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DESIGN REVIEW GUIDE FOR AMUSEMENT RIDES IN SINGAPORE

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1 Introduction

1.1 Purpose

This Design Review Guide is issued by the Commissioner of Amusement Rides Safety (Commissioner) to provide guidance on the requirements for the review of design of amusement rides in Singapore for the purpose of installation or modification permit application.

Every amusement ride must have its design reviewed by a Qualified Person (QP) before it can be installed. Similarly, for existing rides, no major modification should be undertaken before the design of the modification has been reviewed by a QP.

In the review of design, the QP has to thoroughly check, verify and certify that the safety-critical aspects of the design of a patron-carrying amusement ride are sound, and that the calculations are in order. The QP must also ensure that the ride design is in accordance with acceptable standards, and the ride when built will meet the quality expected.

1.2 Responsible Parties in these Guidelines

Installation / Modification Permit Holder

The installation / modification permit holder is someone who holds an installation / modification permit issued by the Commissioner under section 6 / section 24 of the Amusement Rides Safety Act.

Qualified Person (QP)

A qualified person (QP), engaged by the installation / modification permit holder, shall be a registered Specialist Professional Engineer in the discipline of amusement ride engineering under the Professional Engineers Act (Cap. 253).

For major amusement rides, the QP is required to appoint and consider the opinion and advice of a Conformity Assessor (CA) for the purpose of:

(a) Reviewing and certifying the design and specifications and the proposed installation or modification method and programme of a major amusement ride; or

(b) Supervising any installation or modification works in respect of a major amusement ride;

(c) Inspecting and certifying any major amusement ride, including the annual inspection; or

(d) Carrying out any other function under the Amusement Rides Safety Act in respect of a major amusement ride.

Conformity Assessor (CA)

A conformity assessor (CA), engaged by the Qualified Person (QP), shall assist the QP in carrying out the procedures (including inspection, test and certification of amusement rides) for determining whether the design and specifications, the proposed installation or major modification method and programme relating to a major amusement ride conform to applicable standard or requirement prescribed under the Act or Regulations.

1.3 Scope of Work

These are the main areas within the typical review of design of an amusement ride and will be covered in detail in the following sections:

(a) Design and Calculations

(b) Manufacture and Installation Process

(c) Testing Plans

(d) Design Risk Assessment

(e) Operation and Maintenance Manuals

(f) Documentation and Certification

2 General Principles

The review of design is an independent check on the design of the safety-critical aspects of an amusement ride.

The review of design should be carried out prior to the application of the installation or modification permit for the amusement ride. Sufficient time should be allocated for the Commissioner and other technical authorities to review the submission before the granting of the relevant permits. The application, together with the complete documentation and certification, should reach the Commissioner at least one month before the intended commencement of installation or modification works, depending on the complexity of the ride.

This Design Review Guide covers areas of work that are expected to be carried out by the QP (and CA for major amusement rides). The design review report and certification by the QP may be rejected by the Commissioner if the design review is incomplete, even though the scope of work specified in the contract between the QP, CA and owner may be of a limited scope.

An efficient documentation procedure is needed to record the findings of the design review, and any changes made to the design as a result of this review. The QP shall ensure that each version should have a unique version number and date, and have an issue summary sheet at the front of the document folder.

The QP (+CA for major amusement rides) who is appointed to carry out the review of design should be independent of the permit holder and not have any personal or pecuniary interest in the amusement ride. They should not be engaged in any activities that may conflict with their independence of judgement and integrity in relation to their work.

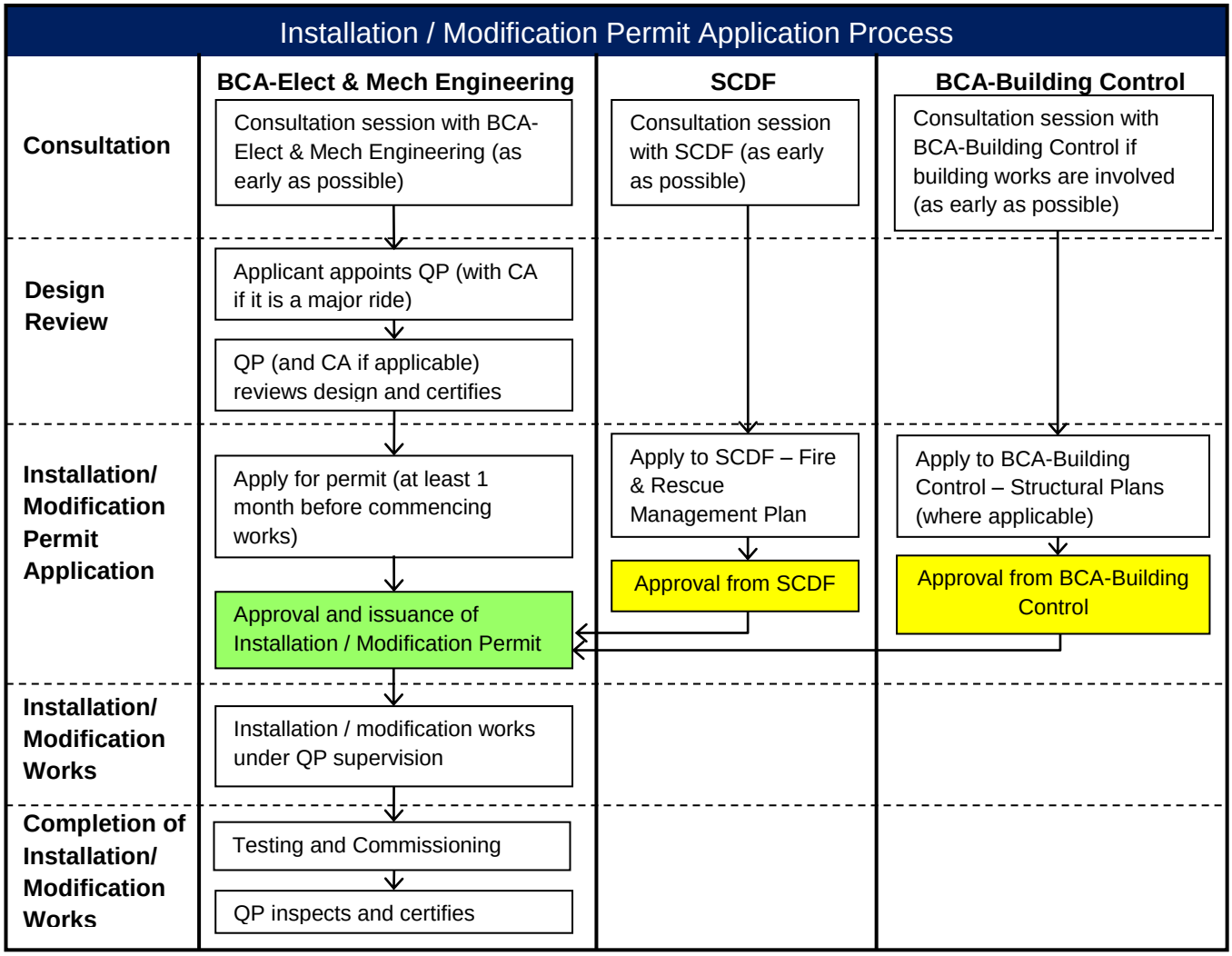
When necessary, the QP may request for additional design information, where these additional information are required. The QP doing the design review may also be the same QP that will perform the inspection of the ride for the purposes of application for Operating Permit. However, it is important that the QP should not work outside his area of competence.

3 Procedures

3.1 Sequence of Application

The owner should submit the application for installation / modification permit at least one month prior to the commencement of work. The typical clearance process of installation or modification permit is in the flowchart below.

No person shall install / modify or cause any amusement ride to be installed / modified unless the installation / modification work on the amusement rides is authorised by, and carried out in accordance with the conditions of a valid installation / modification permit.



3.2 Pre-Consultation

The owner or QP should approach the Commissioner as early as possible for a pre-consultation session on the design and specifications of a new amusement ride, or for an existing ride that is to be modified. The QP must engage a CA to assist him with the review of design and specifications if it is a major amusement ride. During the pre-consultation, the QP can discuss with the Commissioner the programme of work and information necessary to expedite the processing of the permits.

4 Drawings Review

The review of drawings should cover all assemblies, sub assemblies and individual components. Upon the review of the drawings, the QP shall endorse on every drawing and include all these drawings in the application for installation / modification permit.

Drawing details should include drawing dates and revision numbers to identify the exact purpose and use of the drawing. Specific information including schematics, sectional and assembly details must be available. The drawings must also provide dimensions, material, weld and joint specifications, safety clearance distances, tolerances and location of safety-critical components.

Detailing must be sufficient to allow for fabrication and installation, including the identification of critical welds, joints and NDT points.

5 Design and Calculations Review

5.1 General

The QP shall ensure that the design of the amusement ride conforms to the applicable standards listed in the Amusement Rides Safety Regulations. He shall also ensure that the ride, when built, will be in compliance with the Amusement Rides Safety Act and its subsidiary legislations.

5.1.1 Designing for fatigue strength

Sufficient fatigue strength should be designed for those parts of the ride that can result in danger should fatigue failure occurs. The fatigue calculation must take into consideration the load pattern, stress concentration, vibration amplitudes and frequencies (especially in relation to the ride's own natural frequency to prevent onset of resonance) and the resulting expected life of the parts. Reference should also be made to known standards in projecting the ride's fatigue life, such as BSEN 1993-1-9.

Where design software has been used in the design and calculations, the QP should verify the results obtained from such software.

5.1.2 Material

Materials used in the design of the amusement ride should be clearly specified within the design documentation. The material specifications should be tabulated in a list which details the materials used and their locations within the ride. There should also be sufficient information to identify the types and grades of materials used, their origin, and any treatment and testing these materials have been subjected to. The material should also be manufactured to acceptable international standards. Mill certificates should be included whenever available.

The material list should include parts and accessories used for the ride. Parts used for the ride would likely to include pumps, motors, gearboxes, wheels, housings, wire ropes etc. Accessories may include bolts, valves, clamps, and other fittings which are used in conjunction with larger pieces of equipment.

5.2 Foundation and Structural Elements

For the case of a relocatable ride, the design of the foundation and other structural supports of the amusement ride should be reviewed. If necessary, the opinion of a professional civil or structural engineer registered with Professional Engineers Board (PEB) should be sought. The review should cover the adequacy of the ride to withstand both the static and live loads (including impact from dynamic loads during the ride operation). For fixed rides, those parts of the ride that are defined as a “building” will require separate approval under the Building Control Act. Hence, the QP will need to ensure that proper submission by the appropriate QP of plans, clearances and permits are obtained in accordance with the Building Control Act.

5.3 Loads

The design loading conditions of the amusement ride should consider the static and dynamic loads during normal load conditions, and abnormal load conditions such as impacts and jerks, wind gusts, wet weather operation and unplanned patron behaviour.

The design should also look into bracing loads, i.e. the load caused by patrons bracing themselves against restraints and other parts of the containment system. This could be more significant at higher g-levels and at turns and loops, and the containment must be able to endure the extra load. Besides the main body of the containment, the joints, such as pins, locks, and bolts should also be checked to ensure that they can handle this load. Special attention should be given to these seemingly minor parts.

The design should also look into the possibility of uneven load distribution and out of balance loads. The design should indicate the level of uneven load the machine can tolerate safely. If limitations to uneven load situations are prescribed, the QP should assess whether this could reasonably be controlled during operations and if so, the control should be translated to strict operational rules in the operation manual.

5.4 Mechanical and Electrical Systems

All mechanical and electrical systems must be accompanied by their relevant schematic diagrams, process/logic flow charts and block diagrams. The system design should also take into account the proposed response plans for all forms of failures associated with the mechanical or electrical systems that may result in hazards. The QP should check that the response plans are adequate and do not pose any danger to patrons, operators or maintenance crew.

The expected forces acting on these systems must also be within the system's capabilities - whether the ride is being operated, maintained, erected or dismantled. Components that require maintenance must be easily accessible for the maintenance crew as far as practicable.

The need to install analogue or digital meters and Software Interface Consoles which provide essential readings for operation and maintenance purposes should be considered in the design review. These should be located where they are easily accessible for monitoring and maintenance purposes.

The mechanical and electrical systems should always operate within specifications for all acceptable ride load conditions. For example, the ride itself should not at anytime draw a higher load than what the motor was designed and rated for.

Components should also be designed with safeguards against power failures, power surges and spikes and system overloads. Hydraulic and pneumatic systems should be designed with relief valves and bypasses to allow the release of excess pressure. Electrical systems should be fitted with overload protection.

Pipelines and hoses for hydraulic fluid, compressed air and gases, as far as reasonable, must be easily accessible for inspection.

5.5 Safety Related Control Systems

A control system is a device or set of devices designed to manage, command, or regulate the behaviour of other devices or systems. Where any failure or design error of the control system may potentially result in an accident or a loss of life, such control systems should be regarded as a safety related control system. Hence, extra care must be taken to ensure that such control systems are of such reliability that their likelihood of failure is eliminated or minimised as far as possible. Mitigation measures together with the associated failure response plans must be proposed. The more critical the safety related control system, the more reliable and fault resistant it should be, and hence the more comprehensive the mitigation measures and response plans should be. The QP should understand the workings of the control system before reviewing the sufficiency of the control system.

Very often, the control system would include sets of transducers fitted on the ride to read various critical parameters that have impact on safety. Typical example would be the restraint lock detector, collision detector, hydraulic and pneumatic pressure sensor, speed detector, loads and stresses, etc. The readings from these transducers will be input to the PLC or other logic processors, and appropriate action would be taken either to ensure smooth running of the ride, or to mitigate any danger that could arise.

Safety related control system should be designed to achieve the level of safety desired, and the QP should, in the design review, consider the following:

(a) The reliability of the control system hardware

(b) The potential error during interface with humans

(c) The programme logic in mitigating failures and systemic faults

(d) The possible presence of bugs in the software that can cause danger

(e) The possible failure modes of the control system and the impact of each mode

(f) Monitoring of the system, whether automatic or with human input

(g) The presence of redundancies and mitigation measures to kick in during failure

(h) Availability of test modes to test the system functions periodically

5.6 Patron Containment and Restraints

The QP shall review the patron containment method, clearance envelope and clearance (in all axes) for its adequacy, taking into account the safety and risk profile of the ride. A fast ride, for example, must not have any potential patron contact with the structure or theming. Where contact while on a slow moving ride is considered acceptable, the nature of potential contact will have to be assessed, for example the contact must be soft or flexible enough as contact with hard surfaces should be avoided.

Possible patron behaviour during the ride must be factored in for the design of the envelope. The relationship of the forces imposed to the patrons, and their expected responses must be considered. For example, if the ride imposes a strong jerk onto the patron, the sudden movement of the body is to be expected which may result in the body impacting parts of the seat or restraint. Measures would then have to be considered to prevent injury caused by such impact, such as providing thick paddings.

Where the ride is designed to BSEN 13814 or ASTM - F24 standards, reference should be made to the specific requirements on patron clearance envelope in these standards. In relation to these standards, the design of patron seating and restraints should be reviewed for comfort, size, choice of material, and the adequacy of the restraint class. Limits on the size of the patron must be available and verified. The limit on size could be in the form of height limit (minimum or maximum height) or

weight limit. The QP should verify that the design for the size of patrons and the limit of their reach was undertaken using reliable anthropometric data.

The provision of restraints should be reviewed in accordance with appropriate restraint determination (acceleration) diagrams in the prescribed standards. Particular care should be taken that all the safety features / characteristic of the restraint has been provided in accordance with its classification.

5.7 Connections

For welded joints, the welding procedure shall comply with recognised international welding standards such as the standards issued by the American Welding Society (AWS) or equivalent. In particular, the choice of welding materials, procedure and techniques should be reviewed to ensure the integrity of the joint in service. The proposed testing method and qualifications of welders shall meet the standards requirement.

Where bolts are used for connecting elements together, the choice of bolts greatly impacts the safety of the ride. Bolts used shall conform to internationally recognised standards. The torque settings for bolts shall adhere to the manufacturer's specifications. Where there is less redundancy available for the bolt connections, bolts of higher strengths could be used to achieve a higher factor of safety. Bolt positions must be easily accessible for inspection, and adequate measures must also be proposed to detect bolt movement, or prevent the bolts from unfastening during operation.

If exposed to the elements, the ability of the bolt to withstand corrosion is critical, and measures taken to prevent moisture from entering the joint must be considered.

The parent material at the joints must also be able to withstand the shear forces imposed by the bolts. If necessary, reinforcement of the parent material should be considered at these locations.

The design must also specify inspection intervals of the joints. For the case of a bolted joint, the replacement intervals for the bolts must be specified.

6 Manufacture and Installation Processes Review

During the review of manufacture and installation processes, the QP shall ensure that the manufacturers have in place a quality assurance (QA) plan for fabrication and installation. He may need to check the material procurement procedures and dimensional compliance. He also has to check the tolerances allowed for fabricated parts, fabrication techniques used and qualification of workers involved in the fabrication process.

There should also be an NDT inspection plan for parts after fabrication to ensure that the parts meet the quality required.

The QP shall also review the fit-up checks schedule, installation method and programme. All the parts need to be clearly identified and marked in order to prevent errors in assembly.

As good practice, the QP should consider visiting the manufacturing plant to ensure that the manufacturing process meets the QA requirements. He should also, where possible, conduct random sampling of the fabricated parts, inspect factory documentation of materials and inspect the fabrication process - to ensure that the QA plan has been adhered to.

7 Test Plans Review

Amusement rides have to undergo various kinds of tests before they may be commissioned for public use. Before these tests are conducted, the QP is expected to review the test plans to verify that the tests are comprehensive and relevant for the ride. He must also look at the acceptance criteria for these tests, and be assured that these criteria are reasonable and sound. A typical list of test plans for amusement ride would comprise:

(a) Load test plan

(b) Out of balance test plan

(c) Hydraulic and pneumatic test plans

(d) Electrical systems and systems interface test plan

(e) Safety-related control system test plan

(f) Functional test plan

(g) Emergency systems test plan

8 Design Risk Assessment Review

As part of the design process, the designer of the amusement ride will assess all the risks associated with the design, as well as those risks arising during its lifecycle (e.g. assembling, dismantling, transporting, installing, operating, maintaining, inspecting, and testing of amusement ride). These risks will be recorded in the Design Risk Assessment. Based on the Design Risk Assessment, the designer would specify the necessary control measures to mitigate these risks.

The QP should ensure that the Design Risk Assessment process has been clearly documented, and that the measures to address risks are adequate. He also has to be satisfied that the residual risks are at acceptable levels.

The Design Risk Assessment document should include the following details:

(a) Details of the amusement ride design (which should include unique reference numbers and specifications);

(b) Any relevant assumptions which have been made (e.g. loads, strengths, safety factors);

(c) The hazards identified and estimation of the risks;

(d) The control measures proposed; and

(e) Residual risks after the measures are put in place.

There are various protocols in doing risk assessment, most common of these are:

- Failure Mode and Effect Analysis
- Hazard Identification and Risk Assessment Matrix (HIRA)
- Fault Tree Analysis
- What If Analysis

All these methods allows the designer to predict hazards, the risks associated with the hazards and thereafter decide on the control measures to bring the risk down to acceptable levels.

The QP should look through the Risk Assessment provided by the designer, and assess the adequacy of the hazards identification, risk assessment, and mitigation measures. In deciding the adequacy of the mitigation measure, it is to be noted that using procedural control or personal protective devices to mitigate a risk is a less

desirable method compared to elimination of the hazard or using engineering control measures.

Annex A provides a list of common hazards associated with an amusement ride which could help the QP identify potential hazards of the ride. These hazards may be checked against the designer's Design Risk Assessment to see if the identified risks have been mitigated or adequately controlled.

9 Operation and Maintenance Manual Review

The QP shall review the operation and maintenance manual made available by the manufacturer of the ride. The QP shall ensure that the manual is adequate for the purposes of operating and maintaining the ride safely. For completeness, the ride manual must contain the following items, among others:

Operation

i. information on emergency procedures

ii. Information on design and manufacture

iii. Details of operating speeds and permitted loads

iv. Limits of any variation or adjustments which can be made to the ride (eg speed, number of carriages and load)

v. Restrictions on ridership

vi. The Standard Operating Procedures

vii. Details of relevant drawings, including PNIDs and schematics

viii. Additional recommendations to the owner / operator

Maintenance Programme

i. Instructions and information on maintenance, including preventive and corrective maintenance

ii. Replacement intervals for parts, oils, filters, pads and other consumables

iii. Replacement interval for parts such as bolts, wire ropes, bearings and pumps

Inspection Programme

i. List of items to be inspected

ii. Schedules for inspection

iii. Details of daily and periodic inspections

iv. Details of periodic NDTs

Training Requirement for Ride Manager, Attendants and Maintenance Personnel

i. Course syllabus

ii. Training and qualification record forms

For the case of a relocatable ride, information on the ride's storage, transport, installation and dismantling should be provided by the manufacturer. The information must be complete so that the owner can execute what is required in order to perform these tasks safely. Where information provided is inadequate, the QP may request the owners to obtain the information from the manufacturer.

10 Documentation and Certification

Upon completion of the design review, the QP involved should prepare a written Design Review Report for submission. This submission should be made preferably with the permit holder's application for installation / modification permit.

The Design Review Report should cover the following areas:

(a) Scope of the design review

(b) Drawings Review

(c) Review of Design and Calculations

(d) Review of Manufacture and Installation Processes

(e) Tests Plan Review

(f) Design Risk Assessment Review

(g) Operation and Maintenance Manual Review

(h) Any other relevant information, especially pertaining to the safety of the amusement ride.

The QP should attach all documents that have been reviewed in his design review report. A checklist is attached at Annex B to guide the QP in preparing the Design Review Report.

10.1 Certification

The QP should certify at the end of the review that the amusement ride is safe for use as designed. The design review report and certification should be submitted to the Commissioner during the application for installation / modification permit and will form part of the Log Book for the amusement ride.

Annex A – Typical Hazards Associated with Amusement Rides

Hazard	Possible sources of hazard
• Persons struck by falling, ejected or other objects	• Patrons' belongings • Mechanical / structural or other parts coming unfastened or failing in service (including backdrops, scenery, light fittings, speakers) • Tools • Ejected patrons / employees • Other projectiles
• Nausea • Physical injury resulting from intensity, direction and duration of accelerations and jerks (i.e. change of accelerations)	• Forces of motion on patrons • Padding and cushion
• Hazards associated with patron containment including - a. unplanned release of locks b. Ill fitting restraints	• Design of locks and restraints • Failsafe mechanism in the locks • Padding at patron-restraint contact points • Patron size specification
Impact / collision hazards: • Collision of patron unit with pedestrians (e.g. land trains) • Collision of patron unit with structures • Collision with another ride vehicle (except for bumper car where collision is intentional and designed for)	• Sufficiency of cordon and passenger envelop • Availability of proximity detectors and back ups • Despatch Standard Operating Procedure for vehicles
• Squeezing / crushing / pinching • Cutting / severing • Entangling (including patrons' hair and clothing)	• Motion relative to / contact with / or proximity to, machinery or structures • Pinch points • Guarding of machine and moving parts • Patron dress code

Hazard	Possible sources of hazard
• Asphyxiation / poisoning / nausea etc from contact with or inhalation of dust, fluids, gases, mists, fumes, vapours, water	• Protection against unplanned release of fluids or gases • Leak detection • Integrity of connections
For relocatable rides that are not seated on permanent foundations: • Overturning • Tilting	• Ground condition and bearing capacity • Rain • Size of supports • Plumpness or levelness of ride
• Static failure	• Load capacity • Out of balance load • Reserve strength availability
• Fatigue failure	• Adequacy of dynamic analysis or stress analysis • Structural / mechanical vibrations unaccounted for • Secondary dynamic effects unaccounted for • Inspection regime consistency with calculated fatigue life
• Failure of brakes and bearings	• Regular and exceptional wear and tear • Type and suitability of brakes and bearings
• Escape of liquids / gases under pressure (hydraulic / pneumatic systems)	• Design of pipes and joints • In-service deterioration • Ease of inspection

Hazard	Possible sources of hazard
Hazards associated with electricity such as: • Electric shock or burn by direct contact with live parts • Electric shock or burn by contact with parts which have become live under fault conditions • Arcing • Static discharge • Explosion • Lightning strike • Fire risk	• Capacity of equipment vs loads • Circuit isolation (such shielding or sheathing) • Lightning protection • Fire prevention and protection • Current overload protection
Hazards associated with controls / control systems especially: • Over / under speed whether at launch or during travel • Inadequate braking or excessive braking • Software errors	• Operational, safety or emergency stops • Speed detectors and interlocks • Robustness of control system and software • Over-reliance on operator judgement or skill • Likelihood or ease of tampering (e.g. resetting by staff, access by members of public)
Ergonomics and health hazards • Excessive physical effort required to mount and dismount • Excessive physical effort to operate or conduct inspection • Effect of exposure to loud noise or very bright light	• Design ergonomics • Design, location and identification of manual controls • Design or location of visual displays • Visibility of significant parts to operator and maintenance crew • Sound effects • Local and general lighting

Hazard	Possible sources of hazard
Hazards associated with water (lagoon, pools, flume rides, water parks) which may include: • Slipping and falling • Illness due to water borne microbes • Drowning of patron, staff or members of public	• Slippery surfaces • Water quality management • Drowning prevention • Work activities associated with underwater maintenance and inspection, and due to use of electricity in the proximity of a water body.

Annex B – Checklist of Design Review Guide

Section in Guide	Points of Review	S-Satisfactory U-Unsatisfactory	Remarks, if any
4	Drawings review		
5	Design and calculations review		
5.1.1	Designing for fatigue strength		
5.1.2	Material		
5.2	Foundation and structural elements		
5.3	Loads		
5.4	Mechanical and electrical systems		
5.5	Safety related control systems		
5.6	Patron containment and restraints		
5.7	Connections		
6	Manufacture and installation processes review		
7	Test plans review		
8	Design risk assessment review		
9	Operation and maintenance manual review		
	• Operation		
	• Maintenance programme		
	• Inspection programme		
	• Training requirement for ride manager, attendants and maintenance personnel		
10	Documentation and certification		
10.1	Certification		

This is a guide checklist. QPs are expected to develop this checklist to suit the particular ride they are reviewing. Each item used in this list should be expanded to fill in the details.