Analysis, Design and Application of Automatic Loading and Unloading Technology for Electric Power Metering Materials

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Abstract. This paper systematically examines the prevalent implementation forms of contemporary automatic loading and unloading systems for power metering materials, grounded in their distinct characteristics. It further undertakes a comprehensive technical comparison analysis of their respective technical attributes and application prerequisites. Addressing the existing challenges in the current deployment of these systems, the paper introduces an integrated telescopic fork loading system device. Through experimental validation, this device demonstrates the capability to perform mixed loading and unloading operations across diverse vehicle types. This innovation aims to guide the development of automatic loading and unloading systems for power materials, thereby enabling enterprises to acquire a holistic understanding of the research and application landscape in this domain, and to expedite the development of pertinent equipment.

Keywords: electric metering materials; automatic loading and unloading; telescopic fork loading and unloading system

1 Foreword

Currently, the "inspection, storage, and distribution" business of power metering materials is characterized by large-scale centralized production. Power companies across various provinces have integrated fully automated inspection systems that combine automated calibration lines with intelligent three-dimensional warehouses, enabling automated calibration and inventory management. However, research and application in the final stages of automatic loading and unloading are still limited, largely remaining a blank slate. Most loading and unloading operations for power metering materials still rely on manual forklifts, requiring multiple people to work together during the process. Manual control of forklifts makes it difficult and inefficient to enter holes accurately, leading to high labor intensity and a risk of material damage, which fails to meet the

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growing demand for business volume. After years of accumulation and development, a few domestic companies have begun exploring automatic loading and unloading technology[1], And some intelligent loading and unloading equipment will be born[2][3], Based on the balanced load forklift AGV, there are a few applications in the automatic loading and unloading of electric metering materials. This method generally equips laser navigation and 3D vision assistance systems, capable of intelligently positioning materials and pallets, with an automatic adjustment function for the forklifts tines spacing. However, it has the drawbacks of low stability and lower operational efficiency; the automatic loading and unloading method based on handling robots also faces issues such as complex control, alignment operation systems, and stringent application requirements. Other methods of automatic loading and unloading are used in box-packed fast-moving consumer goods[4] Chemical products are bagged[5] It has been applied in some industries, but there are few suppliers of related systems, and some of them are foreign agents. There are basically no application cases in some fine commodity industries with high requirements for automatic loading and unloading.

The following will analyze the characteristics of automatic loading and unloading system for electric power metering materials, analyze the implementation forms and technical comparison of automatic loading and unloading vehicles, and put forward suggestions on the application of automatic loading and unloading technology for electric power materials.

2 Characteristics of Automatic Loading and Unloading System for Electric Power Metering Materials

2.1 Electricity Metering Material Packaging and Storage Form

Electric metering materials primarily encompass electricity meters, low-voltage current transformers, and electricity information collection terminals. In diverse business operations, standardized turnover boxes are uniformly employed for storage and circulation. These turnover boxes adhere to standardized dimensions and are currently predominantly made from plastic and corrugated cardboard materials. Both varieties of turnover boxes are characterized by an open-top design and feature non-sealed structures. As shown in Fig. 1.

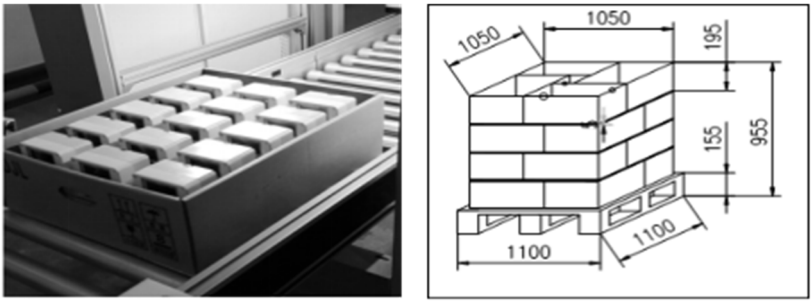

Fig. 1. Pallet material diagram

In the intelligent three-dimensional warehouse, there exist two primary storage methods: single box storage and pallet storage. Typically, single box storage is situated within the material box storage section of the intelligent three-dimensional warehouse, whereas pallet storage is allocated in the dedicated pallet storage area of the same warehouse.

2.2 Electricity Metering Material Automatic Loading and Unloading System Composition

Separated from the business chain, the automatic loading and unloading system for electric power metering materials [6][7] primarily comprises five subsystems: the automatic loading and unloading system, the automatic handling operation system, the automatic stacking and sorting system, the intelligent cache management system, and the intelligent scheduling operation system. As shown in Fig.2.

Fig. 2. Subsystem composition diagram

The primary function of the automatic loading and unloading system is to facilitate unmanned loading and unloading operations. Analyzing existing implementations, this system typically comprises automatic loading and unloading devices, material conveying lines, motion adjustment mechanisms, and visual positioning systems.

The core role of the automatic handling operation system is to execute the handling of entire stacks of materials. The system primarily employs two methods: AGV handling and conveyor line handling.

The fundamental purpose of the automatic stacking sorting system is to classify and stack pallets, as well as to organize orderly group queues for materials awaiting loading.

This ensures compliance with the demands of automatic loading and unloading operations. The system generally includes palletizing robots, material box conveyor lines, pallet conveying lines, and pallet circulation lines.

The essential function of the intelligent cache management system is to manage the intelligent temporary storage of whole stacks of materials destined for loading or unloading. This system effectively records the order, goods, and entry and exit information of warehousing operations, enabling seamless process flows and meeting the criteria for lean production.

The intelligent scheduling operation system primarily facilitates comprehensive scheduling control management across the entire upstream and downstream chain of automated loading and unloading processes for power metering materials. The objective of this scheduling is to seamlessly integrate automated loading and unloading, automated handling, automated stacking and sorting, as well as intelligent caching operations, to achieve efficient, cohesive production operation scheduling management.

3 Automatic Loading and Unloading Technology and Application Analysis

3.1 Typical Implementation of Automatic Loading and Unloading Technology

This paper primarily examines the automatic loading and unloading processes of electric metering materials in pallet storage. The implementation can be achieved through two principal methods: the first involves utilizing an intelligent forklift to perform automatic loading and unloading with either single or double support; the second entails employing a flexible loading platform that facilitates the entire process by pushing the materials as a whole.[8][9]

(1) Intelligent forklift loading and unloading

This method incorporates the use of intelligent forklifts to efficiently load and unload entire stacks of materials. These intelligent forklifts must be equipped with advanced systems such as laser or visual navigation, along with loading platforms that automatically adjust their height. This ensures seamless movement at the same level when the forklifts enter vehicles and return to the warehouse. Intelligent forklifts are available in diverse configurations, including single-fork per stack and multi-fork setups.

(2) Chain plate automatic loading and unloading

The automatic loading and unloading of chain plates primarily relies on power chain plates for seamless operations. These power chain plates are categorized into two types: vehicle-mounted chain plates and loading/unloading chain plates. Vehicle-mounted chain plates are installed within the vehicle, whereas loading/unloading chain plates are positioned on the loading/unloading platform. Additionally, the system incorporates a positioning and docking mechanism along with a loading/unloading control system. Upon initiation of the automatic loading and unloading process, the loading/unloading control system directs the positioning and docking mechanism to execute precise vehicle positioning and horizontal alignment in all directions. Once alignment is achieved,

the loading/unloading chain plates are activated to synchronize with the vehicle-mounted chain plates, facilitating efficient cargo loading and unloading operations.

(3) The drawer is automatically loaded and unloaded

The automatic loading and unloading of drawbars primarily employs drawbars made from high molecular materials for seamless operation. These loading and unloading drawbars are powered by a transmission mechanism driven by an electric motor, integrated with a gantry frame to facilitate the blocking of drawbar movements. Additionally, the system is equipped with a sophisticated positioning and docking system, as well as a dedicated loading and unloading control system. Upon initiation of the automatic loading and unloading process, the control system alerts the positioning and docking system to execute precise vehicle positioning and horizontal alignment in all directions. Once alignment is achieved, the control mechanism expertly pushes the drawbar into the designated position for loading operations. Following the completion of loading, the gantry frame securely blocks the cargo. Ultimately, the control mechanism extracts the drawbar to finalize the process.

(4) Automatic loading and unloading of skis

The automatic loading and unloading of skateboards primarily employs power skates for the process. These power skates are equipped with chain lines capable of independent initiation, enabling goods to be systematically pressed onto the chains. Additionally, a positioning docking system and an unloading control system are integrated. Upon activation of the automatic loading and unloading system, the unloading control system directs the positioning docking system to execute vehicle positioning and horizontal alignment in all directions. Once alignment is achieved, the power transmission skates are maneuvered into the cargo compartment through controlled operations. After loading is completed, the power transmission skates withdraw from the cargo compartment, simultaneously controlling the power chain line to retract inward, thereby conveying the goods into the compartment. The opposing forces ensure that the skates efficiently disengage from the cargo, leaving the goods securely in place within the compartment.

3.2 Application Analysis of Automatic Loading and Unloading Technology

For the various automatic loading and unloading methods discussed in this article, differences arise in application scenarios, loading and unloading functions, operational efficiency, investment costs, and equipment size due to the distinct loading techniques employed. When it comes to the automatic loading and unloading of entire stacks of materials, certain methods necessitate vehicle modifications. For instance, chain plate automatic loading and unloading requires altering the vehicle deck to install onboard chains. Some methods, such as drawer plate automatic loading and unloading and slide plate automatic loading and unloading, are capable of loading but not unloading, restricting their functionality to loading operations only. Additionally, other methods demand civil construction modifications; for example, slide plate automatic loading and unloading requires substantial civil engineering adjustments, as outlined in the table 1 below.

Table 1. Analysis of automatic loading and unloading technology

handling mode	Loading and unloading functions	Renovate vehicles	characteristic
Intelligent forklift AGV	Can be loaded and unloaded	non-essential	Advantages: light equipment, small footprint, low cost, can be installed and unloaded Disadvantages: poor stability, low efficiency
Chain plate automatic loading and unloading	Can be loaded and unloaded	need	Advantages: good stability, high efficiency, moderate cost Disadvantages: heavy equipment, high cost, need to modify the vehicle
The drawer is automatically loaded and unloaded	It can only be loaded The vehicle cannot be unloaded	non-essential	Advantages: good stability, high efficiency Disadvantages: heavy equipment, high cost, large space
Automatic loading and unloading of skis	It can only be loaded The vehicle cannot be unloaded	non-essential	Advantages: good stability, high efficiency Disadvantages: heavy equipment, high cost, large area, civil construction transformation

4 Design and Application Suggestions of Automatic Loading and Unloading Device for Power Materials

According to the packaging circulation form and the characteristics of the in and out warehouse business of electric metering materials, this paper designs an automatic loading and unloading system device with telescopic racks.

4.1 Structure of the Automatic Loading and Unloading System for Telescopic Forks

The automatic loading and unloading system for pallets primarily uses long-arm powered pallets for automated handling, combined with a power chain line for cargo transfer. When the pallets are stationary, they lie below the horizontal plane of the chain line. Additionally, it is equipped with a positioning docking system and a loading and unloading control system. When the automatic loading and unloading system for pallets starts operation, the chain line first completes the loading or unloading of goods. Then, the loading and unloading control system notifies the positioning docking system to complete vehicle positioning and horizontal docking from all directions. Once the docking is complete, the power pallets and the chain line work together to perform the loading and unloading operations.

The main design structure is shown in the following figure 3:

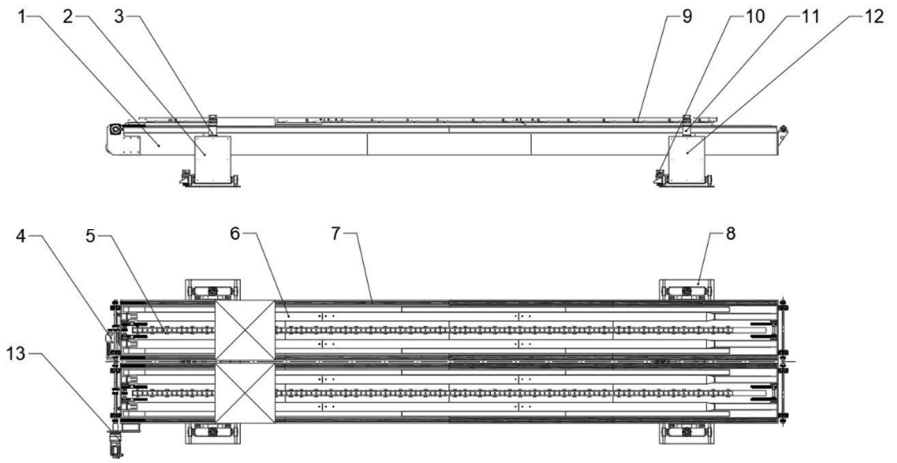

Fig. 3. The structure of the telescopic fork automatic loading and unloading system

4.2 Working Process of Telescopic Fork Automatic Loading and Unloading System

(1) First, place the measuring instrument and the tray at the right end of the machine;

(2) The machine is driven by the chain group 2, which drives the pallet and the measuring instrument to move to the right by the width of a pallet;

(3) Repeat 1~2 times until the total width of the pallet reaches the total length of the loader box;

(4) The front chain group 2 drives and moves all the measuring instrument pallets to the right, so that its leftmost end reaches the leftmost end of the lifting mechanism;

(5) The lifting mechanism 1 moves to lift the measuring instrument tray;

(6) The loading chain group 3 of the machine is driven to move the measuring instrument tray into the car;

(7) The lifting mechanism 1 returns to the original state;

(8) The loading chain group 3 of the machine is driven in three directions to bring the lifting mechanism 1 back to its original position for the next cycle.

4.3 Working Principle of the Automatic Loading and Unloading System for Telescopic Forks

The fork lift raises the upper plate 101 and the lower plate 102, along with the support rod 103 (a total of 18 pieces), which are hinged together by the lower pivot pin 104 and the upper pivot pin 105, forming a parallelogram mechanism. One end of the screw jack 106 is hinged to the upper plate 101, while the other end is hinged to the lower plate 102. When the servo motor 108 rotates in the forward direction, the torque is

transmitted through the reducer 109 to the input shaft 110 of the screw jack, causing the top of the jack 106 to extend, thereby lifting the upper plate 102 to a certain height, along with the material on its upper part. As shown in Fig. 4.

The lifting mechanism drive frame 111 is hinged to the jack; both ends of the lifting drive frame are fixedly connected to the loading chain group 3; when the loading chain group 3 drives forward, it moves the lifting mechanism 1 to the right; when the loading chain group 3 drives backward, it also moves the lifting mechanism 1 to the right. As shown in Fig. 5.

A. unload

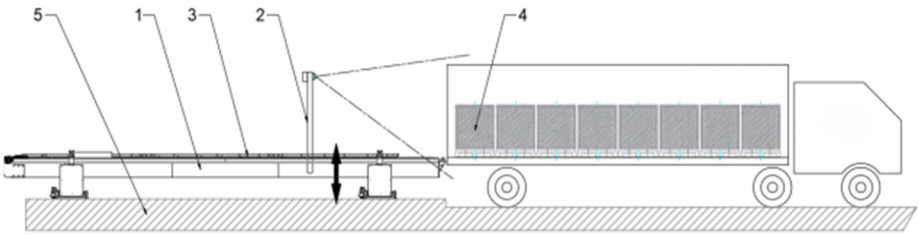

Fig. 4. Schematic diagram of fork work 1

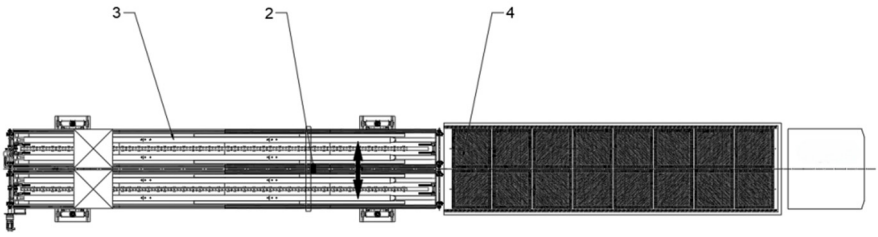

Fig. 5. Schematic diagram of fork work 2

When the vehicle completes its parking and opens the cargo door, the visual system evaluates the vehicle's posture and the position of the pallets comprehensively. It then determines whether unloading is possible and provides instructions on how to adjust the pallet forks to facilitate unloading. After adjusting the posture, the pallet forks roll into the cargo area and insert into the pallet slots. See the figure below. As shown in Fig. 6.

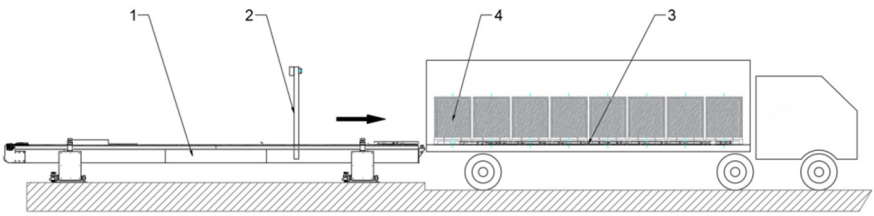

Fig. 6. Fork insertion

After the fork is moved to the specified position, lift the fork and lift the pallet, and move back to take the pallet out of the truck. See the figure below.As shown in Fig. 7.

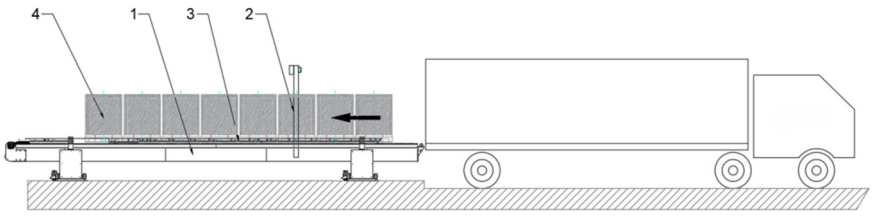

Fig. 7. Fork lift lifting measuring instrument back drawing

B. entrucking
Loading is similar to unloading, but in reverse order.

4.4 Application Suggestions for Telescopic Fork Automatic Loading and Unloading System

When employing the full-stack loading and unloading method, it is crucial to thoroughly consider the comprehensive automation of all subsystems within the automatic loading and unloading system for power metering materials. Utilizing a smart scheduling operation system, the entire loading and unloading process should be systematically coordinated. Once the power metering materials are released from storage, they should automatically form stacks and be sorted by the automatic handling system. These materials will subsequently be transported to the buffer storage area in an orderly fashion by the automatic handling system. The intelligent buffer management system will intelligently manage the information of the loaded and unloaded materials, while the automatic loading and unloading system will execute the loading and unloading operations. Below is an example of an automated loading and unloading layout in a unit mode[10] scheme.As shown in Fig. 8.

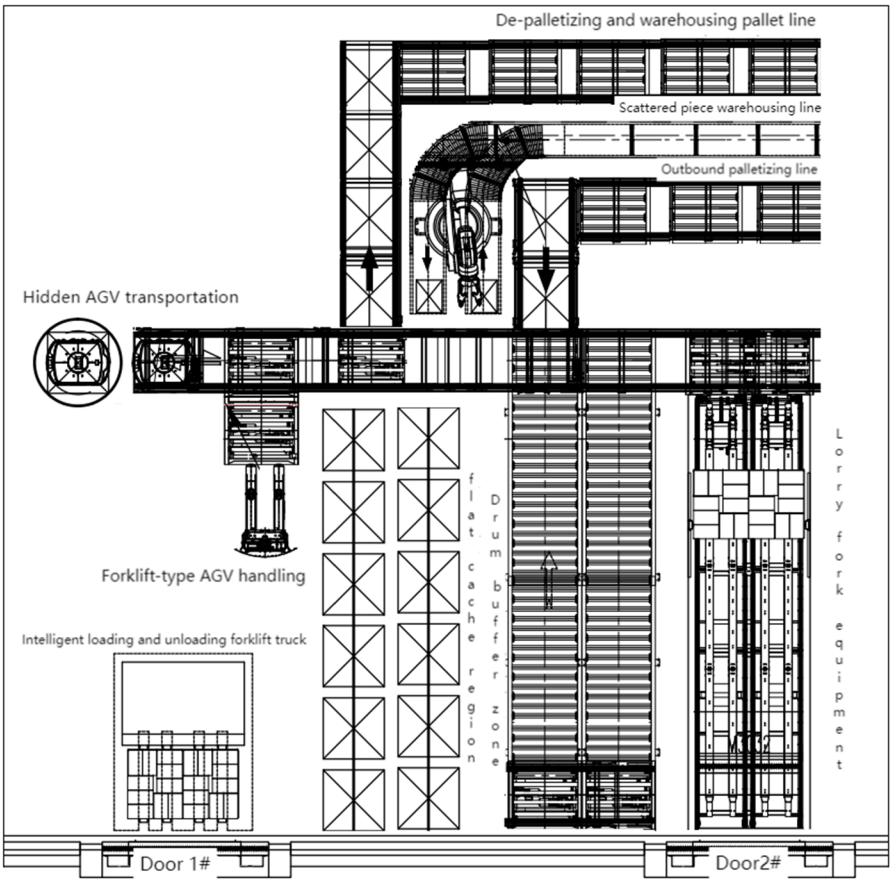

Fig. 8. Automatic loading and unloading layout scheme

The automatic loading and unloading system of the solution is partially realized using intelligent forklifts or whole-pallet automatic loading and unloading devices. The automatic handling operation system is achieved through AGVs and roller conveyors. The automatic palletizing and sorting system is realized using palletizing robots. The intelligent cache management system manages both the flat cache area and the roller conveyor cache area. The smart scheduling operation system realizes an automated loading and unloading platform for the entire robotic production line[11] Scheduling control management.

4.5 Experimental Verification of Automatic Loading and Unloading Pallet Truck Equipment

After the scheme was demonstrated, a fork-like machine was developed for the loading and unloading experimental operation of material warehouses. After testing, all indicators met the design requirements, further demonstrating the feasibility and universal application of this scheme[12][13]. As shown in the following table 2:

Table 2. Test report Test status: 1-test passed 2-test failed 3-test error to be handled 4-not tested

number	Test type	test mode	expected result	Real measurement results	Test scores	Deviation description
1	Mechanical characteristics of lifting point before fork opening	Repeat the given lift height and measure with a measuring instrument	The deviation between the actual measured elevation displacement data and the specified data is less than 5%	The deviation is 3.5%, less than 5%, in line with expectations	1	
2	Mechanical characteristics of the lifting point after rowing	Repeat the given lift height and measure with a measuring instrument	The deviation between the actual measured elevation displacement data and the specified data is less than 5%	The deviation is 3%, less than 5%, in line with expectations	1	
3	Empty lifting mechanical properties of fork teeth	Repeat the command to raise and lower the fork teeth and measure with a measuring instrument	The lifting of the fork teeth meets the requirements, and the deviation of the lifting height is less than 10%	The deviation was 8%, less than 10%, in line with expectations	1	
4	The fork teeth of the row fork are fully loaded and the lifting mechanical performance is good	Repeat the lifting command for the fork tooth belt and measure with a measuring instrument	The lifting of the fork teeth meets the requirements, and the deviation of the lifting height is less than 10%	The deviation was 8%, less than 10%, in line with expectations	1	
number	Test type	test mode	expected result	Real measurement results	Test scores	Deviation description

5	The stability of the fork teeth lifting pallet goods	Observe whether the pallet can be stably lifted, and whether there is a risk of swaying, shaking or even tipping over	The goods on the pallet should be lifted evenly and steadily. The goods should not be overturned or tilted, and the shaking should be within a certain acceptable range	The pallet can lift the goods smoothly, and there is no obvious shaking of the goods during the lifting process. There is no tilting or skewing of the goods	1	
6	The smoothness and reliability of the fork teeth being dragged out with load	The fork lifts the whole vehicle 12 pallet goods and pulls it out of the car, and then retracts into the fork platform. Observe whether the goods have friction and interference with each surface of the car (side, bottom) during this process. Observe whether the goods are stable, whether there is any tipping, skewing or obvious shaking	The whole cargo should be unloaded smoothly and completely from the car with the fork teeth. There should be no interference or friction between the goods, pallets and surfaces of the car. During the dragging process, the pallet goods should not be overturned, tilted or obviously shaken	The whole cargo is dragged out of the car by the fork teeth, and it can be carried out smoothly. There is no interference or friction between the cargo or pallet and each surface of the car. The whole process does not show any tilting or skewing of the cargo. There is slight shaking of individual pallets.	1	
number	Test type	test mode	expected result	Real measurement results	Test scores	Deviation description
7	The mechanical properties and stability of the	Repeat the chain drag the pallet and goods to see if the pallet can	The pallet should run smoothly on the chain, and there should be no tilting	The pallet runs smoothly on the chain	1	

	pallet running on the chain	run smoothly and smoothly on the chain	or dumping phenomenon	without tilting, shaking or tipping		
8	The mechanical properties and stability of the fork teeth that lift the goods on the fork chain	The repeated attempt to lift the goods from the pallet chain with the pallet should be able to meet the lifting height, error less than 10%, and can run smoothly	The pallet should be lifted within the error range, and there should be no tilting or tipping of the pallet, and no obvious shaking	The pallets 12 on the fork chain are lifted by the fork rejection top, and the lifting height error is less than 10%, which meets the error requirements. No pallet tilting or tipping occurs; the pallet has slight shaking.	1	
number	Test type	test mode	expected result	Real measurement results	Test scores	Deviation description
9	The mechanical performance, stability and reliability of the fork teeth that load 12 pallets of goods into the vehicle into the car	Observe the process of loading the whole vehicle 12 pallets into the car body, whether the pallet or goods can run smoothly, and whether there will be interference or friction with the inner surfaces (side and bottom) of the car body. Whether the pallet and goods are overturned or tilted, without obvious shaking	The process of loading the whole vehicle 12 pallet goods into the car body by the fork teeth of the forklift. The pallet and goods should run smoothly without interference or friction with the inner surfaces of the car body	During the process of loading 12 pallets and goods into the car body with the fork teeth, the pallet and goods run smoothly without interference or friction with the inner surfaces of the car body; the pallet and goods do not fall over or tilt. The pallet and goods	1	

				have slight shaking		
number	Test type	test mode	expected result	Real measurement results	Test scores	Deviation description
10	The mechanical performance and stability of the fork in lowering goods in the car	Observe whether the goods can land smoothly, whether the landing process has secondary interference and friction with each surface inside the carriage. Whether the goods have tilted or overturned	The process of lowering the goods should be smooth and light, without obvious vibration. The pallets and goods should not have secondary friction, scraping and interference with the inner surfaces of the car; the pallets and goods should not be overturned or tilted	The process of lowering the goods is smooth, with no obvious sound and vibration; the goods do not scrape, friction or interfere with the inner surfaces of the car body during the lowering process; the pallet and goods do not fall over or tilt in this process	1	

5 Epilogue

This article, aligned with the characteristics of power metering material handling operations, systematically analyzes prevalent automatic loading and unloading methods. It juxtaposes their technical attributes and application prerequisites. Furthermore, it introduces a unit-mode automatic loading and unloading layout scheme, designed to guide the establishment of automated power material handling systems. This facilitates companies in acquiring a holistic grasp of the current research and application landscape of automatic loading and unloading, thereby expediting the development of pertinent equipment.

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