WH

CULTURAL INDUSTRY STANDARD OF

THE PEOPLE'S REPUBLIC OF CHINA

Reference No.: 20729-2007

WH/T 28-2007

Mechanical Equipment on Stages – Upper Stage - Safety Requirements

舞台机械 台上设备安全

Issued on: May 9, 2007 **Implemented on: June 1, 2007**

Issued by: Ministry of Culture of the People's Republic of China

Table of Contents

Foreword 4
1 Scope 5
2 Normative references 5
3 Mechanical equipment 6
3.1 Example for composition of mechanical equipment on upper stage 6
3.2 Structural part 6
3.3 Wire-rope 9
3.4 Chains 12
3.5 Pulley assembly 13
3.6 Drive pulley 14
3.7 Reel components 15
3.8 Drive device 15
3.9 Motor 16
3.10 Speed reducer 17
3.11 Brake 17
3.12 Protective device 17
3.13 Balance weight 18
3.14 Guide rail 18
4 Electrical equipment and control systems 18
4.1 General 18
4.2 Selection of electrical equipment 19
4.3 Power supply 19
4.4 Actual environment and operating conditions 19
4.5 Power supply and equipment separation and disconnection 20
4.6 Electric shock protection 20
4.7 Protection of electrical equipment 21
4.8 Voltage balance 21
4.9 Control circuit and control functions 22

4.10 Safety functions and control functions under fault conditions.....23
4.11 Emergency shutdown and emergency power off function 27
4.12 About wireless control.....29
4.13 Programmable electronic / electrical system 29
4.14 Programmable control system (E / PES) used for safety-independent functions 30
4.15 Electrical components.....30
4.16 Wires and cables 31
4.17 Wiring technology 31
4.18 Protective devices for mechanical brakes 32
4.19 Interconnection of mechanical electrical devices.....32
Annex A (Informative) References standards and specifications 33
Annex B (Normative) Rod use information.....35

Foreword

This Standard was formulated by referring to the German standard DIN 56950 *Entertainment technology - Machinery installations* and Part 1 and 2 of the Austrian standard ÖNORM M9630 *Automatic stage equipment - Part 1: General information* and *Automatic stage equipment - Part 2: Overhead stage machinery*, combining with the actual situation of China's stage machinery industry. This Standard was drafted in accordance with the rules given in GB/T 1.1-2009 *Directives for standardization - Part 1: Structure and drafting of standards*.

Annex A of this Standard is informative. Annex B is normative.

This Standard was proposed by and shall be under the jurisdiction of Ministry of Culture of the People 's Republic of China.

Main drafting organizations of this Standard: China Performing Arts Equipment Technology Association Performance Venues Equipment Professional Committee, General Equipment Department Engineering Design Research Institute.

The drafting organizations of this Standard: Gansu Polytechnic University Machinery Factory (Gansu Gongda Stage Equipment Research Institute), Zhejiang Stage Design & Research Institute Ltd.

Main drafters of this Standard: Zheng Hui, Du Ankun, Sun Yadu, Gong Kuicheng, Wu Jiantong, Chang Song, Xu Qi, Wei Fakong, Song Hong.

Mechanical Equipment on Stages – Upper Stage - Safety Requirements

1 Scope

This Standard is the basic safety technical specification for mechanical equipment on upper stages.

This Standard applies to the mechanical equipment on upper stages installed in various performance venues including theater, multi-function hall, exhibition hall, TV studio, concert hall, auditorium, gymnasium, bar, discotheque and amphitheater, etc. In addition to the stage, the auditorium is also a performance venue so this Standard is also applicable.

This Standard does not apply to the mechanical equipment on stage for temporary use and used for acrobatics.

2 Normative references

The following standards contain the provisions which, through reference in this Standard, constitute the provisions of this Standard. For dated references, subsequent amendments (excluding corrections) or revisions do not apply to this Standard. However, the parties who enter into agreement based on this Standard are encouraged to investigate whether the latest versions of these documents are applicable. For undated reference documents, the latest versions apply to this Standard.

GB/T 3811-198, *Design rules for cranes*

GB/T 6067-1985, *Safety rules for lifting appliances*

GB/T 5905-1986, *Cranes - test code and procedures*

GB 50052-1995, *Code for design of electric power supply systems*

GB 5226.1-2002, *Safety of machinery - Electrical equipment of machines - Part 1: General requirements*

GB/T 16855.1-2005, *Safety of machinery - Safety-related parts of control systems - Part1: General principles for design*

GB 16754-1997, *Safety of machinery - Emergency stop Principles for*

design

GB/T 15706.1-1995, *Safety of machinery - Basic concept, general principles for design - Part 1: Basic terminology, methodology*

GB/T 15706.2-1995, *Safety of machinery - Basic concepts, general principles for design - Part 2: Technical principles and specifications*

GB 19517-2004, *National safety technical code for electric equipment*

GB 5083-1999, *General rules for designing the production facilities in accordance with safety and health requirements*

GB 50169-1992, *Code for construction and acceptance of earthed device electric equipment installation engineering*

GB 1408.5-2001, *Low-voltage switchgear and control gear control circuits - Electrical and switching elements - Part 1: Electromechanical control circuits - Electrical appliances*

GB 4824-2004, *Industrial，scientific and medical (ISM) radio-frequency equipment - Electromagnetic disturbance characteristics- - Limits and methods of measurement*

GB/T 15543-1995, *Quality of electric energy supply - Admissible three-phase voltage unbalance factor*

GB/T 17626.1-1998, *Electromagnetic compatibility - Testing and measurement techniques - Overview of immunity tests*

CECS 49-1993, *Code for the reception criterion for Low-voltage switchgear assemblies*

3 Mechanical equipment

3.1 Example for composition of mechanical equipment on upper stage

The example for composition of mechanical equipment on upper stage is as shown in Figure 1.

3.2 Structural part

3.2.1 Construction requirements

3.2.1.1 The structural design of the main bearing structure shall be simple, with clear force, with direct force and shall try to reduce the impact of stress concentration.

composite truss structure. The wall thickness of main tube shall not be less than 2.5 mm. The rods shall be straight, without distortion or deformation.

3.2.5.2 When confirming the rod structure, it shall note that the deflection between the two lifting points caused by the assigned payload shall be less than 1/200 of the spacing between the two lifting points.

3.2.5.3 The joints of the rods shall be as small as possible. The joints shall use mandrel to work with tube and shall be welded firmly.

3.2.5.4 When using telescopic tubes, there shall be measures to prevent the telescopic part from being fully removed. The length of the tube shall not be less than 1/3 of the length of the extension.

3.2.6 Walkway, ladder and railing

3.2.6.1 The walkway, ladder access to the mechanical equipment on stage and of equipment installation platform must be easily accessible, safe and reliable.

3.2.6.2 The walkaway of metal structure shall have anti-slipping performance. When using perforated steel or grid plate, the size of the hole or lattice shall be minimized to prevent the object from falling.

3.2.6.3 The parts required by use and maintenance but can cause workplace and staff have a risk of falling off shall be set with solid railing. The height of railing shall not be less than 1050 mm. The horizontal railing with a spacing of 350 mm shall be set. A baffle of height not less than 70 mm shall be set at the bottom.

3.2.6.4 The railings shall be able to withstand a horizontal load of 1.0 KN/m.

3.3 Wire-rope

3.3.1 The wire-rope shall use oil-free galvanized steel wire-rope specified in GB/T 8918-2006 *Steel wire ropes for important purposes*. The wire-rope must have a test report and a product inspection certificate.

3.3.2 The safety factor of the wire-rope must be equal to or greater than 10. The safety factor of the wire-rope used for single point crane, manned flight equipment must be equal to or greater than 12.

Select the wire-rope diameter according to the safety factor. The breaking tension of the selected wire-rope shall meet the requirements of the following formula:

$$F_o \geqslant Sn$$

$$S_a \geq S_{max}$$

where,

S_p - the damage load of the selected chain, N;

S_{max} - the maximum static tensile force distributed to single chain at the time of suspension, N;

n - the minimum safety factor of the chain.

3.4.3 The speed of the ring chain shall be less than 0.5 m/s.

3.4.4 The ring chain shall be discarded when one of the following conditions occurs:

a. cracks;

b. when the chain has plastic deformation and elongation reaches 5% of the original length;

c. the abrasion of ring chain reaches 10% of the original diameter.

3.4.5 Other chains, such as roller chains, apply to the requirements of 3.4.1, 3.4.2, 3.4.3.

3.5 Pulley assembly

3.5.1 The pitch diameter of the pulley shall be not less than 20 times the diameter of the wire-rope. The pitch diameter of the pulley used for a maneuverable manual boom system and the balancer of the counterweight system shall not less than 15 times the diameter of the rope.

3.5.2 According to the load, use, speed and other conditions, the pulley is usually made of steel, high quality gray cast iron, high strength cast nylon and other suitable engineering plastics.

3.5.3 The surface of the pulley rope groove shall be machined. The shape and size of the pulley rope groove shall match the size of the wire-rope and comply with JB/T 9005.1-1999.

3.5.4 Pulleys must not affect the use of performance or damage to the appearance of defects such as stomata, cracks, loose, slag, etc.

3.5.5 The pulley shall use rolling bearing or alloy powder oil bearing sliding bearing support.

3.5.6 The pulley shall have a means for preventing the rope from leaking out of the groove.

e - e=2.718 (the bottom of the natural logarithm).

3.6.4 The rope groove of the drive pulley shall make the wire-rope not slip in the rope groove.

3.6.5 Other requirements for drive pulley shall be same with 3.5 Pulley.

3.7 Reel components

3.7.1 The electric drive reel shall use single-layer winding reel. The pitch diameter of the single-layer winding reel shall not be less than 20 times the diameter of the wire-rope.

3.7.2 The grooved reel shall use high quality casting or seamless steel tube or plate by bending welding and machining. The size of the groove, groove spacing shall be matched with the specifications of the wire used and meet the corresponding specifications.

3.7.3 When the wire-rope is wound in or out of the reel, the angle of the wire-rope from both sides of the spiral groove shall not exceed 3°. The rope guider shall be set if it does not comply with this provision.

3.7.4 The reel shall have a suitable length. Each wire-rope wound on the reel shall have at least two turns of safety circle. There shall be at least one turn of rope groove gap at one end of the reel or the starting end of another wire-rope.

3.7.5 The fixation of wire-rope tail on the reel shall use pressure plate, wedge. The fixation must be reliable, firm, with anti-loosing or self-tightening performance. If the fixation uses pressure plate, the number of the pressure plate of each wire-rope end shall not be less than 3.

3.7.6 The reel shall be discarded when one of the following conditions occurs:

a. crack;

b. tube wall abrasion reaches 20% of the original wall thickness.

3.8 Drive device

3.8.1 Suspension equipment must use two separate brakes. Each brake must have sufficient torque. Each brake shall be operated at a reasonable braking distance of 1.25 times the rated load.

3.8.2 Horizontal travel drive can use single brake.

3.8.3 Brake and motor power shall be chained, controlled. The brake can

only be released when the motor is switched on and the load is maintained or controlled.

3.8.4 Hoist and other similar electric drive device, according to user requirements, can be equipped with auxiliary transmission. The auxiliary transmission can be manually combined and operated at low speed. The manual clutch shall be interlocked with the electrical drive so as to prevent electrical operation of the electrical drive during manual operation. The speed of the motor-assisted transmission shall be between 10% and 25% of the rated (or maximum) speed. The auxiliary transmission must be operated locally on the equipment.

3.8.5 In addition to the over-travel limit, the action of the auxiliary drive shall not change the position of any limit device and shall not affect the energization of the equipment.

3.8.6 The hoisting machine shall be provided with a rope device to prevent the wire-rope from falling out.

3.8.7 Manual balancing heavy boom must be equipped with a locking device. The device in the operation of the two directions shall be able to withstand at least the hand operation of two persons (2 × 280N). The locking device is allowed to act on the operating rope. The diameter of the operating rope shall not be less than 22 mm.

3.8.8 Electric-driven rod and single-point lifting speed shall not exceed 1.8 m/s.

3.8.9 When the operating speed of power-driven lighting suspension equipment is greater than 0.1 m/s, it shall take the speed control device or soft start control device.

3.9 Motor

3.9.1 The motor generally uses fully enclosed air-cooled AC asynchronous motor or servo motor. The insulation rating of the motor is not lower than grade F. The enclosure protection level is not less than IP54.

3.9.2 The motor can be designed according to the intermittent work system, but not less than S3 working system.

3.9.3 The power factor of the motor shall be greater than or equal to the current national standard in China.

3.9.4 In the case of design limits, the maximum torque or torque of the motor shall ensure that the equipment needs to be started. In the case of design requirements, the motor shall not overheat.

equipment" during the design and installation (manufacture) and the following standards shall prioritize the following standards:

- GB/T 16855.1-2005, Safety of machinery- - Safety-related parts of control systems - Part 1: General principles for design
- GB/T 15706.2-1995, Safety of machinery - Basic concepts, general principles for design - Part 2: Technical principles and specifications
- GB 50169-1992, Code for construction and acceptance of earthed device electric equipment installation engineering
- GB 16754-1997, Safety of machinery - Emergency stop Principles for design

4.2 Selection of electrical equipment

Electrical components and devices shall meet the requirements of use, and in line with national standards.

4.3 Power supply

The designed electrical equipment shall work as normal under the power supply conditions of GB 50052-1995 "Code for design of electric power supply systems".

4.4 Actual environment and operating conditions

4.4.1 General

The electrical equipment shall be used under the actual environment and operation conditions of GB 1408.5-2001 (6 Normal use, installation and transport conditions).

4.4.2 Electromagnetic compatibility (EMC)

In accordance with GB 5226.1-2002 (4.4.2 Electromagnetic compatibility), the electrical and electronic equipment:

- shall not exceed the electromagnetic disturbance limits specified in GB 4824-2004;
- shall not be less than the degree of cruelty of immunity recommended in GB/T 17626.1-1998.

4.4.3 Ambient air temperature and humidity

4.4.3.1 The electrical equipment must be capable of normal operation at the following minimum conditions:

4.6.1 [Translator note: should be 4.6.1] Protective measures shall be in accordance with the provisions of GB 5226.1-2002 (6.2 Direct contact protection, 6.3 Indirect contact protection).

4.7 Protection of electrical equipment

4.7.1 Protective equipment shall be in accordance with the provisions of GB 5226.1-2002 (7 Electrical equipment protection).

4.7.2 Measures shall be taken to prevent electrical equipment from being affected as follows:

- the over-current due to short circuit shall be in accordance with GB 5226.1-2007 (7.2 Over-current protection);
- the overload shall be in accordance with GB 5226.1-2002 (7.3 Overload protection of motor);
- the loss of pressure or under-voltage shall be in accordance with GB 5226.1-2002 (7.5 Power supply interruption or voltage drop subsequent recovery protection);
- the abnormal temperature shall be in accordance with GB 5226.1-2002 (7.4 Abnormal temperature protection);
- the machine or mechanical parts speed shall be in accordance with GB 5226.1-2002 (7.6 Motor over-speed protection);
- the ground fault shall be in accordance with GB 5226.1-2002 (7.7 Ground fault / residual current protection);
- the phase sequence error shall be in accordance with GB 5226.1-2002 (7.8 Phase sequence protection);
- the over-voltage caused by lightning or switching surge shall be in accordance with GB 5226.1-2002 (7.9 Over-voltage protection caused by lightning or switching surge).

If any of the above errors triggers the safety device to terminate the operation of the equipment, it must be prevented from automatically restarting.

4.8 Voltage balance

User-induced voltage imbalance allowable value shall be determined according to GB/T 15543-1995 *Quality of electric energy supply - Admissible three-phase voltage unbalance factor*.

It must first meet the requirements of asynchronous group operation.

It must monitor the synchronization of synchronous group running, or interrelation of individual mechanisms (whether it is stroke or a time synchronization). Operation in any mode must not exceed synchronous operating tolerances.

If the safety device triggers, exceeds the stroke limit (e.g. via the travel monitoring device) or fails, the entire combined operation must be stopped.

If a mechanism is driven by multiple drives, or by multiple mechanical devices driving the same load, it must ensure its synchronization. Operation in any mode must not exceed synchronous operating tolerances. When the safety device is triggered, the fault shall not exceed the allowable synchronous operating tolerances.

4.9.3.3 Multiple groups of operations

When the same control device is used to operate multiple groups or multiple devices simultaneously, the operation mode of the different groups or devices shall be displayed.

4.10 Safety functions and control functions under fault conditions

4.10.1 General

The safety function of E / E / PES equipment shall be selected on the basis of hazard analysis.

E / E / PES refers to electrical (E) / electronic (E) / programmable electronic system (PES).

E / E / PES integrated function can also be used as security function, for example:

- stop function;
- emergency stop function;
- start function;
- speed limitation;
- overload and underload;
- location restriction;
- speed deviation;

The electronic safety device shall use position switches or safety circuits.

In the event of over-travel, over-speed, overload or deviation from the specific operating trajectory, etc. that can cause danger and damage to mechanical equipment, the safety circuit shall be activated when the emergency stop function is activated.

4.10.4.1 Conditioner failure protection

The speed control device in the drive system shall be able to automatically identify the speed deviation that would cause danger and damage to the mechanical equipment and cut off the power supply and start the mechanical brake.

4.10.4.2 Stroke limit device failure protection

When the stroke limiter fails, the emergency limit switch shall stop the operation of the machine. The stroke limit of the hydraulic cylinder uses a fixed, damped block. The closure is ensured by an additional device, such as a pressure switch, without the need for an emergency limit switch.

Emergency stop function of emergency stop switch shall be Class 0 stop.

The installation position of the emergency limit switch shall be determined by taking into account the maximum operating speed and system delay time of the equipment to ensure safe shutdown before hitting a fixed structure such as the top of the grid.

Emergency limit switch shall have automatic self-locking function, and be based on closed-circuit principle. When using a friction drive system, the emergency limit switch shall be activated directly by the moving parts on the machine.

Allowing the use of electronic components and measuring devices instead of mechanical emergency limit switches. Its safety level must be equal to the mechanical emergency limit switch.

When the emergency limit switch is activated, the drive and braking system of the machine shall be turned off independently.

For switchable equipment, the emergency limit switch shall be set to the appropriate stroke range.

4.10.4.3 Protection of over rated load

When the rated load value exceeds 1.2 times (overload factor), the safety related system shall be used to stop the mechanical equipment. And then start to pay attention to the direction of operation, if necessary, reverse

operation.

4.10.4.4 Protection in relaxation of bearing parts

Mechanical equipment uses wire-rope, chain, belt, etc. as bearing part. When the load or bearing part is guided, the drive shall be stopped under an underload condition (e.g. due to bearing part relaxation). And then start to pay attention to the direction of operation, if necessary, reverse operation.

4.10.4.5 Protection of over rated speed

The speed of the drive of the machine shall be greater than the rated speed in the event of a fault. It must be stopped when the rated speed is 1.25 times.

4.10.4.6 Protection of over synchronization tolerance

When the mechanical device combination is running, the device of the entire group must be stopped when the predetermined synchronization tolerance limit is reached.

It shall be easy to identify which drive is out of sync.

When using friction drives and forced transmission systems, their effectiveness shall be monitored.

4.10.4.7 Stop when limit switch exceeded

A single mechanical device or mechanical device group shall stop if the limit switch is exceeded.

It shall be able to identify which device is causing downtime when combined.

4.10.4.8 Stop when operated not based on intended trajectory

If the combination does not meet the intended trajectory, the entire group of machinery and equipment shall be stopped.

4.10.4.9 Interlocking device

The protection device in hazardous area must be equipped with interlocking device to prevent dangerous movement and stop movement.

This type of interlocking device is a safety device at a hazardous location. It must take flexible protection measures due to scene. It can temporarily lift the security device or interlocking device.

If the failure of a parking device (e.g. brake, switch) can lead to a hazardous situation, an interlocking device must be provided to ensure the safety of the equipment.

4.12 About wireless control

4.12.1 General

The wireless control must comply with the requirements of GB 5226.1-2002 (9.2.7).

The use of wireless (radio, infrared, laser) technology shall be easy to disconnect the operation of the control station power supply measures.

An authorization means shall be provided to prevent unauthorized use of the operational control station.

The control station shall identify its control range.

4.12.2 Stop

The operating control station shall contain separate, clearly identifiable means for initiating the stopping function of the machine or causing a stop function for all movements which can cause a dangerous condition.

Equipment with wireless control shall have a device that automatically triggers a mechanical stop and prevents a potentially hazardous operation in the following cases:

- when a stop signal is received;
- when the system detects a fault;
- if a valid signal is not detected for a specified period of time, but it is not included when the device is being pre-programmed to be executed, it is beyond the scope of the wireless control and there is no danger.

4.13 Programmable electronic / electrical system

4.13.1 General

This section applies to all types of electronic equipment, including programmable electronic devices, components, printed circuit boards, devices and components.

4.13.2 Basic requirements

Programmable electronic / electrical system shall be in accordance with GB 5226.1-2002 (11.2).

4.13.3 Programmable control system

It is necessary to prevent unauthorized personnel from changing the contents

of the memory or to replace the memory to prevent unauthorized use of the operation control station.

4.13.4 Programmable control system for safety functions

The single channel programming control system is not allowed for safety functions.

The dual-channel programming control system (E / PES) can be used for safety functions, but the safety level must meet at least the specified SIL3.

When designing E / PES, it shall be noted that a single error in safety-related components shall not lead to failure of safety functions.

When designing the hardware and software of the safety device, it is important to ensure that the safety of the equipment or the surroundings in the safety device must be guaranteed, or that the machinery and equipment are still in safe condition.

The following standards must be used:

- the control function is in fault in accordance with the provisions of GB 5226.1-2002 (11.3.4);

- a computer control system with a security task can assume the function of a safety device (a control function in a fault condition).

4.14 Programmable control system (E / PES) used for safety-independent functions

If the programmable control system does not have to undertake security-related tasks (such as for the establishment of groups and other selection function), there shall be no special requirements. If the selection function is implemented by a programmable control system, the selection result shall be displayed by an off-line feedback signal. The programmable control system shall not affect the effectiveness of the safety device.

If the velocity value and the position value are not used to implement safety-related movements to reach the predetermined position, it can also be handled by a computer.

4.15 Electrical components

4.15.1 Actuator and mark

The actuator color and mark shall comply with the provisions of GB 5226.1-2002 (10.2 Button).

Annex A

(Informative)

References standards and specifications

In the course of implementation, the following standards and specifications are used for reference.

JGJ 67-2001, *Code for architectural design of the theater*

GH 50017-2003, *Code for steel structure design*

GB 5972-2006, *Wire-ropes for cranes - Code of practice for examination and discard*

GB 7588-2003, *Safety Code on Lift Manufacturing and Installation*

GB/T 16755-1997, *Safety of machinery - Rules for the drafting and presentation of safety standards*

GB 18209.1-2000, *Safety of machinery - Indication，marking and actuation - Part 1: Requirements for visual，auditory and tactile signals*

GB/T 16499-1996, *Guide to the drafting of electrical safety standards*

GB 4943-2001, *Safety of information technology equipment*

SHB-Z06-1999, *Guide for the design of emergency shutdown and safety interlocking system for petrochemical industry*

GB 50171-1992, *Installation work for electric devices code for erection and acceptance of switchboard outfit complete cubicle and tie lines of secondary circuit*

GB 50168-1992, *Code for construction and acceptance of cable levels electric equipment installation engineering*

GB 50256-1996, *Code for construction and acceptance of electric device of crane electrical equipment installation engineering*

GB 50055-1993, *Code for design of electric distribution of general-purpose utilization equipment*

CECS 49-1993, *Code for the reception criterion for low-voltage switchgear assemblies*

This is an excerpt of the PDF (Some pages are marked off intentionally)

------ The End ------