution: shorten drain pipeline, install pressure booster equipment to increase the inlet pressure of variable frequency pump to 0.3MPa. At the same time, independently connect the inlet pipes of the distribution valves of the 6 devices to increase the distribution valve pressure, so that the piston can moves smoothly and normally change station.

(3) The turbidity of inlet water exceeds the standard

Some customers report that the drain outlet of the softener control valve constantly drains water. The maintenance personnel disassembles the control valve for maintenance and find that

the valve core is completely blocked by sludge (as shown in Figure 8-12). After cleaning the valve core, install it again and the valve resumes normal operation. Therefore, for the raw water with excessive turbidity, it is necessary to install a filter or pretreatment of flocculation sedimentation before the softener.



Figure 8-12 Valve core is blocked due to excessive turbidity of inlet water

(4) Piston is blocked by foreign matters

The softening system which is installed in a factory in Taizhou of China and adopts 63640 softener valve (as shown in Figure 8-13), constantly drains water during usage. After on-site inspection, it is found that there is a small plastic part, which made the piston stuck and damaged, resulting in the piston unable to move and cause water leakage. Suggestion: when the inlet water quality is poor or the water quality is unknown, it should be equipped with a disk prefilter before softener to prevent foreign matters from entering the valve body of the control valve.



Figure 8-13 Piston is blocked by foreign matters

8.2.5 Flow meter fails to be accurate

(1) Too small outlet water flow

A softening water treatment system installed in a factory in Shanghai of China is meter type water supply system which is composed of three sets of automatic 63640 control valves. The soft

water tank is set on the roof of the building with a height of 8 meters (as shown in Figure 8-14). The mechanical float switch is installed in the inlet of water tank. After installation and use, the user reports that during service, the remaining water treatment capacity does not decrease, and the softening water system will not regenerate automatically.

After inspection, the mechanical float opens in a very small range due to the low water consumption, so that the outlet water of the softening water treatment system is also very small. It is difficult to drive the turbine of the flow meter to rotate, so that the remaining water treatment capacity displayed on the controller does not decrease. The peak flow rate is 0m^3/h, so that the water treatment capacity of the flow meter accumulated has not reached the set value, and it can't automatically regenerate.

Solution: install a liquid level controller at the inlet of the high level soft water tank to control the solenoid valve at the water outlet. When the soft water tank is at a high water level, the level switch controls the solenoid valve to close; when the soft water tank is at a low water level, the level switch controls the solenoid valve to open and start the softening water system to supply water to the soft water tank. After the improvement, the phenomenon of small flow of the system is avoided.



Figure 8-14 Adopt mechanical float to control the level of water tank

(2) Turbine of flow meter is blocked or broken

As Figure 8-15 shows, turbine is blocked and flow meter is broken because of the poor quality of inlet water. So, it is needed to pay attention that the turbidity of inlet water should not exceed 5FTU. If the turbidity of inlet water is too high, it is necessary to install a prefilter before softener.

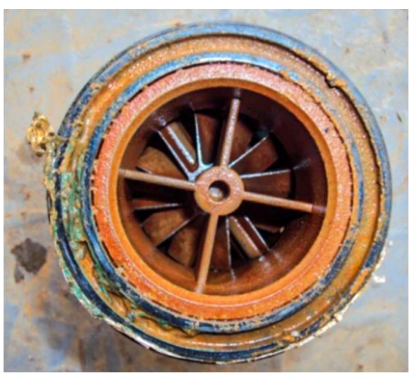


Figure 8-15 The turbine of flow meter is blocked

8.3 Trouble shooting of control valve

8.3.1 Trouble shooting of unqualified outlet water

(1) Fault description: after the installation of a softener, the outlet water is qualified when it is first put into use. But the outlet water is still unqualified after regeneration after using for a period of time.

(2) Fault elimination

a) First, analyze and check whether the bypass valve leaks or opens, whether the salt tank is filled with salt, whether the injector is blocked, whether the turbine is stuck, whether the regeneration time is set correctly, and so on. If it is still difficult to identify the cause, then proceed to the next step:

b) Disassemble the valve body of the control valve, test the hardness of water in the riser pipe (for top-mounted valve) or bottom strainer (for side-mounted valve), and make the following conclusions according to the measurement results:

① If the hardness of water is qualified, it means the unqualified outlet water is caused by the internal water mixing;

② if the hardness of water in riser pipe is similar to outlet water, they are both unqualified, it means the unqualified outlet water may be caused by the unreasonable softener configuration, poor regeneration effect and invalid resin.

8.3.2 Trouble shooting of internal water mixing of piston valve

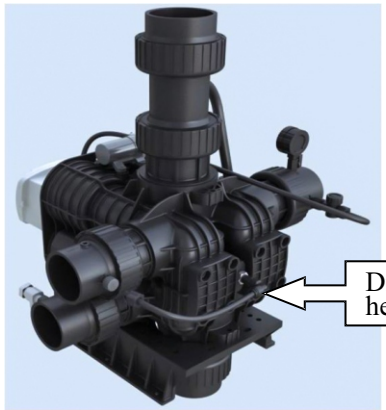
8.3.2.1 Internal water mixing occurs when new equipment is in trial running

① Refer to the instruction manual to check whether the pipeline is properly installed, whether the drain pipe is blocked, and whether there is back pressure. If the drain pipe exceeds 5m or the drain pipeline has back pressure, it needs to shorten the drain pipeline or solve the back pressure of the drain pipe. If the valve meets all above requirements:

② Turn on inlet valve, and switch the valve's status by manual. After the diaphragm pump (the small pump that comes with the control valve) stops working for two minutes in each status, check for internal water mixing. If there is internal water mixing, it indicates that the piston is stuck; if there is no internal water mixing, it can work normally.

8.3.2.2 Internal water mixing occurs when valve is put into use for a period of time

① Find out the internal water mixing occurs in which status: turn on the inlet valve, and switch valve's status by manual. After the diaphragm pump stops working for 1 minute, check for internal water mixing; and manually switch to other status to check for internal water mixing. So as to determine in which status the internal water mixing occurs.



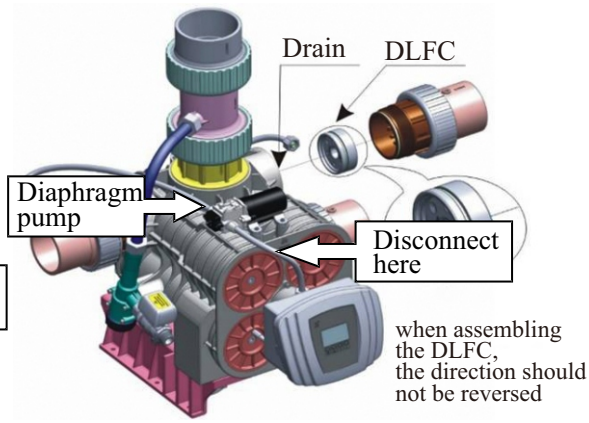


Figure 8-16 The drain pipeline of distribution valve **Figure 8-17 Check diaphragm pump**

② Check if it is caused by the back pressure in drain pipeline: pull out the Φ12 black drain pipe which connects the control valve and the main drain (as shown in Figure 8-16), turn on the water inlet valve, switch the control valve manually, after the diaphragm pump stops working for 1 minute to check if there is internal water mixing. If the status in step ① which occurs internal water mixing, but now does not leak, then do as Figure 8-16, turn on the drain pipeline, plug the main drain pipeline; if the status in step ① which occurs internal water mixing, and now leaks, proceed to next step:

③ Check if the diaphragm pump works normally: disconnect the outlet of diaphragm pump (as Figure 8-17 shows), turn on the diaphragm pump, plug the water outlet with thumb. If the pressure that you feel is not large (generally, it should be more than 0.3MPa), the diaphragm pump needs to be replaced; if the pressure is normal, the main valve chamber needs to be repaired and check whether the main valve pistons are stuck.

8.3.3 Trouble shooting of failure of brine draw of piston valve

(1) Fault description: a softener equipped with piston valve fails to draw brine after a period of use.

(2) Fault elimination:

a) Firstly, check whether the piston valve has internal water mixing, eliminate the internal water mixing fault;

b) Check whether the inlet water pressure meets the requirements: generally, the inlet water pressure in brine draw status is larger than it is in other status (except for constant pressure control system), the inlet water pressure of piston valve should not less than 0.2MPa;

c) Unscrew the union on brine line connector to check whether there is suction. If there is suction but still fails to draw brine, it means brine valve has problems; if there is no suction, then continue to check as following methods:

d) Turn off inlet valve, unscrew the copper joint between the connecting pipe and the top strainer, connect the copper joint with the hosepipe, turn on the water inlet valve, and observe

whether can draw brine.

① If it can draw brine, it may be caused by the blocked top strainer and bottom strainer or other problem in the tank, it is necessary to open the tank to check.

② If it cannot draw brine, it may be the problem of control valve.

8.3.4 Trouble shooting of failure of brine draw of hermetic head face structure valve

(1) Fault description: a softener equipped with the hermetic head face structure valve fails to draw brine after a period of use.

(2) Fault elimination:

a) Firstly, analyze and check whether the inlet water pressure is too low, whether the brine pipeline is too long or blocked, whether the drain pipeline is blocked or too long, whether the strainer is blocked, and whether the internal valve is water mixing. If it is still difficult to identify the specific reasons, further analysis can be carried out according to the following steps;

b) Unscrew the nut or brine pipeline, plug with thumb to check whether there is suction. If there is suction but still fails to draw brine, it means brine valve or brine valve connection leaks; if there is still no suction, the fault may be in the resin tank (the top and bottom strainers are blocked) or the control valve (the injector is blocked or the internal valve leaks);

c) For the control valve without suction at brine line connector, if it is allowed, remove the control valve from resin tank, connect inlet pipeline and brine pipeline, and observe whether it draw brine. Make conclusions as followings:

① If it can draw brine, the failure may happens in the resin tank (for example, top and bottom strainer is blocked, or the resin is broken, there is impurities, etc.)

② If it doesn't draw brine, the problem maybe is caused by the failure of valve.

8.3.5 Trouble shooting of "E1"

(1) Fault description: a 63618 control valve shows "E1" on display screen and makes alarm sounds during use.

(2) Fault elimination:

a) Disconnect the power of the valve and turn it on again; after 10 seconds of all symbols showing, the control valve model will be displayed, and then -00- will be displayed. At this time, pay attention to whether the motor is rotating and make the following judgments:

① If motor doesn't rotate, it means the motor is damaged or the motor plug is loose with the sockets of main board;

② Open the front cover of control valve to check whether the plug of motor is loose. If it is loose, plug it in again and reconnect power after power off; if the motor still cannot rotate when -00 - is displayed, it indicates that the motor is damaged.

b) Check the motor fault of the control valve: disconnect the power supply and then power on.

When - 00 - is displayed, use a multimeter to detect the two motor sockets on the main control board. If the socket outputs DC24V voltage, it indicates that the corresponding motor of the socket is damaged; if user doesn't have a multimeter, the user can check the motors after swapping the positions of the two motors and the socket. The motor that does not rotate is damaged. If the two motors do not rotate, it is possible that both motors are damaged or the main control board is damaged.

c) If valve displays -00-, the motor keeps rotating until screen shows "E1". It is may caused by the slip of the big gear and motor gear, loose or damaged wire of locating board , or broken main board and so on, which are needed to be eliminated separately.

8.3.6 Trouble shooting of "E2"

(1) Fault description: a 63604 control valve shows "E2" on display screen and makes alarm sounds during use.

(2) Fault elimination:

a) Disconnect the power of the valve and open the dust cover, pull out the wire of locating board to check if there is water drops on the plug of locating board wire and corresponding socket on the main board. If there are water drops, wipe or blow dry. Then connecting the wire, power on the control valve, if "E2" is still displayed, check according to the following steps;

b) Open the front cover, do as step a) to check the connection part between locating board and the wire of locating board. If it still shows "E2", it is possibly caused by damaged locating board and main board.

8.3.7 Trouble shooting of abnormal repeated display

(1) Fault description: a 63610 control valve repeatedly shows: all symbols display --display model -- no symbols display

(2) Fault elimination:

a) Open the front cover and disconnect the motor wire, if the display shows -00-, and above "fault description" doesn't occur, it means the motor or transformer is broken; if above "fault description" still shows, it indicates main board is damaged.

b) Check whether motor or transformer is damaged: replace a qualified transformer to check whether the valve can work normally. If not, it means the motor is damaged.

8.3.8 Trouble shooting when the softener valve doesn't work

(1) Fault description: a 63504 control valve doesn't draw brine and brine refill when in trial running.

(2) Fault elimination:

a) Disconnect the power and turn it on again to check whether the model is 63504. If not, disconnect the power of valve again, and power on after press both and until the screen

show model and setting symbol, press the and to change the valve model to 63504, then press to save it.

b) If the screen shows 63504, then check as following steps:

① After unlock, press to enter program inquiry mode, check parameter in each status by pressing or . If the parameter is 0, then reset it to required value; if the parameter is not 0, then check again as following step:

② Open the dust cover and front cover, check whether the wire connection between main board and locating board wire is loose, or the locating board is damaged.

8.3.9 Trouble shooting of no display on screen

(1) Fault description: a 73604 control valve shows no symbols during use.

(2) Fault elimination:

a) Connect the power after power off, and check whether the valve has a sound of "Di".

① If there is, it indicates the display board or wire of display board is damaged.

② If there is not, then the transformer, control board and display board are possibly damaged, then check as following step.

b) Check if the valve works normally by replacing a new transformer. If not, pull out the wires on the main board, then power on.

① If there is not a sound of "Di", it indicates the control board is damaged.

②If there is a sound of "Di", it indicates control board has no problem; then insert the connecting wires into the main board one by one, and observe and eliminate them in turn.

9. Runxin ceramic ball valve

9.1 Introduction

Ball valve is a kind of valve whose opening and closing part is a ball, and it is driven by the valve shaft and revolves on its axis. It is featured with small fluid resistance and quick opening and closing, and is widely used in pipeline transportation system. And it is mainly divided into two types: soft sealing ball valve and hard sealing ball valve.

Soft sealing ball valve indicates that one of ball vale's sealing parts (the valve seat sealing surface and sphere sealing surface) is made of flexible materials such as rubber or plastic; Hard sealing ball valve refers to that the ball valve use metal or ceramic material as the sealing part. The soft sealing ball valve has low requirements on the valve core or valve seat due to its flexible seal; the valve core and valve seat of the hard sealing ball valve are made of high hardness materials, so it has strict requirements for the fitness of the valve core and valve seat which require grinding in pair.

Compared with soft sealing ball valve, hard sealing ball valve greatly improves the sealing pressure, working temperature and service life, so it is applicable to a wider range of media. By selecting different materials, it can be applied to water, steam, oil, organic acid, and inorganic acid, solvents, alkalis, chemicals and other media. Ceramic ball valve is a one of the hard sealing ball valves. Besides of the most advantages of metal hard sealing ball valve, ceramic ball valve also has good performance on corrosion resistance, wear resistance, high temperature resistance and erosion resistance. It is mainly used in pipeline transportation system of various fields, such as electric power, petroleum, metallurgy, mining, papermaking, water treatment and other fields.

9.1.1 Structure of ceramic ball valve

Ball valve is mainly composed of valve body, valve core, the sealing part, valve shaft and driven device. Ceramic ball valve means the valve seat and valve core both adopt ceramic material, the structure is shown as Figure 9-1:

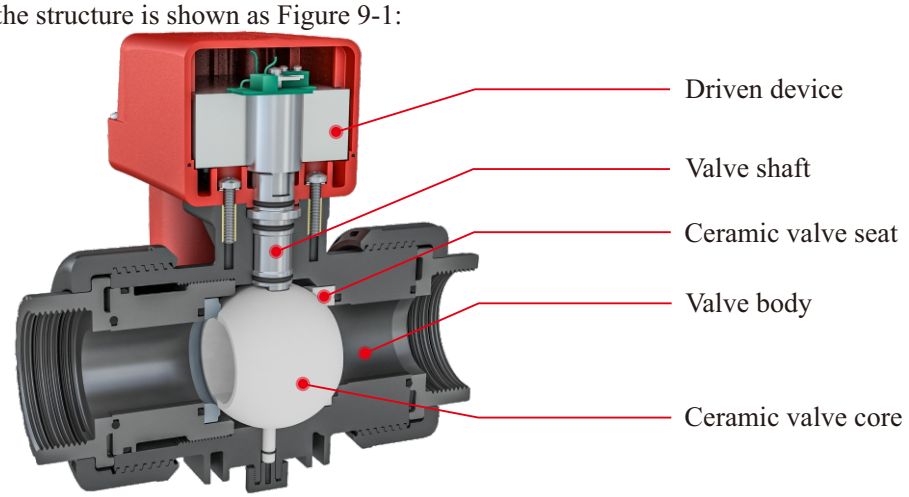


Figure 9-1 Structure of ceramic ball valve

9.1.2 Characteristics of ceramic ball valve

Ceramic materials have the best rigidity and hardness among engineering materials. Most of them have hardness above 1500HV and excellent chemical stability. They are not easy to be oxidized at high temperature and have good corrosion resistance to acid, alkali and salt. The valve core, valve seat and bushing of the ceramic core ball valve are all made of structural ceramic materials sintered at an ultra-high temperature above 1680℃, with extremely high hardness (≥HRA85) and chemical stability. Runxin ceramic ball valve has the following characteristics:

(1) Low torque

Runxin ceramic ball valve adopts a patented low-friction sealing structure, greatly reduces the opening and closing torque of the ball valve, which is much lower than similar products of other companies. The maximum torque comparison is shown in the following table:

Products	Nominal diameter	DN15	DN20	DN25	DN32
	Connector size	1/2 "	3/4 "	1 "	1-1/4 "
Torque of other brand ball valve (N·m)	0.6MPa	12	12	24	30
	1.0MPa	18	27	30	42
Torque of Runxin ceramic ball valve (N·m)	0.6MPa	1.5	1.5	2.0	7
	1.0MPa	2.0	2.0	3.0	12

(2) Corrosion resistance

Ceramic material has excellent chemical stability and do not react with most chemical media.

(3) Wear resistance

Ceramic is sintered at an ultra-high temperature above 1680℃, with extremely high hardness (≥HRA85), it can adapt to various high wear and high erosion working conditions.

(4) No leakage

Ceramic valve core and valve seat are grinded precisely in pair to ensure no leakage.

9.1.3 Classifications of ceramic core ball valves

There are many classifications of ceramic ball valve. According to different structures of ceramic valve core and valve seat, it could be classified into fixed ball valve and floating ball valve; according to different covering areas of ceramic material, it could be classified into full lined

ceramic ball valve and half-lined ceramic ball valve; according to different nominal diameter, it could be divided to full bore valve and reduced bore valve; according to different material of valve core, it could be classified into alumina, silicon carbide, zirconia etc.; according to different valve body materials, they are divided into metal valve bodies (304, 316, 316L, etc.) and non-metal valve bodies (PPO, UPVC, CPVC) Etc.) ball valve; according to different operation control methods, it can be divided into manual and automatic (automatic can also be divided into electronic and pneumatic, etc.) ball valves; according to different connection ways, it can be divided into flange connection, thread connection and butt welding connection; according to the different control modes, it can be divided into two-wire controlling, three-wire controlling, with feedback, AC220V, DC24V, DC12V and other ball valves.

9.1.4 Denomination rule

Denomination rule of Runxin ceramic ball valve:

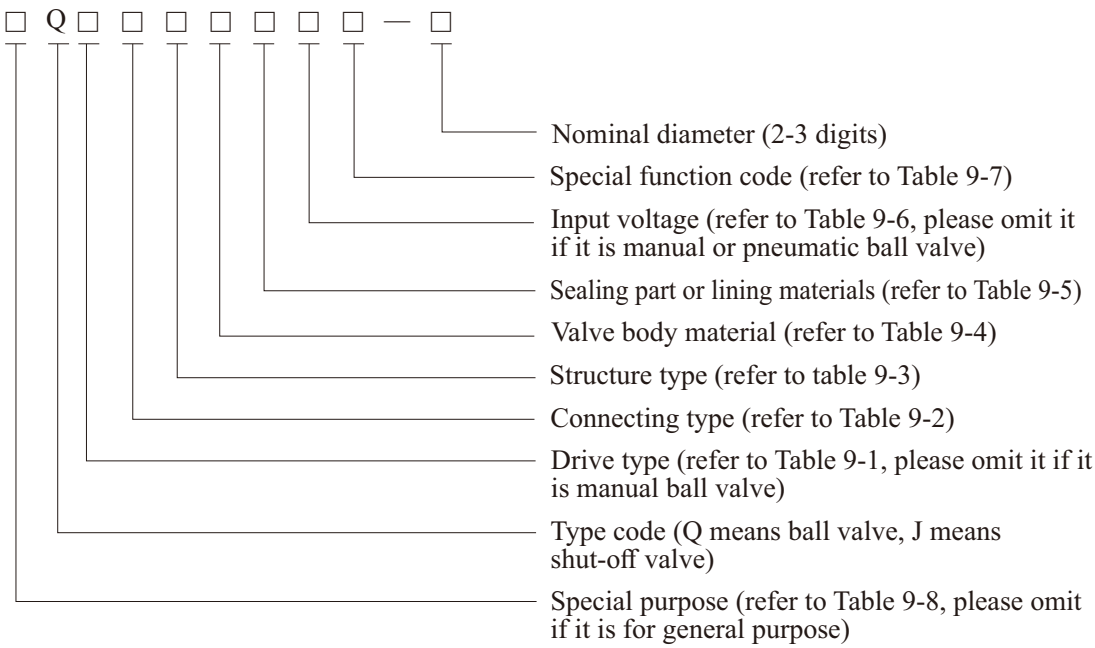


Table 9-1 Drive type code

Drive type	Solenoid driven	Worm gear driven	Bevel gear driven	Pneumatic driven	Electronic driven
Code	0	2	5	6	9

Please omit if it is manual ball valve. For pneumatic driven valve, “6K” represents normal open, “6B” represents normal close.

Table 9-2 Connecting type code

Connecting type	Female thread	Male thread	Glue	Flange	Hot melting	Weld	Butt clamp	Clamp	Clip
code	1	2	3	4	5	6	7	8	9

Table 9-3 Structure type code

Structure type		code		Structure type		code
Floating ball valve	Straight flow channel	1		Fixed Ball valve	Four-way flow channel	6
	Y shape three-way flow channel	2			Straight flow channel	7
	L shape three-way flow channel	4			T shape three-way flow channel	8
	T shape three-way flow channel	5			L shape three-way flow channel	9

Table 9-4 Valve body material code

Valve Body Material	PPO	Hpb59-1	304	316	316L	UPVC	CPVC	PPH
Code	0	1	2	3	4	5	6	7

Table 9-5 Sealing part or lining materials code

Sealing part	$95Al_2O_3$	SiC	ZrO_2	Si_3N_4	$99Al_2O_3$
Code	1	2	3	4	5

Table 9-6 Input voltage code

Input voltage	DC6V	DC12V	DC24V	DC36V	AC220V
Code	1	2	3	4	5

Table 9-7 Special function code

Function	Code		Function	Code
Duration controlling ball valve	A		Three-wires controlling	C
Point-in-time controlling ball valve	A1		Two-wires controlling with position feedback	D
Two wires power reset ball valve	B		Three-wires controlling with position feedback	E
Three wires power reset ball valve	B1		WIFI controlling	S

If ball valve has other function or structure, a letter will be added in front of valve type code, as Table 9-8 shows:

Table 9-8 Other functions or structures valve code

Function	Fireproof Type	Slow-closure Type	Slagging Type	Fast Type	Auxiliary manual type	Adjustable Type	(Shaft seal) Corrugated Pipe Type
Code	F	H	P	Q	S	V	W

9.1.5 Performance of different ceramic materials

The structure strength and performance vary according to different materials. Table 9-9 shows the physical performance of common ceramic materials, and table 9-10 shows the chemical corrosion resistance of common materials. The model selection of Runxin ceramic ball valve is shown in table 9-11.

Table 9-9 Performance of common ceramic material

Ceramic material code	Y-ZrO_2	Mg-ZrO_2	95Al_2O_3	99Al_2O_3	S i_3N_4	SiC
Density g/cm^3	6.0~6.05	5.72~5.74	3.6~3.75	3.9~3.95	3.2~3.33	3.15~3.25
Hardness HRA	87	85	90	92	92	94
Bending strength MPa	1150	900	370	450	1200	470
Compressive strength MPa	2000	1800	2000	2200	2800	--
Coefficient of thermal expansion×10^{-6}/℃	9.6	10	7.8	8.3	3.4	4
Elastic Modulus GPa	200	200	330	350	300	400
Coefficient of crushing strength KN(φ6mm)	15	10	3.6	4	18	3.5
Coefficient of water absorption %	0	0	0.01	0	0	0.5

Table 9-10 Chemical corrosion resistance of common materials

Medium	Temperature	ZrO_2	99Al_2O_3	SiC	S i_3N_4	Fluororubber	PPO	SS304	SS316
20%HCL	60℃	A	A	A	B	A	A	C	B
20%HCL	95℃	A	A	A	C	A	A	--	C
90%H_2SO_4	60℃	A	A	A	A	A	A	C	B
90%H_2SO_4	95℃	A	A	A	B	A	A	C	C
60%H_3PO_4	60℃	A	A	A	C	A	A	C	A
60%H_3PO_4	95℃	A	A	A	C	A	A	C	A
10%HF	60℃	C	B	A	A	A	A	C	B
46%HF	95℃	C	C	A	C	A	A	--	C
60%HNO_3	60℃	A	A	A	C	A	A	A	C
60%HNO_3	95℃	A	B	A	C	A	A	B	C
30%NaOH	60℃	A	B	A	B	A	A	A	A
30%NaOH	95℃	B	B	A	C	A	A	B	A

Notice:

A: <0.1mmg/cm^2/day, indicates that the material is in the medium, and there is no corrosion or can be ignored, it is recommended to use;

B: 0.1~0.3 mmg/cm^2/day, indicates that the material is slightly corroded or less corroded in the medium, suitable for use;

C: > 0.3mmg/cm^2/day, indicates that the material is moderately or mostly corroded in the medium, it is not recommended to use.

Table 9-11 Model selection of Runxin ceramic ball valve

Valve body	Seal ring	Valve shaft	Valve seat	Applicable medium
PPO	EPDM	316L,304 covered by PPO	Single ceramic valve seat (95%Al_2O_3)	It is suitable for non-corrosive media without solid particles and chemical substances such as acids and alkalis, salts, alcohols, and seawater. Not suitable for oxidizing acid, hydrofluoric acid, hydrochloric acid, ferric sulfate, ammonium sulfate, hydrochloride, bromine, hypochlorite salts, aromatic hydrocarbon, chlorinated hydrocarbon, organic acids, ketone, gasoline, synthetic oil etc..
UPVC				
316	EPDM		Single ceramic valve seat (95%Al_2O_3)	It is suitable for non-corrosive media without solid particles and chemical substances such as acids and alkalis, salts, alcohols, and polar solvent. Not suitable for oxidizing acid, hydrofluoric acid, hydrochloric acid, ferric sulfate, ammonium sulfate, hydrochloride, bromine, hypochlorite salts, organic acids, gasoline, synthetic oil etc..
PPO UPVC	EPDM	316L,304 covered by PPO	Double ceramic valve seats (95%Al_2O_3)	It is suitable for non-corrosive media and chemical substances such as acids and alkalis, salts, alcohols, and seawater. Not suitable for oxidizing acids other than nitric acid, hydrofluoric acid, fluorosilicic acid, hydrochloric acid, iron sulfate, ammonium sulfate, hydrochloride, bromine, hypochlorite, organic acids, ketones, gasoline, synthetic lubricants, etc.
316				It is su itable for non-corrosive media and chemical substances such as acids and alkalis, salts, alcohols, and polar solvent. Not suitable for oxidizing acids other than nitric acid, hydrofluoric acid, fluorosilicic acid, hydrochloric acid, iron sulfate, ammonium sulfate, hydrochloride, bromine, hypochlorite, organic acids, ketones, gasoline, synthetic lubricants, etc.
PPO UPVC 316	VMQ	316L,304 covered by PPO	Double ceramic valve seat s (95%Al_2O_3)	Only recommended for non-corrosive media and organic acids.

PPO UPVC	FKM	Hastelloy alloy C	Double ceramic valve seats ($95\%Al_2O_3$)	Except for sulfuric acid and nitric acid, it is only recommended to apply to oxidizing acids, hydrogen peroxide and most sulfates, hydrochloride and oxidizing acids including aluminum and iron salts
		Hastelloy alloy B/ Hastelloy alloy 20		It is only recommended for various concentrations of sulfuric acid, hydrochloric acid, and most of the sulfates and hydrochlorides except aluminum and iron salts.
PPO	FRPM	304 covered by PPO	Double ceramic valve seat (SiC)	It is suitable for non-corrosive media, acids and alkalis, salts and alcohols; it is not suitable for aromatic hydrocarbons, chlorinated hydrocarbons, oils, ketones, esters, ethers and permanganates.
UPVC	FRPM			It is suitable for non-corrosive media, acids and alkalis, salts, alcohols, aliphatic hydrocarbons and oil; it is not suitable for ketones, esters, ethers, aromatic hydrocarbons and potassium permanganate.
316L	EPDM			It is suitable for non-corrosive media and chemical substances such as acids and alkalis, salts, alcohols, and polar solvent. Not suitable for oxidizing acid, hydrofluoric acid, hydrochloric acid, hexafluorosilicic acid, ferric sulfate, ammonium sulfate, hydrochloride, bromine, hypochlorite salts, organic acids, gasoline, synthetic oil etc..

9.1.6 Comparison of ceramic ball valve and shut-off valve

The shut-off valve is a valve whose opening and closing parts are plug-shaped discs and the sealing surface is flat or conical. The opening and closing of the valve is realized by linear movement of the disc along the center line of the fluid. The shut-off valve is a forced sealing valve, so when the valve is closed, pressure must be applied to the disc to force the sealing surface to not leak. The comparison of ceramic ball valve and shut-off valve is shown in Table 9-12.

Table 9-12 Comparison of ceramic ball valve and shut-off valve

Shut-off valve	Hard sealing	Large flow resistance	Good sealing performance	Fast opening and closing	Not suitable for media with particles, high viscosity and easy to coke	Large force to open and close
Ceramic ball valve	Hard sealing	Low flow resistance	excellent sealing performance	Quicker opening and closing	Wider applicable medium	Small force to open and close

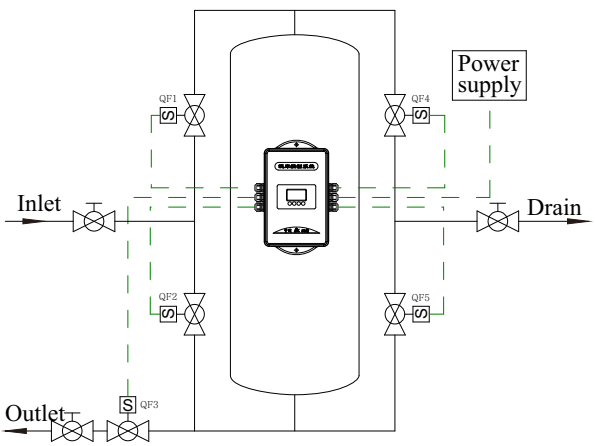
9.2 Application of ceramic ball valve

Ceramic ball valves are widely used. Because of their corrosion resistance, wear resistance, high temperature resistance and erosion resistance, they are mainly used in pipeline transportation systems in various fields, such as electricity, petroleum, chemical industry, metallurgy, mining, papermaking, and water treatment, etc.

9.2.1Application of ceramic ball valve in water treatment system

9.2.1.1 Application in filtration water treatment system

The controller is combined with five ceramic ball valves. By controlling the opening and closing status of different ball valves, they can be used in filtration water treatment systems to realize the functions of filtration, backwashing, and fast rinsing. The opening and closing and structure of the ball valves are shown as Figure 9-2:

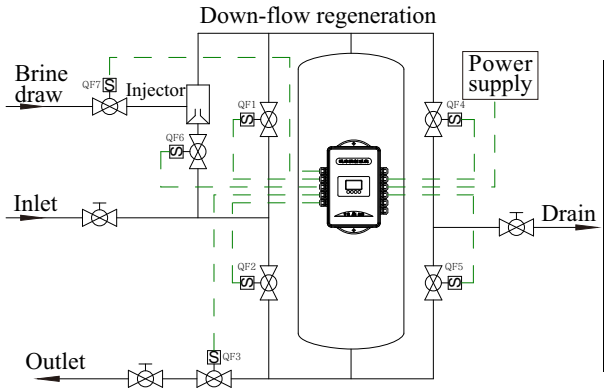


Station	Status of ball valve				
	QF1	QF2	QF3	QF4	QF5
Service	Open	Close	Open	Close	Close
Backwash	Close	Open	Close	Open	Close
Fast rinse	Open	Close	Close	Close	Open

Figure 9-2 The structure diagram of the ball valve applied to the filtration water treatment system and the valve opening and closing state diagram

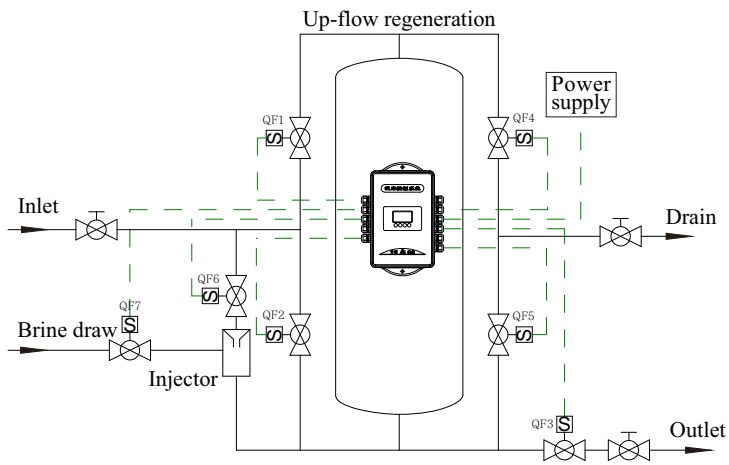
9.2.1.2 Application in softening water treatment system

The controller is combined with seven ceramic ball valves and injectors. By controlling the opening and closing status of different ball valves, they can be used in softening water treatment systems to realize the functions of service, backwashing, down-flow or up-flow regeneration, brine refill and fast rinse. The opening and closing and structure of the ball valve are shown as Figure 9-3 and Figure 9-4:



Station	Status of ball valves of down-flow regeneration system						
	QF1	QF2	QF3	QF4	QF5	QF6	QF7
Service	Open	Close	Open	Close	Close	Close	Close
Backwash	Close	Open	Close	Open	Close	Close	Close
Down-flow brine draw	Close	Close	Close	Close	Open	Open	Open
Slow rinse	Close	Close	Close	Close	Open	Open	Close
Fast rinse	Open	Close	Close	Close	Open	Close	Close
Brine refill	Open	Close	Open	Close	Close	Close	Open

Figure 9-3 The structure diagram of the ball valve applied to the softening water treatment system and the valve opening and closing state diagram of down-flow regeneration system



Station	Status of ball valve of up-flow regeneration system						
	QF1	QF2	QF3	QF4	QF5	QF6	QF7
Service	Open	Close	Open	Close	Close	Close	Close
Backwash	Close	Open	Close	Open	Close	Close	Close
Up-flow brine draw	Close	Close	Close	Open	Close	Open	Open
Slow rinse	Close	Close	Close	Open	Close	Open	Close
Fast rinse	Open	Close	Close	Close	Open	Close	Close
Brine refill	Open	Close	Open	Close	Close	Close	Open

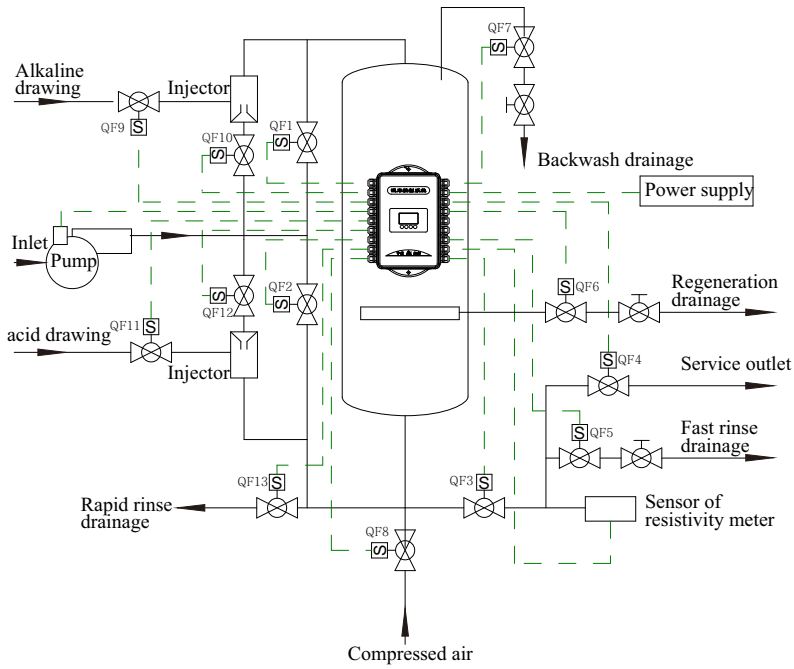
Figure 9-4 The structure diagram of the ball valve applied to the softening water treatment system and the valve opening and closing state diagram of up-flow regeneration system

9.2.1.2 Application in mixed bed system

The controller is combined with 13 ceramic ball valves, acid and alkali absorption injectors, resistivity meter and compressed air device. By controlling the opening and closing status of different ball valves, they can be used in mixed bed water treatment systems to realize the functions

of service, backwashing, settling, alkaline drawing, acid drawing, drainage, mixing and rapid rinse. The opening and closing and structure of the ball valve are shown as Figure 9-5:

Mixed bed regenerated with primary demineralization water



Station	Working status of ball valves and pumps													
	QF1	QF2	QF3	QF4	QF5	QF6	QF7	QF8	QF9	QF10	QF11	QF12	QF13	Pump
Service	Open	Close	Open	Open	Close	Close	Close	Close	Close	Close	Close	Close	Close	Open
Backwash	Close	Open	Close	Close	Close	Close	Open	Close	Close	Close	Close	Close	Close	Open
Settling	Close	Close	Close	Close	Close	Open	Open	Close	Close	Close	Close	Close	Close	Close
Alkaline drawing	Close	Close	Close	Close	Close	Open	Close	Close	Open	Open	Close	Open	Close	Open
Acid & alkaline drawing	Close	Close	Close	Close	Close	Open	Close	Close	Open	Open	Open	Open	Close	Open
Acid/alkaline rinse	Close	Close	Close	Close	Close	Open	Close	Close	Close	Open	Close	Open	Close	Open
Drainage	Close	Close	Close	Close	Close	Open	Open	Close	Close	Close	Close	Close	Close	Close
Mixing	Close	Close	Close	Close	Open	Close	Open	Open	Close	Close	Close	Close	Close	Close
rapid rinse	Close	Close	Open	Close	Open	Close	Open	Close	Close	Close	Close	Close	Open	Close
Air exhaust	Open	Close	Open	Close	Open	Close	Open	Close	Close	Close	Close	Close	Close	Open
Fast rinse	Open	Close	Open	Close	Open	Close	Close	Close	Close	Close	Close	Close	Close	Open

Figure 9-5 The structure diagram of the ball valve applied to the mixed bed primary demineralization water system and the valve opening and closing state diagram

9.2.2 Application cases of ceramic ball valve in water treatment system

9.2.2.1 Application of ceramic ball valve in softening water treatment system

(1) Project background

The integrated softening control valve has more internal passages in the valve body and the structure is more complicated. For water sources containing more impurities such as mud and sand, it is suggested to use coagulation sedimentation before processing to prevent the mud and sand impurities from causing damage to the control valve. However, in some occasions, precipitation cannot be carried out due to installation site restrictions. Therefore, a multi-valve system composed of several ball valves occurs.

In 2012, a coking plant in Shijiazhuang of China adopts the F78A3 to form a water softening system. A few years later, the quality of the raw water changed and the content of mud and sand increased. However, the original system is not designed with a mud filter, resulting in damage to the control valve due to accumulated mud and sand. Later, it is replaced by a softening system composed of 7 ceramic ball valves and a controller.

(2) Project introduction

Since the ball valve is a straight flow channel structure, the water resistance is relatively small. The softening system is composed of 2 sets of DN50 ball valves, 3 sets of DN40 ball valves, 2 sets of DN25 ball valves, as well as injectors and flow meters. The flow rate can reach 20-30m^3/h. The equipment and piping installation are shown in Figure 9-6.

(3) Operation effect

After the installation at the beginning of 2016, it has been running stably so far, the previous problems have been completely solved, and the customers are very satisfied.



Figure 9-6 Application of ceramic ball valve in softening system

9.2.2.2 Application of ceramic ball valve in boiler water softening system

(1) Project background

Excessive raw water hardness of the boiler is very harmful to the boiler. The higher the hardness of the raw water, the easier it is to produce scaling on the heating surface of the boiler,

which will reduce the thermal efficiency, increase the energy consumption and failure rate, and reduce the service life of the boiler. Even boiler safety accidents occurred. Therefore, the hardness of boiler raw water must meet the relevant national standards.

Boiler softening water systems mostly use multi-channel integrated valves and resin tanks to achieve softening, but integrated control valves are not suitable for working conditions with high flow rate requirements. Therefore, several valves are needed to achieve softening through program controlling to achieve softening.

(2) Project introduction

A heating steam boiler of an energy company in Shijiazhuang of China uses tap water as raw water, with an average hardness of about 8.6mmol/L. The hardness of the raw water is seriously exceeding the standard, and it needs to be softened to less than 0.03mmol/L to meet the steam boiler feed water standard, and the required flow rate is 80m^3/h.

The softening water treatment system adopts 2 sets of softeners, matched with 2 sets of ceramic ball valve to form a multi-valve automatic control system, which could realize simultaneous water supply and separate regeneration by interlocking. Each system adopts DN65 ball valves, DN65 flow meter, DN32 injector and so on, respectively matched with a FRP tank with a diameter of 1.5m and a height of 2.4m, filled with 2250L resin, equipped with a 2000L brine tank, and installed F84 online monitor device at the water softener outlet. When hardness of outlet water is higher than 0.03mmol/L, F84 will send a signal to the multi-valve system to automatically start regeneration to ensure the quality of outlet water. The installation of the softening water treatment system is shown as Figure 9-7, and the water treatment processing is as follows:

Tap water→ Filter→ Ion exchanger→ Automatic water hardness test→ Soft water tank→ Booster pump→ Boiler water



Figure 9-7 Application of ceramic ball valve in boiler water softening system

(3) Operation effect

After the test of relevant departments, the quality of outlet water is fully complied with the steam boiler feed water standard. Since October of 2017, this system has been working stably, the quality of the water produced is qualified, and the automation controlling performs nicely. Customers are very satisfied.

Ceramic electronic ball valve can be used in filtration and softening system. The filtration and softening equipment could be operated under best working conditions by selecting ball valve diameter for inlet, outlet, fast rinse and backwash.

9.2.2.3 Application of ceramic ball valve in clearwater, purified water and ultrapure water equipment

In the design and production of pure water and ultrapure water equipment, it is generally necessary to arrange an inlet control valve before the high-pressure pump, and arrange a low-pressure and high-pressure flushing control valve on the concentrated water side and a fresh water discharge control valve in the pure water membrane side. When designing, it is generally to use 220V normally closed solenoid valve. The working principle of the solenoid valve determines that the inlet water control valve before the high-pressure pump needs to be continuously energized as long as the equipment is in operation. Long-term operation will accelerate the aging of the solenoid valve coil, resulting in the decrease of its service life; because the solenoid valve starts and closes is completed instantly, so that every point where the solenoid valve is used needs to withstand the impact of water hammer. In the ultra pure water system, the electric butterfly valve is usually used to cooperate with the water pump to realize soft start or frequency conversion start. The process control needs to be completed by the programmable controller PLC or time relay. Soft sealing electric butterfly valves, electric ball valves and other products have large opening and closing torques, so the actuator motor power is high, the actuator is large and heavy, and it must be arranged in a pure water system with a large space and sufficient pipeline strength support, which increases the burden of equipment design work and also increases production costs.

The light torque characteristic of the ceramic hard sealing ball valve only requires a DC24V safety voltage, and makes it possible to set a 3s-12s to open and close, which can reduce water hammer. And due to the small torque, under the same specification, the ceramic hard sealing ball valve's actuator size is only 20-30% of other brand ball valve products, which greatly reduces the size and weight of the actuator, saves production costs, and provides more space for equipment design.

9.2.2.4 Application of ceramic ball valve in multi-media filter, carbon filter, anion and cation mixed bed and disk filter

In systems with a flow rate of less than 50m^3/h for softening water treatment equipment,

multi-port control valves have incomparable advantages. However, for large flow systems exceeding 80m^3/h, multi-port control valves are difficult to realize whether they are the valve with flat disk structure, piston valves, or cam structure valves due to structural design. Using a multi-valve system consisting of a ball valve controller and multiple ceramic hard sealing ball valves can achieve different flow rates according to the diameter of the matched ball valve.

In filtration system, some filter materials require a backwash flow velocity several times higher than the service flow velocity, which is difficult to achieve with general multi-port control valves. When designing and selecting valve model, the multi-port control valve should be selected according to the backwash flow rate instead of the designed service flow rate, which increases the purchase cost of the control valve. Using ball valve controller and a number of ceramic hard sealing ball valves can solve this problem well. A larger diameter ball valve can be set to meet the requirements on the backwash rate if the system needs larger backwash flow velocity.

The water flow process of anion and cation mixed bed is more complicated, and the material has high requirements for acid and alkali corrosion resistance. It is usually designed with a controller and a pipeline valve. The ceramic valve core and ceramic valve seat of the Runxin ball valve can resist acid and alkali, which is very suitable to apply in this type of anion and cation mixed bed system.

Disk filters used to filter large particles, and it often face the challenges of various types of sediment, residues and other large particles. At present, disk filters that use a large number of diaphragm valves often cause permanent damage to the diaphragm due to the fine particles entering the valve. It will reduce the service life of the diaphragm valve, and affect the quality of filtered water. The ceramic hard sealing ball valve can solve this problem well. The particles cannot pass through the sealed surface of the ceramic ball valve and will not scratch the ceramic surface because of its high hardness, which as a more durable sealing function.

9.2.2.5 Application of ceramic ball valve in special water treatment equipment like iron and manganese removal and fluorine removal

There are various methods for treating water with special characteristics. Compared with water purification equipment such as softened water and activated carbon, special water treatment equipment requires a slower filtration flow velocity, a larger rinse flow velocity, and a more complicated treatment process.

Take iron and manganese removal device as example, after aeration treatment, the ferrous ion will oxidize into ferric ion and form iron oxides that are insoluble in water, which we commonly call "iron rust mud". With valve design systems such as butterfly valves and soft sealing ball valves, the "iron rust mud" oxidized anytime and anywhere can easily enter the sealing element of the valve through the water flow, causing permanent damage to the soft sealing element and causing equipment broken.

The hard sealing feature of ceramic ball valve, make it impossible for the "iron rust mud" to pass though the sealing surface, it nicely protects the sealing part of sealing element, and prolong the service life of sealing element. If the rust is accumulated on the closed sealing surface, but because of the light torque of ceramic ball valve, it makes easier to turn on the ceramic ball valve.

In special water treatment equipment, the regeneration system usually uses a high concentration of acid or alkali solution to regenerate and activate the filter material. The corrosion resistance of ceramic hard sealing ball valves can ensure that the valve sealing elements will not be easily corroded due to strong acid or alkali solutions.

9.2.3 Application of ceramic ball valve in agricultural irrigation

China's annual waste of water resources is serious. The national agricultural irrigation water consumption is about 390 billion cubic meters per year, accounting for 64% of the total water consumption in China. The main reason is that most parts of the country still use the old way of "earth canal for water conveyance, irrigation by flooding", the waste of water is very serious, the effective utilization rate of water is only 50-55%. However, in developed countries, due to the realization of water conveyance canal bleeding prevention, pipelining, field spraying irrigation, drip irrigation, irrigation automation, scientific, the effective utilization rate of water reaches 70-80%.

Runxin ceramic ball valve can be turned on automatically by humidity induction; or turned by time control; or remote controlling. It can save water if applied in agricultural irrigation.

9.2.4 Application of ceramic ball valve in chemical industry

9.2.4.1 Application of ceramic ball valve in heavy metal recovery device of electroplating solution

There is a large amount of heavy metal in electroplating solution, such as chromium, nickel, gold and so on. It will seriously pollute the environment if these heavy metals are discharged directly, and some heavy metals are very expensive also. After the heavy metals are recovered bythe recovery device, the first is to remove the heavy metals in the waste liquid, so that it can meet the emission standards; the second is to extract the heavy metals.



Figure 9-8 Application of ball valve in heavy metal recovery device of electroplating solution

An electroplating plant requires a $2m^3/h$ flow rate while doing waste liquid treatment, and uses anion and cation exchange resins to refine the waste liquid. After the resin is saturated, it needs to be regenerated with acid and alkali, so this system adopts acid and alkali resistant ceramic ball valve, which is controlled by PLC to realize the automatic conversion of each flow channel. This system is composed of 2 FRP resin tanks with the diameter of 340mm and with the height of 1370mm, which are respectively filled with anion and cation resin to form a set of anion and cation bed system to treat the waste liquid. The inlet pressure is 0.2MPa, the installation of equipment is shown as Figure 9-8, the working process is shown as Figure 9-9. When the invalid resin needs regeneration, the anion resin is regenerated with 5% - 7% NaOH solution, and the cation resin is regenerated with 10% hydrochloric acid.

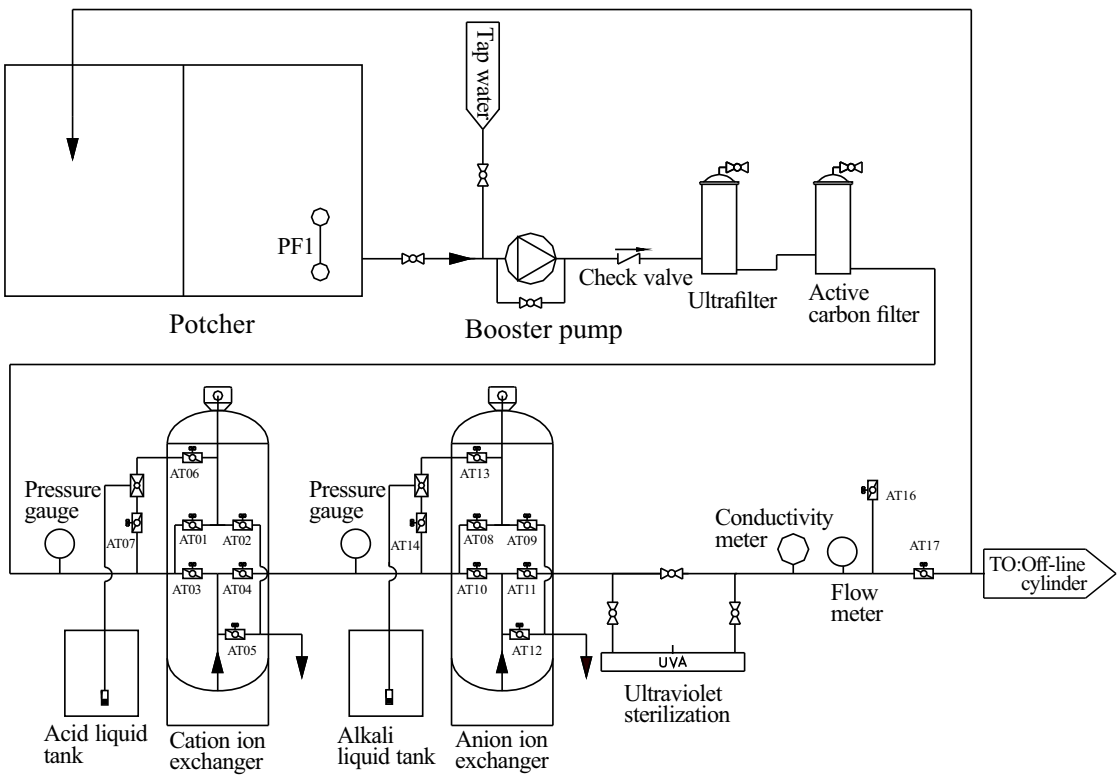


Figure 9-9 Working process of heavy metal recovery device of electroplating solution

9.2.4.2 Application of ceramic ball valve in sodium hypochlorite generator

Runxin ceramic hard sealing ball valve adopts alumina or silicon carbide ceramic valve core, and the sealing structure is ceramic hard seal. So it is featured with the characteristics of corrosion resistance and wear resistance, which overcomes the shortcomings of traditional valves that only wear resistance or corrosion resistance. The unique patented technology of Runxin is adopted to further reduce the torque of the ball valve, and the smaller actuator can be used to save the installation space and power consumption.

In sodium hypochlorite generator, high concentration brine produces sodium hypochlorite solution through electrolytic reaction. High-concentration brine is easy to crystallize and is corrosive. Sodium hypochlorite solution has strong corrosion and strong oxidation. So, it requires valve is resistant to wear and corrosion at the same time. Ceramic are hard sealing ball valve can meet both technical requirements of corrosion resistance and wear resistance at the same time, so that the equipment can operate stably for a long time. Its installation is shown as Figure 9-10.

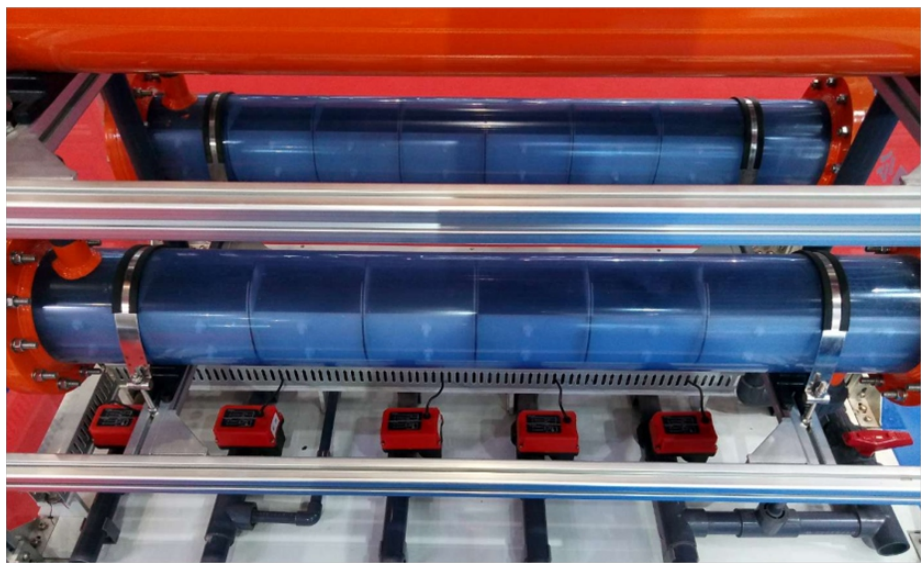


Figure 9-10 Application of ceramic ball valve in sodium hypochlorite generator

Reference

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10. Chinese Patent: ZL200720045551.5 "Automatic Water Processing Apparatus", Invented by Wu Xiaorong, Wu Xianshui, Yang Runde.

11. Chinese Patent: ZL201320732225 "Ball valve", invented by Yuan Hailin, Wu Xiaorong.

Product classification index

Maximum flow rate m^3/h	Filter valve		Manual softener	Automatic softener valve			Floating bed	One valve on duplex tanks	One valve on three tanks
	Manual	Automatic	Down-flow regeneration	Down-flow regeneration	Up-flow regeneration	Down/up-flow regeneration			
1-2 m^3/h	51101 F56B					82502 F79			18601 F120
	51102 F56E	53502 F71	61202 F64B	63502 F65/F117	73502 F69	82502 F79/F105/F122			
3-4 m^3/h						82503 F97/F136		17603 F73	
	51104 F56A	53504 F67	61104 F64A	63504 F63/F116	73504 F68	82504 F82	93504 F83A		18604 F118
5-6 m^3/h				63505 F130	73505 F92			17606 F98	
	51106 F56F	53506 F67B-A	61106 F64F						
8-12 m^3/h		53508 F134		63508 F133				17610 F88/F135	
	51110 F56D	53510 F75	61210 F64D	63510 F74					
15-25 m^3/h				63515 F99					
	51215 F77BS	53518 F77B	61218 F77AS	63518 F77A			91215 F77CS		
		53520 F95B/F111B		63520 F95A/F111A					
30-50 m^3/h	51240 F112BS	53540 F112B							
		53550 F96B	61240 F112AS	63540 F112A			91240 F112CS		
				63550 F96A					

Automatic softener valve can be divided into time type and meter type, there is only time type or meter type in above table. If the third digit of time type is 5, meter type is 6.

There are two models for the same flow rate, which means that the installation method is different or two principles are used to develop control valve with same flow rate.

Product parameter configuration table

Classification	Model	Old model	Inlet/outlet	Drain	Brine line connector	Base	Riser pipe	Maximum flow rate m3/h	Tank diameter range（in）	Remark
Manual filter valve	51101A	F52	1/2″F	1/2″F		M82×3	Φ16.5	1	6″～10″	
	51101B/C	F56B/F56C	1/2″ or 3/4″F	1/2″ or 3/4″F		Tr95×6 or Tr118×6	1.05″OD	1	10"/ 20" Filter shell	
	51102	F56E	1/2″ or 3/4″F	1/2″ or 3/4″F		2.5″-8NPSM	1.05″OD	2	6″～10″	
	51104	F56A	1″F	1″F		2.5″-8NPSM	1.05″OD	4	6″～12″	
	51106	F56F	1″F	1″F		2.5″-8NPSM	1″D-GB	6	6″～14″	
	51110	F56D	2″F	2″F		4″-8UN	1.5″D-GB	10	10″～24″	
	51215	F77BS	2″M	2″M		4″-8UN	1.5″D-GB	18	14″～30″	
	51240	F112BS	DN65	DN65		DN80(Top/bottom strainer)	/	30	24″～42″	Side-mounted installation
Automatic filter valve	53502	F71B	3/4″M	3/4″M		2.5″-8NPSM	1.05″OD	2	6″～10″	
	53504	F67B	1″F	1″F		2.5″-8NPSM	1.05″OD	4	6″～12″	
	53506S	F67B-A	1″F	1″F		2.5″-8NPSM	1″D-GB	6	6″～14″	
	53510	F75A	2″M	2″M		4″-8UN	1.5″D-GB	10	10″～24″	
	53518	F77B	2″M	2″M		4″-8UN	1.5″D-GB	18	14″～30″	
	53520	F95B	2″M	2″M		2"M(Top/bottom strainer)	/	20	18″～36″	Side-mounted installation
	53520	F111B	2″M	2″M		4″-8UN	1.5″D-GB	20	18″～36″	
	53540	F112B	DN65	DN65		DN80(Top/bottom strainer)	/	30	24″～42″	Side-mounted installation
	53550	F96B	DN80	DN80		DN100(Top/bottom strainer)	/	40	24″～48″	Side-mounted installation
Manual softener valve, down-flow regeneration	61202	F64B	3/4″F	1/2″M	3/8″M	2.5″-8NPSM	1.05″OD	2	6″～12″	
	61104	F64A	1″F	1/2″M	3/8″M	2.5″-8NPSM	1.05″OD	4	6″～18″	
	61206	F64F	1.5″M	3/4″M	1/2″M	4″-8UN	1.25″D-GB	6	10″～24″	
	61210	F64D	2″M	1″M	1/2″M	4″-8UN	1.5″D-GB	10	10″～30″	
	61215	F77AS	2″M	1.5″M	3/4″M	4″-8UN	1.5″D-GB	18	24″～40″	
	61240	F112AS	DN65	DN65	3/4″M	DN80(Top/bottom strainer)	/	40	36″～60″	Side-mounted installation
Automatic softener valve, down-flow regeneration	63502	F65	3/4″M	1/2″M	3/8″M	2.5″-8NPSM	1.05″OD	2	6″～12″	
	63504	F63	1″M	1/2″M	3/8″M	2.5″-8NPSM	1.05″OD	4	6″～18″	
	63505	F130	1″M	3/4″M	3/8″M	2.5″-8NPSM	1″D-ANSI	5	6″～22″	
	63508	F133	1.5″M	3/4″M	1/2″M	4″-8UN	1.25″D-GB	8	10″～30″	
	63510	F74	2″M	1″M	1/2″M	4″-8UN	1.5″DGB	10	10″～30″	
	63515	F99	2″M	1.5″M	3/4″M	4″-8UN	1.5″DGB	15	24″～40″	
	63518	F77A	2″M	1.5″M	3/4″M	4″-8UN	1.5″DGB	18	24″～40″	
	63520	F95A	2″M	1.5″M	3/4″M	2"M(Top/bottom strainer)	/	20	24″～42″	Side-mounted installation
	63520	F111A	2″M	1.5″M	3/4″M	4″-8UN	1.5″DGB	20	24″～42″	
	63540	F112A	DN65	DN65	3/4″M	DN80(Top/bottom strainer)	/	40	24″～60″	Side-mounted installation
	63650	F96A	DN80	DN80		DN100(Top/bottom strainer)	/	50	24″～63″	Side-mounted installation

Automatic softener valve, up-flow regeneration	73502	F69	3/4″M	1/2″M	3/8″M	2.5″-8NPSM	1.05″OD	2	6″～12″	
	73504	F68	1″M	1/2″M	3/8″M	2.5″-8NPSM	1.05″OD	4	6″～18″	
	73505	F92	1″M	3/4″M	3/8″M	2.5″-8NPSM	1″D-ANSI	5	6″～22″	
Automatic softener valve, down/up-flow regeneration	82602	F79	3/4″M	1/2″M	3/8″M	2.5″-8NPSM	1.05″OD	2	6″～12″	
	82602	F105	3/4″M	1/2″M	3/8″M	2.5″-8NPSM	1.05″OD	2	6″～12″	
	82603	F97	3/4″M	1/2″M	3/8″M	2.5″-8NPSM	1.05″OD	3.5	6″～16″	
	82603	F136	1″M	1/2″M	3/8″M	2.5″-8NPSM	1.05″OD	3.5	6″～16″	
	82604	F82	1″M	1/2″M	3/8″M	2.5″-8NPSM	1.05″OD	3.5	6″～16″	
One valve on duplex tanks	17603	F73	1″M	1/2″M	3/8″M	2.5″-8NPSM	1.05″OD	3.5	6″～14″	
	17606	F98	1″M	3/4″M	1/2″M	1"M(Top/bottom strainer)	/	3.5	6″～22″	Side-mounted installation
	17610	F88	1.5″M	1″M	1/2″M	1.5"M(Top/bottom strainer)	/	10	10″～30″	Side-mounted installation
	17610	F135	1.5″M	1″M	1/2″M	4″-8UN	1.5″D-GB	10	10″～30″	
One valve on three tank	18601	F120	1″M	1/2″M	3/8″M	2.5″-8NPSM	1.05″OD	2	6″～12″	
	18604	F118	3/4″M	1/2″M	3/8″M	2.5″-8NPSM	1.05″OD	3.5	6″～16″	

Remark: F-Female M-Male OD-Outer diameter D-GB indicates the Chinese national standard nominal diameter.

The old models in the table are the ones compiled earlier, and they are numbered in sequence, which has no practical significance.

Edited by Zhou Ying, Wu Xiaorong, Liu Ying, Wu Xianshui, Yuan Hailin, Ye Maogan

The Chinese title “润新阀之应用” is written by Yang Runde, the chairman of Wenzhou Runxin Manufacturing Machine Co., Ltd.

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