

# Design of Alkali Residue Pretreatment Device Based on PLC

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**Abstract:** In the production process of nuclear fuel elements, a large amount of uranium-containing alkali residue will be produced. In order to solve the problems of low efficiency and long time, a PLC-based alkali residue pretreatment device platform is proposed. Through the overall scheme design of the platform, the work flow is determined, and the communication between the upper computer and the alkali residue pretreatment device, the communication between the upper computer and the PLC are mainly solved. In terms of system hardware, the design and selection of electrical control principle, the selection of PLC model, the design of vacuum pipeline and the design of wiring diagram are carried out. In terms of control system software, STEP 7-Microwin SMART is used to write the control program of PLC as the main controller, and then the human-computer interaction interface is designed by Visual Studio2015, and the measured data is put into the database by connecting with the SQL2012 database. Finally, the human-computer interaction is realized by PC compilation, and the experimental platform is started and debugged. The final experimental results show that the whole platform meets the requirements of industrial production.

**Keywords:** Alkaline residue pretreatment device, Automation, Control system.

## 1. Introduction

The device is a set of relatively high degree of automation, can achieve professional, targeted alkali residue pretreatment device. The operator needs to use the trolley to transport the slag bucket to the feed end conveyor roller. The conveying equipment, lifting mechanism, vibrating screen, microwave drying device, crusher and pumping purification system in the device work to achieve automatic operation[1]. Among them, the turnover mechanism pours the slag in the bucket into the screening and sorting device for manual sorting, and picks up foreign bodies such as metal to fill the bucket. After that, the vibrating screen is opened for mechanical screening, and the material on the screen is loaded on the plate, and whether it needs to be manually sorted again is determined according to the demand[2]. The process control realizes visualization and real-time monitoring of various parameters (such as temperature, position, time, discharge amount, vacuum value).

## 2. The Overall Structure and Working Principle of Alkali Residue Pretreatment Device

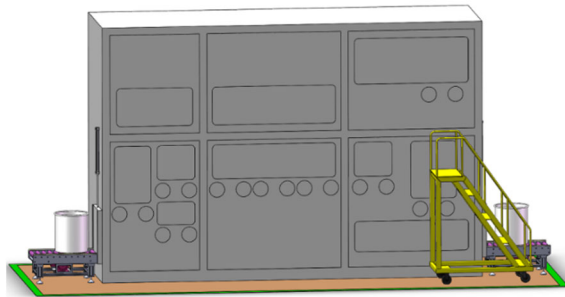
### 2.1. Structure of alkali residue pretreatment device

Use the trolley to transport the slag bucket to the feed end conveyor roller ; open the cover room exhaust fan at the feed end, and open the closed door at the feed end ; start the conveyor roller to send the slag bucket into the opening chamber ; closing the closed door of the feed end and closing the open chamber exhaust fan ; manually open the barrel cover ; the lifting mechanism automatically holds the slag bucket and lifts it to the flip position ; the turnover mechanism

pours the slag in the barrel into the screening and sorting device for manual sorting, detects metal and other foreign objects in the barrel, and then opens the vibrating screen for mechanical screening, and the screen is loaded on the tray<sup>[3]</sup>. According to the demand, determine whether it is necessary to manually sort again, and load the barrel under the screen<sup>[4]</sup> ; the gold picking device is set on the screening and sorting screen for continuous metal recovery ; open the drying heating device and negative pressure air extraction equipment to heat and dry the slag ; after the jaw crusher is opened, the electric lifting mechanism is used to send the dried slag to the vibration feeder, which is transported to the jaw crusher for crushing ; after crushing, it enters the hammer crusher for secondary crushing ; the material with a particle size of 0.5-1mm is discharged<sup>[5]</sup>.

### 2.2. Glove box of alkali residue pretreatment device

The material of the box is stainless steel and organic glass. The sealing grade is grade 3. The air change rate per hour is not less than 10 times. The closed safety doors are set at both ends of the box. There are 9 working stations and 18 gloves. The fluorescent lamp is used for lighting. The size is not large ( length x width x height ) 5000x1500x3350mm. Closed safety doors are set at both ends of the box, and independent closed operating rooms are set between different operating positions. The areas with large dust production, such as the dumping site and the crushing device area, are sealed locally to collect dust separately<sup>[6]</sup>. Negative pressure air extraction interface and lighting equipment are set up in multiple working parts of the glove box to ensure effective dust reduction inside the glove box. In addition, multiple suction holes are reserved to facilitate dust collection in the glove box in the later stage. As shown in Figure 1.

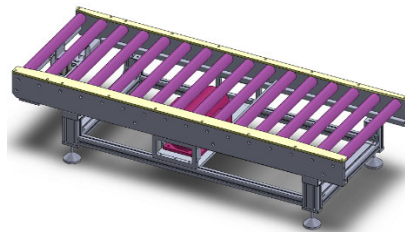


**Figure 1.** Glove box

### 2.3. Glove box of alkali residue pretreatment device

The conveyor roller table includes a feed conveyor roller table, a foreign matter and metal temporary storage barrel conveyor roller table, a dry auxiliary plate conveyor roller table and a discharge conveyor roller table. The main purpose

is to send the slag bucket into the opening chamber, the microwave drying section to transport and send the discharge, and send the foreign matter metal temporary storage barrel out. The conveyor roller table is equipped with a limit switch to ensure that the slag bucket reaches the specified position accurately. As shown in Figure.2.



**Figure 2.** Conveying roller table

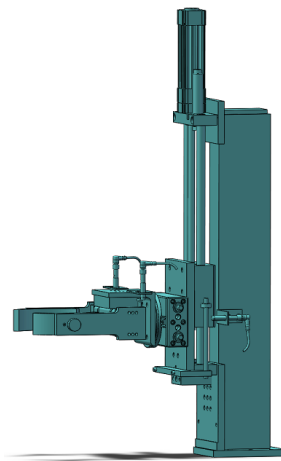
### 2.4. Lifting mechanism of alkali residue pretreatment device

The lifting mechanism is composed of clamping device, turnover device and lifting device.

The clamping device is an automatic clamping mechanism[7]. The servo motor drives the screw to rotate and drive the gripper to open or close, which is used to hold the

slag barrel. The contact surface between the gripper and the slag barrel is equipped with a pressure sensor. According to the feedback pressure value, whether to hold the slag barrel is determined[8].

The lifting device is composed of a servo motor and a ball screw. The servo motor drives the screw to rotate, drives the flip device and the clamping device to upgrade as a whole, and can stay at any position. As shown in Figure 3.



**Figure 3.** Lifting mechanism

## 3. Working Principle of Alkali Residue Pretreatment Device

### 3.1. Process flow of alkali residue pretreatment device

The alkali residue pretreatment device is to screen and sort

the barreled uranium-containing alkali residue in a closed environment, microwave drying and crushing[9]. The process flow mainly includes : feed opening, lifting inverted barrel, screening and sorting, microwave drying, crushing and discharging. The main technical route of the alkali residue pretreatment system is shown in Figure.5.

### 3.2. Control system design of alkali residue pretreatment device

The PLC is used as the communication master station and the helium flow sensor is used as the communication slave station[10]. In order to simplify the programming complexity of Modbus-RTU communication, STEP-7 software provides functional blocks related to Modbus-RTU communication, and real-time communication between PLC and sensors can be completed only through the setting of functional blocks. The Modbus initialization master program is shown in Figure 4-2, and the EN of the enable end of MBUS \_ CTRL is in the normal state ; the value of the ' Mode ' ( Mode ) input is used

to select the communication protocol, and the input is ' 1 ', then the Modbus protocol is selected ; ' Baud rate ' ( Baud ) was set to 9600bps ; the ' Parity ' should be set to match the parity of the slave device, and the input 0 ( no parity ) should be selected through the query ; ' Port ' ( Port ) sets the physical communication port. Since the physical port on the signal board is not used, select the input 0 ( RS-485 port integrated in the CPU ) ; ' Timeout ' ( Timeout ) represents the length of time the Modbus master station waits for a response to send a request, and the commonly used value is selected here to be 1000ms ; set V340.0 as the completion bit ; when the instruction runs incorrectly. The input and output interface address allocation of PLC is shown in Table 3-5.

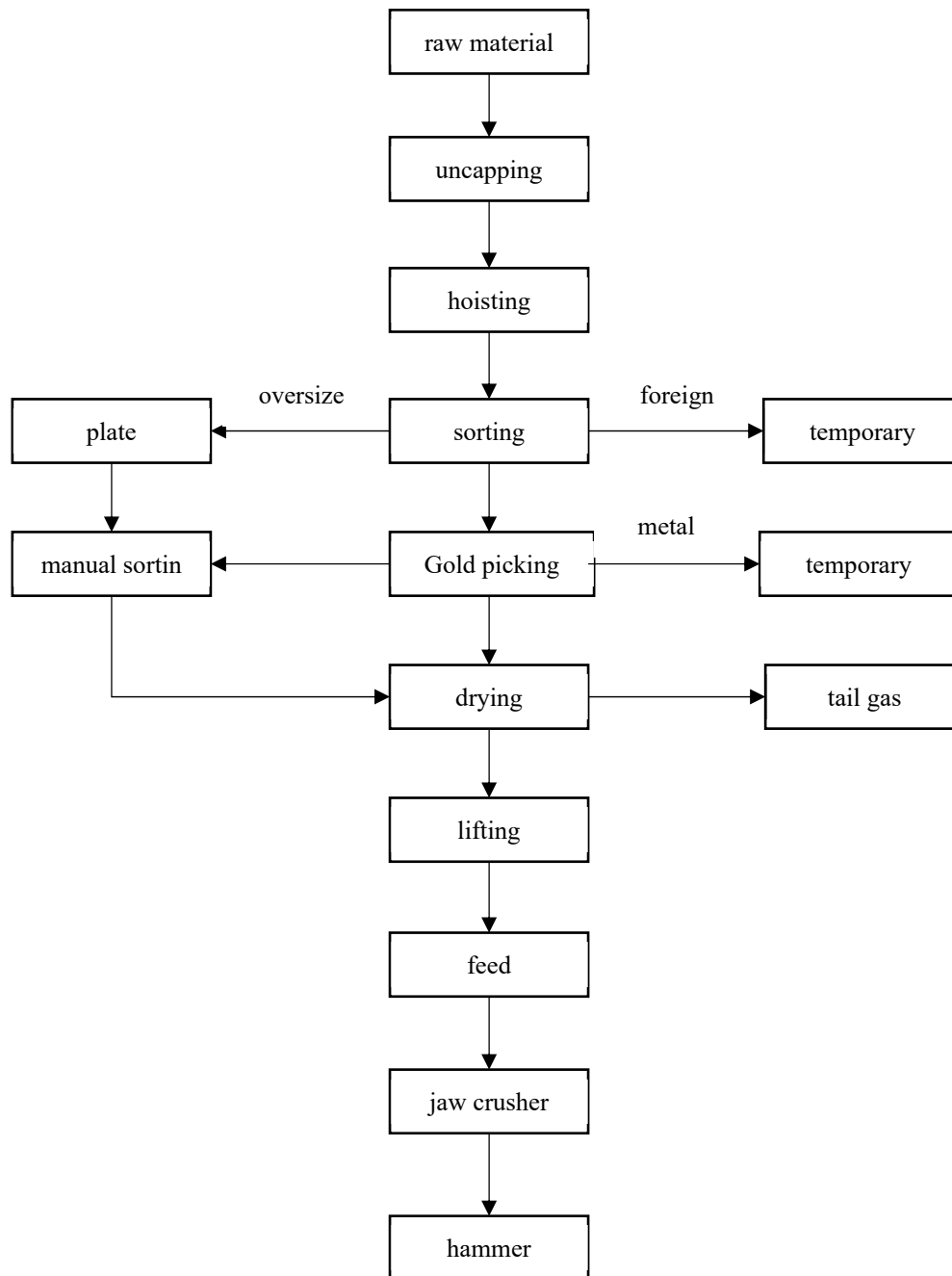


Figure 4. The main technical route of alkali residue pretreatment system

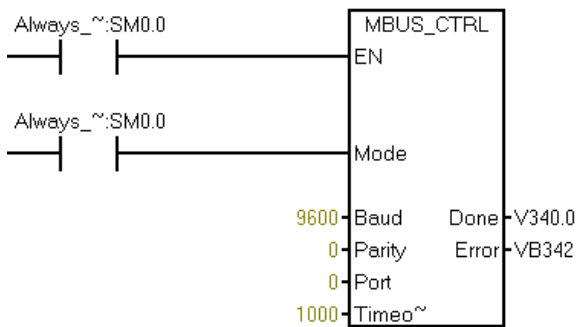


Figure 5. Program for initializing the master station by Modbus

#### 4. Design of Human-computer Interaction Interface

The conveying equipment, lifting mechanism, vibrating screen, microwave drying device, crusher, and air extraction purification system in the alkali residue pretreatment device of this project are integrated into a control panel, with DCS programming control. The human-machine interface is intuitive and realistic, and the real-time monitoring system for various parameters (such as temperature, position, time, discharge amount, vacuum value) is equipped with functions such as alarm for abnormal parameters[11].

Various control and logic program interlocking protection functions, and multiple emergency stop buttons are installed in nearby positions[12].

When the control mode selection switch of the electric control cabinet is set to manual, only manual operation is displayed and the automatic control button is hidden; On the contrary, when the control mode selection switch is set to automatic, only the automatic control button is displayed. The main control interface is shown in Figure 6, The parameter setting interface is shown in Figure 7.



Figure 6. Main control interface

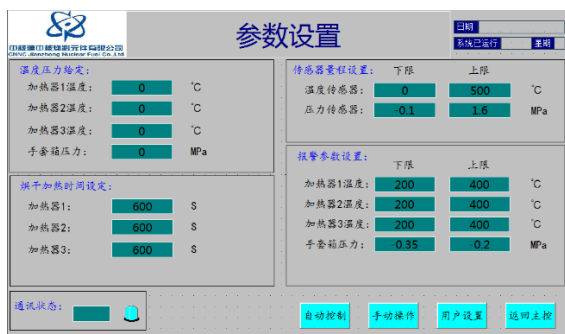


Figure 7. Parameter setting interface

#### 5. Summary

According to the leakage detection requirements, in order to achieve the two working modes of the device, with the key design of the leakage detection platform, a control system composed of PLC, industrial control computer, and stepper system is used to innovatively achieve the leakage detection process of alkali slag. After practical testing, it saves overall time and more accurately detects the leakage rate of alkali residue. The automatic detection process control achieves visualization, allowing operators to clearly observe the operation of any step on the alkali residue. The alkali residue pretreatment device not only improves the automation of the enterprise, but also brings certain economic and social benefits to the enterprise.

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