ROYAL PLAYHOUSE THEATRE, COPENHAGEN

UPGRADE OF PODIUMS & BACK DROP ELEVATOR TO ELECTRICAL DRIVES

ER (S) APPENDIX 1 - EMPLOYER'S REQUIREMENTS (SPECIFIC)

DCPT738-THP-ZZ-ZZ-SP-OT-005011 Rev: 1.2

THEATRE PLANT

Document History

Revision	Issued by	Date	Comments
1.0	Dave Ludlam	03 Dec 2021	For Internal Review
1.1	Dave Ludlam	06 Jan 2022	For Tender
1.2	Dave Ludlam	12 Jan 2022	For Tender (key dates revised)
Notes:			

Employer, Construction & Design Teams

Employer Contact: Søren Nylin	**The Royal Danish Theatre** August Bournonvilles Passage 2-8 Postboks 2185 DK-1017 København K Denmark T: +45 25 51 78 64 E: SONY@kglteater.dk
Theatre Consultant (Referred to herein as "**the Consultant**") Contact: Dave Ludlam Clive Odom	**Theatreplan** 31 Colonnade London WC1N 1JA T: 020 7841 0445 E: dave@theatreplan.com E: clive@theatreplan.com

Contents

1 Glossary

BOH	Back of House, or Backstage
DKT	Det Kongelige Teater (The Royal Theatre)
DMX	An industry standard protocol for control of stage and other lighting (a subset of RS485)
FOH	Front of House, including Foyers
FP	Facility Panel
GUI	Graphical User Interface
I/O	Input / Output
IWB	Internally Wired Bar
MM	Multi-mode (fibre)
PLB	Production Lighting Box
PSU	Power Supply Unit
RCD	Residual Current Device
Redundant Network	A network with all critical components duplicated such that the network continues to function following any single failure of one of its component parts (wired or fibre link, network switch, router, etc.)
SCR	Sound Control Room
SM	Single Mode (fibre)
SMD	Stage Managers Desk
SWL	Safe Working Load
UCI	User Control Interface
UPS	Uninterruptable Power Supply

2 Other Relevant Contracts

EC	Electrical Contractor
PSE	Project Structural Engineer
SEC	Stage Engineering Contractor (this contract)
TEC	Theatre Equipment Contractor

1 General Information

1.1 Contract Details

This specification sets out the operational and performance requirements, location, duty, dimensional constraints, and other parameters for the Upgrade of Podiums & Back Drop Elevator to Electrical Drives detailed in the following table:

Detail	Reference
Contract Name	**Upgrade of Podiums & Back Drop Elevator to Electrical Drives**
Contractor Name	Referred to herein as the **Stage Engineering Contractor (SEC)**
Tender Documents	Appendix 1 - Employer's Requirements (Specific) Appendix 2 - Employer's Requirements (General) Appendix 3 - Employer's Requirements (Technical) Contract drawings: see ER (S) 1.11 Drawings
Details of the Professional Team	See Employer, Construction & Design Teams
Definitions of Terms	See ER (G) 1.1 Definitions and ER (T) 1.2 Definitions
Extent of Works	New Electrical Prime Movers and Electrical Drives for Stage Podiums and Back Drop Elevator and integration with recently installed new control system as specified in this document. For a detailed list of the Contractor's responsibilities see ER (G) 1 General and ER (T) 1.3 Contractor's Duties
Interfaces with Other Trades	See ER (T) 1.4 Interfaces with Other Trades
Applicable Standards	See ER (T) 1.8 Standards

1.2 Application of Related Documents

This document was written in the English language and should not be translated from this language.

This document shall be read in association with the:

- Upgrade of Podiums & Back Drop Elevator to Electrical Drives Appendix 2 - Employer's Requirements (General)
- Upgrade of Podiums & Back Drop Elevator to Electrical Drives Appendix 3 - Employer's Requirements (Technical).

The table below sets out the document versions and applicable sections for this contract.

Document	Version	Relevant Sections
Appendix 2 - Employer's Requirements (General)	1.2	ALL
Appendix 3 - Employer's Requirements (Technical)	1.2	ALL

IMPORTANT NOTE – The indexes and cross-references provided in these documents are for the reader's convenience only and shall not be construed as implying any applicability or non-applicability of particular sections or clauses. It is the Contractor's responsibility to familiarise themselves with all relevant sections of the Appendix 1 - Employer's Requirements (Specific), Appendix 2 - Employer's Requirements (General) & Appendix 3 - Employer's Requirements (Technical).

1.3 Introduction

The re-commissioning of the hydraulic control systems for the stage podiums and back drop elevator within the Royal Playhouse, Copenhagen in the Summer of 2021 has been problematic. The stability of low speed running below 0.05m/s varies significantly between podiums and is also too dependent on podium position and oil temperature.

Whilst the primary focus is to make the stage podiums and back drop elevator run smoothly at all speeds and positions, secondary goals include removing all the remaining wet systems (hydraulics) from the theatre and recouping as much of the abortive expenditure from the Summer 2021 works as possible.

1.3.1 Key Programme Dates

The SEC shall abide by the following programme dates:

Activity	Date
Early works	Any times prior to start on site with Employer's agreement
Start on site	11th June 2022
Handover	25th July 2022

1.3.2 Communications Through Employer

All communications relating to this contract shall be made through the Employer. Where this document refers to "approval" or "requested" by the Consultant or similar such inquiries or instructions shall be made through the Employer.

1.4 Scope of Work

The Upgrade of Podiums & Back Drop Elevator to Electrical Drives can be summarised as the provision of the following fully automated systems:

- Convert 4 No. podium elevators to electrical prime movers with new electrical drives and control.
- Convert the back drop elevator to an electrical prime mover with new electrical drive and control.
- Provide switchable spare drive(s) for the podium and back drop elevators.
- Re-use incremental and absolute encoders and other sensors where practicable.
- Integrate with the new CAT V5 control system re-using AXIO controllers, power supplies and other control equipment where practicable.
- Decommissioning, strip-out and transfer to stage level of all redundant equipment and hydraulic systems including pumps, accumulators, and pump control gear.
- Identify all equipment that has residual value and advise Employer of potential markets.

The SEC shall:

- Prepare and submit for approval shop drawings and samples as specified.
- Supply and install all equipment specified including all associated cabling and containment.
- Terminate all cabling.
- Test and commission the systems. Carry out tests to be witnessed by the Consultant.
- Provide operation and maintenance manuals, and as-built drawings.
- Provide training for the Employer's staff in the operation of the systems at times to be agreed with the Employer.
- Provide a warranty on the complete installation to run for one year from the date of handover.

Works specifically excluded from the SEC scope:

- Disposal of redundant equipment either through re-sale or an approved waste / salvage company.

1.5 General Design Aims

1.5.1 Similarity

Many of the items of equipment to be used in the Upgrade of Podiums & Back Drop Elevator to Electrical Drives are to be similar; they are all to be from the same "family". They need not be identical, but must use the same basic components, such as motors, gearboxes, encoders, brakes, limit switches, winding drums, and the like.

1.5.2 Lifespan

In order to ensure good value for the Employer's investment, all items of technical equipment and control must have reasonable lifespans. The expected lifespan is, in most cases, identified below; should the required lifespan not be specifically identified, it will be as advised by the SEC at the time of tender. In the event that no life span is nominated, then a life span of 40 years is required.

The following points indicate minimum life expectancy:

- Building elements (e.g.: floors, stairways, corridors, tunnels, pits) – 150 years of building.
- Stage steelwork structures (e.g.: grids and galleries) – 150 years of building.
- The mechanical elements of the stage engineering installations (drive motors, gearboxes, brakes, winding drums, diverter pulleys and similar) shall be procured, manufactured, and installed to a standard that will enable them to continue to work satisfactorily for a minimum of 40 years.
- Permanently installed electrical wiring infrastructure – 40 years.
- Flexible electrical cables – 20 years.
- Electrical elements (variable speed drives, axis controllers, encoders and similar) shall be procured, manufactured, and installed to a standard that will enable them to continue to work satisfactorily for a minimum of 15-20 years. The supplier shall provide historical lifespan data to prove the anticipated life.
- Electronic and computer systems and components – at least 10 years.

1.5.3 Reliability

All technical and engineering equipment and its control systems shall be robust and able to withstand continued use (within stated design limits) over its stated lifespan.

Simplicity of design is to be encouraged. In-built design of alternative means of operation in case of failure to provide disaster mitigation and ensure the Employer's continuation of business must be carefully considered. No bespoke systems shall be employed without prior identification, prototype demonstration and express agreement with the Employer and Consultant.

Systems shall generally be planned and developed without a single point of failure that would prevent a show from proceeding. High availability of all functions at all times shall be the main priority in design development and component selection.

1.5.4 Maintenance

All technical and engineering equipment and its control systems shall be designed and installed to make maintenance as simple as possible. In all cases, a method of safe access shall be provided for maintenance work. The design of covers, racks and mountings shall take account of the need for maintenance access.

No equipment shall require frequent servicing.

Regular inspection and maintenance activities shall be required in accordance with statute and best practice and shall be fully described in maintenance documentation. Such documentation shall be provided in software form so that it can be made available at the place where work is to be undertaken.

Fault diagnosis and first-line repair or maintenance shall be able to be undertaken by trained User's staff who should be fully responsible for the equipment that they operate. In the event of a failure of any control system, secure remote diagnosis by the supplier shall be possible with the repair being provided in terms of parts and labour either in-house or by a fully trained local agent.

1.6 Painting & Making Good

All reworked, reused, and new parts of the installation shall be suitably finished. Take particular care priming and finishing bare metal where it has been cut or welded on site. Match paint to the existing colour scheme: details to be agreed with the Consultant. See ER (T) 6.2.3 Paint & Finishes.

1.7 Access Equipment

The SEC is responsible for providing their own access equipment throughout the installation.

1.8 Strip-out of Redundant Equipment

The SEC is responsible for the making safe, disconnection and removal (to a location to be agreed **at stage level**) of all redundant equipment created through this contract to include, inter alia:

- All hydraulic pumps, accumulators, tanks, pipework, control valves and electrical control gear.
- Hydraulic cylinders and related valve-gear, electrical control gear, hoses and hard pipework.
- Redundant secondary steelwork to be agreed with the Consultant.
- Redundant cabling and any containment that is not re-purposed.

The SEC shall identify all equipment **that has residual value** and advise the Employer of potential second-hand markets.

1.9 Protection of Building and Contents

The SEC shall protect all floors, wall surfaces and building contents from any damage during the strip-out and installation works. Areas most likely to sustain damage are the stage floor and any locations in the vicinity of changes to the hydraulic systems. The SEC is encouraged to undertake a **condition survey** before works commence as they shall be liable for the repair or replacement of damaged items.

1.10 Safety & Safety Systems

See also ER (T) 1.11 Personnel Safety and ER (T) 1.8 Standards.

1.10.1 Working Environment

The Stage Podiums and back drop elevator forming part of this Contract shall be used by trained and authorised personnel during room setup when a raised stage is being created or serviced. Safety shall be achieved by strict rules and management regarding the position of personnel relative to any hazards and what they do during elevator motion.

1.10.2 Primary Duty of the SEC

The SEC shall design, construct and install or upgrade all equipment to minimise the risk of structural failure or collapse and to ensure the health, safety and welfare of the building occupants. Adequate barriers or guarding shall be provided in all areas where the SEC's equipment is installed to minimise so far as reasonably practicable the risk of any person falling or suffering guillotine or entanglement injuries.

1.10.3 Elevator Upgrade Principles

All Elevators forming part of this Contract shall continue to be suitable for carrying **persons and goods** following their upgrade by the SEC. They shall be suitable for riding by artists, technicians, or any other suitably trained persons in the following scenarios: -

- At any height above the stage or basement.
- During performances, rehearsals, or any other time.
- With no de-rating of the elevator lifting capacity (Safe Working Load).

The safety of such personnel and others working in the theatre shall be ensured by the thorough and quality-assured design, engineering, installation and testing of the Control System and all the driven equipment carried out by the SEC.

Normal operations shall be from a hand-held control station located where the operator can see the movement of all the equipment. The necessity for the elevators to move with personnel on them and

for unprotected openings to be created during some performance and maintenance operations shall be accepted and included in the safety philosophy.

1.10.4 EN 61508 Functional Safety Assessment

Electrical, electronic or programmable electronic systems will be used to carry out safety functions within the overstage and understage machinery installations. Design, install, commission, certify and document the installations to meet the requirements of EN 61508:2010 (or equivalent).

1.10.5 CE marking and EC Certificate of Conformity

Where appropriate, issue Certificates of Conformity and CE mark the machines specified in this contract in accordance with the European Machinery Directive (2006/42/EC) as amended. If necessary, seek specialist advice to ensure compliance. Include copies of CE Certificates of Incorporation for all safety-related and other significant components in the Operations & Maintenance Manuals.

1.10.6 Work Health & Safety Regulations

The SEC shall provide all information necessary for the on-going management of the overstage machinery installation in compliance with the Danish Occupational Safety and Health Ordinance. Provide an examination scheme with checklists in electronic format. Mark any equipment that is NOT SUITABLE for lifting persons.

1.10.7 Structural Engineering Consultant

Confirm all structural loads and fixing details to the steelwork and concrete structure with the Project Structural Engineering consultant.

1.11 Drawings

This document should be read in conjunction with the following drawings:

Drawing Title	Type	DWG Number
THEATREPLAN CONSULTANTS		
New Drawings		
Electrical Drive Layout for Primary Podiums - Basement plan Layout	PLAN	DCPT 738-THP-01-XX-DR-OT-01-5-07
Electrical Drive Layout for Backdrop Elevator - Basement plan & section Layout	PLAN SECTION	DCPT 738-THP-01-XX-DR-OT-01-5-08
Drawing from 2021 Scheme		
Primary Podiums - Horizontal Locking Devices	DETAIL	DCPT 738-THP-01-XX-DR-OT-01-5-01
Additional Locking devices - Primary Podiums	DETAIL	DCPT 738-THP-01-XX-DR-OT-01-5-02
Stage level and Wagon Level Locks - Primary Podiums	DETAIL	DCPT 738-THP-01-XX-DR-OT-01-5-03
VISUAL ACT		
Full documentation set		

2 Primary Podiums

2.1 Scope of Upgrades

See also ER (T) 3.3 Elevators.

2.1.1 Background

The movable part of the main stage is composed of four stage elevators. Each elevator consists of a **16m** x **4m** double deck primary podium suspended on four ropes at each corner of the podium. These ropes are reeved **1:1** to a hydraulic cylinder with a **5.7m** stroke which is horizontally placed underneath the elevator.

The podiums are in generally good mechanical condition and received a new control system with upgraded hydraulic control valves in Summer 2021. However, the stability of low speed running below 0.05m/s varies significantly between podiums and is also too dependent on podium position and oil temperature.

2.1.2 Summary of Upgrades

The following remedial works are required:

1. Replacement of the hydraulic cylinder prime mover with electrically driven winches (one each side) acting on the existing suspension ropes via multiply purchased clew plates.
2. Provision of new electrical drives including a pluggable / switchable spare drive.
3. Adaption of the existing control system to the new drive arrangement.

2.1.3 Working Environment

The podiums shall be used by trained and authorised personnel during performances, rehearsals, changeovers and similar. Safety shall be achieved by strict rules and management regarding the position of personnel relative to any hazards and what they do during elevator motion.

2.1.4 Elevator Design Principles

All the podiums are required to remain suitable for **personnel to ride on**, while accepting that the equipment cannot be in the form of a conventional lift for personnel movement. Normal operations shall employ a local control station which is connected and used from a position where the operator can see the movement of all the equipment. A full safety philosophy, including pre-motion warning beacons in the machinery pit (basement B2), safety light curtains and safe edges, shall be determined, submitted for comment, and implemented. The necessity for the elevators to move with personnel on them and for unprotected openings to be created during some operations shall be accepted and included in the safety philosophy.

2.1.5 Hazard Analysis

The required mitigations listed in Table 1 below are the minimum criteria which the SEC must satisfy to manage the risk of the hazards associated with the elevators. In its Design Safety Report, the SEC must address these hazards, required mitigations, and residual risks.

Hazard	Required Mitigation	Residual Risk
Falls from the podiums when they are raised	Handrails, barriers, work restraint or administrative controls must be provided as part of the scenic design and show planning.	Unknown
Falls into the machinery pit from the podiums	Handrails, barriers, work restraint or administrative controls must be provided as part of the scenic design and show planning.	Unknown
Various guillotine hazards at the periphery of the podiums as they move	Where practicable hazards have been designed out through full-depth smooth fixed facias Where facias cannot be fitted suitable safety light curtains and compressible safe-edges have been installed There are facilities to monitor the safety of moving podiums with Deadman's Buttons (DMBs) on the lower platforms	Minimal

Hazard	Required Mitigation	Residual Risk
Persons being crushed below a podium platform	The machinery spaces below the podiums is a restricted area. Pre-motion warning beacons operate whenever the podiums are moving. Access is only required for maintenance with safety assured through procedural controls to isolate and prop platforms as necessary	Minimal
Escape from a podium platform should it fail mid-travel	The maximum height differential achievable by the top platforms is only 3000mm so escape is relatively easy. As an option, by keeping the control system and drives energised in a power failure using a small 3-phase UPS it will be possible to move the podiums to a safe position for egress from either level using regenerative energy from the drives.	Minimal

Table 1: Required Mitigation for Anticipated Hazards

2.2 Performance Parameters

The primary design and performance characteristics of the Primary Podiums are to be as set out below. Confirm all estimated figures either by obtaining verification or from calculation.

2.2.1 Functional Parameters

NUMBER OF PODIUMS	**4 No**. Elevators, each identical.
PLAN SIZE OF EACH PLATFORM	**16 m** x **4 m** = 64 m^2.
PLATFORM TRAVEL	**5.5 m** Nominally **+2.5m** and **-3m** from stage. The SEC shall ensure the existing range of travel is retained and available under the new control system.
DEADWEIGHT OF ELEVATOR	**15,000 kg**
STATIC PAYLOAD	**26,500 kg** (4kN/m^2)
DYNAMIC PAYLOAD	**15,000 kg**
SPEED	**0.25 m/s**
SPEED RANGE	At least **250:1**
NORMAL ACCELERATION	Nominal acceleration and deceleration rate of **0.1 m/s²** with an **S-ramp** profile.
PASSING SPEEDS	Where a move requires two elevators to pass each other in opposite directions, the maximum closing speed shall be limited to **0.25m/s**.
TRAVEL ACCURACY	Any number of adjacent podiums shall be able to travel together in synchronisation to within **±2 mm** under any condition of load and speed.
DEAD REPEAT ACCURACY	The podiums shall position reliably within **±1mm** of any fixed datum established anywhere in their travel under any condition of loading and from any speed setting
LEVEL TOLERANCE	The maximum level difference between any position on the upper or lower platform floors to the adjacent fixed floor at Stage Level, Revolve Level (a theoretical datum) or Basement Doors Level when the podium is static shall be less than **±1.5mm** under any condition of loading. The SEC shall take care to adequately size the hauling winch wire ropes and reeving arrangement to ensure the platforms remain within the level tolerance under changing loads of up to **50kN** when not held on the locks at stage and -300 levels.
LATERAL PLATFORM STABILITY	Platforms shall move laterally no more than **2mm** when subject to any lateral force in the range **0.1-5.0kN** in any direction and at any height in the allowable range of travel up to stage level.

GAPS	Gaps between podiums or between podiums and any adjacent fixed flooring shall be maintained between **3mm** and **5mm** anywhere within the normal travel range. See ER (T) 3.3.3 (a) Gaps Between Elevators
POWER FAILURE STOPPING	When the power is removed, a fully loaded podium shall stop within **30mm** of its current position under any condition of loading and from any speed setting, and two or more similarly loaded Elevators shall stop within **10 mm** of each other.
EMERGENCY STOPPING DISTANCE	In a rapid controlled stop, such as under emergency stop conditions, a fully loaded podium shall stop within **15 mm** of its position and two or more similarly loaded podiums shall stop within **5 mm** of each other.
PERSONNEL TRAVEL	It is a basic theatrical requirement that personnel need to travel on the primary podiums. This shall be achieved by strict rules and management regarding their positions relative to any hazards and what they do during podium motion. All such moves shall be fully rehearsed and responsibility for the performers taken by stage management staff who shall be in attendance.
TRAPPING HAZARDS	No positions or conditions shall be created in which a person can be trapped or in which a limb can be trapped or crushed.
NOISE	Movements of the podiums shall be inaudible to the audience during performances when two or fewer podiums are in motion simultaneously at any speed. The operating noise level shall be measured at the worst-case location in the auditorium with the stage empty, but all borders, legs and masking deployed. The following noise criteria shall be met at the worst-case operating point within the indicated ranges of speed and load: — Any two podiums up to 70% speed and up to 70% load: **≤37dB$_{LAeq}$** — Any two podiums up to 100% speed and up to 100% load: **≤40dB$_{LAeq}$** Short peaks of **+3dB** above these levels are permissible during brake and retractable guide lock operations and platform acceleration / deceleration. Measurements shall be taken over podium raise/lower cycles starting at stage level and raising **3m** and lowering **2.5m**. These tests shall be carried out with the podiums loaded and unloaded and at different speeds up to maximum speed to ensure compliance under all operating conditions. See ER (T) 6.1 Acoustic Performance Requirements
DUTY CYCLE	Design for **10 full-load raise and lower** movements in **15 minutes** followed by **15 minutes** rest OR **continuous motion** at minimum speed with **75%** of maximum load for **30 minutes** followed by **30 minutes** rest OR similar load-speed cycles.
CONTROL	The primary podiums shall be operated by the existing Stage Control System. Additional control functions shall include: — Operation restricted to a control desk plugged into a stage level control outlet within the stage area. — Automatic movement to the stage (0 mm) and -300mm revolve levels as part of revolve system operations. Details to be agreed with the Client and Consultant.

2.2.2 Construction

TYPE OF MECHANISM	Electrically synchronised winches each end of the platform acting on the existing suspension ropes via multiply purchased clew plates (see drawings).
WINCH LOCATIONS	Basement B2 rooms each side of stage retaining all access and egress routes and avoiding the large access hatch in the floor of the stage right room. All locations to be agreed with the Consultant
PODIUM MECHANISM SAFETY SYSTEMS	See ER (T) 3.3.2 Elevator Safety The SEC shall interrogate and document the existing podium safety systems to ensure the functionality is understood and accurately reproduced by the new control system. Details to be agreed with the Consultant. Overload shall be detected through **load cells** fitted to the hauling winches and be adjustable between **10% and 115% of SWL**. See Also ER (T) 6.6.4 Overload Detection ER (T) 6.6.8 Speed Error Detection
SAFE EDGE & SAFETY LIGHT CURTAIN PROTECTION	New safe edges or safety light curtains have been provided under the Summer 2021 works. Integrate these safety devices with the modified electrical drive and control system.
PLATFORM LOCKS	New platform locks at stage and -300 levels have been provided under the Summer 2021 works. Integrate these locks with the modified electrical drive and control system.
PLATFORM LOCKING TIME	The locks shall engage or fully unlock within **10 seconds**.
LOCAL CONTROLS	Provide key-switch operated duplicate control on the MCC for maintenance and servicing. Details to be agreed with the Consultant. See Also ER (T) 4.7 (d) Local / Remote Switching Provide facilities to set and bypass the Ultimate Limits with these local controls
SINGLE FAULT TOLERANCE	Ensure any single failure of the necessary systems of synchronisation or positioning, such as encoders, cannot prevent operation of the podiums. Details to be agreed with the Consultant.
CONTROL CABINET LOCATION	New MCC suites in basement B2 rooms each side of stage, exact locations to be agreed with the Consultant.
WARNING BEACONS AND SOUNDERS	Retain any **Beacons** and **Sounder(s)** and ensure they continue to operate in the same way. Details to be agreed with the Consultant. See ER (T) 4.4 Remotely Controlled Equipment
TEST WEIGHTS	The Employer owns at least **20 No**. **1000 litre** water tanks that can be made available for use as test weights for the podiums and back drop elevator.

3 Back Drop Elevator

3.1 Scope of Upgrades

See also ER (T) 3.3 Elevators.

3.1.1 Background

The back drop elevator, or cloth store, is located directly upstage of the primary podiums. Below the 20.7m x 2m platform are a number of 'shelves' for storing scenic cloths and other long items. The back drop elevator is operated by two hydraulic cylinders that are synchronised by means of a control system monitoring absolute draw-string encoders at each end of the elevator.

The back drop elevator is in generally good mechanical condition and received a new control system with upgraded hydraulic control valves in Summer 2021. However, the stability of low speed running below 0.05m/s remains too dependent on oil temperature and with the podiums converted to electrical drives the back drop elevator would be the only hydraulic system remaining in the theatre requiring the expensive ongoing maintenance of the hydraulic pump sets and accumulators.

3.1.2 Summary of Upgrades

The following remedial works are required:

1. Replacement of the hydraulic cylinder prime movers with electrically driven LinkLift rigid chains (two each side) acting on a modified lifting plate attached to the original hydraulic ram gimbal attachments.
2. Provision of new electrical drives including a pluggable / switchable spare drive.
3. Adaption of the existing control system to the new drive arrangement.

3.1.3 Working Environment

The back drop elevator shall be used by trained and authorised personnel during performances, rehearsals, changeovers and similar as the elevator must also be lowered to allow the revolve wagon the move on or off the stage. Safety shall be achieved by strict rules and management regarding the position of personnel relative to any hazards and what they do during elevator motion.

3.1.4 Elevator Design Principles

The back drop elevator is required to remain suitable for personnel to ride on, while accepting that the equipment cannot be in the form of a conventional lift for personnel movement. Normal operations shall employ a local control station which is connected and used from a position where the operator can see the movement of all the equipment. A full safety philosophy, including pre-motion warning beacons in the machinery pit (basement B2) and safe edges, shall be determined, submitted for comment, and implemented. The necessity for the elevator to move with personnel on them and for unprotected openings to be created during some operations shall be accepted and included in the safety philosophy.

3.1.5 Hazard Analysis

The required mitigations listed in Table 1 below are the minimum criteria which the SEC must satisfy to manage the risk of the hazards associated with the elevators. In its Design Safety Report, the SEC must address these hazards, required mitigations and other controls implemented by the SEC, and residual risks.

Hazard	Required Mitigation	Residual Risk
Falls from the back drop elevator when they are raised	Handrails, barriers, work restraint or administrative controls must be provided as part of the scenic design and show planning.	Unknown
Falls into the machinery pit from the back drop elevator	Not possible as the back drop elevator only travels 300mm below stage level.	Unknown

Hazard	Required Mitigation	Residual Risk
Various guillotine hazards at the periphery of the back drop elevator as it moves	Where practicable hazards have been designed out through full-depth smooth fixed facias Where facias cannot be fitted suitable compressible safe-edges have been installed The speed of the back drop elevator is limited to 0.2m/s	Minimal
Persons being crushed below the back drop elevator	The machinery spaces below the back drop elevator is a restricted area. Pre-motion warning beacons operate whenever the back drop elevator is moving. Access is only required for maintenance with safety assured through procedural controls to isolate and prop platforms as necessary	Minimal
Escape from the back drop elevator should it fail mid-travel	The maximum height differential achievable by the top of the back drop elevator is only 4,300mm so escape is relatively easy. As an option, by keeping the control system and drives energised in a power failure using a small 3-phase UPS it will be possible to move the Back Drop Elevator to a safe position for egress from either level using regenerative energy from the drives.	Minimal

Table 2: Required Mitigation for Anticipated Hazards

3.2 Performance Parameters

The primary design and performance characteristics of the Back Drop Elevator is to be as set out below. Confirm all estimated figures either by obtaining verification or from calculation.

3.2.1 Functional Parameters

PLAN SIZE OF EACH PLATFORM	**20.7 m** x **2 m** = 41.4 m^2.
PLATFORM TRAVEL	**4.635 m** Nominally **+4.335m** and **-0.3m** from stage. The SEC shall ensure the existing range of travel is retained and available under the new control system.
DEADWEIGHT OF ELEVATOR	**16,000 kg**
STATIC PAYLOAD	**32,500 kg** (3.89kN/m^2 if the full dynamic payload is in the elevator storage area)
DYNAMIC PAYLOAD	**16,100 kg**
SPEED	**0.2 m/s**
SPEED RANGE	At least **200:1**
NORMAL ACCELERATION	Nominal acceleration and deceleration rate of **0.1 m/s²** with an **S-ramp** profile. SEC to confirm current settings and precise values with the Consultant.
PASSING SPEEDS	Where a move requires the back drop elevator and adjacent podium to pass each other in opposite directions, the maximum closing speed shall be limited to **0.2m/s**.
DEAD REPEAT ACCURACY	The elevator shall position reliably within **±1mm** of any fixed datum established anywhere in its travel under any condition of loading and from any speed setting
LEVEL TOLERANCE	The maximum level difference between any position on the upper platform of the back drop elevator and the adjacent fixed stage floor shall be less than **±1.5mm** under any condition of loading
GAPS	Gaps between the elevator and any adjacent podium or fixed flooring shall be maintained between **3mm** and **5mm** anywhere within the normal travel range. See ER (T) 3.3.3 (a) Gaps Between Elevators

POWER FAILURE STOPPING	When the power is removed, a fully loaded back drop elevator shall stop within **30mm** of its current position under any condition of loading and from any speed setting.
EMERGENCY STOPPING DISTANCE	In a rapid controlled stop, such as under emergency stop conditions, a fully loaded back drop elevator shall stop within **15 mm** of its position.
PERSONNEL TRAVEL	It is a basic theatrical requirement that personnel need to travel on the back drop elevator. This shall be achieved by strict rules and management regarding their positions relative to any hazards and what they do during back drop elevator motion. All such moves shall be fully rehearsed and responsibility for the performers taken by stage management staff who shall be in attendance.
TRAPPING HAZARDS	No positions or conditions shall be created in which a person can be trapped or in which a limb can be trapped or crushed.
NOISE	The back drop elevator may need to move during a performance to facilitate a revolve wagon movement on/off stage. This movement shall be inaudible to the audience during performances at any speed. The operating noise level shall be measured at the worst-case location in the auditorium with the stage empty, but all borders, legs and masking deployed. The following noise criteria shall be met at the worst-case operating point within the indicated ranges of speed and load: — Back drop elevator up to 100% speed and up to 100% load: **≤37dB$_{LAeq}$** Short peaks of **+3dB** above these levels are permissible during brake operations and platform acceleration / deceleration. Measurements shall be taken over a back drop elevator raise/lower cycles starting at stage level and lowering **0.3m** and then returning to stage level. See ER (T) 6.1 Acoustic Performance Requirements
DUTY CYCLE	Design for **10 full-load raise and lower** movements in **30 minutes** followed by **30 minutes** rest.
CONTROL	The back drop elevator shall be operated by the Stage Control System. Additional control functions shall include: — Operation restricted to a control desk plugged into a specific stage level control outlet adjacent to the back drop elevator. — Direct selection of which shelf the back drop elevator should move to. — Automatic movement to the stage (0 mm) and -300mm revolve levels as part of revolve system operations. Details to be agreed with the Client and Consultant.

3.2.2 Construction

TYPE OF MECHANISM	Electrically synchronised LinkLift rigid chains (two each side) acting on the existing gimbal attachments for the hydraulic rams at each end of the back drop elevator (see drawings). See Also ER (T) 3.3.7 Rigid Chain Drives (LinkLift)
ELEVATOR MECHANISM SAFETY SYSTEMS	See ER (T) 3.3.2 Elevator Safety The SEC shall interrogate and document the existing back drop elevator safety systems to ensure the functionality is understood and accurately reproduced by the new control system. Details to be agreed with the Consultant. Overload shall be detected through **load cells** fitted to each LinkLift column and be adjustable between **10% and 115% of SWL**. See Also ER (T) 6.6.4 Overload Detection ER (T) 6.6.8 Speed Error Detection
SAFE EDGE & SAFETY LIGHT CURTAIN PROTECTION	New safe edges or safety light curtains have been provided under the Summer 2021 works. Integrate these safety devices with the modified electrical drive and control system.

LOCAL CONTROLS	Provide key-switch operated duplicate control on the MCC for maintenance and servicing. Details to be agreed with the Consultant. See Also ER (T) 4.7 (d) Local / Remote Switching Provide facilities to set and bypass the Ultimate Limits with these local controls.
SINGLE FAULT TOLERANCE	Ensure any single failure of the necessary systems of synchronisation or positioning, such as encoders, cannot prevent operation of the back drop elevator. Details to be agreed with the Consultant.
CONTROL CABINET LOCATION	New MCC against upstage wall in basement B2, exact location to be agreed with the Consultant.
WARNING BEACONS AND SOUNDERS	Retain any **Beacons** and **Sounder(s)** and ensure they continue to operate in the same way. Details to be agreed with the Consultant. See ER (T) 4.4 Remotely Controlled Equipment

4 Stage Control System

4.1 Scope

See also ER (T) 5 Multi-Axis Stage Control.

4.1.1 Background

A well-established proprietary CAT V5 theatre stage automation system from Waagner Biro has been installed as part of the Summer 2021 works.

The SEC is required to integrate their podium and back drop elevator upgrades with the existing control system and liaise with Waagner Biro as required in this regard. The SEC is responsible for agreeing a works package for the commissioning of the new elevator drives and attendance during testing and commissioning directly with Waagner Biro and to engage them as a sub-contractor.

4.2 Performance Parameters

The specific requirements of the podiums and back drop elevator when integrated with the CAT V5 control systems are summarised in the following table.

EMERGENCY STOP (E-STOP)	All axes to be controlled by a Category 1 Emergency Stop System E-STOP as defined in EN 60204-1 (or equivalent) No single point of failure in the E-STOP system other than the wiring or actuators shall be acceptable.
SYSTEM AVAILABILITY	The system shall provide an exceptionally high level of availability Single points of failure that affect more than one axis will not normally be acceptable The Mean Time to Repair shall be no more than **15 minutes** Extra low voltage (e.g. 24V dc) power supplies shall be redundantly configured and therefore single fault tolerant. Where technology limitations or design choices result in non-redundant subsystems the contractor shall justify these single points of failure with the following information: — Failure mode and effect analysis — Mean Time Between Failures data — Mean Time to Repair data System reliability and resilience to faults will be one of the main criteria in the contractor selection process
FAULT REPORTING WITHOUT FAULT MASKING	Ensure all faults are reliably and unambiguously reported on an OCP or RCP Do not report drive sensor errors (such as a faulty encoder) as a DRIVE FAULT. It is particularly important that component faults that cannot be rectified by a drive cross-patch or connection to a backup drive are clearly reported so the component can be swapped rather than time wasted cross-patching or connecting a spare drive
LOAD CELL OVERRIDE	Ensure a faulty load cell can be quickly overridden by a suitably qualified operator so as not to disable the axis
TELEMETRY	In order to manage the elevator installation effectively, good quality telemetry on every aspect of the system is essential. Unexplained incidents occur with complex systems, and they can only be investigated fully with accurate data recorded at the time of the incident. Provide the following signals for recording by the CAT V5 telemetry system: — All status / error / fault and snag signals from hoists, drives and other subsystems. — Key "analogue" signals during hoist motion such as actual hoist speed, demand speed, motor torque and hoist load. Details to be agreed with Waagner Biro and the Consultant. See ER (T) 5.5 Telemetry

4.3 Motor Drives & Power Supply

LOCATION	Ideally, the drives for the podiums and back drop elevator would be distributed around the K2 basement but this may make the provision of a common spare drive difficult. SEC to advise the maximum distance that is tolerable between drive cabinets and elevator motors and propose the most cost-effective distribution of primary and backup drive locations.
SPARE DRIVES	**One drive per axis** with manually or electrically switched **spare drive(s)** See ER (T) 4.8.2 Integrated Hoist & Drive Provide manually- or electrically-switched spare drives as necessary at each **drive location** with enough capacity to enable any elevator to be driven in the event of a failure of an electronic drive or any single failure of the necessary systems of synchronisation or positioning. A single spare drive will be sufficient provided it can control any of the elevators. If necessary, provide additional spare drives to cover the range of motor sizes to be controlled. Regardless of drive locations, pluggable or switchable spare drives shall be provided for the podiums and back drop elevator. Details to be agreed with the Consultant. See also ER (T) 3.1.3 Secondary Drive Systems
LOCAL MOTOR DRIVE CONTROLS	Provide RAISE, LOWER and SPEED controls on a plug-in pendant It shall be possible to set and bypass the Ultimate Limits with these local controls, see ER (T) 6.6.2 Overtravel (Ultimate) Limits Details to be agreed with the Consultant
SECONDARY CONTROL SYSTEM	Secondary motors have not been specified for any of the understage machinery due to the very high reliability of modern motors. The intention is that the LOCAL controls shall provide a simple and highly available alternative control interface. The SEC shall ensure that any power supplies, encoders, sensors and similar that are **essential to operation** under secondary control are redundantly-configured or can be ignored by the control system. Limited safety systems and a reduced Safety Integrity Level are acceptable under secondary control. Operation under secondary control shall be restricted through the use of a special key or user access level. Details to be agreed with the Consultant.
MOTOR DRIVE	Proprietary **Variable Speed Drive** approved for lifting applications by the manufacturer
DRIVE NOISE	The noise from drive cooling fans are unlikely to be a problem in the Drive Rooms. However, arrange for ALL cooling fans to be thermostatically controlled to minimise noise and conserve fan life.
POWER SUPPLY OVERLOAD PROTECTION	Continuously evaluate the loads to be lifted in each movement of **understage machinery** and calculate the supply current required. Warn the operator if an impending move is likely to overload the power supply.
UPS FOR CONTROL SYSTEM	Already provided under Summer 2021 works
STANDBY UPS FOR ELEVATOR DRIVES (PRICING OPTION)	As an **option** provide an appropriate backup (3-phase) UPS supply to keep the drives and associated equipment energised in the event of an electrical power failure to allow movement of the podiums and back cloth elevator to a safe position for egress using regenerative energy from the drives.

POWER SUPPLY	Minimum of 800A TPN from an uprated Pump Station supply (by others). This supply will be provided and connected by others to switchgear to be provided by the SEC and installed in a location to be agreed. The SEC shall liaise with the Consultant and Project Electrical Engineers to agree the make, design, and location of the switchgear. In addition, the SEC shall provide all UPS, AC/DC converters, active filters and line conditioning equipment as may be required for the installation and connect all outgoing supply cables and CPCs. Ensure a high level of discrimination such that a worst-case elevator failure can never 'trip' the main supply protective devices and cause a significant loss of facility.

4.4 Emergency Stop System

See also ER (T) 4.5 Emergency Stop System.

A new emergency stop systems has been installed as part of the Summer 2021 control system upgrade. Integrate the new podiums and back drop elevator with the new Estop system as set out the table below:

TYPE OF E-STOP SYSTEM	All axes to be controlled by a Category 1 Emergency Stop System stop as defined in EN 60204-1 (or equivalent) A "global" Emergency Stop System for the entire building is not required
EMERGENCY STOP ACTUATORS	Provide sufficient grab-lines or E-STOP mushroom actuators around the basement B2 podium winch rooms to protect personnel near the winches – agree actuator types and locations with the Consultant.
E-STOP GROUP SYNCHRONISATION	Group synchronisation during Emergency Stopping shall be the same as under normal operation; the position between any elevators in a group shall be less than 3mm at the platforms under all speed and acceleration conditions.
E-STOP TRACE DISPLAY	Ensure E-STOPs added under this contract are traced and displayed on all OCPs and RCPs

5 Contract Submissions

5.1 Tender Submissions

Include with the tender the following information in addition to other information required by other tender documents. Only submission items A1-A3 and the fully completed Pricing Schedule will be considered when evaluating the tenders received.

Ref	Item	Received
A1	Detailed programme for the works confirming Tenderer's ability to comply with programme for design, manufacture, delivery, installation, and commissioning related to overall Project Time Schedule	
A2	Full description of the technical approach intended to be followed, particularly stating details of the winches and LinkLifts to be used in the upgrades, and changes to the drives and control system and power supply distribution.	
A3	Names and CVs of team leaders for: 1. Lead mechanical designer 2. Lead electrical designer 3. Lead control system engineer 4. Site mechanical installation manager 5. Site electrical installation manager 6. Project manager	
A4	Manufacturers' specifications for all proposed proprietary equipment	
A5	Written statement of full compliance with these Employer's Requirements or otherwise a full description of all deviations See Appendix B (Additional Information) Section 3.	
A6	Written confirmation that each of the proposed installations will fit into the allocated spaces. Provide details of any changes to loads to be applied to the building structure	
A7	Written acceptance of power supplies specified and indication of environmental and dissipation limits	
A8	Description of any problems foreseen which may affect the satisfactory **implementation** of the works or **performance** of the equipment	

5.2 Management Submissions

Submit the following information within 28 days of contract signing.

Ref	Item	Received
B1	Method statement on envisaged delivery procedures	
B2	Method statement on envisaged installation procedures	
B3	Method statement on envisaged commissioning procedures	

5.3 Contract Submissions

Submit at least the following working drawings, information, and other data, in addition to any documents or samples called for herein or in the Appendix 2 - Employer's Requirements (General), for review, before commencing procurement, fabrication or software preparation. All drawings shall be cross-referenced clearly and submitted as complete sets illustrating fully a part or system. Related data sheets shall be submitted with the drawings. Submissions issue sheet shall be in number sequence, clearly dated and carry the reference from following tables or an X code indicating additional submission. The weight of all parts to be moved manually and the lifting points must be shown. Where alternative solutions have been proposed and accepted, the list shall be modified appropriately.

5.3.1 General

Ref	Item	Received
C1	Design Risk Assessments for all machinery under this contract	
C2	Schedule of all proprietary components together with cut sheets	
C3	Full list of proposed spares with individual costs (see ER (G) 1.9 Spare Parts)	

5.3.2 Primary Podiums

Ref	Item	Received
C4	General arrangement the new winches and multiply reeved clew plates with structural calculations.	
C5	Provide details of electrical drive system and interfacing to existing control system.	

5.3.3 Back Drop Elevator

Ref	Item	Received
C6	General arrangement the new LinkLift drives with structural calculations.	
C7	Provide details of electrical drive system and interfacing to existing control system.	

5.3.4 Stage Control System

Ref	Item	Received
C8	Details of proposed emergency stopping performance for approval by the Consultant. Emergency Stop Risk Category Evaluation and description of E-stop system to be provided.	
C9	Details of all motors and electrical drives including pluggable and switched spare drives and other major components with cut sheets	
C10	Complete electrical block diagram showing all the major elements of the installation and wiring schematics with numbered connections and core sizes Complete electrical containment, power cable and wiring route details.	
C11	Details of switchgear to be provided in the basement machine rooms and the bus-bar distribution systems	
C12	Details of 3-phase UPS and elevator operation under a power failure (if option taken)	

5.4 Pre-Testing & Inspection

Not required.

5.5 On Site Testing & Commissioning

Representatives of the Consultant and of the Employer will carry out general periodic inspections of all aspects of the installation of the equipment, systems and wiring on site. In addition, the Consultant's representatives and others will be present, after the equipment is fully installed, connected and has been set to work, to witness a number of scheduled tests to be carried out by the SEC. The following list indicates the extent of testing required. The SEC shall prepare a full schedule of testing and commissioning procedures, together with a programme, for approval by the Employer and the Consultants. Any further tests which may be considered necessary by the Consultant's representatives shall also be carried out at no extra cost to the contract.

5.5.1 General

Ref	Item	Seen
E1	Check spares provided against proposed list	

5.5.2 Primary Podiums

To be completed an ALL podiums

Ref	Item	Seen
E2	Full static proof load test at 125% of SWL with load evenly distributed on Elevator at stage level. Check for any excessive structural, mounting or cylinder guide deflections. (See ER (T) 1.12.6 Proof Load Tests)	
E3	Test brakes independently and in combination at 110% of SWL. Measure and record stopping distance or holding torque; details of test to be agreed with the Consultant	
E4	Raise and lower the elevators with full dynamic payload over a complete cycle. Move at various speeds, assess noise, inspect drives, and evaluate acceleration, motion and stopping. Test emergency stop system at full load and speed in both directions.	
E5	Carry out similar tests to those above with reduced and zero payloads.	
E6	Carry out noise measurements as specified in the event that there are any concerns about the assessed noise levels during any test.	
E7	Test normal and over-travel detection systems as deemed appropriate by the Consultant.	
E8	Demonstrate operation and indication of all safe-edges and light curtains in individual sections and the effect on moving elevators. Evaluate safety in all guillotine situations.	
E9	Demonstrate operation of platform locks and retractable guide shoes.	
E10	Demonstrate operation of overload detection and load measuring system	
E11	Confirm platform floor is level and aligns with fixed floors; check all gaps are in tolerance	
E12	Carry out duty cycle tests and inspect and check heating of all main working parts as required by the Consultant	
E13	Carry out mechanical and electrical inspections of the elevator, control cabinet, control stations, etc.	
E14	Confirm proper functioning of all controls and indicators and positioning at preset deads under various loads. Details to be agreed with the Consultant.	
E15	Demonstrate all door interlocks	
E16	Demonstrate all error, snag, malfunction, fault detectors and signals including beacons and sounders	

5.5.3 Back Drop Elevator

Ref	Item	Seen
E17	Full static proof load test at 125% of SWL with load evenly distributed on Elevator at stage level. Check for any excessive structural, mounting or cylinder deflections. (See ER (T) 1.12.6 Proof Load Tests)	
E18	Raise and lower the elevators with full dynamic payload over a complete cycle. Move at various speeds, assess noise, inspect drives, and evaluate acceleration, motion and stopping. Test emergency stop system at full load and speed in both directions.	
E19	Carry out similar tests to those above with reduced and zero payloads.	
E20	Carry out noise measurements as specified in the event that there are any concerns about the assessed noise levels during any test.	
E21	Test normal and over-travel detection systems as deemed appropriate by the Consultant.	
E22	Demonstrate operation and indication of all safe-edges or light beams in individual sections and the effect on moving elevators. Evaluate safety in all guillotine situations.	
E23	Demonstrate operation of overload detection and load measuring system	
E24	Confirm platform floor is level and aligns with fixed floors; check all gaps are in tolerance	
E25	Carry out duty cycle tests and inspect and check heating of all main working parts as required by the Consultant	
E26	Carry out mechanical and electrical inspections of the elevator, control cabinet, control stations, etc.	
E27	Confirm proper functioning of all controls and indicators and positioning at preset deads under various loads. Details to be agreed with the Consultant.	
E28	Demonstrate all error, snag, malfunction, fault detectors and signals including beacons and sounders	

5.5.4 Stage Control System

Ref	Item	Seen
E29	Fully exercise all the functions of the OCPs, RCP and, Drive LOCAL controls when controlling the podiums and back drop elevator. Details to be agreed with the Consultant once the contract is placed.	
E30	Demonstrate operation of the spare drive configurations and secondary controls for the podiums and back drop elevator.	
E31	Demonstrate system availability through drive swapping, spare drives, secondary control systems. Demonstrate short time to repair of failed sensors that cannot be overridden such as incremental encoders. Conduct tests as requested by the Consultant	
E32	Demonstrate that all podium and back drop data is being captured by the Telemetry system.	
E33	Demonstrate operation of primary podiums and back cloth elevator on UPS power in a simulated mains failure (if option taken).	

5.6 Test & Measurement Equipment

Provide at least the following test equipment for the duration of the tests. Any other items reasonably required shall be procured in order that the quality of the installation and performance of the equipment can be confirmed. Please ensure that all test equipment has new batteries.

5.6.1 Minimum Equipment Required

Ref	Item	Seen
F1	Easily-moved certified test weights for all types of test (see ER (T) 1.12.6 (b) Test Weights)	
F2	Facilities within the control (Telemetry) system to continuously measure, record and display speed, motor torque and current, position error between elevators and between a elevators and their target position	
F3	Sound level meter, class 1 or 2 to EN 61672-1:2013 (or equivalent) if requested by the Consultant	
F4	Power-quality analyser if requested by the Consultant	

5.7 Operation & Maintenance Manuals

5.7.1 Submittals

Prepare and submit the following in accordance with the Appendix 2 - Employer's Requirements (General). The manual shall contain, amongst other things, the following:

Ref	Item	Received
G1	Direct telephone number for firm providing specified response under warranty	
G2	Schedule of adjustments set on equipment during commissioning	
G3	Full operational instructions and Maintenance Manual covering both bespoke and proprietary equipment (see ER (G) 1.7 Operations & Maintenance Manuals)	
G4	Full maintenance instructions: ensure full information about the systems and full contact addresses are provided	
G5	A complete set of new as-built Record Drawings of all the upgrades based on the changes made during installation as recorded on site office records.	
G6	Provide full as-built 2D CAD drawings of the installation in AutoDesk .DWG format, details to be agreed with the Consultant.	
G7	A schedule of regular maintenance tasks (e.g.: inspect hardware, clean filters, etc.), indicating the dates at which these will first fall due and the frequency required thereafter	
G8	Index of record drawings	
G9	Contact details including email addresses for manufacturers / distributors of all proprietary equipment	

5.8 Training

5.8.1 Submittals

Provide full operational and maintenance training for the appropriate Employer's staff including in-house maintenance personnel (no more than **ten persons** in total, **minimum 10 days**). This shall include both classroom and practical sessions planned to ensure that there are no operational disruptions due to incorrect operation of the equipment.

Prepare and submit the following in accordance with the Appendix 2 - Employer's Requirements (General):

Ref	Item	Received
H1	Provide a detailed training plan for the service set out in ER (G) 1.10 Training of User's Staff Due to the limited time available, ensure that us much training as possible is delivered either off-line or off-site before the system goes live	

5.9 Standby

5.9.1 Submittals

Post completion, provide on-site standby support during rehearsals and performances for a minimum of **5 working days**.

END OF UPGRADE OF PODIUMS & BACK DROP ELEVATOR TO ELECTRICAL DRIVES APPENDIX 1 - EMPLOYER'S REQUIREMENTS (SPECIFIC)
DCPT Appendices 1-3 Podium & Back Drop Elevator Upgrades ER(SGT) Rev 1.2

ROYAL PLAYHOUSE THEATRE, COPENHAGEN

UPGRADE OF PODIUMS & BACK DROP ELEVATOR TO ELECTRICAL DRIVES

ER (G) APPENDIX 2 - EMPLOYER'S REQUIREMENTS (GENERAL)

DCPT738-THP-ZZ-ZZ-SP-OT-005012 Rev 1.2

THEATRE PLANNER

Document History

Revision	Issued by	Date	Comments
1.0	Dave Ludlam	03 Dec 2021	For Internal Review
1.1	Dave Ludlam	06 Jan 2022	For Tender
1.2	Dave Ludlam	12 Jan 2022	For Tender (key dates revised)
Notes:			

Contents

1 General

1.1 Definitions

1.1.1 Specialist Consultants

The specialist consultants handling the Stage Engineering & Theatre Equipment for the Project are Theatreplan, 31 Colonnade, London, WC1N 1JA: telephone +44 20 7841 0440, email engineering@theatreplan.com. In the documents the specialist consultants are referred to as "Theatreplan", "TP", or as "the Consultant".

1.1.2 Stage Engineering Contractor (SEC)

Any firm appointed to undertake part of the Upgrade of Podiums & Back Drop Elevator to Electrical Drives as specified in the documents is hereinafter referred to as Stage Engineering Contractor or "SEC".

1.1.3 Provide

Unless stated otherwise, this term shall mean the design, manufacture, supply, installation, commissioning and testing of the equipment described, including any training required on the equipment and systems.

1.1.4 Approved

The term shall apply to items which have been specifically submitted in the form of cut-sheets or samples, or as otherwise requested, to the Engineer and are passed as acceptable for use on this Contract. Any such approval shall not affect the responsibility of the SEC for full compliance with, and satisfactory operation of every aspect of any contract arising from these Employer's Requirements.

1.1.5 Axis

The term refers to single-driven motion of a piece of equipment, such as a single hoist or Elevator.

1.2 Tender

1.2.1 Tender

By submitting a tender for these works, the Tenderer represents that it has relevant extensive experience in the design, manufacturing and installation of the type of equipment and works described herein and undertakes, if awarded a contract related to these Employer's Requirements, that it will design and provide a safe, reliable and fully operational installation in the defined time scale.

1.2.2 Alternatives

Tenderers shall provide prices for alternatives where described and requested and may give their view as to the preferred option. The alternatives may not be illustrated on the current drawings. Tenderers may also offer clearly described alternatives of their own, provided that these offer economic solutions, comply with the intent and performance described in these Employer's Requirements and can be fitted and maintained in the spaces available.

1.3 Extent of Works

1.3.1 Summary

The Works shall comprise the detailed and final design, manufacture, supply, installation, testing and commissioning of the Upgrade of Podiums & Back Drop Elevator to Electrical Drives and systems specified herein for the contract, including all labour, plant, transport and all necessary training.

1.3.2 Standards & Regulations

The works shall be carried out in accordance with all parts of this specifications, all statuary requirements including all applicable National and European Standards.

1.3.3 SEC's Responsibility

The SEC shall provide all equipment, items, articles, materials, and operations listed, mentioned, scheduled or implied in the documents, including all design skills, tools, plant, scaffolding, labour, supervision and incidentals necessary and required for the completion and testing of the works and for the full and satisfactory operation of the systems described.

1.3.4 Conflict

In case of conflict between individual clauses or between clauses and drawings, the following order of preference shall apply:

- Local Statutory Requirements
- National Statutory Requirements
- Applicable National and European Standards
- Appendix 1 - Employer's Requirements (Specific)
- Appendix 2 - Employer's Requirements (General)
- Appendix 3 - Employer's Requirements (Technical)
- The Relevant Drawings

1.3.5 Clarification

Where the Local Statutory Requirements or applicable National and European Standards affect the design or operation of the equipment or installations, such matters shall be raised with the Employer or Employer's Representative (Consultant) immediately. Where any matter is unclear, or the tenderer is concerned about any aspect of the Employer's Requirements or Drawings, these points shall be brought to the attention of the Employer or Employer's Representative (Consultant) immediately. Tenders shall not be submitted unless the tenderer is confident that they can supply equipment which performs as specified and can be installed, commissioned, and maintained in the spaces, and in the time, available.

1.3.6 Work by Others

Related structural, building, electrical and other work which is so indicated in the documents will be provided by others. Any additional items, whether or not shown on drawings or described in the specification, such as steel required for the mounting of equipment, shall be supplied, and installed by the SEC at no extra cost to the contract.

1.3.7 Timber Work

Where timber work forms part of this contract and is to be carried out by the SEC, the cost of suitably experienced carpenters and their materials, including carcassing and finishing timber and plywood, shall be included in the tender price. This work shall be carried out only by trained and experienced craftsmen under the direction of the SEC in accordance with the timescale for the works.

1.3.8 Final Design

Under this contract the SEC has detail and final design responsibilities. These include, inter alia, interpreting the Appendix 1 - Employer's Requirements (Specific) and Drawings and preparing detailed designs and shop drawings of the equipment and installations which will accomplish the functions described, whilst maintaining the theatre planning and performance concepts set out in the documents. It is accepted that different contractors will offer variations on some of the equipment principles

described. The appointed SEC is responsible for producing and installing equipment which is entirely suitable for the purposes described, fits into the spaces available and performs as specified.

1.3.9 Design Personnel

Mechanical, structural, electrical and control system design work shall only be carried out by suitably qualified and experienced engineers of the appropriate discipline. Specifically, audio and lighting control system design shall not be carried out by unqualified electricians or technicians. Similarly, PLC and computer software shall only be designed, written, and tested by qualified engineers or software professionals. The Consultant reserves the right to demand documented proof of staff competence in the event of there being concern about the quality of work.

1.3.10 Demonstration

All the equipment and systems offered shall be of a type or principle which the SEC can demonstrate in satisfactory use elsewhere or operating as a prototype installation. The SEC shall make all necessary arrangements so that the Consultant or their representatives may attend a working demonstration of specific items of equipment if so required. All demonstrations shall be of a similar installation or equipment to that specified herein which has been designed, manufactured, and installed by the SEC.

1.3.11 Performance

The SEC is solely responsible for the means and methods used for all design, manufacture, assembly, installation, and testing processes and is responsible for the safety of their employees and for coordinating their work with that of other trades on site to avoid conflicts of any sort.

1.3.12 Errors & Omissions

Any errors, omissions or ambiguities in the Specifications or Drawings are not to condition the scope, design, or implementation of the works, but shall be brought to the attention of the Consultant immediately for clarification of their possible effect on the intent of the documents.

1.4 Quality & Project Management

1.4.1 Quality of Product & Workmanship

An essential requirement for the equipment installation and all its ancillary items and accessories is that it shall be of first-rate quality throughout. In addition to operating fully and correctly in accordance with the specification, all systems, items of equipment, materials shall be brand new and workmanship shall be of the highest standard.

1.4.2 Quality Assurance

Demonstrate and operate an acceptable system of quality assurance for all work on this Contract and, if required to do so, submit regular reports, at time periods to be agreed, on the checks and inspections carried out throughout the Contract. Quality assurance shall cover, inter alia, detail design and shop drawings, purchasing, manufacture, factory tests, site installation, testing and commissioning processes.

1.4.3 Review Meetings

Prior to the award of a contract, the SEC shall attend meetings as required with the Consultants and others to examine in detail their design approach to each item of equipment, system and installation, the components to be used and to agree details of power supplies, structural provision and how each item is to be fitted into the building. Further meetings will be required after award of contract to resolve more detailed matters.

1.4.4 Compliance with Timescale

The provision of equipment which performs as specified and which is fabricated, delivered, installed, and tested according to the project timescale is of paramount importance. The SEC shall ensure that sufficient and suitable resources are used on the project so that quality is not compromised by the timescale. Penalties may be imposed if the design, submission, manufacturing, and installation processes are not diligently progressed through the project.

1.4.5 Project Supervisor

Appoint a full-time on-site Project Supervisor whose duty shall be to coordinate and manage this contract. The Project Supervisor shall have previous direct experience of managing contracts of similar size and type. The Project Supervisor shall attend all design review, progress, and site meetings. The Project Supervisor shall keep themselves aware on a day-to-day basis of all aspects of the Works, including progress being made towards completion. Grant the Project Supervisor full authority to make necessary decisions and to direct and control the work on the contract.

1.4.6 Site Supervisor

During the period when any installation work is being undertaken the SEC shall appoint a Site Supervisor or foreman who shall be responsible for progress, the quality of site work and ensuring the availability of all necessary parts and all necessary resources on site as required to maintain the installation, testing and commissioning programme. The Site Supervisor shall be available for liaison meetings as required by the Main Contractor.

1.4.7 Health & Safety

Comply with all Regulations and Ordinances relating to Health and Safety and note particularly all matters set out in the Contract Documents issued by the Main Contractor. Ascertain thoroughly any information required to ensure the safety of all persons involved in the works being carried out on site and during manufacture and implement all necessary safety measures.

1.5 Submittals & Reviews

1.5.1 With Tender

When tendering for the works, submit all information and items set out in the Appendix 1 - Employer's Requirements (Specific).

1.5.2 Works Programmes

Submit with tender a programme for design, manufacture and installation work which complies with the overall project programme. The submitted programme shall include realistic periods for submittal and review of drawings and other required information. Procurement and manufacture shall not commence until drawings are approved. If purchase or manufacture does precede approval, this shall be at the SEC's risk.

1.5.3 General Arrangement Drawings

Prepare and submit full general arrangement drawings of all pieces of mechanical equipment showing all moving parts, with all fittings mounted on them, and the resulting clearances in all operating positions, in addition to any drawings listed for individual items. In addition, the clearances of all runs of wire ropes, ropes, chains, hanging cables and similar and all other moving parts, whether or not these are being supplied by the SEC, shall be laid out in plan, section and elevation to establish the satisfactory working of the total intended installation.

1.5.4 Detail Drawings

Prepare and submit detailed shop and installation drawings and schedules for all disciplines (mechanical, electrical, control, rigging, carpentry, etc.) showing all information necessary to explain fully the design features, appearance, function, fabrication, installation, operation and use of system components. Drawings shall show the rating, size, reference, type number and manufacturer of all proprietary equipment and components or provide a clear, unambiguous reference to other submitted data.

1.5.5 Calculations

Prepare and submit full design calculations for all major structural elements, drive motor, gearbox and brake torque, transmission components and similar in addition to any specifically listed as required for particular items. Structural calculations shall include the maximum working stresses in the materials employed and the deflections. Calculations shall state the safety factors of all the essential structural and mechanical components selected for the installations. Copies of all normal design calculations and those relating to safety factors shall be submitted and copies included in the record information.

1.5.6 Physical Loads

Calculate and report the static and dynamic physical loads imposed on the building structure by each item of equipment. Where any physical loading appears to be in excess of the capacity of the structure or other equipment to which it is to be attached, this shall be brought to the attention of the Consultant immediately.

1.5.7 Data Sheets (Catalogue Cuts)

Submit catalogue cuts for all proprietary equipment except items that are specifically defined by model number in the Employer's Requirements. Catalogue cuts may also be submitted for certain standard equipment items in lieu of drawings. All catalogue cuts must contain full information on manufacturer, supplier, dimensions, construction, applications, and usage, such as to permit proper evaluation. In addition, each must be properly identified as to its intended use and any options or variations selected must be clearly identified. Incomplete information and poor faxed copies will be rejected.

1.5.8 Samples

If the Consultant requires to see samples of equipment for evaluation, particular materials, small specimens of work, the operation of particular features, components, their mountings, or paint finishes these shall be made available at no extra cost to the contract. Samples of all push buttons, indicators and other control panel components and all plugs, sockets, flexible cables, and connectors for use external to equipment shall be provided and must be approved before inclusion in the installation. Other items described as "approved" in the Technical or Equipment Specifications must be formally submitted for acceptance prior to inclusion in the project or delivery to site.

1.5.9 Structural Alterations

All holes in, and attachments or alterations to, the structure (whether concrete, brick, block, steel or whatever) shall be shown clearly on submitted drawings. Such drawings shall be approved by the Project Structural Engineer before the holes, attachments or alterations are made and such work shall then be undertaken subject to all the procedures stipulated in the approval.

1.5.10 Power & Wiring

Provide complete wiring schedules and electrical schematic drawings for each system or item of equipment. These shall give full details of cables types, sizes and routes. Confirm the electrical supplies necessary for the switchgear associated with the installation, including any ancillary circuits, and establish capacities of all the individual circuits required. Submit drawings of all cable tray routes and sizes.

1.5.11 Submission Quantities

Where hard copies of submissions are specified, the numbers of copies of drawings, cut sheets and schedules to be submitted shall be as set out in the Contract Documents. In the absence of any figure therein, four copies shall be submitted. Unless otherwise instructed all drawings and schedules shall be submitted in the first instance to the Main Contractor. Drawings shall be submitted in sets relating to items of equipment, complete systems, or specific areas of the installation. Mechanical and electrical drawings for equipment or systems shall be submitted together. Partial submissions may be rejected.

1.5.12 Drawing Sheet Format

All drawings shall be on standard size sheets, preferably not larger than A1 size. Title blocks shall be located in the bottom right-hand corner of the drawing such that the title shall be fully displayed when the drawing is folded to A4 size for submittal. When a drawing is revised a note describing all significant parts of the revisions shall be added, the revision marked as a cloud and a revision letter added to the drawing number.

1.5.13 Drawing Review

Drawings and other submissions shall be reviewed before fabrication, installation or erection of the items covered by the drawings begins. Review is solely for determining conformance with the design concepts and with the instructions and information given in the Employer's Requirements, drawings and other documentation. Any non-conformance or errors detected during the review will be noted and brought to the attention of the SEC for correction.

1.5.14 Design Responsibility

Review and comment on the drawings does not relieve the SEC of the responsibility for the design or of providing equipment fully in accordance with the Employer's Requirements, Performance Specification and Drawings. The SEC remains responsible for the completeness and accuracy of their drawings and full compliance with the Employer's Requirements.

1.5.15 Drawing & Submission Status

Drawing reviews will follow the Employer's Drawing Review Standards. Each drawing will be marked and returned to the SEC with comments and one of the following codes:

- "A" - Approved - Document reviewed and approved for work / construction.
- "B" - Approved with Comments - Document has been reviewed and approved, work / construction should continue to avoid delays and in compliance with all annotations and as per contract specification. However, the document shall be resubmitted for final verification and approval.
- "C" - Revised and Resubmit - Document has been reviewed with comments and needs to be resubmitted for approval.
- "D" - Rejected - Not accepted, the document is inappropriate, the concept is completely flawed, or the proposed option is not required.
- "E" - Review not Required - Document does not require approval / only for Information.

The SEC shall not commence installation of the equipment until all changes advised or noted on the returned drawings have been made to the relevant master records and the drawings have been resubmitted.

In addition, drawings and documents may be returned directly to the SEC without any review status if they are not in compliance with the Employer's or Main Contractor's document control procedures.

1.5.16 Contract Issue

After review, the appropriate number of "A" status drawings shall be forwarded to the Main Contractor for general issue. The number of copies of each shop drawing to be issued shall be as stated in the Contract Documents. In the absence of this information, six copies shall be supplied.

1.5.17 Site Records

Maintain on site a set of up-to-date drawings of all items of equipment, clearly marked up with any additions, omissions or modifications made during installation. The marked-up copies shall be available for inspection by the Consultant at any reasonable time during the installation period. These records may be kept as computer files provided, they are backed-up and the printed copies are made available when required by the Consultant. These drawings shall form the basis of the as-built record drawings required to be submitted immediately following commissioning of the installations.

1.5.18 Site Changes

Do not make any alterations to details shown on "A" status drawings unless such are instructed and confirmed in writing by the Consultant.

1.6 Delivery & Installation

1.6.1 Packing & Handling

Ensure satisfactory packing and protection of all components and materials for the journey from factory to the site. Any items suffering damage, corrosion, or loss during transit due to unsatisfactory packing or bad handling are to be replaced without charge.

1.6.2 Protection on Site

The SEC shall take full responsibility for protection and security of all parts of the works and the installations until they are accepted and have been handed over. In the event that the SEC fails to protect their installations from damage, another contractor may be instructed to provide suitable protection and the cost of this charged to the SEC. Equipment damaged from any cause shall be replaced with new by the SEC at no extra to the contact price. The SEC shall also be solely responsible for storage and the security of their equipment, plant and tools on site.

1.6.3 Sequence of Installation

The sequence of work on site shall be established by thorough discussion with the Consultant. Storage and access to areas in which work has to be carried out shall be arranged in advance.

1.6.4 Installation Conditions

Electronic equipment and sensitive mechanical assemblies shall not be installed until the area where they are to be installed is clean, dry, dust tight and secure. Such equipment shall include:

- Winches and elevators, including guides.
- Pulleys.
- Lamel grids.
- Tracks including runners and trolleys.
- Electrical Cabinets and any control equipment.

The SEC is solely responsible for any damage and all remedial costs should they prematurely install their equipment before suitable site conditions are in place.

1.6.5 Rubbish

Regularly clear all residual rubbish from work areas.

1.6.6 Employer / Employer's Representative Approval

Carry out the works to the satisfaction of the Employer / Employer's Representative (Consultant) who shall have the right at any time to reject any component, material or workmanship which is, in their opinion, defective, of less than first-class quality or not in compliance with the Employer's Requirements. The SEC shall, immediately they are so instructed, replace defective material or components, rectify poor workmanship, or modify their designs so as to be satisfactory without charge.

1.7 Operations & Maintenance Manuals

1.7.1 Draft Manuals

One draft copy of detailed Operation and Maintenance Manuals shall be submitted for approval to the Consultant not later than 21 days prior to the Consultant's attendance on site to witness any testing. Failure to provide such manuals may delay testing and any consequent payment. The preparation of the Manuals and associated Record Drawings shall proceed in parallel with the installation of the equipment and shall be carried out by personnel experienced in documentation work.

1.7.2 Final Copies of Manuals

Submit Operational and Maintenance Manuals in high-quality lever arch files to provide facilities for updates and additional pages. Give full details for the operation, maintenance and repair of the equipment and shall include full schedules of parts and components, full circuit diagrams, wiring schedules and the record drawings. All items shall be consistently cross-referenced with a unique code number for clarity. The as-built record drawings shall be included in the final issue of the Manuals.

1.7.3 Final copies of BIM models

If required, provide clash free models in native format, or any other formats that may be required depending on the Employer's policies in the General Contract.

1.7.4 Electronic Records

Prepare, in addition to the Manuals, one or more CD-ROMs containing the text and drawings forming the Manuals. These shall allow quick access and searching to the content of the Manuals. Alternative electronic media such as USB-drives may be agreed with the Employer.

1.7.5 Content

The Manuals shall contain, inter alia and where relevant:

- an index of the record drawings
- general descriptions of the systems
- operating instructions
- operational procedures
- safety procedures
- contact details including email for all manufacturers and suppliers
- 24-hour emergency assistance telephone number
- replacement component catalogue numbers
- manufacturers literature
- schedule of equipment duty and performance

- a schedule of items requiring routine maintenance
- frequency and details of maintenance procedures
- other information required by other parts of the contract documentation
- general technical information

1.7.6 Record Drawings

The record drawings shall include, inter alia:

- system schematics
- cabinet layouts
- patch panel layouts
- jackfield layouts
- equipment layouts at not less than 1:50
- cable schedules
- wiring diagrams for all purpose made equipment
- schedules of components for all purpose made equipment
- block diagrams and logic diagrams

1.7.7 Operational Health & Safety

The operational section of the Manuals shall spell out very clearly the health and safety issues related to operation, maintenance and replacement of the equipment. Where necessary this section of the handbooks shall be prepared by a specialist with training and experience of health and safety matters. Particular attention shall be paid to the theatrical operational procedures and maintenance access aspects of the installations.

1.7.8 The Building Manual

Where requested, provide input into the Building Services section of the Building Manual, which is compiled by others. The SEC supplied material shall provide a comprehensive information source and guide for the Employer and end users regarding the safe and efficient operation and maintenance of the specialist theatrical installations.

1.7.9 Copies to be Supplied at Handover

On approval of the Manuals by the Consultant, the number of copies stated in the Contract Documents shall be supplied to the Main Contractor. In the absence of a quantity being given, forward two copies of the Manual, two sets of Record Drawings and four copies of the Electronic Records to the Main Contractor, plus one copy of the Electronic Records to the Consultant. Attention is drawn to the fact that the Works will not be accepted as complete and that payments may not be made until the completed Manual and Record Drawings are submitted and accepted as satisfactory.

1.7.10 Test Certificates

Provide test certificates for all items listed. Test certificates shall be submitted within protective punched A4 sleeves and handed over in complete batches for each item or part of the installation against an advice note. Electronic test certificates may be provided by agreement with the Consultant. If local by-laws require other tests and, consequently, other certificates, these shall also be supplied without additional cost when requested by the Main Contractor. Manufacturer's test certificates are required for the following, inter alia:

- Electric motors
- Wire ropes, chains, shackles, and all similar suspension components
- Proprietary hoisting equipment
- Safety components
- Hydraulic components
- Pressure vessels
- Fabric manufacturers certificates stating that fabrics have been treated with a durable flame retardant or are made of inherently flame-resistant fibres as specified

Unless other Regulations apply, certificates required under EN 17206 (or equivalent) shall be submitted for all suspension items and equipment. All small loose items shall be individually proof tested and marked with an identifying number. A certificate of test covering and identifying a number of individual similar items shall be supplied.

1.7.11 Certification

The whole of the electrical installation shall be certified to the relevant National Standards.

1.7.12 Declarations of Conformity

Where equipment is offered in conformity with the European Machinery Directive, the test certificates shall include EC Declarations of Conformity in respect of the European Low Voltage Directive and European Electromagnetic Compatibility (EMC) Directive.

1.8 Inspections & Tests

1.8.1 Manufacturing Inspections

All parts and components for the installation shall undergo proper inspections and quality checks at appropriate times during manufacture and finishing. Full records shall be kept, and these records shall be available for inspection by the Consultants on request. Any parts or components which do not comply with industry standards, good workmanship, good engineering quality or good practice shall be corrected or replaced by the SEC immediately without charge.

1.8.2 Factory Tests

To control costs and minimise delays on site, so far as possible fully test all systems in the factory prior to delivery to site. All powered equipment and mechanical assemblies shall be tested in the factory in agreed procedures appropriate to their place in the final installation. The operation of all control panels and switching facilities shall be checked. Other items listed in the Appendix 1 - Employer's Requirements (Specific) shall be inspected in their place of manufacture and their basic function demonstrated. Offer the Consultant the opportunity to witness all such tests. All such tests and demonstrations shall take place at least seven days before the equipment is packed for shipment to site. Such tests shall be thorough and the results of the performance of the equipment recorded and copies submitted to the Consultant upon request.

1.8.3 Tests on Site

Carry out the tests listed in the Appendix 1 - Employer's Requirements (Specific) in the presence of a representative of the Consultant and any additional tests necessary, in the sole opinion of the Consultant, to prove that the equipment is operating fully and reliably and achieving an appropriate level of performance. Include full tests on software programmes, all safety features and similar, in addition to load and motion tests.

1.8.4 Employer / Employer's Representative Attendance

Give the Employer / Employer's Representative (Consultant) sufficient advance notice of all tests both in the factory and on site so that they, or their representatives, may be present if appropriate. The Employer / Employer's

Representative (Consultant) must be given at least fourteen days' notice of formal testing on site that they are required to witness.

1.8.5 Test Facilities

Provide suitable facilities, labour and apparatus (including mechanical and electrical loads, signal sources, metering and measuring devices) for all necessary tests whether in a factory, in an independent testing house, or on site. As a minimum, provide the test equipment described in the Employer's Requirements. Where necessary, provide safe and easy access equipment for inspection of inaccessible items. The personnel running the tests must be suitably qualified to perform this work and to carry out such adjustments as may be required. The Project Supervisor and Site Supervisor shall attend during site tests.

1.8.6 Attendance by Other Parties

Where local by-laws, any public authority, the Employer or the Insurers of the Project or any other authorised body require any work, equipment or parts of the installation to be tested, inspected or approved over and above the tests to be witnessed by the Consultant, such inspections and tests shall be arranged by the SEC. Only in exceptional circumstances as determined by the Consultant shall additional payments be made for such tests.

1.8.7 Test Schedule

Arrange a programme of inspection, testing and commissioning to be agreed with the Consultant. The Consultant will witness the tests carried out by the Contractor. Carry out any further tests which may be considered necessary by the Consultant at no extra cost to the Employer.

1.8.8 Test Conditions

At the time of certain inspections or tests on site of audio, video or other particularly sensitive equipment, no other work shall be performed in the same or immediately adjoining areas of the auditorium or stage. This shall particularly apply to tests by others on the installed loudspeaker systems, systems for the hearing disabled, paging, show relay systems and the like.

1.8.9 Equipment Failure

Any equipment which fails to meet the Employer's Requirements or reasonable professional expectations where not set down explicitly shall be modified or replaced with suitable equipment within 14 days and the inspection shall be rescheduled under the same conditions as previously applied. The method of modification, repair or alteration shall be agreed between the Consultant and the SEC but the SEC shall remain responsible for carrying out the work and the costs thereof in order to ensure the equipment functions correctly.

1.8.10 Witnessing

Unless otherwise agreed, testing that is carried out without being witnessed by the Consultant or their representative will not be accepted as evidence of completed work. Final approval and payments will be withheld until all systems have been thoroughly tested and found to be in full compliance with the Employer's Requirements.

1.8.11 Consumables

Replace items with limited life and consumables used during installation or testing immediately following final testing without charge to the Employer.

1.8.12 Additional Attendance Costs

Should any item of equipment or part of an installation fail to operate fully, such that testing cannot be completed, at a time when the Consultant has been scheduled, or requested, to attend on site or in the factory to witness tests or demonstrations, the SEC shall be responsible for all costs for such abortive attendances, including additional travel, accommodation and subsistence costs incurred by the Consultant or their representatives and any additional fee or time work charges.

1.8.13 Partial Completion

If, by reason of default by the SEC, the installations are not complete, tested and satisfactory by the required Completion Date for the Works Package (this not necessarily being the Completion Date of the Contract), any part of the installation which is workable and able to be operated safely by trained personnel may be taken over and used by the Employer as necessary, subject to the SEC being given reasonable opportunity to complete the work. Maintain labour on site to work at times around the Employer's schedule and correct or complete the work in the shortest possible time. The necessity for such action shall be at the sole discretion of the Consultant. Such partial use shall not imply that the equipment is complete or satisfactory and any risks shall remain with the SEC until the items are fully handed over. Completion work may have to be undertaken at night.

1.8.14 Incomplete Equipment

Where equipment which is essential to the Employer is not installed and operable by Completion Date, provide suitable alternative equipment until the contract equipment is accepted as complete and satisfactory, so that the building can be used and the Employer does not suffer loss or expense. Provision of such equipment shall be at no cost to the Employer. The Main Contractor shall determine the necessary equipment in collaboration with the Consultant.

1.8.15 Loose Equipment

Supply all loose, non-installed equipment suitably packed and labelled. Deliver such equipment to an authorised representative of the Employer and obtain an authorised signature on a detailed list of all items.

1.9 Spare Parts

1.9.1 List of Spare Parts

Propose a short list of necessary first-line maintenance spares appropriate to the equipment. The cost of these spares shall be included within the Pricing Schedule and shall form part of the Tender Price Submission. The Employer in conjunction with the Consultant will decide whether or not these spares will form part of the Contract. In the event that they are not purchased, they may be deducted from the total and the remaining figure becomes the Contract Price.

1.9.2 Supply of Spares

Supply all agreed spares supplied suitably packaged and labelled and place these where agreed with the Consultant who will consult the User on this matter. Obtain an authorised signature on a detailed delivery list for all loose spare items so supplied. Copies of the signed delivery note detailing the spares supplied to be passed to the Consultant. Spares used during the acceptance tests or during the period of guarantee shall be replaced by the SEC without charge.

1.10 Training of User's Staff

1.10.1 Requirement

Make a detailed proposal for a period of both operational and technical training on all aspects of the installations. This shall cover working methods, safety and first line maintenance necessary to allow operations to continue in the event of operator errors, equipment malfunctions and minor faults. The training must ensure that a full understanding of the various systems forming part of the installations is imparted and that proper methods of overcoming difficulties are explained.

1.10.2 Staff Involved

Assume that both operators and maintenance staff are to be trained and provide both combined and separate sessions. There is no requirement to train staff in basic theatrical operations or engineering disciplines, but to teach the way this equipment installation is intended to be used and maintained. Arrange timing, periods and numbers of staff with the User through the Main Contractor or as otherwise instructed.

1.10.3 Details

The training shall be both practical and theoretical and shall include clear written instructions on both operations and maintenance matters taken from the Manuals. The training course shall include an introduction to the full Manuals and identification on site of all equipment. Identify and explain all relevant power isolators, circuit breakers and other items that may affect the basic working of the installations.

1.11 Guarantees & Servicing

1.11.1 Guarantees

The SEC shall provide a written guarantee warranting against defects in design, materials or labour from the time of acceptance and takeover for the Defects Notification Period set out in the Particular Conditions of the Employer's General Contract.

Items accepted later shall have their guarantees run from the date of acceptance of each major item. The guarantee shall cover the repair of all defects in design, workmanship, or materials. During the guarantee period the User's staff will be responsible for straightforward trouble-shooting and minor emergency repairs, and for any routine maintenance as specified in the Manuals. In the event of difficulties or problems, the User's staff will contact the specialist contractor directly by phone or email and later advise the SEC in writing.

1.11.2 Exclusions

The guarantee shall exclude failure due to damage caused by neglect or improper use UNLESS the Operation and Maintenance Manuals have NOT been made available by the time when the Employer needs to use the equipment. The guarantee shall exclude failure due to normal wear and tear.

1.11.3 Response Required

During the warranty/guarantee period the SEC shall provide 24/7 telephone support with a 30 minute response time and any essential repair or replacement shall be carried out or provided by the SEC within 24 hours of the SEC being notified. Where the equipment cannot be repaired or replaced permanently in this time, alternative arrangements to allow performances to continue shall be made, or equal or better equipment shall be provided free, on loan, until such time as the repair can be completed.

Any necessary software upgrades or bug fixes shall be implemented in a timely manner free of charge at a time agreeable to the Users.

1.11.4 Service Contract

The SEC shall make arrangements for the prompt repair of normal equipment failures or faults and the regular servicing of all equipment forming part of the Contract. This shall be on the basis of a service contract to be entered into with the User.

Unless requested at the time of tender, within one month of handover the SEC shall quote for the provision of a full repair and service contract for the User's consideration.

Such a contract shall include repair or replacement of equipment affecting operational or safety matters within 24 hours of request, other matters within seven days, and all necessary regular servicing.

1.11.5 Technical Support Staff

Staff who were involved in the installation, setting-to-work and testing of the equipment and systems shall be available to advise and assist with any technical problems which arise with the equipment.

END OF UPGRADE OF PODIUMS & BACK DROP ELEVATOR TO ELECTRICAL DRIVES APPENDIX 2 - EMPLOYER'S REQUIREMENTS (GENERAL)
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ROYAL PLAYHOUSE THEATRE, COPENHAGEN

UPGRADE OF PODIUMS & BACK DROP ELEVATOR TO ELECTRICAL DRIVES

ER (T) APPENDIX 3 - EMPLOYER'S REQUIREMENTS (TECHNICAL)

DCPT738-THP-ZZ-ZZ-SP-OT-005013 Rev: 1.2

THEATRE PLANT

Document History

Revision	Issued by	Date	Comments
1.0	Dave Ludlam	03 Dec 2021	For Internal Review
1.1	Dave Ludlam	06 Jan 2022	For Tender
1.2	Dave Ludlam	12 Jan 2022	For Tender (key dates revised)
Notes:			

Contents

1 General

1.1 Application

This Technical Specification is intended to establish the general type and quality of workmanship, materials and components used on the stage engineering, machinery, rigging and associated installations. This specification is not intended to exclude standard products which can be shown to be of the required quality, that perform as specified and can be shown to have suitable longevity. Such standard products may be proposed for inclusion in the work.

1.2 Definitions

(a) Contract

Within this document this term refers to the works which are the subject of the order or contract to which these documents refer.

(b) Stage Engineering Contractor (SEC)

This term refers to the firm or organisation employed or contracted to carry out Contract.

(c) Provide

Unless stated otherwise, this term shall mean the design, manufacture, supply, installation, commissioning, and testing of the equipment described.

(d) Axis

The term refers to single-driven motion of a piece of equipment, such as a single hoist or Elevator.

(e) Agreed

The term shall apply to items which are acceptable to both Contractors where the contract is split.

(f) Approved

The term shall apply to items which have been specifically submitted in the form of cut sheets or samples, or as otherwise requested, to the Consultant and are passed as acceptable for use on this Contract. Any such approval shall not affect the responsibility of the SEC for full compliance with, and satisfactory operation of every aspect of any contract arising from, these Employer's Requirements.

1.3 Contractor's Duties

1.3.1 Scope

Provide the equipment described or implied herein and in all the relevant associated drawings and Pricing Schedule. Additionally, prepare full and comprehensive operating and maintenance manuals, provide record drawings of the completed installations and train staff in the operation and maintenance of these installations.

1.3.2 Design

Full structural, mechanical, acoustic, electrical, wiring, motor drive and control system design, including submitting all necessary drawings, calculations, data sheets and samples for review.

1.3.3 Manufacture

Procure, fabricate and assemble the equipment and materials for all the specified systems, including the power distribution switchgear and all electrical power and control wiring.

1.3.4 Installation

Deliver to site and install all the specified systems including the on site electrical wiring from a single heavy current supply provided by others and any acoustic and noise control measures incorporated in the design or found to be required.

1.3.5 Work Sequence

Comply with the sequence of work on site established with Employer, Project Manager, Main Contractor or Management Contractor as appropriate. Minimise double handling and allow reasonable time for following trades to complete their work.

1.3.6 Site Facilities

Establish extent of available storage, scaffolding and similar site facilities prior to tendering and make full provision for costs in this connection within tender price. Arrange access to areas in which work has to be carried out with site managers in advance.

1.3.7 Testing

Full pre-testing and commissioning of all the physical and software parts of the installation followed by load and functional testing witnessed by the Consultant and Employer's representatives.

1.3.8 Responsibility for Dimensions

The SEC shall take their own dimensions on site for all fabrications. equipment, cabling, and materials and shall be entirely responsible for their accuracy. They shall not commence manufacture of any item of equipment until they have satisfied themselves that the equipment as designed will fit into, can work satisfactorily in, and can be maintained in the space available. All critical dimensions, particularly those associated with operations and clearances, shall be shown on working drawings.

1.3.9 Drawings

Examine the relevant drawings as listed in the Appendix 1 - Employer's Requirements (Specific), which show the principles of the design envisaged. These drawings should not inhibit further thought or the development of other approaches provided they offer all the required functions and can be fitted into the spaces shown. The SEC is responsible for reviewing and taking into account information on **all other drawings** relating to the building, its structure and services and this installation.

1.3.10 Additional Work Drawings

Prepare drawings of ALL associated work to be undertaken by other trades to ensure this is carried out satisfactorily. This shall include showing and making allowance for all items supplied and fitted by others, for example: flooring, floor traps, seat mountings, air grilles and Work Light fittings. Prepare Builders' Work Drawings for the whole installations as appropriate.

1.3.11 Guarantee of Component Supply

The SEC shall undertake to supply components which are necessary for normal operational replacement for a period of at least ten years after handover. After this period full manufacturing drawings of necessary replacement components shall be made available to the Employer at cost if so requested.

1.3.12 Additional Structure

Provide any additional fixings or fixed or moving steelwork necessary over that indicated on the Engineer's drawings.

1.3.13 Finishes

Undertake full preparation, apply protective coatings and finish painting of all the structural elements of the installation. Identify fixed and moving parts by agreed colours. Provide high-quality finishes on all other items and components.

1.3.14 Electrical Works

Carry out complete electrical design from the point of supply, define distribution requirements and establish circuit capacities, selection and specification of cable types (including any flexible and hanging cables), route specification, location of physical termination points and preparation of drawings of cubicles and panels.

Provide, as specified, power switchgear, all cable tray, bus-bar, power and control wiring, variable speed electrical drives, electrical distribution and similar equipment and items necessary for the full operations of all the equipment forming the contract.

All wiring to equipment or to items identified on the drawings shall also be supplied and connected by the SEC. The SEC shall include for this electrical work in the tender price and shall carry this out in accordance with the overall project programme.

Carry out testing, core identification and sorting and installing cables tidily into cubicles and termination points. Check and correct any faults or incorrect cables or routes. Make all power and control circuit connections. Prepare for power-up and checking of voltage and phase sequence. Undertake full testing and commissioning.

1.3.15 Electrical Supplies

The SEC shall confirm the supply voltage and frequency of the building electrical supplies and design the equipment in accordance with written information obtained from the electrical consultant or Supply Company. The location and anticipated rating of distribution boards for the equipment installations are shown on the project drawings or in the individual specifications. Equipment shall be protected from unexpected mains failure and mains-borne interference.

1.3.16 Sound Reducing Works

Where specified, provide suitable approved sound-reducing slot materials for sealing of penetrations in walls and floors of machine rooms.

1.3.17 Delivery & Handling

The SEC shall be responsible for the satisfactory packing and protection of all mechanical, electrical, electronic, motor drive, computer and similar components of their system for delivery to, movement around and storage on the site. Full allowance shall be made for the anticipated condition of the building site and for the work of other trades in the area. No item shall be unpacked until conditions are such that no damage will occur to the equipment. Covers or temporary enclosures shall be provided while the equipment is not actually being worked on. Any items suffering damage during transit or on site due to unsatisfactory packing or protection shall be replaced by the SEC without charge.

1.3.18 Protection During Installation

The SEC is responsible for protecting all mechanical, electrical and other equipment forming part of this contract from environmental and physical damage at all times during installation and commissioning. This includes exposure to adverse weather while hoist, control and drive equipment is being craned onto site when parts of the building will be open to the external environment. The SEC shall make himself aware of all such risks and take all precautions to ensure no equipment is damaged and, in such an event, shall repair any such damage at no extra cost.

1.3.19 Maintenance Equipment

Where non-standard test equipment, accessories, connectors, fittings or tools are necessary for the adjustment, operation or maintenance of the installation, two sets of such items shall be supplied as part of the contract, unless another number of items is specified. Complement shall include extender cards, test leads, alignment equipment, adjustment tools etc., and is especially applicable where long-reach tools and similar mechanical non-standard devices are required.

1.4 Interfaces with Other Trades

1.4.1 Electrical Power

Design the electrical switchgear to accept a single large-current power supply cable, cables or bus-bar supply as agreed with the Engineers. Procure and install suitable switchgear and isolator / distribution. Take responsibility for the sub-circuits and all equipment supplied from this distribution switchgear, including the supplies for sub-circuits and equipment being installed by others. Confirm that the construction, details, functioning and fault levels of this equipment are as required for such equipment on this project and in compliance with the Project Electrical Specification. Assistance may be sought from the Engineers.

1.4.2 Switchgear Supplier

Liaise with the Project Engineers and Electrical Contractor to ensure switchgear from a common manufacturer is employed throughout the Project. If the Project has not standardised on a particular switchgear supplier, procure main switchgear from Schneider Electric (www.se.com). Control cabinets and purpose-made equipment may be offered from other sources.

1.4.3 Structural

Obtain formal written approval from the Project Engineers (Structural) for all loads passed to the structure and for the way in which all attachments (whether load bearing or not) are made to the structure.

1.4.4 Service Routes

Plan routes for the power and control wiring within the fly tower and around the stage and auditorium. Submit drawings of these to the Consultants for coordination with other services. The use of trays provided for any other systems (lighting, sound, communications, etc.) is strictly forbidden.

1.4.5 Environmental

Provide information regarding the long-term quiescent heat dissipation from machinery and control system equipment to the Engineers on request. Such information to include dissipation from the equipment when operating at maximum duty cycle and the maximum ambient temperature in which any part of the equipment installation may operate.

1.4.6 Grid Decking

The Grid decking is to be in place and boarded over before installation of the diverter pulleys, rolling beams and wire rope drops and any other overhead equipment shall commence. Unless otherwise stated the Grid support, Grid decking panels and pulley mounting steelwork will be fabricated and installed by others.

1.4.7 Flooring (Dividing Doors)

Establish with the Superintending Officer and the Acoustician the floor finish and sub-floor to be used beneath the various types of Dividing Doors and ensure its suitability for fire and or acoustic seals as appropriate.

1.4.8 Other Contractors

Unless specifically stated or agreed in writing, all work in connection with the Contract is to be carried out either directly by the SEC or by one or more approved sub-contractors for whom, and for whose work, the SEC remains entirely responsible.

1.5 Design Principles

1.5.1 Usage

The equipment forming part of the Contract shall be in use every day and shall be powered up continuously except during infrequent maintenance periods. Generally, planned maintenance shall be able to be carried out in less than two hours. Most maintenance work shall be able to be carried out by replacement of cards, units or modules.

During maintenance or repair it is important that only parts of the installation are out of service at a time and that the remainder can provide movement of operational axes to pre-recorded and new positions as appropriate. The SEC shall propose the levels of isolation for maintenance which are practical with their system.

1.5.2 Standardisation

On all equipment forming part of a given system or installation, all like components shall be mechanically and electrically interchangeable. Standardised components of minimum variety shall be used in the equipment design. All control panels and handheld controllers must use the same ranges of components and be consistent in design and operation.

1.5.3 Design Life Span

Design the mechanical equipment for a life in service of twenty-five years without major mechanical overhaul, based on the specified duty cycle being executed twice every 24 hours on average. Electrical drive and basic control systems shall achieve a reliable operational life of at least twenty years and related computer systems shall achieve a reliable operational life of at least fifteen years.

Other electrical systems shall achieve a reliable operational life of at least fifteen years. Electronic and computer systems not used for stage engineering shall achieve a reliable operational life of at least ten years.

Whilst much of the electrical and computer equipment may be obsolete at the end of these periods, the complete control system, both hardware and software, shall consist of components which are fully supported in terms of repairs or replacements by the manufacturers for a period of at least ten years from the Completion Date of the project. Make available to the Employer copies of the record drawings of any purpose-made items on completion of testing and commissioning of the installation.

1.5.4 Design for Maintenance

All equipment shall be designed to require minimum routine maintenance, which shall be able to be carried out in an easy and straightforward manner by the User's staff. Electronic, computer and other control systems shall include hardware test and self-diagnostic systems so as to simplify fault-finding and maintenance. Any component shall be replaceable without the removal of other functioning components unless these are mounted on or carrying the faulty part. All parts shall be replaceable without strain or damage to other parts.

1.5.5 Mechanical Maintenance

Maintenance shall, as far as possible, be designed to be carried out rapidly and without disruption to rehearsals or performances. This shall require simple access without steps, ladders or other equipment. All necessary electrical and mechanical parts shall be readily accessible for inspection, servicing and maintenance with minimum dismantling of the equipment. Components such as gearbox filling and draining plugs shall be easily accessible so that oil inspection, replacement and topping up can be done without dismantling any parts of the installation. All wire ropes and chains shall be able to be inspected over their full length. Limit boxes and other electrical equipment shall be positioned so that it can be inspected, maintained and reset easily and safely.

1.5.6 Electronic Maintenance

Maintenance and repair of the equipment shall not require non-standard tools, test cards and the like, but shall be readily carried out using generally available tools and test equipment. As far as possible such work shall not require the use of stepladders or other access equipment and shall be possible with minimal dismantling of cabinets or racks. All parts requiring adjustment shall be readily accessible.

1.5.7 Environmental Conditions

All equipment shall operate satisfactorily in an ambient temperature of between 10-35°C (50-95°F). The equipment shall withstand a wider temperature cycle of 0-40°C (32-104°F) when not in operation. The equipment shall operate satisfactorily in a relative humidity of between 1% and 90%. When not in operation the equipment shall withstand a relative humidity of 5% to 100% without damage.

1.5.8 Derating

The design of mechanical and electrical systems shall be such that all the components and assemblies employed within them work at less than their maximum ratings. The SEC shall identify any electrical or electronic components that are required to perform above 70% of their nominal rating. Special provision shall be made to accommodate the powering up of electronic equipment which has a high in-rush current. All equipment and components shall be selected for long operating life and reliability.

1.5.9 Timber Specification

All timber, plywood, laminated board and similar materials used in the specified equipment shall be flameproofed by an impregnation process or by other treatment approved by all relevant authorities. Hardwood shall only be employed where specified. All timber shall be first grade and free from splits, rot or damage of any kind, and shall be without an excessive number of knots. All plywood shall be manufactured from softwood unless otherwise specified. All timber to be from renewable resources and able to be so certified.

1.5.10 Captive Parts

Any part, fitting, column, leg, cover, shroud or fixing which has to be taken off and replaced frequently in the course of erecting, dismantling, moving or operating the equipment or any part thereof shall be made captive to the appropriate part of the installation in some approved way. Such parts shall be minimised and alternative arrangements using hinged or captive parts used wherever possible. Fixing down or clamping bolts and all similar shall be captive. A method of restraint for loose parts shall be an appropriate diameter of flexible wire rope properly made off to both parts. Where parts have to rotate or be withdrawn to be removed or fitted, the restraint and its fixings shall be suitable.

1.6 Proscribed Materials

The following, and any other substances or materials not in accordance with applicable and current Standards or Codes of Practice of the British Standards Institution or which are generally considered within the construction industry to be deleterious, shall not be used in the design or implementation of the works. If in doubt, check against list of proscribed materials available from the Architect.

- High Alumina Cement or Concrete
- Woodwool Slabs in permanent formwork or in structural elements
- Concrete or mortar additives containing calcium chloride
- Aggregates for use in reinforced concrete which do not comply with British Standard Specification 882:1992 and aggregates for use in concrete which do not comply with the provisions of British Standard 8110:1985
- Calcium silicate bricks or tiles
- Concrete that may be susceptible to alkali/silica reaction
- Any product or materials containing urea formaldehyde foam or materials which may release formaldehyde in quantities which may be hazardous with reference to the limits set from time to time by the Health and Safety Executive Guidance Notes EH40 / 91 "Formaldehyde Occupational Exposure Limits" or any other limits or criteria set from time to time by the Health and Safety Executive
- Asbestos or asbestos containing products of whatever nature
- Lead or any materials containing lead which may be ingested, inhaled or absorbed except where copper alloy fittings containing lead are specifically required in drinking water pipework by any relevant statutory requirements
- Polyurethane foam
- Materials which are generally composed of mineral fibres, either man-made or naturally occurring, which have a diameter of 3 microns or less and a length of 200 microns or less or which contain any fibres not sealed or otherwise stabilised to ensure that fibre migration is prevented
- Bitumen coated polythene save where the use of bitumen coated polythene is specifically permitted for tanking and damp-proof membranes
- PTFE fabrics, except where the PTFE is used as a jointing tape in plumbing applications and on specialist applications such as valve seats, bearing material or sealing rings in pre-manufactured items of plant and equipment
- Galvanised wall ties

1.6.1 Rigging Spanner

In order to limit the types of tools necessary for normal rigging and fitting up tasks, the standard size of bolted fitting shall be either M10 or M12. These shall be the bolt sizes to be used wherever the Project Rigging Spanner is referred to.

1.7 Design & Selection Criteria

1.7.1 Quality of Materials & Workmanship

All materials used in the fabrication and installation of the equipment shall be new. The whole of the materials and workmanship shall be of first grade quality. In no case will materials of lesser design or workmanship than those specified be acceptable. All fabrication, machining, welding, assembly, joinery, wiring, programming, testing, textile making and other work shall be undertaken only by fully trained and experienced tradesmen or professionals.

1.7.2 Component Reliability

The selection of any components for the mechanics, electronics, computing elements and all other elements of the installation shall take account of the long-term reliability and longevity of each item.

If required, provide a detailed failure risk analysis identifying all critical components and their mean time between failures (MTBF) and mean time to repair (MTTR).

This shall cover all components, including those that are likely to be powered and dissipating 24 hours a day, such as power supply units, video displays and cooling fans. All items that are essential to the operation of the system shall have an MTBF of at least five years and an MTTR of **fifteen minutes**, based on a spare being available in the theatre.

1.7.3 Reference Types

Where a Reference Type or Reference Manufacturer is specified, this shall define the type and quality of equipment and installation required. Such a reference shall not exclude the submission, for specific reasons, of equal and approved equipment which will perform as specified, but the Reference Type or Reference Manufacturer may still be used by the Consultant as the standard for the evaluation of the quality of the installation.

1.7.4 Demonstration Systems

Any demonstration systems shall be running in a theatre or similar venue with a full production model of the proposed control system. Multi-axis systems shall consist of a fully operational set-up of at least thirty axes. The satisfactory control of axes and similar operational control functions to those described shall be able to be demonstrated by any tenderer immediately upon submitting a bid for the works.

1.7.5 Quality of Operation

All moving equipment, unless specifically excluded, shall operate with any load between maximum and minimum and at any speed within its specified range, smoothly and without jerks, inconsistencies, excessive noise or overruns. The quality of design and selection of equipment and materials shall be of the highest standard and equipment which does not perform fully for any reason will incur penalties under the contract.

1.7.6 Minimum Site Time

Equipment shall be designed for easy prefabrication and speedy and effective site assembly and installation. All motorised, electrical and control equipment shall be pre-tested in the factory before delivery to site. Where practicable, control and other connections shall be by

locking or latching plug and socket. Every reasonable step shall be taken to minimise site installation, testing and commissioning time.

1.8 Standards

1.8.1 General

All equipment and components forming part of the installation shall comply with EN 17206 (or equivalent) where applicable and all relevant National and European Standards, Codes of Practice and other Regulations (herein referred to as Standards) except where a Standard is designated as not applying to stage engineering, theatre machinery or rigging installations. All equipment shall comply with currently accepted International Standards.

Where such Standards are in conflict with this Technical Specification or the Individual Specifications, the matter in conflict shall be raised by the SEC for clarification. Where any doubt exists as to the application of a Standard to a particular item or part of the installation, the matter shall be raised for clarification.

List the references and names of all the main Standards to which the equipment in this contract will be designed, constructed and installed with the return of any tender submission.

1.8.2 EC Machinery Directive

All machinery shall comply with the European Machinery Directive (2006/42/EC). If necessary, seek the necessary specialist advice to ensure compliance. Include copies of CE Certificates of Incorporation for all safety-related and other significant components in the Operations & Maintenance Manuals. Submit a list of the components requiring CE Certificates of Incorporation to the Consultant for review.

1.8.3 CE Marked Components

Irrespective of whether the installation is to be CE certified under the European Machinery Directive (98/37/EC), all new components used in the contract shall be CE marked. Copies of CE Certificates of Incorporation shall be provided for all safety-related components and a selection of other key components to be agreed.

1.8.4 Electrical Standards

Unless otherwise advised, all electrical equipment, components and wiring shall comply with the relevant National and European Standards. The electrical wiring and installation shall comply with the relevant Danish or European Standards.

Design and implement all parts of the electrical installation in compliance with EN 60204-1 (or equivalent) and EN 60364 (or equivalent). Take account of any relevant Local and National Regulations and work in accordance with the Project Electrical Specification, prepared by the Engineers.

1.8.5 Approved Electrical Contractor

All electrical work shall be undertaken and certified by an individual or company approved by the Danish Safety Technology Authority (or equivalent). Details to be agreed with the Consultant.

1.8.6 Electromagnetic Compatibility

Ensure that the installation is compliant with the Electromagnetic Compatibility (EMC) Regulations (89/336/EEC or later issues). The cost of any EMC testing and any remedial work that may be required shall be at no extra cost to the contract.

1.8.7 Health & Safety

Comply with the requirements of the relevant Health & Safety Authorities. Assistance can be provided with such contacts if needed.

1.8.8 Building Regulations

Comply with all applicable Building Codes and Regulations.

1.8.9 O&M Manuals

Unless otherwise directed, prepare all technical manuals in accordance with EN 21600 (or equivalent) and operating instructions in accordance with EN 20607 (or equivalent).

1.9 Labels, Signs & Notices

1.9.1 General

Equipment forming part of the installation shall be marked indelibly with tidy, permanent, adequately sized labels giving essential information, basic operating instructions and sufficient information to permit correlation with manuals, drawings and spares lists. All labels containing text information rather than just reference codes shall be in the local language and, where specified, also in English.

1.9.2 Equipment Labelling

All equipment enclosures shall be clearly labelled externally as to function. All controls and indicators shall be clearly labelled for ease of operation. The colours, size and typeface of all labels shall be selected to ensure high legibility in dim lighting.

1.9.3 Internal Labelling

All labelling of components within equipment cabinets and racks shall use proprietary systems suitable for permanent use. Temporary adhesive labels or marker pen identification will not be acceptable.

1.10 Interference

1.10.1 Suppression

All electrical and radio frequency interference from any equipment forming part of the specified installations shall be suppressed to an acceptable level and in compliance with the Electromagnetic Compatibility Regulations (EN 61000 (or equivalent) and 89/336/EEC) and other relevant Standards. Equipment shall be designed in accordance with current National and European Standards.

1.10.2 Harmonics

Under no conditions shall the installed equipment cause harmonics in the electrical supply in excess of those acceptable to the electricity supply authority. If required by the Engineers or Consultant, provide all necessary data on harmonic currents and if necessary, install harmonic filters.

1.10.3 Specific Protection

Interference caused by switching, commutation, pulse generation or thyristor circuits which could affect the Sound, Video, Communication, radio or telephone systems or any other control equipment in or adjacent to the building shall be eliminated. The external electrical and magnetic fields of all equipment shall be kept to a minimum and shall be at a level that will not cause interaction with microphones, magnetic device replay heads, audio or radio-frequency loops, computers, VHF or UHF transceivers, radio microphones or any other apparatus likely to be used in the vicinity.

1.10.4 Equipment Protection

The installed equipment shall be designed so as to be immune from levels of electromagnetic radiation permitted under the specified Standards. All computer, control, audio, video and similar equipment shall be installed in screened enclosures and fitted with effective line conditioners and anti-surge protection on the incoming power lines.

1.10.5 Technical Earth

Where an isolated low-impedance technical earth is provided, this may be used for control equipment subject to other sensitive systems not being affected.

1.11 Personnel Safety

1.11.1 General

(a) Principle

All the equipment and installations shall conform to applicable safety code requirements and with theatre industry standards for operation and working practices. All systems, equipment arrangements and operating procedures shall be in accordance with local Health and Safety requirements and/or legislation and shall allow the users to set-up, use, operate, maintain and de-commission the equipment and installations in a safe working environment.

(b) Working Environment

Stage machinery will be used by trained personnel during fit-ups, technical and general rehearsals, and performances, to move loads around and above the stage where performers, technical personnel and others may be positioned or working. The safety of such personnel and others working in the theatre shall be ensured by the thorough and quality-assured design, engineering, installation and testing of the driven equipment and control system as determined and implemented by the SEC.

(c) Design for Safety

All installed equipment and systems shall be inherently safe. Design out any hazards that can be so eliminated; protect personnel from any remaining hazards to the extent that is practicable. Provide clear warning signs and alarms, ensure that only authorised and trained personnel are allowed to operate the equipment and operate strict exclusion regimes as part of the operational philosophy. All mechanical, electrical and control components and systems shall be designed or selected to be failsafe.

(d) Motion Warning

All transmission shafts shall be painted or marked in such a way that their presence is obvious and that their rotation is indicated by spiral stripes or similar.

(e) Cable Types

Wherever such cable or wiring is available, all external wiring (whether clipped direct, on tray or in containment) and internal wiring in cabinets and racks shall be of the LSF (low smoke and fume) type.

(f) Manual Effort

Design shall concentrate on ease of use, particularly in terms of access, operational facilities and the weights of items which have to be moved manually. Equipment that has to be moved frequently shall be of minimum weight and designed to minimise risk of injury. Handles for lifting, pushing and pulling shall be provided in accordance with the specified Standards. Procedures for setting up and repeating regular operations shall be as simple as possible. Actions and effort necessary to achieve regular repeating operations shall be minimised. This shall also apply to items of equipment which need to be removed for maintenance and inspection.

(g) Weight Marking

Items which have to be lifted and moved manually shall be marked with their weight in kilograms, the approximate centre of gravity and an indication of the number of persons who should carry out the lifting or moving process.

(h) Equipment Starting

No moving, rotating, elevating or reciprocating equipment shall be able to start moving under any circumstances without a positive intentional action by an operator. This shall apply to equipment in any state and following any sequence of events. All equipment shall be provided with a local isolator incorporating a method of locking in the OFF position. Such an isolator shall carry a label clearly identifying the equipment it controls.

(i) Remotely Controlled Equipment

All equipment which can be started from a remote position shall be clearly labelled to this effect and provided with a local isolator incorporating a method of locking in the OFF position.

1.11.2 Guarding

(a) Fixed Machinery Guarding

All parts which can be reached from normal or maintenance access positions and which rotate or move when the equipment is in motion shall be guarded to prevent danger to personnel. This shall include equipment in Elevator pits and all other areas where transmission equipment, rotating couplings, drive belts, screw-jack or equipment is installed. These items shall all be protected with robust sheet metal panels, small-opening wire-mesh grilles or similar guards that can be easily removed for inspection and maintenance. Fixed guards shall require the use of a tool to remove them and shall employ the minimum number of fixings.

(b) Access Doors & Guards

Doors or moveable guards that permit access to danger zones surrounding machinery (e.g.: doors to Elevator pits, cages around winches and, in some cases, access doors to grids) shall be electrically interlocked to prevent the motion of any machinery within the spaces they permit access to. If required, the access doors or guards shall be electrically locked while any related machinery is in motion to physically prevent entry to the danger zone.

The selection of interlock switches on doors or moveable guards and the design of the associated circuitry shall be the same as for safety devices (see ER (T) 6.6.10 Safety Devices).

(c) Other Guards

Counterweights on Safety Curtains, Dividing Doors and similar shall be guarded to at least 2.5m above the adjacent floor level. Manually operated counterweights shall be guarded to a similar height wherever accessible except at operational levels. All maintenance openings in walk- or access-ways shall be fitted with either removable panels which hinge to form guards or other methods of warning personnel of the temporary opening. Such hinged openings shall incorporate simple mechanical interlocks.

1.11.3 Safety Case

If required, develop a written safety case for the machinery and control systems. The safety case shall be a clear embodiment of the evidence and arguments used, so that

agreement can be reached by the SEC and others on the validity of the conclusions. It shall be a document prepared for a diverse readership and shall be suitable for review by well-informed generalists as well as by specialists. It must be suitable for submission to an independent authority for approval.

A robust safety case capable of withstanding thorough examination will require the application of basic safety principles such as simplicity, redundancy, segregation, diversity and failsafe design.

As well as addressing the obvious safety implications of mechanical equipment and control system reliability, the analysis shall also extend to cover:

- Justification for the choice of mechanical brakes for each class of machine and the selection of the gearbox and other components which form part of the safety braking and load-holding system
- The design features of the control system which maintain the safe operation or stopping of any moving item in the event of power failure or failure or malfunction of any component, wiring or communication system
- Management of the risks inherent in sharing loads between two or more machines, including operator and rigging design guidance on how this is to be achieved safely
- The role of the equipment operator in the "safety loop" including the key competencies required and how they may best be assessed

1.12 Safety Factor (FoS)

1.12.1 Definitions

(a) WLL Working Load Limit

The maximum load the device is designed to lift. This load measured under steady state (i.e.: static) conditions.

(b) MDSL Maximum Dynamic Service Load

The load the device will see when operating under "normal" conditions (static plus the acceleration / deceleration load).

(c) MC0 Maximum Class 0 Load

The likely (calculated or tested) load the device will see under worst-case emergency conditions (normally, fully-loaded at max lowering speed and a total power failure).

1.12.2 General Mechanical Components

All devices shall demonstrate adequate FoS in ALL the above load cases. These FoS numbers shall be proposed by SEC and agreed with the Employer on mutual consideration of the risk assessment but as a minimum shall be:

- WLL **4:1**
- MDSL **2:1**
- MC0 **1.5:1**

In all cases a risk assessment must consider the full load path – including where the brakes are in this load path (as this will affect the required FoS on gearbox). Materials should be assessed for fatigue and this factored into the agreed FoS.

OR

All mechanical components shall have a factor of safety of at least **SIX**. Factor of safety is defined as "ultimate stress of material used divided by maximum working stress". In establishing safety factors full account shall be taken of the dynamic performance of the equipment and of possible deceleration under power, in emergency situations and against stops or buffers.

1.12.3 Wire Ropes

Wire ropes used for hoisting or suspension shall have a guaranteed breaking strain of not less than **TEN** times the maximum operating tension. Maximum operating tension shall include the tension caused in the rope by the maximum Safe Working Load plus the inherent loads on the wire and an allowance for any increase in tension due to diverter pulleys in the system which might fail to rotate when the equipment is in operation.

Additionally, it must be demonstrated that if all the diverter sheaves in the rope path fail to turn, with the rope at max operating tension, a residual FoS of at least **FOUR** remains.

1.12.4 Winding Drums

The drum must be considered as part of the load path and comply with the WLL / MDSL / MC0 FoS requirements above.

OR

Winding drums shall have a factor of safety such that the ultimate stress of the material used is at least **TWELVE** times the maximum working stress in any part of the component.

1.12.5 Roller Chain

Suitably sized and rated roller chain may be used for power transmission and load suspension in appropriate applications. Where a chain drive is used for power transmission, it shall be silent roller chain and the safety factor used for selection of chain and sprockets shall be at least **TEN**. Where used for suspension the safety factor shall be at least **FIFTEEN**. A lower safety factor of **EIGHT** may be proposed in control situations such as low-torque servo- or limit-box drives.

Any roller chain used in a lifting device must be fitted with sensors to detect correct tension.

1.12.6 Proof Load Tests

(a) Test Loads

Static proof load shall be 125% of rated static load and dynamic proof load shall be 110% of rated dynamic load, except where specifically agreed otherwise.

(b) Test Weights

If not already provided by the Employer, provide sufficient wheeled weight trolleys so as to be able to load fully each suspension wire or Elevator platform. Ensure trolleys have a simple but secure method of attachment suitable for dynamic stop tests. The trolleys shall be able to accept additional weights so that proof load may be applied and so that full load may be imposed on one less than the number of suspensions as required. Unless stated otherwise, the test weights and trolleys remain the property of the SEC and shall be removed from the site on the satisfactory completion of all testing.

1.13 Proprietary Equipment

1.13.1 Standard Product

As much of the installations as possible shall consist of manufacturers' standard products. In cases where a standard product complying with the individual specifications is not available, the equipment shall preferably be a standard product with modifications made by the original manufacturer, or by the manufacturer's

recognised distributor, and guaranteed by the manufacturer or distributor.

1.13.2 Technical Support

Every standard product and modified product shall be backed by a local manufacturer or local recognised distributor who handles the particular product in the locality of the project and who undertakes to provide spares and service. Products manufactured by the SEC and not distributed or offered for general sale will not be accepted in cases where a generally distributed standard product or approved factory-modified product is available which complies with the specification.

1.13.3 Applications

As incorporated in the installation, each item of proprietary equipment shall be operated according to the manufacturer's recommendations and within the limits of the manufacturer's published specification.

1.14 Purpose-Made Equipment

1.14.1 General

Specific items of equipment may need to be purpose-made for the installation. All relevant design and manufacturing drawings, with full schedules and data sheets for all the significant components, shall be submitted to the Consultant for all equipment that is to be purpose-made.

1.14.2 Samples

Samples of all components intended for use in equipment which is purpose-made for the contract shall be submitted to the Consultant for approval.

1.14.3 Finishes

All purpose-made equipment shall be finished to a high standard. All finishes shall be stove-enamelled, unless agreed otherwise. Finishes on all panels and cabinet facias shall be non-reflective.

2 Electrical

2.1 Electrical Safety

2.1.1 Acceptable Voltages

No voltage in excess of PELV (see ER (T) 4.1.2 (c) PELV Circuits) shall be exposed to touch under normal maintenance conditions in any equipment. This shall include areas exposed by the withdrawal of modules or of any plug or connector, or without the removal of covers. All such covers shall be labelled with a warning and details of the voltages present.

2.1.2 Shrouding of Live Parts

All live parts above PELV (see ER (T) 4.1.2 (c) PELV Circuits), including terminals, shall remain completely shrouded by insulation or earthed metal when the main access panels are removed. The separate shrouds or covers shall require a tool to remove them to prevent inadvertent contact with live parts and shall be suitably labelled.

2.1.3 Mixed Voltages

Where enclosures or items of equipment containing predominantly control, computer, audio or similar low voltage signals also contain voltages in excess of 100V rms AC or 150V ripple-free DC, clear warning notices indicating the maximum voltage present shall be provided on all removable access panels. Similar warning notices shall be provided where voltages exceeding 250V are present in any enclosure or item of equipment and where such a voltage may not reasonably be expected to be present.

2.1.4 Dual Supplies

Where equipment has more than one source of electrical supply, the individual supplies shall be separated and shrouded, and the equipment clearly labelled to this effect. All the isolators to be switched OFF to isolate the equipment totally shall be clearly listed on each label. Warning notices shall also be provided on all equipment which contains live terminals powered from a secondary supply after operation of the primary isolator and these terminals shall be completely shrouded and labelled to prevent inadvertent contact.

2.1.5 Equipotential Bonding

All fixed and moving steelwork, mechanical equipment, control desks, equipment cabinets and racks, enclosures (including doors, backplanes, side panels and removable gland plates) and all metal cases, trunking and conduit and all equipment items shall be adequately bonded to the external protective conductor terminal (main earth terminal or PE). All equipotential bonding arrangements shall be in accordance with EN 60204-1 (or equivalent) and any local electrical standards. Notwithstanding any limitations on equipotential bonding practice specified herein, all parts of the installations shall be securely and adequately earthed. All such bonding points shall be suitably indelibly labelled.

2.1.6 Handheld Equipment

All handheld equipment, such as pendant controllers, shall use voltages less than PELV (see ER (T) 4.1.2 (c) PELV Circuits). Handheld or portable equipment containing voltages in excess of PELV (see ER (T) 4.1.2 (c) PELV Circuits) which is not double-insulated shall have duplicated earthing connections.

2.1.7 Isolators

The mains feed to each cabinet or group of adjacent and related enclosures shall be via an isolator. Where equipment is remotely controlled, a local lockable isolator shall be provided on or close to the equipment. All isolators shall be comprehensively labelled so that no error can be made in isolating the equipment. Where the provision and installation of the isolators is the responsibility of others, the SEC shall ensure that such equipment has been correctly installed, is correctly rated for the installation and operates correctly.

2.1.8 Power On Indication

All enclosures incorporating equipment operating at 230V or higher are to be fitted with large POWER ON indicators mounted in an obvious position near eye level. These indicators shall be WHITE. Where 3-phase supplies are present a separate indicator shall be provided for each phase.

2.2 Electrical Components

2.2.1 Identification

All indicators, controls, fuses, relays, contactors, printed circuit cards, cables and other major electrical and electronic components shall each be fitted with a permanent label indicating their reference and this shall refer to a schedule of type, manufacture, rating and duty to expedite any necessary replacement or fault finding. Where applicable, a means of identifying normally open, normally closed and other contact configurations shall be marked on the component.

2.2.2 Contactors & Relays

All contactors and relays (although not low power types such as reed relays) shall be of the block type and mounted on standard DIN rails. Generally, the contact rating shall be twice the expected maximum operating or inrush current whichever is the greater.

2.2.3 Programmable Logic Controllers

Where there are a significant number of control relays used in a circuit, consideration shall be given to using DIN rail-mounted programmable logic controllers (PLCs). Such PLCs shall be sourced from one supplier and provided with a technical manual, a set of program listings and ladder diagrams and an electronic version of the application program and any software necessary to reinstall the application.

2.2.4 Silent Operation

All contactor, relay, transformer, and other magnetic equipment shall be quiet in operation. Flexible mountings shall be used where necessary to limit transmission of noise and vibration. All frames and enclosures shall be rigid and shall not vibrate as a result of component vibration. Cooling fan noise shall be minimised. The noise level of any electrical, electronic or computer equipment shall be evaluated before purchase or manufacture. Excessively noisy equipment will be rejected.

2.2.5 Indicators

Indicating devices shall be of the LED type with a minimum operating life of 100,000 hours, a high-quality mounting bezel and, wherever possible, shall incorporate integral resistors. Indicators shall be as few different types as possible. Incandescent lamps are not acceptable unless specifically approved.

2.2.6 Modular Construction

Electrical and electronic systems shall be constructed as separately removable equipment modules. Where a system

comprises a large number of similar modules, these modules shall be designed so as to be easily interchangeable. Where such equipment is of a plug-in type, withdrawing or replacing the modules with the power on shall not cause damage to the units or to other equipment. Except where specifically described, electrically dissimilar modules or connectors shall be clearly distinguishable and shall not be interchangeable by virtue of different or keyed connectors.

2.3 Electrical Enclosure Wiring

2.3.1 External Wiring Terminations

Terminal strips shall be logically positioned and indelibly marked in accordance with the shop drawings. All incoming and outgoing circuit terminal blocks shall be mounted on a standard DIN rail. Only one wire shall be terminated in each terminal unless the terminal is specifically designed to take two wires. Generous space shall be left for access and installation of the external cables. Internal and external electrical connections to the equipment shall both be clearly and indelibly labelled.

2.3.2 Internal Wiring

Internal wiring shall be of suitable mechanical strength as well as of adequate electrical current rating. Multi-strand cables shall be used for small current conductors in preference to single cores. The current carrying capacity of all cables within equipment enclosures shall take account of derating factors and ambient temperatures in accordance with the specified Standards. Internal wiring shall be colour coded and contained within wireways. At least 40% space shall be available within wireways as initial spare capacity. All the conductors of an individual power circuit shall be contained within the same wireway, trunking or conduit. All internal wiring shall be protected from mechanical damage.

2.3.3 Internal Terminations

The internal wiring in motor control cabinets and similar equipment enclosures shall be terminated using insulated crimped bootlace ferrules. Certain approved insulation displacement or spring clamp terminations may be acceptable. Other appropriate terminations shall be employed in lighting dimmer, sound, computer and communication system cabinets.

2.3.4 Connectors

Where internal plug and socket connections are required, high-quality connectors shall be used. The use of similar connectors with different pin connections is not permissible unless they are keyed and the choice of all plugs and sockets shall be such as to prevent incorrect connection. Mains power connection to each item of equipment within racks and cabinets shall be by agreed type of plug and socket.

2.3.5 Power Patching

All equipment which can be patched or connected whilst powered shall be protected from damage caused by either open-circuit or hot-patch conditions. Where necessary trace circuits shall be used to remove power unless the connections are made satisfactorily.

2.3.6 Low Power Mains Distribution

Where mains distribution switchgear, fusing and protection equipment is required as part of a low-current, electronics or computing rack, such shall be adequately rated, of a type suitable for inclusion in cabinet equipment and of approved manufacture.

2.3.7 Segregation

Within enclosures, power, control and other signal circuits shall be rigorously separated. All wiring to equipment within racks shall be neatly harnessed and any wiring category segregation shall be maintained throughout.

2.3.8 Maintenance

All equipment within racks shall be arranged and wired so as to facilitate its removal, replacement and maintenance.

2.4 Installed Electrical Wiring

2.4.1 Information

Where the SEC is required to issue information on containment or wiring to be provided by others, any information issued by the SEC shall be totally clear and unambiguous. It shall include, as relevant, trunking, tray and conduit sizes for all runs, the types of cable to be installed, the source and destination of each and the category of segregation. Similar information shall be submitted to the Consultant for approval where the SEC is responsible for installing containment and / or wiring themselves.

2.4.2 Pre-Wired Installations

If specifically required, all control wiring route lengths shall be carefully measured on site, and the cables prepared off site and their connectors fitted to the cables. The tray for such cables shall be installed in such a way that these cables can be installed on site at an appropriate time in the contract. Special clamping and glanding arrangements shall be designed to ensure the cables are mechanically protected and secure.

2.4.3 Spare Cable

All wiring information issued by the SEC shall contain instructions to ensure that sufficient length of cable is left at all terminations for connection of the equipment and for future alterations. Under normal circumstances, sufficient length of cable shall be left to make the initial termination and to remake it twice. Suitable lengths of cable shall be left for any necessary movement of equipment. Excess cable shall be coiled on cable tray, in ducts, risers or in the equipment or enclosure itself and securely retained.

2.4.4 Identification

All cables (including power and control) between separate items of equipment or enclosures shall be permanently marked with the same unique number on each end and at every termination point. Markers shall be of an approved indelible type. The cable markers shall bear the number of the circuit shown on the SEC's shop drawings. These numbers shall appear on the record drawings.

2.4.5 Multicore Cables

The cores of multicore and screened cables used for power or low voltage control circuits shall be readily identifiable by numbers. Colour coding will be acceptable only for cables of less than 25 cores. Cable cores identified by means of their form or order of lay will not be accepted. If a GREEN / YELLOW core is present, it shall only be used as a circuit protective conductor (CPC).

2.4.6 Final Connections

Final connections to motors and other equipment subject to vibration or movement shall be made by terminating the supply conduit in a conduit box adjacent to the motor base frame and running a flexible conduit from the box to the motor terminal box. The conduit box shall be fitted with an integral earth point and an earth continuity conductor provided. Cores terminating at the motor terminals shall be

provided with compression type cable lugs. Where the final connection to any equipment, apparatus or motor is by means of a flexible cable, such flexible cable shall have the same current rating as the rest of the circuit. The current ratings for the appropriate ambient temperature shall be as given in the specified standards.

2.4.7 Flexible Conduit

Flexible conduit may be used only where necessary to bridge vibration gaps and shall be of minimum length. All flexible conduit shall be protected from physical damage both during installation and after, taking into account the need for access to the equipment for servicing and maintenance. All flexible conduit shall be provided with an outer sheath of LSF, not PVC, and secured by means of clamp type glands. Sweated glands will not be accepted. The conduit shall be adequately sized for the cables drawn into it. The maximum length of flexible conduit acceptable is 1m.

2.5 Electrical Equipment Cabinets

2.5.1 Construction

Cabinets and equipment racks for relay, contactor, motor control, electrical switching, electronic and computer equipment shall be rigidly constructed in sheet metal or steel treated with rust preventative, reinforced by bends or angle-section frames as necessary. All cabinets and racks shall be fully enclosed except for ventilation and cable access areas and protected in accordance with IP42 or better as standard.

2.5.2 Form

Cabinets and racks shall be arranged for wall mounting, back-to-back installation or free-standing. Unless free-standing, rear access shall not be required for installation or maintenance. Free-standing cabinets may be mounted side-to-side without side panels provided EMC and cooling is maintained. The depth of each rack shall be such as to ensure adequate space for the equipment and wiring whilst allowing reasonable access space for connections and maintenance. The depth of all cabinets in a particular group shall be the same.

2.5.3 Capacity

Except for proprietary standard (19") cabinets supplied fully fitted, cabinets and equipment racks for modular equipment shall be sized to accommodate all the necessary equipment, whether specified or implied, and to provide in addition spare capacity of not less than 20% of the whole. Spare space shall be covered by blank panels finished to match the rack.

2.5.4 Doors & Access Panels

Hinged doors or removable access panels shall seal tightly around the perimeter of their openings and such doors and panels shall be so designed and have sufficient rigidity to ensure continuing proper alignment between mating parts. Dust-excluding seals shall be fitted. Doors shall not exceed 600mm in width and shall be hung on substantial hinges and fitted with locking handles. Other access panels shall not be larger than can be fitted by one person and shall be restrained by supporting recesses and guides and the minimum number of screws.

2.5.5 Cable Access

Holes required for cables shall be factory cut in required positions and removable panels provided for site trimming. Cable entry points shall take full account of the bending radius and size of the cables involved and shall be suitable for cable glands, trunking or conduit attachment. Cabinets not fed from below the floor shall be fitted with a sheet metal baseplate to complete the enclosure.

2.5.6 Installation

Fixing-down points and mounting gussets which do not distort or strain the equipment during installation shall be provided. Heavy equipment shall include lifting points and markings to indicate the weight and centre of gravity of the assembly.

2.5.7 Ventilation

All static equipment shall be rated for continuous operation in the enclosure used and in the environment specified. Cabinets shall be supplied with adequate ventilation for the maximum heat emission of the equipment therein. Ventilation openings shall be protected with fine mesh or foam grilles to prevent the ingress of any deleterious matter. Fans shall not be used to ventilate cabinets or racks unless specifically approved. When forced air ventilation is essential, the enclosures shall be pressurised, the air intakes filtered, and thermal monitoring and / or fan fail detection shall be included.

2.5.8 Equipment Layout

Equipment shall be arranged within cabinets and racks so as to provide an ergonomically satisfactory layout, whilst ensuring that local areas of high temperature are not caused by adjacent items of high heat dissipation.

2.5.9 Data Pocket

A suitable pocket shall be fitted to the inside of the main door of each enclosure suitable for carrying drawings, schedules and maintenance information relating to the equipment. All the drawings and other papers shall be protected in a plastic envelope.

2.5.10 Finish

All enclosures and panels shall be stove enamelled after full degreasing and rust preventing processes. The SEC may propose a colour but, where not agreed or specified elsewhere, the colour shall be RAL 7032 (PEBBLE GREY).

2.5.11 Lighting & Auxiliary Power

Cabinets that contain field-programmable devices such as drives, and PLCs shall include local lighting within the cubicle. The light source shall be switched and positioned so as to illuminate all the items that may need adjustment. Additionally, at least one switched mains outlet shall be provided to power laptops or other test equipment.

3 Mechanical

3.1 General

3.1.1 Auxiliary Equipment

If hydraulics or pneumatics are used for auxiliary systems such as brakes, decelerating devices and dampers then these shall be self-contained, powered electrically and not supplied by external pipes or feeds.

3.1.2 Drip Trays

Fit suitable drip trays under any hydraulic equipment, however minor the system, as well as under all gearboxes.

3.1.3 Secondary Drive Systems

(a) Secondary Drive

No failure or malfunction of any item, other than of the main electric drive motor itself, shall prevent the equipment from being moved so as to ensure that a performance or rehearsal can proceed. Provide one or more suitably sized variable-speed electrical drives mounted in the motor control cabinets which can be plugged or switched to replace a failed drive. Provide also alternative basic controls so that the system may be operated entirely independently of the main controls in the event of a control system failure. This secondary control system shall operate the equipment at a preset slow speed of approximately 25% of normal speed and shall not be dependent on feedback components or switches other than normal travel and ultimate limit switches.

(b) Secondary Motor

If required, Elevators and other similar electrically-driven equipment shall be provided with a secondary drive motor. This drive shall be able to be manually or electrically engaged and shall operate the equipment at a reduced speed. The secondary operation clutch shall be electrically interlocked to prevent power operation of the unit. The secondary speed shall be between 20% and 25% of normal speed. Engaging the secondary drive shall isolate the main drive. The secondary drive shall generally be operated locally to the equipment and shall be subject to any Emergency Stop system fitted.

Powered Flying and other scenery hoisting equipment will not normally be fitted with a secondary motor unless specified. Secondary operation will be accomplished by other methods.

(c) Secondary Drive Limits

The secondary drive shall not work to any limits except the overtravel limits. Engaging the secondary drive shall not require any tools and shall not alter any limit positions or otherwise affect the power operation of the equipment.

(d) Standby Electrical Power

If required, provide suitable isolators and distribution equipment to enable the equipment power to be derived from a separate standby supply in order that these items may complete their journeys in the event of a power failure.

(e) Maintenance

The secondary drive shall be installed so that the main drive motor can be removed for repair without affecting the use of the equipment under secondary control. The secondary drive shall normally be used to operate the equipment on failure of the main motor or its drive equipment, move the equipment off an overtravel limit or out of a crossed groove situation.

(f) Manual operation

Where secondary operation by hand is specified, this shall include a convenient position for the operator, suitable gearing so that the task is reasonable both in terms of time and effort, a reasonable handle swing clear of all obstructions and a practical method of holding off the brake whilst winding. In the absence of all these conditions an alternative and safe powered method of standby operation shall be provided.

The necessary winding gear or handles shall be provided as part of the contract. The handgrips on winding handles shall rotate. Removal of the winding handle from the storage position shall prevent power operation of the unit. A sign shall be fixed adjacent to the machine containing written instructions for manual operation, including an indication of the amount of effort required (e.g.: how many turns of the handle).

3.2 Hoists & Winches

3.2.1 Design

(a) Performance

Hoists shall be suitable for full operation at any speeds and with loads up to the maximum specified, and where required, in synchronisation in motion and position servo-control giving accurate repeated stopping at recorded deads. The hoists shall directly lift the specified loads, be quiet, smooth and free of any judder, shaking, rattles or similar mechanical degradation under all conditions of load and speed.

(b) Hoist Unit

Each hoist unit shall incorporate, inter alia, the prime mover, a main brake, a secondary brake, continuously-grooved winding drum(s), sensors (see ER (T) 6.6 Sensors) and other feedback components as required. The use of a gearbox and the inclusion of detection and control components on the hoist shall depend on the system provided. All elements of the hoist, other than perhaps the winding drum and its bearings, shall be easy to replace. Each element shall have the minimum of other components mounted on it. It shall be possible to lock mechanically the winding drum to the frame to service or repair the hoist with full payload suspended. This shall be an external device applied by maintenance engineers who will be responsible for disconnecting the hoist under these conditions.

(c) Hoist Frame

Mount the hoist unit within a rigid steel frame that both carries and protects all the elements of the hoist. Pre-assemble, pre-test and deliver to site all Multi-line and Point Hoists as fully-tested working units ready for installation. Supply suitable mounting steels or channels for mounting the hoists together with full setting out details for positioning these and, if necessary, the holes through which the wire ropes pass from Motor Room through to the Grid.

(d) Site Delivery

Include lifting points on the hoist units and, if necessary, provide a frame to ensure the hoists can be safely lifted by the site cranes without damage. Mark hoist units with their weight (kg) and centre of gravity. The SEC is ultimately responsible for ensuring the equipment is safely lifted and placed in the Grid or Overstage Machine Room without damage.

(e) Emergency Stopping

Design the hoist units such that a maximum load moving at maximum speed can be stopped safely by either of the brakes operating alone in the established Emergency Stop travel distance.

3.2.2 Hoist Safety

(a) Mechanical

Design the complete mechanical installation to guarantee that under maximum dynamic stress all the wire rope attachments, pulleys, pulley mountings and similar remain complete and fixed to the structure and that no parts become loose or unattached. Where the payload is removable, the users remain responsible for the strength of the scenery or other suspended equipment and its attachment to the suspension beam, truss or load hook or other driven item.

(b) Safety Sensors

As a minimum requirement, provide the following basic safety sensors:

- ER (T) 6.6.2 Overtravel (Ultimate) Limits
- ER (T) 6.6.3 End-Of-Travel (Initial) Limits
- ER (T) 6.6.4 Overload Detection
- ER (T) 6.6.6 Slack Wire Detection
- ER (T) 6.6.7 Crossed Groove (Winding Error) Detection
- ER (T) 6.6.8 Speed Error Detection

(c) Separate Detectors

Provide separate devices for detecting overload, slack wire and crossed grooves. It is not acceptable for any of these detection systems to be combined and still achieve the required level of detection and performance required, with the exception of the possible combination of end-of-travel and overtravel detection by twin absolute encoders to a suitable Safety Integrity Level.

3.2.3 General

(a) Layout

Set out the hoists logically to achieve the specified flying centres and position them so that all parts may be reached easily and safely for setting up and maintenance. Introduce the minimum number of wire rope diversions into the system.

(b) Prime Movers

The prime movers for hoists in a Powered Flying installation shall be electrical. These prime movers shall be capable of a wide speed range and shall produce full load torque at standstill.

(c) Wire Rope Rigging

When specified or required for operational reasons, hoists or winches may be fitted with manually- or electrically-operated clutches so as to release the winding drum to allow the wire rope to be run out or taken in, for example when setting up a movable diverter pulley system on the Grid. Such winches shall be fitted with a failsafe method of detecting end-of-travel appropriate to the rigging then set up so as to stop the unit without damage to the winch, structure or load being moved. Such equipment shall incorporate an interlock to ensure power drive is not possible during resetting.

(d) Hand Winches

All hand winches shall be a tested, proprietary type incorporating a reliable self-locking device. Pressure on the winding handle or operation of a release lever shall be necessary to unlock the winch and allow lowering motion. Hand winches shall not be used for loads in excess of those able to be handled safely by one person or in locations in which it is difficult to operate them. Generally, hand-winches shall not have a payload of more than 250 kg.

3.2.4 Maintenance

(a) Space Limitations

The equipment and installations proposed must be capable of being installed and easily maintained at the close centres and in the spaces indicated in the drawings. Ensure all parts of the hoist unit are accessible, or can be removed, for maintenance without removing the hoist itself from its position.

(b) On-Load Maintenance

Ensure that maintenance or repair to any part of the unit, other than to the wire ropes, diverter pulleys, suspension bar or winding drum, but including the brakes, can be carried out, if necessary, without removing any suspended load. Motors shall be able to be rapidly replaced in the event of a failure.

(c) Sub-Assembly Weight

All mechanical equipment that might need to be removed from site for repair or maintenance at any time in the future must be capable of disassembly into parts weighing less than 50kg. These sub-assemblies shall fit into the fly tower lift where one is provided.

3.2.5 Brakes

(a) Brake Action

Each brake, operating through the selected gearbox, shall be capable of decelerating and stopping a full load from maximum operating speed within an acceptable travel distance. The SEC shall propose this distance for approval. In normal use, brakes shall only hold the load when stationary after the load has been decelerated and brought to a stop by the control system.

(b) Brake Interlock

On all hoisting equipment the brake and motor power shall be interlocked and monitored so that the brake cannot be released unless the motor power is present and capable of holding or otherwise controlling the load.

(c) Brake Release Speed

Brakes shall have a maximum release time of 400ms, including any time taken for a sensing contact to signal that the brake has released. See also ER (T) 5.4.1 (h) Motion Start Latency.

(d) Emergency Holding Device

All such equipment shall be designed so that, in the event of the primary brake releasing without suitable control being exerted over the load, the load is held stationary or lowers only at a slow controlled speed. In the event of the primary brake failing to operate when power is removed from the motor when lowering, the load shall decelerate to standstill or shall lower only at a slow controlled speed.

Where necessary, additional equipment shall be fitted to the hoist to comply with this requirement. This may require a secondary brake, sprag brake or friction device.

(e) Independent Test

It shall be possible to check the effectiveness of each braking device separately.

3.2.6 Winding Drums

(a) Grooved Winding Drums

Where wire ropes are wound on drums, a grooved drum shall be used in which the wire rope is wound in a single layer. The drum groove shall have a form and pitch to suit the size of wire rope used in accordance with the wire rope manufacturer's recommendations. For each wire rope wound on a drum, there shall be a minimum of two dead turns and a clearance of at least two empty grooves to the end of the drum or to the start of the next winding. Compliance with this requirement shall be checked carefully at both extremes of travel during installation.

(b) Form of Grooved Winding Drums

Grooved winding drums shall be machined from high-quality castings or from a welded construction using seamless steel tubing and end plates. The bore shall be machined such that the concentricity of the groove pitch diameter in relation to the rotational axis is within ±0.5mm. The groove form shall be in accordance with applicable Standards.

(c) Wire Rope Retention

All grooved winding drums shall be fitted with a method of preventing the wire rope coming out of, or crossing, a groove either when under load or slack if such a condition can occur. Where adjustable retaining pulleys or rollers covered with polyurethane or similar are proposed, these shall be of a diameter such that they do not rotate at excessive speed or cause noise.

(d) Crossed Groove Detection

A wire rope crossing a groove shall be detected immediately and the mechanism stopped safely. This condition shall be designated a FAULT and shall require attention by maintenance personnel. The mechanism shall not be able to be run under main power until the fault is cleared.

(e) Use of Pile Winding Drums

Pile winding drums may only be employed in situations where a grooved winding drum is not practicable. The design and fabrication of such drums shall take full account of the lateral forces exerted on the drum side plates. Only wire ropes approved by the manufacturer for such service shall be employed.

(f) Form of Pile Winding Drums

The minimum diameter of pile winding drums shall be not less than 30 times the diameter of the wire rope and two full dead turns shall be remain on the drum at all times. The radius of the side plates and dividers shall be greater by at least twice the wire rope diameter than the maximum radius of the turns of wire rope to be wound on the drum. The side plates and dividers shall be free of all burrs and sharp edges and the drum aligned so that the wire rope passes clear of the side plates and dividers.

(g) Wire Rope Termination

Each wire rope that terminates on a winding drum shall be provided with an easily-accessible positive fixing point. Passages from the groove to a remote fixing point shall be formed so as not to distort or damage the wire rope or affect the operation of the crossed groove detector and shall be free of burrs and sharp edges.

(h) Shaft Mountings

Winding drums shall be fitted with integral hubs which will accept suitably-sized continuous solid steel shafts passing through both hubs and both mounting bearings. Keys shall engage the full dimension of the hubs and bearings. The drum hubs shall be keyed to the shaft with keys and keyways suitably sized for the maximum torsional load exerted. The keys shall be locked or approved proprietary torque bushes employed.

3.3 Elevators

3.3.1 Design

(a) Performance

Elevators shall be capable of lifting and lowering the specified loads at the designated speed and accurately stopping at predetermined levels. In normal operation the Elevators shall be decelerated and brought to a stop in the preset position by the internal control system. Brakes and any additional secondary holding devices shall also be capable of decelerating and stopping a fully loaded Elevator from the specified maximum operating speed for that load within the specified travel distance.

(b) Raise / Lower Mechanism

Propose a suitable raise / lower mechanism for the Elevator. Unless otherwise approved, this shall be a proprietary device capable of supporting and moving the specified loads from beneath. Locking the transmission shall lock the mechanism and the Elevator in position without need for additional equipment. Mount the raise / lower mechanisms on steels on the floor slab in the Elevator pit and take all the loads of the Elevator back to these slabs. In some positions it may be necessary to cantilever the supports outside the pit slab.

(c) Brakes

Fit both a main brake and a secondary brake, either of which shall be capable of decelerating and stopping a full load from maximum operating speed within an acceptable travel distance. The SEC shall propose this distance for approval. If agreed with the consultant, both brakes may operate through the selected gearbox. In normal use, brakes shall only hold the load when stationary after the load has been decelerated and brought to a stop by the control system.

(d) Brake Interlock

The brake and motor power shall be interlocked and monitored so that the brakes cannot be released unless the motor power is present and capable of holding or otherwise controlling the load.

(e) Installation

Install all the motors, gearboxes, brakes and transmission components on pre-aligned steel frames in the factory which are then positioned, levelled, bolted and grouted in position in the pit.

(f) Space Limitations

The dimensions and depth of each Elevator pit is fixed and unless informed otherwise, these pits will be largely constructed and may be inspected on site. Verify all site and other dimensions before fabrication or construction and be entirely responsible for their accuracy.

(g) Setting Out of Equipment

Set out the Elevator taking full account of the alignment of the stage centre line, the stage front line and any other setting out references in the Appendix 1 - Employer's Requirements (Specific). Allow, and show on the drawings, clearances and tolerances to be finished by the timber flooring, edges and facias whether provided by the SEC or others. Ensure the steelwork platforms are accurately

horizontal and remain horizontal during motion over the full travel distance.

(h) Cable Management to Elevators

Cable management systems shall carry the required cables, pipes or hoses safely and securely over the full travel of the equipment. See also ER (T) 6.7.2 Cable Feed Devices.

(i) Services to Elevators

If required, provide agreed spaces for a number of Production and Work Lighting, and Sound, Video and Communications cables on at least two separate cable management systems to the Elevator. Control signals to the platform may be run within the Production and Work Lighting cable management system if additional capacity is provided but not with the Sound, Video and Communications cables.

(j) Dip Traps

If required, allow for the provision of electrical services to outlets, provided by others and for the provision for traps in the floor to access these. Show traps and outlets on the Elevator drawings for coordination purposes. See also ER (T) 6.2.1 (j) Dip Traps.

3.3.2 Elevator Safety

(a) Safety Sensors

As a minimum requirement, provide the following basic safety sensors plus those specific to the lifting mechanism being employed:

- ER (T) 6.6.2 Overtravel (Ultimate) Limits
- ER (T) 6.6.3 End-Of-Travel (Initial) Limits
- ER (T) 6.6.4 Overload Detection
- ER (T) 6.6.8 Speed Error Detection

(b) Operating Positions

Provide movable portable or handheld control panels for operation of Elevators. The operator will be responsible for moving into a position in which they can see the moving equipment so as to carry out the movements safely.

(c) Guillotine Hazards

Design Elevators to minimise the hazard presented by passing edges or other parts which have a guillotine action. This shall be achieved by long correctly angled, tapered lead-in edges on the underside of each floor section and the provision of suitable safe-edges and presence detectors. The philosophy of use must clearly state that Elevators do not move while any person is in a position that could put them at risk from guillotine hazards.

(d) Trapping Hazards

No positions or conditions shall be created in which a person can be trapped or in which a limb can be trapped or crushed.

(e) Safe-Edges

Employ safe-edges of a failsafe type in accordance with EN 13856-2 (or equivalent) and EN 61496-1 [safety of machinery] (or equivalent). Install on separate steel brackets. Provide within the Contract sufficient safe-edge to cover the **total periphery** of each Elevator and any other guillotine hazards. Trace each section individually so that the activated section can always be identified.

(f) Access to Machinery Spaces

Provide easy access to the mechanism for authorised engineering staff both when the equipment is operating normally and also when an Elevator has failed in its lowest position. Electrically interlock all doors, trap doors, hatches and similar access ways to the machinery spaces. Subject to approval by the Consultant, secure locks or fixings that require a special tool to unfasten them may be substituted for electrical interlocks.

(g) Pit Primary Lighting

If required, install sufficient light fittings on the underside of the Elevator platform to achieve an average illuminance of at least 150lx in the pit area. Luminaires shall be sealed "bulkhead" fittings or similarly-protected industrial grade units. Provide and install all containment wiring and light switches and wire back to a junction box in the pit area. The junction box containing a permanently-live lighting circuit will be provided by others. See also ER (T) 3.3.1 (i) Services to Elevators.

(h) Pit Secondary Lighting

If required, install emergency escape lighting in the pit area to meet the requirements of EN 30061 (or equivalent). The system may be non-maintained or primary maintained as part of the Pit Primary Lighting. Provide and install all containment wiring and light switches and wire back to a junction box in the pit area. The junction box containing a permanently-live lighting circuit will be provided by others. See also ER (T) 3.3.1 (i) Services to Elevators.

(i) Multiple Elevator Motion

Design the control system to allow more than one Elevator to move at one time only if the selected Elevators are adjacent and are travelling in the same direction. Restrict the closing motion of two Elevators travelling in opposite directions to the maximum speed of a single Elevator.

(j) Temporary Barriers

If required, provide sufficient temporary barriers to protect the periphery of the Elevator installation. Barriers to be retractable webbing type with epoxy-coated 995mm high posts and 7kg cast bases. Barrier posts to be finished in YELLOW with YELLOW / BLACK retractable webbing. Barriers available from www.rs-online.com.

3.3.3 Gaps & Facias

(a) Gaps Between Elevators

Ensure that the gaps between Elevators and between Elevators and the fixed surrounding floor at any level are maintained. Eliminate any contact between passing Elevators at any position in their travel without this resulting in excessive gaps.

(b) Elevator Facias

Design and install facias on all parts of an Elevator where such can be fitted. These shall be in good-quality prepared 18mm fire-proof plywood, ready for finish painting by others. Support all facias with steel support frames so that they are rigid and robust and do not become misaligned and scrape on passing elements. Note the **possible** need for air grilles to be mounted in the facias by others.

3.3.4 Elevator Guidance

(a) Function

The guides fitted to Elevators and other moving equipment shall be in the form of low-friction sliding or roller guide shoes running on a smooth, machined guide surface. Except in special applications, the guide shall be fitted rigidly to the structure or to some other item of equipment. The guide system shall resist all the likely forces which will be applied to the moving item in normal operations and shall maintain the position of the moving item in relation to its surroundings.

(b) Position

Determine the most satisfactory positions at which to guide each Elevator. Where possible, ensure the guides do not interfere with scenery or orchestra settings.

(c) Adjustability

All guide shoes shall be provided with a suitable degree of adjustability to ensure that, after installation and setting to work, the specified clearance can be set up and maintained. Separate adjustment in the two necessary directions at 90° shall be provided. This adjustment shall allow for a degree of wear. The guides shall be accessible for cleaning and all the guide shoes removable for servicing and replacement.

(d) Proprietary Equipment

Guides and guide shoes shall wherever possible be proprietary items used on normal lift installations outside the theatre.

3.3.5 Screw-Jack Mechanisms

(a) Types

Solid screws may be loaded in compression or in tension depending on the application and individual specifications.

(b) Description

Screw mechanisms shall consist of high-quality carbon steel screws with proprietary screwboxes containing correctly meshed worms and wheels. The criteria for design shall be based on the data published by Benzlers of Sweden or approved equal. The screw thread used shall be full or modified Acme form in accordance with the specified Standards. All turning shaft supports and Acme nuts shall be supported on taper roller bearings. Individual jack screws, operating nuts and assemblies shall be sized for 50% more than the maximum loads expected to be encountered in motion or static. Provision shall be made to lubricate the bearings and thread engagement as required.

(c) Safety Nuts

In order to comply with National and European Safety Regulations and unless otherwise agreed, screw-jacks used in a stage or platform lifting installation shall be fitted with travelling safety nuts so as to stop the motion of the Elevator in the event that no other sustaining device is operational.

(d) Protection

Where used in potentially dirty or dusty conditions, such as in stage basements, a wiper of felt or bristle brushes shall be fitted to the top and bottom of the screw housing to remove dirt and particles that might otherwise enter the screw box. Where possible the lower part of Elevator screws shall be enclosed in grease-packed enclosures or totally within expanding bellows. All cavities within the housing and bearings shall be packed with an appropriate grease before delivery to site.

(e) Design

The design of the screws shall take both axial load and duty cycle into consideration. The end fixing details shall be carefully considered, taking into account any angular loads which can be imposed by deflections in the platform. All screw-jack equipment shall be designed and fabricated such that after installation it is not possible to disengage the screw and drive nut inadvertently. Such restraining devices shall not overstress any part of the assembly, the adjoining equipment or structure and may operate by disengaging the drive automatically at the extremes of travel. In normal operation this zone shall not be entered, being protected by the overtravel limit. Similarly, overtravel by compression jacks shall not impart a reverse thrust to the structure they support. Where suspended screws are used, adequate allowance shall be made for differential vertical movement between screws and gearboxes.

(f) Over Temperature Protection

Ensure adequate screw-jack cooling under worst-case duty. Fit all screw-jack gearboxes with thermistors to stop the drive in the event of excessive heat being generated.

3.3.6 Tubular Thrust Screws (Spiralift)

(a) Definition

Tubular thrust screws shall refer to the form of raise / lower mechanism patented by GALA Theatrical Equipment and sold under the trade name "Spiralift", or any similar mechanism which is highly efficient and needs to be maintained in compression. Such tubular thrust screw or self-erecting jacking equipment using metal bands shall be used in compression only. The particular requirements of guiding and of maintaining a permanent load on such equipment shall be rigorously complied with in all installations.

(b) No-Load Detection

No condition of loading shall be such as to reduce the load on any tubular thrust screw to zero or less. To ensure that this situation is monitored at all times, approved no-load detectors shall be fitted at the top of all tubular thrust screws and linked to the control system to inhibit further downward motion. A section of the control system shall be permanently powered and shall cause an alarm to be sounded in the event of the load on any tubular thrust screw reducing to less than an agreed minimum figure. The alarm sounder shall be different to any others in use in the vicinity, especially those indicating imminent motion and shall be mounted in an agreed location.

(c) Sustaining Device

Each individual tubular thrust screw shall be fitted with a sustaining device which will hold the full rated load of the thrust screw in the event that no other mechanism or brake is applied. This device shall be entirely mechanical and failsafe and shall operate automatically without electrical connections or without creating noise. It may take the form of a mechanical sprag brake or similar device which is always effective unless drive power is applied to the thrust screw mechanism.

(d) Chain Drives

Any chain drive to tubular thrust screw or similar mechanisms shall be duplicated, with each chain being rated for the full load.

(e) Protection

Where used in potentially dirty or dusty conditions, such as in stage basements, a wiper of felt or bristle brushes shall be fitted to the drive housing to remove dirt and particles that might otherwise enter the drive mechanism.

(f) Guidance

The guides shall ensure no lateral forces are imposed on the tubular thrust screws such as to cause misalignment, malfunctioning or damage.

3.3.7 Rigid Chain Drives (LinkLift)

(a) Suitability

Where a LinkLift rigid chain is used in Elevator systems ensure that the chain is suitable for the application. Forward all the details of the application and of the

intended use to Serapid for approval before commencing manufacture.

(b) Alignment

Ensure that the installation is correctly aligned in all respects but particularly that the chains are operated plumb and true. Provide a suitable degree of adjustment in the attachments at the ends of the chains and, if necessary, in the drive mechanism to achieve this. Guidance of the platform or other moving parts must ensure vertical movement within the tolerance of the rigid chain.

(c) Cleanliness & Lubrication

Do not install the rigid chain unless the site is relatively clear of concrete dust or other harsh debris. Keep the rigid chain covered whenever building work is carried out in the vicinity. Before operation the chain must be lightly oiled in accordance with Serapid's instructions. Provide and fit covers over all rigid chain storage cassettes. Keep dust and dirt off rigid chain installations.

(d) Noise

Where mechanical noise from the installation may be a problem, raise this with Serapid and ensure that suitable pinion inserts are used in the storage cassettes.

4 Drives & Control Systems

4.1 General

4.1.1 Definition of Terms

(a) Payload & Speed

Each AXIS shall be able to perform all the motions described with any payload from zero to the maximum load specified. Where bands of loads and associated maximum speeds are given, the AXIS shall have a maximum speed approximately proportional to the load. Where payload is not defined the maximum speed shall be that specified.

(b) Speed Range

The range of available operational speed over which the AXIS may be controlled. There shall be a DEFAULT PRESET SPEED for each type of driven AXIS.

(c) Change of Speed

The system acceleration or deceleration rate shall be proportional to the speed up to the maximum rate specified. This rate shall be variable to suit the movements required, but shall DEFAULT to a preset fixed rate for normal operations.

(d) Dead Repeat Accuracy

Since the position of a suspended load will be affected by load and wire rope stretch, the dead repeat accuracy for hoisting units is given as a tolerance on the winding drum periphery. For other rigid AXES the dead repeat accuracy shall be that of the main performance feature. The system shall achieve reliably the specified position repeat accuracy over the whole travel distance under any specified conditions of load and speed.

(e) Travel Accuracy (Following Error)

The term refers to the maximum difference in position during motion (acceleration, travel and deceleration) between any specified AXES operating as a GROUP. The system shall reliably maintain the synchronous accuracy in motion under any conditions of load and speed to the tolerances specified.

(f) Positioning Accuracy

It shall be possible to set and record the position (height) of an AXIS to within the specified tolerance using the controls provided on the system. The screen readout stability shall be such as to allow setting to this accuracy.

(g) Travel

The term refers to the operational distance through which an AXIS can move under the control of the system without invoking a software or mechanical limit. Deads can be recorded and recalled anywhere within this travel range.

(h) Initial Limits

See ER (T) 6.6.3 End-Of-Travel (Initial) Limits.

(i) Ultimate Limits

See ER (T) 6.6.2 Overtravel (Ultimate) Limits.

(j) Overload

See ER (T) 6.6.4 Overload Detection.

(k) Slack Wire

See ER (T) 6.6.6 Slack Wire Detection.

(l) Crossed Groove (Winding Error)

See ER (T) 6.6.7 Crossed Groove (Winding Error) Detection.

(m) Emergency Stop

Stopping distance and method of deceleration and stopping to be evaluated by the SEC as part of the Risk Assessment for the Emergency Stop System.

See also ER (T) 4.5 Emergency Stop System.

(n) Duty Cycle

The term refers to the period during which any AXIS may be in continuous operation under the load specified. Where no load is specified this shall be deemed to be maximum load. Full rating = maximum load at maximum speed. The control system shall be rated for continuous operation.

4.1.2 Control Facilities

(a) Remote Control Panels

Each motor drive shall have to be switched to REMOTE at its local control unit for it to respond to the controls on a remote panel or panels. The fixed, mobile or pendant control panels, which are normally used to operate the equipment, shall be classified as remote units. Control may be switched between alternative remote-control panels. The control panels for a number of similar items of equipment in the same area or which work together shall be combined.

(b) Control Circuit Power

Power for a single main control panel may be derived from the equipment drive circuit, but that for a combined panel shall be derived independently.

(c) PELV Circuits

All control circuits shall be designed to protect persons against electric shock by the use of Protective Extra Low Voltages [PELV, see EN 61140 (or equivalent) and EN 60204-1 (or equivalent)]. Nominal control voltages shall be limited to 25V rms AC or 60V ripple-free DC such that each panel is safe for maintenance if only locally isolated. One side of the control circuit, or one point of the source of supply shall be connected to the protective bonding circuit associated with the higher voltages.

All remote circuits shall be short-circuit protected with maximum currents limited (in case of failure) to 1A AC or 0.2A DC. Control circuits shall be arranged so that no potentially dangerous motion of any equipment can be initiated or allowed by their malfunction.

(d) Equipment Cooling

The SEC is responsible for the internal temperatures within their equipment. Ensure that the temperature within the electrical power, drive, computer and control equipment and within items such as motors and gearboxes under all operating conditions remains at a level consistent with reliability and longevity.

(e) Keyed Power Switching

Unless otherwise specified, a key switch shall control the power to the equipment, prime movers and other items (generally via contactors) as well as to the control system and control panels. This key switch is to utilise a voltage of 24V rms AC, 24V DC, or less to control the power switching. Under no circumstances shall any item of

equipment remain powered up when the key switch is in the OFF position with the exception of the power source for the key switch. Key to be captive except in the OFF position.

(f) Key Switches

All key switches shall be of 22mm diameter, industrial specification, employing multiple key combinations, as manufactured by major international firms. The keys shall be of the type for which blanks are readily available. Master and secondary level key systems shall be proposed to suit the operational staff. The type of key switch to be employed shall be approved before purchase.

(g) Indicator Test

All equipment shall have a method of testing that all indicator lights are operational. This shall be by means of a TEST position on the ON-OFF key switch. In this position all indicators shall light, and no operations shall be possible.

4.1.3 Equipment Controls

(a) Push Button Actions

All push buttons shall be momentary action. Push button control circuits shall either be HOLD TO RUN so that motion is only maintained while the button is pressed or PRESS AND RELEASE where the motion is initiated by the push action and continues when the push is released. Press and release action latches a circuit which continues the motion until a dead is reached, or STOP, or some other acceptable function button is pressed.

(b) Touchscreen Controls

Touchscreen controls may be used to select equipment to be controlled, dead positions and similar. However, touchscreen controls **shall not** be used to initiate motion.

(c) Movement Buttons

These shall initiate or stop motion of equipment. Typically, they will be RAISE, LOWER, GO, STOP, all of which initiate or cancel motion. These pushes may have PRESS AND HOLD or PRESS AND RELEASE action, depending on their application, although all STOP pushes are PRESS AND RELEASE.

(d) Operational Controls

Movement of major items of equipment which need to be under the constant supervision of the operator shall be controlled by PRESS AND HOLD push button circuits. This type of circuit shall normally be used on pendant controllers. Control circuits of the PRESS AND RELEASE type are intended for initiating equipment movements which do not endanger personnel or for operating complex cues on a performance control panel. PRESS AND RELEASE circuits require an adjacent STOP button. Where movement has been halted by operation of a normal STOP button or by releasing a PRESS AND HOLD push button, it shall be possible to select a new limit or the opposite direction for travel without having to complete the interrupted motion. All control panels and pendants that control moving equipment shall be provided with a push button forming part of the Emergency Stop System, either on or immediately adjacent to the panel.

(e) Dead Selectors & Indicators

Applicable to Elevators, basic hoisting and wagon systems. These buttons permit selection of position (end-of-travel limits or intermediate deads) to which the equipment is required to move. Selected push button or adjacent indicator shall SLOW FLASH WHITE. LED indicators at present position of equipment are illuminated STEADY WHITE and remain on during motion to indicate departure position. When the equipment reaches selected position, this indicator shall go STEADY WHITE and the departure indicator shall extinguish. Selector buttons shall be PRESS AND RELEASE type and shall be electrically mutually exclusive.

(f) Equipment Selector Switch

This shall permit the required item or items of equipment to be selected for control by one pendant or control unit. Where a number of items of equipment can be selected to one or more pendants or control unit, an indication of the equipment selected shall be incorporated. Selectors may be toggle switches, rotary switches or push buttons depending on the application. If the chosen selection technology allows, prevent the intentional or accidental selection of equipment while another item of equipment is in motion. Indication shall be steady WHITE.

(g) Equipment Selector Outlet

Where a pendant or control unit operates only one item of equipment or incorporates selection facilities within it, it shall be able to be directly connected into the appropriate outlet on the main control panel. The outlets shall be clearly labelled.

(h) Transfer Switch & Indicators

Where equipment is to be controlled from more than one remote location the transfer switch shall permit selection of the required control location. Typically, this may be a key switch, rotary switch or mutually exclusive push button set. The transfer function may alternatively be on a "take-control" basis using a key switch or individual push button at each remote location. The status of the control shall be indicated. In some installations the transfer function may be achieved by additional positions on the ON-OFF key switch. Irrespective of the method chosen, it shall not be possible to transfer control whilst the machine is in motion.

(i) Speed Controls

Speed controls shall be either a rotary or linear slider control giving fully variable speed, or a rotary switch or push buttons selecting preset speeds. Rotary and linear controls shall be firm and positive, shall allow change of speed in motion and shall set speed directly proportional to position. These controls shall require a positive action to move them and settings shall not be changed by casual contact.

(j) Dead Man's Buttons

Design the Dead Man's Buttons (DMB) such that constant pressure is required on the actuator button or lever to permit the initiation and continuation of motion. A momentary release of pressure shall stop the machine immediately even if pressure is reapplied to the actuator. Only allow initiation of motion from an operator's control panel and prevent the automatic start or restart of machinery when a DMB is pressed. The DMB must be pressed before the command to start motion is entered at the control panel.

4.2 Basic Control Systems

4.2.1 General

(a) Common Controls

Similar controls and indicators on each control panel and pendant shall carry out similar operations and indications. The colour and type of controls and indicators shall also be common between control units. Wherever possible the colour of buttons and indicators shall be to EN 60204 or equivalent standards.

(b) Basic Controls

Where the equipment only requires a few control push buttons in one or more fixed positions, for example RAISE, STOP, LOWER on a large dividing door or shutter, a rugged wall-mounted proprietary push button control unit shall be installed.

(c) Flashing Speed

Indicators shall flash either FAST at approximately 60 flashes per minute or SLOW at 30 flashes per minute.

(d) Power On Status

A STEADY WHITE indicator shall generally indicate POWER ON status. Where drive power is separately switched, two indicators shall be provided, one indicating CONTROL POWER ON and the other DRIVE POWER ON.

(e) Errors

These are caused when an operator uses an unacceptable key or an unacceptable sequence of keys on a more advanced control system. An example would be trying to initiate an action without selecting a dead for the equipment to go to. Generally, a keying error shall be indicated by a soft buzzer or beep. Where the system has a visual display screen, it may be appropriate to "flash" a portion of the screen RED to indicate a keying error.

(f) Snags

An operational difficulty shall be classified as a SNAG. A SNAG is a protective situation from which the equipment can be extricated by a relatively simple process, such as reverse operation. Typical SNAGS are OVERLOAD, NO-LOAD, SLACK WIRE, OPERATIONAL TRACE, SAFE-EDGE TRIP, OBSTRUCTION and similar. Indication of SNAGS shall be FAST FLASHING YELLOW.

(g) Malfunctions

A more serious operational difficulty shall be classified as a MALFUNCTION. A MALFUNCTION requires the operator or an assistant to investigate and take corrective action before the equipment can be operated again. Typical MALFUNCTIONS are REMOTE NOT SELECTED, SAFETY SWITCH ACTIVATED, SECONDARY DRIVE ENGAGED, WINDING HANDLE REMOVED, DOOR INTERLOCK OPEN. Indication of MALFUNCTIONS shall be BLUE (to indicate mandatory intervention is required). Where necessary, malfunctions shall be provided with a reset button.

(h) Faults

A FAULT is a failure of part of the equipment or system and requires first-line maintenance or the attention of an engineer. Typical FAULTS are OVERTRAVEL, CROSSED GROOVE, OVERHEAT, OVER-CURRENT, DRIVE FAULT. Indications of FAULTS shall be STEADY RED.

4.2.2 Safety

(a) Authorised Personnel

Unless specified otherwise, restrict the operation of the Stage Control System to authorised and trained personnel by including a password, PIN or RF tag on all controls.

(b) Speed & Position Monitoring

Continually monitor both speed and position signals to ensure they remain within system tolerances and within an acceptable band related to the command signal. In the event that either is outside these ranges, the AXIS or AXES in the GROUP shall be stopped. Where both signals are derived from one source, such as an encoder, this signal must be constantly monitored, and its failure or degradation shall result in the hoists being brought to a stop. Alternatively, a second approved monitoring signal shall be provided and failure of either of these outputs shall result in the AXES being brought to a stop.

4.3 Control Stations

4.3.1 Control Panels & Components

(a) Fixed Control Positions

Where the equipment is used during performances and the functions are such that an operator will be standing or seated at a fixed panel or desk, the operational controls, including those initiating motion, shall be set out on the panel. The panel shall be located in a position from which sight of the moving equipment can be obtained. The detailed requirements of such a panel will be described in the appropriate section of the Appendix 1 - Employer's Requirements (Specific).

(b) Components

Particular attention shall be paid to the selection of operational components used on desks, control panels and pendant controllers. All such shall be selected for long life under arduous conditions, including rough use in a dusty and dirty environment. Push buttons, faders, knobs, switches and similar shall all be rugged, sealed components, firmly mounted and capable of giving long trouble-free service.

(c) Layout & Samples

The detailed layout of all control, mimic, display, touchscreen and switch panels, together with a sample of each type of control, push button, switch, display, indicator and other components proposed, must be supplied with full technical information for approval prior to manufacture. The samples will generally be returned for use in the project.

(d) Panel Finish & Labels

A high-grade finish is required on all control panels. Extreme clarity must be achieved in all labelling to enable panels to be read in dim lighting. Durable silk screening is preferred for control panels.

(e) Construction

All panels shall be of suitable thickness for their size and shall be framed or supported so as not to flex or bend in operation. Generally, all sides of a panel are to be fully supported. Captive fixings shall be provided for all removable panels or parts. Any inaccessible nuts shall be fixed. Countersunk or instrument head screws shall be used on external surfaces. Snap action fixings shall be restricted to access panels or covers and shall not be used as load bearing or main control panel fasteners.

(f) Silent Operation

Where a control panel is to be used in an operational area, such as on stage, a gallery or control room, the acoustic noise shall be minimal and any internal cooling fans or similar moving or magnetic equipment shall be silenced effectively. Operation of switches, push buttons, relays, solenoids and similar shall not be audible to members of the audience (even in a control room with the window open).

4.3.2 Pendants, Portable & Mobile Controllers

(a) General

Equipment which is largely used for fit-ups and pre-setting the form of the stage or auditorium shall be moved by handheld, or pendant, controllers which may be taken by

the operator to a position in which he or she can see the equipment being moved. Functions which need to be preset shall be selected either on wall-mounted control panels or on the pendant itself depending on the operational requirements and as defined in the Appendix 1 - Employer's Requirements (Specific) or drawings.

(b) Pendants

Pendants must be of a size and form which allows them to be held and operated in the hand. They shall be of rugged construction and, where not wireless, shall be supplied with a trailing cable securely plugging into a recess in the underside or lower part which would normally be towards the operator. They shall be provided with a suspension hook or clip which permits easy storage. Wherever practicable, small pendant units shall be robust proprietary moulded units in rubber or shock-resistant plastic fitted with custom arrays of push buttons.

(c) Portable Controls

Portable control units shall be designed to be as light as practicable whilst being robust and strong. They shall generally be made of sheet steel or aluminium with a raised lip to protect the push buttons, indicators and switches from damage should the unit be dropped or mishandled. The unit must be designed for use on a wall, hanger, table, desk or similar and provided with suitable fittings for this. Convenient handles for lifting and carrying the unit shall be fitted. These may also provide protection for the control panel face.

(d) Low-Voltage Operation

Handheld control panels and pendants shall not contain mains voltage unless they are proprietary items designed and tested for such use. Special arrangements to feed movable items with both mains and control circuits must provide suitable mechanical protection and ensure segregation of services and use the correct category of cable defined in the specified Standards.

(e) Control Cables

Control cables used on pendants, mobile controllers and similar shall be a flexible multicore power control cable of either type CY (screened) or YY (non-screened) with a minimum core diameter of 0.75mm^2. Cables used shall be an appropriate type of multicore with non-kink characteristics, good resistance to crushing, flexibility at all temperatures and good abrasion resistance. Cables shall be physically matched to the equipment and cable restraints, and the connectors used shall be adequate for the duty and weight imposed on them.

(f) Extendable & Replaceable Cables

All controller cables and extension leads shall be fitted with connectors of opposite sex on each end which can be "mated" in-line. This shall allow easy extension or replacement of cables. Extension cables shall allow use of the pendant or control from all anticipated positions as set out in the project specification. Normal trailing cables and extension cables shall be 10m long.

(g) Connectors

Connectors used shall be rugged, locking multi-pin plugs and sockets capable of in-line coupling and heavy-duty use (for example Lemo B-Metal Series from www.lemo.com). They shall be selected to match number of connections, cable weight, entry direction and controller size. They shall be fitted to the pendant or mobile control so that short control cable tails are not required.

(h) Storage Facilities

All pendants and portable control units shall be provided with a suitable storage position for the pendant or mobile unit. This shall support the body of the pendant or control unit and not strain the cable attached to it. Storage shall be adjacent to the main control panels into which the unit is normally connected. Storage for the trailing cable on hangers or similar shall be provided.

(i) Mobile Control Consoles

Mobile control consoles shall be lightweight and ruggedly-built and suitable for moving by one person. They shall be similar in form to a large laptop computer or similar portable electronic device. The internal electronic components shall not, unless essential and approved, include any device likely to be damaged by knocks or shocks. The amount of electronic equipment in each shall be minimised and mounted so as to be shock resistant. The maximum weight without cables but including any power supplies shall not exceed 10kg. Such mobile control panels, where specified, shall be provided with a wall, gallery rail or desk-mounting frame or stand. These control consoles shall be very robust and designed and manufactured to the highest standards. The external design shall also take account of the shocks they will receive in use. Mobile consoles shall be able to be left connected and closed in an operational position around stage.

4.3.3 Wireless (Radio) Control

(a) RF Interference

Design the system such that interference does not cause spurious movement of any equipment. Use radio communications technology that is already approved for industrial crane control. Submit details of the radio system supplier and agree radio frequencies with the Consultant prior to any commitment or purchase.

(b) Failure to Safety

Ensure that any temporary or permanent loss of radio signal results in an immediate and secure stop of all AXES under the control of the radio linked device.

(c) Battery Charger

Provide a removable battery pack and a charger for each unit. Provide one spare battery for each unit supplied or as specified.

(d) Battery Level Indication

Provide a battery level indication within the controller's user interface or on the enclosure where it can easily be seen. The indicator shall reliably signal at least the following discrete levels of charge: EMPTY, 25%, 50%, 75% and FULL.

(e) Signal Strength Indicator

Provide a radio signal strength indication to warn the user that they are approaching the maximum range of the device. Agree details with the Consultant.

4.4 Remotely Controlled Equipment

(a) Warning Lights

When specified in the Appendix 1 - Employer's Requirements (Specific), a system of bright RED or AMBER mirror beacons or other approved indicators shall be installed in suitable locations in areas of the stage, stage basement, fly tower and / or adjoining corridors to warn performers and staff of the movement of major items of equipment (primarily Elevators). The beacons shall be selected for long and reliable service and shall be so

positioned as to warn of the hazard. These lights shall illuminate whenever power is ON the control panel AND motion of the equipment is preselected. In some installations the lights shall flash for 2-5 seconds BEFORE motion commences. The lights shall continue to flash until the equipment is stationary. The rate of flash and pre-motion flash period shall be easily adjustable after installation.

(b) Warning Sounders (Buzzers)

Where specified, a buzzer or buzzers shall sound for an adjustable period of 2-5 seconds before the equipment moves. Buzzer sound shall be loud enough to be heard by those in the vicinity of the moving equipment. The buzzers shall be able to be silenced by an authorised person using a switch in the equipment cabinet. The pre-motion buzz period shall be easily adjustable after installation.

4.5 Emergency Stop System

4.5.1 General Requirements

(a) Principle

The Emergency Stop System shall provide to any person in the vicinity an accessible and rapid method of stopping all specified powered items of equipment in a given area in the event of an emergency or potential accident. The Emergency Stop System shall operate in accordance with local applicable codes and regulations.

(b) Effect

Invoking the Emergency Stop System in any part of the stage or platform shall cause all the motorised stage equipment (unless specifically excluded) in that area to be de-energised and brought to a stop as quickly as possible without creating other hazards. This shall include all items of equipment however controlled and in whatever mode of operation, including items operating on secondary drives and under maintenance control. Each item shall be brought rapidly to a halt in the most effective and safe way.

(c) Failsafe System

The Emergency Stop System shall be designed to be extremely reliable but in the event of a fault it shall fail so as to invoke the Emergency Stop condition in all controlled units. The main safety relay for the Emergency Stop System shall conform to the criteria specified in EN 13850 (or equivalent) to enable compliance with related Standards. Other electro-magnetic relays incorporated in the Emergency Stop control circuits of individual items shall conform to the relevant parts of EN 60947 (or equivalent).

(d) Reset Conditions

After releasing the pushes and resetting the grab-lines, the Emergency Stop System shall be self-resetting unless specified otherwise in the Appendix 1 - Employer's Requirements (Specific). None of the controls shall require keys to release or have reset buttons. All equipment systems shall be designed such that the resetting of the Emergency Stop condition does not, of itself, initiate motion of any equipment. All equipment shall remain stationary until manually restarted using normal operating routines.

(e) Quantities

Too many Emergency Stop buttons can lead to nuisance tripping. Experience shows that those used by the operators on the control panels and those adjacent to moving machinery are most frequently actuated. Provide Emergency Stop actuators on all operator control stations (control panels, pendants, panels and similar) in addition to those specified in the Appendix 1 - Employer's Requirements (Specific).

4.5.2 Category of E-STOP

(a) Type of Stop

The Emergency Stop System shall function as either a Category 0 or a Category 1 stop as defined in EN 60204-1 (or equivalent). The choice of the category for each machine shall be determined by a risk assessment.

(b) Category 0 Stop

Stopping shall be by the immediate removal of power to the machine actuators. This is considered an uncontrolled stop and will not be acceptable for stored energy or high inertia machines. Where a Category 0 stop is used for the Emergency Stop function, it shall have only hardwired electromechanical components. In addition, its operation shall not depend on electronic or programmable electronic logic or on the transmission of commands over a communications network or link.

(c) Category 1 Stop

This is a controlled stop with power to the machine actuators available to achieve the stop and then removal of power when the stop is achieved. This will usually be the preferred form of Emergency Stop since most theatre machinery stores considerable energy and this approach will offer the fastest and most predictable form of stopping. Where a Category 1 stop is used for the Emergency Stop function, final removal of power to the machine actuators shall be ensured by a secure timer and shall be by means of electromechanical components.

(d) Risk Assessment

A risk assessment shall be carried out on each item or groups of items to determine the appropriate risk category using the approach defined in EN 12100 or some other approved method. It is the responsibility of the SEC to develop a **written** safety case, especially the identification of all potential hazards and the analysis of every conceivable failure mode.

4.5.3 Physical Provision

(a) Actuators

The Emergency Stop System shall be operated by large RED mushroom head stop buttons and / or by fluorescent RED grab-lines and switches designed to EN 60947-5-5 (or equivalent). These components shall be specifically constructed for this function. The push buttons shall have a press-to-operate, twist-to-release or similar mechanism. The grab-line switch shall have a reset button or lever on the unit for the line attached to it.

(b) Actuator Locations

Emergency Stop facilities shall be installed in all positions where personnel could be at risk or from where they could observe others at risk from the movement of powered equipment. Incorporate additional push buttons or grab-lines to those identified in the Appendix 1 - Employer's Requirements (Specific) if considered necessary for personnel safety or where additional units are required by the layout or form of the final installation, as agreed with the Consultant. Operation of any button or grab-line at any time and under any circumstances shall activate the Emergency Stop circuit.

(c) Push Locations

Emergency Stop buttons shall generally be mounted at 1500mm above floor level so as to be visible and accessible. Where the buttons are mounted separately

from the control panels they shall be incorporated in proprietary Emergency Stop units or the buttons mounted on a 300mm x 300mm RED panel so as to be readily identifiable. They shall not be mounted where they could be accidentally depressed, but shall be in view of personnel in the area. Any Emergency Stop buttons adjacent to equipment controls shall generally be mounted separately from, but nearby, these controls.

(d) Grab-line Location

Grab-lines shall be mounted either above head height at 2000mm above floor level where personnel need to move under them or at a lower level (not less than 1500mm above floor level) along walls or galleries. They shall not be mounted where they can interfere with operations or maintenance of the equipment.

(e) Tracing

Indicators shall be installed adjacent to or within each Emergency Stop button and grab-line switch to show that it has been operated. The indicators shall FLASH FAST. This individual indication, together with an overall status indicator, shall be repeated on the Emergency Stop System control panel. Repeaters of the individual indication shall be provided elsewhere as required by the project specification or drawings.

(f) Wireless (Radio) E-STOPs

In most cases wireless control devices will include an E-STOP actuator. Arrange for the E-STOP actuator to be disabled when the wireless device is switched OFF or is in STANDBY mode. When an installation includes wireless control devices, ensure E-STOP "mushroom" actuators ON ALL EQUIPMENT forming part of the contract are of the illuminated type. Arrange for active (enabled) E-STOP actuators to be permanently illuminated so that the user is aware that they will function if pressed. For the avoidance of doubt, the E-STOP actuators on unplugged Control Panels and wireless devices that are switched OFF or in STANDBY are not be illuminated.

(g) Actuator Numbering

For clear identification during installation and maintenance later, each Emergency Stop actuator shall be identified with a number or code, to be agreed with the Consultant. The code number shall be clearly indicated on each control.

(h) Extension of System

If required, the Emergency Stop System shall be designed to enable additional items of controlled equipment to be added to it during and after the installation of the system. The system shall have capacity to accept a number of additional actuators as specified in the Appendix 1 - Employer's Requirements (Specific).

4.5.4 Global E-STOP Systems

Section not included in this Issue.

4.6 Drive Units

(a) Value Engineering

The design of all drive units offered shall evaluate the required speed and final total load, the power and torque requirements, the available motors, gearbox ratios and other parameters. The SEC shall offer a proposed value-engineered design with similar payload and speed to those specified for approval. Load and speed changes shall not normally be greater than 5% and any changes to specification shall be made and recorded at this time before manufacture or installation on site. The SEC shall make full allowance for all friction, efficiencies and other losses during design.

(b) Assembled Unit

Wherever practicable, on electric hoists, winches and other electrical drive units the motor, brake, gearbox, winding drum, limit box assembly and electrical isolator shall be mounted on a substantial mild steel base frame of minimum size. The frame shall be suitably braced. Where necessary and appropriate this assembly shall be installed on suitable anti-vibration mounts to minimise vibration transmitted to building structure. Such an assembly shall be tested prior to delivery to site.

(c) Internal Wiring

All electrically-operated mechanical equipment shall be supplied complete with all internal wiring associated with each unit, an isolator or isolators suitable for the equipment connected and, where appropriate, all necessary motors, motor starters, control units, limits, overloads and other detectors and protection devices, etc. All motor starters, controllers, soft-start and variable speed drive devices shall be proprietary items, fully assembled, wired and tested in the factory before supply to site. Units shall be designed for minimum site wiring.

4.7 Drive Controls

(a) Power Supplies

Wherever practicable, the power supply cable for one or more items of stage machinery, hoisting, winching and rigging equipment shall be terminated directly into an isolator provided as part of the control or drive equipment for these items. Where an isolator is provided as part of the electrical installation by others, this isolator shall be labelled by the SEC in accordance with the equipment served and the building services electrical reference.

(b) Drive Cabinets

For each physically separate set of control or drive systems, a power cabinet or cabinets shall house (inter alia) an integral isolator, phase indicators, power contactor.

(c) Power Contactor

Each equipment system shall be provided with a suitably-rated power contactor which shall isolate all power to the drives and control circuits. A separately-fused circuit may power a low-voltage output for the contactor coil via the ON-OFF key switch, or other control, on the main operational control panel.

(d) Local / Remote Switching

Each item of equipment shall be able to be fully tested and checked out using the local controls and indicators without connection to the remote operational controls. Each shall be provided with a LOCAL-REMOTE switch which transfers control to the remote panels. Provide an Emergency Stop actuator with the local controls.

(e) Single Units

Single pieces of equipment, such as direct-on-line hoists and similar small power units, do not require individual drive cabinets provided they have individual isolators and are fed from a supply or supplies which can be switched ON-OFF remotely from an operational position in the building.

(f) Local Facilities

The controls and indicators necessary on each local panel depend on the complexity of the equipment but shall allow for all functions to be checked. This will not extend to

complex commands to the drive equipment where the computation of these signals is part of the remote equipment. Typical controls shall include all motion controls, system reset buttons and individual SNAG, MALFUNCTION and FAULT indicators, together with a POWER ON indicator. Where electronic controls or drives are provided, the indicators and controls for these – including all diagnostics – must be available. Facilities must be available for checking all the encoder or similar feedback signals from each machine.

4.8 Motor Drives & Control

See also ER (T) 4.9 Electrical Drives.

4.8.1 General

(a) Phase Monitoring

All electrical drives shall be fitted with individual indicators on all three phases and shall include under-voltage and phase-loss detection to prevent danger or malfunction in the event of excessive voltage reductions or loss of one or more phases. Such protection equipment shall ensure the release of brakes only when adequate motor torque is being developed to drive or hold the load.

(b) Duty Cycle

Most items of stage machinery are not operated continuously and can be considered to be intermittently rated. Where not otherwise specified, the duty cycle for any non-continuous motion equipment shall be taken as a run of SIX full operations under the most onerous load conditions followed by fifteen minutes rest. Continuous motion equipment, such as revolves, shall be continuously rated.

(c) Motor Types

DC motors with brushes shall not be used unless no other suitable type is available. Brushless AC and DC servo-motors are acceptable. AC motors shall be three-phase for sizes larger than about 2.2kW. Motors larger than 10kW shall not use direct-on-line starting. Fixed speed operations shall be powered by AC squirrel-cage induction motors. Totally-enclosed fan-cooled motors to National and European Standards shall be used in all major stage rigging and machinery installations.

(d) Power Factor

Where practicable all motors and drive equipment shall be power factor corrected by the supplier to 0.85 lagging or better, unless otherwise agreed. Torque calculations, motor ratings, full load and starting currents shall be given on the shop drawings and included in the record information.

(e) Electrical Overload

Electrical overload protection shall be provided on all drives. Reset may be from a remote position or locally, depending on the equipment. Operation of overload and other trips shall be indicated on the local controller and in other positions as specified and when operated shall leave the equipment in a safe condition both electrically and mechanically.

(f) Over-Temperature Detection

All motors shall have thermistors or other heat detection devices within the windings and the appropriate control device which shall be connected so as to prevent operation if overheated. The class of insulation shall be appropriate to the operating conditions.

(g) Powering-Up

Phase rotation and earthing on each motor and drive unit shall be checked before powering and running the equipment. Each motor, its drive and associated mechanism shall be run initially under careful observation and satisfactory operation verified before attempting remote control or full load tests.

(h) Associated Equipment

Many items of equipment will require remote switching, and control and feedback components, associated with the drive unit. Such equipment shall be mounted securely in positions where it will not be damaged. Such equipment and the necessary remote-control connections shall remain accessible after the equipment is installed.

4.8.2 Integrated Hoist & Drive

(a) Principle

In order to maximise the amount of off site assembly and testing, integrate the hoist mechanics and drive electronics as a single package. The only connections to each hoist are to be AC power, control networks and Emergency Stop wiring. Fit each hoist with its own drive and control electronics "on-board": unless specifically called for, drive-to-hoist patching systems are not acceptable.

(b) Packaging

Package all drive, axis control and local interface electronics in cabinets that can either be swung clear of the hoist or which can be mounted adjacent to each hoist to allow easy access for commissioning and servicing. This shall be an independent item which can be bolted to the hoist frame or nearby steelwork and connected to the hoist components using approved, high-quality, lockable electrical connectors. Hardwire the power supply, control network and Emergency Stop wiring to suitable termination points.

(c) Cross-Connection

The electrical, control and other connections to the driven, load holding or detection equipment on the hoists shall all be via approved plugs and sockets so as to simplify maintenance, fault-finding and emergency operation using an alternative drive system. Provide facilities so that control of a given hoist can be transferred to another unit by re-plugging, unless this facility is provided by some other means. Suitable extension leads shall be provided for this purpose. The drive system in use shall operate the cross-plugged hoist fully and satisfactorily without requiring any reprogramming or resetting. Breaking of any connection when powered or in operation shall result in a safe stopping, including of GROUPs and holding of any load up to maximum. Such a cross-plugged or disconnected condition shall be indicated to the operator.

4.8.3 Standby Electrical Supply

If required, make provision in the control system to limit the payload or the number of machines which can operate together when the main electrical supply is not available. Use an agreed signal, provided by others, from the electrical switchgear which will indicate that a reduced-capacity standby electrical supply from a separate transformer is in use. This standby supply will be fed, via a changeover contactor, to the main electrical supply cable feeding the equipment. The limitation shall allow for the movement of any single machine or groups of machines provided that the standby power supply capacity is not exceeded. The standby supply is primarily to ensure that any personnel who may be suspended on any part of the

hoist system when the power fails may be lowered to the stage or otherwise rescued.

4.9 Electrical Drives

4.9.1 General

(a) Brake Sequence

Design the control and drive system to ensure the brakes are only released once sufficient motor torque has been established to prevent the load "snatching" in either direction after the brake holding torque is removed. Do not assume that releasing the brakes after a set time delay or at a preset inverter output frequency will be acceptable.

Propose a strategy for achieving smooth brake release under all anticipated loads for approval by the Consultant.

(b) Residual Current Devices

Ascertain whether any drive equipment is required to operate from supplies protected by a residual current sensing device. Ensure low earth leakage filters are installed and confirm with the drive manufacturer that the equipment will operate reliably on the supply being offered. Where RCDs are specified for personnel protection it will only be possible to increase their tripping current above 30mA in **exceptional** circumstances.

4.9.2 Fixed Speed Drives

(a) Motors

Each fixed speed drive shall use an AC motor drive provided with local controls and with a fully-interlocked magnetically-operated motor starter or electronic equivalent, in addition to any remote controls. In the simplest installations, thermal overload relays or equivalent shall be provided, designed to trip at 115% to 120% of the rated full load current of the motor.

(b) Soft-start

Where low-efficiency mechanics or equipment requiring large starting torques is involved, suitable proprietary electronic "soft-start" devices of a reliable type shall be incorporated in the motor drive installation. This shall apply particularly to large multi-screw-jack Elevator and similar installations requiring large starting torques.

(c) Accelerations

Normal accelerations and decelerations for fixed speed power driven hoisting equipment shall be a maximum of $0.3m/s^2$ and for power driven revolves, wagons or Elevators shall be $0.15m/s^2$.

4.9.3 Variable Speed Drives

(a) AC Drives

Major variable speed AC motor drives shall be of the flux-vector or direct-torque control types. Frequency control using simple frequency inverters shall only be used in minor applications and when specifically approved.

(b) Dynamic Braking

Stored energy systems such as hoists and Elevators will require some form of dynamic braking using resistors or regeneration back into the supply to dissipate the braking energy. Ensure there is sufficient capacity in these systems for the worst-case duty cycle of each class of machine.

Provide adequate cooling and include temperature and any other sensing necessary to ensure the safe and proper functioning of the dynamic braking system at all times. Advise the Consultant of the maximum anticipated heat dissipation from braking resistors at any one time and for any extended period.

In certain instances, it may be allowable to share a single regenerative DC-link controller amongst several drives.

(c) Hoisting Applications

Ensure that variable speed drives used for controlling hoists are approved by the manufacturer for such applications. Follow all the manufacturer's recommendations in this respect.

(d) Types

Modern AC variable-speed drive systems are very applicable to stage equipment. Final acceptability will depend on the performance and parameters of the system proposed. The drive systems shall incorporate self-diagnostics, full system monitoring and malfunction and fault reporting to the operator. Powered Flying installations shall incorporate both a tachogenerator and a position encoder in each hoist unit in order to provide full and independent monitoring of system parameters.

(e) Power Trading

If specified, automatically restrict the maximum speed of the machine depending on the dynamically measured load. Refer to the Appendix 1 - Employer's Requirements (Specific) for the precise details of the load / speed limiting curve. The default control law is to maintain power above 50% speed and 100% payload power point, by reducing the payload from 100% SWL at 50% speed to 50% SWL at 100% speed.

5 Multi-Axis Stage Control

5.1 General

5.1.1 Requirements

(a) Proprietary System

The requirement is for the development of a proprietary control system. The Control System shall ensure secure, safe and reliable operation of all controlled AXES. Control system developments are expected to relate mainly to the operator interfaces, panel formats and display facilities.

(b) Architecture

Provide a full control system based on computers offering the highest level of operational control function and reliability, and incorporating duplicated processing and communications. The basic requirement is that the movement of any item can be selected and controlled from one of the portable **Operational Control Panels** (OCPs) or **Rigger's Control Panels** (RCPs) forming part of the control system. These can be located, where appropriate, around the stage and gallery levels for each show. The range of functionality available from each control position shall relate to the type of control panel, the equipment that has been designated to be controllable from that location and the level of operator training. In addition, supply a **Secondary Control Panel** (SCP) that works independently of the computer control system and operates a Secondary Backup System for the Powered Flying AXES.

5.1.2 Summary of Main Control Functions

(a) User Levels

There shall be no difference in status between setting-up and running a show except the level of operator training which may be considered necessary and controlled by the user's access level.

(b) Setting Controls

Setting controls shall include single and multiple AXIS selection and the making of GROUPs of hoists which can be temporary, must move synchronously or in which different AXES (hoists) can move different distances at different speeds. AXES or GROUPs shall be able to be moved, raised or lowered at preset or variable speeds using a joystick, indented wheel or similar approved control, and a whole GROUP, or individual AXES, trimmed to a DEAD (preset) position. Operation of the joystick or wheel shall be able to be switched, or used with another control, to provide slow-speed operation for position setting. Individual AXES shall be able to be "picked" to be adjusted separately, or skipped to remain stationary. DEADs shall be able to be recorded for all AXES. AXES, GROUPs, DEADs, SCENERY HEIGHT and other data shall be able to be recorded for a particular named SHOW and AXES disabled if not required to be operational in a given SHOW.

(c) Running Controls

Having set up AXES and GROUPs with their DEADs for a SHOW, the controls shall permit the creation and recall of an ACTION. An ACTION shall be the movement of an AXIS or GROUP to a new position in a preset (but adjustable) time or speed with a particular acceleration and deceleration. The system shall learn a complete manual motion including acceleration and deceleration profiles.

A CUE shall consist of a number of ACTIONs which lead to a particular position for all the controlled AXES and shall be able to be recorded with its individual ACTIONs or AXES available for overriding during motion. ACTIONs shall be able to be repeated and included in a number of CUEs.

System shall be able to cycle continuously between two DEADs or entered positions and to accept a new DEAD or position in place of that to which it was moving at any time. AXES travelling different distances shall move proportionally in the time set and shall recalculate whenever the time is changed. If time set or remaining is too short to complete a movement, relevant AXES shall travel at maximum speed and indicate a time setting error and the time required for the movement to the operator. Overall time for an ACTION or CUE shall be able to be adjusted at any time including during any motion.

5.1.3 System Availability

(a) Philosophy

As the scenery and lighting suspension system is essential to the operation of the building, there shall be a number of levels of redundancy and a secondary backup system available at all times. Provide secondary control facilities to ensure that no component or system failure results in any AXIS being unmovable except in the event of major mechanical or prime mover failure. This backup philosophy must primarily ensure that the performance continues more or less unaffected and only extreme circumstances shall prevent a selected AXIS being moved.

(b) Functional Requirement

It is not required that a secondary system be included to cover failure of a prime mover itself. The following clauses demonstrate the degree of secondary operation required. This list is not exhaustive and the ability to operate a show fully, except in extreme circumstances (circumstances to be agreed between the Consultant and the SEC) shall be demonstrated as part of the testing and commissioning.

(c) Controller Redundancy

Any OCP or RCP, depending only on where it is connected, shall be capable of accessing all the recorded data for the show and of carrying out the movement of any AXIS in any GROUP, ACTION or CUE in any rehearsal or performance operation.

(d) Secondary Backup Controller

A plug-in Secondary Control Panel (see ER (T) 5.2.3 Secondary Control Panel (SCP)) can be used to move one hoist or a group of hoists at a slow speed by direct control of the motor drive units on the hoists. This shall offer limited movement facilities to cover the total failure of all central control equipment. In the event of this level of failure, the additional controlled axes shall be operated using their basic control systems.

(e) Fault Tolerance

The Control System shall include redundant power supplies, duplicated central processing and duplicated memory facilities, and shall be operated by two or more standard approved computers with additional processors and / or programmable logic controllers as necessary. The non-redundant components tabled below are permitted:

Fault Tolerance: Non-redundant Subsystems	
Main electrical intake and Standby Electrical Supply	Format and assignments of circuits to sub-distribution boards to be agreed with Consultant
Emergency Stop System	All wiring to be physically protected; external connections can be unplugged to restore sensing loop
High level control network cabling	Designed to tolerate a single fault and to both detect and report location of such a fault

(f) Dual System

Configure the Stage Control System as two independent entities with separate control networks and power supplies. As far as is practicable, distribute the AXES on different systems so that a single system failure will leave every other hoist or lift working. Distribute control outlets between the two sub-networks and link them in a manner least likely to propagate any fault from one network to the other. Where hoists and cable management devices are always linked ensure they are on the same subsystem. Submit and agree details with the Consultant.

(g) Single Failure Modes

Identify and duplicate, or protect in some way, all components in the Stage Control System that cannot tolerate a single failure and whose failure would disable one or both halves of the system.

(h) Redundant Power Supplies

Derive all control system DC power supplies from a number of smaller units operating in parallel to offer a degree of redundancy. The failure of at least one unit in each group shall not affect system operation. Indicate any failures clearly to the operators as soon as they occur. Use the minimum number of different types of power supply unit. Individual hoist unit power supplies need not be duplicated.

(i) Duplicated Data Highways

Duplicated data highways shall be provided:

- For data distribution to the driven units and additional controlled axes.
- To enable the controllers to be used on a second data highway if the first were to malfunction.

(j) Network Speed

The network operating speed shall ensure that a fault or malfunction on any hoist in a GROUP is communicated to others in the group so that the GROUP is brought to a stop without excessive differences in travel distance.

(k) Active Network Components

If the high-level network that links the control panels and axis controllers incorporates active hubs or switches, ensure that a failure of one of these components cannot disable the system.

(l) Duplicated Server

Duplicated control, data storage and processing functions shall be provided on all central equipment. One of these shall normally operate the system and it shall be the responsibility of an operator with a suitable level of training to make the change to the other in the event of difficulty.

(m) Drive Cross-Plugging

The failure of an electrical drive unit on a single hoist shall be covered by cross-plugging to the electrical drive on another hoist. No realignment or reconfiguration of the control system shall be necessary following such a patching operation.

(n) Position Feedback Devices

Encoders and all similar feedback devices shall be easily accessible and readily replaceable, and the system shall be able to be recalibrated quickly in the event of a change being necessary. If a laptop computer or other equipment is required to set up a replaced encoder, provide a suitable laptop and other such equipment as part of the contract. Individual hoists shall be able to be driven directly using the Secondary Backup Controllers described above even when the position feedback components have failed.

5.2 Control Panels

5.2.1 Operational Control Panels (OCP)

(a) General Description

OCPs shall be interchangeable. They shall be able to load hoist and other data, preset shows and operate equipment during fit-ups, rehearsals and shows. They shall each incorporate all necessary push button and other operational controls and clear and bright alphanumeric and graphic displays, such as an active matrix LCD colour screen. These screens shall be 14" minimum. The presetting facilities may be offered as an approved form of touchscreen panel with clear, rapidly-accessible displays. All touchscreen operations must also be possible with push buttons or mouse. The operational keying sequences necessary shall relate to operational theatrical requirements, and not to system engineering.

(b) Physical Form

OCPs shall be lightweight and ruggedly built and suitable for moving by one person. They shall be similar in form to a large laptop computer or similar portable electronic device. If any internal components include anything other than solid state components these shall include anti-shock mountings to provide protection up to 10 g. The maximum weight of the panels without cables but including power supply shall not exceed 12kg.

(c) Connecting Cables

Design the OCPs and RCPs to require only one flexible cable and one connector in order to simplify the connection and disconnection process. Use a cable of minimum diameter and weight for its function and provide approved opposite sex connectors at each end to enable cables to be extended easily if necessary. Cables and connectors shall be suitably protected for rough usage. The OCPs and RCPs shall have a frame-mounted receptacle for the connector in an accessible position on the frame. It shall be possible to easily connect and disconnect the cable without risk of dropping the control panel. Ensure that the cable does not strain the connector or connections. See also ER (T) 5.4.2 (b) Outlet Units.

(d) Management Levels

Arrange that any OCP will support alternative or restricted functionality dependent on a user's access level. The system shall record login and logout times, functions used and operators' identity codes. Five management levels shall be provided.

(e) Summary of Controls

Each Operational Control Panel shall include, inter alia, a keypad with a check display and facilities for selecting AXES, GROUPs, DEADs and similar; for setting POSITION; for recording GROUPs, DEADs, SCENERY HEIGHT, etc.; loading AXES, GROUPs, ACTIONs, CUEs, etc. onto four independent "playbacks", each with a single control enabling speed / time / position to be adjusted; a master speed / time controller; cancelling controls; facilities for pre-setting TIME, SPEED, DISTANCE, DEAD; selection of alternative displays; setting of ACTIONs, CUEs and CONDITIONs; and an Emergency Stop button.

(f) External DMBs

Allow for the connection of an external Dead Man's Button to an OCP, RCP or ER (T) 5.4.2 (b) Outlet Units so that an assistant may monitor motion of an item which cannot be seen properly by the operator. Arrange that particular moves or CUEs may be pre-recorded to require the connection of an external DMB in a remote position, allowing the assistant to enable the movement of the item when safe, and to stop the movement in the event of their seeing a dangerous situation. The allocation of a DMB to a move or CUE shall be restricted to an operator with a high authorisation level, details to be agreed with the Consultant. Provide an indicator in the DMB that illuminates when a CUE is loaded that requires the activation of the DMB. The DMBs shall function reliably with up to 30m of cable. See also ER (T) 4.1.3 (j) Dead Man's Buttons.

(g) Support Stand

Provide lightweight, robust, stable, adjustable height stands for OCPs suitable for use on the stage floor and fly galleries. These shall include locking castors for easy positioning. The stands shall accommodate the screen panel at a suitable working angle and height and shall not obstruct the normal sightlines to the stage. Make provision for mounting auxiliary equipment, such as cue lights and a ring intercom unit, on the stand. Agree details and a solution with the Consultant.

5.2.2 Rigger's Control Panel (RCP)

(a) General Description

RCPs shall be interchangeable. They shall be able to load hoist and other data, preset and operate equipment during get-ins, fit-ups, rehearsals and shows. The main difference between an RCP and an OCP is their physical size and the number of controls. Incorporate in the RCPs all necessary push button and other operational controls and clear and bright alphanumeric and graphic displays, such as an active-matrix LCD colour screen. Include pre-setting facilities in the form of an approved touchscreen panel with clear, rapidly accessible displays. The operational keying sequences necessary shall relate to operational theatrical requirements, and not to system engineering.

(b) Physical Form

RCPs shall be handheld, lightweight and ruggedly built, and would be preferable if suitable for single-handed use. They shall be similar in form to a small tablet computer or similar portable electronic device. If any internal components include anything other than solid state components these shall include anti-shock mountings to provide protection up to 10 g. The maximum weight without cables but including power supply shall not exceed 2.5kg.

(c) Wireless RCP Option

If required, make the RCP a battery-powered wireless device. See also ER (T) 4.3.3 Wireless (Radio) Control.

(d) Management Levels

Arrange that any RCP will support alternative or restricted functionality dependent on a user's access level. The system shall record login and logout times, functions used and operators' identity codes. Five management levels shall be provided.

(e) Summary of Controls

Each Rigger's Control Panel shall include, inter alia, a visual display, programmable "soft-keys" and facilities for selecting AXES, GROUPs, DEADs and similar; for setting POSITION; for recording GROUPs, DEADs, etc.; loading AXES, GROUPs, ACTIONs, CUEs, etc. onto a "playback" with a single control enabling speed / time / position to be adjusted; cancelling controls; facilities for pre-setting SPEED, DISTANCE, DEAD; selection of alternative displays; and an Emergency Stop button.

(f) Storage Racks

Provide storage racks for Rigger's Control Panels suitable for fixing to a wall or steelwork. The racks shall hold the RCPs securely, offer reasonable protection against passing "knocks" and be lockable with a single common key (minimum of 5No. keys to be issued). Agree design details with the Consultant.

5.2.3 Secondary Control Panel (SCP)

(a) Purpose

The Secondary Control Panel (SCP) is required to provide very basic control of a single hoist or a group of hoists with or without auxiliary equipment such as lighting windlasses. Design it to work independently of the Computer Control System. The SCP must still function even when there is a partial or total failure of the Central Control System, including a **partial** failure of the communications network. It is accepted that some form of functioning control network will be required to transmit "commands" to multiple axes in a GROUP.

(b) Design Principles

It is envisaged that the SCP system will "inject" a speed demand signal directly into the motor drives with only minimal additional circuitry as necessary to perform safety functions and apply an acceleration / deceleration ramp. No single DC power supply failure, other than at the hoist, shall disable the SCP. Closed loop synchronisation of AXES in a GROUP is not required.

(c) Physical Form

The SCP is envisaged as being a handheld control station. It shall have a simple press-to-run ENABLE button and a joystick, rotary potentiometer or similar to control the slow-speed motion of the selected AXES. See also ER (T) 4.3.2 Pendants, Portable & Mobile Controllers.

(d) Location

Install outlets so that the SCP can be used in an emergency on the Fly Gallery and for maintenance work in the Grid or Overstage Machine Room, the exact locations to be agreed with the Consultant.

(e) Summary of Controls

The SCP shall include, inter alia, a keypad with a check display and facilities for selecting AXES or GROUPs onto a single control enabling speed to be adjusted; cancelling

controls; facilities for pre-setting SPEED; and an Emergency Stop button.

(f) Limits

While under control of the SCP all the safety sensors and mechanical limits shall continue to operate as normal. However, the SCP system is not required to position to pre-recorded DEADs.

5.2.4 Control Panel Hardware

(a) Language & Ergonomics

Ensure panels are ergonomically laid out. Seek clarification from the Consultant as to the language in which the legends and displays are to be provided.

(b) Buttons

Use only dedicated high-quality illuminated push buttons with a positive and tactile feel to them. Provide push buttons for initiating movements, stopping and similar functions. Provide an immediate return to an initial menu or similar to assist an operator if confused. Particular forms of touchscreen display with positive action and wide viewing angle may be acceptable for pre-setting functions.

(c) Keyboard

Provide an alphanumeric keyboard to be used for engineering operations, monitoring, setting up and inputting text information including SHOW, GROUP, hoist, ACTION and CUE names and operational and maintenance notes. Inclusion of touchscreen shall also allow provision of a QWERTY keyboard facility on the OCPs.

(d) Displays

Displays shall be clear, uncluttered, viewable from a wide angle and show only essential information for that operation. Include single button reselection of alternative screens or specific data, such as components of a GROUP or detailed profile information. Separate displays are required for setting DEADs, running, ACTIONs, CUEs, faults, engineering, etc. Screens must refresh without noticeable delay.

5.2.5 Miscellaneous Items

(a) Task Lighting

All the Control Panels shall incorporate back-lit screens and simple and effective task lighting so that the panels can be used easily in poor general lighting conditions. This shall include the background illumination of all push buttons and the identification of controls that are operational at any time by a higher level of illumination.

(b) Dust Covers

All the Control Panels and similar control equipment items shall be provided with new, strong, shaped, plastic dust covers on final handover.

(c) Rigging Plan

A large-scale drawing of the rigging plan of all the hoists shall be prepared by silk-screening or some other agreed process. This diagram shall be laminated or otherwise protected from damage and mounted adjacent to the main equipment control position on the Fly Gallery level.

5.3 Operational Control Functions

5.3.1 Confirmation of Functions

All the principles behind the main specified functions shall be provided within the system offered. The SEC shall indicate clearly and unambiguously the functions with which the offered system is compliant, those which are offered in a different way and those which are not provided. Considerable review and final definition of the exact form of the operational facilities and displays will be required between the Consultant and the SEC during the early stages of the contract. All such customisation and finalisation shall be carried out within the fixed contract price.

5.3.2 Functional Logic

The control and display logic must be clear and comprehensive, and consistent throughout the system, except where there are extenuating reasons for differences. It must be possible to understand the system with minimal training, although full training will be necessary for unsupervised operation.

5.3.3 Parameters & Functions

The following terms are used herein to define and explain the important parameters and functions of the required system. These terms and letters, or acceptable alternatives shall be used in the development of the system. The functions associated with each of the parameters are generally described therein. Each of these functions is required to be available on the multi-axis control system or to be achievable in some way, unless agreed with the Consultant before the "Functions Milestone".

(a) Axes

AXIS	X	The generic term for each MULTI-LINE, LIGHTING or SINGLE POINT HOIST(S) or other driven UNITS or EQUIPMENT An AXIS shall be a control element in its own right and DEADs, ACTIONs and CUEs shall be able to be created for individual AXES
SIMULTANEOUS OPERATION		The SYSTEM shall allow for up to **40 AXES** of any type and mix to operate simultaneously. When less than 40 are in motion, others may be selected, and further movements initiated

(b) Groups

GROUP	The generic term for a recorded assembly of more than one AXIS or a combination of AXES and / or pre-recorded GROUPs, including a mixture of different TYPES of GROUP
TYPES	A GROUP may be FREE, SAFE or LOCKED It shall be possible to change a pre-recorded GROUP between FREE, SAFE and LOCKED as required

NUMBERS		GROUPs shall relate to SHOWs At least 99 GROUPs shall be able to be formed and recorded per SHOW Any combination of FREE, SAFE and LOCKED GROUPs may be formed as required
SIZE		Each GROUP shall be able to contain at least 30 AXES
LOCKED GROUP	L	A number of AXES which can move together such that each AXIS shall always move the same distance at the same speed within AXIS or SYSTEM parameters; any AXIS getting outside speed, position or load profile window shall cause all AXES in the GROUP to stop A GROUP is therefore an assembly of AXES normally suspending one or more rigidly-interconnected pieces of scenery Having made a LOCKED GROUP, these AXES can be moved confidently to new positions without strain on the scenery
SAFE GROUP	G	Motion of a SAFE GROUP shall be such that individual AXES in a GROUP shall be able to move at different speeds and different distances within AXIS or SYSTEM parameters SAFE GROUPs shall require higher authority to create but shall allow three-dimensional moving and tilting of suspended scenery when different positions are recorded for various AXES Where a complex motion is to be carried out, intermediate positions for intermediate hoists shall be calculated by the system
FREE GROUP	F	In a FREE GROUP there is no interdependence between the AXES A FREE GROUP is a temporary assembly of more than one AXIS or a combination of AXES and / or GROUPs Generally used as a temporary assembly recorded and used within a SHOW for ease of calling up items that are frequently to move together In a FREE GROUP, ONLY any AXIS getting outside speed, position or load profile window will stop; others in the GROUP continue to their destinations

(c) Height, Load & Limit

HEIGHT (COLOUR: BLUE)	H	Overall vertical dimension of scenery or other attachment to an AXIS Scenery HEIGHT shall be able to be recorded for each AXIS Normally associated with REFERENCE DEAD
LOAD	W	The LOAD on each AXIS shall be monitored and displayed on demand A LOAD window for each AXIS shall be able to be set up to monitor the LOAD on an AXIS and to stop the AXIS in the event that the LOAD is outside this window The value of a LOAD WINDOW shall be able to be increased or decreased from the default on an OCP
LIMIT		Preset fixed end-of-travel position beyond which an AXIS will not move under normal operations Exist as SOFTWARE and HARDWARE LIMITS

(d) Deads

DEAD	D	Recorded position (normally height above stage) to which an AXIS will move when instructed
NUMBERS		DEADs shall be able to be recorded as numbers between 0 and 99 The SYSTEM shall support 20 DEADs per AXIS per SHOW
REFERENCE DEAD		One DEAD shall be designated as the **reference from which all the other DEADS are measured** This REFERENCE DEAD must be recorded before all others before or during the hanging of scenery This DEAD shall normally be with the bottom of suspended scenery touching the stage
SETTING DEADS		Selected AXES, individually or as part of a recorded GROUP, shall be able to be MOVED to the required positions and the required DEAD number relating to this position recorded The **individual** position of each AXIS in a GROUP shall be recorded **If enabled**, a position may be keyed in numerically in millimetres above stage level and this recorded as a DEAD number
AVAILABILITY		A recorded DEAD shall be immediately repeatable: there shall be no learning process It shall be possible to record DEADs from any OCP without recourse to any other position or the inputting of any other data
TRANSFER		The DEADs recorded for a given AXIS in a SHOW must be able to be transferred to an alternative AXIS; this will be necessary when an AXIS used to rig one show is not available when that show returns in the repertoire

(e) Moves

MOVE	M	The motion of one or more AXES and / or GROUPS from wherever they happen to be, OR from a DEAD to another position OR to another DEAD either: — At preset SPEED — In a preset TIME (subject to the system maximum speed) — Subject to "joystick" or "indented wheel" control
CONTROLS		The joystick or indented wheel shall be switchable and shall provide both the full speed range and a suitable slow speed for setting operations The slow and fast speeds shall be set as defaults during commissioning
LIMITS		Normal motion shall be between GRID (top software limit) and STAGE (lower software limit) unless a DEAD is selected: this will limit range of travel until deselected
POSITIONING		It shall be possible to position an AXIS easily within the specified tolerance of a required position using the controls and a display on the screen or by following instructions from the stage
TRANSIENT		A MOVE shall be set up on an operational panel each time and initiated using the controls: it is **not** recorded for replay
GO TO DEAD		If a DEAD is selected during a MOVE, an AXIS / GROUP shall move to that DEAD Where more than one AXIS is moving, each shall go to its individual position represented by that DEAD
DISTANCE		It shall be possible to instruct an AXIS or GROUP to move a preset distance in a given direction

(f) Pick & Skip

PICK	Selection of one or more AXES and / or GROUPS from a number called up so it may be MOVED or otherwise adjusted independently while the others remain stationary AXES and / or GROUPS may be added to, or deleted (by subtraction) from, a selection in a PICK operation PICK may be an alternate action key and illuminated when active PICK and SKIP shall be mutually exclusive
SKIP (OR REMAINDER)	Selection of one or more AXES and / or GROUPS from a number called up so it remains stationary while the others MOVE as instructed AXES and / or GROUPS may be added to, or deleted (by subtraction) from, a selection in a SKIP operation SKIP may be an alternate action key and illuminated when active PICK and SKIP shall be mutually exclusive.

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(g) Maximum Speed

MAXIMUM SPEED	The speed set for an AXIS or, if none is set, the default SYSTEM SPEED as determined by the LOAD on the AXIS The speed of the AXES forming a GROUP may therefore be different If no speed is set for an AXIS it will, unless otherwise instructed, travel at the default speed

(h) Actions

ACTION	A	The **recorded** motion of one or more AXES and / or GROUPS normally from one DEAD to another DEAD: — In a preset TIME (subject to MAXIMUM SPEED) — At a preset SPEED — With non-default ACCELERATION or DECELERATION — To a recorded PROFILE (using joystick or indented wheel) — With CYCLING between DEADs in preset TIMEs When TIME is preset, the SPEED of each AXIS shall be recorded An ACTION may be run from any position (whether a recorded DEAD or not) and shall run to the finish DEAD at the ACTION SPEED recorded The REMAINING TIME which the ACTION will take shall be indicated The time for all ACTIONs shall be able to be altered during playback, subject to the MAXIMUM SPEED for each AXIS, using joystick or indented wheel controls

RECORDING	An ACTION shall be recorded by selecting the required ACTION number, initiating RECORD, carrying out the motion(s) required and then selecting RECORD On selection of a previously-recorded ACTION, the movements shall be indicated An ACTION may be cleared
OVERWRITING	The ability to **re-record** or overwrite a previously recorded ACTION shall be subject to a suitable level of identity code
RUN	A pre-recorded ACTION shall be able to be operated, reversed and reset on any suitable operational panel The degree of completion of a movement being run or reversed shall be indicated clearly on the panel To record and play up to four simultaneous ACTIONs on one control panel with the ability to see the operational data and take control and override any or all of these ACTIONs, including changing SPEED, DEAD and other parameters An action created or performed on the operational panel shall be able to be recorded against an ACTION number for the SHOW selected
CAPACITY	The minimum number of recordable ACTIONs per AXIS or GROUP shall be typically 20 per show

(i) Cues

CUE	Q	A **recorded** sequence of one or more ACTIONs with the start of each ACTION simultaneous OR subject to a CONDITION A CUE shall be able to be recorded as the state of the OCP with different AXES, GROUPs and / or CUEs loaded onto separate playbacks or masters to provide individual access to and control of a given AXIS, GROUP or ACTION during playback A pre-recorded CUE shall be able to be operated, reversed and reset on any OCP CUES shall be able to be rerecorded and extended Compiling and recording CUEs and inserting CONDITIONs shall be carried out on the OCPs Up to 9 decimal CUEs shall be able to be inserted between integers The maximum number of recorded CUEs per SHOW shall be 400, including decimal inserts A typical CUE shall consist of 2 ACTIONs and 2 CONDITIONs
SETBACK		It shall be possible to SETBACK all AXES to the positions that correspond to a CUE state, without having to execute all CUEs in sequence

(j) Conditions

CONDITION	A predetermined condition that can be used to start an ACTION forming part of a CUE Required conditions include — The TIME DELAY (in seconds, e.g. T=15) from the initiation of the CUE or from another CONDITION — The POSITION of an AXIS (A36>13000 or D=5) which has to have been reached — The SPEED of another AXIS (A53=50%) which has to have reached a preset figure

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(k) Names & Comments

NAME	N	The alphanumeric name of the scenery attached to an AXIS or to a GROUP A NAME may consist of any QWERTY characters and shall be of up to 50 characters
COMMENT	C	The alphanumeric description of the scenery attached to an AXIS or to a GROUP A COMMENT may consist of any QWERTY characters and shall be of up to 50 characters

(l) Snag, Error, Malfunction & Fault

SNAG	Operational protective situation from which the equipment can be extricated by a relatively easy process, such as reverse operation Typical Powered Flying snags include OVERLOAD, SLACK-WIRE or NO-LOAD
ERROR	Keying mistake by operator; indicated by a soft buzz (software0adjustable) and ERROR message where help can be given
MALFUNCTION	A serious operational difficulty, which requires the operator or an assistant to investigate and take corrective action before the equipment can be operated again Typical Powered Flying malfunctions include POINT HOIST NOT RESET, CONTROL NOT CONNECTED, DRIVE NOT CONNECTED

FAULT	A failure of part of the equipment or system requiring first-line maintenance or the attention of an engineer Typical Powered Flying faults include OVERTRAVEL, CROSSED GROOVE, OVERHEAT, OVER-CURRENT, DRIVE FAULT, SYSTEM FAILURE

(m) Show

SHOW	The alphanumeric description of the PRODUCTION A SHOW must be selected on the Engineering Desk or one of the OCPs in order to allow operations A suitably-authorised operator must make the selection of SHOW The selected SHOW shall apply to all OCPs thereafter until reselected SHOW can only be selected when no motion or pre-setting is taking place.

(n) Kill

KILL K	Lock out a particular AXIS (or GROUP) which is unserviceable or required not to be used in any SHOW Such an action shall also be able to be taken with unserviceable DRIVES in an electrical system employing a matrix system to select DRIVES to AXES

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5.3.4 Control Panel Functions

Table 3 below describes the **minimum** set of control functions to be carried out by each type of Control Panel. The Control Panel software shall be written for true multi-user operation, with a suitable hierarchy which allows access to functions dependent on operator access level, priority of selection and AXIS or GROUP designation.

Functions	Description	OCP	RCP
MOVES	Carry out MOVEs, set and hang scenery and lighting; MOVEs shall be able to be to DEADs or to POSITIONS under the control of a PLAYBACK	✓	✓
SET UP GROUPS	Create and record GROUPs; set GROUP TYPES	✓	✓
DEADS	Create and record DEADs	✓	✓
ACTIONS	Create, record and run ACTIONs	✓	✓
SELECT SHOW AND RUN CUES	Select a SHOW and run pre-existing CUEs	✓	✓
RECOVER FAULT CONDITIONS	Take control of an AXIS or GROUP at will, reset SNAG or FAULT conditions and either restart the original MOVE, ACTION or CUE or otherwise MOVE the AXIS or GROUP so as to permit the performance to continue	✓	✓
FAULT DISPLAYS	Display SNAG, ERROR, MALFUNCTION and FAULT information	✓	✓
ESTOP TRACE	Display E-STOP condition for entire Stage Control System	✓	✓
SETTING PANEL	Provide a section of the control panel with, inter alia, a numeric keypad, +, -, CLEAR and similar controls, AXIS, GROUP, GROUP TYPE, DEAD, ACTION, CUE, TIME/SPEED, DISTANCE, SHOW, RECORD, PICK, SKIP, SCREEN SELECTION, RESET, MASTER, GO/STOP, push buttons and related indicators.	✓	✓
CREATE CUES	Create and record CUEs, including CONDITIONs	✓	
SET SCENERY PARAMETERS	Set REFERENCE DEAD, SCENERY HEIGHT, MAXIMUM SPEED, LOAD WINDOW and similar parameters	✓	
NAMES AND COMMENTS	Edit NAMEs and COMMENTs associated with AXES, GROUPs, DEADs, ACTIONs, CUEs and SHOWs	✓	
SETBACK	Dynamically create MOVEs to take all axes to a particular CUE state	✓	
OTHER MANAGEMENT FUNCTIONS	TRANSFER DEADs to another AXIS Trim the axes in a GROUP using PICK or SKIP Edit and save SHOW information KILL axes or GROUPs and all other Control Panel functions	✓	
ENGINEERING FUNCTIONS	Engineering and diagnostic functions as set out in ER (T) 5.3.7 Engineering Functions	✓	

Functions	Description	OCP	RCP
PLAYBACKS	Provide the specified number of joysticks or indented wheels on which AXES and / or GROUPS can be moved between DEADs, ACTIONs and CUEs replayed, the individual speed of which can be preset and manually adjusted; this shall allow the movements to be better synchronised with the performers or other scenery movements on stage The speed of the movements shall be altered pro rata provided the maximum AXIS or system SPEED is not exceeded Includes LOAD and CLEAR facilities LOADing may take place from the setting panel or directly from the keypad	4	1
CAPACITY	Total number of Control Panels to be supported by system and used simultaneously	8	

Table 3: Control Panel Functions

5.3.5 Control Function Details

(a) Envisaged Operations

The operations shall be as described and implied in this document and in other relevant individual equipment specifications. The system shall allow all reasonable motions, positioning, control and functioning of the equipment items.

(b) Independence

Ensure that all the pre-recorded data for a SHOW shall be able to be used by any OCP or RCP, which shall also be able to operate all functions of any SHOW. Such data shall be available very rapidly when demanded and the Control System shall take full account of the needs of all the specified Control Panels being in full use simultaneously. It shall be possible to operate all the described functions on any Control Panel without any other Control Panel connected.

(c) Visual Feedback

The operator shall always be able to view and check all aspects of a MOVE, ACTION or CUE before initiating motion. The operator shall be given warning of all RECORD functions, which might overwrite previous information and shall have to take further action to carry out the recording.

(d) Double Key Presses

Where double presses of push buttons or keys are agreed to be suitable operational requirements, the system shall respond to these in rapid succession and not require operators to reduce their dexterity.

(e) Movement Buttons

All pushes or keys initiating motion, such as buttons in joysticks or GO buttons, shall be PUSH AND HOLD (Dead Man's Buttons) except in specified circumstances. Such buttons or keys shall not be used for other functions, such as changing state or displaying data.

(f) Show Pre-setting

Shows shall be able to be loaded onto the system using the keyboard and mouse and shall be displayed in as much detail as has been entered previously. Such recall shall either be directly from the hard disk or via the network, or a USB flash drive. The system shall indicate any additional essential information required for safety or logical operation as a consequence of loading of additional or alternative AXES before any sequence can be run.

(g) Recording

All data recorded on any Control Panel shall be stored in RAM and on the main system hard disks. Subject to operator authorisation level, such data may also be recorded in other places within the system, including on to any online backup. For example: data shall be able to be recorded from any Control Panel to any REPERTOIRE SHOW database and such information shall add to or update the existing information for that SHOW.

(h) Changing Parameters

It shall be possible to record or modify DEADs and SCENERY HEIGHT for any AXIS or GROUP from any authorised OCP without recourse to any other Control Panel or the creation or inputting of any other data. It shall not be necessary explicitly to create a GROUP in order to record any number of DEADs or other data for an AXIS.

(i) Load Window

The LOAD WINDOW for an AXIS shall be able to be set to monitor the load on an AXIS and to stop the AXIS in the event that the load is not within this window. The default for this LOAD WINDOW shall be as specified but it shall be able to be increased or decreased from this value using controls on the OCP. See also ER (T) 6.6.5 Dynamic Load Monitoring.

(j) Power Trading

Where bands of loads and associated maximum speeds are given, the AXIS shall have a maximum speed approximately proportional to the load. The maximum speed of a LOCKED or FREE GROUP shall be defined by the most heavily-loaded AXIS in motion.

(k) Hoist Protection System

Design the system to evaluate the load on **all** flying hoists and the speed at which they are moving and hence the power consumption so that the maximum number of bars may be used without exceeding the limits on the power supply. Ensure the system will not allow a set of hoists to be moved if the loads carried exceed the maximum supply rating.

(l) Maximum Speed

It shall also be possible to enter a maximum SPEED for an AXIS or GROUP in a given SHOW, either as a preset, when scenery is being hung, or later, and this speed shall not be exceeded in that SHOW. This speed setting shall be able to be increased or decreased from this value using controls on the OCP or RCP. When first selected in a SHOW all AXES shall operate at the default maximum speed.

(m) Cue Start Point

All ACTIONs and CUEs must be able to be operated without scenery being moved to a preset start point. All DEAD positions must be attainable without being recorded

in an ACTION or CUE. While scenery will normally be in preset positions before CUEs in a performance, in rehearsals it is often necessary to go to a new position from other indeterminate positions. Under these conditions, the AXES shall all travel at an appropriate medium speed to achieve the position at the end of the cue. System maximum speed, or maximum preset speed for an AXIS, shall not be exceeded whatever the travel distance.

(n) Setback Facility

Normally CUEs are made up of a collection of AXES with corresponding DEADs to which to move. This makes it difficult to recreate the positions of ALL AXES that correspond to a CUE without first running all the preceding CUEs in sequence. The Setback facility shall keep a record of where ALL AXES should be at the end of each CUE. If requested to set back to a particular CUE state, the system shall present the operator with a list of moves necessary to achieve that state. The operator will then be able to select which moves they want to execute. The required moves will be ordered by relevance, i.e.: AXES that form part of the current show will be displayed first.

(o) Reset

In order to assist an operator who has become confused, the operations on the operational panels shall be logical sequences. It shall be possible to return from **any condition** through each of these stages using the equivalent of an ESCAPE key.

(p) Operator Warning

Most scenery changes take place in a comparatively short period and it shall be the responsibility of the operator(s) to observe the movements for which they are responsible and to stop the AXES in the event of a dangerous situation occurring. For normal operations this shall be achieved by PUSH AND HOLD buttons or a single Dead Man's Button on the Control Panel.

For long moves which shall be able to take place automatically after being started, the system shall flash an indicator constantly and quietly buzz after a preset time to check that the operator is still at the controls. To allow the move to continue the operator shall have to momentarily press a conveniently-placed push button. If the button is not pressed within 5 seconds, the moves in progress come to a controlled stop. The move time and maximum speed shall be defaults. This "overriding" of the Dead Man's Button principle shall have to be enabled on an individual cue-by-cue basis by an operator with a high authorisation level, details to be agreed with the Consultant.

(q) Motion Profiles

Trapezoidal and S-ramp acceleration / deceleration profiles shall be provided as standard. The default profiles shall be S-ramps. Programmable motion profiles of an action (acceleration curve, variation in speed, deceleration curve and similar) as carried out by the operator using the joystick shall be able to be recorded as part of an ACTION and reproduced automatically. Such a profile, and any ACTION or CUE, shall also be able to be entered and edited using standard computer procedures on any OCP or any suitable external computer either via disk or via the LAN / WAN network. Each OCP shall include a mouse or approved tracker ball or equivalent for use in this procedure.

(r) Direction Changes

Motion profiles that include one or more smooth changes of direction shall be easily programmable without needing to record the profile being executed by the operator with the joystick.

(s) Acceleration & Deceleration

It shall be possible to change from the default settings of acceleration and deceleration for a movement. Where these parameters need changing in an ACTION, they shall be able to be RECORDED either as a PROFILE or by setting a suitable trapezoidal or S-ramp. Default acceleration and deceleration shall not be displayed to the operator unless requested.

(t) Speed Changes

The system shall accept any logical change or new instruction at any time, including during the motion of hoists, and shall process and implement the new instructions. The result shall be a smooth transition and continuing motion of the hoists at a new speed or direction, or controlled deceleration and stop. Where the new instruction requires hoists to travel at greater than maximum speed, they shall travel only at the maximum for each AXIS and related hoists shall travel at the correct pro rata speed. Under these circumstances the operator shall be advised that the move is not being carried out as instructed.

(u) Restricted Control of Axes

Allow for a System Administrator to be able to limit which AXES may be controlled from a particular OCP / RCP outlet. A default selection, agreed by the Consultant, to be set during commissioning.

5.3.6 Screens & Display

(a) Graphics

Specially-designed graphics shall be used for the Control Panel displays. These shall take special account of the difficult lighting conditions and stress sometimes involved in operating such systems and shall provide clear and uncluttered images. The colour of graphic elements and backgrounds shall be user-configurable and include the option of a BLACK background for maximum display contrast.

(b) Information Display

All visual display units, and character and graphic displays shall be positioned so as to be readable by any typical height operator and of a size so that the display can be interpreted correctly with normal eyesight from a distance of 2m. Displays shall show primary data at all times relating to the functions being carried out and shall be selectable rapidly and simply to provide information on other activities and additional data (such as LOAD, processes in an ACTION or CUE, special ACCELERATION and DECELERATION) when required. The screens shall NOT be confused by the inclusion of superfluous additional data. The data on and form of each screen shall be agreed in detail with the Consultant before implementation.

(c) Displays

Each OCP or RCP shall be able to display the following data (inter alia) in some approved form. The basic operating screen shall provide clear alphanumeric data of the current activities on that Control Panel. Support data shall be available immediately in the form of pop-up displays or similar operated by push buttons, the tracker ball and / or touchscreen. By moving the icon to specific parts of the screen, further data on that element or function shall be available. Access to some data shall be able to be restricted depending on management level.

(1) **BASIC OPERATING SCREEN**: details of the AXES and GROUPs selected, the types and contents of GROUPs, their STATUS, the AXES and GROUPs on each PLAYBACK, condition of the MASTER, the actual

or preset motion as an ACTION or CUE, position and destination whether as DEADs or not, TIME and / or SPEED, SETTING PANEL or PLAYBACK loads, and similar data necessary to carry out the operations.

(2) PICTURE SCREEN: screen illustrating the selected suspended AXES as vertical bargraphs, showing GROUPING, SCENERY HEIGHT, recorded DEADs and similar. Where large numbers of AXES have to be displayed, two or more alternative screen pages shall be provided. Screen also has limited alphanumeric data.

(3) 2D and 3D VIEWS: screens offering two- and three-dimensional views of all current and future AXES connected to the system shall also be provided.

(4) POP-UP – DATA: SCENERY HEIGHT, AXIS and GROUP NAMES, non-recorded DEADs, non-default ACCELERATION and DECELERATION, physical LOADs and similar supporting information.

(5) POP-UP – DEADs: all DEADs recorded and available for a given AXIS and / or members of a GROUP, with names where keyed in.

(6) REPERTOIRE SCREENS: a number of screens showing all AXES with their GROUPs, DEADs and other data which are used in other REPERTOIRE SHOWs.

(7) DEVELOPMENT SCREEN: creation, numbering and sequencing of ACTIONs and CUEs, inputting of CONDITIONS, creation of PROFILEs and similar.

(8) POP-UP – AVAILABILITY: AXES, GROUPs, ACTIONs and CUEs in use on other OCPs and RCPs.

(9) ENGINEERING FUNCTIONS SCREENS: screens relating to the status of all hoists, drives, processing, memory and similar.

(d) Problems

All screens shall contain a specific area for display of data relating to SNAGs, MALFUNCTIONs and FAULTs. This data shall appear, together with the cause and the immediate remedial action which the operator can take.

(e) Load Display

The load suspended from an AXIS displayed in full units of kilograms (kg). The load weighing system or device shall be accurate to ±5% and the display rounded up. It shall be possible to monitor load with the AXIS in motion.

(f) Position Display

The position of the bottom of a bob-weight eye above the stage at nominal zero level shall be displayed in units of 1mm. The display shall preferably show full metres in large numerals and 3 places of decimals in smaller numerals. If all characters have to be the same height, the position shall be displayed as full metres, decimal point and 3 places of decimals. Other figures shall be rounded up or down. The display shall be static when the hoist is not moving.

(g) Hoist Display

The Engineering Functions display shall be able to show a vertical representation of the hanging of the Multi-line Hoists used in a SHOW and, where entered, the HEIGHT of the hanging pieces. The whole installation shall be shown on 2 or 3 switched screens and parts of the installation, such as GROUPs or SHOWS, shall be accessible for operations, setting up and planning work. These displays shall show a clear graphical representation of the hoists in motion. All these displays shall include the status of selected hoists (AXES, GROUPs, POSITION, LOAD, ACCELERATION, DECELERATION, use in ACTIONs and CUEs and similar). Screens shall be available showing only hoists used in the SHOW or those selected to move.

(h) E-STOP Display

The activation of an Emergency Stop control shall be indicated on each OCP and RCP along with data as to which AXES were in motion and the status of the system so that the actuating device can be speedily identified. Each activation and reset shall be recorded, together with the time, in the system event log. A number of indications can be shown at a time if more than one control has been activated. Each indicator shall remain illuminated until the relevant push button or grab-line is reset locally. A test condition shall be provided to verify the operation of all the indicators.

(i) Names & Comments

It shall be possible to enter and save full text NAMEs and COMMENTs for AXES, GROUPs, ACTIONs, CUEs and DEADs using a QWERTY keyboard to assist the operator. Where text names or comments have been added, these shall be able to be displayed as part of relevant screen or display. It must be possible to input and access such data at any time from the QWERTY keyboard on another OCP or computer without having to be in a different mode or state.

5.3.7 Engineering Functions

(a) Access

The engineering functions shall be accessible from any OCP or a PC running the Engineering Functions Software and having the appropriate security clearance. The software shall include all the facilities to set up the system, load hoist and other driven AXIS data, load and upgrade the operating systems, preset shows, carry out hardware and software engineering service and maintenance functions, log usage and operate all the management functions offered. Access to the Engineering Functions shall require a higher-level authorisation than shall be required for the normal OCP operation.

(b) Safety

Under no circumstances shall it be possible to set into, alter or stop the motion of any machinery from within the Engineering Functions Software even if it is running on an OCP. The initiation, alteration or cessation of machinery motion shall only be possible using the physical control buttons / wheels on an OCP or RCP.

(c) Simulation

It shall be possible to operate ACTIONs and CUEs using the Engineering Functions to simulate on the visual display unit the sequencing and motion of the hoists without movement occurring on stage. The visualisation shall be able to include all the AXES in use in a SHOW and to indicate DEAD positions, SCENERY HEIGHT and similar data. The video display shall use colours related to control buttons and other displays where applicable.

(d) Show Preparation

DEADs, GROUPs, HEIGHTs, NAMEs, ACTIONs and CUEs shall also be able to be set up using the Engineering Functions on a compatible computer remote from the system and downloaded using standard computer peripherals, the local LAN network and other interfaces. Basic keying operations shall be similar between OCPs and a regular PC or laptop.

(e) Network Link

The computer system link into the Building LAN shall be such that pre-setting, engineering and fault analysis can be carried out from other compatible computers elsewhere in the building. The ability to link into this proprietary network

shall be demonstrated fully during the commissioning process.

(f) Maintenance

The software shall include maintenance programs that shall complement the information in the manuals by providing a real-time reminder of works to be carried out. This shall include the operating duty and service records of each item of mechanical equipment. The engineers shall be able to login and update the servicing record of each item as part of the system database.

(g) Technical Support

The Engineering Functions Software shall provide access to Fault-Finding and Remote Diagnostic programmes. The SEC shall provide, within the tender price, for the following support and response over the first **12 months** from date of hand-over of the complete system:

(1) Telephone support 24 hours a day for the first 3 months of use of the installations.
(2) Telephone support for a period from 0800 to 2200 (local time at the site of the installation) daily 7 days a week for the next 9 months.
(3) Attendance at site within 24 hours of notification when formally requested for a reason when the User's staff cannot correct a significant malfunction or fault.
(4) Carrying out of any physical or hardware repair or replacement within 36 hours of formal notification.

Ensure suitable experienced staff, who were involved in the installation, setting to work and testing of the systems and installations are available to advise and assist with any technical problems that arise. This technical support forms part of the full warranty required by the contract.

(h) Upgrades

The ER (T) 5.4.2 (f) Remote Diagnosis facility shall allow the easy installation of software upgrades and other developments made by the SEC. The SEC shall undertake to provide any developments, that are made to the Control System software for other users and are required by the User, free-of-charge for at least the first five years.

5.4 Central Control System

5.4.1 General

(a) Purpose

The Central Control System shall provide the central processing necessary to carry out all the operations offered by the Stage Control System. The Central Control System shall also incorporate extensive hard disk servers and methods of transferring data on removable media to and from the system.

(b) Engineering Approach

The engineering monitoring of the computer hardware and software depends on the details of the system offered and shall be proposed by the SEC. The system shall boot up automatically and most of the Engineering Functions shall be hidden from the operator unless affecting their use of the system. In this event, clear visual statements and, where relevant, audible warnings shall be given.

(c) Distributed Control

The Control System may include distributed processing as represented by current motor drive technology. This shall enable each hoist to monitor its own performance, to respond to detailed commands and to send messages back to the central Control System as appropriate.

(d) Safety

The Control System shall provide brake release signals only when drive power, velocity and positional signals are present and correct and shall respond immediately to speed, position or load errors, motor overheat and similar safety-related trips and act immediately to make the system safe. Any system SNAG, ERROR, MALFUNCTION or FAULT of any type or nature shall result in any motion being brought to a stop safely. Fully demonstrate this feature of the installation during commissioning.

(e) Group Stopping

If an AXIS in a GROUP has to stop for any reason such as a FAULT or SNAG, ensure that all other members of the GROUP stop with the same ramp profile in order to maintain the required GROUP position synchronisation. Do not stop AXES using maximum drive current as the stopping distance will vary with load resulting in a loss of synchronisation. If one or more AXES make an uncontrolled stop then perform a synchronous stop on all remaining AXES in the GROUP using the fastest deceleration rate that is consistent with safety of the hoist, rigging and payload.

(f) Multi-User Operations

Any number of OCPs or RCPs shall be able to be used at the same time up to the maximum specified. The AXES to be used on a particular Control Panel shall be designated to it by the System Administrator. These will depend on the position of the outlet into which the Panel is connected. Otherwise, selection from a Control Panel shall be on a first-selected basis, with selected AXES and their related GROUPs being made inaccessible from other OCPs or RCPs until released.

(g) User Interface Latency

Stage Control Systems are frequently operated under extreme time pressure. Table 4 below sets out the absolute maximum user interface delays for essential functions. Irrespective of the response times given here, the operator shall not perceive a need to wait for the control system.

User Interface Response Times	
Load AXIS or GROUP ready to MOVE	300ms
Load a CUE ready to START	500ms
Record DEADs, ACTIONs, CUEs	1s
Load a SHOW	5s
OCP / RCP start up from POWER OFF to READY to accept commands	30s
OCP / RCP start up from STANDBY or SLEEP to READY to accept commands	5s

Table 4: User Interface Response Times

(h) Motion Start Latency

Movement must initiate immediately a GO or equivalent button is pressed. The control system latency between the operator pressing a button to set an AXIS or group of AXES into motion and the AXIS drive(s) receiving a command to move shall be no more than 100ms. It is accepted that there will be mechanical delays for brakes, etc., to release (see ER (T) 3.2.5 (c) Brake Release Speed) but the "command" part of the Control System shall not impose a significant delay. Minimise mechanical delays so that the overall control and mechanical delay does not exceed **500ms**.

(i) System Setup

The system shall be set up automatically and shall carry out test, self-diagnosis and any calibration functions without recourse to the operator except in special circumstances. Any OCP keyboard shall allow interrogation and adjustment of the system setup parameters using the engineering displays. It shall also be possible for the System Administrator to initialise the system this way and to change passwords, hoist and system parameters (such as software limits, default speeds, default accelerations and decelerations, load windows, etc.).

(j) System Database

The data relating to AXES, DEADs, LOADs, HEIGHTs, NAMEs, COMMENTs, GROUPs, servicing processes, etc., and the use of AXES in SHOWs, GROUPs, ACTIONs and CUEs shall be maintained in a computer-industry standard database and shall be available for interrogation using standard computer equipment both inside and outside the main system.

(k) Data Backup

The Central Control System shall provide some form of online backup so that information being recorded on any OCP or RCP as part of the operation of the system is backed up automatically without interfering with the operations or requiring specific actions by the operator(s). This may mean that data is recorded rapidly in two locations simultaneously and that only the recent changes are recorded.

(l) Event Log

The system shall keep a continuous and timed software data record of all operator keying by username and Control Panel, ERRORs, SNAGs, Emergency Stop activations and both system and AXIS MALFUNCTIONs and FAULTs. These shall be able to be analysed and printed out from the OCPs or a PC on the LAN or WAN.

(m) Software

All necessary software to operate and maintain the system shall be provided, including that to format and print reports and to analyse the operational keying and ERRORs, SNAGs, MALFUNCTIONs and FAULTs experienced by the system.

(n) Fault-finding

The system shall have advanced diagnostics to minimise the time necessary to trace and eliminate faults. These shall be suitable for use by trained operational personnel and shall not depend on attendance by the SEC.

(o) Hoist Disable

Provide facilities to disable certain hoists and control features if they are unserviceable or would be dangerous to make available to all users.

5.4.2 Hardware Requirements

(a) Location

Locate the central computer systems and other peripherals in a secure, lockable cabinet or room; details to be agreed with the Consultant.

(b) Outlet Units

The OCPs and RCPs must share a common outlet mounted in approved panels at agreed heights in positions to be detailed on site. On each panel include a second outlet for a remote DMB push. Stove-enamel or powder-coat the panels to a high standard and clearly identify them with a single discrete number at least 20mm high.

If required, incorporate an Emergency Stop connection in each Control Panel outlet, and arrange that, if no Control Panel is connected, the E-STOP sensing loop shall be automatically closed.

(c) Data Storage

Provide a USB flash drive interface on each server and all OCPs. With each OCP supplied, include a USB flash drive of sufficient capacity to store twenty SHOWs. These storage devices shall be able to be used for system upgrades, diagnostics, downloading and uploading SHOW data and similar operations

(d) Printer

Provide a high-quality reliable and silent printer to print out data from the system. It shall be able to print easily and quickly lists of the status of all the AXIS features, including information on the electrical drives, hoist settings and other physical parameters. Such listings shall be clear and shall highlight the abnormal. The printer shall be able to be switched to prepare, as standard forms, other engineering and operational records such as SHOW information, AXES and GROUPs used, DEADs, SCENERY HEIGHTs, LOADs, ACTIONs, CUEs, etc., in a range of operator-designed formats.

(e) Uninterruptible Power Supply

The system shall include **at least two** Uninterruptible Power Supplies (UPS) to maintain in operation all the electronics and processing for **each** "half" of the control system. This shall be a transformer, line interactive type providing changeover from mains to inverter with minimum break. This shall ensure no loss of data and an assured shutdown sequence in the event of mains failure. Any AXES in motion shall be brought safely to a stop.

The operation of the Central Control System, Control Panels, and all necessary peripherals shall be maintained by a UPS for a minimum of 15 minutes. Arrange for a clear warning message to be displayed on all OCPs and RCPs advising of the power failure and the remaining time before the UPS shuts down.

In the event of a UPS failure, any "common" loads such as control desks shall automatically be transferred to another UPS. The inputs and outputs of the UPSs shall be pluggable so that the entire UPS can easily be bypassed in the event of failure and the system run without a UPS.

Noise from the UPS units is to be included within the overall noise limits set out in ER (T) 6.1.2 Noise Limits. The units shall be selected for quiet operation and located accordingly and, where necessary, mounted on vibration-isolating pads.

(f) Remote Diagnosis

The system shall include some form of remote interface with software so that, if necessary, its operations may be monitored remotely and advice as to problems sent direct from the manufacturer's design team to the onsite maintenance crew. Use a permanent connection such as a dedicated ADSL line or a LAN routed to the Internet. Due regard must be given to security issues and the use of a VPN and/or a suitable security appliance is mandatory. Arrange to provide this service during normal working hours for **5 years** from date of handover.

(g) Security of Control LAN Ports

All physical access to the control system network must be protected by either:

- The use of non-standard connectors (**not** RJ45).
- Installation of ports in lockable enclosures.

— Installation of ports in lockable rooms, subject to Consultant approval.

(h) LAN / WAN Interface

Provide an interface between the Control System and the LAN / WAN (Intranet) within the rest of the Building for engineering diagnosis, production planning and pre-setting of show data. The transmission protocols should be restricted to a small number of ports. Obtain details of the Building IT system from the Employer.

Protect the Stage Control System network from the Building LAN / WAN with a high-quality, commercial security appliance to be approved by the Consultant.

5.4.3 System Default Settings

The system defaults as set out in Table 5 below shall be software-adjustable by the System Administrator.

Default Settings	
DEFAULT SPEEDS	STAGE FLY SETS and POINT HOISTS: 50% of their maximum speed at the applied load
OVERRIDE DEAD MAN'S CONTROLS	For non-maintained Dead Man's Button operation: less than 0.3m/s and a move taking more than 15s
ACCEL & DECEL	Set these to be proportional to the Default Speeds given above
MOVE SPEEDS	Set in consultation with Consultant during commissioning
SCALE FACTORS	Set during commissioning
LOAD CHANGE	Set up initially to detect a load change of ±20%

Table 5: Control System Defaults

5.5 Telemetry

5.5.1 Purpose

In order to manage a Powered Flying installation effectively, good quality telemetry on every aspect of the system is essential. Unexplained incidents occur with complex systems and they can only be investigated fully with "hard: data, much like the "black box" provides on an aircraft.

5.5.2 Signals to be Monitored

Table 6 below summarises the important system parameters that should be monitored and when they should be continuously recorded. Arrange to identify and monitor any other key variables within the equipment that the Consultant deems appropriate. The spare inputs shall be accessible at Grid or Machine Room level for the temporary connection of telemetry signals, details to be agreed with the Consultant.

Analogue signals refer to continuous variables that can be physically sampled using A-D converters or transferred from the drives or control system digitally via a fieldbus or similar.

Sub-System	Analogue	Digital	Recorded When
Drives	Motor Torque Actual Speed Demand Speed	Drive Enable Drive Ready Line Fault Over Temperature	During moves
Hoists	Load Cell	Top Ultimate Limit Bottom Ultimate Limit Top Initial Limit Bottom Initial Limit Slack Wire Overload Crossed Groove Brake Trace Motor Overheat Local 24V PSU Isolator Status	During moves
E-STOP System		Activated	State changes
System Power Supplies	ALL	ALL	State changes
UPS (all)		Online	State changes
Spares	4	8	During moves or state changes

Table 6: Schedule of Typical Telemetry Signals

5.5.3 Sampling Performance

Table 7 below sets out the minimum quality of the sampled telemetry data:

Data Acquisition Performance	
Analogue sampling rate	Minimum of 100Hz (10ms sample period)
Digital sampling rate	Same as analogue sampling rate
Sampling skew	Maximum of ±½ sample period worst case between channels
Analogue resolution	8 bits (unipolar or bipolar)
Analogue conversion	Monotonic, linearity ±½ bit
Galvanic isolation	Yes

Table 7: Data Acquisition Performance

5.5.4 Service Records

Any hoist "incidents" such as safety trips shall be automatically recorded in the hoist's service records. In addition, the date, time and duration of all hoist moves shall be recorded, and a total running time accumulated for each item.

5.5.5 Failure

Design the telemetry system so that no malfunction or failure of the telemetry system shall affect the Powered Flying or Stage Control System, or the control of other stage machinery in any way.

5.5.6 Universal Reference Clock

The telemetry system shall share a common time reference with the Control System ER (T) 5.4.1 (I) Event Log so that all system events can be correctly sequenced. Any system event shall be time-stamped to a time resolution equal to the analogue sampling rate.

5.5.7 Presentation of Data

Telemetry data shall be accessible from any OCP or a standard computer on the LAN or WAN running the Engineering Functions software. The database of telemetry events shall be searchable by time, date, hoist number, cue number, show details, etc., so as to make it easy to find and display all recorded information pertinent to a particular incident.

5.5.8 Telemetry Software

Base the telemetry software on commercial off-the-shelf (COTS) data acquisition, manipulation and display software. The Principal shall be able to modify and adapt the display screens and produce printed records of incident data. The choice of COTS software shall be agreed with the Consultant.

5.5.9 Storage Capacity

Design the telemetry system to store at least two months' worth of events assuming a worst-case usage factor to be agreed with the Consultant. Include a utility that allows either days, weeks or months of records to be archived to CD / DVD-RW or other storage media for later retrieval and analysis.

5.5.10 Garbage Data Removal

Provide facilities to automatically delete the oldest telemetry records should the system run short of storage space. No data shall be deleted without a clear instruction from the System Administrator. Arrange for an email notification to be sent so that an instruction to archive or delete records can be given. The email shall identify the exact periods of operation for which records are about to be deleted.

6 Components

6.1 Acoustic Performance Requirements

6.1.1 General

(a) Acoustic Terms

The technical acoustic term used herein is: $L_{Aeq,T}$ the "A-weighted" equivalent continuous sound level that is used to measure intermittent noise. This noise level, which is defined below for each item of equipment, shall be measured (with an "F" meter response) over the duration of the move at the worst-case location in the auditorium, mostly likely the front row of the stalls.

(b) Acoustical Responsibilities

The SEC is responsible for minimising both electrical and acoustic noise from the equipment forming part of the Contract. The noise limits given for the equipment apply at all times and to electrical drive equipment, brakes, locks, clutches, cooling fans and similar peripheral items. Design noise out of the installations such that minimum adjustments are made in late corrective measures. All stage machinery equipment and installations shall be designed in accordance with the acoustical performance requirements set out in the Appendix 1 - Employer's Requirements (Specific) which, where applicable, take precedence over these clauses.

(c) Noise Generally

All equipment shall operate quietly and all mechanical rattles, squeaks, guide noise, gearbox coupling and other extraneous noise chatter shall be eliminated. All elements of the construction shall be sufficiently rigid to avoid excessive generation of noise by panel excitation, as a result of movement or impacts on the surface or from other causes.

The SEC shall comply with maximum noise levels specified in the Individual Specifications. Wherever sound insulation is necessary, this shall be provided by the SEC who shall ensure that such sound insulation does not cause overheating of the equipment or other problems. Sound insulation shall not be used to eliminate noise caused by unsatisfactory engineering or poor component selection.

(d) Achievement & Tests

Further assistance in respect of this term and achieving the noise levels required may be sought from the Project Acoustics Consultant. The Acoustics Consultant will witness noise testing carried out by an independent organisation at the cost of the SEC in the event that there is any concern about the noise levels achieved.

(e) Vibration Control

All equipment shall operate without undue vibration. Sympathetic vibration of any parts due to manual or mechanised operation of any equipment under performance conditions shall be eliminated. All parts shall be fitted with vibration-proof fixings. All nuts and bolts shall be fitted with shake-proof washers, Nyloc nuts or similar. This shall apply to all machinery, portable items, suspended items and to any part of the installations which may vibrate, flex or move in use.

(f) Vibration Isolation

Motors, gearboxes, brakes, transmissions, switchgear, etc., and all associated services shall be isolated from the building structure via resilient mounts or other appropriate flexible connections as necessary to meet the noise limits. A good quality vibration isolation system should provide 95% isolation efficiency at typical drive rotational frequencies.

(g) Sound Reducing Slots

If required, install sound reducing enclosures around each of the openings through which wire ropes pass into the external motor rooms. Make the height of the slots at least **ten times** the minimum slot dimension and face the interior of the slots with 25% open area perforated metal with a maximum hole diameter of **3.5mm**. Back the perforate with **50mm** thick tissue-faced mineral wool of minimum density **48kg/m^3**.

(h) Motors & Drives

Where possible, select motor control equipment so as to use low speed motors and high frequency control units and inverters (16kHz or above). Provide sound absorbent enclosures around the motors where necessary to reduce high frequency noise whilst ensuring maximum temperatures are not exceeded. Remove cooling fans attached to motor drive shafts where these are operating at low duty cycle and their removal would not cause degradation of performance or premature failure. Otherwise select all fans for low noise operation and attenuate all fans as necessary to meet the noise limit.

6.1.2 Noise Limits

(a) Base Noise Levels

The noise-creating elements of moving equipment which is remote from the stage area shall be enclosed and the resulting noise shall be baffled so as to reduce the sound pressure level to a maximum of **60dB(A)** at a distance of 1m from the unit. The noise level generated by any Control Cabinet or other ancillary equipment shall be **≤30dB$_{LAeq}$** at 1m from the unit.

(b) Powered Flying

A Powered Flying System will often be operated as part of a performance and in the presence of an audience. The operating noise level from **three or more** flying sets, operating together at **half the final maximum speed** and carrying **half the full specified load**, shall be **≤25dB$_{LAeq}$** in any part of the auditorium.

(c) Stage Control System

The operating noise level from the Stage Control System shall be **≤20dB$_{LAeq}$** in any part of the auditorium. To achieve this limit, the control equipment cabinets may have to be located outside the fly tower in an overstage machine room. Where practicable, control racks shall be convection cooled. Noise from Operational Control Panels and Rigger's Control Panels and other equipment used within the fly tower shall be **≤30dB$_{LAeq}$** at 1m from the panel.

6.1.3 Performance Noise Levels

All equipment used during performances (including all rotating, moving or reciprocating parts, pneumatic exhausts, contact breakers, transformer and thyristor controls and similar) shall be designed and / or enclosed so as to not cause the noise level to exceed the criteria set out in the Appendix 1 - Employer's Requirements (Specific). Where no other criterion are given, the noise level shall not exceed the following criteria at any point in the defined areas, measured at between 1m and 2m above floor level:

In any part of the auditorium	NR20

In any part of the performance area	NR20
In control or translation rooms	NR25

6.2 General Mechanical

6.2.1 Structure & Steelwork

(a) Building Structure

The building structure, including any grid, galleries, head and loft steels and other major parts of the building indicated as being load bearing will all be constructed to carry the loadings indicated or implied by the project drawings and specifications. Any discrepancy in respect of loading and apparent structural strength identified or noticed by the SEC shall be reported immediately.

(b) Secondary Steelwork

All stage rigging and machinery steelwork supplied and installed by the SEC, including welding, drilling and all steel bolts, nuts and washers used in assembly and installation, shall be provided in accordance with the specified Standards. The steelwork may be of bolted or welded construction except where a specific construction is indicated on the drawings. The SEC's working drawings shall show clearly the detailed construction of the steelwork, the type and size of nuts and bolts and the size and types of welds. Site welding shall be minimised and only carried out where specifically approved.

(c) Design of Steelwork

All component members of any frame or structure shall be rigid enough to ensure unrestricted operation of all equipment under any load up to maximum and any specified or implied operating condition. Such frames and fixings to them shall withstand shock loads including those imposed by Emergency Stops.

(d) Lateral Loads

Ensure the steelwork supporting Multi-line and Point Hoists and all diverter and drop pulleys, rolling beams, and similar are efficient and well-planned, and arranged so that minimum lateral forces have to be taken out to the building structure. Details of any required constraints and of the final loads on the building structure shall be formally submitted to the Engineers for approval prior to fabrication.

(e) Progressive Collapse

Any stage rigging and machinery steelwork shall be designed to preclude the possibility of progressive collapse. All frames and structures shall be designed to minimise the effect, and likelihood, of welding failures. In the event of any such failure no stress in excess of the maximum permissible shall be imposed on any other member, but deflections in excess of those specified would be allowed until corrective action can be taken.

(f) Deflection

Generally, stage equipment shall be designed with maximum deflections less than those specified or implied in Standards relating to normal building structural components. Particular members will have to be designed for a lesser deflection in order to comply with the operational requirements and accurate alignment of the parts of the equipment. Comply with all detailed parameters given in the Appendix 1 - Employer's Requirements (Specific) which take precedence over these clauses.

(g) Stage Floor Loadings

Main stage, rear or side stage **fixed** floor surfaces shall be designed to carry a distributed load of 7.5kN/m^2. The local or point load supportable shall be not less than 5kN applied over a 300 x 300mm square. Where particularly heavy items are to be moved over the stage area floors, such as orchestra shell towers, audience seating or similar, or equipment on air bearings, the loading shall be increased appropriately. Similarly, stage, side stage or orchestra pit **Elevators** shall be designed to take a distributed load of 5kN/m^2 when static. The local or point load supportable shall be not less than 3.6kN applied over a 300 x 300mm square.

(h) Natural Frequency

The stiffness of all structures forming part of a stage or performance surface shall provide a satisfactory natural frequency for setting scenery and acting. Such surfaces shall include stage and forestage Elevators, stage wagons, rostra and similar. All such parts shall be designed to prevent the sympathetic vibration of scenery or properties caused by movement by actors, performers or technicians. The natural frequency shall not be less than 10Hz under a loading of 2.5kN/m^2. This necessitates designing for the required small deflections under this working load. Larger deflections are permissible under the maximum static load that the structure may have to carry.

(i) Flooring

In designing parts of the installation to which flooring or panels are to be fitted by others, the SEC shall provide suitable fixings or holes to which the material may be conveniently attached. The SEC shall ensure that any moving parts maintain suitable clearances at all times and shall specify these, and show the flooring or panels, on their drawings. Gaps between elevators, revolves and fixed stage floors shall not exceed 8mm or reduce below 2mm.

(j) Dip Traps

Unless stated otherwise, use #216 SOSS Invisible (secret) hinges from www.soss.com. If required, provide a pressed steel tray below the trap opening to support loose cables and other items.

(k) Lighting Rails

These shall be either 48mm ±2mm steel or aluminium tubes or standard DIN rail back-to-back channels as specified. Lighting rails shall be clear of other fittings and obstructions to allow the mounting of luminaires. Where lighting rails are to be adjustable, this shall be achieved using hinged or sliding devices which can be locked in position using the Project Rigging Spanner.

6.2.2 Fixings & Anchorages

(a) General

All fixings to steelwork, walls and structural ceilings shall be appropriate for the loads carried and shall be positioned so that the equipment is plumb and level. Fixings shall be designed so as to minimise eccentric loads on structural members. All anchorages and fixings shall be pre-planned, submitted for approval and shown on the shop drawings. All fixings and anchorages are the responsibility of the SEC.

(b) Safety Factor

All fixings carrying significant loads shall be adequately sized and designed generally for a minimum factor of safety of **SIX**.

(c) Suspension Points

Any general-purpose suspension points shall be proof tested with an agreed load. An approved label shall be permanently fixed adjacent to the suspension point stating the Safe Working Load, a unique identifying code and any usage restrictions such as the direction(s) in which a load may be safely applied.

(d) Preferred Form

All major loads, particularly those of stage engineering equipment, shall be taken back to steel members or to steel plates embedded into concrete walls or ceilings.

(e) Expansion Bolts

Appropriately sized expansion bolt fixings may be used in shear in concrete walls. In no circumstances shall pre-cast concrete panels or in situ concrete be drilled without the prior specific approval of the Employer's Structural Engineer. All expansion bolts shall be correctly fitted.

(f) Other Fixings

Where other constructions are used, equipment shall be mounted using appropriate and approved proprietary anchorages. Proprietary chemical fixings, which are in general use, may be acceptable. All fixings shall be secure and rigid. Inadequately fixed equipment will be rejected.

(g) Lightweight Fixings

All lightweight fixings to masonry or concrete walls and ceilings shall be made with greased sherardised steel woodscrews and shaped plastic plugs. Wood or fibrous plugs shall not be used. All fixings shall be fitted to the correct depth in the wall material and not in gaps between the masonry. In damp or exposed situations greased brass screws and soft metal non-deteriorating plugs shall be used. Approved proprietary fixings which are driven into specific types of wall by hammering or rotating are acceptable.

(h) Bolts & Screws

The diameter of bolts or screws used shall be the largest permitted by the diameter of the hole in the apparatus concerned and bolts and screws shall be to metric standard and of adequate length. When attaching any item of equipment all bolt or screw holes designed or provided for fixing therein shall be used and the attachment in each hole shall be secure. Bolts shall have at least three full turns of thread showing above the final nut or locknut.

6.2.3 Paint & Finishes

(a) Preparation

All parts shall have a smooth finish and have all burrs and sharp edges removed. Rough cuts and rough welds will not be accepted. All parts shall be degreased prior to painting. All ferrous surfaces shall have rust removed and shall be prepared with a rust preventative. Structural members shall be sandblasted and treated with a rust preventative prior to leaving the factory.

(b) Painting

All components which have to be painted shall have one coat each of primer and undercoat and shall be finished in accordance with the equipment specification. Any damage to the preparatory coats of paintwork must be made good without delay and all rust patches cleaned back to bright metal and correctly painted.

(c) Omissions

Technical equipment items such as motors, gearboxes, brakes, transmission components, load and rating plates, serial numbers, connectors and similar items shall NOT be painted. Where instructions are given for components for use on stage to be painted, load, rating and serial number plates shall be left untouched.

(d) Site-Welding

All welds shall be cleaned down and correctly painted immediately they are finished. Tubes and similar components with interior surfaces which cannot be protected shall have their ends completely sealed to prevent rusting from the inside.

(e) Permanent Marking

All demountable parts shall be tidily and indelibly labelled to ensure correct reassembly. All factory identification marks shall be removed after installation and checking on site.

(f) Finishes

All fixed and moving steelwork in the lower part of a theatre stage area shall be finished MATT BLACK. In other areas it shall be as specified in the individual specification. The SEC shall seek confirmation and detail of all painting instructions before undertaking the work.

(g) Purpose-Made Equipment

All purpose-made equipment shall be finished to a high standard whatever the material or detail. All finishes shall be stove-enamelled, unless agreed otherwise. Finishes on all panels and cabinet facias shall be non-reflective.

(h) Aluminium

Aluminium tubes and sections which are specified as being other than natural finish shall be powder-coated or treated by some similar approved method. Sections used in structural or equipment applications which may be seen in view shall be finished MATT BLACK.

6.2.4 Labels, Signs & Notices

(a) Serial Numbers

Mark every machine indelibly with a unique serial number, the format, sequence and method of such marking to be reviewed with the Consultant.

(b) Warning & Safety Notices

Mount suitable durable and approved notices advising of the safe procedures for operation of the equipment and for treatment for electric shock and similar in all equipment and operational areas. Typically, notices shall be fitted to equipment cabinets, each row of hoists, switchgear and at the access points to Machine Rooms, on the Grid and other work areas. Manufacture only when wording, size, colour and format proposed by SEC are approved by the Consultant.

(c) Informative Notices

Provide all equipment with suitable signs and labels indicating pressures, Safe Working Loads, voltages present, maximum simultaneous operations and other safety information. The weight of safety curtains, stage dividing doors, their counterweights and similar major loads shall be displayed on the item.

(d) Equipment Labelling

All equipment enclosures shall be clearly labelled externally as to function. All controls and indicators shall be clearly labelled for ease of operation. The colours, size and typeface of all labels shall be selected to ensure high legibility in dim lighting.

(e) Specific Signs

Each hoist and motor drive unit, isolator, control cabinet and similar shall be clearly labelled with its established number or reference. These labels shall enable the unit to be quickly identified from the nearest easy access location without difficulty. Minimum character size shall be 30mm high.

(f) Loading Information

Each section of the installation shall be fitted with clear signs designating the loading which may be imposed on equipment and suitable safety, operational and access limitation signs. These shall be in accordance with any current legislation. Minimum character size shall be 30mm high.

(g) Safety Notices

These shall define the Safe Working Load (SWL) which can be imposed on the equipment and shall give information on loading restrictions, operations and safety. Safety signs shall be fitted in agreed positions for all items of equipment unless otherwise agreed.

(h) Manufacture

All signs relating to the equipment installation, access, safety, load and design limits shall be purpose made by a sign company in a consistent style. Signs shall be designed to be visible in the anticipated normal lighting at a distance of 3m. Such signs shall be in accordance with the specified Standards and shall be produced by a silk-screening process on 3mm thick rigid plastic or a similar hard-wearing method.

(i) Approval

Proper drawings of all signs and notices shall be prepared for approval before manufacture. The location and fixing of all signs and notices shall be established on site and agreed before erection.

(j) External Labels

External numbering and similar labels on mechanical equipment shall be of engraved plastic construction revealing a contrasting colour character, using a material such as Traffolite or similar. Such labels shall be screwed in place with brass screws. Numbers on motors and similar large items shall be large proprietary labels fitted with a permanent adhesive.

(k) Internal Labelling

All labelling of components and units within equipment cabinets and racks shall use proprietary systems suitable for permanent use. Temporary adhesive labels or marker pen identification will not be acceptable.

6.3 Machinery

6.3.1 Gearboxes

(a) Types

Except for specific applications (such as in a safety curtain hoist requiring a reversible gear ratio) gear speed-reducers transmitting substantial torques shall generally be of the worm gear or cyclo-gear type. Other gearboxes of proven reliability may be acceptable in particular applications. The efficiency of the gearbox and the changes in efficiency on starting shall be taken into account in the design of transmission systems.

(b) Rating

All geared drives shall be selected to transmit safely the required torque, power and impact. The service factor used shall take account of the type of drive, rating factor and any shock loads which may be applied through the gear.

(c) Design

Reducer gear cases shall be high-quality cast iron or steel, fully machined and fitted with an oil filler, drain and simple method of checking oil level. All gear and screw boxes shall be filled with suitable good-quality oil and checked and topped up if necessary on handover. All shafts extending through gearbox and similar casings shall be provided with suitable oil seals to ensure no leakage. No fixing holes shall penetrate through the casings.

(d) Worm Gearing

Worm gearing shall consist of a precision-machined, centrifugally-cast phosphor bronze worm wheel on a machined cast iron shaft carried on suitable roller bearings. The worm shall be high carbon steel with ground profile and bearing surfaces and also carried on roller bearings.

(e) Drip Trays

All units shall be fitted with drip trays which extend under all points where oil or grease is used for whatever purpose. The drip tray shall cover all positions above which oil or grease is likely to be channelled and shall have capacity to hold all the oil stored in the unit. All the fixings for the tray shall be arranged so as not to provide further leakage paths for oil. All drip trays shall have drain plugs provided in an accessible position.

6.3.2 Belt Drives

(a) General

All belt drive transmissions shall be designed, and the components selected to transmit safely all applied loads and torques, taking full account of all impact loads such as at starting and Emergency Stopping, with a safety factor of TEN. Belt speed shall not exceed 15m/s.

(b) Vee-belts

High speed drives, for example in certain applications between motor and gearbox, may employ proprietary vee-belt transmission. Pulleys shall be aligned accurately to avoid belt flank wear and the drives shall be correctly tensioned by adjustment of drive centres using measuring instruments both initially and after run-in as recommended by the supplier. Where parallel drives are used, matched belts shall be installed.

(c) Timing Belts

Toothed belt transmissions shall employ proprietary pulleys and belts. Pulleys shall have a pitch diameter of not less than the belt width and shall be selected so as to maintain a minimum of six belt teeth meshed in the pulley grooves. At least one pulley shall have side flanges. Pulleys shall be aligned accurately and the belt correctly tensioned.

(d) Tensioning Pulleys

Tensioning pulleys will not be permitted in either vee-belt or toothed belt drives. Allowance must be made in design for easy belt replacement. All pulleys shall be closely supported by a bearing or bearings and shall be fitted to their shafts by keys and locking devices.

(e) Belt Break Detection

Some form of belt beak sensor shall be fitted to all power transmission belts. A broken belt shall be detected immediately, and the mechanism stopped safely. This condition shall be designated a FAULT and signalled to any high-level control system. If required, a broken belt indicator shall be provided on the machine.

6.3.3 Brakes

(a) Principles

All brakes shall be of the failsafe type, being applied by pressure of a spring when power is removed and held off (released) by the connection of an electrical supply. Brakes shall be supplied by an established manufacturer and shall be able to decelerate safely the maximum load in the specified time and to hold the equipment static under the proof test load.

(b) Types

Brakes shall either be of the disc or calliper type. Brakes shall remain effective under all conditions and their performance shall not be degraded by vibration and wear. Brakes shall normally be rated higher than the drive motor torque, the application determining the over-sizing.

(c) Brake Operating Signal

In order to simplify control, minimise noise and increase security the brake operating signal shall be direct current. AC brakes are only acceptable in specifically approved applications. Where AC brakes are permitted additional steps shall be taken to ensure they are released and applied gently and without causing excessive noise.

(d) Brake Sequencing

Irrespective of the type of prime mover, design the control circuit to prevent the brakes from being released until the prime mover is sufficiently energised to support the load when the brake holding torque is removed. If a load signal is available, use this to derive a torque offset signal so that the correct torque for supporting the load is established before the brakes are released. Ensure there is no visible "snatching" of the load in either direction when the brakes are released and motion begins.

(e) Brake Interlocks

So far as is reasonably practicable, interlock all related power control devices such as motor starters, soft-starters, variable speed drives, hydraulic pumps and similar such that the brakes are immediately applied should any of these devices fail or de-energise the prime mover for whatever reason. Protect against the loss of the prime mover power supply by energising the brakes from the same supply.

(f) Rating

Brakes can be intermittently rated, depending on the anticipated service. The brakes selected shall operate quietly and gently, shall be easy to maintain and set-up correctly and shall be of a type in which the brake shoes or disc are completely clear of rotating parts when the brake is powered.

(g) Position

Brakes shall generally be fitted to the high-speed part of the mechanical system and gearboxes and other components shall be designed to withstand the deceleration forces imposed by the application of the brake. All brakes shall be adequately keyed to shafts. Where vee-belts or timing belts are incorporated in a transmission, the brake shall be incorporated in the driven (output) side of the system and linked directly with solid shafts and / or gearing to the load being carried or moved.

(h) Manual Release

All brakes shall be fitted with a manual release. Where non self-cancelling is appropriate, the manual release device shall be such that it indicates clearly on cursory examination that the brake is in a released state.

(i) Bedding-In

All working brakes shall be bedded-in during factory tests such that the final setting to work on site can be achieved with minimum delay.

6.3.4 Bearings & Transmissions

(a) Bearings

Bearings shall be tapered roller, precision ball or accurately sized phosphor bronze (oil impregnated bush type), depending on the application. The appropriate bearing shall be selected for each task and installed and used strictly in accordance with the manufacturer's recommendations. All bearings other than sealed-for-life types shall be greased packed and provided with a means of lubrication.

(b) Transmission Shafts

All shafts, keys and keyways shall be in accordance with specified Standards and shall be designed to transmit safely all applied loads, torques and their combinations with full and proper allowance for impact loadings. Keys shall engage fully with the appropriate component. Shafts shall be fitted at each end with suitable flexible couplings to accommodate possible misalignment and to reduce noise. Transmission and link shafts shall be designed to limit twist to less than 0.3° per metre at maximum torque.

(c) Roller Chain

Removable chain links and fittings to connect roller chain to other items shall be of a proprietary manufacture and shall have a strength equal to or greater than that of the roller chain itself.

(d) Transmission Noise

Where necessary to comply with noise limitation requirements, transmission components shall be installed on suitable anti-vibration mountings. Advice as to the correct mounting type shall be sought from established manufacturers with experience of the particular problem.

6.4 Rigging

6.4.1 Diverter Pulleys

(a) Drop Pulleys

Pulleys shall be arranged such that the corresponding drops for each bar are on parallel lines accurately at right angles to the up-down centre line of the stage. The passing wire ropes shall be positioned to either side of the earlier drops.

(b) Pulley Size

Wherever practicable, pulleys for working wire ropes shall be of pitch circle diameter not less than twenty-five times the rope diameter in order to minimise the wear on the wire rope. Where specifically approved, pulleys which have a very low duty cycle or around which the wire rope is deflected less than 45°, may have a diameter of not less than twenty times rope diameter. Each application of less than thirty times rope diameter shall be clearly indicated on the drawings.

(c) Pulley Blocks

All pulley blocks used for turning, aligning, supporting and separating load-carrying wire ropes or other ropes shall be proprietary items selected for the application or shall be designed specifically for the application and purpose made. The selection and design of each item shall take full account of the loads to be carried, the speed of operation and the mounting position.

(d) Multi-Groove Blocks

Where pulley blocks are required to accommodate more than one wire rope (or a combination of wire ropes and fibre ropes) for manual operations, such ropes may be carried in independent grooves machined in the same pulley or in separate pulleys within the common pulley block as may be appropriate. In all instances where more than one pulley is included in a block, each pulley shall be enclosed on both sides by side plates. The pitch circle diameter of all grooves in a common pulley block shall be the same.

(e) Pulley Blanks

Pulley blanks shall generally be solid steel, high-quality close-grained grey iron castings, high-strength cast nylon or approved stable plastic depending on the loading and use. The potential noise of wire ropes running over the drop pulleys must be considered when specifying the pulley material. Grooves for the appropriate number of wire ropes shall be machined in the rims to a profile and tolerance appropriate for the rope to be used. The grooves shall be sufficiently deep so that the flange projects above the seated rope. The outer part of the groove shall be flared at about 15° to permit the specified fleet angle without rubbing.

(f) Side Plates

Pulley side plates shall be steel of a thickness determined by the maximum load on the block. The side plates shall enclose the majority of the pulley assembly and be attached to one another by at least three spacers. The spacers shall prevent the rope leaving the pulley groove under any circumstances. The block shall be installed so that no ropes bear on the spacers.

(g) Pulley Form

Each pulley shall be faced and bored concentrically with the groove pitch circle to receive a sealed ball or roller bearing. The groove and flange shall be concentric to within ±0.5mm with the axle. The bearings shall be carried on solid steel shafts fitted with spacers and lock nuts between steel side plates. The shaft size shall take full account of shear and bending. Ensure the resultant pulley sheave assembly is free-running and can be reeved with the specified rope without any dismantling.

(h) Pulley Mountings

Pulley blocks shall be designed to be retained to the supporting steelwork under all conditions of loading by correctly fitted proprietary or purpose-made flange clamps in order to retain the possibility of future adjustment. This particularly applies to Grid and loft diverter pulleys. Swivel diverter units shall have a means of locking the pulley at the correct installed angle. Where the steelwork / pulley configuration results in forces that are parallel to the axis of the steel members, a positive shear fixing such as through bolts or welded stops shall be incorporated.

(i) Diversion

The relative positions of pulleys and / or drives shall ensure that for all conditions of use the wire ropes are diverted by a minimum of 5° round every pulley and that the pulleys are always rotated by the movement of the wire rope.

(j) Fleet Angle

The fleet angle of wire ropes to pulleys and winding drums shall not exceed 2.5° and shall be minimised wherever possible by careful design. The alignment of wire ropes onto pulleys and winding drums, under all conditions of operation, shall be carefully checked during installation and this condition fully complied with.

6.4.2 Hemp Sets

(a) General

Multiple line hemp sets shall be designed for a maximum load of 120kg. Hemp sets and cleats shall be designed to be able to be mounted at 200mm centres and where possible shall be limited to three lines. Cleats shall generally be mounted at an angle of 20° on timber rails. Where full height hemp flying is to be carried out a higher working rail and a lower deading rail of cleats shall be provided.

(b) Grid Pulley Blocks

Grid pulley blocks shall be 3-way, 2-way and single sheaves designed for the specified rope which can be bolted to the Grid in any position so that the hemp rope will fall through the centre of the Grid lagging slots. Design the pulley mounting to allow the rope to pass to the head pulleys. Lock the unit in position on the Grid using hand-operated captive clamping devices.

(c) Head Pulley Blocks

Shall be suitable for a maximum of three lines of the specified rope. Make the pulleys up into blocks with suitable lightweight bases to locate and clamp easily to the hemp slot steels on either side of the Grid using captive fixings.

(d) Clewed Hemp Systems

Suspend the scenery bar on wire ropes coupled to a horizontally travelling clew block. The clew block is then hauled by one double-purchased hemp rope and tied off to a cleat on the gallery in the usual way. Maximise the diameter of the double purchase pulley on the clew block to minimise operating friction: diameter to be not less than **eight** times rope diameter. Guide the clew block in a low friction track.

(e) Cleats

Unless stated otherwise these shall be proprietary 450mm overall size, malleable iron castings with smooth rounded wearing surfaces. Fit suitable mounting bolts so that there is timber both above and below the cleat body.

(f) Sandbags

Sandbags shall be of high-quality reinforced double-sewn canvas, size 300mm x 200mm, supplied filled with dry sand and sewn up. Securely and permanently fasten a 70mm galvanised ring to each sandbag.

(g) Pulleys & Cleats

All hemp ropes shall be provided with sufficient pulleys to be fully supported throughout their travel. Separate pulley sheaves shall be provided for each rope in head pulleys or where ropes pass diverters. Suitable sizes of pulleys and cleats shall be established for the particular application prior to manufacture or purchase.

6.4.3 Fibre Ropes

(a) Type

Unless otherwise specified, fibre ropes for counterweight hauling lines and general hemp set use shall be Grade 1 4-strand natural hemp rope or an approved equivalent.

(b) Rope Properties

Only offers ropes that are already in use in counterweight installations elsewhere and have very low stretch qualities. Ropes shall be able to be easily marked for deads, shall not create splinters or be affected by use through a rope lock. Purchase rope in pre-cut lengths with spliced eye and thimble for connection to the cradle tie-off point or clew plate.

6.4.4 Wire Ropes

(a) General Specifications

Suspension wire ropes shall be of preformed flexible steel with a steel centre core. Unless the manufacturer recommends against it, all wire ropes shall be supplied pre-stretched. All wire ropes shall be coated with a protective coating of zinc to an agreed thickness by hot dip galvanising or similar process. All wire ropes shall be supplied against a detailed performance specification from a major supplier.

(b) Pre-Testing

All wire ropes shall be pre-tested in batches by an authorised testing house and supplied in clearly labelled pre-cut lengths with batch test certificates.

(c) Site Handling

Wire ropes shall be handled with care during installation and not kinked or damaged in any way. Damaged or deformed wire ropes will not be accepted. All cut ends shall be correctly finished to prevent unlaying or fraying.

(d) Installation

In normal operation of the equipment wire ropes shall not be allowed to rub on fixed or moving parts of the installation. Wire ropes used to operate remote mechanisms in locations where there is risk of damage or jamming shall be properly protected. Moving wire ropes used for hoisting or traction shall be guarded where necessary to protect personnel. After installation the SEC shall specifically check that all wire rope fixings are secure and locked.

(e) Catenary Support

Wire ropes passing loft diverter pulleys, or in other situations where catenary support is necessary, shall be themselves supported on full diverter pulleys complying with the pulley specification unless otherwise specifically agreed.

6.4.5 Steel Bands

(a) Certification

Provide independent certification that the steel bands being offered exhibit the same strength and durability as a conventional wire rope. If required, provide the full test data on which the type approval certification was based to the Consultant for further assessment by a third-party expert.

(b) Third-party Testing

If required, the SEC shall organise, at no additional cost to the contract, independent third-party testing of the steel bands being offered. The programme of destructive load and fatigue testing shall be decided by the Consultant and their expert advisors. The SEC is required to satisfy the Consultant and the expert advisors as to the suitability of steel band hoists in regard to strength, durability and ability to withstand shock loads.

6.4.6 Standard Flying Suspension Beams

(a) Application

The details in this section apply primarily to multi-line suspensions as provided by counterweight, motorised suspension and Powered Flying systems. All bars, pipes, ladder beams and trusses shall be straight and true. Deformed or curved equipment will be rejected.

(b) Rigging

The centre of each bar shall be on the up-down centreline of the stage. Bars shall be horizontal, parallel to stage floor and one another.

(c) Pipe Suspensions

Where load suspension pipes are specified, these shall be 48mm ±2mm outside diameter x 5mm wall thickness steel tube or other sizes as set out in the individual equipment specification. See also ER (T) 6.4.6 (f) Pipe & Bar Joints.

(d) Rectangular Bar Suspensions

Where specified, the suspension bars shall be in rectangular hollow steel tube, nominally 50 x 100mm x 4mm wall thickness (approx. 9kg/m). See also ER (T) 6.4.6 (f) Pipe & Bar Joints.

(e) Truss Suspensions

Where specified, trusses shall be constructed as welded ladders with two 48mm ±2mm outside diameter x 3mm wall thickness steel tube at 300mm centres separated by plates or tubes at approximately 1000mm centres. The centres shall be adjusted to provide separation tubes near each wire rope suspension but to be clear of the levelling adjustment clamps. A separator tube shall be fitted at the ends of each truss. Removable end trusses shall plug into the end of the flown truss and be retained positively by captive pins or similar.

(f) Pipe & Bar Joints

Joints shall be minimised and shall be securely dowelled, and the two parts fitted together permanently without any external obstructions. Dowels shall be solid bar and a tight fit in the tubes/bars. The ends of the tubes/bars shall be undercut, securely welded and ground flush. Removable jointing pieces shall only be supplied where specified, such as on plug-in extensions.

(g) Conventional Levelling Adjustment

Suspension wire rope tie-off points shall be individually adjustable by means of clamps fitted to the tubes. The wire ropes shall be diverted to the clamps along the tube around suitable grooved quadrants plumb beneath each drop. The quadrants shall be securely clamped to the tube and shall restrain the wire rope without damage. The tubes shall be levelled by moving and locking the clamps.

(h) Levelling Adjustment using Wedge Anchors

If specifically permitted by the Appendix 1 - Employer's Requirements (Specific), this method has the operational advantage of not having a wire rope running along the top of the suspension beam. The wire rope shall be passed through the wedge device and levelled by adjustment before the wedge is pulled home. The eye on the wedge device shall be clamped to the top member of the beam.

(i) Extension Tubes

Telescopic extension tubes of suitable diameter or section and specified length shall be provided in each end of each suspension pipe or bar or in the lower pipe of each truss. These shall be able to be pulled out and clamped in position using a captive bolt suitable of use with the Project Rigging Spanner or with a fitted knob for hand operation. The section of pipe to remain in the pipe shall not be less than one third of the length of the extension and shall be finished bright RED.

(j) Tube Ends

The ends of tubes and of telescopic extensions shall be permanently fitted with brightly coloured plastic caps.

(k) Finishes

Unless otherwise specified, finish all suspension beams MATT BLACK.

(l) Beam Marking

Number each suspension beam at each end on the upstage side with at least 50mm high BLACK painted numerals on an approved WHITE plate or background. The set numbers are to be as shown on the drawings.

Mark the Safe Working Load (SWL) of each beam at each end on the upstage side in 25mm high YELLOW characters on an approved BLACK plate or background. The SWL shall be given as a uniformly distributed load, a maximum point load under each wire rope and a maximum point load between suspensions.

(m) Up-Down Stage Beams

Use similar beams for any up-down stage suspensions as for the across-stage multi-line suspensions, preferably with the same section length dimensions, but otherwise with the dimensions adjusted appropriately. They shall be similarly suspended, levelled and finished. Label and mark on the offstage sides.

6.4.7 Non-Standard Flying Suspension Beams

(a) General

If required, develop non-standard suspension beams within the general parameters of ER (T) 6.4.6 Standard Flying Suspension Beams. The sections shall be bolted together and easily assembled and disassembled. Different length end sections which can be attached to provide offstage extensions to the beams will be acceptable.

(b) Fabrication

Fabricate the suspension beams in standard sections, related to the wire rope suspension positions, to assist with spares holding and replacement in the event of damage. There shall be no joints in the material forming any of the standard sections.

(c) Levelling Adjustment

The top of the beam shall include small limited-motion pulleys and horizontal tie-off points for the suspension wire ropes. Make suspension wire rope tie-off points individually adjustable by means of tested eyebolts fitted to clamping plates which lock in the top section of the suspension beam. Mount the limited-motion pulleys plumb beneath each wire rope drop. Fit these pulleys with all necessary keeps and securely fix them to the beam so they restrain the wire rope without damage. Level the beams by adjusting the eyebolts. Ensure that at least 75mm of adjustment is available on the eyebolts. Fit the adjusters with Nyloc nuts and insert split pins through the ends of the threads.

(d) Beam Extensions

Provide only a limited number of extensions, equivalent to extensions for 15% of the installed across-stage beams. Ensure levelling, marking and extensions are compliant, unless otherwise detailed.

(e) Linear Scale

Prepare an approved laminated scale, giving clear dimensions along the beam, and attach this securely to the upstage side of the suspension beam. Establish the details of this scale with the Consultants before manufacture

6.4.8 Suspension Fittings

(a) Certificated Components

All springs, shackles, strainers, snap-hooks, karabiner-type hooks and other wire rope and fittings and lifting accessories shall be cadmium-plated or galvanised. All fittings shall be load tested by an authorised testing house and marked with a Safe Working Load and a unique identifying code. Test certificates shall be supplied.

(b) Lifting Applications

Unless specifically permitted, use only ER (T) 6.4.8 (f) Wedge Sockets or ER (T) 6.4.8 (c) Swaged Ferrules for wire rope terminations in lifting applications. Ferrule terminated wire ropes shall be supplied as pre-tested and certificated assemblies.

(c) Swaged Ferrules

Terminations shall comply with EN 13411-8 (or equivalent) and be fitted in accordance with EN 17206 (or equivalent) and the manufacturer's instructions . Test the termination to TWICE the SWL, identify the termination with a unique mark and issue a test certificate.

(d) Thimbles

All thimbles shall comply with EN 13411-1 (or equivalent) and fittings shall be the correct size for the wire rope. Where wire ropes are fixed by means of grips, the correct number of approved and correctly fitted grips shall be used for each fixing. A sample of the type of grip proposed for use shall be submitted with supporting data before purchase. Wire rope grips to BS 462 shall not be used. After fitting, excess wire shall be cut off and the end taped.

(e) Wire Rope Grips

All wire rope grips shall be to EN 13411-5 (or equivalent) and shall be fitted with the U-bolt fitted on the dead or tail side of the thimble. The correct number of grips shall be fitted at the specified separation given in the Standard and the bolts greased and tightened using an appropriate torque wrench. The grips must be retightened in the period shortly after fitting in order to ensure the correct load rating and the SEC shall allow for carrying out this process.

(f) Wedge Sockets

Wedge sockets to EN 13411-7 (or equivalent) may be offered as an alternative to thimbles and grips to provide a simple method of adjustment of position. Symmetrical and asymmetrical wedge sockets shall be used in accordance with the manufacturer's instructions and in accordance with EN 17206 (or equivalent). The wire rope end shall be retained above the wedge by a single approved grip. This grip shall only retain the wedge in place under no-load conditions and shall not have any effect on the load carrying or levelling. The end of the wire rope shall also be taped to the drop.

(g) Turnbuckles

Where appropriate, adequately rated open-centre straining screws may be employed. All wire rope fittings to such screws shall be as specified and the straining screws shall incorporate split pins to prevent them coming apart under any circumstances. All straining screws shall also be wired or fitted with tightened locknuts on installation.

(h) Shackles

All shackles that form part of a permanent installation shall be wire locked.

(i) Long Link Chain

Such chain shall not be used for load suspension even when tested, as its failure cannot be predicted. However, where its use is essential in providing a preset adjustment of height, such chains may be used with a safety factor of TWENTY and with a tested safety bond fitted loosely through it as security.

6.5 Scenic Masking

6.5.1 General

(a) Fixings

Obtain approval for fixings to structure from the Employer's Structural Engineer.

(b) Site Survey

The SEC is responsible for conducting a detailed site survey before preparing drawings and procuring tracks, curtains and other masking items.

(c) Tracks

Tracks to be suitably rated for the specified curtains or other loads, supplied complete with bobbins or roller trolleys and fixings to suit the load.

(d) Track Colour

Tracks to be BLACK unless stated otherwise.

(e) Reference Suppliers

All cloth materials shall be made up by an approved specialist theatre drapes supplier such as:

- J & C Joel Ltd, Corporation Mill, Corporation Street, Sowerby Bridge, Halifax, HX6 2QQ, UK
- J.D. McDougall Ltd, 4 McGrath Road, Stratford, London, E15 4JP, UK
- Gerriets GmbH, Im Kirchenhürstle 5, 79224 Umkirch, Germany
- Prompt Side Ltd, 14 Mulberry Court, Bourne Road, Crayford, DA1 4BF, UK

6.5.2 Soft Masking

(a) General

Ensure all masking cloths are suitably protected from dust and dirt for transport and storage on site. Do not hang any masking until advised to do so by the Consultant or Managing Contractor when the site is clean and all major works are complete.

(b) Flameproofing

All curtains forming part of this contract shall be either inherently flameproof or shall be materials which can be durably flameproofed by an acknowledged proprietary method which complies with EN 13773 (or equivalent). The SEC shall provide flameproofing certification for all the materials offered. Materials requiring flameproofing shall be so durably flameproofed before curtain manufacture and the test certificate shall state the date of flameproofing and the particular batch used.

(c) Material

Unless stated otherwise, all curtains, legs and borders shall be BLACK light-proof high-quality wool serge of minimum weight 500g/m^2, similar to "Super Wool Serge" supplied by J & C Joel (www.jcjoel.com).

(d) Curtains

Curtains shall have strong **50mm** wide flame-retardant webbing along top and be fitted with eyelets and strong ties at **300mm** centres. The curtains shall also be fitted with suitable snap-hooks for use with curtain track bobbins at **300mm** centres and an additional pair at 75mm separation at both the leading and trailing edges. Sides of curtains shall be hemmed. The bottom shall be fitted with a pocket and shall have a suitable galvanised weighting chain in a Bolton Twill sleeve sewn in 50mm above the bottom hem. The bottom hem shall be replaceable when worn.

(e) Borders

Borders shall have strong 50mm wide flame-retardant webbing along top and be fitted with eyelets and strong ties at 300mm centres. Hem sides of borders and fit bottom with pocket for 25mm outside-diameter weighting pipe.

(f) Legs

Legs shall have strong 50mm wide flame-retardant webbing along top and be fitted with eyelets and strong ties at 300mm centres. Hem sides of legs and fit bottom with pocket for a 25mm outside-diameter weighting pipe and fit a suitable galvanised weighting chain in a Bolton Twill sleeve sewn in 50mm above the bottom hem. The bottom hem shall be replaceable when worn.

(g) Tie Tapes

Ties tapes hall be at least 620mm long x 20mm wide cotton webbing tape so that when fitted correctly through the eyelets each tie end shall be approximately 300mm long. The ties shall not be sewn under the header webbing. The centre tie of each heading shall be coloured RED. The eyelets shall be plated heavy-duty steel.

(h) Labels & Storage

Each traveller curtain, leg or border shall be indelibly labelled on each top offstage corner on reverse side of material with its description, size, hanging position (on-stage or offstage, stage left or stage right), project name, material and date of manufacture / supply. Each item shall be supplied in a strong, high-quality, soft canvas bag similarly labelled and fitted with carrying handles, eyelets and draw cord for closing.

6.5.3 House Curtains

See also ER (T) 6.5.2 Soft Masking.

(a) Offstage Guides

A black nylon-coated vertical guide wire shall be permanently tensioned each side of the stage to align with the offstage edge of the curtain. These wires shall offer a smooth hard-wearing outer surface to the snap-hooks attached to the curtain. The guide wires shall be removable and tensioned by adjusters at stage level. High level fixings shall be to Grid steelwork.

(b) House Curtain Attachment

The House Curtain shall be tied to the suspension pipe in the conventional way with the bows knotted in the ties. Offstage trailing edges shall be fitted with suitable chromium-plated snap-hooks at 300mm centres to attach to the offstage guide wires. These snap-hooks shall be of a type, and so sewn to the material, that their loops are horizontal.

(c) Additional Curtain Make-Up Details

The two curtains shall be handed and made up with specified fullness. The bottom edge shall be **double thickness** and the leading edges of both curtains shall have paging handles sewn on at 1100mm above floor level.

(d) Bounce Ropes

Suitable slightly-elastic ropes shall be attached to the suspension pipe to restrain the pipe at the bottom of its descent so that the curtain can be easily bounced on the stage before rising again in a curtain call or returning to its lowered dead position. Allow for trying different ropes and for adjustment on site.

(e) Hanging

The SEC shall hang the House Curtains when all the wet-trades, painting, sanding and other dust- and dirt-producing trades have completely finished and after the House Curtain counterweight set or hoist has been satisfactorily tested. The SEC shall lay sheets of polythene or other protective material on the stage so as to keep the curtains as clean as possible during the hanging operations.

6.5.4 Hard Masking (Tormentors & Headers)

(a) Panel Frames

To be of rectangular and square hollow sections fully welded and ground flush.

(b) Panel Front Face

Unless stated otherwise, clad with 12mm Fireproof Class 0 hardwood plywood; fixings to be stainless steel screws flush with or recessed below surface. If required, radius edges to prevent damage to covering material.

(c) Fix Cladding

Fix cladding at not greater than 500mm centres. Use sufficient fixings to ensure joints between adjacent panels are totally smooth.

(d) Softwood Battens

Softwood battens o be fitted to all four sides of frame at rear using countersunk fixings for fixing of finish fabric using staples.

(e) Track Bracing

Ensure the suspension track is adequately braced to prevent up / down stage movement at the top of the Tormentors.

(f) Floor Guides

If required, fit a proprietary roller and channel guide, or similar, in the floor to guide the base of the hard masking and to allow for an off-axis centre of gravity when a panel is folded. Minimise the slot in floor required for guide track. Finish each side of the slot in floor with black nylon strip 5mm thick. Supply this to the Flooring Contractor for installation.

6.6 Sensors

6.6.1 Limit & Dead Switches

(a) Acceptable Switch Types

Select all end-of-travel limits and intermediate dead switches to be in accordance with ER (T) 1.8 Standards. The use of small case micro-switches below size V3 will not be accepted. The SEC must submit a sample of the type they wish to use for approval. Limits and deads shall be set up by the SEC but shall be able to be safely and easily adjusted by the User's staff after instruction.

(b) Mounting

Show limit switches and their mountings on the drawings and do not "site-fit" these items.

(c) Circuitry

All limit switches and similar contacts shall be closed wherever possible during normal motion of equipment. Latching circuits will not be acceptable unless there is no reasonable alternative.

(d) Accuracy

The switches must be able to be set with appropriate accuracy. The quality of the limit box and the drive thereto shall be equal to or surpass other parts of the installation. Play and backlash shall be minimised. All couplings, roller chain or toothed belt pulleys in the drive to the limit box shall use proper keyways or locked keys. The limit or dead shall be repeated within the specified tolerance from whichever direction approached and under any conditions of loading or speed.

(e) Intermediate Deads

Where appropriate, intermediate dead switches and slow-down switches may be included in the limit box. Where proximity switches, potentiometer, optical or magnetic encoder devices are proposed for these functions they shall be selected for reliability and to provide at least the accuracy called for in the equipment specification.

(f) Setting Threshold

Limit switches, particularly for intermediate deads, must be able to be set as close to each other as is appropriate in the application. For Elevator equipment this shall be within ±50mm and for normal hoisting equipment within ±10mm. Closer deads of ±2mm or better shall require encoders or resolvers and a position control system.

(g) Repeat Accuracy

Motorised hoists, winches and similar suspension equipment shall reposition to within ±2mm. Stage and forestage Elevators and other floor moving equipment shall reposition to within ±1mm. All limit switches or positional control systems shall be arranged to operate and to stop the equipment within the tolerance specified, from either direction and, on variable speed systems, at any speed setting.

(h) Direct Struck Limits

Direct struck limits shall be mounted so as to be reliably operated by, but not damaged by, motion of the equipment. Excess motion shall be accommodated within the available overtravel of the switch selected or by arranging for passing action. Only substantial industrial-grade switches will normally be acceptable. Normal limit switches shall be self-resetting when the mechanism is run in reverse.

(i) Rotary Limit Switches

Rotary limit switches shall be directly and positively coupled to the hoist mechanism with a keyed shaft or similar. Grub screws locking collars to shafts are not acceptable.

(j) Screw-Driven Limits

Approved types include screw driven units consisting of a precision-machined lead screw with one or more bronze operating nuts restrained by a linear guide, with the ends of the screws undercut to allow the actuating nuts to turn freely in overtravel. The nuts actuate operational end-of-travel and intermediate dead switches. Other and proprietary limit boxes must be specifically approved for the proposed application.

(k) Labels

Clearly label all limit switches with their function.

6.6.2 Overtravel (Ultimate) Limits

See also ER (T) 6.6.1 Limit & Dead Switches.

(a) Function

Provide separate overtravel switches on all powered equipment to prevent physical damage in the event of a software **and** end-of-travel limit failing. Fit and connect these limit switches so as to give maximum reliability.

(b) Direct Struck Limits

Direct struck limits are the preferred form of overtravel detector. Use safety-grade lever-arm types with forced disconnect contacts to EN 60947-5-1 (or equivalent), operated by the motion of the equipment. The switches shall be operated reliably within the specified overtravel distance. On some hoist and winch units the overtravel switch can be operated by the travel of the wire rope on the winding drum.

(c) Electronic Overtravel Limit Switches

When permitted in the Appendix 1 - Employer's Requirements (Specific), shall be implemented and certified as a SIL3 safety function under EN 61508 (or equivalent) irrespective of the actual risk reduction required.

(d) Rotary Limit Switches

Use ONLY proprietary "limit boxes" with force break contacts that are intended for safety applications.

(e) Action

Design the ultimate limit function such that it acts directly on the motor drive to stop the hoist at maximum deceleration rate **independently** of the control system.

(f) Override Switch

Provide a key switch or similar approved mechanism to override each overtravel limit to allow the machine to be move away from the ultimate limit position. Arrange for the operation of the override device to automatically inhibit further motion in the direction of overtravel.

(g) Overtravel Distance

Design all drive mechanisms and guides to allow sufficient overtravel distance for deceleration under the worst conditions after operation of an overtravel switch.

6.6.3 End-Of-Travel (Initial) Limits

See also ER (T) 6.6.1 Limit & Dead Switches.

(a) Function

Provide sensors to detect the limits of normal travel (top and bottom initial limits) and bring the machine to a controlled operational stop. Generally, the end-of-travel limits shall be in a proprietary or purpose-built switch unit mounted on the drive assembly but may be direct struck limits.

(b) "Intelligent" Position Sensors

"Intelligent" position sensors or similar electronic devices that include a limit switch function that is independent of the primary position sensing system may be acceptable subject to approval by the Consultant.

(c) Action

Design the initial limit function such that it acts via the control system to bring the hoist to a smooth stop before the ER (T) 6.6.2 Overtravel (Ultimate) Limits are reached, irrespective of the hoist speed when the stop was initiated. Do not inhibit motion away from the limit of normal travel.

6.6.4 Overload Detection

(a) General

All winch, Elevator and hoist units shall incorporate overload detection. Operation of the overload device shall stop motion in the direction which would increase the overload. It shall be possible to operate the unit under power in the reverse direction only to clear the fault, for example by lowering a load back onto the stage. Indicate an overload condition as an operational snag to the operator for correction.

(b) Principle

Provided each individual wire rope suspension and its pulley connections to the structure are such that each can carry the maximum imposed load under any operating conditions within their safety factors, a load cell to monitor the whole load imposed on the hoist can be employed. Such a load cell shall prevent the hoist from operating if the load exceeds the specified maximum for the hoist. Otherwise the load in the individual wire ropes shall each be monitored, and the hoist stopped if the load in any wire rope

(c) Overload Setting

Calibrate the overload setpoint using certified test weight to nominally 10% above the specified design load.

(d) Load Measurement

Unless otherwise specified or agreed, load cells shall be used for determining overload. In some less critical applications, motor torque measurement may be used to determine overload. In all cases, ensure that excessive overload does not strain any part of the installation.

(e) Load Cell Electronics

Ensure load cell signal processing electronics are failsafe in the event of a strain-gauge or wiring fault.

(f) Indication

If no specific overload indicator is provided, overload shall be signalled by flashing, at 30 times per minute, the top and bottom limit indicators on the panel.

6.6.5 Dynamic Load Monitoring

(a) Function

If required, design a system to provide a high degree of sensitivity to load using direct real-time load cell measurements. Machines shall be brought to a rapid but safe stop if they catch on fixed parts of the building or on heavy scenery. Catching on these items shall be detected by load, position, velocity, acceleration, or other change which shall be monitored at all times that a machine is not both stationary and not selected. Classify such a situation as a snag and indicate it to the operator for correction.

(b) Sensitivity

It is accepted that picking up light additional loads is a normal hazard and that the equipment cannot be expected to detect reliably a change of load **in motion** of less than 15% of payload. Provide an adjustable load detection window with a default value. The system must differentiate between an operational load-change and a full-load overload situation from standstill.

(c) Computer Control

Where a computer or programmable logic controller is operating the drive, the load cell signal shall be monitored, and any sudden change used to signal a snag.

6.6.6 Slack Wire Detection

(a) Direct Sensing

Include a no-load or slack wire system to detect **each** individual slack wire rope and maintain any slack wire ropes in position on the winding drum and in diverter pulleys so that, when the load is again applied, the wire ropes are correctly reeved. Classify a no-load situation as an operational snag and, in addition to stopping the hoist, indicate it to the operator for correction. No-load shall

permit the hoist to be raised under power so as to reinstate the tension in the suspension wire ropes.

(b) Load Cells

In certain situations, subject to the Consultant's approval, load cells may be used to measure changes in load to detect a slack wire rope situation.

(c) Grounding Sensors

Design crossed groove or slack wire sensors that rely on the steel wire rope grounding an electrically isolated metal electrode to be failsafe. Ensure the monitoring circuit can sense a broken connection to the sensing electrode and is sensitive enough to detect wire rope contact with contaminated electrodes. Assume a worst-case contact resistance of 500Ω.

(d) Indication

If no specific slack wire or no-load indicator is provided, slack wire or no-load shall be signalled by flashing, at 30 times per minute, the top and bottom limit indicators on the panel.

6.6.7 Crossed Groove (Winding Error) Detection

(a) Function

Include a crossed groove sensor to detect if a wire rope leaves its groove on the winding drum. Consider using a failsafe grounding contact circuit to detect the misplaced wire rope. Such a condition shall stop the hoist at the maximum deceleration rate and inhibit any further motion until all the wire ropes are correctly reeved.

(b) Reset

Due to the potential risk of continuing to run a hoist with a crossed groove, arrange that the operator has to manually clear the fault and reset the equipment through some deliberate action **at the hoist**. Classify a crossed groove condition as a malfunction which requires attention at the hoist unit for resetting. Provide a local control facility to enable the hoist to be run to assist with clearing such a malfunction.

6.6.8 Speed Error Detection

If required, arrange to directly measure the actual speed of the machine using an encoder or tacho. Compare this "actual speed" with the speed demanded by the control system and securely stop the machine if the actual speed deviates from the demand speed by more than 5% of the maximum speed. Signal this fault condition as a SPEED ERROR. The "speed error function" built into an open loop (sensorless) "vector drive" may be used to implement this requirement without an external speed sensor subject to the Consultant's approval.

6.6.9 Speed & Position Feedback

(a) Application

Where specified, include devices for speed and position feedback that are directly and positively coupled to the motor with a keyed shaft or approved similar arrangement. Where absolute and incremental devices are incorporated into a single unit, ensure there are no failure modes that could create danger.

(b) Couplings

Ensure that the drives to any of the feedback devices cannot be misaligned and that the mounting puts no strain on the unit or onto the drive shaft. These items must not be subject to premature failure or any cause of unreliability.

(c) Ease of Replacement

Encoders and all similar feedback devices shall be easily accessible and readily replaceable, and the system shall be able to be recalibrated quickly in the event of a change being necessary.

(d) Approvals

Submit full details of any proposed encoders to be used in the installation to the Consultant for approval. Encoders which provide separate absolute and incremental signals within a single device may be acceptable.

6.6.10 Safety Devices

(a) Application

In all places where moving parts pass in a guillotine action, safety devices shall be installed. Such safety devices and the stopping mechanism(s) on the equipment shall operate totally reliably and in such a way as to ensure that the equipment causes no damage or injury to the obstruction. All safety switch devices shall be inherently failsafe and connected in a series configuration.

(b) Risk Assessment

A Risk Assessment shall be carried out on each safety function to determine the appropriate risk category and risk reduction using the methodologies set out in EN 62061, EN 13849, EN 61508 or some other approved standard. It is the responsibility of the SEC to develop the risk assessment in writing, especially the identification of all potential hazards and the analysis of every conceivable failure mode.

(c) Activation

Safety switches, including tape, optical, laser, air pressure or similar devices, shall be shown to be able to cause the stopping of the equipment within half the effective travel of the safety switch under any condition of payload and speed. In many cases these additional safety functions will trigger the category 0 or category 1 Emergency Stop System (see ER (T) 4.5.2 Category of E-STOP to ER (T) 4.5.2 (c) Category 1 Stop).

(d) Guard & Door Solenoid Interlocks

Where guards or access doors have to be locked shut during motion, fit only approved metal-cased heavy-duty solenoid locking safety interlock switches to EN 14119 (or equivalent). Unless specified otherwise, solenoid locks shall be energised to unlock (failsafe). Provide at least three override (unlock) keys for each type of lock supplied.

(e) Devices

All safety devices shall be proprietary equipment, conforming to National and European Standards. Each device shall have been independently tested or type approved as appropriate.

(f) Operation

Operation of safety switches shall prevent any further motion of the equipment onto the obstruction. Only operation in the reverse direction so as to release the obstruction shall be possible from any control panel.

(g) Indication

Activation of a safety switch shall be classified as a MALFUNCTION and shall be indicated on the control panel. All safety switches shall be traced in sections and the section activated indicated on the control panel. Where necessary a reset button shall be fitted to the panel.

6.7 Electrical

6.7.1 Flexible Cables

(a) Responsibility

Where the equipment installation requires control or power circuits fed to moving components, the flexible cable feeds to these components and the connectors, fixed termination boxes and connections at each end shall be supplied and installed by the SEC. Connections and termination boxes shall all be permanently labelled.

(b) Types

Any flexible cables used shall be selected giving consideration to ambient and conductor temperatures, EMC performance and to wear-resistance, flexing and mechanical stress. Vulcanised rubber, butyl rubber, EP or silicone rubber sheathed cables to the relevant Standard) shall be used in preference to PVC sheathed types. Where suitable cables are available, LSF (low smoke and fume) types shall be used. If required, cables to be used shall be agreed with the Local Authority and 1m long samples of all flexible cables shall be made available on request.

(c) Cables in Tension

Flexible cables used under constant tension for hanging or trailing leads for power or control circuits shall be fitted with a strain-relief centre core or an external continuously-moulded catenary wire which shall be made off or clamped at both ends to relieve the strain on conductors.

(d) Protection

Additional physical protection shall be provided where more than one trailing cable connects between the same two points. This shall be in the form of a fire-resistant sheath or binding around the cables.

(e) Segregation

The segregation of conductors carrying different category circuits as defined in the specified Standards) shall be maintained in all flexible cables. Adequate insulation shall be ensured on all multicore and control circuits.

(f) Terminations

Where flexible cables join other flexibles or fixed wiring the termination shall be a block with all the connections permanently labelled.

6.7.2 Cable Feed Devices

(a) Types

Cable reeling drums or energy management systems shall be used in preference to flip-flop cable trays wherever a suitable product or purpose-made unit is available.

Generally, proprietary self-reeling drums using Tensator springs or equivalent shall be proposed for situations with limited numbers of power or control circuits. Major numbers of circuits may require windlass equipment or proprietary cable management systems as used on industrial machinery: Igus chain (www.igus.co.uk) or equivalent. Custom-made solutions such as "flip-flop" trays will not be accepted.

(b) Rating of Wound Cables

Where cables are wound on cable reeling drums or windlasses they shall be derated in accordance with the applicable regulations and the manufacturers recommendations. Most theatre lighting applications require the full circuit rating whether the cable is wound or not and full allowance shall made for use when wound on the drum or windlass. Where a windlass operates with two different diameter drums, the cables used on each shall be the same rating. Windlasses shall be designed to take up and hold the cable without putting excess strain on any part of the cable.

(c) Slip Rings

Full account shall be taken in design or selection of slip rings for cable reeling equipment of the potential electrical noise on control circuits. Slip rings and brushes shall be complementary materials proven in practice to have the current-carrying capacity and to provide the required low contact resistance.

(d) Capacity

Drums and windlasses shall have sufficient cable capacity to permit the total travel of the relevant equipment, including to positions required for maintenance. Adequate and accessible terminals shall be provided on all cable feed equipment to facilitate replacement of cables.

(e) Windlass Design

Where cables are wound on a windlass in a pile winding format, each cable shall have an individual groove of appropriate depth. The minimum diameter of each cable groove shall be arranged so that each pays out a similar amount of cable, even where the diameters of the cables are very different. Where some cables of small diameter and reduced strength are installed on the same windlass as heavier cables, the small cables shall be allowed to hang and shall not be put under strain. They shall be gently restrained by an appropriately rated spring or similar free device at the lower end.

Interconnections to other equipment shall be made by professional quality active interfaces that provide the appropriate balanced or unbalanced signal at the correct level for the connected equipment.

END OF UPGRADE OF PODIUMS & BACK DROP ELEVATOR TO ELECTRICAL DRIVES APPENDIX 3 - EMPLOYER'S REQUIREMENTS (TECHNICAL)
DCPT Appendices 1-3 Podium & Back Drop Elevator Upgrades ER(SGT) Rev 1.2

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